State of California

The Natural Resources Agency

DEPARTMENT OF WATER RESOURCES

Bay-Delta Office

Engineering Solutions to Further Reduce Diversion of Emigrating Juvenile Salmonids to the Interior and Southern Delta and Reduce Exposure to CVP and SWP Export Facilities

Phase I — Initial Findings

Prepared in Response to the

National Marine Fisheries Service 2009 Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project, Reasonable and Prudent Alternative Action IV.1.3

December 2013

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Acronyms and Abbreviations

Action	Action IV.1.3
BAFF	Bio-Acoustic Fish Fence
BiOp	*Biological Opinion And Conference Opinion On The Long-Term Operations Of The Central Valley Project And State Water Project*
cfs	cubic feet per second
CDFG	California Department of Fish and Game (recently renamed to Department of Fish and Wildlife)
CFR	Code of Federal Regulations
CPUE	Catch-per-unit-of-effort
CV	Central Valley
CVP	Central Valley Project
dBs	decibels
DCC	Delta Cross-Channel
DFG	Department of Fish and Game (California)
Delta	Sacramento-San Joaquin River Delta
DPS	Distinct Population Segment
DWR	California Department of Water Resources
EFH	Essential Fish habitat
EIR/EIS	environmental impact report/environmental impact statement
ESA	Endangered Species Act
ESU	evolutionarily significant unit
F	Fahrenheit
FR	Federal Register
ft	feet
HOR	Head of Old River
HORB	Head of Old River barrier
Hz	hertz
IEP	Interagency Ecological Program
mm	millimeter
MSL	mean sea level
NAVD88	North American Vertical Datum of 1988
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPB	non-physical barrier
OCAP	Operation Criteria and Plan
RBDD	Red Bluff Diversion Dam
Reclamation	U.S. Bureau of Reclamation
RM	river mile
RPA	Reasonable and Prudent Alternative
SCW	State Water Contractors
SDIP	South Delta Improvement Program
SDWA	South Delta Water Agency
SWC	State Water Contractors
SWP	State Water Project
TBP	Temporary Barriers Project
TL	total body length
TWG	technical working group
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
VAMP	Vernalis Adaptive Management Plan

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Executive Summary

The Department of Water Resources (DWR) has completed Phase I responding to requirements of the National Marine Fisheries Service (NMFS) *2009 Biological Opinion and Conference Opinion on the Long-Term Operations Of The Central Valley Project And State Water Project* (BiOp) Reasonable and Prudent Alternative (RPA) Action IV.1.3 (Action). The Action requires the U.S. Bureau of Reclamation (Reclamation) and/or DWR to consider engineering solutions to further reduce diversion of emigrating juvenile salmonids to the interior and southern Delta, and reduce exposure to Central Valley Project (CVP) and State Water Project (SWP) export facilities. The Action is a multi-year study consisting of three phases.

Phase I of the Action has consisted of convening a Technical Working Group (TWG), reviewing possible locations to reduce the diversion of salmonids, developing proposed initial engineering solutions summarized in this initial findings report, and subjecting the report to independent peer review. The TWG is comprised of agency representatives from DWR, Reclamation, NMFS, U.S. Fish and Wildlife Service (USFWS), and the California Department of Fish and Game (CDFG, recently renamed to Department of Fish and Wildlife). The independent peer review was coordinated through the Delta Stewardship Council Science Program.

Phase II of the Action will consist of studying the engineering solutions proposed in this report, developing a solution for each of the possible locations, preparing preliminary engineering drawings and cost estimates, and preparing a Phase II final report. The study of proposed solutions may include performing pilot studies to further evaluate solutions and their application. The Phase II final report will summarize the study and findings, include recommended approaches, and will be submitted to NMFS by March 30, 2015. Quarterly meetings with the TWG will take place to provide study updates and receive input from each agency representative.

Phase III of the Action will consist of NMFS reviewing the Phase II final report and if a recommended approach is accepted, NMFS would likely direct DWR and Reclamation to proceed with permitting, final design, and construction.

This Phase I report identifies and describes five locations or study sites for which engineering solutions are proposed for consideration. Three of these locations are identified in the Action text and include one location on the Sacramento River and two locations on the San Joaquin River. On the Sacramento River, Georgiana Slough near Walnut Grove is identified and on the San Joaquin River, the Head of Old River (HOR) and Turner Cut are identified. Two additional locations, one at Columbia Cut just downstream of Turner Cut on the San Joaquin River and the other at Threemile Slough near Sherman Island on the Sacramento River, were included by the TWG. These locations are unique; each with varied characteristics of hydrology, migratory passage for the movement of native and non-native fish species, and recreational opportunities including fishing and boating.

The primary aquatic species to be addressed by the Action are juvenile salmonids and steelhead migrating through the Delta. These species include winter-, spring-, fall-, and late-fall-run Chinook salmon, and Central Valley (CV) steelhead. Years of studies have shown that the loss of out-migrating salmonids selecting a route through Georgiana Slough and the Delta interior is approximately twice that of fish

remaining in the Sacramento River main stem. Keeping out-migrating fish in the Sacramento River using engineering solutions could increase their survival rate. The Action is also intended to address the San Joaquin River/Southern Delta corridor, particularly for out-migrating CV steelhead. Other sensitive species considered to have critical habitat in the Delta include green sturgeon and delta smelt. These species are of interest because of potential effects on their migration and survival resulting from implementing potential engineering solutions.

Previous engineering solutions to control fish passage have been studied at Georgiana Slough and the HOR. Solutions have included behavioral barriers such as non-physical acoustic technologies, a Bio-Acoustic Fish Fence (BAFF™), and temporary rock barriers. Behavioral barriers were evaluated at Georgiana Slough during 1993-1996 and again in 2011 and 2012. The 1993-1996 study was done to evaluate the effectiveness and feasibility of installing and operating an underwater acoustic sound system to deter (guide) juvenile salmon from entering the slough. The 1993-1996 study results showed that the system provided an average guidance efficiency of up to 57 percent. A temporary rock barrier was considered for study at Georgiana Slough in 1993. However, the barrier was not installed and tested because of concerns over potential effects on water quality, flow, upstream fish migration, boating and recreation. A BAFF™ was installed and tested at Georgiana Slough in 2011. This potential solution included the use of sound, light, and air bubbles and showed a two-thirds reduction in entrainment into Georgiana Slough when “on” versus when “off.” A second installation was done in 2012 to evaluate different operating conditions and gather additional data. The report for this installation is being finalized.

Since 1992, under the Temporary Barriers Project (TBP), a temporary rock barrier has been installed in the spring of most years at the HOR to guide out-migrating salmon and CV steelhead smolts. A rock barrier at the HOR has been installed in the fall of most years to improve water quality for up-migrating fall-run Chinook salmon adults. A BAFF™ was installed and tested at the HOR in the spring of 2009 and 2010. Testing showed deterrence efficiencies as high as 81 percent.

Ten potential engineering solution options are identified in this Phase I report and include non-physical barriers, electric barriers, over-flow gates, under-flow gates, floating barriers, guidance walls, screens, rock barriers, and possibly a hybrid or combination of solutions. Habitat restoration and transportation barges are also identified. These options were proposed by the TWG based on scientific and engineering expertise and knowledge of past, current, and evolving methods for fish diversion.

Data and results from past and ongoing study efforts will be used to further evaluate and develop recommended approaches in Phase II. The evaluation will include a comparison of engineering solutions using a number of proposed criteria. These criteria include: deterrence ability, environmental impacts, effects on upstream migration, flow effects, predation effects, tidal effects, boat passage, implementability, operation and maintenance, uncertainties, and costs. These criteria have been defined, assigned a metric, and ranked in order of importance. Other criteria identified during the Phase II study will be added as appropriate and the ranking of criteria adjusted as needed.

In summary, this Phase I report serves as a basis for continuing the evaluation of proposed engineering solutions in Phase II of the Action study. The planned outcome of this continued evaluation will be a Phase II final report which presents recommended approaches for further consideration by NMFS.

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Introduction

On June 4, 2009, the National Marine Fisheries Service (NMFS) completed the final Biological and Conference Opinion (BiOp) based on the proposed long-term operation of the Central Valley Project (CVP) and State Water Projects (SWP). The BiOp evaluated the effects on listed anadromous fishes and marine mammal species and designated and proposed critical habitats in accordance with Section 7 of the Endangered Species Act (ESA) of 1973. NMFS concluded that the project, as proposed, would likely jeopardize the continued existence of several federally listed species under NMFS' jurisdiction, and would destroy or adversely modify designated critical habitat for these listed species. NMFS provided a Reasonable and Prudent Alternative (RPA) to the proposed project that met the criteria of 50 Code of Federal Regulations (CFR) 402.02. The RPA is comprised of a suite of actions to be implemented by the CVP and SWP to prevent jeopardy to the listed species and avoid destroying or adversely modifying designated critical habitat.

As a result, the U.S. Bureau of Reclamation (Reclamation) and/or the Department of Water Resources (DWR) is tasked with addressing RPA Action IV.1.3 (Action) to "Consider engineering solutions to further reduce diversion of emigrating juvenile salmonids to the interior and southern Sacramento-San Joaquin River Delta (Delta), and reduce exposure to CVP and SWP export facilities."

This document is the Phase I report and transmits the initial findings to NMFS on the options to be considered further and how these options will be evaluated. By March 30, 2015, a Phase II report will be provided to NMFS recommending the preferred option for each of the project sites.

The NMFS BiOp describes the objectives, actions, and rationale behind the Action. The relevant text in the NMFS BiOp follows.

> *Action IV.1.3 Consider Engineering Solutions to Further Reduce Diversion of Emigrating Juvenile Salmonids to the Interior and Southern Delta, and Reduce Exposure to CVP and SWP Export Facilities*
>
> ***Objectives****: Prevent emigrating salmonids from entering the Georgiana Slough channel from the Sacramento River during their downstream migration through the Delta. Prevent emigrating salmonids from entering channels in the south Delta (e.g., Old River, Turner Cut) that increase entrainment risk to Central Valley steelhead migrating from the San Joaquin River through the Delta.*
>
> ***Action****: Reclamation and/or DWR shall convene a working group to consider engineering solutions to further reduce diversion of emigrating juvenile salmonids to the interior Delta and consequent exposure to CVP and SWP export facilities. The working group, composed of representatives from USBR, DWR, NMFS, U.S. FWS, and California Department of Fish and Game (DFG), shall develop and evaluate proposed designs for their effectiveness in reducing adverse impacts on listed fish and their critical habitat. USBR or DWR shall subject any proposed engineering solutions to external independent peer review and report the initial findings to NMFS by March 30, 2012. USBR or DWR shall provide a final report on recommended approaches by March 30, 2015. If NMFS approves an approach in the report, USBR or DWR shall implement it. To avoid duplication of efforts or conflicting solutions, this action should be coordinated with*

USFWS' Delta smelt biological opinion and BDCP's consideration of conveyance alternatives.

***Rationale**: One of the recommendations from the CALFED Science Panel peer review was to study engineering solutions to "separate water from fish." This action is intended to address that recommendation. Years of studies have shown that the loss of migrating salmonids within Georgiana Slough and the Delta interior is approximately twice that of fish remaining in the Sacramento River main stem (Kjelson and Brandes 1989; Brandes and McLain 2001; Vogel 2004, 2008; and Newman 2008). Based on the estimated survival rate of 35 percent in Georgiana Slough (Perry and Skalski 2008), the fraction of emigrating salmonids that would be lost to the population is 6 to 15 percent of the number entering the Delta from the Sacramento River basin. Keeping emigrating fish in the Sacramento River would increase their survival rate. This action is also intended to allow for engineering experiments and possible solutions to be explored on the San Joaquin River/Southern Delta corridor to benefit out-migrating steelhead. For example, non-physical barrier (i.e., "bubble curtain") technology can be further vetted through this action.*

Site Descriptions

In the Action, there are three project locations identified to investigate engineering solutions to reduce the emigration of salmonids into the interior and central delta. Of these three locations, one is on the Sacramento River, and the other two are on the San Joaquin River (Figure 1). Columbia Cut, just downstream of Turner Cut on the San Joaquin River, and Threemile Slough, located between the Sacramento and San Joaquin rivers, will also be considered. Each of the five locations is unique and described in the next pages.

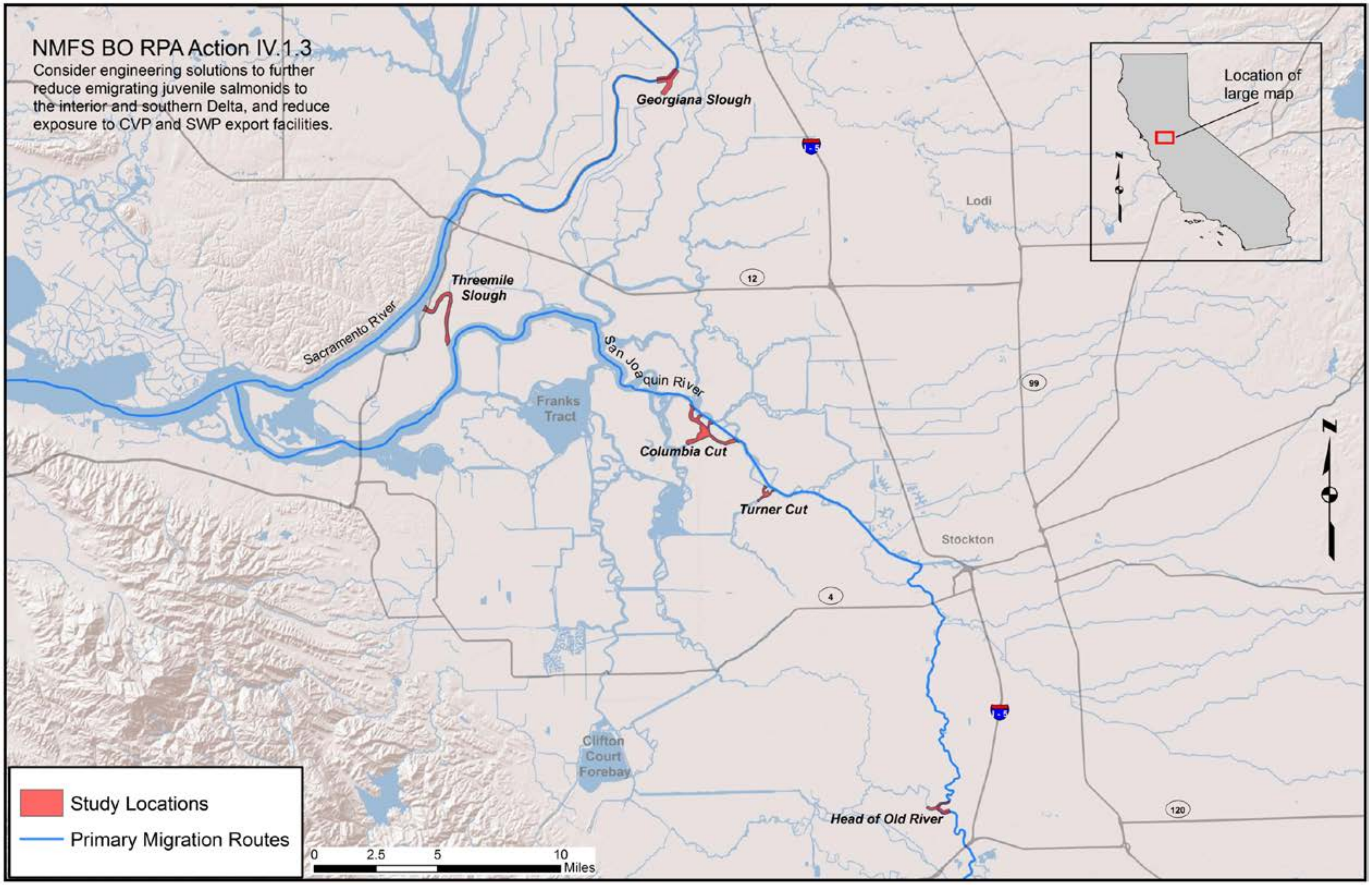


Figure 1: NMFS BiOp RPA Action IV.1.3 Study Locations

Sacramento River

The locations on the Sacramento River to be considered for engineering solutions are Georgiana Slough near Walnut Grove and Threemile Slough near Sherman Island.

Georgiana Slough

The Georgiana Slough study site is located in the northern Delta at the divergence of the Sacramento River and Georgiana Slough, just downstream of the town of Walnut Grove in Sacramento County (Latitude 38.23947^{o}, Longitude -121.51726^{o}). The Georgiana Slough study location consists of land on the south bank of the Sacramento River, which includes farmlands, public/private properties, and the public docks located southwest of the Walnut Grove Bridge (Figure 2).

Georgiana Slough provides a migratory corridor for the movement of a variety of native and non-native fish species passing between the Sacramento River and the San Joaquin River. These fish species include Chinook salmon (*Oncorhynchus tshawytscha*), American shad (*Alosa sapidissima*), steelhead (*O. mykiss*), green sturgeon (*Acipenser medirostris), and white sturgeon (Acipenser transmontanus*). A variety of resident fish species are known to inhabit Georgiana Slough, including, striped bass (*Morone saxatilis*), largemouth bass (*Micropterus salmoides*), tuleperch (*Hysterocarpus traski*), Sacramento pikeminnow (*Ptychocheilus grandis*), Sacramento splittail (*Pogonicthys macrolepidotus*), and various species of catfish (Ictaluridae).

In addition, Georgiana Slough provides a variety of recreational opportunities, such as fishing and boating. Boaters choose this route for its scenic quality as well as its ease of navigation and linkages to other Delta destinations. Approximately 15-20% of the Sacramento River flow enters the interior Delta through Georgiana Slough, depending on Sacramento River flows and the 28-day tidal cycle. Typical average monthly river flows through Georgiana Slough range between 2,200 cubic feet per second (cfs) and 6,200 cfs. The Georgiana Slough channel is approximately 600 feet (ft) wide and 20-30 ft deep at its divergence from the Sacramento River.

Figure 2: Georgiana Slough Study Location

Threemile Slough

The Threemile Slough study site is located in the northern Delta within Solano and Contra Costa Counties. The site is downstream of Rio Vista and is bounded by the area formed by the Sacramento River and the lower San Joaquin River (Figure 3). The Threemile Slough study location consists of the land on Twitchell, Sherman, and Brannan Islands. Though the Threemile Slough location was not identified in the Action, it will be considered since it is the next divergence on the Sacramento River downstream of Georgiana Slough where fish may be diverted.

Threemile Slough provides a variety of recreational opportunities to the public, including fishing and boating. Boaters choose this route for its scenic quality, as well as its ease of navigation and linkages to other Delta destinations. Threemile Slough project area also provides a migratory corridor for the movement of a variety of anadromous native and non-native fish species. These include Chinook salmon, American shad, CV steelhead, and green and white sturgeon.

Typical average monthly flows in Threemile Slough are about 2,000 cfs depending on the Sacramento River and San Joaquin River flows and 28-day tidal cycle. Maximum tidal flows are as high as 30,000 cfs. The slough is over 600 feet wide with depths greater than 20 feet in the vicinity of its connection to the Sacramento River.

Figure 3: Threemile Slough Study Location

San Joaquin River

The three locations on the San Joaquin River to be considered for engineering solutions are the Head of Old River near the city of Lathrop, and Turner and Columbia Cuts near the city of Stockton.

Head of Old River

The Head of Old River (HOR) study site is located in the Delta near the City of Lathrop (Latitude 37.8076°, Longitude -121.3277°). Major waterways at the HOR location are Old River and the San Joaquin River. The HOR study location consists of farmlands and public/private properties (Figure 4).

The HOR location provides a variety of recreational opportunities to the public, including fishing and boating. Boaters choose this route for its scenic quality, ease of navigation, and its linkages to other destinations in the South Delta. The HOR site provides a migratory passage for the movement of a variety of native and non-native fish species. These species include Chinook salmon, CV steelhead, white sturgeon, Sacramento pikeminnow, Sacramento splittail, and striped bass.

Approximately 50% of the net San Joaquin River flow enters the interior Delta through the channel split at the HOR location. Typical average monthly HOR flows range between 1,000 and 3,000 cfs, but this can vary substantially depending on flows in the San Joaquin River upstream of the HOR location. Average monthly flows are typically higher during winter and spring due to runoff from rain and snowmelt events into the San Joaquin River basin. The HOR location is approximately 225 ft wide and 3-8 ft deep. There is a large scour hole on the San Joaquin River just downstream of Old River where a large number of predatory fish are suspected to congregate.

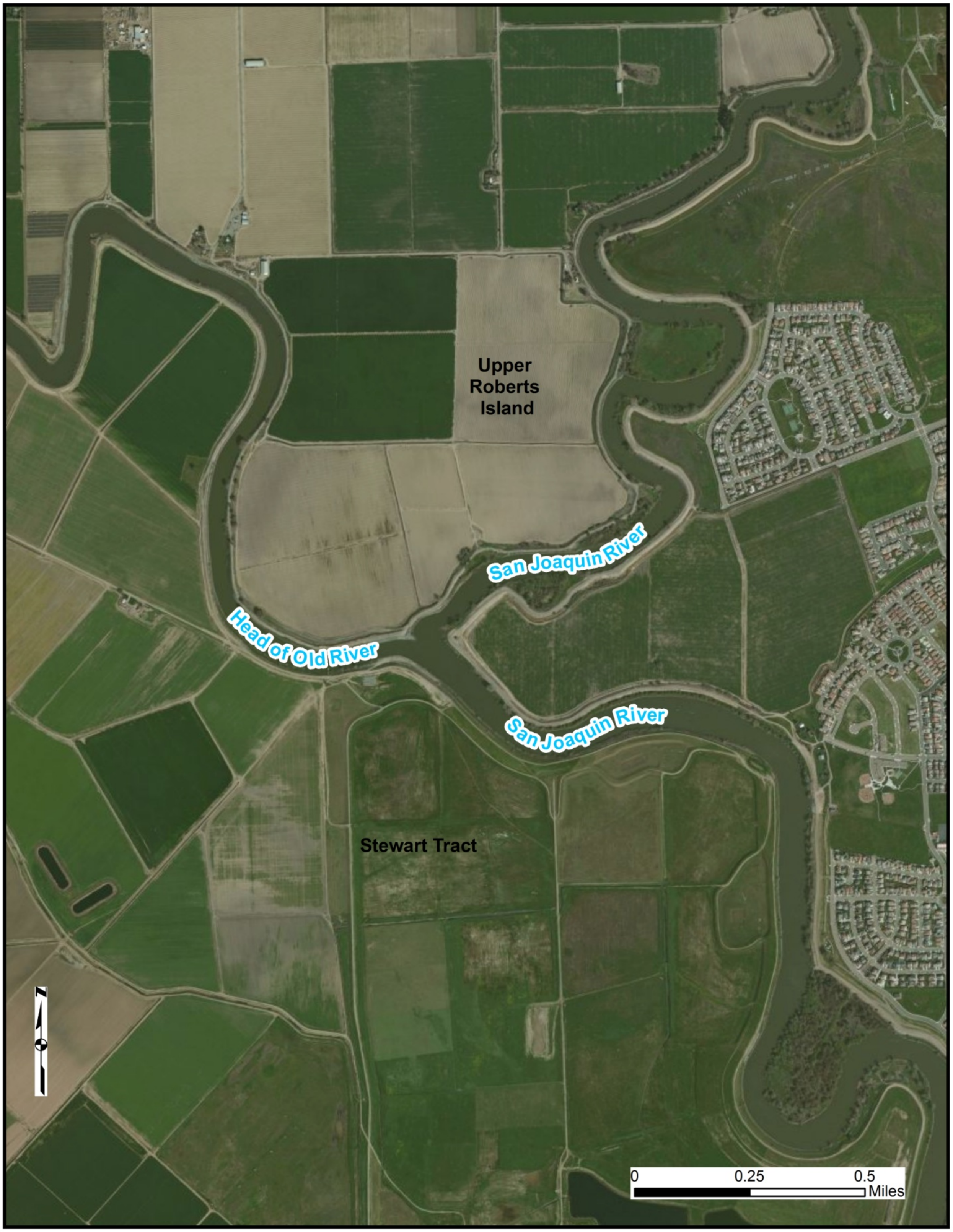


Figure 4: Head of Old River Study Location

Turner Cut

The Turner Cut study site is located in the Delta near the City of Stockton (Latitude 37.9990°, Longitude -121.4489°). Turner Cut is split into two equivalent secondary channels prior to its junction with the main stem of the San Joaquin River, forming Acker Island. The Turner Cut location consists of land on the south bank of the San Joaquin River on Roberts Island, including farmlands, and public/private properties (Figure 5).

Turner Cut provides a variety of recreational opportunities to the public, including fishing and boating. Boaters choose this route for its scenic quality as well as ease of navigation and linkages to other Delta destinations. Turner Cut provides a migratory passage for the movement of a variety of native and non-native fish species. These species include Chinook salmon, American shad, CV steelhead, white and green sturgeon, striped bass, delta smelt, Sacramento pikeminnow, Sacramento splittail, and various species of catfish.

Approximately 20 to 25 percent of the San Joaquin River flow enters the interior Delta through Turner Cut during a flood tide. Typical average monthly Turner Cut flows range between 1,800 and 2,300 cfs, depending on San Joaquin River flows and the 28-day tidal cycle. The two secondary channels of Turner Cut at the divergence with the main stem San Joaquin River are each approximately 275 to 285 ft wide and 20 to 30 ft deep. The main channel of Turner Cut is approximately 360 ft wide at the confluence of the two secondary channels and is 20 to 30 ft deep.

Figure 5: Turner Cut Study Location

Columbia Cut

The Columbia Cut study site is located in the Delta near the city of Stockton (Latitude 38.0344°, Longitude -121.4855°). Columbia Cut is split into two secondary channels prior to flowing into the San Joaquin River. The Columbia Cut location consists of land on the south bank of the San Joaquin River on McDonald Island, farmlands, and public/private properties (Figure 6).

Columbia Cut provides a variety of recreational opportunities to the public, including fishing and boating. Boaters choose this route for its scenic quality, as well as ease of navigation and linkages to other Delta destinations. Columbia Cut provides a migratory passage for the movement of a variety of native and non-native fish species. These species include Chinook salmon, American shad, CV steelhead, white and green sturgeon, striped bass, delta smelt, Sacramento pikeminnow, Sacramento splittail, and various species of catfish.

Approximately 30 to 35 percent of the San Joaquin River flow enters the interior Delta through Columbia Cut during a flood tide. Typical average monthly Columbia Cut flows range between 3,000 and 4,000 cfs depending on San Joaquin river flows and the 28-day tidal cycle. The two secondary channels of Columbia Cut at the divergence with the main San Joaquin River are each approximately 350 ft wide and 10 to 15 ft deep. The main channel of Columbia Cut is approximately 550 ft wide at the confluence of the two secondary channels and is 10 to 15 ft deep.

Figure 6: Columbia Cut Study Location

Fish Species

The Delta is a unique aquatic ecosystem that provides a spectrum of complex habitats for a diverse variety of fish species. Many of the fish species inhabit the estuary year-round, while other species inhabit the system on a seasonal basis, utilizing it as a migratory corridor between freshwater riverine habitats and coastal marine waters, as habitat for seasonal foraging, or for reproduction and juvenile rearing. Geographic distribution of fish species within the estuary is determined, in part, by salinity gradients, which range from freshwater zones within the Sacramento and San Joaquin River systems, to full marine conditions near the Golden Gate Bridge (Moyle et. al 1982), with transitional brackish and low salinity zones in the western Delta, Suisun Bay, and San Pablo Bay.

Fish Species of Concern

A number of fish species inhabiting the San Francisco Bay estuary support recreational and commercial fisheries, such as fall-run Chinook salmon (*Onchorynchus tshawytscha*), Pacific herring (*Clupea pallasi*), northern anchovy (*Engraulis mordax*), starry flounder (*Platichthys stellatus*), striped bass (*Morone saxatilis*), largemouth bass (*Micropterus salmoides*), white sturgeon (*Acipenser transmontanus*), and many others. The estuary and Delta waters have been identified as Essential Fish habitat (EFH) for Pacific salmon, northern anchovy, and certain species of Pacific groundfish (e.g., starry flounder) (NOAA Web 2010). EFH is defined in the Magnuson-Stevens Act as "*...those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.*"

The ESA requires the federal government to designate "critical habitat" for any species listed under the ESA. "Critical habitat" is defined as: (1) specific areas within the geographical area occupied by the species at the time of listing, if they contain physical or biological features essential to conservation, and those features may require special management considerations or protection; and (2) specific areas outside the geographical area occupied by the species if the agency determines that the area itself is essential for conservation (NOAA - http://www.nmfs.noaa.gov/pr/species/criticalhabitat.htm). USFWS and NMFS have designated the majority of the legal Delta as critical habitat for delta smelt, California Central Valley (CV) steelhead, and Southern Distinct Population Segment (DPS) green sturgeon. Portions of the Delta, in particular the Sacramento River and channels within the northern Delta have been designated as critical habitat for winter-run and spring-run Chinook salmon.

The abundance, distribution, and habitat used by these fish have been monitored over a number of years through investigations conducted by CDFG, NMFS, USFWS, DWR, and other organizations. Results of these monitoring programs have shown changes in species composition and abundance within the system over the past several decades (DWR 1995). Many fish species within the Delta region have experienced a general decline in abundance (Moyle et al. 1995). Consequently many of these species require special management strategies, including winter-run and spring-run Chinook salmon, CV steelhead, delta smelt, long-fin smelt, and green sturgeon. These species are either listed or being considered for protection under the Federal or California Endangered Species Acts (Table 1).

Although many of these species are of general concern, USBR and DWR are tasked with considering engineering solutions to further reduce diversion of emigrating juvenile salmonids into the interior and southern Delta. The other species are described herein as general background for future assessment of potential impacts from possible solutions. In particular, green sturgeon and delta smelt are included because of their likely occurrence in the study areas. In the following section, detailed life stage occurrence and Delta migration information is provided for salmonids. Additional life history information for these salmonids and other species of concern is presented in Appendix B.

Table 1: Federal- and State-Listed Fish Species in the Delta

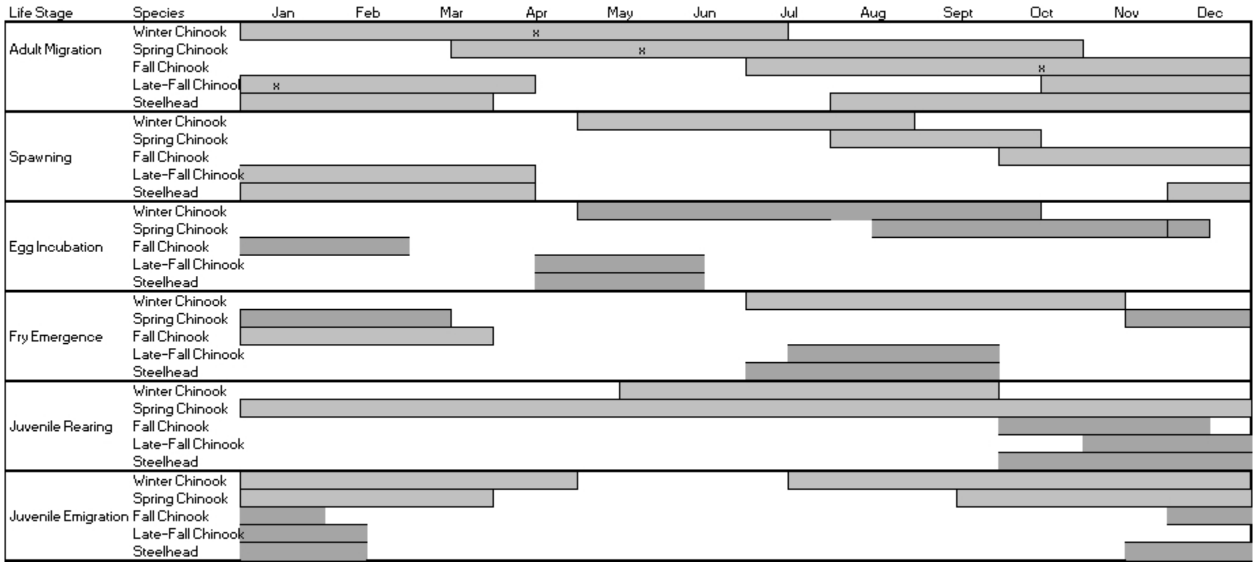
Species	Listing Status: Federal[1]	Listing Status: State[2]	Designated habitat[3]
Chinook salmon (winter-run) (*Oncorhynchus tshawytscha*)	FE	CE	EFH
Chinook salmon (spring-run) (*Oncorhynchus tshawytscha*)	FT	CT	EFH
Chinook salmon (fall/late fall-run) (*Oncorhynchus tshawytscha*)	FC	CSC	EFH
Central Valley steelhead (*Onorhynchus mykiss*)	FT	--	CH
Delta smelt (*Hypomesus transpacificus*)	FT	CT	CH
Green sturgeon- southern DPS (*Acipenser medirostris*)	FT	CSC	CH
Longfin smelt (*Spirinchus thaleichthys*)	FC	CT	--
River lamprey (*Lampetra ayresii*)	--	CSC	--
Hardhead (*Mylopharodon conocephalus*)	--	CSC	--
Pacific smelt (*Thaleichthys pacificus*)	FT	CSC	--
Sacramento perch (*Archoplites inrerruptus*)	[4]	CSC	--
Tidewater goby (*Eucyclogobius newberryi*)	FE	CSC	--
Rough sculpin (*Cottus asperrimus*)	--	CT; FP	--
Northern anchovy (*Engraulis mordax*)	--	--	EFH
Pacific sardine (*Sardinops sagax caerulea*)	--	--	EFH
Starry flounder (*Platichthys stellatus*)	--	--	EFH

[1]Federal Status: FE = Endangered, FT = Threatened, FC = Federal species of concern
[2]State Status: CE = Endangered, CT = Threatened, CSC = Species of special concern, FP = Fully protected
[3]Designated Habitat: CH = Critical habitat, EFH = Essential fish habitat
[4] Essentially extirpated from the Delta

Salmonids

There are five distinct populations of salmonids that utilize the Delta system: winter-run, spring-run, fall-run, late-fall-run, and CV steelhead. The life history characteristics that differentiate the populations include the time of year adults return to freshwater to spawn and state of sexual maturity upon arrival to natal streams. During any month of the calendar year, at least one life stage of at least one race can be found in the Sacramento River system (Table 2).

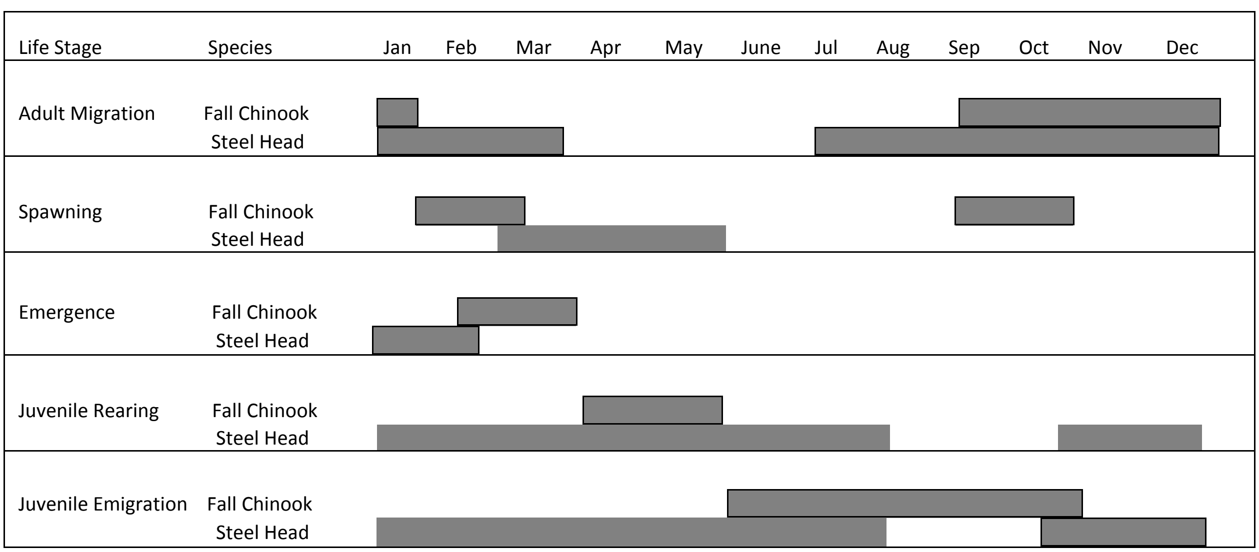
Table 2: Life stage occurrence of salmonids in the Sacramento River



Source: Jones & Stokes 2005,.

Chinook salmon that use the San Joaquin River basin exhibit a fall-run life history strategy (Yoshiyama and others 1998), which means adults migrate upstream from September through January and young of the year and juveniles migrate downstream and rear in the Delta from March through June (Moyle 2002; Yoshiyama and others 1998). CV steelhead adults are migrating into the San Joaquin River from July through March, and juveniles migrate downstream and rear in the Delta November through July (NMFS 2009 Public Draft Recovery Plan), with peak migration occurring in April and May (Table 3).

Table 3: Life stage occurrence of salmonids in the San Joaquin River



Note: These San Joaquin River Salmonid temporal occurrences are estimates and are subject to other variables such as fishery stock characteristics, hydrological conditions, local conditions, and water quality. (Brown 2012)

Salmonid Emigration through the Delta

Juvenile salmonid emigration through the Delta, which includes all runs of salmon and CV steelhead as noted previously, usually occurs during the fall, winter, and spring months, depending on the particular species and run (Vogel 2011). Emigration tends to occur in groups and pulses, and these pulses may correspond with increased flow events (Vogel 2011). For example, USFWS salmon research by Kjelson et al. (1982) and Vogel (1982, 1989) reported increased downstream movements of fry Chinook corresponding to increased river flows and turbidity, respectively.

There are many variables and consequent interactions associated with the migratory behavior of young salmon that are complex and not well understood (Kreeger and McNeil 1992). Abiotic factors, which may have primary influence on young salmon migration, include photoperiod/date, water temperature, and flow. Other abiotic or biotic factors which may affect migration include barometric pressure, turbidity, flooding, rainfall, wind, species, life history stage, degree of smoltification, parental origin (e.g., hatchery or wild), size of juveniles, location (e.g., distance from ocean), food availability, etc. (Burbner 1991, as cited by Vogel 2011).

Within the estuarine habitat, juvenile Chinook salmon movements are dictated by the tidal cycles, following the rising tide into shallow water habitats from the deeper main channels, and returning to the main channels when the tide recedes (Levy and Northcote 1982, Levings et al. 1986, Healey 1991). As juvenile Chinook salmon increase in length, they tend to school in the surface waters of the main and secondary channels and sloughs, following the tides into shallow water habitats to feed (Allen and Hassler 1986). In Suisun Marsh, Moyle et al. (1989) reported that Chinook salmon fry tend to remain close to the banks and vegetation, near protective cover, and in dead-end tidal channels. Kjelson et al. (1982) reported that juvenile Chinook salmon demonstrated a diel migration pattern, orienting themselves to near shore cover and structure during the day, but moving into more open, offshore waters at night. The fish also distributed themselves vertically in relation to ambient light. During the night, juveniles were distributed randomly in the water column, but would school up during the day into the upper 3 meters of the water column. Available data indicate that juvenile Chinook salmon use Suisun Marsh extensively both as a migratory pathway and rearing area as they move downstream to the Pacific Ocean.

Studies indicate that juvenile Chinook salmon spend about 40 days migrating through the Delta to the mouth of San Francisco Bay and grew little in length or weight until they reached the Gulf of the Farallones (MacFarlane and Norton 2002). Based on the mainly ocean-type life history observed (*i.e.*, fall-run), MacFarlane and Norton (2002) concluded that unlike other salmonid populations in the Pacific Northwest, Central Valley Chinook salmon show little estuarine dependence and may benefit from expedited ocean entry.

Delta Migration Routes

The Delta is a vast and complex system of channels and bypasses (Figure 7). As fish emigrate downstream in both the Sacramento and San Joaquin rivers, they are faced with multiple channels to choose from on their way to the Ocean. The pathways used by outmigrating juvenile anadromous fish from the river through the Delta are known to affect their survival. Each of these migration routes present unique characteristics that could be beneficial or detrimental to the survival and growth of juvenile fish (Vogel 2011).

For example, studies using coded-wire tagged fish have shown that juvenile salmon utilizing Steamboat Slough or Sutter Slough generally exhibit higher survival than fish exposed to the Delta Cross Channel (DCC) and Georgiana Slough (Kjelson 1989 as cited in Vogel 2011). Studies using coded-wire tagged fry- and smolt- sized Chinook salmon have demonstrated that fish survival is lower in the central Delta relative to the north Delta (Vogel 2011).

Adverse Effects on Salmonids

Migrating fish entering the central and south delta are exposed to a variety of adverse conditions that are likely to lower their survival rate. Studies of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) migration from the Sacramento River basin have shown loss rates of approximately 65% for fish entering the waterways of the interior and southern Delta, a considerably higher loss rate than for fish remaining in the main-stem Sacramento River (Perry 2010). Movement and/or diversion of these fish into the interior and southern Delta increases the likelihood of losses (i.e., mortality) through predation, entrainment into non-project Delta diversions, and mortality associated with the SWP and CVP pumping facilities in the south Delta (Perry 2010; NMFS 2009).

Additional information on life histories and other species of concern can be found in Appendix B.

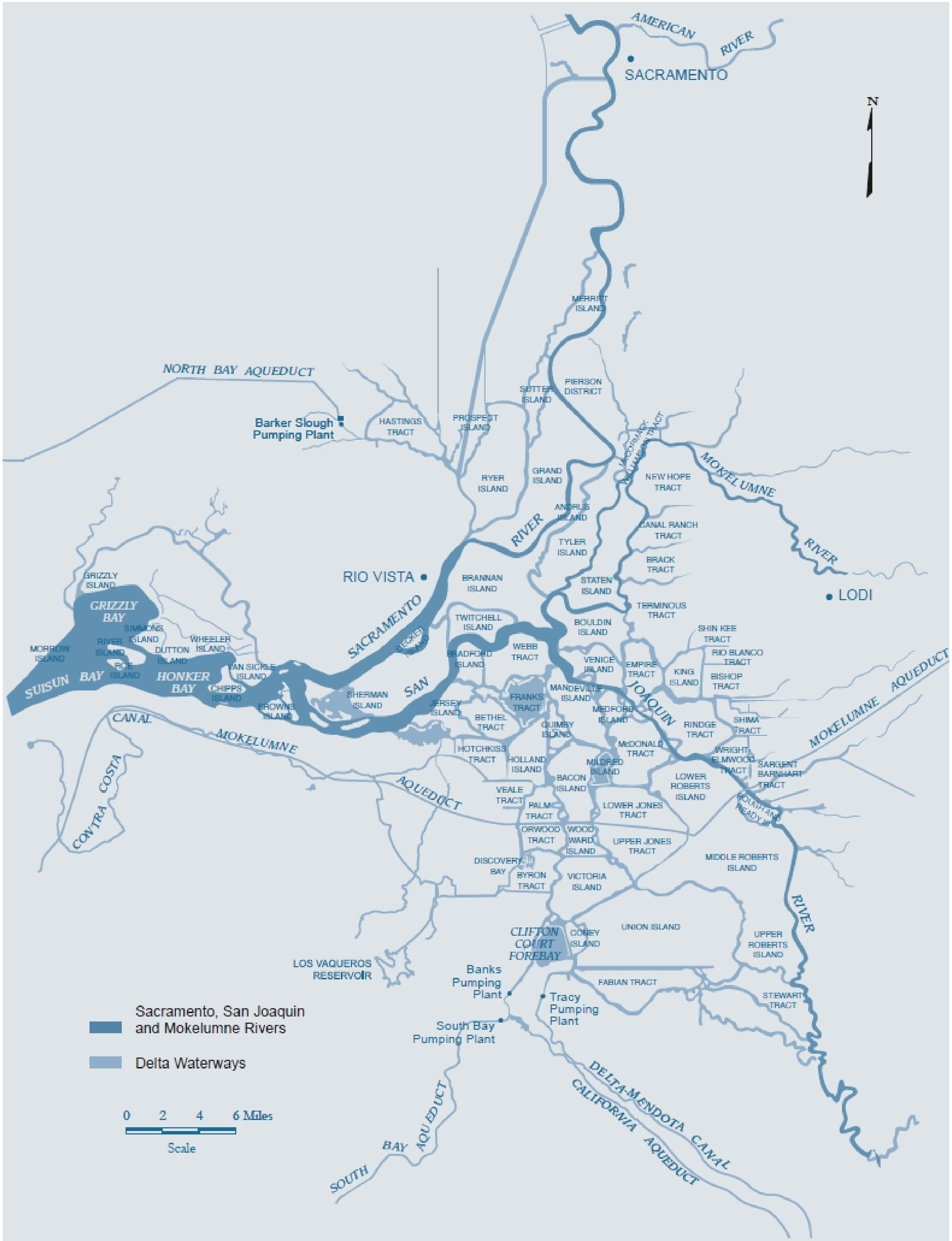


Figure 7: Sacramento San Joaquin Delta

Previous Engineering Solutions and Outcomes

This section describes previous studies conducted at Georgiana Slough, HOR, Columbia Cut, and Turner Cut project sites and studies reported in literature that provide information, outcomes, or knowledge used in this study.

Georgiana Slough Behavioral Barriers

Two types of behavioral barriers have been tested for use in controlling fish passage at the Georgiana Slough diversion point. One type used sound only and was tested in 1993-1996. The test of the second type, which uses lights, air bubbles, and sound, was recently completed. The associated reports are 1) Hanson, Charles H., Darryl Hayes, & Kevan A.F. Urquhart, 1997 Biological evaluations of the Georgiana Slough Experimental Acoustical Fish Barrier, Phases I-IV during 1993-1996; and 2) DWR, 2011 Georgiana Slough Non-Physical Barrier Performance Evaluation Project Report.

Non-Physical Barriers Acoustic Technologies

This section discusses various past non-physical acoustic technologies tested at Georgiana Slough.

1993-1996 Phases I-IV Biological Evaluations of Georgiana Slough

From 1993 to 1996, (Phases I through IV) tests were conducted at the divergence of the Sacramento River and Georgiana Slough to evaluate the effectiveness and feasibility of installing and operating an underwater acoustic sound system designed to deter juvenile salmon from entering Georgiana Slough without affecting flows, flood protection, water quality, or navigation. This project was planned and implemented through the IEP Fish Facilities Committee, which includes participation by DWR, NMFS, DFG, USFWS, USBR, San Luis & Delta-Mendota Water Authority, State Water Contractors (SWC), and support from Hanson Environmental, Inc.

The barrier utilized a proprietary acoustic sound system to influence the targeted fish species migration path. Evaluations of the barrier were based on results from Kodiak trawls of equal effort within the Sacramento River and Georgiana Slough when the barrier was on and off. Trawls were approximately 10-minutes in duration and were equipped with a rigid-framed live car to reduce capture and handling stress. Fish were held in water prior to processing and were released immediately after sample processing. All sample collection and processing activities were subject to periodic inspection by representatives of either the DFG or NMFS. The project objectives, descriptions, and results follow.

Phase I (1993)

Description: The Phase I acoustic barrier tests were performed from May - June, 1993. During the period of each weekly test sequence, the Delta Cross-Channel (DCC) remained closed. Flows within the Sacramento River (as measured at Freeport, about 15 miles upstream of the study site) were averaged at approximately 31,000 cfs during the study. Daily average flows, as measured at Freeport, ranged from approximately 19,000 to 55,000 cfs. The underwater acoustic array targeted Chinook salmon smolts with 10 to 12 transducers. The speakers were suspended at a depth of 6 ft from the surface. Sound levels ranged from 135 to 165 decibels (dBs) at 300 and 400 hertz (Hz) and sound levels were measured 24 and 36 ft from the array at depths of 3, 6, or 12 ft. Fish collections were made using two sampling techniques; 1) fixed location fyke nets, and 2) Kodiak trawls. Results of the Kodiak Trawl collections were normalized to account for variation in sampling effort (catch-per-unit-effort). Location and configuration of the acoustic barrier was modified weekly based on results of biological surveys and underwater mapping was performed to document the acoustic signal associated with the barrier.

Objectives:

- Test the feasibility of installing and operating an underwater acoustic guidance system,
- Measure the sound parameters of the resulting optimally-tuned array; and
- Determine whether specific fish sampling methods were effective at generating information suitable to develop an index of guidance efficiency; a means to measure the effectiveness of the barrier in keeping out-migrating salmon in the Sacramento River by preventing them from entering Georgiana Slough.

  The index of guidance efficiency was used to determine guidance efficiency of the acoustic signal. The index is defined as the ratio of mean catch-per-unit-of-effort (CPUE) of juvenile Chinook salmon collected in Georgiana Slough and downstream in the Sacramento River when the barrier was on and when it was off.

  Index of guidance efficiency = (1-(a/b))*100

  a = mean CPUE within Georgiana Slough when the barrier is on divided by the mean CPUE within the Sacramento River when the barrier is on.
  b = mean CPUE within Georgiana Slough when the barrier is off divided by the mean CPUE within the Sacramento River when the barrier is off.

Results:

- Installation and operation of the underwater guidance system may be an effective method for diverting fish from Georgiana Slough into Sacramento River.
- Kodiak trawls were found to be effective, but floating fyke nets were not found to be effective at collecting adequate information in developing an index of guidance efficiency.
- Salmon smolts were found throughout the water column with higher concentrations near the surface.
- The indices of guidance efficiency ranged from negative to positive. (Calculated guidance efficiency was not reported due to change in analysis procedures for future studies-Phase III planning documentation suggests a Phase I efficiency of at least 50%.)

Phase II (1994)

Description: Results from the Phase I study were encouraging but did not provide the necessary degree of replication to support precise statistical analysis calculations of absolute guidance efficiency, or detailed analyses on changes in the distribution pattern of juvenile Chinook salmon in response to acoustic barrier operations. Therefore, additional investigations were designed for the Phase II study to provide more comprehensive documentation on environmental conditions such as flow, velocity, and acoustic signal mapping. The Phase II acoustic barrier tests were performed from April - June 1994 and again from October - November 1994. The Phase I data was used to develop more robust analysis techniques and to refine barrier installation techniques in this phase of the study. The underwater acoustic array consisted of 21 transducers; the generated sound had the following characteristics:

- Background levels were 88-97 dB;
- Sound levels near the array were 130-150 dB at 300 or 400 Hz;
- Maximum sound levels were 160 dB at 300 Hz; and
- Elevated sound pressure levels could be detected up to ¼ mile from barrier.

Objectives:

- Further test the guidance efficiency of the barrier on fall-run Chinook salmon smolts.
- Evaluate potential blockage or delay in the upstream migration of adult Chinook salmon (fall- or late-fall-run); and
- Measure delayed effects of acoustic exposure on Chinook salmon smolts, striped bass, delta smelt, and other fish species produced by two different technologies, EESCO (300 & 400 Hz) and Sonalyst (10 Hz).

Results:

- Average barrier guidance efficiency was 57.2%.
- Daytime guidance efficiency was 58.5%.
- Nighttime guidance efficiency was 6.6% (very few fish collected so no firm conclusions were made).
- Guidance efficiency during ebb tides, 60%; flood tides, 39.2%.
- Acute and delayed mortality for adult fish did not change after exposure to the sound barrier.
- No evidence of changes in hatching success or increases in embryonic abnormalities was found in eggs exposed to the sound barrier.
- No evidence was found of increased susceptibility to predation.
- Potential blockage or delay in fish migration or movement.
- Trawl data suggested the possibility of up to a 24-hour delay in downstream smolt migration.
- Hydroacoustic tagged fish data suggested fish moved freely up and downstream through the area when the barrier was on.
- The direction of movement was tidally associated, not related to the barrier operation.

Phase III (1995)

Description: Additional field studies, similar to those conducted in Phase II, were planned for the spring and fall of 1995. High flows in the Sacramento River and equipment problems prevented the installation of the barrier during spring 1995. The Phase III acoustic barrier tests were performed from October to November 1995. Kodiak trawling was conducted 4 days per week, 10 hours per day, downstream of the barrier site in the Sacramento River and Georgiana Slough. The underwater acoustic array consisted of 21 transducers, and the generated sound has the following characteristics:

- Sound levels near the array were 140-153 dB at 300 Hz and 130-145 dB at 400 Hz.
- Maximum sound levels were 162 dB at 400 Hz; and
- Elevated sound pressure levels could be detected up to ¼ mile from barrier.

Objectives:

- Evaluate the potential for any adverse effects of acoustic signal exposure on delta smelt and Sacramento splittail egg development and hatching success.
- Evaluate the potential for increased susceptibility of juvenile fall-run Chinook salmon, juvenile striped bass, and other fish to predation by sub-adult striped bass after exposure to the acoustic signal.
- Evaluate the potential for acute and delayed mortality on adult delta smelt, and both juvenile and adult Sacramento splittail as a result of exposure to the acoustic signal.
- Thoroughly evaluate potential blockage or delays in the migration of adult fall-run Chinook salmon to expand on Phase II results.

Results:

- No evidence of increased acute or delayed mortality was found in larvae exposed to the sound barrier.
- The predation studies this year were not successful, no conclusions were made.
- Possibility of increased milling behavior.
- The barrier had no effect on upstream migrating fish.
- Overall (all fish transits): It is estimated there may be up to a 9 minute delay in fish transit time.
- Available literature suggests a delay of less than an hour will have no effect on spawning success.

Phase IV (1996)

Description: The Phase IV study plan was developed based upon the findings of the previous three phases. The study was conducted from April - June 1996. The underwater acoustic array consisted of 21 transducers, but was reduced to 18 after the original array was damaged by a submerged tree; the generated sound characteristics were not summarized in this report.

Objectives:

- Measure the effects of the acoustic barrier on the guidance efficiency of juvenile fall-run Chinook salmon under higher flows than occurred in 1994.
- Re-evaluate the potential for the barrier to cause delays in the out-migration of juvenile Chinook salmon observed in the spring of 1994.

Results:

- Average guidance efficiency was 15%.
- No evidence of fish passage delay was found.

2011 Georgiana Slough Bio-Acoustic Fish Fence Pilot Study

Description: DWR installed a non-physical barrier consisting of a Bio-Acoustic Fish Fence (BAFF) at the divergence of Georgiana Slough and the Sacramento River from March to May 2011. The experimental tests were conducted to provide data to support the feasibility study and subsequent field testing required under the Action. The year 2011 was the first year of a possible multiyear evaluation of the barrier. The barrier was intended to create a behavioral deterrent for out-migrating juvenile salmonids to prevent entry to Georgiana Slough using sound, bubbles, and lights. Acoustic tag tracking systems were continuously monitoring the area surrounding the barrier for fish presence, position, and passage through the area. Juvenile late fall-run Chinook salmon produced in the USFWS Coleman National Fish Hatchery were used in the 2011 study.

The barrier employs the same technology that was used in 2009 and 2010 at the HOR non-physical barrier. The 2011 BAFF was approximately 630 ft long, with 15 piles and 16 separate frame sections each about 39 ft in length. Approximately 30 hydrophones were deployed in the Sacramento River and Georgiana Slough to receive the acoustic “ping” from the tagged fish. In order to evaluate the efficacy of the barrier as a fish deterrent at this location, during barrier operation, 1,500 controlled releases of acoustically-tagged juvenile salmon smolts were released approximately 6 miles upstream of Georgiana Slough near the divergence of Steam Boat Slough.

Objectives:

- Provide data to support the feasibility study and subsequent field testing required under the Action.
- Evaluate barrier fish deterrence efficiency at the Georgiana Slough.

Results:

Results of the study for an operating and non-operating BAFF condition showed:

- Percentage reduction of salmon smolts passing into Georgiana Slough from 22.1% (BAFF Off) to 7.4% (BAFF On), a reduction of approximately two-thirds

- Overall efficiency of 90.8%, i.e., 90.8% of fish that entered the area when the BAFF was on exited by continuing down the Sacramento River

- Based on the similarity between estimates of protection and overall efficiency, the effects of predation on juvenile salmon in the study area were low.

- The location of the fish in the cross section was the most important driver of an individual fish’s probability of entrainment into Georgiana Slough at higher discharges.

A similar study was conducted in 2012 and a study report is expected to be completed in 2013.

Temporary Rock Barrier

Description: DWR intended to install a Temporary Rock Barrier at the Head of Georgiana Slough from February to April 1993. An Initial Study and Mitigated Negative Declaration was completed and released in August 1992. The proposed barrier was composed of sand, gravel, and quarry rock of graded size to provide structural stability and adequate resistance to seepage flow, and was erodible if overtopped during a flood. The proposed barrier had a trapezoidal cross section, a crest elevation of about 11 ft, a top width of about 10 ft, a bottom width of about 150 ft, a side slope of about 2:1, and was comprised of about 8,000 cubic yard of material.

Objectives:

- Improve survival of the out-migrating winter-run Chinook salmon smolts.
- Collect data concerning the effects of the barrier on fish, water flows, and water quality.
- Evaluate barrier construction techniques.

Results:

The proposed study was not implemented due to:

- Potential adverse effect on water quality within the slough and South Delta.
- Potential effect on natural flow patterns, levee stability, and flood control.
- Concerns with upstream migration of adult fish.
- Potential boating and recreational hazards.

Head of Old River Behavioral Barriers

Two types of behavioral barriers have been tested over the years for use in controlling fish passage at the HOR diversion point. They are 1) a rock barrier and 2) a non-physical barrier consisting of lights, air bubbles, and sound.

Rock Barriers

1963-2008 South Delta Temporary Barriers Project

Description: The use of temporary barriers in the south Delta began with the installation of a control structure at the head of Old River in fall 1963 to increase dissolved oxygen levels in the San Joaquin River and improve conditions for migrating adult salmon. In 1987, DWR began to install rock barriers in south Delta channels to improve conditions for agricultural diversions. Collectively, these barriers became the South Delta Temporary Barriers Project (TBP). The objectives of the project are to increase water levels, improve water circulation patterns and water quality in the southern Delta for local agricultural diversions, and improve fish conditions. The project consists of the construction, operation, and monitoring of four temporary rock fill barriers. Three of the barriers are located in three south Delta channels (Grant Line Canal, Old River, and Middle River) and mainly operated during the agricultural season, usually April though November. They are designed as a short-term solution to improve water level and circulation patterns for agricultural users and to collect data for the design of permanent barriers. The fourth barrier is located at the HOR.

The HOR rock barrier is installed each spring as a method to prevent juvenile fall-run Chinook salmon and juvenile CV steelhead from leaving the main stem of the San Joaquin River during their migration downstream to the ocean and entering the Old River channel, which leads toward the CVP and SWP export facilities. The HOR barrier (HORB) is also installed in the fall to increase water quality downstream in the San Joaquin River by increasing flow into the Stockton Deep Water Ship Channel and increasing dissolved oxygen for migrating adult salmon.

The fall HORB has been put in place most years since 1963. The TBP began in 1991. Under the TBP, the barrier was also installed in the spring between April and May of 1992, 1994, 1996, 1997, 2000, 2001, 2002, 2003, 2004, and 2007 (high San Joaquin River flows prohibited installation in 1993, 1995, 1998, 1999, 2005, and 2006). In 2008, the spring HORB was not installed due to a court decision by U.S. District Court Judge Wanger to increase protections for delta smelt. However, the fall HORB installation was not affected by this court decision.

The HORB installation and removal dates are based on the U.S. Army Corps of Engineers (USACE) 404 Permit, the DFG 1601 Permit, and various Temporary Entry Permits required from landowners and local reclamation districts. Flow and water year types potentially have an effect on the barrier installation and removal as well. The current design of the spring barrier is a rock barrier with eight 48-inch operable culverts. It is approximately 225 ft long, 85 ft wide at the base of the barrier, has a crest elevation of 12.3 ft North American Vertical Datum of 1988 (NAVD88), and is composed of approximately 12,500 tons of rock. There is a 75-ft notch protected with concrete grid mats and back filled with clay at an elevation of 8.3 ft to accommodate high river flows. The fall barrier is similar in design but smaller in size. It is constructed with six 48-inch operable culverts and a 20-foot notch at an elevation of 2.3 ft. It is approximately 225 ft long, 55 ft wide at the base of the barrier, has a crest elevation of 8.3 ft , and it is composed of approximately 7,500 tons of rock.

In 1997, the South Delta Water Agency (SDWA) expressed concern about water volume and quality in upper Old River due to the installation of the spring HORB. To address this concern, the DWR requested authorization from the DFG, through section 1601 of the Fish and Game Code, to modify the existing spring HORB design and install two 48-inch culverts. The DFG, USFWS, and NMFS agreed to the modification with the provision that DFG would monitor fish entrainment through the newly installed culverts.

In 2000, DWR again modified the spring HORB to include six 48-inch gated culverts. The culverts allow a minimum flow of approximately 500 cfs to flow through the barrier and down Old River. The culvert gates were operated to meet water level needs of the SDWA. In 2001, the spring HORB was modified with trash racks to control the amount of debris flowing into the culverts. These racks were small enough to stop most debris from entering the culverts but large enough to allow the passage of Chinook salmon smolts. The design of the spring HORB had not changed since 2001 until 2012 when NMFS requested an additional two culverts be added, bringing the total to eight, to improve flows into the south Delta and reduce risk of delta smelt entrainment at the CVP and SWP pumping facilities. Prior to 2012, the last time the HORB rock barrier was installed was in 2007. The 2007 barrier was assembled with six culverts that were gated and operated to address water level concerns of the SDWA. A 2007 study was designed to increase our understanding of salmon entrainment at the spring HORB and help develop operational scenarios to minimize the impacts to out-migrating salmon and other species of concern. Because the culverts were not screened, juvenile Chinook salmon and other fish species that pass near the culverts were vulnerable to entrainment. DFG designed and implemented a fish monitoring program to evaluate and quantify fish entrainment at the spring HORB.

Objectives:

- Increase water levels, circulation patterns, and water quality in the south Delta for agricultural purposes.
- Improve operational flexibility of the State Water Project to help reduce fish impacts and improve fish conditions.
- Collect baseline data for use in the design of the permanent barriers and for its future use as a reference in permanent barrier operations.

Results:

- The TBP has proved an effective means for maintaining sufficient water levels for agricultural diversions upstream of the barriers under most tidal and water demand conditions.
- The HOR rock barrier effectively protects out-migrating salmon and steelhead juveniles from being diverted down Old River into the south Delta channels where they would be exposed to CVP and SWP export facilities and numerous agricultural diversions.
- The agricultural barriers improve circulation in the south Delta channels, potentially reducing the number of localized poor water quality areas.
- The TBP operations have improved the operation flexibility of the CVP and SWP, providing for additional water supply opportunities.

Non-Physical Barriers Acoustic Technologies

2009-2010 Non-Physical Barrier

Description: In 2008, 2009 and 2010, the rock barrier at the HOR was not installed. However, DWR worked in coordination with USBR to design, implement, and monitor a type of non-physical barrier called the Bio-Acoustic Fish Fence (BAFF) at the HOR. This was done to evaluate barrier efficacy in deterring fish from traveling down Old River from the confluence of the San Joaquin River and Old River using sound, bubbles, and lights. During 2009 and 2010 the BAFF was installed and tested on the San Joaquin River where Old River diverges from the San Joaquin River. The study was conducted throughout the Vernalis Adaptive Management Plan (VAMP) period from April to May. The monitoring of the BAFF was conducted by USBR and DWR in cooperation with the VAMP team.

In 2009, the length of the barrier was approximately 367 ft and was oriented at a 24 degree angle eastward from the point of origin on the San Joaquin River west shore. The barrier was comprised of 17 separate sections supported by two piles, and 68 sound projectors. To monitor the acoustic tags implanted in the juvenile Chinook salmon, 4 hydrophones were deployed to provide for 2D tracking in the vicinity of the barrier. Each hydrophone was connected by cable to the 4-port receiver. The VAMP team released 947 Chinook salmon smolts with inserted acoustic transmitters. These fish were released in seven groups upstream of the barrier at Durham Ferry. There were approximately 135 Chinook smolts per release.

In 2010, the barrier had the same deterrence components but was longer at approximately 446 ft and had a 30 degree angle eastward at the origin. The VAMP team released 508 Chinook salmon smolts with inserted acoustic transmitters during April and May, 2010. These fish were also released in seven groups upstream of the HOR at Durham Ferry.

Objectives:

- Evaluate barrier fish deterrence efficiency at the HOR.
- Collect and evaluate data to determine how water flows, water quality, and other environmental variables affect BAFF effectiveness.

Results:

Results are based on the 2009 and 2010 draft reports. Data from the 2009 and 2010 studies are being evaluated.

- In 2009 and 2010 the BAFF did not impede flow down Old River and therefore allows positive downstream flow contributing to Old-Middle River flows.
- The predation rates before arriving at the BAFF ranged from 25.2% to 61.6% in 2009, and from 2.8% to 30.9% in 2010 for each release group. Predation rates in the area of the BAFF ranged from 11.8% to 40.0% in 2009, and from 16.9% to 37.0% in 2010.
- 2009 high predation rates were likely a function of the dry year in the San Joaquin River, the BAFF angle, and the presence of predators in the area of the BAFF.
- The grand Deterrence Efficiency when the barrier was active was 81.4% in 2009 and 23% in 2010.

  Deterrence Efficiency is the total number of fish deterred, summing all seven releases, divided by the sum of all fish for which the response could be determined.

  Deterrence Efficiency is calculated as:

  D = E/(E+U) x 100

  D = Deterrence Efficiency,
  E = number of fish deterred, and
  U = number of fish undeterred.

- The grand Protection Efficiency when the barrier was on was 30.9% in 2009 and 43.1% in 2010.

  Protection Efficiency is the total percentage of acoustic-tagged fish that moved through the area and continued downstream.

  Protection Efficiency is calculated as:

  P = S/(S+O) x 100

  P = Protection Efficiency,
  S = number of fish passing down into the San Joaquin River, and
  O = number of fish passing down into the Old River.

South Delta Improvement Program

The South Delta Improvement Program (SDIP) was designed to improve water levels and water quality, protect out-migrating salmon, and increase the allowable pumping limit of the SWP. It was to be implemented in two stages with increasing the allowable pumping limit as the second stage. A final environmental impact statement/environmental impact report (EIS/EIR) for the SDIP was issued in December 2006.

In Stage 1, the temporary rock barriers installed under the TBP (see **Rock Barriers**) would be replaced with permanent operable gates. The gate at the HOR would be operated to keep migrating fish in the San Joaquin River. All of the gate structures would be bottom-hinged lift gates using a water-filled bladder system to raise and lower the gate. This design would provide operational flexibility and be an efficient and effective way to protect migrating salmon and meet water needs for local agriculture.

Prior to DWR obtaining necessary permits for the SDIP, NMFS issued its 2009 *Biological Opinion and Conference Opinion on the Long-Term Operations Of The Central Valley Project And State Water Project* (BiOp). The BiOp directed DWR to not implement the SDIP. Per the BiOp, DWR may seek permitting for the SDIP after completion of three years of fish predation studies at the south Delta temporary barriers. These studies have been completed but data analysis continues. NMFS is expected to review the study results when available and DWR and Reclamation will consider preparing a request to re-consult.

Turner Cut

No known technologies or studies have been implemented at the Turner Cut study location site thus far.

Columbia Cut

No known technologies or studies have been implemented at the Columbia Cut study location site thus far.

Threemile Slough

The Franks Tract Project is designed to protect fish resources and reduce seawater salinity intrusion into the Delta. DWR and Reclamation are evaluating installing operable gates to control the flow of water at key locations (Threemile Slough and/or West False River) to limit the entry of higher salinity water into Franks Tract. In addition to improving water quality, the gates would be operated to encourage movement of fish species of concern away from the central and south Delta where their survival rates are reduced to areas that provide more favorable habitat conditions. By protecting fish resources, this project is also expected to improve operational reliability of the SWP and CVP because curtailments in water exports (pumping restrictions) likely would be less frequent.

The project gates would be operated seasonally and during certain hours of the day, depending on fisheries and tidal conditions. Boat passage facilities would be included to allow for passing of watercraft when the gates are in operation. The Franks Tract Project is consistent with ongoing planning efforts for the Delta to help balance competing uses and create a more sustainable system for the future. Various project study reports have been completed including an Initial Alternatives Information Report for the North/Central Delta Improvement Study (Delta Cross Channel, Franks Tract, and Through-Delta Facility Evaluation) (Reclamation 2010). This report identifies two alternatives to be carried forward for further analysis: an operable gate on Threemile Slough and an operable gate on West False River. Further work on the project has been delayed. (Reclamation 2010).

Engineering Options to Consider

This section presents the engineering options that will be evaluated during Phase II of the study.

Non-Physical Barrier

A NPB is a fish deterrence system that is made up of components that are known to influence fish behavior while minimizing flow obstruction in a waterway. Some components, or stimuli, of a NPB can include lights, sound, vibration, electricity, and bubbles (Figure 8). These components may be used in a stand-alone fashion or in a multitude of different combinations. The combination that is chosen depends on the species of fish and other site-specific variables. Fish behavior upon contact with the stimuli depends on the species and their current life stage.

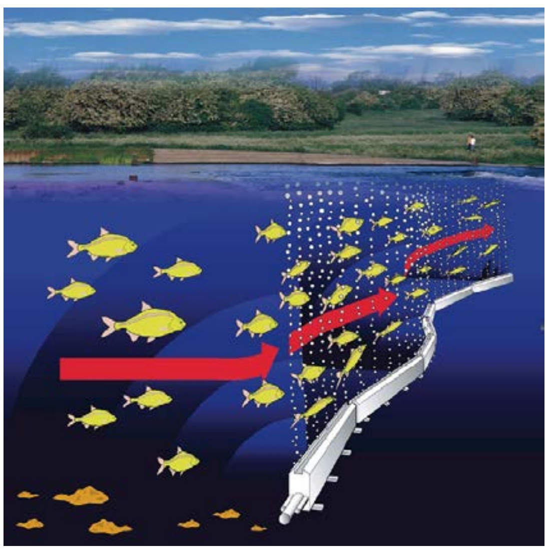


Figure 8: NPB Image Depicting Fish Deterrence (Source: Ovivo)

DWR, through the Bay-Delta Office, implemented a pilot NPB study in 2011 and 2012 (as discussed under **Previous Engineering Solutions and Outcomes**) at the convergence of the Sacramento River and Georgiana Slough. The system that was deployed at this location was composed of sound, lights, and a bubble curtain. The NPB's purpose was to keep juvenile out-migrating salmonids in the Sacramento River while preserving the natural flow. The 2011 study report is final and preliminary analysis of the 2012 collected data shows positive results, although a more detailed analysis is underway.

DWR has also implemented a NPB at the convergence of the San Joaquin River and the Head of Old River. This barrier was used during the spring of 2009 and 2010 and was also composed of sound, lights, and a bubble curtain. The NPB's purpose was to keep juvenile out-migrating salmonids in the San Joaquin River while preserving the natural flow. Initial results of the two years of studies were discussed under **Previous Engineering Solutions and Outcomes**. An additional year of study was considered in 2011 but did not occur due to high flows that prevented installation of the barrier. Figure 9 shows preparation of the NPB frame before placement.

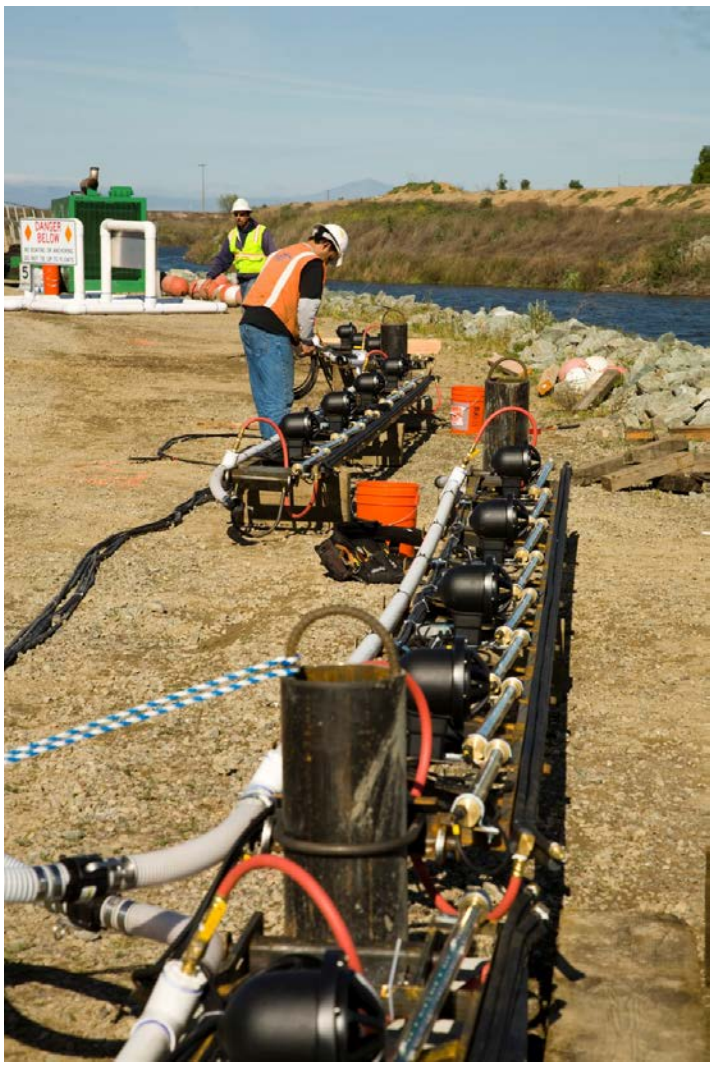


Figure 9: Head of Old River NPB Preparation

Electric Barrier/Guidance System

An electrical fish guidance system is another option that may prevent juvenile salmonid entrainment into the interior and southern Delta. With this system, two or more probes are submersed in the waterway and short pulses of DC voltage are applied between the probes to deter fish. The current that flows through this electrical field, in theory, causes a sensation of pins and needles in the fish, and repels it away from the electrical field and toward a safer waterway. Flows can be an important variable in the type of response created by this type of downstream fish guidance system. Studies have shown that velocities of at least one to two fish body lengths per second, at the approach to the electrical field, is best in creating the desired response. The velocity in the desired downstream waterway is also an important factor in a successful system. Velocities of one to two feet per second are desirable in the downstream bypass to help ensure that the fish do not reject their new path.

As seen in Figure 10, this type of system has been used in California rivers in the past. This image shows a portable electrical fish guidance array at the confluence of the San Joaquin River and the Merced River. This system was put in place to guide immigrating adult salmon into the Merced River where the water quality and spawning environment is better.

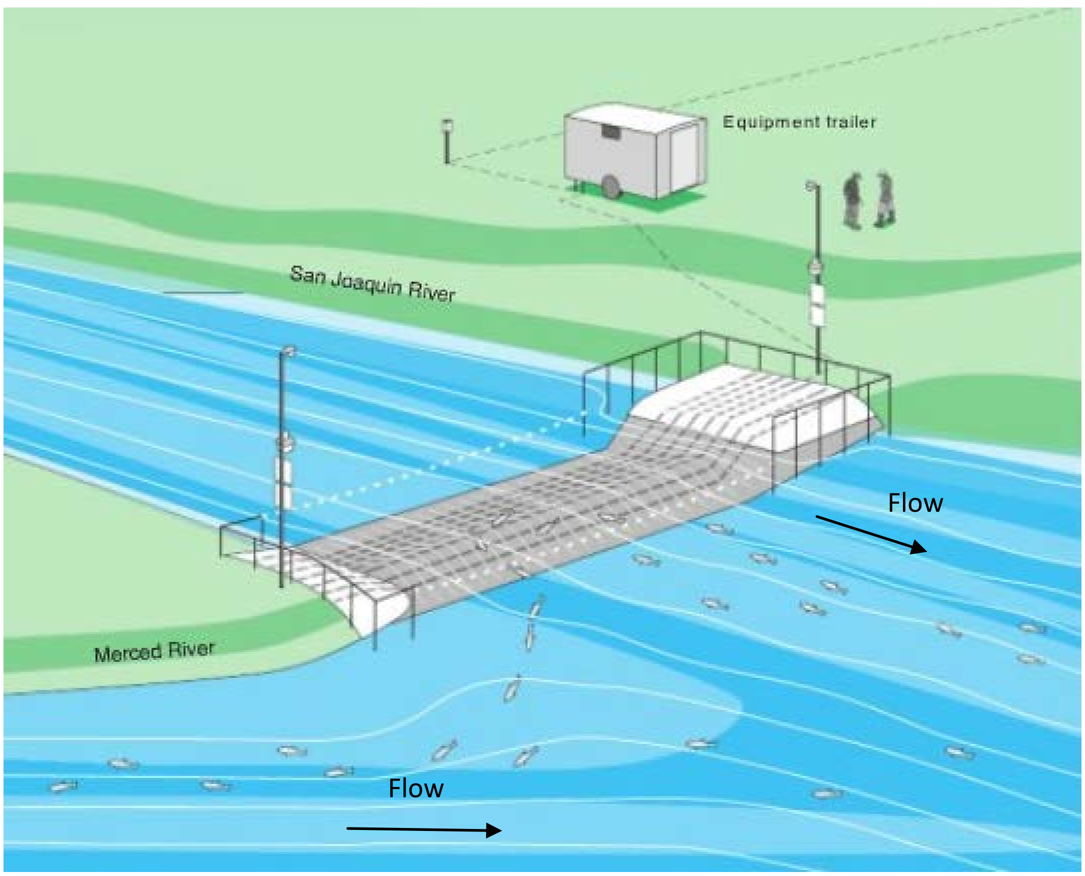


Figure 10: Portable Array from Smith-Root's Fish Barriers and Guidance

Fish Screen

Fish screens are positive barrier devices that guide fish to a safe area while allowing water to pass through. Polymers or noncorrosive metal is typically used as the screening material. A wide variety of designs have been used for fish protection, which is determined by species, life stage, hydraulics, and other site specific conditions. DFG, along with the NMFS, have created a set of guidelines and criteria that are aimed at providing fish with a safe transition through the screening process. Some of the criteria set forth by these agencies address issues such as structure placement, approach velocity, sweeping velocity, screen opening dimensions, and other construction and operational concerns. Figure 11 shows an example of a screen face.

The various types of fish screens include fixed vertical plate screens, vertical traveling screens (belt and panel), non-vertical fixed plate screens, and horizontal fixed plate screens. The traveling screen systems have the advantage of debris shedding. As the belt or panel travels to the downstream side of the system, debris is washed away from the screen. The screen depth and area of coverage depends on the geometry of the waterway and the limitations of the system's components. Fish screens are typically used in areas where the flows and velocities are relatively predictable and consistent.

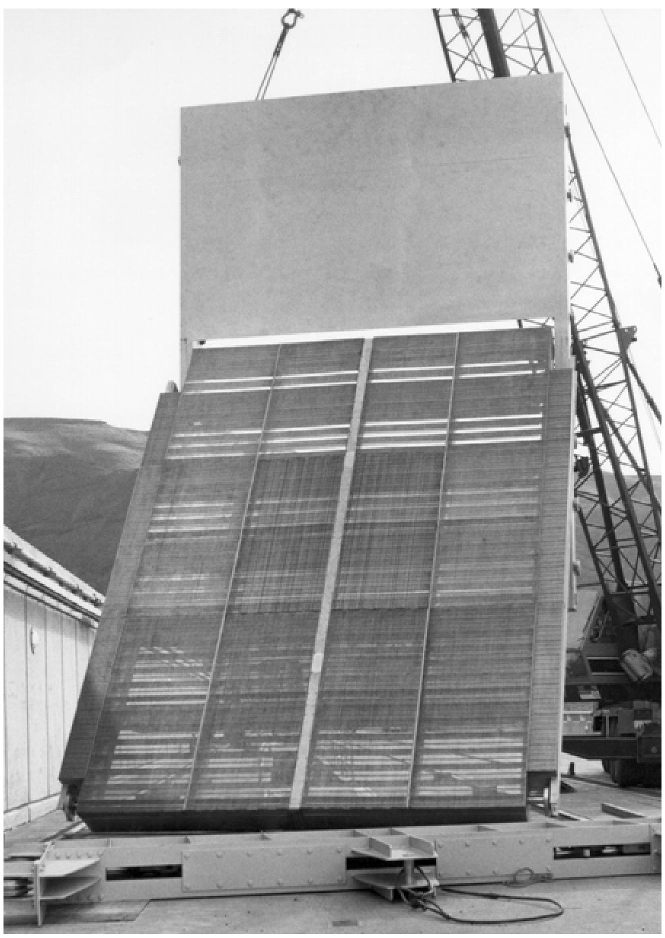


Figure 11: Photo of a Screen Panel from Hedrick Screen Company

Gate Structure — Bottom Hinged Overflow and Sluice Gate

A bottom hinged overflow gate is a controllable system that is capable of adjusting to different ranges of flow, water elevations, and other project specific variables. The gate structure works by lifting a steel gate with an inflatable rubber bladder (Figure 12). The gate is hinged on the upstream side of the channel where the bottom of the gate and the channel floor meet. In the closed position, the entire gate is flush with the bottom of the waterway, maintaining the existing hydraulic profile. When the gate is opened, the bladder is filled with compressed gasses, which push the gate up from the bottom of the channel. The bladder is typically protected by steel panels on all sides to ensure protection from harmful objects. A wide variety of control systems may be used, depending on the design of the gate and existing site conditions. This type of system can provide a constant upstream water level, constant downstream flow, or a combination of both. A multi-sectional design could be used in cases where fish guidance and/or fish passage is a concern.

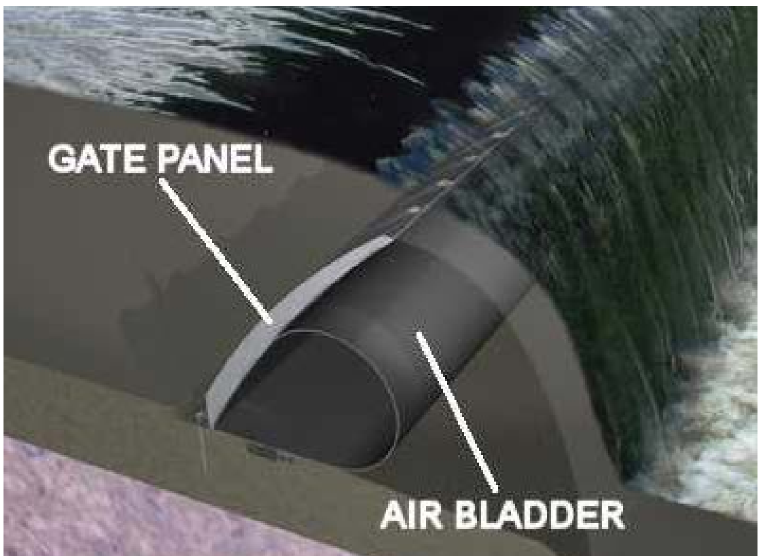


Figure 12: Obermeyer Spillway Gate

As an engineering solution concerning fish migration issues, this gate could be used as a stand-alone option, or used in conjunction with other engineering solutions. A wide range of designs and operations could be possible depending on different individual site locations and needs. A hybrid version of this system was designed for the SDIP. A boat lock and a vertical slot fishway were incorporated into the design to provide navigational and fish passage.

This type of gate structure has been used around the world for many different reasons. Flood control, recreational and drinking water storage, water quality assurance, and fish guidance are some of the applicable uses for this type of system.

The underflow or sluice gate type of system is another potential engineering solution to address fish emigration issues. This type of system has many varieties, and can be used in multiple applications. The operation of the underflow gate, compared to the overflow gate, provides for water passing under the structure instead of flowing over the top of the structure. An underflow gate can provide a physical diversion in the top portion of the water column while keeping the bottom portion open for adult salmon, sturgeon, and other species to pass. This feature may be ideal for out-migrating juvenile salmon because they tend to travel in the upper portions of the water column. Also, allowing water to pass through the system can help preserve the natural flow of the river.

Figure 13: Sluice Gate with Multiple Panels

A wide variety of systems can be designed depending upon channel width, hydraulics, and other site specific challenges. A simple bulkhead, secured by piles along the alignment of the diversion and on either side of the waterway, is an example of a simple underflow design option. A system that contains multiple gates, as shown in Figure 13, is another option to consider. The sluice gate or underflow approach can be combined with other systems in order to best fit the needs of the habitat.

Radial Arm Gate

Radial arm gates provide a positive barrier system that can be lowered and raised to specific elevations in order to meet environmental and water resource needs. This type of system could physically divert fish away from areas of concern. A cable and drum hoist system is typically used in the opening and closing of the gates (Figure 14). The gate's face, which is fabricated with a radius specific to the conditions, is connected to support arms and pivots around a secured pin. Motorized or manual operations are used depending on the size, accessibility, and weight of the gates.

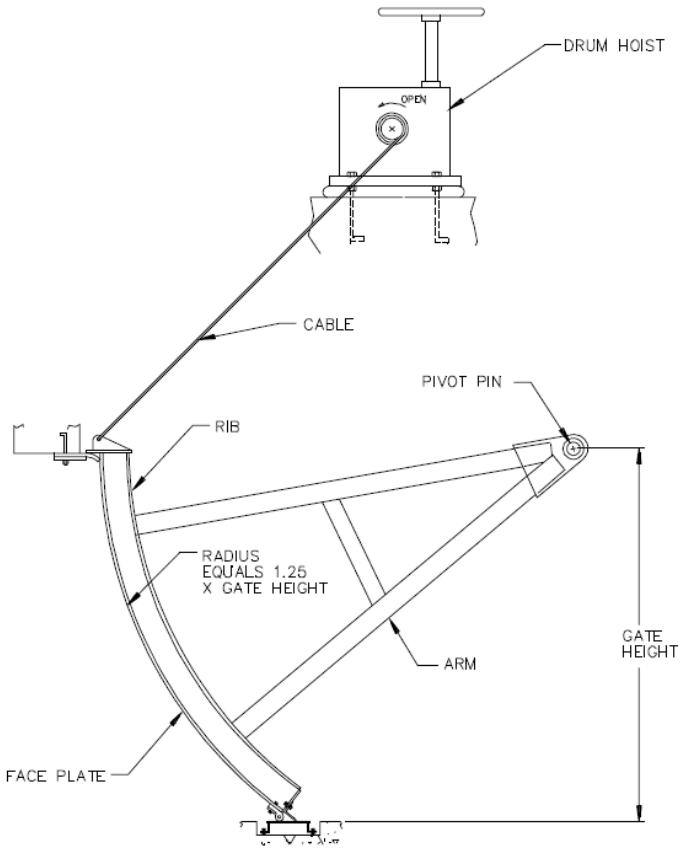


Figure 14: Typical Radial Arm Gate System

The DCC gates are an example of a radial arm gate system (Figure 15). The DCC was constructed in 1951 and is used to divert water from the Sacramento River to the San Joaquin and Mokelumne Rivers. The DCC uses two radial arm gates to control the flow. This gate system is either completely open, or completely closed, in order to avoid excessive forces on the gate's face due to potentially high flows.

Figure 15: DCC Radial Arm Gates (Photo Courtesy: U.S. Bureau of Reclamation**)**

Floating Barrier — Fish Guidance System

Floating barrier systems are an option to consider when exploring possible engineering solutions for juvenile salmonid emigration issues in the Delta. This type of system is designed to minimize entrainment, reduce stress on the fish, reduce mortality, and ultimately aid in a successful negotiation through the area of concern. The system utilizes fish behavior and hydrodynamics to effectively guide fish away from hazardous areas.

The physical barrier is typically made up of cylindrical flotation devices that are connected in a continuous chain-like fashion (shown in Figure 16), which makes it relatively easy to shorten or lengthen the barrier. This type of connection also makes it possible to create a nonlinear barrier design if the need arises. Installation and removal of this type of system is simple and practical. Slotted panels, typically made from corrosion resistant metal, hang from the floatation devices. The panels act as the physical barrier for the species of concern.

Design specifications such as the panel slotting dimensions, depth, and orientation of the system itself are all predetermined by species-specific fisheries studies. The design configuration also depends on hydraulics, geometry of the waterway, and other site specific challenges. The system is anchored at the banks of the channel and/or the bottom of the channel, to ensure design and structural integrity. This type of system is being used at Cowlitz Falls Dam in Washington State where there are water velocities up to 9 ft/s.

Figure 16: Three-piece Floating Barrier/Fish Guidance System

Floating barriers are being used in many different applications worldwide, and for many different reasons, such as safety, debris containment, and fish guidance. Examples of some safety applications are hazard identification, boating proximity to intake facilities, and anti-terrorist security fences. Floating barrier systems have been designed to contain various types of debris, including logs, ice, vegetation, and other intrusive and unwanted objects.

DFG, along with the NMFS, have created a set of guidelines and criteria aimed at providing fish with a safe transition through the screening process. Some of the criteria set forth by these agencies address issues such as structure placement, approach velocity, sweeping velocity, screen opening dimensions, and other construction and operational concerns. These guidelines and criteria would need to be addressed in any floating barrier system design.

As a fish guidance system, the floating barriers have been used in both small and large projects. For example, the USACE used a floating fish guidance system at Bonneville Dam on the Columbia River (Figure 17). This system was designed to keep migrating salmon and steelhead out of the intakes and divert them toward the fish ladder. A study of this facility reports guidance percentages between 64 to 85 percent for salmon and steelhead. Guidance percentages for steelhead have been reported as high as 92 percent at the Lower Granite Dam in Washington.

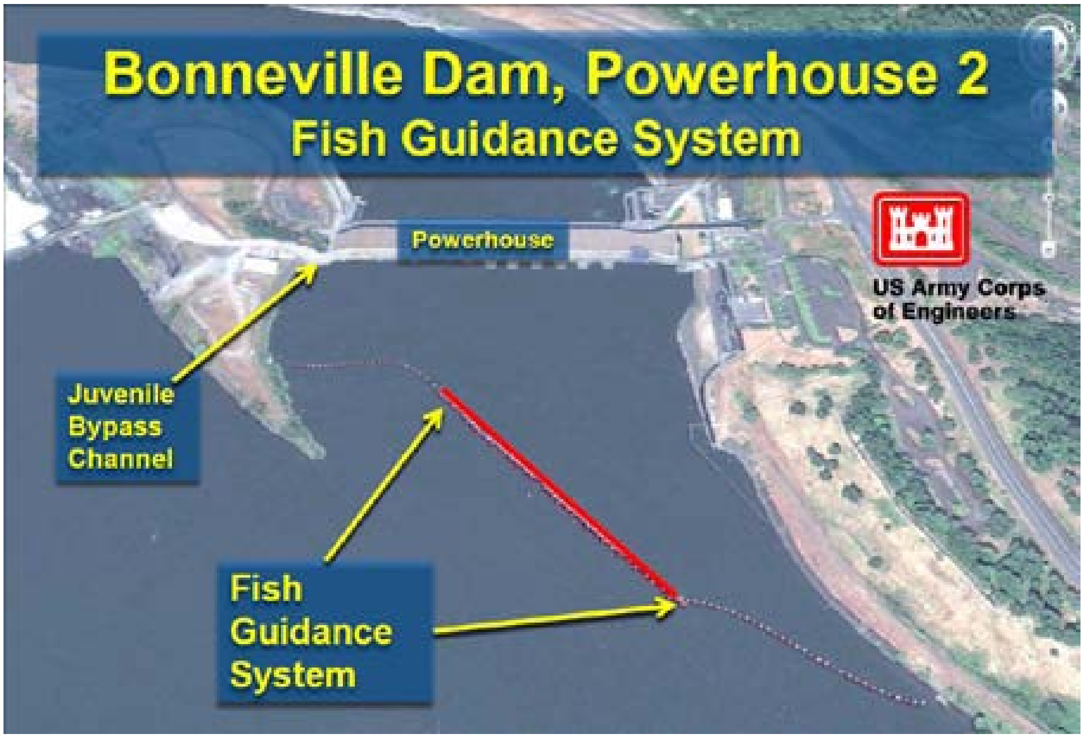


Figure 17: Bonneville Dam Fish Guidance System for USACE

Note: Both images used in this section where taken from, with permission by phone, a report written by Shane Scott. The report is titled *A Positive Barrier Fish Guidance System Designed to Improve Safe Downstream Passage of Anadromous Fish, 2011*.

Fish Guidance Wall

The fish guidance wall is a simple concept using a physical barrier, made from a noncorrosive material that could be placed in the river or stream in order to divert fish away from the area of concern (Figure 18). The wall could be strategically placed in the waterway in order to optimize diversion, minimize stress on the fish, provide boaters with sufficient passage and safety, and minimize affects to the natural flow of the water. Multiple walls could be placed around the divergence area in the case of reverse flows or other variable hydraulic situations. Depending on specific site challenges, many different arrangements could be deployed. This type of system would be relatively easy to install, and in cases where only seasonal deployment is required, it would also be easy to remove. Similar to most of the other optional engineering solutions, this idea could be incorporated into many different combinations or hybrid-type systems.

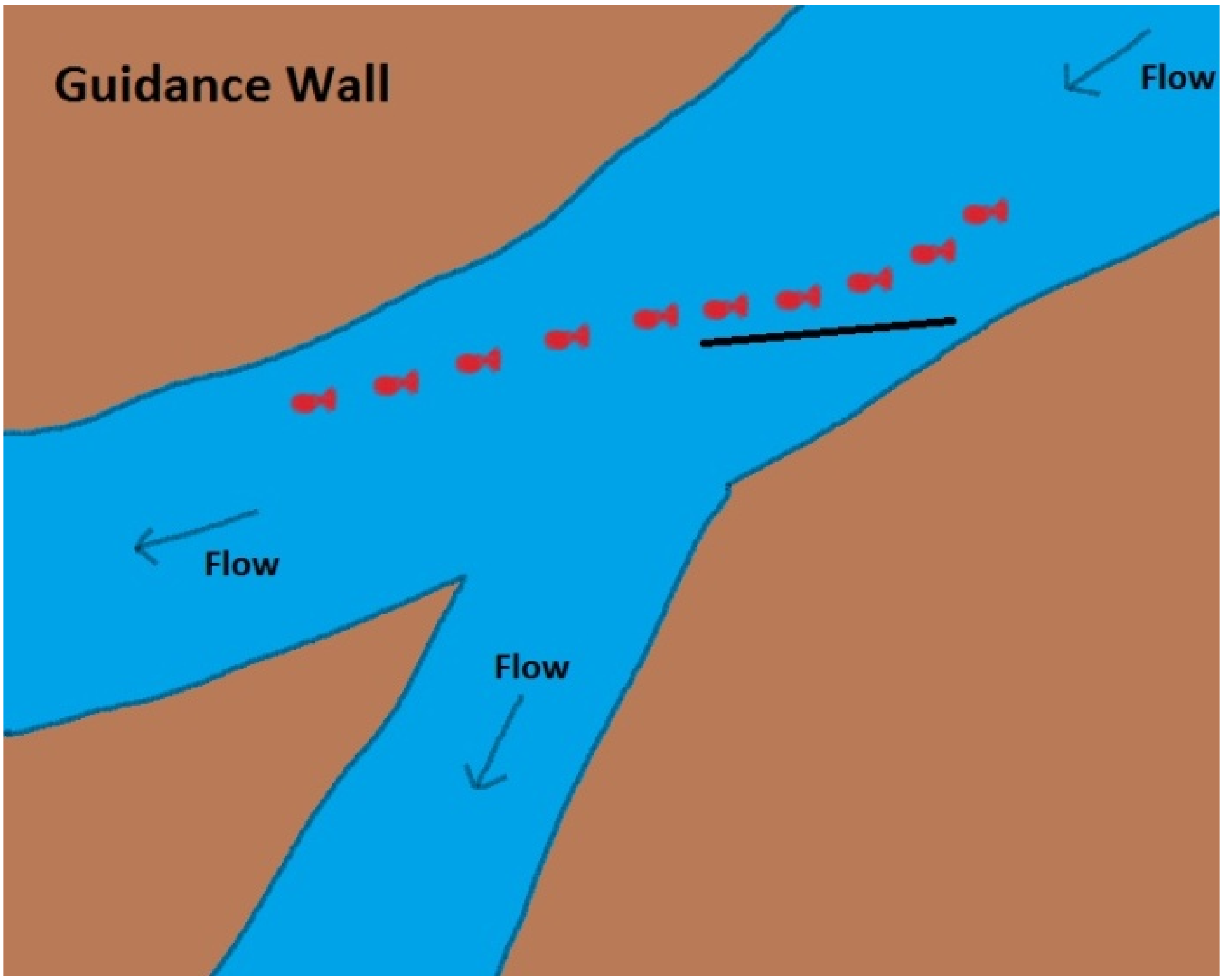


Figure 18: Fish Guidance Wall

Rock Barrier

A rock barrier is a physical wall typically composed of rocks ranging from 6 inches to 18 inches in diameter. Equipment such as bulldozers, cranes, hauling trucks, and excavators are typically used in the installation and removal of the rocks and other barrier equipment. Figure 19 shows an excavator working on the fish barrier at the divergence of the Old River and the San Joaquin River. In order to better control flow and water levels between the upstream and downstream sides of the barrier, culverts with gates may be integrated into the design and operation of the rock barrier.

Figure 19: Excavator Working on the HOR Rock Barrier

Rock barriers have been and are being used for different purposes in the south Delta. The rock barrier that is placed at the HOR site is used specifically as a fish barrier, but the rock barriers on Middle River, Old River, and Grant Line Canal are barriers used for maintaining water elevations for agricultural water diversions and improving water quality through changes in the circulation patterns within the channels of the south Delta. Figure 20 shows the HORB with the culverts and gates located on the left side of the barrier.

Figure 20: The Head of Old River Fish Barrier

Hybrid or Combination Possibilities

The hybrid or combination type of barrier and/or fish guidance system is another possibility when exploring solutions to the fish emigration issues in the Delta. Each site within the Delta has its different challenges and concerns. Water quality, boat passage, predation, tidal influences, and feasibility of construction are just a few examples of concerns that will need to be considered. Combining some of the engineering solutions presented in this report might be a better solution at a specific site. Analysis of the site specific challenges and obstacles will be paramount in the design selection process. The pros and cons of each system, along with the compatibility between them, will also play an important role in the selection and design of the engineering solution.

Habitat Restoration

This section evaluates the option of implementing habitat restoration programs at each of the study sites in order to reduce entrainment of juvenile emigrating salmonids to the interior and southern Delta.

In addition to entrainment, habitat degradation and predation in the Delta have also been attributed as key stressors that are contributing to the decline of anadromous fish populations in the Central Valley. Habitat restoration is considered in this report because each of the study locations are known to be primarily composed of degraded, habitat that favors predatory fish, and that lead emigrating juvenile salmonids into the interior and southern Delta where there is a much lower probability of survival.

Habitat restoration describes actions that would attempt to return form and function of the specified aquatic and or terrestrial habitats to resemble its pre-disturbed state in order to benefit native fish species. In this report, habitat restoration may include, but is not limited to, reclaiming or recreating endemic habitat types, such as shallow tidal wetlands, by restricting flow into non-natural channels. This has the effect of improving anadromous fish habitat and preventing native fish entrainment.

At this stage, no specific habitat restoration actions at any of the study locations are suggested. Only the feasibility and value of conducting further studies at each location is discussed.

The following is a brief analysis of each of the five study locations as potential habitat restoration locations.

Georgiana Slough and Threemile Slough are natural features that hydrologically connect the Sacramento River to the lower San Joaquin River. Implementing a habitat restoration plan at these sloughs that impairs the diversion of Sacramento River flows may be impractical due to the nature of their locations, hydrodynamics, and multiple uses by the public.

Head of Old River is also a natural feature that hydrologically connected to the San Joaquin River. It is a major connection into the South Delta channels, and a pathway for water moving toward the SWP/CVP pumps in the South Delta. Implementing a habitat restoration plan at the HOR that stops the diversion of San Joaquin River flows may be impractical due to the nature of its location, hydrodynamics, and multiple uses by the public.

Columbia Cut and Turner Cut are hydrologically connected to the San Joaquin River and are man-made features. The channels are used to some degree for agricultural irrigation and recreation purposes. However, there may be some potential for implementing a variety of habitat restoration actions. Design elements could include acquisition of lands in fee-title or through conservation easements; establishment of new levees that would discontinue the flow of water from the San Joaquin River into the Cuts; re-establishment of intertidal and subtidal habitats allowing riparian vegetation to naturally establish on the floodplain; and re-contouring the restored floodplain surface, if needed, to avoid potential for stranding juvenile and adult fish following inundation events.

Transportation Barges

This section discusses the option of using modified barges to transport ocean-bound juvenile salmonids from upriver collection points to release sites closer to the San Francisco Bay as an effort to reduce diversion of juvenile emigrating salmonids to the interior and southern Delta.

Developing and using fish transportation systems to reduce mortalities or blocked passageways associated with water project activities is a decades old technique. Generally, fish transportation systems include capturing juvenile salmonids at upriver locations using various techniques, loading them onto a modified boat or vehicle designed to hold and support juvenile salmon, transporting them downriver to a desired location, and releasing them where, in theory, they will continue their journey to the ocean and then return as adults to successfully spawn in their natal streams.

There are several examples of agencies using transportation systems to move migrating salmon, most notably, on the Snake and Columbia rivers. In the late 1970s, NMFS and USACE used modified barges to transport juvenile salmon and steelhead on the Columbia River to protect them from entrainment at Boonville Dam (McCabe et al 1979).

Columbia River operations used a barge that was designed to simulate a modern hatchery pond (raceway) environment. The principal mode of operation was the continual pumping of river water through the barge to minimize the buildup of metabolites in the barge and to provide a continual river water experience for the fish to avoid interference with their natural homing process. A recirculation and oxygenation system served as a backup if local chemical contaminants or other factors limiting river water quality were encountered. Mortalities associated with loading, transporting, and unloading were estimated to be less than 0.5 percent of the transported population (McCabe et al. 1979).

However, some scientists have discovered that using barges to assist migrations of salmon and steelhead trout can have unintended consequences for fish populations. There is evidence that juveniles that are transported downstream on boats can lose the ability to migrate back to their breeding grounds, reducing their survival and altering adaptations in the wild (Keefer et al. 2008).

One study found that, when compared to fish that migrated naturally, transported juveniles had lower survivorship as adults and were less likely to find their way home (Keefer, Matthew L., Christopher C. Caudill, Christopher A. Peery, and Steven R. Lee 2008. TRANSPORTING JUVENILE SALMONIDS AROUND DAMS IMPAIRS ADULT MIGRATION. Ecological Applications (Ecological Society of America), Volume 18, Issue 8, Pages 1888-1900, December 2008).

It is thought that being carried on a barge prevents young fish from learning about important environmental signals during a formative time of their juvenile lives. Artificially transporting juvenile salmon appears to garble the natural cues these fish use to find their way home.

Implementing a transport system for Sacramento and/or San Joaquin river juvenile salmonids through the delta would require an in-depth formal study and analyses to determine its feasibility as a mechanism to protect juvenile salmonids from becoming entrained in the central and south Delta.

No Action

This option would result in taking no action at a specific site to reduce diversion of emigrating juvenile salmonids to the interior and southern Delta.

Framework for Evaluation

The detailed evaluation of options will occur in Phase II and comprises five general steps. These steps are: 1) an initial identification of options for consideration, 2) identification of evaluation criteria for use in detailed analysis, 3) a comparative prioritization and ranking of the relative importance of the evaluation criteria, 4) a comparative evaluation of options applying the ranked criteria defined in the third step, and 5) identification of preferred options for each of the five study sites. The initial identification of options will be accomplished by the TWG, whose members have unique scientific and engineering expertise. The TWG will use this expertise to screen-out options that will not be considered in the more detailed evaluation. The reasons supporting screening-out options will be documented in the final report.

The prioritization and ranking of the evaluation criteria and options in the subsequent steps will be accomplished through application of the USACE Waterways Experiment Station (WES) Water Resource Assessment Methodology (WRAM) [USACE 1977]. The WRAM was developed by the USACE WES for their use in evaluating water resource project impacts and alternatives. The WRAM is a parametric method using a systematic-weighting ranking technique to assess project impacts and alternatives. Application of the WRAM will also be used in the third step to evaluate the options that remain from the first step for more detailed study. Application of the WRAM will support decision making for preferred options in each of the study areas.

Background

WES considered 54 methods from various sources, determining that eight methods were to be considered for assessment of water resource project alternatives. These eight methods were used to define the WRAM. The salient feature of the WRAM is the weighting of the importance of impacted variables and scaling the impacts of alternatives on the variables. Through weighting and scaling, a team cognizant of the study area needs, objectives, and public preferences can assess variables and evaluate alternatives on a comparable basis. The outcome of the WRAM is identification of a recommended alternative based on a quantitative score. The USACE uses the WRAM to address beneficial and adverse effects to economic development, environmental quality, regional development, and social well-being.

General Description

A project team develops a list of options for consideration. Examples of options for the purpose of the OCAP IV.1.3 study are those previously described under Engineering Options to Consider (e.g., non-physical barriers, fish screens, etc.). Next, the team develops a list of important variables which would be a measure of the abilities, effects, or impacts of implementation (e.g., construction, operation and maintenance) of an option. The variables could include cost, environmental impacts, effectiveness, permitting constraints, public acceptance, etc. The impacted variables of importance are then analyzed relative to each other to establish a weighted pair-wise (variable-by-variable) importance comparison value. Examples of variables for the purpose of the OCAP IV.1.3 study are described below (e.g., deterrence ability, flow effects, implementability, etc.).

The next step in the process is the calculation of a "relative importance coefficient" or RIC value for each variable. A RIC value for a variable is determined by adding the importance comparison values for all variable-comparisons to generate a sum, then adding the importance comparison values for all variables, and dividing this sum into the importance comparison sum value for each individual variable. The RIC establishes a numerical ranking of importance of each variable relative to each other.

The next step in the process is "impact scaling" in which project options are comparatively analyzed for their relative impact on a variable. The comparisons are done through a "choice comparison" process. Like the variable-by-variable comparison above, a pair-wise comparison is done for the options. Similar to the determination of RIC values, a coefficient called the "option choice coefficient" or OCC is determined for each option and corresponding variable.

The OCC values are then combined with RCC values for each option in order to calculate a final coefficient (FC). All OCC values for an option are multiplied by the corresponding RIC value to generate intermediate coefficient values for each option/variable combination. The FC for a given option is calculated by adding together all of the intermediate coefficient values. The option with the largest FC value would be considered to be the preferred option to achieve the desired project objectives.

A more illustrative description of the proposed application of the WRAM process is presented in Appendix E.

General Variable Descriptions and Definitions

Eleven variables (or criteria) are proposed for the comparative evaluation of options. These variables include aspects of engineering, biological, and social importance. The TWG will further refine the number of variables and their definitions during the WRAM evaluation described above. A general description and definition of each variable is presented below in Table 4.

Table 4. Variable Descriptions and Definitions

VARIABLES	DESCRIPTION
Boat Passage	Measure of the ability of an option to allow for the passage of boat traffic.
Cost	Measure of the cost of initial, annual, and long-term implementation of an option.
Deterrence Ability	Ability of an option to deter emigrating fish from entering a non-preferred migration route.
Environmental Impacts	Measure of the impacts of an option on the environment including aquatic, terrestrial, and air resources.
Flow Effects	Measure of the effects of an option on water flows based on its implementation.
Implementability	Measure of the ability of an option to be constructed in a timely manner in response to the need to deter emigrating fish.
Operation and Maintenance	Measure of the effort required to keep an option operating and maintained.
Predation Effects	Measure of the effects of an option on predation beyond that which would be considered to be naturally occurring.
Tidal Effects	Measure of the effects of tidal stage variations as well as reverse flows on the performance of an option.
Uncertainties	Measure of the uncertainties associated with an option.
Upstream Migration	Measure of the effects of an option on the upstream migration of fish that should not be deterred.

Technical Review Process

During the Phase II portion of the study, quarterly meetings will be held with the TWG. The TWG will be updated on the progress of the study through the quarterly meetings and will be provided presentations by DWR staff on the progress of preliminary designs. Feedback from the TWG will be important as the study progresses.

Input from the TWG on the evaluation of the options will also be used to assist in scoring each option as the study proceeds when enough information is available to do so. Options will be eliminated as the study proceeds, and the focus will be on the options that have the most merit.

Option Recommendations

A final recommendation of a preferred option or options for each study site will be determined by the TWG and included in the final report, due to NMFS on March 30, 2015.

Additional Research and Monitoring Needs

Available research and monitoring data will be utilized as much as possible to help in making a sound evaluation of the engineering options. In addition, in-progress studies, such as the 6-year steelhead study being conducted by Reclamation, as well as recent and future research and monitoring will also be considered and utilized prior to completion of the final report.

Adaptive Management Needs

During Phase II of the study, flexible decision-making will be necessary to determine the recommended engineering solutions for each study location. In addition to the specific Action being addressed in this report, other studies currently being completed, in progress, or planned could provide helpful information in determining the recommended solutions. This Phase I report lists a suite of options that will be considered, however the TWG may consider other options not listed that could be developed during Phase II. Additional data on the numbers and behavior of juvenile salmonids at the study locations, if considered to be beneficial, will be utilized to the extent possible. Utilizing an adaptive management approach during Phase II of the study will be key to selecting the best possible solutions to address the Action.

Timeline with Key Milestones

Phase I

- June 2011 — Technical Working Group formed with staff from DWR, USBR, NMFS, DFG, and USFWS.
- December 2011 — Develop Options and Evaluation Criteria for Consideration
- December 2011 — Draft Report of Initial Findings
- May 2012 — Independent Science Advisory Panel Review
- December 2013 — Final Phase I Report to NMFS

Phase II

- April 2012 to November 2014 — Begin Options Evaluation and Investigation of Options
- November 2014 — Draft Phase II Final Report
- March 30, 2015 — Final Phase II Report to NMFS

Phase III

- Implement preferred option if approved and required by NMFS

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Appendix A — Meeting Summaries

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OCAP Action IV.1.3
Technical Working Group Meeting Summary
Meeting Date/Time: 11/10/2011, 10:00pm – 12:00pm

Participants:

George Heise, CDFG
Steve Thomas, NMFS (phone)
Khalid Ameri, DWR
Jacob McQuirk, DWR
Bill McLaughlin, DWR
Josh Israel, USBR (Phone)
Maral Kasparian, USFWS
Jeff Stuart, NMFS
Ben Geske, DWR
Ryan Reeves, DWR
Bob Pedlar, DWR
Josh Brown, DWR

Meeting Summary:

Discussion on the Phase I Draft Report

The group discussed the preliminary draft Phase I report and Bill requested comments on the report from the group. Jeff will provide the San Joaquin River migration table and the table will be added to the species of interest section of the report. The most complete draft report with TWG review will be completed by December 16th.

Science Panel Review

Independent science panel formation is still ongoing. Bill will screen possible candidates to structure the Independent review panel. The goal is to have the panel review the report by end of February 2012. Josh Israel proposed to have at least one fish Behaviorist on the panel. Bill proposed to form one Independent science panel to review both the Phase I draft report and the 2011 Georgiana Slough Non Physical Barrier study report.

Franks Tract Project/Other Projects

Bill showed concerns how the Franks Tract project should be discussed in the Phase I report. It was pointed out that to add the Franks Tract project in our report as an ongoing project that may potentially have an effect on the OCAP study.

Action Items and Next Steps

- Provide feedback and comments on the preliminary draft Phase I report (all).
- The most complete draft report will be sent out by December 16th, 2011.
- Look into creating a new science review panel.
- Next TWG Meeting will be scheduled in January, 2012 at the time the full draft is provided to the group in December.

OCAP Action IV.1.3
Technical Working Group Meeting Summary
Meeting Date/Time: 10/06/2011, 10:00pm – 12:00pm

Participants:

George Heise, CDFG
Maral Kasparian, USFWS(phone)
Steve Thomas, NMFS (phone)
Jeff Stuart, NMFS
Josh Israel, USBR
Ryan Reeves, DWR
Jacob McQuirk, DWR
Bill McLaughlin, DWR
Bob Pedlar, DWR
Khalid Ameri, DWR
Josh Brown, DWR

Meeting Summary:

Franks Tract Project/Other Projects

The group discussed the Franks Tract project at Threemile Slough. Bill indicated that the Franks Tract project should be at least briefly discussed in the phase I report if not as an option.

Josh Israel added that the Yolo Bypass fish passage projects, BDCP, and other projects that may potentially have an effect on our study should also be discussed in the report. The various life cycle and passage models that are currently being developed will be extremely helpful in assisting with investigating engineering solutions under this particular OCAP action.

Discussion on the Report Write-Ups

Bill requested comments on the site description and species of interest write-ups form the group. A request for a San Joaquin River migration table and chart to be included in the species of interest section was made. DWR staff will write a majority of the report with the assistance of pertinent information provided from various agencies. The draft report will be completed by November 15th for the group to review.

Science Panel Review

Bill added that after discussing with the Delta Stewardship Council, a science review panel will not be available to review the draft report in January 2012. A different independent science panel will need to be sought to review the report. The group will send contact information to Bill of possible candidates to structure a new Independent review panel. The goal is to have the panel review the report by January 2012.

Bathymetric Surveys/Other Data Source

Bill added that bathymetric surveys for use in further evaluation of options at Turner and Columbia Cuts will be completed sometime before the end of June 30, 2012.

There is a concern that there is limited fish survival or fish behavioral data available. Essential data that is being processed and analyzed from the VAMP and six year studies will be helpful. Additional information may be needed in the future.

Action Items and Next Steps

- Next TWG Meeting scheduled for November 10th at 10:00am – 12:00pm.
- Additional draft sections of the report will be sent out in the coming weeks.
- Provide feedback on developed sections of the report (all).
- Look into creating a new science review panel (all).

OCAP Action IV.1.3
Technical Working Group Meeting Summary
08/25/2011
Meeting Date/Time: 08/25/2011, 10:00pm – 12:00pm

Participants:

George Heise, CDFG	Mark Holderman, DWR
Maral Kasparian, USFWS	Jacob McQuirk, DWR
Steve Thomas, NMFS	Bill McLaughlin, DWR
Jeff Stuart, NMFS	Bob Pedlar, DWR

Meeting Summary:

Franks Tract Project

The group discussed the Franks Tract Project at Threemile Slough presented by Teresa Geimer to the group at the last meeting. Maral added that the existing project utilizing a gate could have nutrient flow concerns and possible predator concerns. It was suggested to include the additional site within the upcoming report in a narrative format.

Jeff added that NMFS is not limiting which channels are considered.

Discussion on the draft table of contents/maps

The latest draft of the table of contents sent out August 4th was discussed with no additions suggested. DWR staff will write a majority of the report with the assistance of pertinent information provided from various agencies. Draft sections of the report will be sent out beginning in September for the group to begin review.

Project Sites

DWR staff discussed a tour of the Turner and Columbia Cuts sites that were toured by DWR staff the week before. If members of the group are interested, a tour of the sites can be arranged.

Bathymetric surveys of Turner and Columbia Cuts will be planned for use in further evaluation of options at the sites. The need for further fishery information was briefly discussed but additional research needs to be completed on existing documents.

Performance objectives/criteria

No additional objectives/criteria added.

Options

Maral commented that USFWS prefers flow friendly and submerged structures and that predatory behavior prevention is important.

No additional options added.

Independent Review Panel

DWR staff is still waiting to hear back from the Delta Stewardship Council (Sam Harader) to discuss forming an Independent Review Group in January 2012 to review the draft report.

Action Items and Next Steps

- Next TWG Meeting scheduled for September 15th at 10:00am – 12:00pm
- Provide feedback on the Franks Tract project (all)
- Look into science panel involvement (Pedlar/McLaughlin)
- Provide feedback on options and criteria (All)

OCAP Action IV.1.3
Technical Working Group Meeting Summary
07/07/2011
Meeting Date/Time: 07/07/2011, 2:00pm – 4:00pm (PST)

Participants:

Mark Holderman, DWR	George Heise, CDFG
Jacob McQuirk, DWR	Bob Pedlar, DWR
Josh Israel, USBR	Daniel Kratzville, CDFG (phone)
Ryan Reeves, DWR	Maral Kasparian, USFWS (phone)
Khalid Ameri, DWR	Jeff Stuart, NMFS
Bill McLaughlin, DWR	Josh Brown, DWR

Meeting Summary:

1. Purpose of Call

The primary purpose of the meeting was to discuss the draft table of contents for the report that Josh provided and to discuss/brainstorm options to be considered for all sites to further reduce diversion of emigrating juvenile salmonids. Also, to discuss performance objectives of the options that will be considered.

2. Discussion on the draft table to contents

BM: Introduced meeting topics, June 16th TWG meeting summary, and overall intent of the meeting.

JM: Suggested adding a flow/hydraulics section.

There were no major comments on the outline at this moment. However, detailed comments will be provided to Josh prior to the next TWG meeting. Josh discussed the ELAM model used on the Columbia River (provided documents through e-mail). He added that this model will be beneficial in validating fish behavior. Also, there was concern whether there is enough hydrodynamic data to run the ELAM model.

3. Option Brainstorming

A floating buoy fish barrier was introduced which is currently used at the Bonneville Dam on the Columbia River to direct migrating salmon away from the intakes. It's was noted that this type of structure might only work effectively in low flow environment. George will provide us with more detailed information regarding this type of barrier.

GH: Suggested to consider partially blocking the channel. For example Head of Old River; instead of having a 50/50 split we could reduce the split to 80/20. By achieving this we will be able to keep fish in the main channel. However, this option might work only at the HOR and not at other locations.

BM: Talked about the DSM2 hydrodynamic data analysis at a few of the project sites, since there is insufficient observed historical data available. Preliminary DSM2 hydraulic data analysis results will be available to the group prior to the next TWG meeting.

JS: Suggested consideration of behaviorial-systems in combination with physical barrier. Also mentioned that NMFS Seattle office as having some experience with tidally influenced estuaries.

JI: Suggested to consider independent science review panel members involvement earlier in the study.

GH: Discussed the electric fish ladder technology used in the Merced River. However, he was concerned that this technology might not be feasible for juvenile entrainment.

JI: Introduced an option to transport fish by using a barge to a desired location downstream. This method is used in the Columbia River to increase returns of fish to the hatchery. In order for this option to work effectively we need to determine when the majority of fish will be present at a specific location. All agreed that a most common downside to this option would be increased predation and capturing different type of fish species simultaneously. Jeff was concerned that the life history of fish is an important part to fish behavior, so we need to have some type of criteria in place to determine when to use this option.

JI: Discussed the benefits of randomly releasing fish rather than at specific release points.

A permanent operable gate option was also discussed.

Flow vanes/louvers should be considered.

MH: Proposed to consider flow when operations of an option are needed.

JM: Indicated that no matter what option we select, we need a lead time to properly execute that particular option. BM pointed out that having a permanent permitting option in place to execute a preferred option instead of having to go through annual permitting would have its advantages.

MK: Proposed to consider the effects on Delta smelt as one of the criteria. She also added that other species such as longfin smelt might also be listed as an endangered species by the time we are done with the study and should also be considered. The timing of barrier operations effects on Delta smelt should be considered.

4. Action Items and Next Steps
   - Next TWG Meeting scheduled for 07/28/11 at 1:00pm – 3:00pm (PST)
   - Provide comments on the report outline to Josh (all)
   - Look into science panel involvement (Stuart)
   - Provide DSM2 hydraulic data analysis at each site (McLaughlin/Ameri)
   - Update list of options and criteria (McLaughlin)
   - Prepare site maps for each location (McLaughlin/Brown)
   - Look into available bathymetry data (McLaughlin)
   - Ftp site access information (Ameri)
   - Talk with Steve/Rick about draft objectives criteria (Stuart)
   - Look into EPRI, contact Ned Taft (McLaughlin)

OCAP Action IV.1.3
Technical Working Group Meeting Summary
07/28/2011
Meeting Date/Time: 07/28/2011, 1:00pm – 3:00pm

Participants:

Josh Israel, USBR (phone)
Ryan Reeves, DWR
Bob Pedlar, DWR
Steve Thomas, NMFS (phone)
Jeff Stuart, NMFS
Maral Kasparian, USFWS (phone)
Khalid Ameri, DWR
Bill McLaughlin, DWR
Teresa Geimer, DWR

Meeting Summary:

Purpose of Meeting

The primary purpose of the meeting was to further discuss the draft table of contents and performance objectives for the report. Also, to brainstorm options to be considered for all sites.

Franks Tract project

Teresa talked about the Franks Tract project and inquired about whether the project would fit or tie in to the OCAP IV.1.3 action. Jeff indicated that Threemile Slough could be a potentially significant site and important to consider subsequent to Georgiana Slough. The project reviewed 3 different site locations as alternatives but did not investigate other engineering alternatives. The group will review the project and provide input to Teresa.

Discussion on the draft table of contents/maps

Bill Introduced meeting topics, discussed the July 7th TWG meeting summary. There were no comments on the outline.

Bill will add more details under each heading and send out the updated draft to the group next week.

There was a discussion on how and where to block Columbia and Turner Cuts since there are multiple channels at the mouth of those two channels. Josh proposed to

include this issue into our investigation. It was pointed out that the 2010 VAMP study results will give us better understanding of flows and how many fish will potentially take the Columbia and Turner Cuts routes. The 6-year acoustic tag study and telemetry studies also will have information of numbers of fish passing through the area. Dave Vogel also has done some fish predation studies at those two sites and produced a 2008 or 2009 study.

Performance objectives review

Bill indicated that the performance objective list was updated, and he requested feedback from the group. Jeff proposed to add flood risk under the flow objective category. It was also suggested that the Environmental Impacts criteria may need to be divided into sub categories.

Developed Options

The options were updated based on the discussion at our previous TWG meeting. Some of the options could be combined together for specific project sites if needed. Steve asked if we have the option to reduce flow down some of the channels. Steve mentioned that on a recent Yuba River project, rock barriers were not a preferred option of NMFS due to the leakage that occurs and the potential for fish passing through the structure. Steve commented on experience with deterrent efficiencies - screen efficiencies as high as 95% could be achieved but other technology efficiencies are site-specific.

Independent Review Panel

Bill and Bob met with the Delta Stewardship Council (Sam Harader) regarding the Independent Review Panel (IRP) that will be required. There is an existing panel that conducts an annual review of OCAP actions in early November which may be too soon since a draft document will not be completed by then. It was suggested to have an initial review of a non-final product in addition to a full review. Josh commented that the panel only provided a summary review on a prior project and suggested consideration of a review "group" rather than a full review panel. This type of review group review was done for the 6-year acoustic tag study and was effective. Jeff provided concurrence on this approach. Bob and Bill will coordinate and discuss some of the options on how to complete the review with Sam Harader.

Action Items and Next Steps

- Next TWG Meeting scheduled for August 25th at 10:00am – 12:00pm
- Ftp site access information (hydraulic data, background information, maps, etc…) (McLaughlin/Ameri)
- 2-D flow view model info (Reeves)
- Provide feedback on the Franks Tract project (all)
- Update table of contents (McLaughlin)
- Look into science panel involvement (Pedlar/McLaughlin)
- Provide feedback on options and criteria (All)

OCAP Action IV.1.3
Technical Working Group Meeting Summary
06/16/2011

Meeting Purpose: In accordance with the NMFS OCAP BiOp Action IV.1.3 this Technical Working Group (TWG) has been formed to evaluate engineering solutions for minimizing salmonid diversion into the central and southern Delta. This meeting was the TWG kick-off meeting for the project.

Attendees:

Mark Holderman, DWR	Daniel Kratzville, CDFG (phone)
Jacob McQuirk, DWR	Steve Thomas, NMFS (phone)
Josh Israel, USBR	Khalid Ameri, DWR
Ryan Reeves, DWR	Maral Kasparian, USFWS (phone)
George Heise, CDFG	Jeff Stuart, NMFS
Bob Pedlar, DWR	Bill McLaughlin, DWR

Discussion Notes:

- BM: Introduced meeting topics and overall intent of the meeting.
- BM: Provided overview of BiOp Action IV.1.3 and intent of BiOp language and asked what other project sites to consider such as Columbia Cut which is clearly not stated in the BiOp.
- JS: Provided explanation and intent of BiOp Action IV.1.3 language. It was confirmed to perform engineering evaluation at Head of Old River, Georgiana Slough, Turner Cut, and Columbia Cut. He also added to identify technology/alternative that can be used to protect salmonids and maximize flexibility for water deliveries. He also added that having a fish behavior model may be valuable in performing this evaluation.
- BM: Proposed to put in place a proposal for all of the alternatives. The alternatives need to be submitted to NMFS by March 2012.
- RR: Suggested that the specific installation location of a proposed alternative could be a significant deciding factor. For example Turner Cut has multiple entry points along the SJR making this a difficult construction location, but downstream in the cut there is a more defined channel where construction would be simpler.
- JS: Suggested the intent of the RPA was to keep fish in the main stem of the river systems, so an alternative technology downstream in the cut would not meet the intent.
- JM: Suggested to consider collecting background hydrodynamic data at a few of the project sites to observe flow regime at each site.
- BM: DWR has flow split information broken down monthly from 1990-2011 for Columbia and Turner Cut.
- JS: Suggested to have independent panel to review the proposed options to make sure it's consistent with SWP and CVP operations.
- JI: Proposed to consider pros and cons for each option.
- JM: Proposed to have a model simulation in place for some of the project sites, since it's feasible compared to conducting a pilot study at that particular site.
- RR/JI: We have enough data under various hydrologic conditions from our past studies at the Head of Old River and more recent study at the Georgiana Slough that will be useful for model validation.
- JI/JS/JM: Suggest that we need to define which type of fish species the barrier will be used for. Also, we need to determine what the actual fish survival rate is prior to the

Barrier deployment. Also need to consider periods when salmonids/steelhead pass and when operations of an option are needed. It was suggested to use the period tables right out of the BiOp.

- JS: We may want to modify our actions to year-by-year hydrology at each site.
- JS: Recommends the need to consider social acceptance of the selected technology. Altering navigation is difficult.
- JS/JI: Point out that one particular technology might not work for all fish species.
- BM/MH: Indicated that the Phase 1 consist of identifying technologies and options that will be summarized in a report to be completed March 30, 2012. Pilot testing of selected options would be conducted in subsequent years (Phase II) with a completed recommended alternative submitted to NMFS by March 30, 2015. Flow limits of options should be determined or estimated.
- BP: Spoke with Sam Harader of the Delta Stewardship Council staff and with the Center for Independent Experts (CIE) regarding the Independent Review Panel (IRP) that will be required. Each organization indicated they could assist in IRP coordination.
- JI: A charter statement of what is expected by the IRP should be developed.
- MH: Suggests that fish agencies need to inform us about type of fish that will be present during certain month of the year in the vicinity of the Georgiana Slough and other locations to be evaluated as part of the study.
- JI: We need to coordinate with other project working groups such as BDCP, since this is a multi-year project. Also coordinate with USFWS on the Delta Smelt BiOp. This coordination hopefully will avoid future conflicts with other projects.
- JI: Should look at the ELAM model used on the Columbia River as a good proven model to help in validating fish behavior. – *Josh sent out documents for TWG review.*
- JI: Recommends eliminating term “alternative” from future discussions as this can be confused with CEQA/NEPA environmental documentation and other project permitting language. Possible terms to be used instead of alternatives are: options, concepts, measures.
- DK: Provided recommendation to consider tidal marsh restoration at mouths of Cuts/Sloughs as a means of minimizing fish passage.
- JS: Indicated an ideal efficiency criteria would be 80-90% deterrence.
- JS: Indicated the intent of the RPA was not to have each alternative taken to a given level of construction design, but to have more of a narrative description with scientifically based/objective evaluation.

<u>Action Items:</u>

- Prepare a draft table of contents. (JI)
- Speak to Garwin Yip about setting up independent reviews through NMFS (JS)
- Begin brainstorming options to discuss at the next meeting. (All)
- Create an email reflector for the group (JM)

<u>Next Meeting:</u>

- <u>July 7th from 2:00 pm to 4:00 pm at DWR HQ, Room 210.</u>
- Starting July 7th we will meet every other Thursday for at least next few months.

Appendix B — Life Histories and Other Species of Concern

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Life Histories of Salmonids in the Sacramento/San Joaquin River Systems

Chinook salmon (Oncorhynchus tshawytscha)

Chinook salmon are anadromous, meaning they are spawned and hatched in freshwater, spend a portion of their juvenile life in freshwater prior to emigrating to the marine environment as smolts, and then spend much of the adult portion of their lives in the ocean prior to returning to freshwater as adults to spawn. There are four runs of Chinook salmon found in the study area: winter-run, spring-run, fall-run, and late-fall-run. A description of characteristics common to each run follows below; descriptions specific to each run are included afterward.

The major factors that limit the range and abundance of Chinook salmon include flow and water temperature, barriers to upstream migration, entrainment in water diversions, and ocean conditions. Climate change and its impact on water temperatures, hydrology, and ocean conditions, will have potentially substantial effects on Chinook salmon populations within the Central Valley in the future.

Chinook salmon spawn in gravel-bedded areas in rivers and creeks with moderate flow and depths typically greater than 9.5 inches (Allen and Hassler 1988). Upon finding a suitable site, the female excavates the nest (called a redd) with her tail, deposits her eggs into the excavated pocket, and once they have been fertilized by the attending male, pushes gravel back over them by beating her tail to dislodge the gravel in the current upstream of the redd. The female then moves slightly upstream and constructs another redd and the process is repeated until the female has deposited all of her eggs. Gravels free of excessive fines (less than 5 percent) that allow movement of water through the gravel surrounding the egg pockets are important for egg development and survival. Water circulation through the egg pocket delivers oxygen and removes metabolic waste (Platts et al. 1979, Reiser and Bjornn 1979). It is also important that excessive fine sediment does not block the emergence of fry from the gravel (Allen and Hassler 1988). After spawning, adult Chinook salmon die, often within a few days. The carcasses of the spawned-out adults provide vital nutrients and minerals of marine origin to the aquatic environment in which the eggs have been laid, enriching the food web upon which the juvenile salmon will depend on to grow.

Chinook salmon exhibit two generalized fresh water life history types (Healey 1991). “Stream type” Chinook salmon, enter fresh water months before spawning with immature gonads and hold in-river for several weeks to months prior to spawning as their gonads mature. Their young may reside in fresh water for a year or more following emergence of the fry from the gravel before emigrating to the ocean as smolts. In contrast, “ocean-type” Chinook salmon have mature gonads in an advanced state of ripeness when the adults leave the ocean to migrate upriver and will spawn soon after entering fresh water. Their young will migrate to the ocean as young-of-the-year within their first year of life.

Embryos in fertilized eggs develop in the gravel in about 40 to 60 days depending on water temperature. After hatching, the yolk-sac fry remain in the gravel for another four to six weeks until the yolk sac is absorbed. The rate of embryonic development increases with increasing water temperature (NMFS 1997) up to a certain point. Appropriate temperatures for egg incubation are between 42º Fahrenheit (F) and 56ºF, with 52ºF considered ideal (DWR 1988). At 57.5ºF, significant mortality of the embryo begins to occur and total mortality results at 62ºF (NMFS 1997). Following absorption of the yolk sac, fry begin to emerge from the gravel (Allen and Hassler 1988). Timing of emergence varies among populations. Post-emergent fry inhabit calm shallow waters with fine substrates and depend on fallen trees, undercut banks, and overhanging riparian vegetation for refuge (Healey 1991, as cited by NMFS 1997). During the post-emergent fry and juvenile stages, water temperatures that range between 53ºF and 57ºF are generally beneficial (NMFS 1997, DWR 1988). Juvenile Chinook salmon are generally present in the Sacramento River and Delta all year, but high water temperatures limit their presence in the lower river sections during summer and early fall. Optimal rearing habitat includes abundant instream cover such as undercut banks, subsurface and emergent aquatic vegetation, logs, roots, and dense riparian vegetation occurring along the stream margin. These features provide cover and refuge from predators and the appropriate habitat conditions for an abundant supply of invertebrate and larval fish prey. Before becoming independent swimmers, salmon fry also depend on calm shallow water areas along the margins of their natal waterways to avoid getting continually swept downstream (DFG 1998). Ephemeral habitats such as seasonally inundated floodplains and the lower reaches of small tributary streams are also very important to rearing Chinook salmon (Maslin et al. 1995, Sommer et al. 2001). These areas can be much more productive than the main channel and provide a safe haven from predatory fish. For example, the Cosumnes River floodplain was found to support a high abundance of invertebrates, which are critical to rearing salmon as a food source (Swenson et al. 2003). The value of floodplain habitat for Chinook salmon has been corroborated by Sommer et al. (2001) on the Yolo Bypass. The use of side channels and low gradient floodplains also subjects fry and fingerlings to stranding when high flows subside quickly (NMFS 1997). Lower in the system, in the intertidal zone, mudflats and tule marshes become important habitat for juveniles during high tides. In Suisun Marsh, Moyle et al. (1986) reported that Chinook salmon fry tend to remain close to the banks and vegetation, near protective cover, and in dead-end tidal channels. The status, general life history, spawning, rearing, estuarine areas, and near-shore and marine characteristics of each salmon-run are presented in the following sections.

Winter-Run Chinook Salmon

Status

Federal ESA Sacramento River winter-run Chinook salmon were originally listed as threatened by an emergency interim rule, which was published on August 4, 1989 (54 Federal Register [FR] 32085). A new emergency interim rule was published on April 2, 1990 (55 FR 12191). A final rule listing Sacramento River winter-run Chinook salmon as threatened was published on November 5, 1990 (55 FR 46515). The evolutionarily significant unit (ESU) consists of only one population confined to the upper Sacramento River in California. The ESU was reclassified as endangered on January 4, 1994 (59 FR 440), due to increased variability of run sizes, expected weak returns as a result of two small year classes in 1991 and 1993, and a 99 percent decline between 1966 and 1991. The Livingston Stone National Fish Hatchery population has been included in the listed Sacramento River winter-run Chinook salmon population (70 FR 37160, June 28, 2005). In 2005, NMFS conducted a 5-year status review of 16 salmon ESUs, including Sacramento River winter-run Chinook salmon, and concluded that the species' status should remain as previously listed (70 FR 37160, June 28, 2005). The possibility of extinction of winter-run Chinook salmon is linked to the lack of access to their historical spawning grounds and the population remains below the recovery goals for the run (NMFS 1997).

NMFS designated critical habitat for winter-run Chinook salmon on June 16, 1993 (58 FR 33212). Critical habitat was delineated as the Sacramento River from Keswick Dam at river mile (RM) 302 to Chipps Island (RM 0) at the westward margin of the Delta, including Kimball Island, Winter Island, and

Brown's Island; all waters from Chipps Island westward to the Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and the Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge; and all waters of San Francisco Bay north of the San Francisco-Oakland Bay Bridge.

Critical habitat includes the river water, river bottom, and the adjacent riparian zone. Riparian zones on the Sacramento River are considered essential for the conservation of winter-run Chinook salmon because they provide important areas for fry and juvenile rearing. For example, studies of Chinook salmon smolts in the middle reaches of the Sacramento River found higher densities in natural, eroding bank habitats with woody debris than other habitat types (Michny 1984).

Dam construction has greatly diminished the range of winter-run Chinook salmon. Historically, winter-run used winter high flows during their migration to access the headwaters of the Sacramento River, such as the Upper Sacramento, McCloud, Pit, and Fall rivers, where they took advantage of the consistently cool spring water available in the lava and basalt regions of the southern cascades to survive over the summer following hatching. The upper reaches of Battle Creek also may have supported winter-run before the development of hydroelectric dams, but was considered a minor component overall. Winter-run Chinook salmon may have also ascended into the upper reaches of the Feather and American rivers (Yoshiyama et al. 2001). However, since the construction of Shasta Dam, winter-run Chinook salmon have been confined to the mainstem Sacramento River and Battle Creek. Today they are highly dependent on cool water releases from Shasta Dam in order to survive.

In contemporary records, winter-run Chinook salmon have been less numerous than either spring-run or fall-run. There has been a dramatic decline in the abundance of returning adult winter-run salmon in the Sacramento River in the last half century. Winter-run Chinook salmon adult returns have declined from about 120,000 in the mid- to late 1960s to a few hundred in the early 1990s. Since the mid-1990s, abundance was increasing and adult returns had been numbering in the thousands (DFG 2002), with a peak of almost 17,000 in 2006. However, since 2006 escapement has declined dramatically to historically low numbers. In 2011, the estimated adult escapement is less than 1,000 adults (824 fish).

General Life History

Adequate streamflows are also necessary to allow adult passage to upstream holding habitats and are probably an important migratory cue. The preferred temperature range for upstream migration is 38 ºF to 56 ºF (Bell 1991DFG 1998). Adult winter-run Chinook salmon enter San Francisco Bay from November through June (Hallock and Fisher 1985) and migrate past Red Bluff Diversion Dam (RBDD) from mid-December through early August (NMFS 1997). The majority of the run passes RBDD from January through May, and peaks in mid-March (Hallock and Fisher 1985). The timing of migration may vary somewhat due to changes in river flows, dam operations, and water year type.

Adults hold in deep cold pools until they are sexually mature and ready to spawn in spring or summer. This trait distinguishes winter-run salmon from the other Central Valley runs. Winter-run Chinook salmon hold in the Sacramento River mostly between Bend Bridge and Keswick Dam (NMFS 1997), where the river is confined between natural bluffs and volcanic formations, and pools between 20 and 60 feet deep have formed at the tail of high gradient sections.

In holding areas, water temperatures between 55ºF and 56ºF are ideal for gamete development and egg viability. Suitability for holding adults begins to decline when water temperatures climb above 59ºF to 60ºF (NMFS 1997, DWR 1988). Temperatures above 69.8ºF begin to cause mortality (McCullough

1999). During migration, water temperatures between 57ºF and 67ºF are suitable (Berman and Quinn 1991, NMFS 1997).

Winter-run Chinook salmon primarily mature as three (67 percent) and two (25 percent) year olds (the remaining 8 percent are four+ year olds), unlike spring- and fall-run Chinook salmon which mature primarily as three and four year olds (NMFS 1997, Fisher 1994).

Spawning

Onset of spawning begins in late April, peaks in May and June and usually subsides by mid-August (NMFS 1997). Compared to the other runs, winter-run Chinook salmon may select deeper spawning sites over seemingly equally suitable shallow sites. Winter-run Chinook salmon have been observed spawning at depths in excess of 21 feet in Lake Redding (NMFS 1997). Most winter-run Chinook salmon spawn in the upper reaches of the Sacramento River.

Rearing

Juvenile winter-run emigrate down the Sacramento River from mid-July to mid-April and may arrive in the Delta as early as September. Movement through the system depends on flows and turbidity during the emigration period, but peak emigration generally occurs between January and April (Schaffter 1980, Meddersmith 1966, DFG 1989, DFG 1993, USFWS 1992; USFWS 1993; USFWS 1994; Hood 1990; all cited by NMFS 1992).

Upon arrival in the Delta, winter-run Chinook salmon tend to rear in the more upstream freshwater portions of the Delta for about the first two months (Kjelson et al. 1981, 1982). Based on their size prior to entering the ocean, it is estimated that winter-run juveniles inhabit fresh and estuarine waters for 5 to 9 months (NMFS 1997).

Winter-run Chinook salmon begin entering the ocean from January through June. Before entering the ocean, juveniles undergo a physiological change known as smoltification that allows them to adapt to the ocean’s saltwater environment.

Estuarine Areas

Winter-run Chinook salmon fry remain in the estuary (Delta/Bay) until they reach about 118 millimeter (mm) (*i.e.*, 5 to 10 months of age) and then begin emigrating to the ocean as early as November and continue through May (Fisher 1994; Myers et al. 1998). As juvenile Chinook salmon increase in length, they tend to school in the surface waters of the main and secondary channels and sloughs, following the tide into shallow water habitats to feed (Allen and Hassler 1986). In Suisun Marsh, Moyle et al. (1986) reported that Chinook salmon fry tend to remain close to the banks and vegetation, near protective cover, and in dead-end tidal channels.

Near-Shore and Marine

At present, information on winter-run Chinook ocean distribution is scarce. The data are derived from ocean fisheries, and are biased in favor of locations where ocean fisheries activities occur. Returns from marked winter-run Chinook salmon indicate that most winter-run salmon caught in the ocean are landed between Monterey and Fort Bragg, though mixed results make it difficult to tell if any winter-run Chinook salmon were landed north of Fort Bragg (Hallock and Fisher 1985). Regardless, it is believed that winter-run Chinook salmon, like all Central Valley Chinook, remain localized primarily in California coastal waters.

Spring-Run Chinook Salmon

Status

The Central Valley spring-run Chinook salmon ESU is listed as a threatened species pursuant to both the ESA and California ESA. The state and federal listing decisions were finalized in February 1999 and September 1999, respectively. Critical habitat for Central Valley spring-run Chinook salmon was designated on September 2, 2005 (70 FR 52489). Following litigation challenging the spring-run listing decision, the spring-run ESU was re-listed as threatened in 2005 (70 FR 37160). Critical habitat for Central Valley spring-run includes the mainstem Sacramento River to Keswick Dam and its major tributaries from Clear Creek downstream to the Delta.

Critical habitat was designated for Central Valley spring-run Chinook salmon and CV steelhead on September 2, 2005 (70 FR 52488). Critical habitat for Central Valley spring-run Chinook salmon includes stream reaches such as those of the Feather and Yuba rivers, Big Chico, Butte, Deer, Mill, Battle, Antelope, and Clear creeks, the Sacramento River, as well as portions of the northern Delta. Critical habitat includes the stream channels in the designated stream reaches and the lateral extent as defined by the ordinary high-water line. In areas where the ordinary high-water line has not been defined, the lateral extent will be defined by the bankfull elevation (defined as the level at which water begins to leave the channel and move into the floodplain, it is reached at a discharge that generally has a recurrence interval of 1 to 2 years on the annual flood series) (Bain and Stevenson 1999; 70 FR 52488). Critical habitat for Central Valley spring-run Chinook salmon is defined as specific areas that contain the primary constituent elements and physical habitat elements essential to the conservation of the species.

Spring-run Chinook salmon populations once occupied the headwaters of all major river systems in the Central Valley up to any natural barrier (Yoshiyama et al.2001). Spring-run were at least the second most abundant run in the Central Valley prior to the 20th century (DFG 1998) and may have been the most abundant (NMFS 1997). The Central Valley river drainages are estimated to have supported spring-run Chinook populations as large as 600,000 fish in the early 1880s. In the Sacramento-San Joaquin River Basin, runs were estimated to be between 127,000 and 600,000 during the late 1800s. A gill-net fishery in the Delta, established around 1850, initially targeted spring- and winter-run due to their fresher appearance and better meat quality than fall-run (Fisher 1994). Commercially, spring-run were the most important run of Chinook up until 1900 (Fisher 1994). Early gill-net landings reported between 1881 and 1882 were in excess of 300,000 spring-run per year (DFG 1998).

By the early part of the 20th century, declines in spring-run Chinook salmon abundance became evident and were likely the result of the inland gill-net fishery and habitat degradation and loss from mining and construction of water diversions and dams (DFG 1998). Approximately 72 percent or 1,066 miles of available salmon spawning, holding, and rearing habitat have been lost due to the construction of dams, barriers, and the dewatering of streams in the Sacramento-San Joaquin Basin (Yoshiyama et al. 2001).

The loss and degradation of habitat have diminished the current annual returns of spring-run Chinook salmon to between 5,000 and 15,000 adults (DFG 2002). There have been numerous restoration efforts focused on spring-run recovery, such as gravel augmentation and channel restoration on Clear Creek, improvement of fish passage with the construction or reconstruction of fish ladders, and the removal of dams on Mill, Deer, Butte, and Clear creeks. More recently, the San Joaquin River Restoration Program began a comprehensive long-term effort to restore flows and a self-sustaining spring-run Chinook salmon population between Friant Dam and the Merced River confluence, where they have been extirpated since the late 1940's. Regulatory agencies have also negotiated agreements with hydroelectric plant operators and water agencies to increase flows during holding and spawning periods.

General Life History

Spring-run Chinook salmon enter the Sacramento River between mid-February and July. The peak of the migration occurs in May (DFG 1998). Adults hold in deep cold pools in proximity to spawning areas until they are sexually mature and ready to spawn in late summer and early fall (DFG 1998). Spring-run Chinook salmon use high spring flows caused by snowmelt to gain access to the upper reaches of tributaries to the Sacramento River. The largest populations of spring-run Chinook salmon are found in Mill, Deer, and Butte creeks, and the Feather River, although the Feather River population is primarily of hatchery origin (Sommer et al. 2001). Clear Creek and Cottonwood Creek also support populations of spring-run Chinook salmon. Small numbers of spring-run Chinook salmon have been observed intermittently in the recent past in other Sacramento River tributaries (DFG 1998).

The survival of spring-run Chinook salmon during the summer relies on access to the upper reaches of mid- to high elevation creeks or cold water releases from dams that sustain cool water temperatures throughout the summer and into early fall in the lower elevation tailwater sections of these dammed watersheds. Habitat that would naturally sustain the Central Valley population in the Feather River and Sacramento River has been blocked with the construction of numerous hydroelectric dams in the upper watersheds and finally by Oroville Dam (Feather River) and Keswick/ Shasta Dam (Sacramento River). Conversely, the distribution of the natural populations of spring-run Chinook salmon in Mill, Deer, and Butte creeks is much the same as it was historically (DFG 1998). Some spring-run Chinook salmon may hold and spawn in the Sacramento River between the RBDD and Keswick Dam, but these fish have declined substantially since the late 1980s. Since the early 1990s, spring-run spawning in the main-stem Sacramento River have only numbered in the hundreds and more recently have not exceeded fifty fish. Because the present day spring- and fall-run Chinook salmon spawning distributions overlap spatially and temporally in the mainstem Sacramento River, the later spawning fall-run Chinook salmon may dig up the eggs of spring-run Chinook salmon that have previously spawned in the river during their redd construction in the spawning gravels (DFG 1998). This is known as superimposition of the redds. In addition, the temporal and spatial overlap between the spawning behaviors of spring and fall-run Chinook salmon can lead to interbreeding between the two runs on the spawning grounds, leading to genetic introgression. Historically, spring-run Chinook salmon would have spawned in areas upstream of Keswick Dam that were inaccessible to fall-run Chinook salmon because river flows leading to the upper watersheds are typically lower during the fall-run Chinook salmon migration period, and passage upstream is blocked by these low flow conditions (DFG 1998, Yoshiyama 2001). Temporal and spatial overlap of spring- and fall-run spawning behaviors is also a problem in the Feather River and has likely led to hybridization between the two runs (DFG 1998).

Spawning

Spring-run Chinook salmon spawn in the upper reaches of tributaries to the Sacramento River and generally begin entering these waters in late spring and early summer when flows are sufficient to allow passage upstream. Within the upper reaches of accessible tributaries, adult spring-run Chinook salmon hold over summer in the deeper pool habitats with cooler water conditions, especially from late April through August. The adults hold over summer in these cooler waters, allowing their gametes to mature before beginning their spawning behaviors in early to mid-August, continuing through approximately mid-October.

In the Sacramento River watershed, spawning begins in mid- to late-August through early October. Initiation of spawning behavior depends on the stream and the elevation at which the fish are holding. Fish holding in cooler upper elevation reaches tend to begin spawning earlier (DFG 1998). The current NMFS and DFG characterization of the spring-run spawning season extends further into the fall than historically occurred and could reflect hybridization with fall-run Chinook (DWR and USBR 2000).

Rearing

In the Sacramento River watershed, the period from spawning until fry begin to emerge from the gravel is from three to six months. The duration depends on water temperature. In Butte and Big Chico creeks, fry begin to emerge in November after an incubation period of about three months. In the colder Mill and Deer creeks, incubation can occur over a period of six months (DFG 1998) due to the slower development of the eggs and fry.

Emigration timing depends on fall and winter flows. Large numbers of juveniles begin to migrate during high flows; low flows may delay migration timing (DFG 1998). Some spring-run populations will over-summer in their natal streams and emigrate as yearlings (DFG 1998).

Juvenile spring-run Chinook salmon occur in the Delta from October through early May (DFG 1998). Older juveniles, *i.e.*, yearlings, which have spent their first year rearing in their natal tributaries, tend to emigrate downstream in late fall and early winter. Young-of-the-year juveniles emigrate downstream in late winter through spring following their emergence from the gravel the previous fall. Upon arrival in the Delta, juvenile young-of-the-year spring-run Chinook salmon tend to rear in the more upstream, freshwater portions of the Delta for about two months before leaving the Delta and moving into the marine environment (Kjelson et al. 1981, 1982).

Estuarine Areas

There is little information about the residence of the juvenile Chinook salmon in the estuary. MacFarlane and Norton (2002) found that the juveniles (these were fall-run Chinook salmon) spent about 40 days migrating through the estuary to marine waters, and demonstrated little or no real estuarine dependence in their growth and development.

Near-Shore and Marine

At present, information on Chinook ocean distribution is scarce. The data are derived from fisheries, and are biased in favor of locations where fisheries activities occur. It is believed that spring-run Chinook salmon, like all Central Valley Chinook salmon runs, remain localized primarily in California coastal waters.

Fall-Run and Late-Fall-Run Chinook Salmon

Status

The Central Valley fall-run Chinook salmon ESU is comprised of two runs: fall and late-fall. NMFS designated the Central Valley fall-run ESU as a Species of Concern on April 15, 2004 (69 FR 19975). Fall and late fall-run Chinook are both California Special Concern species (Moyle et al. 1995).

Following a status review of the Central Valley fall- and late fall-run Chinook salmon ESU, NMFS determined that listing this ESU as threatened or endangered was not warranted. Long-term population trends appear generally stable or increasing; however, it is unclear if natural populations are self-sustaining. Fall- and late-fall run populations are heavily augmented with hatchery production and natural fall-run Chinook are not readily distinguishable from hatchery fall-run Chinook (Federal Register, 1999).

Currently, fall-run Chinook salmon are the most abundant of the four runs of salmon in the Sacramento and San Joaquin river drainages (NMFS, 1997). In the Sacramento and San Joaquin river systems, total abundance of adult fall-run Chinook salmon has varied from approximately 50,000 to more than 300,000 adults. In the Central Valley, the historical area of usage for fall-run Chinook salmon spawning and rearing has not been substantially diminished like that of spring- and winter-run Chinook salmon (Fisher, 1994). Late fall-run Chinook salmon are less abundant than fall-run Chinook salmon. Run size estimates for late fall-run Chinook salmon in the Sacramento and San Joaquin rivers have steadily declined from approximately 35,000 adults in the late 1960s to 9,982 adults total in 2009 (DFG GrandTab, 2011).

General Life History

The Central Valley fall and late fall-run Chinook salmon ESU includes both fall and late-fall Chinook salmon runs spawning in the Sacramento and San Joaquin rivers and their tributaries. These populations are presently the most abundant and widely distributed salmon in the Central Valley and enter the Sacramento and San Joaquin rivers from July through April. Spawning occurs during the months of October through February. Both runs are ocean-type Chinook salmon, emigrating predominantly as fry and sub-yearlings and remaining off the California coast during their ocean life history stage. The primary differences between the two runs are related to timing of migration into freshwater, timing of spawning, timing of juvenile emergence, and length of time juveniles remain in freshwater (Moyle 2002).

Spawning

Fall-run Chinook salmon typically spawn shortly after they leave the marine environment and migrate upstream. Their gonads are fully developed and eggs and milt are ready for spawning. This is in contrast to both the winter-run and spring-run Chinook that mature in the river over a period of months. Late fall-run typically mature in freshwater also and begin spawning from one to three months after entering the river (Moyle, 2002). Fall-run migrate up-river to their spawning grounds between June and December with a peak in September and October. Spawning begins in late-September and October, peaks in November, and subsides by late December. Late fall-run migrate upstream between October and mid-April with a peak in December. Spawning begins in January, peaks in February and March, and subsides by late April (Yoshiyama, 1998, cited by Moyle, 2002).

Fall- and late fall-run spawn in the main-stem of the Sacramento River and its tributaries. Although fall-run are found in the San Joaquin Basin as well, late fall-run chiefly persist in the Sacramento River Basin (Fisher, 1994). Spawning in the Sacramento River occurs primarily from Keswick Dam to the RBDD, but spawning has been observed as far downriver as Hamilton City.

Rearing

Fry emerge from December into April, depending on the date of spawning and water temperatures during incubation. Some yolk sac/alevins/fry move downstream out of natal rivers to the Delta where they rear when conditions warrant it (i.e., high flows, overcrowding). Other individuals rear in natal streams for several months until they are approximately 70 to 90 mm then move quickly through the system to the bay and ocean (NMFS, 2010).

Estuarine Areas

As juvenile Chinook salmon increase in length, they tend to school in the surface waters of the main and secondary channels and sloughs, following the tide into shallow water habitats to feed (Allen and Hassler 1986). In Suisun Marsh, Moyle et al. (1986) reported that Chinook salmon fry tend to remain close to the banks and vegetation, near protective cover, and in dead-end tidal channels.

Juvenile Chinook salmon use Suisun Marsh extensively both as a migratory pathway and rearing area as they move downstream to the Pacific Ocean (Spaar 1988). Fall-run Chinook salmon fry remain in the estuary (Delta/Bay) until they reach about 80 mm (i.e., 4 to 7 months of age) and then begin emigrating to the ocean as early as March and continue through July (Fisher 1994; Myers et al. 1998). Late fall-run Chinook salmon spend 7 to 13 months in freshwater prior to emigrating to the ocean from October through May at an average length of 160 mm (Fisher 1994).

Near-Shore and Marine

Juvenile fall-run Chinook salmon enter the ocean in spring and stay in near-shore waters in the vicinity of their natal rivers for the first few months of their lives in the ocean. For Central Valley fish this is the Gulf of the Farallones, where the rivers of the Central Valley all discharge to the ocean. Following this period, they remain between Central California and Southern Washington over the continental shelf. The timing of the onset of ocean upwelling is critical for juvenile salmon that migrate to the ocean in the spring. Juveniles can grow rapidly and survival is good if upwelling is well developed when they reach the ocean. If upwelling is not well developed or is delayed, growth and survival can be poor (NMFS 2009).

*Central Valley Steelhead (*Onchorynchus mykiss*)*

Status

The CV steelhead ESU was listed as a threatened species pursuant to the ESA in March 1998 (Federal Register, 63(53):13447-13371, March 19, 1998); threatened status was reaffirmed on Jan. 5, 2006 (January 5, 2006, 71 FR 834). NMFS then issued results of a five-year review on Aug. 15, 2011, (76 FR 50447), and concluded that this species should remain listed as threatened.

Critical habitat for the CV steelhead ESU was designated on September 2, 2005 (Federal Register, 70 (170):52488-52627, September 2, 2005). Critical habitat includes the mainstem Sacramento River and its major tributaries from Clear Creek downstream to the legal Delta, Suisun Bay, San Pablo Bay and the northern San Francisco Bay north of the bay Bridge. Critical habitat was also designated in the San Joaquin Valley, extending from the Bay-Delta upstream to the Merced River and the adjacent mainstem San Joaquin River. Critical habitat includes the river, river bottom, and the adjacent riparian zone. Riparian zones are considered essential for the conservation of CV steelhead because they provide important areas for fry and juvenile rearing.

Historically, adult populations may have numbered between 1 and 2 million (McEwan 2001). In the 1960s, returning adults were estimated to number about 26,000 (DFG 1965). Counts at RBDD showed obvious decline in CV steelhead returns to upper Sacramento River between 1967 and 1993. Current escapement data are not available for naturally spawned CV steelhead, in large part because of the more frequent gates-out operations at RBDD after 1993 and the lack of CV steelhead monitoring programs elsewhere in the valley (DFG 1996).

The majority of CV steelhead historical spawning habitat is now inaccessible because of the construction of large dams; an estimated 80% of the spawning grounds in the Central Valley have been blocked due to power and irrigation dams (DFG 1996, McEwan 2001).

General Life History

CV steelhead are the anadromous form of rainbow trout (McEwan 2001). Much like Chinook salmon, the distribution of CV steelhead has been greatly reduced with the construction of dams for hydroelectricity, water diversion, and storage. The range of CV steelhead in the Sacramento River drainage was likely as extensive as that recorded for Chinook salmon and probably stretched farther into the headwaters (Yoshiyama et al. 2001). Currently, CV steelhead are found in the Sacramento River downstream of Keswick Dam and in the major rivers and creeks in the Sacramento River watershed. The other major CV steelhead populations in the Sacramento River watershed are found in Battle, Mill, Deer, and Butte creeks. CV steelhead also occur in Stony and Thomes creeks (Yoshiyama et al. 2001, McEwan 2001) and many of the other tributaries to the Sacramento River, including intermittent streams in the Redding area. The tributary creeks support naturally spawning populations, although Battle Creek populations are augmented by Coleman Hatchery. In the San Joaquin Valley system, naturally producing populations are found in the eastside watersheds and the mainstem San Joaquin River upstream possibly to Friant Dam when flows are suitable.

The life history traits of CV steelhead are similar to that described for Chinook salmon, but have distinct differences. CV steelhead are iteroparous, which means that adults have the capacity to spawn more than once and do not necessarily die after spawning.

CV steelhead can be divided into two life history types, summer-run steelhead and winter-run steelhead, based on their state of sexual maturity at the time of river entry, the duration of their spawning migration, and stream-maturing and ocean-maturing. Only winter-run steelhead are currently found in Central Valley rivers and streams (McEwan and Jackson 1996), although there are indications that summer-run steelhead were present in the Sacramento river system prior to the commencement of large-scale dam construction in the 1940s [Interagency Ecological Program (IEP) Steelhead Project Work Team 1999]. At present, summer-run steelhead are found only in North Coast drainages, mostly in tributaries of the Eel, Klamath, and Trinity river systems (McEwan and Jackson 1996).

CV steelhead generally leave the ocean from August through April (Busby et al. 1996), and spawn from December through April with peaks from January through March in small streams and tributaries where cool, well oxygenated water is available year-round (Hallock et al. 1961, McEwan and Jackson 1996). Timing of upstream migration is correlated with higher flow events, such as freshets or sand bar breaches at river mouths, and associated lower water temperatures. Unlike Pacific salmon, CV steelhead are iteroparous, or capable of spawning more than once before death (Barnhart et al. 1986, Busby et al. 1996). However, it is rare for CV steelhead to spawn more than twice before dying; most that do so are females (Busby et al. 1996). Iteroparity is more common among southern steelhead populations than northern populations (Busby et al. 1996). Although one-time spawners are the great majority, Shapovalov and Taft (1954) reported that repeat spawners are relatively numerous (17.2 percent) in California streams.

Spawning

Returning CV steelhead exhibit two strategies: stream-maturing steelhead (summer steelhead), which enter fresh water with immature gonads and consequently must spend several months in the stream before they are ready to spawn; and ocean-maturing steelhead (winter steelhead), which mature in the ocean and spawn relatively soon after entry into fresh water (McEwan 2001). Stream-maturing steelhead typically enter fresh water in spring, early summer, and fall. They ascend to headwater tributaries, hold over in deep pools until mature, and spawn in winter.

Ocean-maturing steelhead typically begin their spawning migration in fall, winter, and spring and spawn relatively soon after freshwater entry. Ocean-maturing steelhead generally spawn from January through March, but spawning can extend into spring and possibly early summer months. This variability in life history patterns probably confers a survival advantage, especially in unstable, variable climatic and hydrographic conditions (DFG 1996).

CV steelhead spawn in stream habitats with gravel bottoms and moderate current with depths between 6 and 24 inches (Reiser and Bjornn 1979). CV steelhead will also spawn on streambeds comprised of cobble and sand. As described for Chinook salmon, substrates with only a small amount of silt and sand (less than or equal to 5 percent) are important for successful spawning (DFG 1996). Optimal temperatures for spawning are between 48°F and 52°F (Bjornn 1971, Bjornn & Reiser 1991). Unlike Pacific salmon, not all CV steelhead die after spawning. Adults may return to spawn as many as three times, but the percentage that repeat the spawning cycle is generally low (DFG 1996). Eggs usually hatch within four weeks depending on stream temperature. The yolk sac fry remain in the gravel after hatching for another four to six weeks (DFG 1996).

Rearing

Once the fry emerge, they inhabit shallow areas along the stream margin and seem to prefer areas with cobble substrates (DFG 1996). As fish grow older, the juveniles will use a variety of additional habitats (DFG 1996). Habitat use is affected by the presence of predators, and juvenile CV steelhead survival increases when cover like wood debris and large cobble are present (Mitro and Zale 2002). Juvenile CV steelhead typically migrate to the ocean after spending from one to three years in freshwater (DFG 1996).

Migration

CV steelhead do not necessarily migrate at any set age or seemingly at any set season (DFG 1996). Some individuals will remain in a stream, mature, and even spawn without ever going to sea; others will migrate to sea at less than a year old, and some will return to fresh water after spending less than a year in the ocean (DFG 1996). Attempts to classify CV steelhead into seasonal runs seem to have led to further confusion rather than clarification (Lindley et al 2006, McEwan 2001, DFG 1996). Hallock et al. (1961) found that juvenile CV steelhead migrated downstream during most months of the year, but the peak period of emigration occurred in spring, with a much smaller peak in fall. The emigration period for naturally spawned CV steelhead juveniles migrating past Knights Landing on the lower Sacramento River in 1998 ranged from late December through early May, and peaked in mid-March (McEwan 2001).

Estuarine Areas

Estuaries can be important rearing areas for juvenile CV steelhead, especially in small coastal tributaries (DFG 1996). Summer temperatures are moderated by the marine influence of the nearby San Francisco Bay and Pacific Ocean (Lindley et al 2006). Due to this, residency time in the estuary tends to be longer in the CV steelhead than other salmonids. During their residency in the estuary, pumping operations of the Federal Central Valley Project and the State Water Project can have a detrimental impact on smolt escapement to the ocean (DFG 1996).

Other Fish Species of Concern

Green Sturgeon (*Acipenser medirostris*)

Status

NMFS identified two Distinct Population Segments (DPSs) for North American green sturgeon, the Northern DPS and Southern DPS. In April 2006, NMFS listed the Southern DPS of green sturgeon as threatened on April 7, 2006 (Federal Register 71 FR 17757). Green sturgeon are also listed as a State Species of Special Concern by DFG. The listing of the Northern DPS under ESA was assessed, but was not warranted. The DPSs are based on the rivers in which they spawn and findings of preliminary genetic studies.

The Northern DPS includes all green sturgeon populations starting with the Eel River and extending northward. The Southern DPS includes all green sturgeon populations south of the Eel River. The only known population in the southern DPS exists in the Sacramento River (NMFS 2003), however green sturgeon fertilized eggs were collected in the Feather River in 2011, indicating that successful spawning occurred in that river system. There is no documentation of green sturgeon spawning in the San Joaquin River at present. Young green sturgeon have been taken occasionally in the Santa Clara Shoal area in the San Joaquin delta but these fish likely originated from elsewhere, most likely the Sacramento River (NMFS 2003).

Critical habitat was designated for Southern DPS green sturgeon on October 9, 2009 (Federal Register 74 (195): 52300-52351). The population size of the southern DPS is not known, but is considered substantially smaller than the northern DPS (NMFS 2002). The abundance of adult green sturgeon is not known, but all indications are that numbers are low in the Sacramento-San Joaquin River system. During tagging studies by DFG, the majority of sturgeon captured are white surgeon; and an average of only one adult green sturgeon has been captured for every 134 adult white sturgeon. Thus, adult green sturgeon abundance is much lower than adult white sturgeon abundance. In addition, recent preliminary genetics information that became available in September 2005, support the notion that numbers are low in the Sacramento-San Joaquin River system, indicating that fewer than 20 green sturgeon spawning above RBDD contributed to the production of juveniles in 2003 and 2004 (DFG 2006).

Although there is no direct evidence that populations of green sturgeon are declining in the Sacramento River, the small size of the population increases the risk that a decline in numbers would be difficult to detect until a collapse in the population occurs. The population is threatened by habitat loss or degradation, lethally high Delta temperatures, entrainment in water diversions, and exposure to toxic materials (Moyle et al. 1995).

General Life History

Less is known about the biology and abundance of green sturgeon than the white sturgeon. Unlike white sturgeon, green sturgeon are not highly regarded as a sport fish. Sport fishing for green sturgeon is currently closed in California, Oregon, and Washington. However, some green sturgeon are still taken as incidental bycatch during commercial fishing. On the Klamath River, in California, there is a Native American gillnet fishery (NMFS 2002).

Green sturgeon are a slow growing fish specially adapted for feeding on the bottom. In the Delta, juvenile fish feed on opossum shrimp (*Neomysis mercedis*) and amphipods, (*Corophium spp.*). The diet of adult fish includes shrimp, mollusks, amphipods, and small fish (NMFS 2002). Green sturgeon can grow to be 386 pounds and 106 inches, but do not often exceed 39.3 inches and 198 pounds in the Delta (Moyle 2002).

Green sturgeon spend more time in the ocean than any of the other species of sturgeon. Sexually mature adults are those fish that have fully developed gonads and are capable of spawning. Female green sturgeon are typically 13 to 27 years old when sexually mature and have a total body length (TL) ranging between 145 and 205 cm at sexual maturity (Nakamoto et al. 1995, Van Eenennaam et al. 2006). Male green sturgeon become sexually mature at a younger age and smaller size than females. Typically, male green sturgeon reach sexual maturity between 8 and 18 years of age and have a TL ranging between 120 cm to 185 cm (Nakamoto et al. 1995, Van Eenennaam et al. 2006). The variation in the size and age of fish upon reaching sexual maturity is a reflection of their growth and nutritional history, genetics, and the environmental conditions they were exposed to during their early growth years.

Spawning

During spawning, green sturgeon show fidelity for individual rivers (Bemis and Kynard 1997), and adults are thought to return to spawn about every 3 to 5 years (Beamesderfer and Webb 2002, NMFS 2002). Adult female green sturgeon produce between 60,000 and 140,000 eggs, depending on body size, with a mean egg diameter of 4.3 mm (Moyle et al. 1992, Van Eenennaam et al. 2001). They have the largest egg size of any sturgeon, and the volume of yolk ensures an ample supply of energy for the developing embryo. The outside of the eggs are adhesive, and are more dense than those of white sturgeon (Kynard et al. 2005,). Adults begin their upstream spawning migrations into freshwater in late February with spawning occurring between March and July (CDFG 2002. Heublin 2006, , Vogel 2008). Peak spawning is believed to occur between April and June in deep, turbulent, mainstem channels over large cobble and rocky substrates with crevices and interstices. Females broadcast spawn their eggs over this substrate, while the male releases its milt (sperm) into the water column. Fertilization occurs externally in the water column and the fertilized eggs sink into the interstices of the substrate where they develop further (Kynard et al. 2005, Heublin et al. 2009). In the Sacramento River system, spawning has only been substantiated in the Sacramento River. They spawn upstream of Hamilton City and possibly as far upstream as Keswick Dam (DFG 2002). Opening of the RBDD gates during the winter-run Chinook migration has likely benefited green sturgeon by re-opening access to spawning areas (NMFS 2002). After June 2012, the RBDD gates will remain permanently in the open position (NMFS 2009). The Feather River may also be an important spawning river (Moyle 1995). Fertilized green sturgeon eggs were recovered during monitoring activities in 2011 by DWR on the Feather River following a high water year. In January 2012, the falls at Shanghai Bend were breached by high flows on the river, removing the passage impediment of the falls to green sturgeon migrating into the Feather and Yuba rivers. Green sturgeon may have spawned elsewhere in the Sacramento-San Joaquin Basin before the development of major hydroelectric and water projects (NMFS 2002).

Green sturgeon have a complex anadromous life history. They spend more time in the ocean than any other sturgeon. USFWS estimated that green sturgeon spawn in the Sacramento River between April and

July and found spawning to occur about twenty river miles upstream and nine river miles downstream of the RBDD (Poytress et. al. 2009). The upper and lower extent of the spawning area on the Sacramento River is not definitively known, but the lower extent is thought to be in the vicinity of Hamilton City. The upper extent may be limited by cold water temperatures in the Redding area. In the laboratory, embryos thrived at temperatures between 62^{o} and 64^{o} F, while hatching rates and the length of embryos began to decrease at 57^{o} F (Van Eenennam et. al. 2005). USFWS's study results indicate that green sturgeon choose a spawning site based on habitat characteristics or fidelity for a specific spawning site. The USFWS found eggs (using artificial substrate mats) at depths ranging from 0.6 to 7.6 meters with an average depth of 4.5 meters. In areas where eggs were found, the dominant substrate was medium sized gravel (Poytress et. al. 2009).

Little is known about sturgeon spawning habitat, but it is likely that they use deep turbulent pools in the mainstem of rivers with gravel substrates; however, they may also use areas with sandy or bedrock bottoms. Large numbers of eggs (60,000 to 140,000) are broadcast over the bottom where they settle and become lodged in the spaces between cobbles, held in place by their adhesive surface (NMFS 2002). Eggs sink rapidly to the bottom into cover; they do not drift (Kynard et al. 2005).

During incubation, water temperatures above 68ºF are lethal (Cech et al. 2000, cited by NMFS 2002). Eggs hatch in about 7 to 9 days at 59ºF and the larva develop into juvenile fish in about 45 days (Van Eenennaam et al. 2001). USFWS found green sturgeon juveniles to be much less common in rotary screw traps in years when there is relatively low flow in the spring. This may be because fewer adults migrate upstream and spawn in low flow years (Poytress et. al. 2009).

Rearing

In the laboratory, Klamath River hatchlings preferred cover, were poor swimmers, and could not move farther than a few centimeters to cover. For this reason, green sturgeon females are probably adapted to depositing their eggs in places along the stream bottom that provide cover for egg and hatchling stages. Green sturgeon larvae do not exhibit the initial pelagic swim-up behavior characteristic of other Acipenseridae. They are strongly oriented to the bottom and exhibit nocturnal activity patterns. After 6 days, the larvae exhibit nocturnal swim-up activity (Deng et al. 2002) and nocturnal downstream migrational movements (Kynard et al. 2005). Juvenile fish continue to exhibit nocturnal behavior beyond the metamorphosis from larvae to juvenile stages. Kynard et al.'s (2005) laboratory studies indicated that juvenile fish continued to migrate downstream at night for the first 6 months of life. When ambient water temperatures reached 46.4^{o}F, downstream migrational behavior diminished and holding behavior increased. This data suggests that 9 to 10 month old fish would hold over in their natal rivers during the ensuing winter following hatching, but at a location downstream of their spawning grounds. An exclusive nocturnal migration like this has not been found in other sturgeon species. Later in development, green sturgeon larva and juveniles (up to day 84) forage day and night, but activity peaks at night. At day 110 to 118, juveniles were found to move downstream at night and habitat preference suggests that wild juveniles prefer deep pools with low light and some rock structure (Kynard et. al. 2005). Growth is substantially impaired once temperatures reach 75ºF. Spring and summer water temperature controls for winter-run Chinook have likely improved conditions for larval green sturgeon (NMFS 2002). Mayfield and Cech (2004) found that temperatures between 59ºF and 66ºF were optimal for bioenergetic performance of green sturgeon juveniles.

Larval and juvenile green sturgeon are susceptible to entrainment in pumps and diversions in the Delta and rivers. Screens designed to protect Chinook salmon and CV steelhead may not protect green sturgeon, however, the behavior of juvenile and larval green sturgeon in the river environment may decrease their encounters with diversions and pumps. For example, larval and juvenile sampling conducted at the RBDD experimental pumping plant (Borthwick et. al. 1999 and 2001) indicates that entrainment of green sturgeon is rare.

Migration Corridors

Juvenile green sturgeon apparently spend very little time in the freshwater, rather they drift down from the spawning areas to rear in the estuarine areas, notably the Bay-Delta (Moyle et al 1992). A number of larval and post larval green sturgeon up to 16 inches in length are caught each year in a rotary screw trap at the RBDD on the Sacramento River, however, no larvae have been captured in any of the Sacramento River tributaries, indicating that spawning occurs in the mainstem (Beamesderfer et al 2004). The presence of larval green sturgeon in salmon out-migrant traps on the Feather River has been reported and indicates that the Feather River may support a spawning green sturgeon population (Environmental Protection Information Center et al. 2001).

Estuarine Areas

Juveniles appear to spend up to 1 to 4 years in fresh and estuarine waters and disperse into salt water at lengths of 1 to 2.5 feet (Moyle, 1995, Beamesderfer and Webb 2002). Water temperatures of 59ºF are optimal for growth during this rearing stage (NMFS 2002). Green sturgeon juveniles feed on the abundant benthic invertebrates including shrimp and amphipods, small fish, and possibly mollusks.

Near-Shore and Marine

After leaving the Bay, green sturgeon disperse widely in the ocean (Moyle 1992, cited by NMFS 2002). They have been encountered in marine waters between Baja, California, and the Bering Sea (Erickson et al. 2002; Moyle 2002), and they typically remain in waters less than 100 m deep (Erickson and Hightower 2007). Green sturgeon also frequent certain bays and estuaries of nonnatal rivers during summer and early fall (Moser and Lindley 2007).

Delta Smelt (*Hypomesus transpacificus*)

Status

Currently, the USFWS has the delta smelt listed as a Threatened species under the ESA (CFR 58 12854). In March 2006, a petition seeking to relist delta smelt as an endangered species was submitted to the USFWS. The proposal to elevate the listing status remains under review and USFWS has, as yet, not acted on the petition.

Delta smelt are found only in the Sacramento-San Joaquin River Delta Estuary and were once one of the most common fish species in the Delta (Moyle 2002). However, in recent decades the delta smelt, along with other pelagic fish species, have experienced a substantial decline in population abundance as described earlier**.** The substantial declines in the delta smelt population in recent years, as well as declines in other pelagic fish species, have led to widespread concern regarding the pelagic fish community of the Bay-Delta estuary. A number of recent and ongoing analyses by agencies and organizations, including the Interagency Ecological Program (IEP), have focused on identifying the factors potentially influencing the status and abundance of delta smelt and other pelagic fish species within the estuary. Suspected causes under investigation by the IEP include: stock-recruitment effects, a decline in habitat quality, increased mortality rates, and reduced food availability due to invasive species.

Critical habitat for delta smelt has been designated by USFWS within the Sacramento-San Joaquin River system. Critical habitat for delta smelt is defined (USFWS 1994) as: *"Areas and all water and all 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."*

General Life History

Delta smelt are a relatively small fish (2 to 4 inches long), endemic to the San Francisco estuary of California. Delta smelt are moderately euryhaline (can tolerate a wide range of salinities), however, salinity requirements vary by life stage (Moyle 2002). They are a pelagic species, inhabiting open waters, away from the bottom and shore-associated structural features (Nobriga and Herbold, 2008). They live primarily in or just upstream of the mixing zone between the fresh and salt water interface in the Bay-Delta. Suisun Bay is usually the vicinity of this mixing zone, though changes in streamflow can affect how far downstream low salinity waters occur (Moyle 2002).

Delta smelt spawn from March through April over sand or gravel substrates in fresh or slightly brackish water. The fertilized eggs are adhesive and stick to submerged hard surfaces (Moyle 2002). Typically delta smelt live about one year. Some individuals live a second year and can reach lengths of 90-120 mm Generally by spring, smelt populations have matured to spawning adults, migrated upstream into the shallow, freshwater channels and sloughs to spawn, and by summer they have died and given rise to the next generation of juveniles (Moyle 2002)..

Distribution

Delta smelt spend their entire lifespan within the San Francisco-Bay Delta. Their abundance and distribution have been observed to fluctuate substantially within and among years. Distribution and movements of all life stages are influenced by water transport associated with flows in the estuary, which also affect the quality and location of suitable open-water habitat (Dege and Brown 2004; Nobriga et al. 2008). Smelt are short burst swimmers that feed on plankton and therefore they are typically found in places with low water velocities where the water is cool and well oxygenated (Moyle 2002). Water turbidity and salinity are also factors affecting their distribution.

Delta smelt occur primarily below Isleton on the Sacramento River side and below Mossdale on the San Joaquin River side (Moyle 2002). They are found seasonally throughout Suisun Bay and in small numbers in larger sloughs of Suisun marsh. Delta smelt have also been found in the Sacramento River as far upstream as the confluence with the American River (USFWS 1994; Moyle 2002; CDFG unpublished data).

Spawning

Delta smelt spawn in shallow, fresh, or slightly brackish water upstream of the mixing zone (Wang 1991). Most spawning occurs in tidally-influenced backwater sloughs and channel edgewaters (Moyle 1976, 2002; Wang 1986, 1991; Moyle et al. 1992). Some researchers believe the adhesive, demersal eggs attach to substrates such as cattails, tules, tree roots, and submerged branches in shallow waters (Moyle 1976, 2002; Wang 1991). Most spawning is thought to occur in the upper delta and in the Sacramento River above Rio Vista. Spawning has also been recorded in Montezuma Slough near Suisun Bay and may occur in Suisun Slough in Suisun Marsh and in the Napa River "estuary" (Moyle 2002).

Adult delta smelt begin their spawning migration into the upper Delta beginning in December or January. Adults migrate upstream from the brackish-water estuarine areas into shallow fresh or slightly brackish waters in tidally influenced backwater sloughs and channel edge-waters (Wang 1986). Though the timing and duration is variable, spawning generally takes place during March and April (Moyle 2002). The smelt spawn most often during overnight forays into spawning microhabitats on sand or gravel substrates, leaving them before dawn (Moyle 2002). Most spawning seems to take place at 44.6°F to 59°F (Moyle 2002). Temperatures optimal for embryo and larvae have not yet been determined but it is likely that survival decreases as temperature increases beyond 64.4°F (Moyle 2002).

Laboratory observations indicate that delta smelt are broadcast spawners (DWR and Reclamation 1994) and eggs are demersal (sinks to the bottom) and adhesive, sticking to hard substrates such as rock, gravel, tree roots or submerged branches, and submerged vegetation (Moyle 1976; Wang 1986). Embryonic development to hatching takes 9-14 days at 57-61°F (R. Mager, UCD, unpublished data).

Newly hatched delta smelt have a large oil globule that makes them semibuoyant, allowing them to maintain themselves just off the bottom (R. Mager, UCD, unpublished data), where they feed on rotifers (microscopic crustaceans used by fish for food) and other microscopic prey. Once the swimbladder (a gasfilled organ that allows fish to maintain neutral buoyancy) develops, larvae become more buoyant and rise up higher into the water column. At this stage, 16-18 mm (.6-.7 inch) total length, most are presumably washed downstream into the mixing zone or the area immediately upstream of it (Moyle 2002).

Rearing

Larval and juvenile delta smelt rear within the estuary for a period of about 6 to 9 months (Moyle 2002). Young smelt tend to feed on immature stages of calanoid copepods while adult smelt may feed on all life stages as well as other large planktonic organisms. Growth is rapid and juvenile fish are 40-50 millimeters (1.6-2 inches) long by early August (Erkkila et al. 1950; Ganssle 1966; Radtke 1966). The most rapid growth occurs when they reach 30 mm fork length and are large enough to prey on a wider variety of food sources.

Larvae and juvenile smelt need shallow, food-rich nursery habitat for survival. Adequate flow and suitable water quality is required for adult access to spawning habitat and transport of juveniles to Bay rearing habitat (Moyle 2002). Estuarine rearing habitat for juvenile and adult delta smelt is typically found in the waters of the lower Delta and Suisun Bay where salinity is between 2 and 7 parts per trillion. Delta smelt of all sizes are found in the main channels of the Delta and Suisun Marsh and open waters of Suisun Bay where the waters are well oxygenated and temperatures relatively cool, usually less than 68-71°F. Smelt tend to be concentrated near the zone where incoming salt water and out flowing freshwater mix (mixing zone). This area has the highest primary productivity and is where zooplankton populations (on which delta smelt feed) are usually the most dense (Knutson and Orsi 1983; Orsi and Mecum 1986).

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Appendix C — Science Advisory Review Comments

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June 19, 2012

George Isaacs
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Dear George,

As a final step in our review of the DWR Draft Report on Engineering Solutions to Reduce Diversions of Juvenile Salmonids to the Interior and Southern Delta, the three reviewers (John Pizzimenti, Steve Railsback and Mark Stacey) discussed our individual reviews. While there are differences in our perspectives and experiences and, therefore, the emphases of our reviews, we believe that the individual reviews are, in fact, complementary and we are supportive of one-another's individual reviews. We see no significant conflict among the individual reviews.

Through our discussion, we found four broad themes that cut across all of our reviews:

1. The proposed Phase II framework, which consists of a matrix of 3-level scores ("high, moderate, low", e.g.), would be ineffective as a decision tool because it lacks the site-specific analysis needed to evaluate—and possibly adapt—technologies meaningfully. At the same time, a revised set of similar criteria (suggested in some reviews) would be effective early in Phase II in helping to prioritize, and eliminate, alternatives.

2. This matrix framework, particularly the criteria proposed, is flawed. Key problems include assigning quite different impacts equal weight (i.e., environment impacts and recreation), and individual criterion being poorly defined (environmental impacts, e.g.). This can be remedied by application of published ranking methods. One of us recommends recasting the criteria into less ambiguous variables; another recommends use of the Water Resource Assessment Method developed by the US Army Corps which uses a panel of experts familiar with the challenges and options available. These are complementary recommendations.

3. Phase II activities should immediately eliminate unrealistic alternatives so that the bulk of Phase II can be used to study the feasibility and cost effectiveness of the most attractive alternatives. This filtering of alternatives can use other data on effectiveness of certain approaches (behavioral barriers, e.g.) and apply specific constraints that would prohibit certain approaches (permanent hard barriers, e.g.). For alternatives that merit further consideration in Phase II, it is critical that sufficient resources be invested to ensure a complete, detailed analyses that address the key scientific, engineering or

economic uncertainties associated with each approach. It is not clear to us that behavioral and non-physical barriers are the only actions to consider. Habitat and predators need to be factored into Phase II; and transportation if viable has unique elements that may preclude barriers altogether.

4. Phase II should include system-wide as well as site-specific analyses. System-level analyses should look at potential interactions (actions at one site can affect other sites, especially if flow is modified) and cost-effectiveness (what combination of actions across all sites provides the best investment).

Please note that these four points are in no way a summary of the individual reviews, which stand on their own. The goal of this summary is simply to emphasize the broad points of agreement between the individual reviews and to affirm there are no conflicting recommendations or disagreements among the three reviewers.

Respectfully submitted,

Mark Stacey

On behalf of
Steve Railsback and John Pizzimenti

Independent Peer Review

of

Draft Initial Findings Report

'Engineering Solutions to Further Reduce Diversion

of Emigrating Juvenile Salmon

to the Interior and Southern Sacramento Delta'

Prepared by
John J. Pizzimenti, Ph.D., PMP

June 19, 2011

Submitted to

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Organization of the Review

The main body of the report is organized **Section by Section** as in the Draft Phase I Report.

Each section of the Phase I Report is briefly described with a header and short paragraph. This is followed by sections entitled: **Comments, Details, Recommendations** and sometimes **Background Information.**

In each section, I provide text on the materials that provide guidelines for the Phase I Report authors to make changes. The Phase I report should be revised to enhance the outcomes and work products of Phases II and III. Phase I is interpreted as a blueprint for how to proceed in Phase II.

I use a limited set of citations to reference background or rationale for specific comments. These are contained in a section called **References.** Many can be accessed by the Internet with URLs provided.

Following the References is a section Called **Personal Communications.** It is list of experts that I consulted and their expertise. Discussion helped to clarify facts or research I used in the review.

The final two sections are Appendices. **Appendix I** is a reproduction of a graphic from a previous study on the changes in annual discharge averages in the San Joaquin over time. **Appendix II** contains my answers to the Questions that were defined in the Scope of Work. Appendix II is not a complete synopsis of all of the comments made in the main body of the report. It should not be used to summarize all of my comments. However, the statements are consistent with my review.

I wish to acknowledge and thank those at Delta Science Program that assisted me with my review. I also wish to acknowledge the time spent discussing these issues with colleagues who gave of their expertise and time. I know it helped me develop my thoughts, more confident of the facts and data available. Any errors of omission or commission are however strictly my own.

Section by Section Review and Comment

The Executive Summary

Phase I Identifies all options and engineering solutions to meet NMFS directive: …"consider engineering solutions to further reduce diversion of emigrating juvenile salmonids to the interior and southern Delta, and reduce exposure to Central Valley Project (CVP) and State Water Project (SWP) export facilities"

Phase II …"consist(s) of studying the engineering solutions proposed in this (Phase I)report, developing a solution for each of the possible locations, preparing preliminary engineering drawings and cost estimates, and preparing a Phase II final report.

Phase III is the NMFS Review process where they will direct agencies to implement specific projects based on the Phase II Report.

Comments: I have concerns that the levels of engineering required in Phase II as defined cannot be adequately completed in the time allotted (by March 30, 2015). Reasons include: (1) 13 alternatives at five sites and every possible combination suggests a final configuration potential of over 100 different possibilities (2) structural solutions may be very challenging at sites that have as much as 25,000 cfs discharging through them (3) impact assessment of the various alternatives will be challenging if done sufficiently well to allow an informed decision on how to proceed; (4) the potential hydraulic interactions of new structures on water supply and water quality will require application of Bay Delta hydraulic / hydrologic models; and (5) the scope of Phase II includes costs, and in order to rank the projects and establish feasibility, cost-effectiveness and rank order selection must also be included.

Details: My concerns are further raised on the potential "use of pilot studies" which are undefined and whose costs and scopes are not explained; the need to consider "solutions unique to each site" including hybrids; and the question of prioritizing the various sites and their potential interactive affects on pumping, water quality and biological consequences to smolt survival. If pilot studies include more behavioral guidance studies, how will one more year of results change more than 15 years of experience and data?

The approach to conduct a comparisons analysis in Phase II is an important step. The criteria identified in Table 4 include: deterrence ability, environmental impacts, effects on upstream migration, flow effects, predation effects, tidal effects, boat passage, implementability, operation and maintenance, maturity (acceptance of technology), land acquisition, and costs. I suggest the use of a more rigorous and widely accepted ranking process such as the US Army Corps, WRAM (Water Resource Assessment Method) and the NED (National Economic Development) methods discussed elsewhere in this review.

The "preparation of engineering drawings and cost estimates" is a costly endeavor and may be premature except at conceptual or pre-feasibility levels; or for one or two projects that rise clearly to the top during feasibility studies in Phase II. Until it is clear whether one or all sites should be developed, cost estimating and preliminary designs of many sites that will not "make the cut" will slow the process of implementation because it creates work that may not be timely or necessary.

Recommendation: Phase II should be devoted primarily to an in depth feasibility study to define the final configuration recommendation for the three sites NOAA identifies. There are only three choices:

Physical Structure, Behavioral Structure or No Action. This is the first decision that needs to be made. The many different gates and structural details are important, but less so than deciding whether a diversion (physical) structure is feasible at each site and what effects it would have on primarily water supply and water quality. Focus should also be on their combined cost and cost : effectiveness of each.

Introduction

The need for the study is clearly enunciated here and the approach required by NMFS. Although NMFS recommended three sites, Phase I is suggesting five sites.

Comments: In rank order of priority, NMFS has probably identified the three most important sites: Georgiana, Old River and Turner Cut. Columbia Cut will have similar benefits and potential design solutions to Turner Cut and evaluation of one or the other can be used as lessons learned to make the next design easier, if needed.

Details: Three-Mile is most downstream in the Delta and it is unclear why there is a strong case or data that identify biological benefits to be gained here. In fact, fish in the San Joaquin or the Sacramento would need to make sharp turns to enter either end and the distance from Suisun is not dramatically different either way. Here the tides are most influential; and flows up to 25,000 cfs rip through this large channel daily suggesting hydraulic structures of much larger size and cost would be needed compared to more problematic areas with less structural demands upstream. In contrast, fish at Georgiana and Old River don't need turn but only be on the "wrong side of the river" to enter a slow moving tributary that transports fish to known problem areas. By limiting the study to three sites, Phase II report can be stronger and implementation may come earlier. Phase II can also be extended and overlap Phase III to complete any additional sites or alternatives that arise during Phase II investigations.

Recommendation: Because of concerns about ability to meet the schedule with quality work products, recommend following NMFS recommendation for only three sites this time. Others can follow later.

Site Descriptions

These narratives contain limited technical information and could be improved by commentary on the potential for problems or issues that are of known concern or that need to be developed in Phase II.

Comments: Phase I Report should include preliminary information on the criteria identified for ranking: some sites will require more substantial structures due to larger hydraulic loads; some may have larger recreational impacts; or water quality or water delivery impacts. Laying out the preliminary challenges and questions helps focus where the levels of effort in Phase II will be; and pre-existing concerns should be at least hypothesized if not clearly identified.

Details: The maps are good and bring several thoughts to mind. Both Georgiana and Old River tend to divide the main channel into two very large tributaries that can attract large numbers of smolts. This sets up a hydraulic condition that may be potentially addressed by reconfiguring the channel or constructing guidewalls or gabions such that more water and fish are likely to be guided past these sloughs without construction a diversion dam. Commentary on these would tee-up potentially options with higher priority than to just consider equally every possible engineered fix. Channel reconfiguration was not mentioned as an option. Is it known to be infeasible?

The Turner Cut description that includes 25% of the river discharge during flood tides suggests that a tide gate might be an option at this location. Tide gates are commonly used on the Columbia estuary to prevent fish entrainment (and salt water) during incoming tides. Ditto Columbia Cut. The configuration of the channel at Columbia cut suggests a potential tide gate at the upstream entrance coupled with an overflow weir at the junction of the river split just upstream of the downstream entrance to Columbia Cut. Downstream migrants could be diverted around the island using the right channel. At flood levels, river water would pass over the low weir in the left channel. Tidal flows moving upstream would pass around the right channel. I am not trying to write Phase II, but tide gates may be a tool to consider for fish exclusion in tidally affected locations.

Recommendations: Phase I should more clearly lay out the challenges of each site and how they differ among each other. This should lead to a clear plan of how Phase II will be scheduled and completed. There is potential for use of tide gates and gabions and diversion structures at other locations that should be identified.

Fish Species

The descriptions are generally good; but they are uneven in places and the citations are incomplete in the reference section. If this is to be a public document, there are significant errors of omission that should be corrected and a thorough editing. In other sections of this review, I suggest other information that should be incorporated in Phase I Report to better define the Phase II Work Plan.

Comments: Proposed actions herein may help all runs of chinook and steelhead; however, ocean type runs are much more likely to respond to the fixes because they are lower in the system and less impacted by upriver conditions especially in the San Joaquin.

Details: Stream type salmonids, like spring and winter run fish are the most difficult to recover for the following reasons: (1) they move the furthest upstream compared to ocean types; (2) juveniles and adults reside in river for longer periods of time compared to ocean types; (3) they require higher water quality and flushing flows to leave the system. These are real challenges for the San Joaquin system in its current depleted state (See Figure from VAMP Review, 2010 in Appendix I).

Delta smelt are a concern and have been possibly incorrectly identified as being impacted by being drawn into the lower end of Old River if flows are reduced at the Head of Old River. This was discussed during VAMP Review (2010). Data suggest this may be incorrect; and it is not clear that Delta smelt traverse from the North Delta to the clearer water of the south Delta from the Sacramento estuary. Improved flows in the Sacramento as a result of reducing discharge into Georgiana Slough may further improve Delta smelt conditions. Limiting or controlling inflows into the south Delta has potential to improve survival of Delta smelt and salmonid migrants in both North and south Delta.

Recommendations: Recovering stream type migrants will be more difficult than ocean types. Setting up expectations will enable more realistic targets and measures of success in the future. They will also require differences in recovery techniques especially related to either restoring flows in the San Joaquin mainstem or implementing transportation (discussed elsewhere in the review).

Georgiana Slough Behavioral Barriers

Comments: Review of Hansen et al. (1997) suggests behavioral barriers tested at Georgiana Slough were not sufficiently successful to make much difference in deterring smolts from Georgiana Slough. Hansen reported guidance efficiencies of 15% in 1996. In 1994 he reported guidance efficiencies ranged from 58% to 28% from day to night; guidance efficiency was 60% at ebb tide vs. 39% at flood tide. Using a different index in 1993, he reported guidance efficiencies ranged from – 156 to + 74; negative meaning net increase of smolts into the slough rather than a reduction with sound systems operating. The Phase I draft report does not report these data and also identifies two technologies employed; one using high frequency (300 hertz) and one using low (10 hertz). Hansen's report only identified high frequencies. It is not clear which technologies were used where; this may matter based on research conducted by Sand et al., (2001).

Details: The behavioral data are obfuscated because it is not fully established how much flow, velocity and tides are responsible for the data. At ebb flows, velocities in the main channel may be near 3.75 fps; at flood tides near they are near zero or even minus (reverse direction). Migrants swim, but they are also carried by the velocity of the water. The problem is that numbers of tagged fish reaching the experimental area are not known precluding estimates of actual percent diverted versus passed. If PIT tags combined with acoustic tags were employed a more accurate estimate of total numbers of fish diverted from the slough(s) could be estimated.

Sound frequencies reported at Georgiana were in the 300-400 hertz range. Sand et al. (2001) reported Atlantic salmon better respond to infrasonar signals of 10 hertz or less than to higher frequencies. He shows that particle acceleration and not sound pressure is eliciting the response. To produce these signals, very large sonar devices are needed compared to those used for higher frequencies (300-400 hertz). The sounds mimic the hydrodynamics of fish swimming and may be a predator avoidance mechanism. Similar low frequency sounds may come from rapids or shoals in rivers which migrating smolts are known to avoid (ELAM modeling, John Nestler).

Unimpacted salmon populations (very few remain) in the Pacific Northwest have return rates of 1-20% annually with a 4-6% return of smolts to adult (SAR) being a very healthy average. The return rates Bay Delta are less than a fraction of 1% (VAMP review, 2010). All smolts that enter Georgiana Slough are lost to the population.

Recommendation: Data from Georgiana Slough suggest behavioral barriers are not providing enough benefit to make any difference in population levels especially at smolt to adult return rates in the system. Unless data can clearly demonstrate effective (95%) deterrence under all flow / tide / light conditions, recommend proceeding to physical barriers.

2011 Georgiana Slough Bio-Acoustic Fish Fence (BAFF)

No results were presented and the draft plan was not made available for review.

Comment: This technology was used at HOR with mixed to negative results (VAMP Review 2010; Vogel, 2011).

Recommendation: If low frequencies (10 hertz or lower) are employed, specifications should be identified. Further comments are contained in review of Old River section of the report.

Temporary Rock Barrier at Georgiana Slough

The section of the Phase I reports that USBR designed structure, but it was never installed due to reported adverse effects on water quality, natural flow patterns, levee stability, flood control; upstream migrating adults; boating and recreation. A report is cited in text ("Initial Study and Mitigated Negative Declaration was completed and released in August 1992") but no reference or data are provided to understand the basis of the decision not to test the barrier.

Comments: Why was any effort expended on the design since the reasons for not implementing had nothing to do with the design; usually designs come after feasibility level studies. Do the data in the un-referenced report support the intent to reject the concept of a physical barrier at Georgiana Slough in Phase II?

Recommendation: Phase I Report needs to clarify the question of whether physical barriers are open for consideration at all sites including Georgiana Slough. Feasibility studies should be completed in Phase II before any designs are completed.

Rock Barriers

The Report says four temporary barriers have been in use: one at Old River since 1963 and two additional locations since 1987 at Middle River and Grant Line. "They are designed as a short-term solution to improve water level and circulation patterns for agricultural users, and to collect data for the design of permanent barriers."

Comments: What data are being collected to make a decision on a permanent barrier? Since Obermeyer gated structures can essentially be lowered to near river bed level, has there been any cost : benefit evaluation of comparing a one-time constructed fixed barrier, to constructing and deconstructing four or more barriers each year? This data might be valuable for scoping or supporting the Phase II Study.

The explanation of how the barriers and culvert operations are affecting and benefiting the SDWA as well as salmon needs further explanation and would be improved with a graphic. It is not apparent how changing the numbers of culverts helps both increased water supply and quality and salmon migration. If it helps salmon (presumably fewer are passed into Old River?), why did DFG and NMFS require enhanced salmon counts through the two culvert design compared with the six culver design?

What are the results of salmon passage rates through these structures? Data should be provided. And how many of these fish (percentage) were captured in the fish salvage facilities comparing the two designs vs. six designs vs. no barrier in place?

Recommendation: Phase I Report should identify what data exist to demonstrate that these physical barriers, temporary or not, are reducing smolts entering the salvage operations or increasing fish survival to the lower Delta via the mainstem channel. Work of Brandes and Newman and others enumerating salvage counts should be cited.

Non-Physical Barriers Acoustic Technologies at HOR

Predation rates before arriving at the BAFF ranged from 25.2 to 61.6% in 2009; and 2.8 to 30.9% in 2010 for each release group. Predation rates in the area of the BAFF ranged from 11.8 to 40.0% in 2009; and 16.9 to 37.0% in 2010.

Comments: Are the predation rates are high enough in such a short section of river that if extrapolated the remaining distance down raise the concern that there will be essentially zero survival? Does this suggest that the barrier performance is inconsequential whether it is diverting smolts away from Old River on not? These questions were raised during the VAMP Review (2010) and during discussions of the predation rates estimated by Vogel (2011).

Details: Grand deterrence (81%) is based on the number of fish detected in contact with the structure, not the total number of migrants passing Old River. Thus it is not clear what the actual net benefit of the structure provides. If for example only 30% of the fish encountered the structure and 70% passed along the right bank, then the net benefit of the structure would be 0.8 *0 .3 = 0.24. If predation takes are representative, then the net survival from the structure is reduced to 0.23 to as low as 0.14 (14%) of the fish passed alive as a result of the structure. Those that cross into Old River are estimated to have a survival of near zero.

The results as presented suggest that the BAFF solves the problem because it diverts most of the fish (80%) that encounter it away from the structure and downstream. The actual survival rate of smolts passing Old River may be in reality closer to 25%. There are data on rates of survival per mile for salmon smolts in natural unimpacted system and impacted systems like the Columbia River. Comparison of survival rates in the San Joaquin may be indicative that even a fixed barrier at Old River has limited net benefits.

One observation that was made during the VAMP Review (2010) was that the placement of even a fixed barrier several hundred feet inside the Head of Old River creates predator habitat and slows smolt movement due to slackened velocities. If a permanent barrier were constructed, it should confine the main channel to maintain velocities at this location and potentially involve channel reconfiguration to eliminate scour holes and holding areas for predators. The VAMP Review also noted the following:

"San Joaquin River mainstem survival estimates from Mossdale or Dos Reis to Jersey Point were just slightly greater than 1 percent in 2003 and 2004 and the estimate was only about 12 percent in the very high flow year of 2006. This compares to survival estimates that ranged between about 30 and 80 percent in the years 1995 and 1997-2000. The recent survival estimates are significantly lower than the long-term average survival estimate of about 20 %, which itself is considered low when compared to the Sacramento River and other estuaries like the Columbia River (which is in excess of 60%). The very low recent survival rates seem unlikely to be high enough to support a viable salmon population, even with favorable conditions for ocean survival and upstream migration and spawning success for adults." Predation may not be the only cause of mortality, but data support that it is or has become a significant source or smolt mortality in recent years.

Recommendation: Transportation of smolts in the Columbia and Snake rivers has shown itself equal to returning adults compared to in-river smolt survival (60%). With smolt survival rates in the San Joaquin averaging less than 10% recently and even as low as 1%, the consideration of smolt transport may deserve more emphasis in Phase II than is suggested by information provided in the Phase I Report.

South Delta Improvement Program

SDIP planned to install a fixed barrier at Old River using Obermeyer like technology as recommended earlier. Rationale for the delay was not explained except to say NMFS Biological Opinion 2009 stopped it until predation studies are completed at the South Delta temporary barriers.

Comment: Since predation data is not available for the Phase I Report, it is difficult to comment on it. However, assuming predation is not zero, and possibly high at these locations, it is unclear how any finding will facilitate a better decision about permanent barriers that can be instantly removed with gate operations at Old River or other key locations identified in this report. There is only one disbenefit to preclude construction of a permanent barrier at Old River. If a concept is selected to attract migrants into Old River for improved "transport" around South Delta, at the pumps themselves or at a new facility upstream of the pumps, then a permanent physical gate will not have any value at least as conceived to block flows into Old River. If a transport system is developed, but it is located upstream of the Head of Old River, a permanent gate would have less value but still have benefits as many of the migrants, but not all, will have been removed prior to arriving at Head of Old River.

Recommendation: Unless transportation options are recommended in Phase I at the pumps, a physical barrier at Old River should be constructed with Obermeyer type control as soon as possible.

Non Physical Barrier

This option has been discussed in detail elsewhere in the Phase I Report and review comments provided.

Comment: The most successful behavioral guidance systems that have been demonstrated repeatedly are those involving non-salmonids and mostly in lentic systems (lakes, bays, estuaries and some canal diversions). Here fish are not fighting large volumes of bulk flow with the built in negative rheotactic instinct (swim with the flow downstream to the ocean). They are also not fighting the complexity of flow reversals where much of the day upstream looks like downstream. The most successful applications involve water supply diversions where intakes are small and the species they are repelling have very different aural capacities compared to salmon.

Details: There is promising research that suggests better results with salmonids can be obtained with infrasound and ELAM models (Sand et al., 2001; Nestler et al.). That said it is unclear that even 100 percent behavioral or physical exclusion is sufficient by itself to address smolt survival rates of less than 10%.

That is why addressing predators must accompany any plans for addressing diversions into unwanted sloughs. One way to decrease predation at Old River would be to redesign the channel to increase velocity at the structure and remove the existing scour hole downstream of the diversion point. Predators however, will just find the next best ambush location up or downstream.

Thus predator control by a variety of methods must also accompany efforts to redirect smolts into the mainstem channels. This will be a non-stop commitment as eradication is not feasible. But because some of the species are desirable have food and recreational value, increasing take limits by sport fisherman would be one way to do this cost effectively. For non-game species, use of bounties was successfully employed in the Columbia / Snake system for pikeminnow at specific locations (mostly dams) where predation rates were especially egregious due again to the creation of slack water in a lotic (flowing) system.

Recommendation: Drop behavioral guidance options at Old River and Georgiana Slough unless evidence can show definitively that they can fully deter most smolts from passing into these sloughs at all flows. The cost differences are negligible and the certainty of physical barrier effectiveness outweighs any potential cost saving on water. The exact operation of these structures to meet other needs including water supply, water quality and navigation will be an important component of the design and operating phases.

Electric Barrier/Guidance System

Smith Root (2012) is a design leader and provides information that may be useful in deciding if or where it could be helpful. There are other commercial vendors that are easily found.

Comment: Electric barriers have potential drawbacks in Bay Delta. The amount of amperage must be set to the smallest fish to be repelled. Higher amperages can injure or kill larger fish; smaller amperages allow small fish to pass the barrier more easily. Since there is a large and diverse fish fauna, including simultaneous presence of adult and juvenile salmonids, and in some locations Delta smelt, such systems are unlikely to deliver the intended results for all species and fish size classes in one any location. Electric current is affected by the dissolved solids in the water. Salinity is an important variable in Bay Delta. As salinity changes with tidal flux, so will conductivity. As depth changes with river and tidal flows, the effectiveness of the current from surface to bottom will change. Although safe to operate in controlled environments, many of the locations will not be secure from the public, including boaters.

Recommendation: Minimize efforts to study this option unless it is in a controlled environment with only single species of fish as targeted. It could be useful at a collection or transport facility.

Fish Screens

Fish screens are primarily used to separate fish from water. There are numerous types and designs that vary by application.

Comment: Costs for screening small fish are very high; in excess of $4000 per cfs. And they have high O&M costs. The primary place screens would have application will be in development of a fish removal and transportation system. If this option is studied, designs now in operation in the Pacific Northwest or the Northeast U.S. should be studied. One caveat is that there are very few examples of fish screens at low head dams; however, applications at hatcheries, including those in northern California may be helpful.

Recommendation: Limit study of fish screens to fish removal and transport system; they could have some options where use of tide gates or other barriers are employed and water but not fish need to be passed.

Obermeyer-Type Spill Gates

Comments: There are numerous makers of inflatable dams. Obermeyer is one in Colorado. The Europeans have been a leader in inflatable dams and more research should be conducted to insure a cost effective and competitive selection process. The main advantage of these gates are they handle low head applications very well and enable diversion dams to be fully open or closed to natural flows and natural river elevations. Elements to keep in mind are that the gates may operate multiple times per day based on day/night and tidal cycles as well as remain in fixed positions during the non-migratory season. The environment includes saline waters at times and this will create additional concerns for corrosion and mechanical operation.

Under-Flow Gates

The description of underflow gates is confusing but potentially applicable but only in some highly specialized situations. Passage of sturgeon and other bottom dwellers may be effective; but there is a limited literature on experience.

Comments: An underflow gate will create some unusual hydraulic environments that are not particularly fish friendly or attractive. Juvenile salmonids often resist or delay passage through submerged orifices and gates. If the goal is to guide smolts to a new location, while also allowing discharge and bottom dwelling species into a diversion, such as a slough for non-salmonids, it might be applicable. A better solution is to exclude fish would be use of screens. These will be costly, high maintenance and of suspect value since there are multiple passages throughout the Delta that would enable fish to enter or egress side channels and sloughs.

Sluice Gates and Radial Arm Bottom Discharging Gates

Comments: Although lower in cost that Obermeyer gates, sluice gates are not easily raised and lowered. They generally do not operate in partially open / closed positions. If gate operations are to be infrequent and either full open or closed, this might be a choice; but given the goals to keep smolts out of sloughs during migration while still allowing discharges at on tidal or diurnal cycles, a design that allows frequent gate level changes and surface elevation adjustments would be a better choice.

Note also that sluice gates open from the bottom so, if some designs allow partial discharge, it would be drawing from the bottom. A gate that is designed to be cracked open to various levels from the bottom and operate moderately frequently is a Tainter type or radial gate. Typically these are associated with ogee spillways and at higher heads than are associated with most levees in the Delta. Likely these might be considered where flows are higher, like at Three-Mile Slough and Georgiana Slough as exemplified by gates at the DCC in Figure 15.

Floating Barrier – Fish Guidance Systems

These types of systems are typically used in the forebays of high head dams, those with over 70 feet of head. Their purpose is to laterally move fish to one side of the forebay or the other and to direct them into a downstream fish passage entrance and away from powerhouse intakes. These are unsuitable for areas of high velocity where stability may be a problem.

Comments: One use that could be effective for floating guidewalls might be to test the effectiveness of guiding fish temporarily away from specific slough entrances or areas of high predation. The strategy would be to move the structure from time to time, gather data on fish guidance efficiency, predation rates and channel hydraulics as a precedent to installing a permanent guide wall or other hydraulic channel modification.

Recommendation: Consider use of floating guide walls as research tools to increase fish passage in areas of high predation. Once a design is proven successful, it would be replaced with a more permanent and low maintenance guidewall.

Guide Walls

This is a euphemism for any hydraulic structure designed to direct discharge in a specific direction; or to protect a shoreline from erosion. Gabions are rock weirs that have some hydraulic permeability and can be submerged during flood flows.

Comments: In general smolts will be either randomly or uniformly distributed around the deeper portions of the channel, but more surface-oriented during the day. The advantage of a guide wall over a floating system is that is provides directional flow from bottom to surface unless submerged and as shown in Figure 16 (Phase I Report), could direct fish (and water) to the opposite side of channel to enable greater likelihood of not being swept or directed into a slough.

Details: A caveat for the implementation of guidewalls is they may actually increase habitat for predators if they create backwater areas that reduce velocity. Gabions are cheap to construct and can be flood resistant, but will provide hiding places for ambush style predators like black bass and catfish in crevices between boulder size rock.

The hydraulics of both guidewalls and floating barriers are complicated by ebbing and flooding flows of varying depths and velocities. Thought would be needed as to the creation of eddies and how much discharge they might distract from a given slough. Diminished flows may be good for fish, but could negatively affect water quality, water supply, erosion and unintended flooding.

Recommendation: Guidewalls may be useful for directing smolts away sloughs and predator habitat. They could increase local velocity by narrowing certain sections of the channel. These should be considered in concert with especially predator control.

Rock Barriers

Questions: Have costs of constructing and deconstructing been compared to a permanent Obermeyer design been addressed? The Report explains that NOAA placed a hold in 2009 on the barrier; and my comments were already provided if the rationale was Delta smelt. Further explication in the Phase I Report and how this will be addressed in Phase II would improve this report.

Why not install tide gates instead of culverts in the next barrier? There may be need from some control and that could be accomplished with a gated culvert or other control structure. But this would set up set and forget type barriers to smolts from moving into sloughs on flood tides. Would a fuse plug spillway work with the water surface elevations to make the structure flood worthy and prevent back flooding as well as to preserve the structure in the event of a large runoff?

Comment : Riprap provides increased habitat for predators and increased attraction for small non-migratory fish to take up nearby residence. This further invites more predators.

Recommendation: The location of the temporary barrier inside the Head of Old River undoubtedly reduces cost for construction and deconstruction (narrow channel), but if temporary structures are to continue for the indefinite future, why not make them semi-permanent by putting the alignment close to the main river channel, narrowing it, and possibly covering the riprap with material that smoothes out the surface? That would reduce friction and discourage predators and a community of food from developing in the structure.

Hybrid Combinations

Comment: These are good ideas. The only issue is the complexity of the task and the time limitations of Phase II as already addressed above.

Habitat Restoration

Comments: I generally agree with the comments that there are significant impacts to close off Head of Old River, Georgiana Slough and Three-Mile with permanent natural barriers. However, especially Old River and Georgiana Slough, appear to be good candidates for temporary hydraulic control to reduce smolt migration into these channels at some times of the year and some periods of the tidal cycle.

I am generally not a very strong proponent of riverine habitat restoration. Too many good intentions in river modifications are simply undone by the next big flood. The proposal to close off Columbia and Turner Cuts sound interesting but depend on tradeoff analyses of impacts and costs. This in itself is a significant study if added to the already large lists of tasks for Phase II.

Details: One other area of habitat restoration that might be considered emerges from comments on predation from Vogel (2011; personal communication). Vogel reported the following predation rates on acoustic tagged test fish by location in 2010: Chips Island 59%; Old River 75%; Deep Water Shipping Canal 59%; aggregate of all 65%.

Every instream structure that has been placed in these sloughs and the mainstem River channel represents habitat to deflect current, reduce velocity and add resting and hiding places for predators. Areas of high predation should be considered for either predator removal or modification (getting structure out or modifying the channel to increase velocity). This unfortunately will have un-measurable net benefits to smolt survival because the Delta is vast and hydraulically complex.

Recommendation: Temporary closure (gated structures) may be as effective as permanent closure for improving smolt survival. If this has fewer impacts, it should be compared with the proposed option for permanent closure using rigorous alternatives analysis that consider costs and benefits.

Transportation Barges

Transportation means collecting smolts and moving them artificially around migratory habitat which is unsuitable to meet survival targets due to impacts too costly or difficult to remove. This can be done in trucks as takes place at the fish salvage facilities near the pumps; or if it makes more sense in barges.

Comments: Existing salvage and transport facilities were an afterthought of saving the fish attracted to the pumps. Clifton Court has very poor hydraulics for capturing fish as currently designed. The average fish spends up to 72 days prior to capture and the average is many days to weeks (VAMP Review, 2010). Predation estimates of marked salmonids that ended up at this area in 2010 were 98% (Vogel, 2011). If transportation is to be considered, it will be a major facility and take significant effort on its own to come up with a location and conceptual facility. The existing fish salvage facilities were studied for improvement at least conceptually by Ott (2005). If the pumps are feasible sites, and there are many reasons why likely they are not, major modifications would be needed to more rapidly attract, separate and transport smolts from predators and water. Since distances are short compared to the Columbia, trucks are the likely choice over barges for transport vehicles

Details: The current size and layout of Clifton Court with confined entrances make predation a huge obstacle. The reason to at least review this location: pumps provide an attraction flow from the San Joaquin that might attract most smolts from the Head of Old River with some hydraulic help at that location. It would also insure large amounts of water for export, a potential win-win solution. Other sites to consider would be further up the San Joaquin River to minimize the effects of tidal influence and predation. Fish would be transported to Suisun Bay at improved release sites to minimize the high predation rates experienced because predators have become habituated to the release (feeding) schedules and locations. I do not see the sense in transporting fish from the Sacramento if they can be passed downstream of DCC and Georgiana Slough in improving percentages.

Background Information: The Columbia Snake system instituted major programs to improve in-river survival, with transportation showing moderately good survival at least to the estuary. The fact that populations were still declining led to major reevaluations of new capital intense projects, including removing some of the largest dams in the U.S. (Pizzimenti, 1996). Currently federal agencies use both transport and in-river bypass with more smolts in river during high flow years. Collection efficiency is lower when there is more spill and juvenile survival and adult return rates are higher in-river during high flow years. Although barging is less costly NMFS uses both pathways as they return similar adult numbers. Until more flows are returned to the natural channel in the San Joaquin (see Figure in Appendix I reproduced from the VAMP Review) these high flow years would be rare events.

No Action

Comment: Presumably this is a formality. Clearly actions are needed if extinction is not an option.

Framework for Evaluation

The current framework is a Qualitative approach to listing options and impacts similar to an NEPA analysis found in a Biological Opinion or EIS.

Comments: Phase II will form the basis of environmental and economic acceptability. It will require justification that the configuration of options selected provides the best combination of facilities at the lowest cost to improve smolt survival. Options must be defensible using peer reviewed methods and that are clearly in the best interest of the "public". If the method of ranking options is not quantifiable and transparent, disgruntled special interests could stop the process from legitimately moving forward. Earlier in this review, I recommended review of WRAM (Soloman, 1977) and use of NED standards. The

Phase I Report suffers for absence of clear methods and tasks that show how the action agencies will arrive at a Phase II Report on time and meeting NMFS requirements.

Details: USACE Water Resource Assessment Method, a non-parametric pair-wise comparison is one option that can employ Delphi (expert panel) participation. It is not very confining or data demanding; but it is formal; it is published; it has been used to rank major water resource development projects by the Corps and it is easy for non-expert modelers to understand how the analyses are done.

Regardless of the method, the Phase II effort should include some means to scale and weight the variables. If not, how will results that include water supply impacts as high and recreational impacts as high separate the fact that one may involve hundreds of millions of dollars and the other tens of thousands of dollars (cf., Pizzimenti, J.J. and D.O.Olsen, 2009). The use of NED (1993) techniques should also be considered to add rigor and formality to methods that are widely accepted in justifying costs for large public projects.

Recommendation: Action agencies may want to consult both the Corps of Engineers and Bureau of Reclamation Tech Center for more widely accepted and rigorous methods of ranking and project selection. Economic comparison of recommended configuration and their impacts need to be incorporated in the Phase I Plan that would be implemented at the feasibility level in Phase II and finalized in Phase III.

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Personal Communications

During preparation of my review, I consulted with the following individuals regarding their research and publications. I wish to acknowledge and thank them for sharing their personal knowledge of factors, methods and state-of-art- status of science and engineering relevant to the Phase I report. They understood the purpose of my communication and gave freely of their knowledge and expertise. This review however remains exclusively my own.

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Mark Bowen, Ph.D. Senior Fisheries Scientist , AECOM (formerly, US Bureau Reclamation); Fish behavioral guidance systems including BAFF; Bay Delta salmon recovery; predation monitoring technologies; fish behavior; statistics; fish behavior experiments

Andrew Goodwin, Ph.D. Bio-Engineering Research Engineer, US Army Corps of Engineers; Expertise: Modeling; Eularian Lagrange Agent Methods (ELAM); smolt behavior models; fish passage; salmon behavior; Columbia Basin fisheries research

Kenneth Ham, Ph.D. Senior Research Engineer, Battelle Pacific Northwest National Laboratory; Expertise: fish passage; fisheries engineering; hydraulic and water quality modeling; Columbia basin salmon recovery

John Nestler, Ph.D. Senior Research Ecologist US Army Corps of Engineers; Expertise: fisheries biology; fish passage, hydroelectric dam affects on smolt behavior; salmon behavior Eularian Lagrange Agent Methods (ELAM)

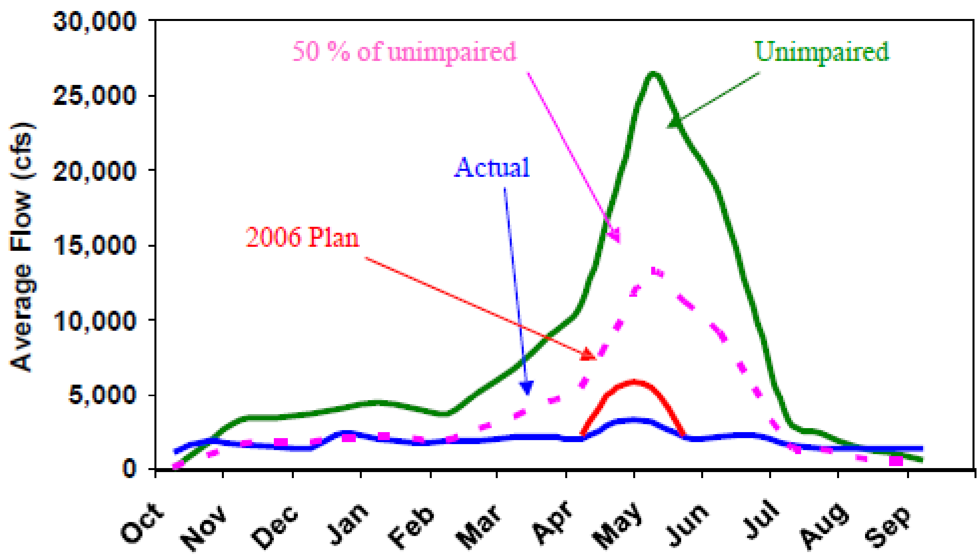
Kevin Malone, MS. Senior Consulting Fisheries Scientist, Sole proprietor; Expertise: Colombia basin salmon recovery; fish passage; fish transportation; fish mitigation at dams; statistics

Peter Smith, Ph.D. Senior Research Engineer, US Geological Survey (retired); Expertise: Modeling; Bay Delta hydrologic and hydraulic models; endangered species recovery Bay Delta;

Appendix I

Graphic depiction of flow changes in the San Joaquin Drainage

(VAMP Review, 2010)


30,000
25,000
20,000
15,000
10,000
5,000
0
Average Flow (cfs)
50 % of unimpaired
Unimpaired
Actual
2006 Plan
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep

Appendix II

Synopsis to Questions in the Scope of Work

Approach

Are site descriptions complete and do they contain the necessary information from which to evaluate the application of a given engineering solution and the effects on aquatic species of concern?
Response: The site descriptions can be improved and a more descriptive narrative provided as to how the Phase II report will be accomplished. There is no discrimination about the differences between ocean type and stream type salmonid recovery actions. These two life history forms present very different challenges. Also the San Joaquin and Sacramento drainages present different hydrologic / biologic conditions that suggest different outcomes and tools may be appropriate. One is seriously hampered by low flows; the other presents major hydraulic challenges due to higher flows. A major concern is whether the Phase II work can be complete in the schedule provided. I recommend limiting the study to the three sites NMFS recommended. Details are provided in specific sections of the report.

Are potential engineering solutions clearly defined and described?
Response: The report is more of a generic approach or a tool box as opposed to a plan for proceeding to Phase II. The Report should contain more definitive tasks and actions that will be taken at each site in Phase II. I am concerned that since Phase I does not lay out clearly what must be accomplished in Phase II that it is unclear whether they can meet the schedule. In particular, the level of rigor to rank and select options or combinations of options is inadequate to define what is essentially a Feasibility or at least Pre-Feasibility level analysis of multiple sites, options and combinations including impact assessments and net benefits in specific terms of costs. Recommendations are made in specific sections of the Phase I Report.

Are the evaluation criteria clearly defined and described?
Response: The primary evaluation criteria must be whether to use physical versus behavioral barriers at each of the five sites. There are no criteria as to how effective behavioral barriers need to be; or how to reach specific smolt survival goals in the system. This is a serious shortcoming. I recommend that unless behavioral guidance at Old River can be shown to divert 95% of the migrants down the main channels, that physical structures be employed. A similar standard may be needed at other locations, but data is inadequate. There is a general lack of criteria throughout all sections of the document and comments and recommendations are provided in each.

Is the DIFR internally consistent and the initial findings scientifically valid?
Response: Consistency is not an issue in the Phase I Report. I am unsure whether the document contains initial findings. I recommend that the site descriptions should be more detailed as to what is considered to be the likely candidate for a design or action, even if preliminary and with caveats.

Are linkages between elements of the report clear?
Response: The report consists of disparate sections that are not related to one another. The biology section is not mentioned in any of the engineering sections. Nowhere is there a cohesive synopsis that defines how biology, hydrology, hydraulics and economics will be integrated as they must be during Phase II.

Content

Is the DIFR of sufficient robustness and scientific quality that it appropriately: identifies and considers applicable target and related aquatic species; identifies and considers applicable solutions; identifies, defines, and considers applicable evaluation criteria?
Response: The target species are listed in the biological section. The engineering sections list a variety of gated structures and behavioral guidance sections that can be constructed. It is not the lack of appropriate pieces; the primary problem is a lack of integration so that it is clear how this will be done in Phase II.

What, if any, additional species of concern need to be considered?
Response: None recommended

What, if any, additional engineering solutions need to be considered?
Response: A few specific suggestions are made for better analytical methods in the Approach Section; recommendations for a more rigorous look at Transportation is included in that section; and use of tide gates and fuse plug spillways are included on sections related to physical barriers.

What, if any, additional evaluation criteria need to be considered?
Response: There is a need for a more quantitative approach to selection and evaluation criteria. Economic (NED) and Ranking (WRAM) methods developed and employed by the Corps of Engineers would be a starting point.

Feasibility

Are the engineering solutions described in the DIFR feasible to implement?
Response: If by feasibility it is meant, is it possible to construct without consideration to cost or will they be effective, yes. If by feasible there is an economic analysis of costs and benefits or cost : effectiveness, no. More work needs to be completed to determine feasibility in Phase II.

If not, what limitations need to be considered to improve the feasibility of given solutions?
Response: The primary limitations are a lack of recognized feasibility methodologies described that define cost : benefits or cost : effectiveness and selection of the best configuration. Further, there is no analysis presented that recognizes targeted survival goals to meet NMFS recovery actions.

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May 30, 2012

Delta Stewardship Council
980 Ninth Street
Room 1500
Sacramento CA 95814

Subject: Review of Phase I report, OCAP RPA Action IV.1.3, under Agreement 2069

Dear Sirs:

This letter report is my product for Task 1 of the subject Agreement. Task 1 is to review and provide detailed comments on the California Department of Water Resources report "Engineering Solutions to Further Reduce Diversion of Emigrating Juvenile Salmonids to the Interior and Southern Delta and Reduce Exposure to CVP and SWP Export Facilities; Phase I—Initial Findings".

The report addresses Action IV.1.3, which is to consider engineering solutions to reduce diversion of downstream-migrating salmonids into the south delta and thereby reduce their risk of loss to the delta export pumps. Phase I includes reviewing potential locations for new facilities and proposing initial solutions. In Phase II, the proposed solutions are to be developed in sufficient detail to recommend specific approaches for engineering design and construction.

The fundamental problem addressed by Action IV.1.3 is that juvenile salmon and steelhead migrating toward the ocean appear less likely to survive if they enter the interior delta (via Georgiana Slough) or south delta (via channels connected to the San Joaquin main channel on its south bank). Reducing fish movement into these channels presumably would increase survival to the ocean. Lower survival in the interior and south delta could result from entrainment in the delta export pumps or from delayed outmigration and hence longer exposure to predation risk.

The report starts (after the Introduction) by describing five sites where facilities were considered. The site descriptions include relevant physical characteristics (e.g., length and depth of channel entrances) and biological and recreation characteristics that could affect facility design and feasibility. Next is a detailed description of the salmonid species and runs of concern, including their traits (migration timing and routes) that potentially affect facility design. The section "Previous Engineering Solutions and Outcomes" provides a very useful summary of past and current efforts directed at similar objectives, including both behavioral and physical barriers. Then potential facility types are identified and briefly described in the section "Engineering Options to Consider". The final major section provides a framework for evaluating options: a list of criteria for scoring each potential facility type.

My review is in three parts. First are seven general comments, followed by a few specific comments. Last are summary responses to the questioned posed in the "Charge to Delta Science

Program Independent Science Advisors", Attachment 1 to our contract's Scope of Work. I am sure that some of my comments would best be addressed in Phase II instead of Phase I of this Action.

General Comments

1. Framework for Evaluation. My primary recommendation is to consider using more of a standard engineering design process instead of the proposed evaluation framework. The report describes a process of identifying a large list of potentially applicable technologies, then ranking each by a set of general criteria. My experience with such ranking processes is that they are less likely than a standard engineering design process to either be efficient or successful in identifying the best alternatives—or, critically, to develop new alternatives. The criteria described in this report are quite general and unspecific, and the evaluation process appears likely to be subjective and qualitative instead of based on analysis of the available information. The proposed process does not clearly use the information available for each site and alternative facility type to determine which criteria are most important at each site, nor does it provide a clear target (a set of site-specific objectives and constraints) for evaluating or designing alternatives. Consequently, the proposed evaluation framework is likely to be time-consuming and inefficient.

Instead of identifying and ranking existing technologies, I recommend looking carefully at the specific objectives and constraints for each site and *designing* ("develop", in the wording of Action IV.1.3) good alternatives. A standard design process includes definition of specific objectives and constraints, identification of alternatives that meet the objectives and constraints, and evaluation of the alternatives by expected costs and benefits. (In situations such as this where objectives and constraints are not "hard"—clearly met or not met—the evaluation of alternatives can also consider the extent to which objectives and constraints are met.) Such a process should rapidly exclude infeasible alternatives so no effort is wasted on them, and focus more of the effort on the most promising ones. It should also encourage the engineers to modify designs or even develop new ones instead of just looking at existing approaches—which could be important because this problem has unusual characteristics such as tides to deal with.

A process for designing and evaluating alternatives could include the following steps.

a) Define objectives that are as specific as possible, for each potential site. More detailed objectives will make the design and evaluation process less subjective. The objectives should address questions such as:
—Which fish species and runs are targeted?
—Just as importantly, which life stages or sizes of fish are targeted—fry (which may be least likely to survive to adulthood anyway), larger pre-smolts, etc. Facility designs may have very different success rates for different size fish. It can be very difficult for agency biologists to express priorities for specific life stages or species when they are charged with protecting them all, but doing so will increase the chances of designing a facility that works.
—At which times of year (or other criteria affecting outmigration, perhaps flow) does the facility need to operate? What times of day?

b) Define constraints for each site. The report currently provides some information related to constraints but not with sufficient specificity to use directly in the design and evaluation process. Constraint information could address questions such as:
—Boat passage: Is unrestricted boat passage essential? At what times of year (or day), for what kinds of boats? Would some kind of lock-like facility to let individual boats through be acceptable? (E.g., there are public docks on Georgiana Slough; does that mean boat passage is more critical there than at other sites?)
—Channel flows and capacity: What reduction in flow through the channel would be acceptable at the times of year and flows when fish deterrence is required? Are solutions that completely or nearly block the flow (e.g., rock barriers) feasible? How much change in flood elevation is acceptable? (Or: what are the negative effects of various changes in flow or flood elevation?)
—Effects on other species or life stages: What impacts on other species or adult salmon would be considered unacceptable? (Impacts that cannot be predicted reliably during the design phase would not be useful as constraints.) The report currently implies, for example, that restricting movement of delta smelt and sturgeon is undesirable but acceptable; is there a consensus to that effect? Is unimpeded upstream migration of adult salmonids into the delta ever important at each site?
—Are there physical constraints due to space, access, etc.?

c) Select or design alternative facility types. What kind of facilities appear likely to meet the objectives within the constraints? If no existing facility types appear feasible, what characteristics are needed in a new design?

d) Evaluate the alternative facility types by (at least) cost and expected benefits. (It would make sense to integrate this step with the NEPA/CEQA process so that environmental impacts are part of the evaluation.) See the following comment concerning expected benefits.

2. Site selection and site-specific benefits. The report does not state clearly how the five sites were selected—except that three of the five were specified in the Action—nor how they might be prioritized for full design and construction. Site selection is a major step, so some justification for it would be appropriate. For Phase I it may be sufficient just to say something such as that the five sites are those that convey the most flow into the central and south delta. But for prioritizing sites (as well as for NEPA analysis) it seems important to analyze the site-specific benefits of fish deterrence facilities. (My comment 7 is closely related to this one.)

One consideration for analysis of site-specific benefits is how many outmigrants go through each site. Are there any data on this? If not, then options include conducting new surveys or explicitly assuming flow as an indicator of fish movement: the proportion of fish moving through a channel is equal to the proportion of flow through the channel.

A second consideration is the extent to which fish at each site are exposed to outmigration delays and the export pumps if they enter the delta. For example, are fish that leave the San Joaquin at Head of Old River more likely to end up in the pumps that those leaving at Turner and Columbia cuts? Are fish leaving the Sacramento at Georgiana Slough likely to be delayed more than those leaving at Threemile Slough? At the least, simulation experiments with one of the delta particle tracking models could provide information on how delays and pump exposure varies among sites, assuming fish passively follow flow. Such simulations could also analyze how other restoration projects such as Franks Tract and San Joaquin River flow restoration could affect the benefits of this Action. Perhaps this kind of analysis was done in the OCAP process and could be cited here.

(In about 2008, I helped supervise a Cal-Fed post-doc, Annjanette Dodd, who worked on developing the RMA particle tracking model of the delta into a model of juvenile salmon outmigration. The project got as far as modifying the model to incorporate fish behavior and developing ways to test alternative rules for outmigrant behavior against the newly-abundant acoustic tag data. The next step would be to propose such alternative rules, test them by how well they reproduce tag data, and identify the best assumptions about fish behavior for modeling how delta flow operations affect salmon outmigration. Even without fish behavior, this model would be valuable for analyzing relative benefits of the different sites. Patricia Brandes of the Stockton Fish and Wildlife Service office, Pat_Brandes@fws.gov, is familiar with this work.)

A third potential consideration is local hydraulics at each site. For example, I understand that some studies in the delta have indicated that the likelihood of an outmigrant going into a channel depends on whether the channel entrance is on the inside or outside of a bend. What do we know about each site's configuration that might make fish deterrence more or less important? Predation is another potential local hydraulic issue: would a proposed facility produce (or remove) conditions particularly conducive to predation?

3. Habitat restoration as a potential alternative. To me, the discussion of habitat restoration as a potential solution (starting p. 61) seemed to write this option off due to concerns that were not so clearly valid. First, the description of the solution defines it *a priori* as involving major changes such as converting channels into shallow wetlands; this definition of habitat restoration excludes smaller, more targeted habitat modifications that might better meet the Action's objectives. Second, the discussion of habitat restoration at specific sites essentially evaluates the alternative (saying that it would be impractical) against constraints (location, hydrodynamics, multiple uses) that have not yet been clearly defined or justified. The other potential solutions were generally not evaluated against these criteria.

Habitat modification may deserve consideration as a realistic alternative to hydraulic and electro-mechanical facilities. Habitat "modification" might be a better term than "restoration" because the objective would not be to restore native habitat but instead to meet the Action's objectives of reducing fish entry into delta channels. Instead of treating restoration as a fixed approach, try to design habitat modifications specific to each site and its objectives and constraints. Are there, for example, local habitat changes that could attract fish to the mainstem and (just as importantly) scare them away from the delta channels?

Especially for habitat modification, fish size is likely to be an important design variable. As the report discusses, habitat use changes as fish increase in size. Fry are highly vulnerable to predation by other fish but less vulnerable to birds, so they tend to prefer shallows. Pre-smolts and smolts, though, are vulnerable to birds and hence more likely to avoid conditions where they are visible from above. My collaborator Bret Harvey (US Forest Service, Pacific Southwest Research Station) has shown conclusively that wild trout 100-175 mm in size are extremely reluctant to use shallow, open habitat where they are highly visible. These kinds of relations could be useful in designing habitat modifications that either attract or deter fish.

4. Limitations of recent pilot studies. The report describes recent behavioral barrier studies at Georgiana Slough and Head of Old River. I am sure that these studies will be invaluable in designing and evaluating alternatives. I have a couple of questions and concerns that I expect are already being addressed.

First, I am concerned about basing evaluations on releases of tagged hatchery fish. If their release in this study was the first experience of these fish outside a hatchery, then it seems doubtful that their behavior represents that of wild fish very well. Do we have any information on how representative their behavior was? (The high mortality rate is not encouraging.) This technique is no doubt helpful, and I realize other techniques for evaluating deterrence success also have important limitations; but I would be hesitant to base important decisions on its results alone.

Second, I wonder if any information on predators was collected in addition to reporting mortality of tagged hatchery fish. Were trawls, electrofishing, hook and line sampling, etc. used to determine whether predator fish were more or less abundant with the Bio-Acoustic Fish Fence operating? (A bubble curtain seems like a great ambush location, and, if I recall the old literature on such devices correctly, fish can acclimate to them quickly.)

5. Literature on behavioral fish guidance. I am sure the report's authors are familiar with the extensive literature on fish guidance technologies such as sound, lights, bubble curtains, and electric barriers; but it would be reassuring to see it cited and made use of explicitly. Much of the literature is from the 1980s and 1990s and focuses on species of the eastern U.S., but it may still be relevant. Many of the studies were conducted by EPRI, so can be accessed through DWR's EPRI account manager (Chris Horner, 972-556-6514, Chorner@epri.com). The Corps of Engineers has also conducted some important studies through their Waterways Experiment Station (a contact is David Smith, ERDC Environmental Laboratory, David.L.Smith@usace.army.mil).

6. Evaluation criteria. The 12 evaluation criteria seem comprehensive but not especially well-designed. (The engineering design process I suggest in my first comment would supersede the proposed use of these criteria as the sole basis for selecting facility types for each site, but criteria such as these are still likely to be useful as "soft" objectives and constraints, for comparing alternative engineered designs, and in NEPA assessment.) Some concerns are:
—"Tidal effects" is just one element of "Deterrence ability". To deter fish effectively, a facility needs to work at all tide conditions (and also over ranges of flow, turbidity, etc.; all of which should be specified in the design objectives) during which fish deterrence is considered important.
—While most of the criteria clearly range from bad to good values, "Flow effects" does not. Is it necessarily bad if a facility restricts flow by some amount? At all times, or only in some seasons

or flow levels or water quality conditions? This concern seems better addressed as a set of design constraints: what ranges of flow or water elevation change are acceptable under what conditions?
—"Implementability" seems mainly a cost consideration: the more complex a design is to construct, then the more it will cost to have completed by some particular date.
—"Operations and maintenance" seems to refer to reliability, not O&M cost? If so, it would be clearer to call the criteria "Reliability" and link the metric to expected frequency and duration of failures.
—"Maturity" seems really to refer to certainty about effectiveness; the implied (but questionable) assumption is that more mature technologies are more reliable. It might be clearer to call this something like "Certainty in effectiveness" (and it could be factored into the rating of deterrence effectiveness).
—The report does not specify how the different criteria will be weighted in arriving at overall recommendations. A process such as the one I recommend in my first comment would identify criteria to treat as hard constraints, as objectives that must be met, and as "soft" objectives for which more is better.

7. Cumulative effects and interactions among sites. This draft of the report does not include any process or mechanism for looking at the problem from a system level; instead, it is focused on individual sites without consideration of how actions at one site may affect the costs or benefits of actions at other sites. Interactions among the sites seem very likely, for at least some kinds of facility. For example, any facility that significant reduces flow through one of the delta channels (e.g., a rock barrier at Georgiana Slough) seems likely to *increase* flow through other channels leading to the export pumps (assuming pumping rates do not change). Hence, (a) a "solution" at one site could be a problem at another, but (b) a problem at one site could be part of a good system-wide solution (e.g., diverting more flow out of sites where/when fewer salmon are present).

Because of such potential interactions, a system-level analysis seems likely to be beneficial (as well as appropriate as part of NEPA/CEQA assessment). (I do not know whether such an analysis was conducted by OCAP in designing the Action.) A system-level analysis could address questions such as:
—To what extent would complete barriers such as rock walls really reduce diversion of fish toward the south delta vs. move it to other locations?
—How would any changes in flow at individual sites affect flow through other channels (possibly including pathways other than the five potential action sites)? How would the system-wide level of outmigrant delay and pump exposure change?
—Can system-wide effectiveness be improved by expending more effort at one site and less at others? Are, for example, 3-5 partial barriers more or less effective than a complete barrier at 1-2 sites?

The flow and particle-tracking models mentioned above (Comment 2) may be useful for addressing these questions.

Specific Comments

8. (Section numbering would make it much easier to understand and comment on the report.)

9. In discussing previous engineering solutions, it would be helpful to use the same measures when describing different studies, when possible. For example, in the Executive Summary (middle of p. xii) different measures such as "average guidance efficiency" and "percent improvement in deterrence efficiency" are used for different studies, so there is no way to directly compare results across studies.

10. Description of San Joaquin River sites: To what extent, if any, will the San Joaquin River Restoration Program flows affect the numbers provided for these sites?

11. Table 2 and 3 captions: These are for the river *basins*, not just the rivers?

12. Tables 2 and 3: Much in these tables did not make sense to me. For example, in Table 2, how can fall Chinook emergence start at the same time that spawning starts? How can fall Chinook juvenile rearing not start until 6 months after the fry emerge? In Table 3, how are there two migration and spawning periods for fall Chinook, with spawning ending before (and starting before) migration does?

13. Many references are missing from Literature Cited or incomplete.

14. What are "operable" culverts and gates? (Why would you install ones that didn't operate?) Do you mean gated culverts, and adjustable gates?

15. Non-physical barrier and Electric barrier (pp. 49-51): To what extent are these options barriers to recreational use due to safety? Could bubble curtains sink small boats or swimmers? Could some kinds of boats cross an electric barrier? Or would all such uses likely be excluded due to safety concerns?

Responses to Questions in Scope of Work Attachment 1

16. <u>Do the engineering solutions meet the RPA list of issues?</u> The potential solutions listed in this report certainly are relevant to the Action's objectives; the design work to determine which are likely to be feasible or good solutions remains to be done.

17. <u>Have uncertainties been minimized?</u> It does not appear that the design process has yet reached the point where uncertainties can be fully addressed. More review of existing literature and recent studies (comments 4, 5 above) would provide more confidence that available understanding of uncertainties is being considered.

18. <u>Does the plan meet experiment objectives?</u> The report directly addresses the objectives of the Action.

19. Are site descriptions complete and contain necessary information? The site descriptions are adequate for the material covered in this report. However, a more detailed development of site-specific issues, objectives, and constraints will be necessary for actual design and evaluation of alternative facilities.

20. Are potential solutions clearly defined and described? The report provides a useful comprehensive list of potential facility types. Additional information on specific solutions are addressed in comments 3 and 15.

21. Are the evaluation criteria clearly defined and described? I believe that the evaluation criteria will need quite a bit of site-specific refinement and analysis before they can be applied effectively (see comment 6). Some of the criteria would best be treated as objectives and constraints in an engineering design process (comment 1).

22. Are linkages among report elements clear? Yes.

23. Is the report of sufficient robustness and quality? This report provides a useful overview of the Action's problem and potential solutions. Considerably more analysis will be needed design and evaluate good alternative solutions (comments 1, 7).

24. What, if any, additional engineering solutions need to be considered? I am not aware of any other technologies that deserve consideration as potential solutions.

25. What, if any, additional evaluation criteria need to be considered? My main concern about evaluation is the potential need for system-level evaluation: how do the proposed solutions at each site affect each other and what is their total benefit (comment 7).

26. Are the engineering solutions feasible to implement? The analysis needed to determine feasibility of each technology at each site does not seem to be done yet.

27. If not, what limitations need to be considered? Identification of feasible, and good, alternatives would be facilitated by developing objectives and constraints that are as specific and detailed as possible for each site (comment 1).

Thank you very much for the opportunity to provide this review. I look forward to any opportunity to discuss it further with participants in the Action process.

Sincerely,

Steven F Railsback

Steven F. Railsback, P.E.
Partner, Lang Railsback & Associates
Adjunct Prof., Department of Mathematics, Humboldt State University

Review, Phase I Draft Report
Mark Stacey

I provide here my review of the Phase I Draft Report from DWR regarding Engineering Solutions to Reduce Diversions of Juvenile Salmonids to the Interior and Southern Delta. It was difficult to know how to frame this review, or even how to interpret the report, due to the fact that I had no knowledge of how much effort had gone into the work during Phase I nor the resources available for Phase II. As such, it is impossible to know what tools are appropriate for the analyses that need to be performed. To be clear, what can and should be done with large-scale effort (team of people, funding for experiments and modeling) is quite different from what can and should be done with minimal effort (one or two people working part time without funding for supplemental studies). With this in mind, in the following review, I will comment on the approaches that have been applied or are proposed to be applied, and will note how I think those approaches should be used; I will limit my comments on additional analyses that may be considered.

To summarize, during Phase I, background was developed regarding both the species of interest (Salmonids) and two other species of concern (Green Sturgeon and Delta Smelt), and alternative approaches were developed for each of 5 diversion sites (Georgiana Slough, Three Mile Slough, Head of Old River, Turner Cut and Columbia Cut). Included in the Phase I report was some background on the success rates of various engineering solutions. The Phase II work, as described in this report, would use a set of 12 evaluation criteria to evaluated each engineering approach using "low", "moderate" and "high" scoring.

I'm afraid that I cannot support this matrix approach as a Phase II decision tool. Instead, "low", "moderate" and "high" ratings should be used as the culmination of the Phase I activity in order to prioritize more complete analyses and studies during Phase II. In order to do so, the matrix framework *must* include evaluation of the uncertainty associated with the evaluations contained in the matrix. Further, even as a preliminary screening mechanism, the criteria and evaluation approaches used in the framework must be much more carefully developed and refocused.

In the following sections, I provide more detailed comments. I will divide my comments into those that are responsive to the report on Phase I activities; those that are responsive to the described actions for Phase II; and recommendations for action during Phase II.

Detailed comments on Phase I activities.

1. The background on species of interest and their use of estuarine habitats is clearly developed and appears thorough and complete (although I would defer to others with more direct expertise). What is lacking, however, is a clear summary of where the largest uncertainties lie in the biological and physical processes that are described in this section of the report. It is important that uncertainties be woven into the narrative, in addition to the matrix evaluation to come, so that (a) decisions can be made appropriately; and (b) future work can be correctly prioritized.
2. The list of engineering solutions, which consists of 12 different approaches (including a "no action" and a "hybrid" alternative), is quite well developed, and I believe the report has accurately assessed the state of the technologies. Once again, however, there are not clear statements about what is *not* known about the technologies and where the biggest performance uncertainties may lie. I will comment on some of these specifically below, but, for example, scour around tidal gates may undermine the structural integrity of the gates or change turbidity locally; but these effects would require much further study to understand.

3. Although the list of engineering solutions to be deployed at the 5 sites is quite complete, I feel that there was one obvious alternative that was missing, which was to place structures (perhaps temporary floating barriers) along the Sacramento River to positively direct juvenile salmonids into Steamboat and Sutter Sloughs. I know other reviewers are suggesting reducing the number of sites from 5 to 3, but if you think of 3 *diversion* points (Georgiana Slough, Head of Old River, Turner Cut), then structures to direct fish into Steamboat and Sutter Sloughs are just other approaches to addressing the Georgiana Slough (and Threemile Slough) diversions.
4. Habitat restoration, as presented here, appears to be using natural structures (whether intertidal or higher elevation) to block flows; in which case the effectiveness of them for the objectives here would really be the same as a rock barrier. I had expected habitat restoration to focus on other restoration in the region that might reduce diversions; for example, if habitat were restored on the opposite bank from the diverting channel, it may bias the distribution of juvenile salmonids to the opposite bank and reduce diversions. This approach may be assisted by upstream diversion walls that direct juvenile salmonids away from the bank where the diversion occurs.
5. I find myself confused by and concerned about the technical methods used to quantify deterrence, protection and other metrics of barrier performance. Specifically, in the calculation of a Deterrence Efficiency, it isn't clear how a "fish response" is identified (the denominator of this factor). In the Guidence Efficiency, different values are reported on flood and ebb tides, but I'm confused as to what this quantity means within a tidal phase: on one phase flow is splitting and entering the diverting channel; on the other phase flow is exiting the diverting channel and merging into the main channel. Finally, the Protection Efficiency has no baseline value stating how many fish enter the diverting channel (I think this was reported for Head of Old River) in the absence of control measures.
6. The function of fish barrier walls will be highly site-specific. For example, the function of the walls at Georgiana Slough or Head of Old River, where the diversion channel sits on the outside bank of a curve in the main channel, will be quite different from their function at the other sites. Even at Georgiana Slough and Head of Old River, there will be site-specific flows that make the effectiveness of the walls distinct at each location. In order to evaluate the performance of these walls, high-resolution site-specific hydrodynamic models would be required to define the resulting flow patterns; some assumptions about juvenile behavior would need to be layered on the flow field to understand the net effect on exposure to the diverting channel. This is a significant effort if it is to be done correctly, and without it I don't think even "Low", "Medium" or "High" values could be effectively judged.
7. In the description of the use of Transportation Barges, there is no quantification of the effects on adult in-migration. If that information is available from previous studies, it should have been reported here. If it is not available, then this should be noted as a large uncertainty for the approach.

Review on the approach proposed for Phase II

As noted in the introduction, I don't believe the proposed matrix framework is appropriate for a Phase II decision-making tool. I do believe that the development of a matrix of high, moderate, low scores would be valuable now at the conclusion of Phase I so that Phase II could target the most critical and uncertain aspects of the decision. As such, I suggest that this matrix be developed immediately, but with the inclusion of uncertainty, so that the process can be more effectively pushed towards a real decision by the conclusion of Phase II. In the development of this prioritization matrix (not a decision matrix), I recommend the following detailed comments be considered:

1. The matrix cannot be used as a substitute for narrative. Discussion of the underlying processes and how the evaluations are made should be included with the matrix.
2. There is no place in the framework for statements about uncertainty. It is critical that any evaluation matrix include a “score” for the degree of uncertainty (another High, Moderate, Low rating).
3. Several of the criteria seem to address the benefits of the approach for the targeted species. Specifically, these include deterrence ability, effects on upstream migration and predation effects. Since this is being converted into a “high”, “medium”, “low” rating, it seems that it would be best to combine these into a single metric of total increase in survival for the targeted species/run.
4. The criterion “Environmental Impacts” is far too broad and there is no hope that it could be effectively reported as a single score (“High, Moderate, Low”). Evaluation of this criterion, as currently framed, would have to consider effects on Sturgeon, Delta Smelt, Water Quality (In-Delta use, South Delta Pumps, others?), and even other salmonid runs. An action may have positive effects in one area (i.e., no action at head of old river might be protective of Delta Smelt), but negative in others (i.e., deteriorated water quality in the South Delta). This criterion should be split into more narrowly defined criteria (see below).
5. Throughout the criteria, it isn’t clear if they should be applied to each run individually. It seems that they should be, since temporary barriers may have a positive effect for juvenile salmonids from one run, but a negative effect for adult migration from another.
6. I don’t know what it means to score “Flow Effects” as “High, Moderate or Low”. It isn’t clear what flows are being considered (net flows, tidal flows, diversion of flows out of primary channels, net transport towards the pumps…) or why “Flow Effects” in and of themselves should be a criterion. Instead, it seems that concerns about flow effects are due to the effects of flows on other conditions, such as entrainment of other species, water quality, sediment scour and transport. Many of these other impacts are seemingly contained in “environmental impacts”, and I think it is important to be specific about the impacts of concern, particularly if it is to be scored as “High”, “Moderate” or “Low”.
7. Implementability, Operation & Maintenance, Land Acquisition & Easement all have cost elements, plus “Cost” is included separately. The “Cost” criterion should include cost elements associated with each of these others (Note: it isn’t clear whether the “cost” would be calculated as Net Present Value or how the scoring of this criterion would be done) and the non-cost components of each need to be the focus of these other criteria. Operation & Maintenance might then be recast as “Reliability”; Implementability might be about “Timeliness”; it isn’t clear what would remain in Land Acquisition once the cost of acquisition is incorporated into the “Cost” criterion. Finally, “Tidal effects” seems to be the same as Operation & Maintenance (the discussion of the criterion is focused on the performance of the structure under different stage/flow conditions).
8. The Maturity criterion seems to be trying to capture uncertainty in the performance and/or reliability of an approach. I suggest this be eliminated as an independent criterion and instead incorporate these concerns into the uncertainty of the “Reliability” or other criteria (including the Benefits to target species and the Environmental Impacts).

Recommendations:

1. The matrix framework described here should be used in the near-term to prioritize Phase II activities. This prioritization should be based on both the potential benefits of the approach and the uncertainties associated with it. For example, an approach that has “low” benefits and “high” uncertainty would not merit further study, but one with “high” benefits, “low” negative impacts and “high” uncertainty of the benefits would merit

investment (numerical studies in many cases, including hydrodynamics and particle tracking). I don't want to get ahead of the evaluation process, but an example of this case might be diversion barrier walls upstream of the diversion points.

2. In conjunction with the matrix, a brief narrative must be included to make clear what thinking is behind the scoring in the matrix.
3. The resulting matrix and prioritization for Phase II activities should be reviewed, either by the TWG or external reviewers (or both).
4. The matrix must include evaluation of uncertainties for each alternative and criteria. To be clear, each matrix entry should include an evaluation (high, moderate, low) as described in this report *and* an uncertainty score associated with the evaluation.
5. Reorganize the criteria as:
    a. Benefits for survival of target species and run (currently deterrence, upstream migration, predation)
    b. Impacts on Delta Smelt (currently Environmental Impacts, Flow Effects)
    c. Impacts on Green Sturgeon (currently Environmental Impacts, Flow Effects)
    d. Impacts on other runs of salmonids (I'm not sure where this appears in current structure)
    e. Impacts on water quality for agriculture (currently Environmental Impacts, Flow Effects)
    f. Impacts on water quality at South Delta pumps (currently Flow Effects?)
    g. Cost (currently cost, O&M, Land acquisition)
    h. Reliability (O&M, Tidal Effects)
    i. Recreation (boat passage)

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Appendix D — DWR's Response to Comments

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Comment and Response Summary

Delta Stewardship Council Science Program

Science Advisor's Comments

August 2012

Initial Response Legend	
Action Code	**Response**
R	Recommend – revision recommended to be made
C	Comment to be considered further – discuss with TWG and BDO Management ("C" responses will become I, N or R following further consideration)
N	Comment noted – recommended revision already planned to be addressed during Phase II
I	Comment noted – informative comment but no revisions planned

Item	Comment	Action	Response
	Panel Summary		
1PS	As a final step in our review of the DWR Draft Report on Engineering Solutions to Reduce Diversions of Juvenile Salmonids to the Interior and Southern Delta, the three reviewers (John Pizzimenti, Steve Railsback and Mark Stacey) discussed our individual reviews. While there are differences in our perspectives and experiences and, therefore, the emphases of our reviews, we believe that the individual reviews are, in fact, complementary and we are supportive of one another's individual reviews. We see no significant conflict among the individual reviews. The proposed Phase II framework, which consists of a matrix of 3-level scores ("high, moderate, low", e.g.), would be ineffective as a decision tool because it lacks the site specific analysis needed to evaluate—and possibly adapt—technologies meaningfully. At the same time, a revised set of similar criteria (suggested in some reviews) would be effective early in Phase II in helping to prioritize, and eliminate, alternatives.	N	The Water Resources Assessment Method (WRAM) will be used for evaluating the viable options. Site specific analysis will be part of the Phase II study.
2PS	This matrix framework, particularly the criteria proposed, is flawed. Key problems include assigning quite different impacts equal weight (i.e., environment impacts and recreation), and individual criterion being poorly defined (environmental impacts, e.g.). This can be remedied by application of published ranking methods. One of us recommends recasting the criteria into less ambiguous variables; another recommends use of the Water Resource Assessment Method developed by the US Army Corps which uses a panel of experts familiar with the challenges and options available. These are complementary recommendations.	N	Considerations are being made for adjusting the criteria matrix. The framework will be adapted to weigh criteria that are obviously more important than others. This will be done in Phase II
3PS	Phase II activities should immediately eliminate unrealistic alternatives so that the bulk of Phase II can be used to study the feasibility and cost effectiveness of the most attractive alternatives. This filtering of alternatives can use other data on effectiveness of certain approaches (behavioral barriers, e.g.) and apply specific constraints that would prohibit certain approaches (permanent hard barriers, e.g.). For alternatives that merit further consideration in Phase II, it is critical that sufficient resources be invested to ensure a complete, detailed analyses that address the key scientific, engineering or economic uncertainties associated with each approach. It is not clear to us that behavioral and non-physical barriers are the only actions to consider. Habitat and predators need to be factored into Phase II; and transportation if viable has unique elements that may preclude barriers altogether.	R	This will be done early in Phase II.
4PS	Phase II should include system-wide as well as site-specific analyses. System-level analyses should look at potential interactions (actions at one site can affect other sites, especially if flow is modified) and cost-effectiveness (what combination of actions across all sites provides the best investment). Please note that these four points are in no way a summary of the individual reviews, which stand on their own. The goal of this summary is simply to emphasize the broad points of agreement between the individual reviews and to affirm there are no conflicting recommendations or disagreements among the three reviewers.	I	In order to use time and resources efficiently, system-wide analyses should wait until it is necessary. If flow neutral options are chosen, there will be no need for this type of analysis.
	Reviewer: John J. Pizzimenti		
1P	**The Executive Summary** **Phase I** Identifies all options and engineering solutions to meet NMFS directive: …"consider engineering solutions to further reduce diversion of emigrating juvenile salmonids to the interior and southern Delta, and reduce exposure to Central Valley Project (CVP) and State Water Project (SWP) export facilities" **Phase II** …"consist(s) of studying the engineering solutions proposed in this (Phase I)report, developing a solution for each of the possible locations, preparing preliminary engineering drawings and cost estimates, and preparing a Phase II final report. **Phase III** is the NMFS Review process where they will direct agencies to implement specific projects based on the Phase II Report. **Comments:** I have concerns that the levels of engineering required in Phase II as defined cannot be adequately completed in the time allotted (by March 30, 2015). Reasons include: (1) 13 alternatives at five sites and every possible combination suggests a final configuration potential of over 100 different possibilities (2) structural solutions may be very challenging at sites that have as much as 25,000 cfs discharging through them (3) impact assessment of the various alternatives will be challenging if done sufficiently well to allow an informed decision on how to proceed; (4) the potential hydraulic interactions of new structures on water supply and water quality will require application of Bay Delta hydraulic / hydrologic models; and (5) the	I	Elimination of unrealistic alternatives will occur early in Phase II reducing the number of alternatives for in-depth evaluation. While the schedule is of concern the need to address uncertainties through further pilot studies may require extending the current schedule. The WRAM will be used for evaluating the viable options.

Item	Comment	Action	Response
	scope of Phase II includes costs, and in order to rank the projects and establish feasibility, cost-effectiveness and rank order selection must also be included. **Details:** My concerns are further raised on the potential "use of pilot studies" which are undefined and whose costs and scopes are not explained; the need to consider "solutions unique to each site" including hybrids; and the question of prioritizing the various sites and their potential interactive affects on pumping, water quality and biological consequences to smolt survival. If pilot studies include more behavioral guidance studies, how will one more year of results change more than 15 years of experience and data? The approach to conduct a comparisons analysis in Phase II is an important step. The criteria identified in Table 4 include: deterrence ability, environmental impacts, effects on upstream migration, flow effects, predation effects, tidal effects, boat passage, implementability, operation and maintenance, maturity (acceptance of technology), land acquisition, and costs. I suggest the use of a more rigorous and widely accepted ranking process such as the US Army Corps, WRAM (Water Resource Assessment Method) and the NED (National Economic Development) methods discussed elsewhere in this review. The "preparation of engineering drawings and cost estimates" is a costly endeavor and may be premature except at conceptual or pre-feasibility levels; or for one or two projects that rise clearly to the top during feasibility studies in Phase II. Until it is clear whether one or all sites should be developed, cost estimating and preliminary designs of many sites that will not "make the cut" will slow the process of implementation because it creates work that may not be timely or necessary. **Recommendation:** Phase II should be devoted primarily to an in depth feasibility study to define the final configuration recommendation for the three sites NOAA identifies. There are only three choices: Physical Structure, Behavioral Structure or No Action. This is the first decision that needs to be made. The many different gates and structural details are important, but less so than deciding whether a diversion (physical) structure is feasible at each site and what effects it would have on primarily water supply and water quality. Focus should also be on their combined cost and cost effectiveness of each.		
2P	**Introduction** The need for the study is clearly enunciated here and the approach required by NMFS. Although NMFS recommended three sites, Phase I is suggesting five sites. **Comments:** In rank order of priority, NMFS has probably identified the three most important sites: Georgiana, Old River and Turner Cut. Columbia Cut will have similar benefits and potential design solutions to Turner Cut and evaluation of one or the other can be used as lessons learned to make the next design easier, if needed. **Details:** Three-Mile is most downstream in the Delta and it is unclear why there is a strong case or data that identify biological benefits to be gained here. In fact, fish in the San Joaquin or the Sacramento would need to make sharp turns to enter either end and the distance from Suisun is not dramatically different either way. Here the tides are most influential; and flows up to 25,000 cfs rip through this large channel daily suggesting hydraulic structures of much larger size and cost would be needed compared to more problematic areas with less structural demands upstream. In contrast, fish at Georgiana and Old River don't need turn but only be on the "wrong side of the river" to enter a slow moving tributary that transports fish to known problem areas. By limiting the study to three sites, Phase II report can be stronger and implementation may come earlier. Phase II can also be extended and overlap Phase III to complete any additional sites or alternatives that arise during Phase II investigations. **Recommendation:** Because of concerns about ability to meet the schedule with quality work products, recommend following NMFS recommendation for only three sites this time. Others can follow later.	I	Columbia Cut was agreed to be included in the study by the TWG which included NMFS. Threemile Slough is being added to coordinate with actions of the proposed Franks Tract project and was not objected to by the TWG. In Phase II the sites will be re-assessed and eliminated if found unsuitable for further analysis.
3P	**Site Descriptions** These narratives contain limited technical information and could be improved by commentary on the potential for problems or issues that are of known concern or that need to be developed in Phase II. **Comments**: Phase I Report should include preliminary information on the criteria identified for ranking: some sites will require more substantial structures due to larger hydraulic loads; some may have larger recreational impacts; or water quality or water delivery impacts. Laying out the preliminary challenges and questions helps focus where the levels of effort in Phase II will be; and pre-existing concerns should be at least hypothesized if not clearly identified. **Details:** The maps are good and bring several thoughts to mind. Both Georgiana and	C	The structural suggestions for Turner/Columbia Cut are interesting, and will be looked at during Phase II. Additionally, channel reconfiguration can be added as an option. Many of the suggestions are to be addressed in Phase II. The challenges of each site will be evaluated and discussed in the final report during Phase II.

Item	Comment	Action	Response
	Old River tend to divide the main channel into two very large tributaries that can attract large numbers of smolts. This sets up a hydraulic condition that may be potentially addressed by reconfiguring the channel or constructing guidewalls or gabions such that more water and fish are likely to be guided past these sloughs without construction a diversion dam. Commentary on these would tee-up potentially options with higher priority than to just consider equally every possible engineered fix. Channel reconfiguration was not mentioned as an option. Is it known to be infeasible? The Turner Cut description that includes 25% of the river discharge during flood tides suggests that a tide gate might be an option at this location. Tide gates are commonly used on the Columbia estuary to prevent fish entrainment (and salt water) during incoming tides. Ditto Columbia Cut. The configuration of the channel at Columbia cut suggests a potential tide gate at the upstream entrance coupled with an overflow weir at the junction of the river split just upstream of the downstream entrance to Columbia Cut. Downstream migrants could be diverted around the island using the right channel. At flood levels, river water would pass over the low weir in the left channel. Tidal flows moving upstream would pass around the right channel. I am not trying to write Phase II, but tide gates may be a tool to consider for fish exclusion in tidally affected locations. **Recommendations:** Phase I should more clearly lay out the challenges of each site and how they differ among each other. This should lead to a clear plan of how Phase II will be scheduled and completed. There is potential for use of tide gates and gabions and diversion structures at other locations that should be identified.		
4P	**Fish Species** The descriptions are generally good; but they are uneven in places and the citations are incomplete in the reference section. If this is to be a public document, there are significant errors of omission that should be corrected and a thorough editing. In other sections of this review, I suggest other information that should be incorporated in Phase I Report to better define the Phase II Work Plan. **Comments:** Proposed actions herein may help all runs of chinook and steelhead; however, ocean type runs are much more likely to respond to the fixes because they are lower in the system and less impacted by upriver conditions especially in the San Joaquin. **Details:** Stream type salmonids, like spring and winter run fish are the most difficult to recover for the following reasons: (1) they move the furthest upstream compared to ocean types; (2) juveniles and adults reside in river for longer periods of time compared to ocean types; (3) they require higher water quality and flushing flows to leave the system. These are real challenges for the San Joaquin system in its current depleted state (See Figure from VAMP Review, 2010 in Appendix I). Delta smelt are a concern and have been possibly incorrectly identified as being impacted by being drawn into the lower end of Old River if flows are reduced at the Head of Old River. This was discussed during VAMP Review (2010). Data suggest this may be incorrect; and it is not clear that Delta smelt traverse from the North Delta to the clearer water of the south Delta from the Sacramento estuary. Improved flows in the Sacramento as a result of reducing discharge into Georgiana Slough may further improve Delta smelt conditions. Limiting or controlling inflows into the south Delta has potential to improve survival of Delta smelt and salmonid migrants in both North and south Delta. **Recommendations:** Recovering stream type migrants will be more difficult than ocean types. Setting up expectations will enable more realistic targets and measures of success in the future. They will also require differences in recovery techniques especially related to either restoring flows in the San Joaquin mainstem or implementing transportation (discussed elsewhere in the review).	C	The reference section will be updated to address omissions and incomplete citations. The action states "reduce diversion of juvenile salmonids" and no distinction is drawn between stream or ocean-type. All seasonal runs are expected to be addressed in this action. Consideration of limiting or controlling flows is not a component of this action but is expected to be considered under other BiOp actions. Flow effects on and by a potential alternative will be evaluated as a criteria under this action. Potential effects of an alternative on the migration and predation of other species of interest (eg, Delta smelt) will be evaluated as criteria under this action.
5P	**Georgiana Slough Behavioral Barriers** **Comments:** Review of Hansen et al. (1997) suggests behavioral barriers tested at Georgiana Slough were not sufficiently successful to make much difference in deterring smolts from Georgiana Slough. Hansen reported guidance efficiencies of 15% in 1996. In 1994 he reported guidance efficiencies ranged from 58% to 28% from day to night; guidance efficiency was 60% at ebb tide vs. 39% at flood tide. Using a different index in 1993, he reported guidance efficiencies ranged from – 156 to + 74; negative meaning net increase of smolts into the slough rather than a reduction with sound systems operating. The Phase I draft report does not report these data and also identifies two technologies employed; one using high frequency (300 hertz) and one using low (10 hertz). Hansen's report only identified high frequencies. It is not clear which technologies were used where; this may matter based on research	I	Non-Physical barriers should not be taken off the table at this point. The barriers tested in the 90's were ineffective which is why a new non-physical barrier (BAFF – bubbles, sound, lights) is being studied. NMFS does not have a criteria for successful deterrence of salmonids with a BAFF. Non-Physical barriers offer many benefits for some of the other major concerns in this topic (flow neutral, boat passage, unimpeded upstream migration…etc…). Data from recent studies, and in conjunction with other options (guidance walls), still warrant further consideration and discussion

Item	Comment	Action	Response
	conducted by Sand et al., (2001). **Details:** The behavioral data are obfuscated because it is not fully established how much flow, velocity and tides are responsible for the data. At ebb flows, velocities in the main channel may be near 3.75 fps; at flood tides near they are near zero or even minus (reverse direction). Migrants swim, but they are also carried by the velocity of the water. The problem is that numbers of tagged fish reaching the experimental area are not known precluding estimates of actual percent diverted versus passed. If PIT tags combined with acoustic tags were employed a more accurate estimate of total numbers of fish diverted from the slough(s) could be estimated. Sound frequencies reported at Georgiana were in the 300-400 hertz range. Sand et al. (2001) reported Atlantic salmon better respond to infrasonar signals of 10 hertz or less than to higher frequencies. He shows that particle acceleration and not sound pressure is eliciting the response. To produce these signals, very large sonar devices are needed compared to those used for higher frequencies (300-400 hertz). The sounds mimic the hydrodynamics of fish swimming and may be a predator avoidance mechanism. Similar low frequency sounds may come from rapids or shoals in rivers which migrating smolts are known to avoid (ELAM modeling, John Nestler). Unimpacted salmon populations (very few remain) in the Pacific Northwest have return rates of 1-20% annually with a 4-6% return of smolts to adult (SAR) being a very healthy average. The return rates Bay Delta are less than a fraction of 1% (VAMP review, 2010). All smolts that enter Georgiana Slough are lost to the population. **Recommendation:** Data from Georgiana Slough suggest behavioral barriers are not providing enough benefit to make any difference in population levels especially at smolt to adult return rates in the system. Unless data can clearly demonstrate effective (95%) deterrence under all flow / tide / light conditions, recommend proceeding to physical barriers.		within the TWG.
6P	**2011 Georgiana Slough Bio-Acoustic Fish Fence (BAFF)** No results were presented and the draft plan was not made available for review. **Comment:** This technology was used at HOR with mixed to negative results (VAMP Review 2010; Vogel, 2011). **Recommendation:** If low frequencies (10 hertz or lower) are employed, specifications should be identified. Further comments are contained in review of Old River section of the report.	N	The 2011 Georgiana Slough report is finalized and referenced in this report. The frequencies used don't appear in the report and are proprietary to the vendor.
7P	**Temporary Rock Barrier at Georgiana Slough** The section of the Phase I reports that USBR designed structure, but it was never installed due to reported adverse effects on water quality, natural flow patterns, levee stability, flood control; upstream migrating adults; boating and recreation. A report is cited in text ("Initial Study and Mitigated Negative Declaration was completed and released in August 1992") but no reference or data are provided to understand the basis of the decision not to test the barrier. **Comments:** Why was any effort expended on the design since the reasons for not implementing had nothing to do with the design; usually designs come after feasibility level studies. Do the data in the unreferenced report support the intent to reject the concept of a physical barrier at Georgiana Slough in Phase II? **Recommendation:** Phase I Report needs to clarify the question of whether physical barriers are open for consideration at all sites including Georgiana Slough. Feasibility studies should be completed in Phase II before any designs are completed.	I	Phase I is used to introduce the available options that could be used as a solution. Phase II will be used to analyze what option is best for each site. As such a physical barrier is an option for consideration in Georgiana Slough as well as the other sites.
8P	**Rock Barriers** The Report says four temporary barriers have been in use: one at Old River since 1963 and two additional locations since 1987 at Middle River and Grant Line. "They are designed as a short-term solution to improve water level and circulation patterns for agricultural users, and to collect data for the design of permanent barriers." **Comments:** What data are being collected to make a decision on a permanent barrier? Since Obermeyer gated structures can essentially be lowered to near river bed level, has there been any cost : benefit evaluation of comparing a one-time constructed fixed barrier, to constructing and deconstructing four or more barriers each year? This data might be valuable for scoping or supporting the Phase II Study. The explanation of how the barriers and culvert operations are affecting and benefiting the SDWA as well as salmon needs further explanation and would be improved with a graphic. It is not apparent how changing the numbers of culverts helps both increased water supply and quality and salmon migration. If it helps salmon (presumably fewer are passed into Old River?), why did DFG and NMFS require enhanced salmon counts through the two culvert design compared with the	C	The quantitative effectiveness of the rock barriers will be reported in Phase II of the report while we are evaluating each option for each individual site. Barriers have been used in the past for fish deterrence and is why they are listed in the Phase I report as a general option. A rock barrier with open culverts will not deter fish very effectively.

Item	Comment	Action	Response
	six culver design? What are the results of salmon passage rates through these structures? Data should be provided. And how many of these fish (percentage) were captured in the fish salvage facilities comparing the two designs vs. six designs vs. no barrier in place? **Recommendation:** Phase I Report should identify what data exist to demonstrate that these physical barriers, temporary or not, are reducing smolts entering the salvage operations or increasing fish survival to the lower Delta via the mainstem channel. Work of Brandes and Newman and others enumerating salvage counts should be cited.		
9P	**Non-Physical Barriers Acoustic Technologies at HOR** Predation rates before arriving at the BAFF ranged from 25.2 to 61.6% in 2009; and 2.8 to 30.9% in 2010 for each release group. Predation rates in the area of the BAFF ranged from 11.8 to 40.0% in 2009; and 16.9 to 37.0% in 2010. **Comments:** Are the predation rates are [sic] high enough in such a short section of river that if extrapolated the remaining distance down raise the concern that there will be essentially zero survival? Does this suggest that the barrier performance is inconsequential whether it is diverting smolts away from Old River on [sic] not? These questions were raised during the VAMP Review (2010) and during discussions of the predation rates estimated by Vogel (2011). **Details:** Grand deterrence (81%) is based on the number of fish detected in contact with the structure, not the total number of migrants passing Old River. Thus it is not clear what the actual net benefit of the structure provides. If for example only 30% of the fish encountered the structure and 70% passed along the right bank, then the net benefit of the structure would be 0.8 *0 .3 = 0.24. If predation takes are representative, then the net survival from the structure is reduced to 0.23 to as low as 0.14 (14%) of the fish passed alive as a result of the structure. Those that cross into Old River are estimated to have a survival of near zero. The results as presented suggest that the BAFF solves the problem because it diverts most of the fish (80%) that encounter it away from the structure and downstream. The actual survival rate of smolts passing Old River may be in reality closer to 25%. There are data on rates of survival per mile for salmon smolts in natural unimpacted system and impacted systems like the Columbia River. Comparison of survival rates in the San Joaquin may be indicative that even a fixed barrier at Old River has limited net benefits. One observation that was made during the VAMP Review (2010) was that the placement of even a fixed barrier several hundred feet inside the Head of Old River creates predator habitat and slows smolt movement due to slackened velocities. If a permanent barrier were constructed, it should confine the main channel to maintain velocities at this location and potentially involve channel reconfiguration to eliminate scour holes and holding areas for predators. The VAMP Review also noted the following: "San Joaquin River mainstem survival estimates from Mossdale or Dos Reis to Jersey Point were just slightly greater than 1 percent in 2003 and 2004 and the estimate was only about 12 percent in the very high flow year of 2006. This compares to survival estimates that ranged between about 30 and 80 percent in the years 1995 and 1997-2000. The recent survival estimates are significantly lower than the long-term average survival estimate of about 20 %, which itself is considered low when compared to the Sacramento River and other estuaries like the Columbia River (which is in excess of 60%). The very low recent survival rates seem unlikely to be high enough to support a viable salmon population, even with favorable conditions for ocean survival and upstream migration and spawning success for adults." Predation may not be the only cause of mortality, but data support that it is or has become a significant source or smolt mortality in recent years. **Recommendation:** Transportation of smolts in the Columbia and Snake rivers has shown itself equal to returning adults compared to in-river smolt survival (60%). With smolt survival rates in the San Joaquin averaging less than 10% recently and even as low as 1%, the consideration of smolt transport may deserve more emphasis in Phase II than is suggested by information provided in the Phase I Report.	I	The predator issue is a serious and valid concern, but possibly outside of the scope of work for this project. Predation is a biological occurrence that has and will continue to exist. This action calls for investigating engineering options to deter salmonids. Not sure what can be done about the natural occurrence of predation. In evaluating options, minimizing predation effects is a criteria that will be considered and evaluated as possible. Some studies have occurred and are ongoing but the relationship of predation and options considered will be very difficult to predict. The transportation barges alternative will receive the appropriate level of consideration for each site, including the HOR.
10P	**South Delta Improvement Program** SDIP planned to install a fixed barrier at Old River using Obermeyer like technology as recommended earlier. Rationale for the delay was not explained except to say NMFS Biological Opinion 2009 stopped it until predation studies are completed at the South Delta temporary barriers. **Comment:** Since predation data is not available for the Phase I Report, it is difficult to comment on it. However, assuming predation is not zero, and possibly high at these locations, it is unclear how any finding will facilitate a better decision about	I	A 3-year predation study has been completed for the Temporary Barriers Program. A report on the findings will be submitted to NMFS. DWR will consider whether to request a reconsultation on the permanent barriers. Coordination between the engineering solutions study analysis and the SDIP will be done as needed.

Item	Comment	Action	Response
	permanent barriers that can be instantly removed with gate operations at Old River or other key locations identified in this report. There is only one disbenefit to preclude construction of a permanent barrier at Old River. If a concept is selected to attract migrants into Old River for improved "transport" around South Delta, at the pumps themselves or at a new facility upstream of the pumps, then a permanent physical gate will not have any value at least as conceived to block flows into Old River. If a transport system is developed, but it is located upstream of the Head of Old River, a permanent gate would have less value but still have benefits as many of the migrants, but not all, will have been removed prior to arriving at Head of Old River. **Recommendation:** Unless transportation options are recommended in Phase I at the pumps, a physical barrier at Old River should be constructed with Obermeyer type control as soon as possible.		
11P	**Non Physical Barrier** This option has been discussed in detail elsewhere in the Phase I Report and review comments provided. **Comment:** The most successful behavioral guidance systems that have been demonstrated repeatedly are those involving non-salmonids and mostly in lentic systems (lakes, bays, estuaries and some canal diversions). Here fish are not fighting large volumes of bulk flow with the built in negative rheotactic instinct (swim with the flow downstream to the ocean). They are also not fighting the complexity of flow reversals where much of the day upstream looks like downstream. The most successful applications involve water supply diversions where intakes are small and the species they are repelling have very different aural capacities compared to salmon. **Details:** There is promising research that suggests better results with salmonids can be obtained with infrasound and ELAM models (Sand et al., 2001; Nestler et al.). That said it is unclear that even 100 percent behavioral or physical exclusion is sufficient by itself to address smolt survival rates of less than 10%. That is why addressing predators must accompany any plans for addressing diversions into unwanted sloughs. One way to decrease predation at Old River would be to redesign the channel to increase velocity at the structure and remove the existing scour hole downstream of the diversion point. Predators however, will just find the next best ambush location up or downstream. Thus predator control by a variety of methods must also accompany efforts to redirect smolts into the mainstem channels. This will be a non-stop commitment as eradication is not feasible. But because some of the species are desirable have food and recreational value, increasing take limits by sport fisherman would be one way to do this cost effectively. For non-game species, use of bounties was successfully employed in the Columbia / Snake system for pikeminnow at specific locations (mostly dams) where predation rates were especially egregious due again to the creation of slack water in a lotic (flowing) system. **Recommendation:** Drop behavioral guidance options at Old River and Georgiana Slough unless evidence can show definitively that they can fully deter most smolts from passing into these sloughs at all flows. The cost differences are negligible and the certainty of physical barrier effectiveness outweighs any potential cost saving on water. The exact operation of these structures to meet other needs including water supply, water quality and navigation will be an important component of the design and operating phases.	N	There is no criteria from NMFS on how well a NPB would need to perform. Though deterrence of juvenile salmonids may not be as effective as a physical barrier, other criteria such as effects on flows and passage of other species appear to be favorable with a NPB. A determination of what the best overall option to address deterrence and not introduce negative impacts will need to be weighed to determine the best solution for each site.
12P	**Electric Barrier/Guidance System** Smith Root (2012) is a design leader and provides information that may be useful in deciding if or where it could be helpful. There are other commercial vendors that are easily found. **Comment:** Electric barriers have potential drawbacks in Bay Delta. The amount of amperage must be set to the smallest fish to be repelled. Higher amperages can injure or kill larger fish; smaller amperages allow small fish to pass the barrier more easily. Since there is a large and diverse fish fauna, including simultaneous presence of adult and juvenile salmonids, and in some locations Delta smelt, such systems are unlikely to deliver the intended results for all species and fish size classes in one any location. Electric current is affected by the dissolved solids in the water. Salinity is an important variable in Bay Delta. As salinity changes with tidal flux, so will conductivity. As depth changes with river and tidal flows, the effectiveness of the current from surface to bottom will change. Although safe to operate in controlled environments, many of the locations will not be secure from the public, including boaters.	I	We appreciate your comments on this type of barrier and will be researching this option further. Some good reports on previous studies that will help support our scoring decision during the selection process have been located and will be reviewed.

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	Recommendation: Minimize efforts to study this option unless it is in a controlled environment with only single species of fish as targeted. It could be useful at a collection or transport facility.		
13P	**Fish Screens** Fish screens are primarily used to separate fish from water. There are numerous types and designs that vary by application. **Comment:** Costs for screening small fish are very high; in excess of $4000 per cfs. And they have high O&M costs. The primary place screens would have application will be in development of a fish removal and transportation system. If this option is studied, designs now in operation in the Pacific Northwest or the Northeast U.S. should be studied. One caveat is that there are very few examples of fish screens at low head dams; however, applications at hatcheries, including those in northern California may be helpful. **Recommendation:** Limit study of fish screens to fish removal and transport system; they could have some options where use of tide gates or other barriers are employed and water but not fish need to be passed.	I	Initially the fish screen technology will be included as part of evaluating options for each site and then we will determine if it's feasible for a specific site.
14P	**Obermeyer-Type Spill Gates** **Comments:** There are numerous makers of inflatable dams. Obermeyer is one in Colorado. The Europeans have been a leader in inflatable dams and more research should be conducted to insure a cost effective and competitive selection process. The main advantage of these gates are they handle low head applications very well and enable diversion dams to be fully open or closed to natural flows and natural river elevations. Elements to keep in mind are that the gates may operate multiple times per day based on day/night and tidal cycles as well as remain in fixed positions during the non-migratory season. The environment includes saline waters at times and this will create additional concerns for corrosion and mechanical operation.	I	Comment noted.
15P	**Under-Flow Gates** The description of underflow gates is confusing but potentially applicable but only in some highly specialized situations. Passage of sturgeon and other bottom dwellers may be effective; but there is a limited literature on experience. **Comments:** An underflow gate will create some unusual hydraulic environments that are not particularly fish friendly or attractive. Juvenile salmonids often resist or delay passage through submerged orifices and gates. If the goal is to guide smolts to a new location, while also allowing discharge and bottom dwelling species into a diversion, such as a slough for non-salmonids, it might be applicable. A better solution is to exclude fish would be use of screens. These will be costly, high maintenance and of suspect value since there are multiple passages throughout the Delta that would enable fish to enter or egress side channels and sloughs.	N	Comment noted. We have clarified the description of an underflow gate. Underflow gates are bottom opening gates such as a radial arm gate versus an overflow gate which is a surface releasing gate such as a weir gate.
16P	**Sluice Gates and Radial Arm Bottom Discharging Gates** **Comments:** Although lower in cost that Obermeyer gates, sluice gates are not easily raised and lowered. They generally do not operate in partially open / closed positions. If gate operations are to be infrequent and either full open or closed, this might be a choice; but given the goals to keep smolts out of sloughs during migration while still allowing discharges at on tidal or diurnal cycles, a design that allows frequent gate level changes and surface elevation adjustments would be a better choice. Note also that sluice gates open from the bottom so, if some designs allow partial discharge, it would be drawing from the bottom. A gate that is designed to be cracked open to various levels from the bottom and operate moderately frequently is a Tainter type or radial gate. Typically these are associated with ogee spillways and at higher heads than are associated with most levees in the Delta. Likely these might be considered where flows are higher, like at Three-Mile Slough and Georgiana Slough as exemplified by gates at the DCC in Figure 15.	I	Comment noted.
17P	**Floating Barrier – Fish Guidance Systems** These types of systems are typically used in the forebays of high head dams, those with over 70 feet of head. Their purpose is to laterally move fish to one side of the forebay or the other and to direct them into a downstream fish passage entrance and away from powerhouse intakes. These are unsuitable for areas of high velocity where stability may be a problem. **Comments:** One use that could be effective for floating guidewalls might be to test the effectiveness of guiding fish temporarily away from specific slough entrances or areas of high predation. The strategy would be to move the structure from time to time, gather data on fish guidance efficiency, predation rates and channel hydraulics as a precedent to installing a permanent guide wall or other hydraulic channel modification.	I	These barriers can be designed to perform in very high velocities. Having flexibility to move them, based on river conditions, could be beneficial as well. Studies in the Pacific Northwest have shown these guidance systems to have some effectiveness in deterring juvenile salmonids and will be researched further.

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	Recommendation: Consider use of floating guide walls as research tools to increase fish passage in areas of high predation. Once a design is proven successful, it would be replaced with a more permanent and low maintenance guidewall.		
18P	**Guide Walls** This is a euphemism for any hydraulic structure designed to direct discharge in a specific direction; or to protect a shoreline from erosion. Gabions are rock weirs that have some hydraulic permeability and can be submerged during flood flows. **Comments:** In general smolts will be either randomly or uniformly distributed around the deeper portions of the channel, but more surface-oriented during the day. The advantage of a guide wall over a floating system is that is provides directional flow from bottom to surface unless submerged and as shown in Figure 16 (Phase I Report), could direct fish (and water) to the opposite side of channel to enable greater likelihood of not being swept or directed into a slough. **Details:** A caveat for the implementation of guidewalls is they may actually increase habitat for predators if they create backwater areas that reduce velocity. Gabions are cheap to construct and can be flood resistant, but will provide hiding places for ambush style predators like black bass and catfish in crevices between boulder size rock. The hydraulics of both guidewalls and floating barriers are complicated by ebbing and flooding flows of varying depths and velocities. Thought would be needed as to the creation of eddies and how much discharge they might distract from a given slough. Diminished flows may be good for fish, but could negatively affect water quality, water supply, erosion and unintended flooding. **Recommendation:** Guidewalls may be useful for directing smolts away sloughs and predator habitat. They could increase local velocity by narrowing certain sections of the channel. These should be considered in concert with especially predator control.	I	Comment noted.
19P	**Rock Barriers** **Questions:** Have costs of constructing and deconstructing been compared to a permanent Obermeyer design been addressed? The Report explains that NOAA placed a hold in 2009 on the barrier; and my comments were already provided if the rationale was Delta smelt. Further explication in the Phase I Report and how this will be addressed in Phase II would improve this report. Why not install tide gates instead of culverts in the next barrier? There may be need from some control and that could be accomplished with a gated culvert or other control structure. But this would set up set and forget type barriers to smolts from moving into sloughs on flood tides. Would a fuse plug spillway work with the water surface elevations to make the structure flood worthy and prevent back flooding as well as to preserve the structure in the event of a large runoff? **Comment :** Riprap provides increased habitat for predators and increased attraction for small nonmigratory fish to take up nearby residence. This further invites more predators.	C	Costs will be considered in evaluating viable options. The comment on the use of riprap is duly noted.
20P	**Recommendation:** The location of the temporary barrier inside the Head of Old River undoubtedly reduces cost for construction and deconstruction (narrow channel), but if temporary structures are to continue for the indefinite future, why not make them semi-permanent by putting the alignment close to the main river channel, narrowing it, and possibly covering the riprap with material that smoothes out the surface? That would reduce friction and discourage predators and a community of food from developing in the structure.	I	Agreed, as a fish deterrent structure it should be located adjacent to the main river channel.
21P	**Hybrid Combinations** **Comment:** These are good ideas. The only issue is the complexity of the task and the time limitations of Phase II as already addressed above.	I	Comment noted.
22P	**Habitat Restoration** **Comments:** I generally agree with the comments that there are significant impacts to close off Head of Old River, Georgiana Slough and Three-Mile with permanent natural barriers. However, especially Old River and Georgiana Slough, appear to be good candidates for temporary hydraulic control to reduce smolt migration into these	I	Habitat restoration was initially thought of as restoring man made channels to their original state. Turner Cut and Columbia Cut were previously natural channels. Due to Turner and Columbia Cuts being altered in the past, this option would be best

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	channels at some times of the year and some periods of the tidal cycle. I am generally not a very strong proponent of riverine habitat restoration. Too many good ntentions in river modifications are simply undone by the next big flood. The proposal to close off Columbia and Turner Cuts sound interesting but depend on tradeoff analyses of impacts and costs. This in itself is a significant study if added to the already large lists of tasks for Phase II. **Details:** One other area of habitat restoration that might be considered emerges from comments on predation from Vogel (2011; personal communication). Vogel reported the following predation rates on acoustic tagged test fish by location in 2010: Chips Island 59%; Old River 75%; Deep Water Shipping Canal 59%; aggregate of all 65%. Every instream structure that has been placed in these sloughs and the mainstem River channel represents habitat to deflect current, reduce velocity and add resting and hiding places for predators. Areas of high predation should be considered for either predator removal or modification (getting structure out or modifying the channel to increase velocity). This unfortunately will have un-measurable net benefits to smolt survival because the Delta is vast and hydraulically complex. **Recommendation:** Temporary closure (gated structures) may be as effective as permanent closure for improving smolt survival. If this has fewer impacts, it should be compared with the proposed option for permanent closure using rigorous alternatives analysis that consider costs and benefits.		considered at these locations.
23P	**Transportation Barges** Transportation means collecting smolts and moving them artificially around migratory habitat which is unsuitable to meet survival targets due to impacts too costly or difficult to remove. This can be done in trucks as takes place at the fish salvage facilities near the pumps; or if it makes more sense in barges. **Comments:** Existing salvage and transport facilities were an afterthought of saving the fish attracted to the pumps. Clifton Court has very poor hydraulics for capturing fish as currently designed. The average fish spends up to 72 days prior to capture and the average is many days to weeks (VAMP Review, 2010). Predation estimates of marked salmonids that ended up at this area in 2010 were 98% (Vogel, 2011). If transportation is to be considered, it will be a major facility and take significant effort on its own to come up with a location and conceptual facility. The existing fish salvage facilities were studied for improvement at least conceptually by Ott (2005). If the pumps are feasible sites, and there are many reasons why likely they are not, major modifications would be needed to more rapidly attract, separate and transport smolts from predators and water. Since distances are short compared to the Columbia, trucks are the likely choice over barges for transport vehicles **Details:** The current size and layout of Clifton Court with confined entrances make predation a huge obstacle. The reason to at least review this location: pumps provide an attraction flow from the San Joaquin that might attract most smolts from the Head of Old River with some hydraulic help at that location. It would also insure large amounts of water for export, a potential win-win solution. Other sites to consider would be further up the San Joaquin River to minimize the effects of tidal influence and predation. Fish would be transported to Suisun Bay at improved release sites to minimize the high predation rates experienced because predators have become habituated to the release (feeding) schedules and locations. I do not see the sense in transporting fish from the Sacramento if they can be passed downstream of DCC and Georgiana Slough in improving percentages. **Background Information:** The Columbia Snake system instituted major programs to improve in-river survival, with transportation showing moderately good survival at least to the estuary. The fact that populations were still declining led to major reevaluations of new capital intense projects, including removing some of the largest dams in the U.S. (Pizzimenti, 1996). Currently federal agencies use both transport and in-river bypass with more smolts in river during high flow years. Collection efficiency is lower when there is more spill and juvenile survival and adult return rates are higher in-river during high flow years. Although barging is less costly NMFS uses both pathways as they return similar adult numbers. Until more flows are returned to the natural channel in the San Joaquin (see Figure in Appendix I reproduced from the VAMP Review) these high flow years would be rare events.	I	The intent is to keep fish in the river at all times and not remove them to truck them. The objective is to keep salmonids in contact with their migration path.
24P	**No Action** Comment: Presumably this is a formality. Clearly actions are needed if extinction is not an option.	I	It also serves as a baseline if another project is built that would eliminate the need to pursue the action (e.g., removal of intake at CC)
25P	**Framework for Evaluation**	C	We will look into the Corps and Reclamation ranking

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	The current framework is a Qualitative approach to listing options and impacts similar to an NEPA analysis found in a Biological Opinion or EIS. **Comments:** Phase II will form the basis of environmental and economic acceptability. It will require justification that the configuration of options selected provides the best combination of facilities at the lowest cost to improve smolt survival. Options must be defensible using peer reviewed methods and that are clearly in the best interest of the "public". If the method of ranking options is not quantifiable and transparent, disgruntled special interests could stop the process from legitimately moving forward. Earlier in this review, I recommended review of WRAM (Soloman, 1977) and use of NED standards. The Phase I Report suffers for absence of clear methods and tasks that show how the action agencies will arrive at a Phase II Report on time and meeting NMFS requirements. **Details:** USACE Water Resource Assessment Method, a non-parametric pair-wise comparison is one option that can employ Delphi (expert panel) participation. It is not very confining or data demanding; but it is formal; it is published; it has been used to rank major water resource development projects by the Corps and it is easy for non-expert modelers to understand how the analyses are done. Regardless of the method, the Phase II effort should include some means to scale and weight the variables. If not, how will results that include water supply impacts as high and recreational impacts as high separate the fact that one may involve hundreds of millions of dollars and the other tens of thousands of dollars (cf., Pizzimenti, J.J. and D.O.Olsen, 2009). The use of NED (1993) techniques should also be considered to add rigor and formality to methods that are widely accepted in justifying costs for large public projects. **Recommendation:** Action agencies may want to consult both the Corps of Engineers and Bureau of Reclamation Tech Center for more widely accepted and rigorous methods of ranking and project selection. Economic comparison of recommended configuration and their impacts need to be incorporated in the Phase I Plan that would be implemented at the feasibility level in Phase II and finalized in Phase III.		methods in Phase II. The issues involved with each one of these sites are complex and highly variable. Discussion amongst the professionals that have been involved in this project (TWG) will be used to decide on where to focus our resources and energy. The WRAM will be used to evaluate the viable options. The framework will be adapted to weigh criteria that are obviously more important than others. This will be done in Phase II
	Reviewer: Mark Stacey		
1S	I provide here my review of the Phase I Draft Report from DWR regarding Engineering Solutions to Reduce Diversions of Juvenile Salmonids to the Interior and Southern Delta. It was difficult to know how to frame this review, or even how to interpret the report, due to the fact that I had no knowledge of how much effort had gone into the work during Phase I nor the resources available for Phase II. As such, it is impossible to know what tools are appropriate for the analyses that need to be performed. To be clear, what can and should be done with large-scale effort (team of people, funding for experiments and modeling) is quite different from what can and should be done with minimal effort (one or two people working part time without funding for supplemental studies). With this in mind, in the following review, I will comment on the approaches that have been applied or are proposed to be applied, and will note how I think those approaches should be used; I will limit my comments on additional analyses that may be considered. To summarize, during Phase I, background was developed regarding both the species of interest (Salmonids) and two other species of concern (Green Sturgeon and Delta Smelt), and alternative approaches were developed for each of 5 diversion sites (Georgiana Slough, Three mle Slough, Head of Old River, Turner Cut and Columbia Cut). Included in the Phase I report was some background on the success rates of various engineering solutions. The Phase II work, as described in this report, would use a set of 12 evaluation criteria to evaluated each engineering approach using "low", "moderate" and "high" scoring. I'm afraid that I cannot support this matrix approach as a Phase II decision tool. Instead, "low", "moderate" and "high" ratings should be used as the culmination of the Phase I activity in order to prioritize more complete analyses and studies during Phase II. In order to do so, the matrix framework *must* include evaluation of the uncertainty associated with the evaluations contained in the matrix. Further, even as a preliminary screening mechanism, the criteria and evaluation approaches used in the framework must be much more carefully developed and refocused. In the following sections, I provide more detailed comments. I will divide my comments into those that are responsive to the report on Phase I activities; those that are responsive to the described actions for Phase II; and recommendations for action during Phase II. ***Detailed comments on Phase I activities.*** 1. The background on species of interest and their use of estuarine habitats is clearly	I	The WRAM will be used to evaluate the viable options. Uncertainty will be added. The framework will be adapted to weigh criteria that are obviously more important than others. This will be done in Phase II

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	developed and appears thorough and complete (although I would defer to others with more direct expertise). What is lacking, however, is a clear summary of where the largest uncertainties lie in the biological and physical processes that are described in this section of the report. It is important that uncertainties be woven into the narrative, in addition to the matrix evaluation to come, so that (a) decisions can be made appropriately; and (b) future work can be correctly prioritized.		
2S	2. The list of engineering solutions, which consists of 12 different approaches (including a "no action" and a "hybrid" alternative), is quite well developed, and I believe the report has accurately assessed the state of the technologies. Once again, however, there are not clear statements about what is *not* known about the technologies and where the biggest performance uncertainties may lie. I will comment on some of these specifically below, but, for example, scour around tidal gates may undermine the structural integrity of the gates or change turbidity locally; but these effects would require much further study to understand.	I	Comment noted.
3S	3. Although the list of engineering solutions to be deployed at the 5 sites is quite complete, I feel that there was one obvious alternative that was missing, which was to place structures (perhaps temporary floating barriers) along the Sacramento River to positively direct juvenile salmonids into Steamboat and Sutter Sloughs. I know other reviewers are suggesting reducing the number of sites from 5 to 3, but if you think of 3 *diversion* points (Georgiana Slough, Head of Old River, Turner Cut), then structures to direct fish into Steamboat and Sutter Sloughs are just other approaches to addressing the Georgiana Slough (and Threemile Slough) diversions.	C	The Action is written to address specific junctions to keep juvenile salmonids in the Sacramento and San Joaquin Rivers. Routing fish through Steamboat and Sutter Sloughs may have merit, however, addressing these sites in Phase II is not likely due to time constraints.
4S	4. Habitat restoration, as presented here, appears to be using natural structures (whether intertidal or higher elevation) to block flows; in which case the effectiveness of them for the objectives here would really be the same as a rock barrier. I had expected habitat restoration to focus on other restoration in the region that might reduce diversions; for example, if habitat were restored on the opposite bank from the diverting channel, it may bias the distribution of juvenile salmonids to the opposite bank and reduce diversions. This approach may be assisted by upstream diversion walls that direct juvenile salmonids away from the bank where the diversion occurs.	I	Comment noted.
5S	5. I find myself confused by and concerned about the technical methods used to quantify deterrence, protection and other metrics of barrier performance. Specifically, in the calculation of a Deterrence Efficiency, it isn't clear how a "fish response" is identified (the denominator of this factor). In the Guidence Efficiency, different values are reported on flood and ebb tides, but I'm confused as to what this quantity means within a tidal phase: on one phase flow is splitting and entering the diverting channel; on the other phase flow is exiting the diverting channel and merging into the main channel. Finally, the Protection Efficiency has no baseline value stating how many fish enter the diverting channel (I think this was reported for Head of Old River) in the absence of control measures.	I	The comment appears to be in reference to the 1990s studies. These terminology were used in the study reports and provided as back ground information.
6S	6. The function of fish barrier walls will be highly site-specific. For example, the function of the walls at Georgiana Slough or Head of Old River, where the diversion channel sits on the outside bank of a curve in the main channel, will be quite different from their function at the other sites. Even at Georgiana Slough and Head of Old River, there will be site specific flows that make the effectiveness of the walls distinct at each location. In order to evaluate the performance of these walls, high-resolution site-specific hydrodynamic models would be required to define the resulting flow patterns; some assumptions about juvenile behavior would need to be layered on the flow field to understand the net effect on exposure to the diverting channel. This is a significant effort if it is to be done correctly, and without it I don't think even "Low", "Medium" or "High" values could be effectively judged.	I	Thank you for this information. We will consider the use of multi-dimensional hydrodynamic modeling as part of the evaluation.
7S	7. In the description of the use of Transportation Barges, there is no quantification of the effects on adult in-migration. If that information is available from previous studies, it should have been reported here. If it is not available, then this should be noted as a large uncertainty for the approach.	I	Some prior study information is available but the studies were not conducted under conditions similar to the five study sites. Uncertainties will be acknowledged as needed in Phase II.
8S	***Review on the approach proposed for Phase II*** As noted in the introduction, I don't believe the proposed matrix framework is appropriate for a Phase II decision-making tool. I do believe that the development of a matrix of high, moderate, low scores would be valuable now at the conclusion of Phase I so that Phase II could target the most critical and uncertain aspects of the decision. As such, I suggest that this matrix be developed immediately, but with the	I	Discussion will be included in Phase II. We agree the matrix is not a substitute for discussion.The WRAM will be used to evaluate options in Phase II and will include discussion.

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	inclusion of uncertainty, so that the process can be more effectively pushed towards a real decision by the conclusion of Phase II. In the development of this prioritization matrix (not a decision matrix), I recommend the following detailed comments be considered: 1. The matrix cannot be used as a substitute for narrative. Discussion of the underlying processes and how the evaluations are made should be included with the matrix.		
9S	2. There is no place in the framework for statements about uncertainty. It is critical that any evaluation matrix include a "score" for the degree of uncertainty (another High, Moderate, Low rating).	R	Uncertainty will be added to the matrix and evaluated in Phase II.
10S	3. Several of the criteria seem to address the benefits of the approach for the targeted species. Specifically, these include deterrence ability, effects on upstream migration and predation effects. Since this is being converted into a "high", "medium", "low" rating, it seems that it would be best to combine these into a single metric of total increase in survival for the targeted species/run.	I	It is important to score each criteria individually as this will provide the appropriate level of detail for assessing the beneficial and adverse impacts. Melding the scores to produce a metric of "total increase in survival" appears to be too broad of a category and may mask uncertainties or other important aspects of each individual criteria.
11S	4. The criterion "Environmental Impacts" is far too broad and there is no hope that it could be effectively reported as a single score ("High, Moderate, Low"). Evaluation of this criterion, as currently framed, would have to consider effects on Sturgeon, Delta Smelt, Water Quality (In-Delta use, South Delta Pumps, others?), and even other salmonid runs. An action may have positive effects in one area (i.e., no action at head of old river might be protective of Delta Smelt), but negative in others (i.e., deteriorated water quality in the South Delta). This criterion should be split into more narrowly defined criteria (see below).	C	Consideration will be given to refining the criteria.
12S	5. Throughout the criteria, it isn't clear if they should be applied to each run individually. It seems that they should be, since temporary barriers may have a positive effect for juvenile salmonids from one run, but a negative effect for adult migration from another.	I	Criteria should apply to all runs when juvenile salmon runs occur. The Action does not specify runs. It states "juvenile salmonids" which is believed to be all runs.
13S	6. I don't know what it means to score "Flow Effects" as "High, Moderate or Low". It isn't clear what flows are being considered (net flows, tidal flows, diversion of flows out of primary channels, net transport towards the pumps…) or why "Flow Effects" in and of themselves should be a criterion. Instead, it seems that concerns about flow effects are due to the effects of flows on other conditions, such as entrainment of other species, water quality, sediment scour and transport. Many of these other impacts are seemingly contained in "environmental impacts", and I think it is important to be specific about the impacts of concern, particularly if it is to be scored as "High", "Moderate" or "Low".	I	Impacts to flows in the area of the project are very important as to not affect the current conditions. The focus of addressing the Action is to deter fish and not create additional issues. Reducing flows at the junctions is assumed to be a potential issue with the exception of the HOR which has a current Temporary Barrier program that seasonally reduces flows. The WRAM will be used to evaluate flow effects as well as other environmental impacts.
14S	7. Implementability, Operation & Maintenance, Land Acquisition & Easement all have cost elements, plus "Cost" is included separately. The "Cost" criterion should include cost elements associated with each of these others (Note: it isn't clear whether the "cost" would be calculated as Net Present Value or how the scoring of this criterion would be done) and the non-cost components of each need to be the focus of these other criteria. Operation & Maintenance might then be recast as "Reliability"; Implementability might be about "Timeliness"; it isn't clear what would remain in Land Acquisition once the cost of acquisition is incorporated into the "Cost" criterion. Finally, "Tidal effects" seems to be the same as Operation & Maintenance (the discussion of the criterion is focused on the performance of the structure under different stage/flow conditions).	C	Cost is defined as "the cost to implement an option initially, annually, and long-term" and was intended to include all cost elements as noted. Re-defining Operation & Maintenance to "Reliability" and Implementability to "Timeliness" seem reasonable and will be considered. Tidal Effects needs remain a separate criteria to clearly distinguish options that are compatible. Land acquisition and associated easement requirements for some options may preclude their use at some sites and is planned to be retained.
15S	8. The Maturity criterion seems to be trying to capture uncertainty in the performance and/or reliability of an approach. I suggest this be eliminated as an independent criterion and instead incorporate these concerns into the uncertainty of the "Reliability" or other criteria (including the Benefits to target species and the Environmental Impacts).	R	Agreed. Maturity will be deleted but it will be incorporated into a new "Uncertainties" criteria (see Comment 1S).
16S	***Recommendations:*** 1. The matrix framework described here should be used in the near-term to prioritize Phase II activities. This prioritization should be based on both the potential benefits of the approach and the uncertainties associated with it. For example, an approach that has "low" benefits and "high" uncertainty would not merit further study, but one with "high" benefits, "low" negative impacts and "high" uncertainty of the benefits would merit investment (numerical studies in many cases, including hydrodynamics and particle tracking). I don't want to get ahead of the evaluation process, but an example of this case might be diversion barrier walls upstream of the diversion points.	I	Agree

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17S	2. In conjunction with the matrix, a brief narrative must be included to make clear what thinking is behind the scoring in the matrix.	I	Agree
18S	3. The resulting matrix and prioritization for Phase II activities should be reviewed, either by the TWG or external reviewers (or both).	I	Agree
19S	4. The matrix must include evaluation of uncertainties for each alternative and criteria. To be clear, each matrix entry should include an evaluation (high, moderate, low) as described in this report *and* an uncertainty score associated with the evaluation.	I	Agree
20S	5. Reorganize the criteria as: a. Benefits for survival of target species and run (currently deterrence, upstream migration, predation) b. Impacts on Delta Smelt (currently Environmental Impacts, Flow Effects) c. Impacts on Green Sturgeon (currently Environmental Impacts, Flow Effects) d. Impacts on other runs of salmonids (I'm not sure where this appears in current structure) e. Impacts on water quality for agriculture (currently Environmental Impacts, Flow Effects) f. Impacts on water quality at South Delta pumps (currently Flow Effects?) g. Cost (currently cost, O&M, Land acquisition) h. Reliability (O&M, Tidal Effects) i. Recreation (boat passage)	C	Environmental impacts will remain as a single item but will certainly include items a., b., c., d., e., and f. Cost and boat passage will remain, uncertainties will be added.
	Reviewer: Steven Railsback		
1R	**1. Framework for Evaluation.** My primary recommendation is to consider using more of a standard engineering design process instead of the proposed evaluation framework. The report describes a process of identifying a large list of potentially applicable technologies, then ranking each by a set of general criteria. My experience with such ranking processes is that they are less likely than a standard engineering design process to either be efficient or successful in identifying the best alternatives—or, critically, to develop new alternatives. The criteria described in this report are quite general and unspecific, and the evaluation process appears likely to be subjective and qualitative instead of based on analysis of the available information. The proposed process does not clearly use the information available for each site and alternative facility type to determine which criteria are most important at each site, nor does it provide a clear target (a set of site-specific objectives and constraints) for evaluating or designing alternatives. Consequently, the proposed evaluation framework is likely to be time-consuming and inefficient. Instead of identifying and ranking existing technologies, I recommend looking carefully at the specific objectives and constraints for each site and *designing* ("develop", in the wording of Action IV.1.3) good alternatives. A standard design process includes definition of specific objectives and constraints, identification of alternatives that meet the objectives and constraints, and evaluation of the alternatives by expected costs and benefits. (In situations such as this where objectives and constraints are not "hard"—clearly met or not met—the evaluation of alternatives can also consider the extent to which objectives and constraints are met.) Such a process should rapidly exclude infeasible alternatives so no effort is wasted on them, and focus more of the effort on the most promising ones. It should also encourage the engineers to modify designs or even develop new ones instead of just looking at existing approaches—which could be important because this problem has unusual characteristics such as tides to deal with.	I	The evaluation framework will include an engineering design process utilizing the WRAM. Evaluation of each alternative will be done to address the specific objectives, constraints, costs and benefits in relation to other alternatives and the site using this method .
2R	A process for designing and evaluating alternatives could include the following steps. a) Define objectives that are as specific as possible, for each potential site. More detailed objectives will make the design and evaluation process less subjective. The objectives should address questions such as: —Which fish species and runs are targeted? —Just as importantly, which life stages or sizes of fish are targeted—fry (which may be least likely to survive to adulthood anyway), larger pre-smolts, etc. Facility designs may have very different success rates for different size fish. It can be very difficult for agency biologists to express priorities for specific life stages or species when they are charged with protecting them all, but doing so will increase the chances of designing a facility that works. —At which times of year (or other criteria affecting outmigration, perhaps flow) does the facility need to operate? What times of day?	I	The objectives are the same for all sites. All salmonids and runs are targeted. The facility may need to be run in any month depending on the request of the fish agencies and in response to specific annual runs.
3R	b) Define constraints for each site. The report currently provides some information related to constraints but not with sufficient specificity to use directly in the design	I	Boat passage will be considered for all sites. This could be in the form of a boat lock or some other

Item	Comment	Action	Response
	and evaluation process. Constraint information could address questions such as: —Boat passage: Is unrestricted boat passage essential? At what times of year (or day), for what kinds of boats? Would some kind of lock-like facility to let individual boats through be acceptable? (E.g., there are public docks on Georgiana Slough; does that mean boat passage is more critical there than at other sites?) —Channel flows and capacity: What reduction in flow through the channel would be acceptable at the times of year and flows when fish deterrence is required? Are solutions that completely or nearly block the flow (e.g., rock barriers) feasible? How much change in flood elevation is acceptable? (Or: what are the negative effects of various changes in flow or flood elevation?) —Effects on other species or life stages: What impacts on other species or adult salmon would be considered unacceptable? (Impacts that cannot be predicted reliably during the design phase would not be useful as constraints.) The report currently implies, for example, that restricting movement of delta smelt and sturgeon is undesirable but acceptable; is there a consensus to that effect? Is unimpeded upstream migration of adult salmonids into the delta ever important at each site? —Are there physical constraints due to space, access, etc.?		form of a passable portion of a deterrence option. Flow options will be looked at during Phase II.
4R	c) Select or design alternative facility types. What kind of facilities appear likely to meet the objectives within the constraints? If no existing facility types appear feasible, what characteristics are needed in a new design?	I	Identification of facilities likely to meet the objectives within the constraints and specific required characteristics will be addressed in Phase II.
5R	d) Evaluate the alternative facility types by (at least) cost and expected benefits. (It would make sense to integrate this step with the NEPA/CEQA process so that environmental impacts are part of the evaluation.) See the following comment concerning expected benefits.	I	Costs, benefits and impacts will be considered.
6R	**2. Site selection and site-specific benefits.** The report does not state clearly how the five sites were selected—except that three of the five were specified in the Action—nor how they might be prioritized for full design and construction. Site selection is a major step, so some justification for it would be appropriate. For Phase I it may be sufficient just to say something such as that the five sites are those that convey the most flow into the central and south delta. But for prioritizing sites (as well as for NEPA analysis) it seems important to analyze the site-specific benefits of fish deterrence facilities. (My comment 7 is closely related to this one.)	R	Sites were identified in the Action and selected through consultation with the TWG which included NMFS representation.
7R	One consideration for analysis of site-specific benefits is how many outmigrants go through each site. Are there any data on this? If not, then options include conducting new surveys or explicitly assuming flow as an indicator of fish movement: the proportion of fish moving through a channel is equal to the proportion of flow through the channel.	I	Unfortunately there is minimal biological information. NMFS has made the determination that there is sufficient information to direct DWR/Reclamation to conduct the study.
8R	A second consideration is the extent to which fish at each site are exposed to outmigration delays and the export pumps if they enter the delta. For example, are fish that leave the San Joaquin at Head of Old River more likely to end up in the pumps that those leaving at Turner and Columbia cuts? Are fish leaving the Sacramento at Georgiana Slough likely to be delayed more than those leaving at Threemile Slough? At the least, simulation experiments with one of the delta particle *4* tracking models could provide information on how delays and pump exposure varies among sites, assuming fish passively follow flow. Such simulations could also analyze how other restoration projects such as Franks Tract and San Joaquin River flow restoration could affect the benefits of this Action. Perhaps this kind of analysis was done in the OCAP process and could be cited here.	I	The Action implies that NMFS would like to see the fish stay in the Sacramento and San Joaquin Rivers which are their historic migration paths.
9R	(In about 2008, I helped supervise a Cal-Fed post-doc, Annjanette Dodd, who worked on developing the RMA particle tracking model of the delta into a model of juvenile salmon outmigration. The project got as far as modifying the model to incorporate fish behavior and developing ways to test alternative rules for outmigrant behavior against the newly-abundant acoustic tag data. The next step would be to propose such alternative rules, test them by how well they reproduce tag data, and identify the best assumptions about fish behavior for modeling how delta flow operations affect salmon outmigration. Even without fish behavior, this model would be valuable for analyzing relative benefits of the different sites. Patricia Brandes of the Stockton Fish and Wildlife Service office, Pat_Brandes@fws.gov, is familiar with this work.)	I	DWR/Reclamation are evaluating the application of life cycle models to consider outmigrant behavior. This includes the incorporation of a behavior algorithm in the DWR DSM2 particle tracking model, similar to the RMA model, as well as the development of individual based models for site specific evaluation. Application of these models is not planned to be a part of the current engineering solutions report but once completed they are expected to be utilized to support decision making.
10R	A third potential consideration is local hydraulics at each site. For example, I understand that some studies in the delta have indicated that the likelihood of an	I	These considerations and issues will be addressed in Phase II.

Item	Comment	Action	Response
	outmigrant going into a channel depends on whether the channel entrance is on the inside or outside of a bend. What do we know about each site's configuration that might make fish deterrence more or less important? Predation is another potential local hydraulic issue: would a proposed facility produce (or remove) conditions particularly conducive to predation?		
11R	**3. Habitat restoration as a potential alternative.** To me, the discussion of habitat restoration as a potential solution (starting p. 61) seemed to write this option off due to concerns that were not so clearly valid. First, the description of the solution defines it *a priori* as involving major changes such as converting channels into shallow wetlands; this definition of habitat restoration excludes smaller, more targeted habitat modifications that might better meet the Action's objectives. Second, the discussion of habitat restoration at specific sites essentially evaluates the alternative (saying that it would be impractical) against constraints (location, hydrodynamics, multiple uses) that have not yet been clearly defined or justified. The other potential solutions were generally not evaluated against these criteria. Habitat modification may deserve consideration as a realistic alternative to hydraulic and electromechanical facilities. Habitat "modification" might be a better term than "restoration" because the objective would not be to restore native habitat but instead to meet the Action's objectives of reducing fish entry into delta channels. Instead of treating restoration as a fixed approach, try to design habitat modifications specific to each site and its objectives and constraints. Are there, for example, local habitat changes that could attract fish to the mainstem and (just as importantly) scare them away from the delta channels? Especially for habitat modification, fish size is likely to be an important design variable. As the report discusses, habitat use changes as fish increase in size. Fry are highly vulnerable to predation by other fish but less vulnerable to birds, so they tend to prefer shallows. Pre-smolts and smolts, though, are vulnerable to birds and hence more likely to avoid conditions where they *5* are visible from above. My collaborator Bret Harvey (US Forest Service, Pacific Southwest Research Station) has shown conclusively that wild trout 100-175 mm in size are extremely reluctant to use shallow, open habitat where they are highly visible. These kinds of relations could be useful in designing habitat modifications that either attract or deter fish.	C	Initially, the intent was to restore the man made channels (Turner and Columbia Cut) if it makes sense. However, habitat "modification" might be a better term than "restoration".
12R	**4. Limitations of recent pilot studies.** The report describes recent behavioral barrier studies at Georgiana Slough and Head of Old River. I am sure that these studies will be invaluable in designing and evaluating alternatives. I have a couple of questions and concerns that I expect are already being addressed. First, I am concerned about basing evaluations on releases of tagged hatchery fish. If their release in this study was the first experience of these fish outside a hatchery, then it seems doubtful that their behavior represents that of wild fish very well. Do we have any information on how representative their behavior was? (The high mortality rate is not encouraging.) This technique is no doubt helpful, and I realize other techniques for evaluating deterrence success also have important limitations; but I would be hesitant to base important decisions on its results alone. Second, I wonder if any information on predators was collected in addition to reporting mortality of tagged hatchery fish. Were trawls, electrofishing, hook and line sampling, etc. used to determine whether predator fish were more or less abundant with the Bio-Acoustic Fish Fence operating? (A bubble curtain seems like a great ambush location, and, if I recall the old literature on such devices correctly, fish can acclimate to them quickly.)	N	Using tagged wild fish in the studies was not an option. The use of hatchery fish was the best available alternative. Data is available and being analyzed from the Georgiana Slough studies that may be referenced in the scoring of the BAFF option. The portion of the GS 2012 study that extended after the removal of the BAFF may provide information to address the question of whether or not a bubble curtain attracts predators. Predator information is still limited.
13R	**5. Literature on behavioral fish guidance.** I am sure the report's authors are familiar with the extensive literature on fish guidance technologies such as sound, lights, bubble curtains, and electric barriers; but it would be reassuring to see it cited and made use of explicitly. Much of the literature is from the 1980s and 1990s and focuses on species of the eastern U.S., but it may still be relevant. Many of the studies were conducted by EPRI, so can be accessed through DWR's EPRI account manager (Chris Horner, 972-556-6514, Chorner@epri.com). The Corps of Engineers has also conducted some important studies through their Waterways Experiment Station (a contact is David Smith, ERDC Environmental Laboratory, David.L.Smith@usace.army.mil).	C	Chris Horner from EPRI was contacted and we should have access to the database, where some of these studies reside, as soon as the membership agreement is in place. Further effort will be made to locate additional information.
14R	**6. Evaluation criteria.** The 12 evaluation criteria seem comprehensive but not especially welldesigned. (The engineering design process I suggest in my first comment would supersede the proposed use of these criteria as the sole basis for selecting facility types for each site, but criteria such as these are still likely to be useful as "soft" objectives and constraints, for comparing alternative engineered designs, and in NEPA assessment.) Some concerns are:	C	The WRAM will be used to evaluate viable options.

Item	Comment	Action	Response
	—"Tidal effects" is just one element of "Deterrence ability". To deter fish effectively, a facility needs to work at all tide conditions (and also over ranges of flow, turbidity, etc.; all of which should be specified in the design objectives) during which fish deterrence is considered important. —While most of the criteria clearly range from bad to good values, "Flow effects" does not. Is it necessarily bad if a facility restricts flow by some amount? At all times, or only in some seasons *6* or flow levels or water quality conditions? This concern seems better addressed as a set of design constraints: what ranges of flow or water elevation change are acceptable under what conditions? —"Implementability" seems mainly a cost consideration: the more complex a design is to construct, then the more it will cost to have completed by some particular date. —"Operations and maintenance" seems to refer to reliability, not O&M cost? If so, it would be clearer to call the criteria "Reliability" and link the metric to expected frequency and duration of failures. —"Maturity" seems really to refer to certainty about effectiveness; the implied (but questionable) assumption is that more mature technologies are more reliable. It might be clearer to call this something like "Certainty in effectiveness" (and it could be factored into the rating of deterrence effectiveness). —The report does not specify how the different criteria will be weighted in arriving at overall recommendations. A process such as the one I recommend in my first comment would identify criteria to treat as hard constraints, as objectives that must be met, and as "soft" objectives for which more is better.		
15R	**7. Cumulative effects and interactions among sites.** This draft of the report does not include any process or mechanism for looking at the problem from a system level; instead, it is focused on individual sites without consideration of how actions at one site may affect the costs or benefits of actions at other sites. Interactions among the sites seem very likely, for at least some kinds of facility. For example, any facility that significant reduces flow through one of the delta channels (e.g., a rock barrier at Georgiana Slough) seems likely to *increase* flow through other channels leading to the export pumps (assuming pumping rates do not change). Hence, (a) a "solution" at one site could be a problem at another, but (b) a problem at one site could be part of a good system-wide solution (e.g., diverting more flow out of sites where/when fewer salmon are present). Because of such potential interactions, a system-level analysis seems likely to be beneficial (as well as appropriate as part of NEPA/CEQA assessment). (I do not know whether such an analysis was conducted by OCAP in designing the Action.) A system-level analysis could address questions such as: —To what extent would complete barriers such as rock walls really reduce diversion of fish toward the south delta vs. move it to other locations? —How would any changes in flow at individual sites affect flow through other channels (possibly including pathways other than the five potential action sites)? How would the systemwide level of outmigrant delay and pump exposure change? —Can system-wide effectiveness be improved by expending more effort at one site and less at others? Are, for example, 3-5 partial barriers more or less effective than a complete barrier at 1-2 sites? The flow and particle-tracking models mentioned above (Comment 2) may be useful for addressing these questions.	I	A system-wide analysis would be appropriate as part of a CEQA/NEPA compliance and would be useful to determine redirected impacts of constructing barriers, however, such an analysis is beyond the scope of this effort to comply with the action which is focused on individual junctions
16R	**Specific Comments** 8. (Section numbering would make it much easier to understand and comment on the report.)	I	Comment noted.
17R	9. In discussing previous engineering solutions, it would be helpful to use the same measures when describing different studies, when possible. For example, in the Executive Summary (middle of p. xii) different measures such as "average guidance efficiency" and "percent improvement in deterrence efficiency" are used for different studies, so there is no way to directly compare results across studies.	C	We appreciate this situation. The recent studies use different terminology compared to the older studies, which cannot be changed. Text to clarify the difference in the various study measures will be noted as needed.
18R	10. Description of San Joaquin River sites: To what extent, if any, will the San Joaquin River Restoration Program flows affect the numbers provided for these sites?	I	Potential future conditions will be addressed as an uncertainty.
19R	11. Table 2 and 3 captions: These are for the river *basins*, not just the rivers?	I	Comment noted.
20R	12. Tables 2 and 3: Much in these tables did not make sense to me. For example, in Table 2, how can fall Chinook emergence start at the same time that spawning starts? How can fall Chinook juvenile rearing not start until 6 months after the fry emerge? In Table 3, how are there two migration and spawning periods for fall Chinook, with	C	Life stage information will be confirmed and revised as needed.

Item	Comment	Action	Response
	spawning ending before (and starting before) migration does?		
21R	13. Many references are missing from Literature Cited or incomplete.	C	Reference information will be confirmed and updated as needed.
22R	14. What are “operable” culverts and gates? (Why would you install ones that didn’t operate?) Do you mean gated culverts, and adjustable gates?	N	The term “Operable gates” has been used in previous reports. Consideration will be given to using other terms for clarity including “gated” or “adjustable”.
23R	15. Non-physical barrier and Electric barrier (pp. 49-51): To what extent are these options barriers to recreational use due to safety? Could bubble curtains sink small boats or swimmers? Could some kinds of boats cross an electric barrier? Or would all such uses likely be excluded due to safety concerns?	I	These questions will be addressed in Phase II.
24R	**Responses to Questions in Scope of Work Attachment 1** 16. Do the engineering solutions meet the RPA list of issues? The potential solutions listed in this report certainly are relevant to the Action’s objectives; the design work to determine which are likely to be feasible or good solutions remains to be done.	I	Comment noted.
25R	17. Have uncertainties been minimized? It does not appear that the design process has yet reached the point where uncertainties can be fully addressed. More review of existing literature and recent studies (comments 4, 5 above) would provide more confidence that available understanding of uncertainties is being considered.	I	Comment noted.
26R	18. Does the plan meet experiment objectives? The report directly addresses the objectives of the Action.	I	Comment noted.
27R	19. Are site descriptions complete and contain necessary information? The site descriptions are adequate for the material covered in this report. However, a more detailed development of site-specific issues, objectives, and constraints will be necessary for actual design and evaluation of alternative facilities.	I	Comment noted.
28R	20. Are potential solutions clearly defined and described? The report provides a useful comprehensive list of potential facility types. Additional information on specific solutions are addressed in comments 3 and 15.	I	Comment noted..
29R	21. Are the evaluation criteria clearly defined and described? I believe that the evaluation criteria will need quite a bit of site-specific refinement and analysis before they can be applied effectively (see comment 6). Some of the criteria would best be treated as objectives and constraints in an engineering design process (comment 1).	I	Comment noted.
30R	22. Are linkages among report elements clear? Yes.	I	Comment noted.
31R	23. Is the report of sufficient robustness and quality? This report provides a useful overview of the Action’s problem and potential solutions. Considerably more analysis will be needed design and evaluate good alternative solutions (comments 1, 7).	I	Comment noted.
32R	24. What, if any, additional engineering solutions need to be considered? I am not aware of any other technologies that deserve consideration as potential solutions.	I	Comment noted.
33R	25. What, if any, additional evaluation criteria need to be considered? My main concern about evaluation is the potential need for system-level evaluation: how do the proposed solutions at each site affect each other and what is their total benefit (comment 7).	I	Comment noted.
34R	26. Are the engineering solutions feasible to implement? The analysis needed to determine feasibility of each technology at each site does not seem to be done yet.	I	Comment noted.
35R	27. If not, what limitations need to be considered? Identification of feasible, and good, alternatives would be facilitated by developing objectives and constraints that are as specific and detailed as possible for each site (comment 1).	I	Comment noted.

Appendix E-Application of Water Resource Assessment Methodology

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Application of Water Resource Assessment Methodology (WRAM)

The Water Resource Assessment Methodology (WRAM) [USACE 1977] was developed by the USACE Waterways Experiment Station (WES) for their use in evaluating water resource project alternatives. Application of the WRAM in the OCAP IV.1.3 Evaluation of Engineering Solutions would support the identification of possible recommended options for each of the study areas.

Description of Method

The application of the method for evaluation of alternatives will comprise five steps. These steps are: (1) identification of potential alternatives (the term "option" is used in this document), (2) identification of comparative variables, (3) comparative analysis of the relative importance of each variable, (4) comparative analysis of the impact each option could have on each variable, and (5) calculation of a numerical score for each option and comparative analysis of scores.

1. Identification of Potential Options A project team identifies potential options (engineering solutions) for consideration.
2. Identification of Comparative Variables A project team develops a list of important variables which would be a measure of the abilities, effects, or impacts of implementation (e.g, construction, operation and maintenance) of an option. The variables could include cost, environmental impacts, effectiveness, permitting constraints, public acceptance, etc.
3. Comparative Analysis of the Relative Importance of Each Variable The variables of importance are analyzed relative to each other to establish a weighted pair-wise (variable-by-variable) importance comparison. The most important variable in each comparison is assigned "1", the other variable a "0", and if they are of equal importance they are both assigned "0.5". In addition to the variables of importance a dummy variable is always included to represent the condition of no relative impact. This variable value is always assigned a "0" for all comparisons and it's use allows some level of importance to be assigned to all other variables. These values are added for each variable to generate a sum. The sum of the values is used to calculate a "relative importance coefficient" or RIC value for each variable. Examples of variables for the purpose of the OCAP IV.1.3 study are the evaluation criteria (e.g., deterrence ability, flow effects, implementability, etc.). The calculation of the Relative Importance Coefficient is illustrated in a subsequent section.
4. Comparative Analysis of the Impact of Each Option on Each Variable The project options are comparatively analyzed for their potential benefit or impact on each variable (e.g., an option installed in a water channel may have the potential to significantly impact (affect) the flow of water in the channel). The comparisons are done through a "choice comparison" process similar to the variable-by-variable

comparison in Step 3 but of options for each variable. An "option choice coefficient" or OCC value is calculated for each option-variable comparison. The calculation of the Option Choice Coefficient is discussed in a subsequent section.

5. Calculation of Numerical Score for Each Option A numerical score or "final coefficient" (FC) is calculated for each option. The FC is based on the calculation of "intermediate coefficients" using the RIC and OCC values calculated in steps 3 and 4. The FC value for an option is then compared to the FC values of all other options to determine the option with the highest score. The largest FC value would indicate a preferred option. The calculation of the Final Coefficient is discussed in the last section of this appendix.

Calculation of Relative Importance Coefficient

The third step in the process summarized above is the calculation of a "relative importance coefficient" or RIC value for each variable. A RIC value is determined by: summing the importance comparison values for all variable-comparisons to generate a sum (Sum A); adding each of the Sum A values to generate a "sum of sums" (Sum B); and then dividing Sum B into the Sum A value for each variable to generate a RIC. The RIC establishes a numerical ranking of importance of each variable relative to each other. As described in Step (3) above a "dummy" variable is included which by definition will have a "0" value for all comparisons and a RIC value of "0". Table A presents an example RIC table. The Sum C value shown in Table A is a check value where the sum of all RIC values should always equal "1.0". If Sum C does not equal "1.0" an error has been made in the calculations.

Table A. Example RIC Table

Item	Variable	Importance Comparison						Sum A		RIC
1	Deterrence Ability	1	1	1				3		0.5
2	Flow Effects	0			0	1		1		0.167
3	Implementability (Timeliness)		0		1		1	2		0.333
4	Dummy			0		0	0	0		0
							Sum B	6	Sum C	1.0

Sum A = the sum of a variable importance comparison values
Sum B = the sum of all Sum A values
RIC = each Sum A value divided by Sum B
Sum C = the sum of all RIC values (always = 1.0)

<u>Calculation of Option Choice Coefficient</u>

The fourth step in the process summarized above is “impact scaling” in which project options are comparatively analyzed for their benefit or impact, as applicable, on a variable. The comparisons are done through an “option choice comparison” process similar to the variable-by-variable comparison in Step 3. A pair-wise comparison is done but of options using the same rating method of assigning a 1, 0, or 0.5. A “1” is assigned to the paired-option which would provide the most benefit or least impact, a “0” assigned to the paired-option which would provide the least benefit or most impact, and “0.5” assigned if the options would provide equal benefit or impact. Similar to the determination of RIC values, a coefficient called the “option choice coefficient” or OCC is determined for each option and corresponding variable. The OCC establishes a numerical ranking of benefit of an option relative to the other options for each variable.

Table B presents an example OCC table. The OCC for each option-variable combination is determined by: summing choice comparison values (Sum A); adding all of the Sum A values to generate a “sum of sums” (Sum B); and then dividing Sum B into the Sum A value for each option to generate an OCC. The OCC establishes a ranking of impact of each option on a variable relative to each other. A dummy option is not needed to determine OCC values because the impact of an option on each variable could all be rated “0” resulting in an option’s OCC values all being “0”. For the example in Table B a “No Action” option is included which differs from the “dummy” alternative. A “No Action” option is included to represent baseline conditions. The Sum C value shown in Table B is a check value where the sum of all OCC values should always equal “1.0”. If Sum C does not equal “1.0” an error has been made in the calculations.

Table B. Example OCC Table (Deterrence Ability)

Item	Option	Choice Comparison			Sum A		OCC
1	Non-Physical Barrier	0	1		1		0.333
2	Rock Barrier	1		1	2		0.667
3	No Action		0	0	0		0
				Sum B	3	Sum C	1.0

Sum A = the sum of a option comparison values for impact on deterrence
Sum B = the sum of all Sum A values
OCC = each Sum A value divided by Sum B
Sum C = the sum of all OCC values (always = 1.0)

OCC tables for the other two example variables (Flow Effects and Implementability) are presented in tables C and D.

Table C. Example OCC Table (Flow Effects)

Item	Option	Choice Comparison			Sum A		OCC
1	Non-Physical Barrier	1	0		1		0.333
2	Rock Barrier	0		0	0		0.0
3	No Action		1	1	2		0.667
				Sum B	3	Sum C	1.0

Table D. Example OCC Table (Implementability)

Item	Option	Choice Comparison			Sum A		OCC
1	Non-Physical Barrier	0	0		0		0
2	Rock Barrier	1		0	1		0.667
3	No Action		1	1	2		0.333
				Sum B	3	Sum C	1.0

Calculation of the Final Coefficient

The fifth step in the process summarized above is the calculation of a numerical score or “final coefficient” (FC) for each option. RCC values calculated in Step 3 and OCC values calculated in Step 4 are combined for each option in a final coefficient table. All OCC values for an option are multiplied by the corresponding RIC value to generate intermediate coefficient values for each option/variable combination. No dummy variable is necessary to calculate the FC value because all comparisons are completed as part of the RIC and OCC steps. The FC for a given option is calculated by adding together all of the intermediate coefficient values. Table E presents an example FC table.

Table E. Example FC Table

Item	Variable	RIC	OCC of Options				Intermediate Coefficients and Final Coefficient (FC)		
			Non-Physical Barrier	Rock Barrier	No Action		Non-Physical Barrier	Rock Barrier	No Action
1	Deterrence Ability	0.5	0.333	0.667	0.0		0.167	0.333	0.0
2	Flow Effects	0.167	0.333	0.0	0.667		0.056	0.0	0.056
3	Implementability (Timeliness)	0.333	0	0.667	0.333		0.0	0.222	0.111
						FC	0.223	**0.555**	0.167

Intermediate Coefficient = RIC value x OCC value
FC = the sum of all intermediate coefficient values

The option with the largest FC value would be considered to be the preferred option, assuming there are no over-riding considerations, to achieve the desired project objectives. The example Rock Barrier option shown in Table E has the largest FC value and would be considered as the preferred option.