Appendix K. Synthesis of Fish Migration Improvement Opportunities in the Central Valley Flood System

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

This page left blank intentionally.

Table of Contents

List of Figures

List of Tables

1.0 Introduction

Many instream structures in the Central Valley adversely affect native anadromous fish migration. These structures, often referred to as fish passage barriers, reduce or eliminate longitudinal habitat connectivity; prevent or limit access to critical spawning, rearing, and refuge habitat; create migration delays; and create lethal or sublethal conditions for native anadromous species (California Department of Water Resources [DWR] 2012a, 2014; National Marine Fisheries Service [NMFS] 2014). Fish passage barriers associated with the Central Valley flood system trigger compliance requirements under the federal and California Endangered Species Acts; necessitate recurring fish rescues; and impel additional permitting requirements, such as long-term mitigation (NMFS 2009; Vogel 2011; DWR 2012b; Johnson and Vincik 2012; Cannon 2013; Heise 2013; Hendrick and Swart 2013).

Identification of migration impediments and associated improvement opportunities in the flood system is needed for integrated flood management planning. Fish migration improvements can be integrated into flood risk reduction projects[1] to yield cost efficiencies in the project planning and implementation phases, and they may result in long-term economic and environmental benefits (DWR 2014). Two documents, the *Fish Passage Assessment* (Attachment 9C of the Central Valley Flood Protection Plan [CVFPP]) and the *Draft Central Valley Flood System Fish Migration Improvement Opportunities* (FMIO) report have been prepared to assist in identifying and prioritizing fish migration improvement opportunities in the flood system.

1.1 Central Valley Flood Protection Plan 2012, Attachment 9C: Fish Passage Assessment

The *Fish Passage Assessment* (Attachment 9C of the CVFPP) (DWR 2012b) provides a broad overview of targeted anadromous fish species migration needs. The document discusses:

- Ecological flows for fish habitat and migration
- Barriers identified (by the California Fish Passage Assessment Database) in the Systemwide Planning Area
- An interim prioritization of fish passage barriers, based on species recovery plans, the ownership status of structures (i.e., in relation to the State Plan of Flood Control [SPFC]), NMFS geographic priorities, and biological opinion deadlines

[1] For a discussion and tabulation of how fish passage improvements can be integrated with beneficial flood risk management projects, see Conservation Strategy Section 6.0, “Integrated Flood Risk Management and Conservation Approaches.”

Attachment 9C also recommends an assessment related to identifying non-SPFC barriers and remediating known barriers, as well as improving understanding of fish stranding.

1.2 Central Valley Flood System Fish Migration Improvement Opportunities Report

To fulfill Attachment 9C recommendations and provide detailed planning information to support CVFPP planning processes, DWR prepared the FMIO draft technical report (DWR 2014). The FMIO draft report includes:

- Background information on native anadromous species and fish migration improvement alternatives (i.e., species biology and behavior, structural impediments to migration, and passage improvement alternatives and benefits)
- Migratory corridor overviews and structure profiles that include structure descriptions, mechanisms of structural impediments to migration, site-specific considerations and passage improvement concepts, and site photos
- Identification of known and potential stranding areas in SPFC bypasses
- A barrier prioritization based on relative fish impacts and benefits of passage improvement, using available site information
- FMIO in the Upper Sacramento River, Lower Sacramento River, Feather River, and Upper San Joaquin River Conservation Planning Areas (CPAs)
- Planning guidelines to improve project effectiveness

Information from the FMIO draft report was condensed into this Conservation Strategy appendix. This appendix provides information related to native anadromous fish migration impediments and improvement opportunities at specific locations in the flood system. It also provides best practices to increase the efficiency of project planning and implementation and to increase ecosystem benefits from integrated flood improvement projects. A summary of background information is provided on fish migration, mechanism of structural impediment (the various ways in which structures impede passage), fish straying, and fish stranding. Methods used to identify fish migration impediments (barriers and stranding areas) and to prioritize them for remediation are detailed. Results include specific barrier locations in tabular and map formats. Finally, strategies to reduce fish stranding and planning guidelines are provided. All information contained herein, extensive references, and additional information is available in the FMIO draft report (DWR 2014).

2.0 Background

In this section, background information is summarized to describe and define fish migration, straying, and stranding and to identify how structures physically and behaviorally impede or delay fish passage.

2.1 Fish Migration

Migration is an inherent part of a fish's life history, from young to mature life stages. Fish migrate in search of food, to avoid predators, to avoid lethal environmental conditions, and to find refuge and suitable habitat for reproduction (Gough et al. 2012). They migrate upstream, downstream, and laterally into river floodplains. Longitudinal movement occurs on both a daily and seasonal basis over varying distances. For example, in response to seasonal cues, such as flood pulses, adult salmonids migrate from saltwater or estuarine habitats toward freshwater streams to reproduce. Lateral movement, into floodplains and ephemeral side-channel habitats, also occurs in the active channel and during periods of inundation. These movements may range from short distances (e.g., when fish move from midchannel to littoral areas) to longer distances (e.g., when juvenile fish access an extended floodplain system in search of food and refuge).

Central Valley migratory corridors are used at different times of the year by native anadromous fish species. Species type, life stage, and environmental conditions (e.g., flood pulses, water temperature, food supply, and predator presence), among other factors, determine the timing and duration of migrations and use of freshwater and estuarine habitat for reproduction and rearing (DWR 2014). Water management features that adversely affect migration include those that totally impede upstream or downstream passage, delay fish migration, subject fish to lethal or sublethal conditions (e.g., by causing fish to become stranded in structures), or cause fish to stray into undesirable or dead-end waterways.

2.2 Mechanism of Structural Impediments to Migration

The ability of a fish to pass a structure depends on species physiology and behavior related to site conditions such as hydraulics and structure dimensions. Depending on site conditions, a structure can impede passage through a variety of mechanisms. It may impede upstream migration as a result of structure height, water depth or velocity, site alterations (above or below the structure) affecting channel morphology and habitat structure, attraction flow from undesirable passage routes (e.g., over the dam crest), or lack of attraction flow from fishway entrances. Fishway hydraulics (e.g., shallow water depth, elevated water velocities and turbulence) and design issues or structural deterioration can also create passage inefficiencies through fishways. Passage inefficiencies may allow only a portion of the migrating fish population to effectively pass through the fishway.

Total barriers completely block passage during all flow events for all species. However, many Central Valley structures are considered temporal barriers because they do not allow fish passage of one or more species or life stages under a range of hydrologic conditions. Depending on site conditions, upstream passage at temporal barriers may be delayed for a few days until flow conditions change, or it may be delayed until lethal or sublethal environmental conditions cause significant harm or mortality. Downstream migration can also be blocked or temporally impeded by structure height, structural features that strand or otherwise injure migrating fish, reach-scale alterations that influence passage ability or juvenile survival, and entrainment into unscreened water diversions. In some cases, temporal barriers impede mobility and block access to critical habitat throughout the migration period of targeted species. Passage conditions and species effects may vary temporally and spatially because of watershed hydrology, water diversion amounts and timing, and localized site conditions (e.g., as channel incision, scouring, and sediment deposition occurs).

2.3 Fish Straying

Fish straying is generally discussed in the context of upstream migration of salmonids. Fish straying occurs when salmonids do not return to natal streams or hatcheries to reproduce and instead stray into nonnatal streams. In general, some fish naturally stray and reproduce in nonnatal streams; this behavior is thought to support population distribution and resilience (Quinn 1997). However, straying can also occur because of system operations and provision of attraction flows from waterways that do not provide suitable habitat. In the Central Valley, flows are routed through a complex network of waterways, including river and stream channels, bypasses, water diversions, and irrigation canals or ditches. Attraction flows from multiple waterways can create confusion and attract fish into unsuitable habitat, where they are subjected to lethal or sublethal conditions. Straying can have population-level effects if a significant proportion of the population is not rescued and allowed to reproduce (Hendrick and Swart 2013; Thomas et al. 2013).

2.4 Fish Stranding

Fish stranding is any event in which fish are restricted to detrimental conditions as a consequence of physical separation from a main body of water (Nagrodski et al. 2012). Stranding may occur in natural floodplains or altered floodplains, such as in engineered bypasses, borrow sites, and gravel pits, or in association with water management structures. An unquantified amount of stranding occurs in natural systems, and some evidence suggests that ecosystem benefits result from small incidences of stranding (Nagrodski et al. 2012). However, physical alterations to riverine ecosystems may create stranding conditions that result in adverse population effects (e.g., see Thomas et al. 2013). Stranding in altered riverine ecosystems is frequently associated with downramping of water releases from dams (Golder Associates, Ltd. 2012), and human-made features that trap fish when water levels recede (e.g., gravel pits, borrow sites, and weir stilling basins) (Johnson and Vincik 2012; Thomas et al. 2013). Stranding typically occurs when (1) fish are present when the active channel overflows into seasonally inundated areas; (2) physical features, such as isolated ponds or other topographic depressions, are located in areas that experience seasonal inundation; and (3) surrounding water levels decrease to a point that would physically preclude escape from the location. When these conditions coincide, fish may be stranded and exposed to lethal or sublethal conditions (e.g., low oxygen, high water temperatures, predation, and poaching).

3.0 Methods

This section details the methods used to identify migration impediments, including fish passage barriers and stranding areas.

3.1 Barrier Identification

Barriers are defined as instream, channelwide water management structures that block, delay, or otherwise adversely influence juvenile and adult anadromous fish as they migrate upstream or downstream (i.e., longitudinal migration). Structures that block or delay lateral migration of fish species into non-SPFC-designated floodplains were not covered in this report.[2] The geographic scope of barrier identification was limited to the flood system CPAs and to waterways containing at least one SPFC structure. Within those waterways, all barriers were identified, regardless of ownership, to support regional planning.

To identify structural barriers, data were collected from multiple sources (e.g., literature, memoranda, and ancillary data) and/or during site evaluations to determine whether standard passage criteria were met. If possible, specific mechanisms of impediment were identified at each structure to provide planners in solution and design development with more information.[3] Methods of barrier identification differed slightly for the Sacramento and San Joaquin River Basins because the data available for the two basins differed and because of uncertainty related to the implementation timeline of the San Joaquin River Settlement Agreement and restoration flows.

3.1.1 Sacramento River Basin

The Sacramento River Basin includes the Lower Sacramento River CPA, Upper Sacramento River CPA, and Feather River CPA. In these CPAs, barriers were identified using multiple data sources, including telemetry studies that track fish movement, screw trap data, documented fish rescues, video monitoring, and documented observations of fish stranding. However, additional

[2] Information related to improving lateral connectivity (i.e., floodplain access) and the management actions necessary to provide access is available in Appendices H and I.

[3] Additional information, including waterway overviews, structure descriptions, and improvement considerations/concepts, is provided in DWR (2014). New information was provided to the California Department of Fish and Wildlife for California Fish Passage Assessment Database (PAD) updates. The current PAD version may not reflect this updated information.

technical evaluation (e.g., hydrogeomorphic assessment and hydraulic modeling) is needed at several temporal barriers to determine the range of conditions that impede passage.

3.1.2 San Joaquin River Basin

In the San Joaquin River Basin, specific data related to fish movement and distribution are much more limited than in the Sacramento River Basin. However, the San Joaquin River Restoration Program (SJRRP), initiated in 2006 to reintroduce adult Chinook salmon into the San Joaquin River below Friant Dam, has identified fish passage barriers in the Upper San Joaquin River CPA.[4] Barriers were identified by modeling site hydraulics and evaluating sites using standard species passage criteria. Modeled structures were located in the mainstem San Joaquin River between Friant Dam and the Merced River and in the associated Chowchilla-Mariposa-Eastside flood bypass system. This modeling effort identified barriers to the upstream migration of adult Chinook salmon during a specific range of modeled flows (DWR 2012a). The model flow range for the San Joaquin River was 25–4,500 cubic feet per second (cfs), and for the bypasses was 25–8,500 cfs. The flow range relates to the actual flow at the structure and does not correlate to Friant Dam releases. See DWR (2012a) for a discussion of model limitations and additional details.

3.2 Barrier Prioritization

All identified barriers in the Sacramento River Basin flood system were prioritized, regardless of ownership (or legal SPFC designation), to support decision making. A barrier prioritization method was developed to determine the relative biological significance of barriers in the basin. A detailed explanation of method development and basis is discussed in the FMIO draft report (DWR 2014). This method could not be applied in the San Joaquin River Basin because necessary data were unavailable and because of uncertainty associated with the pathway of SJRRP restoration flows (SJRRP 2012).

3.2.1 Sacramento River Basin

Identified barriers in the Sacramento River Basin were prioritized relative to other structures in each waterway using a score and rank method. Barriers were scored and ranked using several metrics to define the structure's impact on anadromous fish migration and the potential benefit of remediation to those species (i.e., structure impact/benefit prioritization method). These metrics were used to define values relating to impediment frequency, barrier intensity, and upstream habitat. The impediment frequency category represents the frequency at which the structure impedes passage, using waterway hydrological regime and barrier status as metrics. The barrier intensity category represents the structure's intensity of impact on species movement, using the barrier location in the target area and species diversity and presence as metrics. The upstream habitat category represents the quantity and type of habitat that could become more accessible with passage improvements, using miles of upstream waterway and type of upstream habitat as metrics. See the FMIO draft report (DWR 2014) for detailed methods and scoring.

[4] DWR will identify existing barriers and migration concerns for the Lower San Joaquin River CPA in 2014.

3.2.2 San Joaquin River Basin

San Joaquin River Basin barriers were not prioritized in this work effort because data were insufficient and because of uncertainty about future hydrologic operations (e.g., restoration flow path) associated with restoration efforts (U.S. District Court 2006; SJRRP 2012). For example, sections of the San Joaquin River are currently dewatered, although restoration of those flows and habitat improvements are required as part of a settlement agreement that is being implemented through the SJRRP (U.S. District Court 2006).

Flood management planning and efforts to improve fish passage in the Upper San Joaquin River CPA require close coordination with the SJRRP. The SJRRP has developed an internal preliminary barrier prioritization in accordance with expected restoration flow paths and mandated channel and structure improvements (U.S. District Court 2006; DWR 2012a). The SJRRP prioritization method differs from the one used in the Sacramento River Basin in that the SJRRP method involves prioritizing structures according to their presence on the restoration flow path and the severity of passage impediment. All barriers on the restoration flow path require passage improvements, whereas barriers not on the restoration flow path may require special operating procedures to prevent fish from straying into undesirable migratory pathways and becoming stranded. The restoration flow path, which is the target migratory corridor under normal flow conditions, is described in the 2015 *Revised Framework for Implementation* (SJRRP 2015). Channel and structural improvements for fish migration are envisioned to be implemented in five-year increments through 2029.

3.3 Stranding Area Identification

SPFC bypasses in the Sacramento River Basin were evaluated to identify stranding locations. Stranding locations were divided into two categories: known stranding locations and potential stranding locations. Known stranding locations are areas where fish have been observed stranded or carcasses have been recovered. These locations are discovered by resource agency personnel, including DWR and California Department of Fish and Wildlife (CDFW) staff members. These observations usually occur when agency personnel are conducting field surveys in the bypasses after a flood event. CDFW also receives reports from anglers of fish stranded in isolated ponds and reports of poaching at the SPFC weirs (primarily the Fremont and Tisdale Weirs), where fish are trapped in the weir's stilling basin. Fish rescues have also been documented at known stranding locations (DWR 2014). Potential stranding locations were identified by extrapolating the physical characteristics of known stranding locations to areas with similar features (e.g., areas with isolated pools of standing water).

4.0 Results

The results of the barrier identification and prioritization and of the stranding area identification are provided below.

4.1 Barrier Identification and Priorities

Tables 1[5] and 2 identify barriers in the flood system and summarize pertinent information, including the migratory corridor in which each barrier is located, the structure name, the structure type, whether it is part of the SPFC, barrier status, a description of the mechanism of structural impediment, and identifies additional assessment needs or important information. Table 1 also includes the priority of structures for the Sacramento River Basin. Figure 1 identifies barrier locations and priorities for the Sacramento River Basin. Figure 2 identifies barrier locations and barrier status in the Upper San Joaquin River Basin (in lieu of priorities).

4.1.1 Sacramento River Basin

Twenty-six structures were identified as fish passage barriers in the Sacramento River Basin (Table 1, Figure 1) of which fourteen structures were identified as priority barriers. Five priority barriers are located in the Upper Sacramento River CPA, and four priority barriers (8 total structures) are located in the Lower Sacramento River CPA. One priority barrier is located in the Feather River CPA. Twelve structures in the basin were not prioritized for different reasons. The three types of nonprioritized structures are (1) those that are in a CPA but not on waterways with an SPFC structure (these were not profiled in the main FMIO draft report and include Shasta Dam, Keswick Dam, Anderson-Cottonwood Irrigation District Diversion Dam, New Bullards Bar Dam, Englebright Dam, Daguerre Point Dam, Black Butte Dam, Folsom Dam, and Nimbus Dam), (2) those that could not be prioritized because of inadequate information (Big Chico Creek Five-Mile Dam, Sutter Bypass [five structures], and Oroville-Thermalito Complex [three structures]), and (3) those that could not be prioritized because they are not “barriers” as defined by this report but could potentially be operated to improve migration (Knights Landing Outfall Gates and Wallace Weir).

4.1.2 San Joaquin River Basin

Twenty-three structures in the Upper San Joaquin River CPA were identified as either total or temporal fish passage barriers to the migration of adult Chinook salmon during a range of modeled flows (Table 2 footnotes, Figure 2). Three structures in the Upper San Joaquin River CPA were also identified as potential barriers requiring future evaluation. Multiple structural and nonstructural migration impediments exist in the Lower San Joaquin CPA (DWR 2014). However, most of the structural impediments on the lower reaches of San Joaquin River tributaries are owned by local agencies and are not part of the SPFC.

[5] Table 1 is a summary of the information available in structure profiles provided in the FMIO draft report. See DWR (2014) for more information.

A fish migration improvement prioritization of Upper and Lower San Joaquin River CPA structures is not provided for potential flood management projects because of uncertainty associated with implementation of the settlement agreement under the SJRRP. Thus, the SJRRP should be regularly consulted to determine changes in project priority as flood improvement planning progresses. Additional considerations include structure operations and migration conditions under flood conditions. The effect of structure operations during various flood scenarios on fish migration are not currently addressed under the SJRRP and may require future evaluation.

4.2 Identification of Stranding Areas

Stranding areas were identified in the Sacramento River Basin bypasses. Both known and potential stranding areas were outlined in the Yolo, Sacramento, and Tisdale Bypasses. Potential stranding areas were identified in the Colusa Bypass and Butte Basin Overflow Area. See the FMIO draft report, Section 3 and Appendix C (DWR 2014), for location identification.

Identification of potential San Joaquin River Basin stranding areas is forthcoming.

5.0 Fish Migration Improvement Opportunities

FMIO were developed for each identified migration impediment based on the type of passage impediment and the types of solutions that could be implemented to remediate the issue. FMIO categories and descriptions are provided in Table 3. Improvement opportunities at specific locations are identified in Table 4.

To meet CVFPP ecological objectives, integration of the FMIO into flood improvement projects should be considered. The contribution of this integration to ecological objectives (i.e., the significance of benefits) will depend on the type of migration improvement made (e.g., structure removal versus technical fishway construction), site-specific characteristics, proximity to major migratory corridors, and project design.

Table 1. Channel-wide Structures Affecting Fish Migration in the Sacramento River Basin

Migratory Corridor	Structure Name	Structure Type	Part of SPFC?	Barrier Status[a]	Mechanism of Structural Impediment	Priority	Additional Assessment Needs or Update
Lower Sacramento River Conservation Planning Area (Figure 1)							
Yolo Bypass	Lisbon Weir	Rock berm reinforced with sheet piling, flap gates	No	Temporal	At low tide, the downstream water surface elevation can be up to 2.5 feet below the weir crest and impede fish passage for salmon, steelhead, and sturgeon. At high tide, the weir is submerged and may be passable for salmon and steelhead, but it is likely not passable for sturgeon. During large flood events, the weir is passable for sturgeon, salmon, and steelhead.	2	Passage improvement alternatives in the Yolo Bypass are being developed as part of the DWR and U.S. Bureau of Reclamation–led *Yolo Bypass Restoration Project* (DWR and USBR 2012).
	Wallace Weir	Earthen crossing with gated control structure	No	Temporal	When Wallace Weir is breached, fish can enter the Knights Landing Ridge Cut (Ridge Cut) by swimming northwest from the Tule Canal. Because the Ridge Cut connects to the Colusa Basin Drain where fish are stranded, fish passage into the Ridge Cut is undesirable. During the irrigation season, when Wallace Weir is installed and the control structure gates are closed, salmonid and sturgeon passage into the Ridge Cut is blocked. During high-flow conditions, Wallace Weir is washed out and becomes passable. When flood flows recede, the timing of when Wallace Weir is breached or installed is highly dependent on irrigation demands and operations at the Knights Landing Outfall Gates, located 40 miles upstream.	–	
	Tule Canal Crossings (five structures)	Earthen crossings, some with culverts	No	Temporal	Five agricultural crossings can impede fish passage or trap fish in the Tule Canal during low flows. During large flood events, the crossings are usually washed out and become passable. The crossings are reconstructed postflood, and exact crossing configuration (e.g., number/size of culverts, road width) varies. The northernmost crossing does not contain culverts and is impassable except during large flood events.	2	
	Fremont Weir	Passive concrete weir	Yes	Temporal	Inflow over Fremont Weir, from the Sacramento Bypass and from westside tributaries, can attract salmon, steelhead, and sturgeon from the Delta into the Yolo Bypass via the toe drain. The existing fish ladder at Fremont Weir is highly inefficient at passing salmonids and does not pass sturgeon. Following flood events, anadromous fish are commonly found trapped in the weir's stilling basin and in isolated pools downstream of the weir in the Yolo Bypass.	1	

Table 1. Channel-wide Structures Affecting Fish Migration in the Sacramento River Basin

Migratory Corridor	Structure Name	Structure Type	Part of SPFC?	Barrier Status[a]	Mechanism of Structural Impediment	Priority	Additional Assessment Needs or Update
Cache Creek	Cache Creek Settling Basin Weir	Roller-compacted concrete weir	Yes	Temporal	The Cache Creek Settling Basin Weir is not passable, except potentially during extreme high-water events when floodwaters in the Yolo Bypass are highly elevated. Passage through the outlet structure culvert may be possible during some low-flow conditions but should be evaluated.	_	Determine feasibility and need for passage improvement.
Sacramento Bypass	Sacramento Weir	Manually operated weir	Yes	Temporal	When Sacramento River stage at the I Street Bridge is greater than or equal to 27.5 feet National Geodetic Vertical Datum, the Sacramento Weir gates are manually opened to allow floodwater to spill into the Sacramento Bypass, which feeds into the toe drain of the Yolo Bypass. During these events, fish may enter the Sacramento Bypass from two directions: (1) from the Sacramento River, by flushing through the open weir gates, or (2) from the Yolo Bypass, attracted by flows coming from the Sacramento Bypass. Many fish have been found trapped at the weir and in the Sacramento Bypass when flows recede. When the gates are not open, water leaking through the weir gates may also attract fish into the Sacramento Bypass from the Yolo Bypass. Stranding has been documented in the weir's stilling basin and in isolated ponds in the bypass.	1	Identify (1) passage alternatives aligned with flood management goals, (2) feasibility of low-flow channel connectivity, and (3) strategies to reduce stranding.
Feather River Conservation Planning Area (Figure 1)							
Feather River (Lower)	Sunset Pumps Diversion Dam	Rock diversion dam	No	Temporal	Video monitoring suggests that green sturgeon migration is impeded at the Sunset Pumps Diversion Dam at flows less than 6,000 cfs, although it is expected that there is a flow range that enables passage below 6,000 cfs. A recent acoustic telemetry study suggests that the upstream passage of spring-run Chinook salmon is impeded at the Sunset Pumps Diversion Dam during flow conditions less than 930 cfs. Study results show that the survival rates of juvenile salmon and steelhead could also be adversely affected by the Sunset Pumps Diversion Dam.	1	Determine (1) structure operations and (2) passage alternatives that improve overall habitat connectivity.
	Oroville-Thermalito Complex (three structures)	Various	Yes	Total	The three channel-wide structures (Fish Barrier Dam, Thermalito Diversion Dam, Oroville Dam) in the Oroville-Thermalito Complex are total barriers to fish passage, ranging from 91 to 770 feet in height. Collectively, they block access to the upper Feather River watershed.	_	Passage is not being pursued based on the Oroville Dam FERC relicensing

Table 1. Channel-wide Structures Affecting Fish Migration in the Sacramento River Basin

Migratory Corridor	Structure Name	Structure Type	Part of SPFC?	Barrier Status[a]	Mechanism of Structural Impediment	Priority	Additional Assessment Needs or Update
							Settlement Agreement.
Upper Sacramento River Conservation Planning Area (Figure 1)							
Sycamore Slough and Colusa Basin Drainage Canal	Knights Landing (or Sycamore Slough) Outfall Gates	Flood control and drainage structure with 10 control gates	Yes	Unknown	This structure reduces flood risk to the lower Colusa Basin from Sacramento River backwater during flood events, but it provides drainage from the Colusa Basin to the Sacramento River during low flow. When it provides drainage (of water originally diverted from the Upper Sacramento River), spring- and winter-run Chinook salmon in the Sacramento River, migrating to spawn in the Upper Sacramento River, are potentially attracted into the slough. These fish attempt to pass through the gates into the Colusa Basin Drain, which leads to a dead-end network of water control structures, diversion pumps, and agriculture drainage ditches. Under specific hydrologic conditions, passage is possible through the gates. An additional pathway to the Colusa Basin Drain is through the Yolo Bypass and Knights Landing Ridge Cut. In May 2013, 300 spring- and winter-run Chinook salmon were rescued from the Colusa Basin Drain. Additional fish were not rescued. An incident of such magnitude threatens the genetic integrity of the various runs and poses a serious risk to species viability.	_	Efforts are underway to identify the pathway of fish entrance at Knights Landing Outfall Gates versus the Knights Landing Ridge Cut, and to develop short- and long-term solutions, including operational adjustments at Knights Landing Outfall Gates
Sutter Bypass: both canals	Multiple (five) structures	Various	No	Partial	The East and West (Barrow) Canals of the Sutter Bypass contain multiple channel-wide structures (see Figure 1) where passage improvements (e.g., the construction of fish ladders) have been made within the last two decades. However, the fish ladders were designed for passage of salmonids and remain barriers to green sturgeon. The Sutter Bypass is designated by NOAA Fisheries as critical habitat for green sturgeon.	_	Determine habitat suitability for green sturgeon in Sutter Bypass during normal flows.
Sutter Bypass: West Canal	Weir No. 1 (Parks Weir)	Fixed concrete weir with vertical slot fishway	No	Temporal, Partial	This inefficient fishway does not meet standard passage criteria for salmonids at low-flow conditions, is a barrier to sturgeon, and is no longer necessary for the USFWS-constructed purpose. During low-flow conditions, the head differential between fishway pools is greater than the 1-foot passage height standard. Adult spring-run Chinook salmon were trapped	1	Identify (1) flow conditions when fish kills occur and (2) feasibility and benefits of structure removal.

Table 1. Channel-wide Structures Affecting Fish Migration in the Sacramento River Basin

Migratory Corridor	Structure Name	Structure Type	Part of SPFC?	Barrier Status[a]	Mechanism of Structural Impediment	Priority	Additional Assessment Needs or Update
					at the site, and their carcasses recovered, in May 2012 and 2013.		
Tisdale Bypass	Tisdale Weir	Passive concrete weir	Yes	Temporal	Recurring fish rescues are conducted at this site to rescue juvenile and adult salmon, steelhead, and sturgeon from the weir's stilling basin. While trapped in the stilling basin, fish are subject to lethal and sublethal conditions; their survival is dependent upon a timely CDFW fish rescue (i.e., removal and release). Site conditions, including structure height, make it a barrier during most flood events. During extremely large flood events, passage may be possible for a period if the weir is backwatered from the Sutter Bypass. No fishway is provided at the site. This weir overflows the most frequently of the SPFC passive weirs. Potential stranding areas exist in the bypass but need further assessment.	1	Identify (1) passage alternatives aligned with flood management goals, (2) feasibility of low-flow channel connectivity, and (3) strategies to reduce stranding.
Butte Basin Overflow Area	Moulton Weir	Passive concrete weir	Yes	Temporal	Juvenile steelhead have been observed trapped in the stilling basin at this weir. No fish passage channel or ladder is provided. This weir overflows the least frequently of the SPFC passive weirs. Potential stranding areas exist in the bypass but need further assessment.	2	Monitoring is needed to determine significance.
Big Chico Creek (Lower)	One-Mile Dam and Sycamore Pool	Operable dam with pool and chute fishway, concrete pool	No	Temporal	The existing fish ladder at One-Mile Dam (located at the downstream end of Sycamore Pool) does not meet standard fish passage criteria. During low-flow conditions, the water surface drop height between baffles is greater than the 1-foot passage height standard. Velocity thresholds may also be exceeded. During a site visit, multiple resident trout were seen holding in the pool downstream of the dam. No passage attempts were observed. During periods when One-Mile Dam is not raised to backwater the city pool (located within the stream channel, constructed for city recreation purposes), the upstream end of the pool can develop high-gradient, high-velocity, shallow sheet flow, which could affect adult migration. The pool itself is not stated to be a SPFC facility, but the Big Chico Creek channel containing the pool is part of the SPFC.	1	Identify operational adjustments or modifications needed to improve passage. Passage conditions at the upstream end of the pool also need to be evaluated.
	Big Chico Flood Control	Concrete dam with four gate-	Yes	Potential	The Big Chico Creek Gates structure, or Five-Mile Dam, at the upper end of the SPFC, is a box culvert structure that limits flow down Big Chico Creek during moderate- and high-flow	_	Determine (1) frequency and typical duration of

Table 1. Channel-wide Structures Affecting Fish Migration in the Sacramento River Basin

Migratory Corridor	Structure Name	Structure Type	Part of SPFC?	Barrier Status[a]	Mechanism of Structural Impediment	Priority	Additional Assessment Needs or Update
	Structure (Five-Mile Dam)	controlled box culverts			events. This structure allows flow to be diverted into Lindo Channel and Sycamore Bypass (channel divergence is just upstream of Five-Mile Dam). During periods of moderate and high flows, the culverts are inundated and may create a pressure gradient, with velocities that may be too high for upstream fish passage. Detailed assessment is needed to determine the conditions under which the structure potentially impedes passage.		passage delays and (2) effect of flow proportion in Big Chico Creek and Lindo Channel on selection of main migration route.
Lindo Channel	Lindo Channel Flood Control Structure	Concrete dam with seven gate-controlled box culverts	Yes	Total	Lindo Channel is an intermittent stream activated by moderate and high flows from Big Chico Creek. The Lindo Channel Flood Control Structure is located at the upper end of Lindo Channel. The structure can be operated to limit flow down Lindo Channel and divert water into the Sycamore Diversion Channel. Grouted riprap was placed downstream of the structure to limit scour at the site and provide a low-flow passage channel. The passage channel has deteriorated, and large cracks have developed in the grout, creating a sieve through which water strains at low flows. At high flows, high-velocity and turbulent hydraulic conditions are created by the steep gradient and pressure flow through the box culverts, creating a barrier. In addition, stranding of 2,334 natural-run salmon was documented in isolated pools throughout Lindo Channel in the fall of a low-water year.	2	Determine (1) flow range that allows passage, if any; (2) fishway alternatives; and (3) channel stranding impacts and strategies to reduce stranding.

Key: CDFW = California Department of Fish and Wildlife; cfs = cubic feet per second; DWR = California Department of Water Resources; FERC = Federal Energy Regulatory Commission; NOAA = National Oceanic Atmospheric and Administration; SPFC = State Plan of Flood Control; USFWS = U.S. Fish and Wildlife Service.

Notes:

[a] Barrier Status Definitions: Total = Impassable (downstream and upstream) to all fish at all flows; Partial = Impassable to some fish species during part or all life stages at all flows (dependent on species biological characteristics); Temporal = Impassable to all fish at certain flow conditions (dependent on flow conditions). Unknown = Additional assessment is needed.

– = Nonprioritized structure.

Table 2. Channel-wide Structures Affecting Fish Migration in the Upper San Joaquin River Conservation Planning Area

Migratory Corridor	Structure Name	Structure Type	Part of SPFC?	Barrier Status[a]	Mechanism of Structural Impediment	Additional Assessment Needs or Notes
Upper San Joaquin Conservation Planning Area (Figure 2)						
San Joaquin River	Beaver dams	Natural	No	Partial	Several beaver dams in the San Luis Wildlife Refuge have potential to impede passage at various flows. However, no studies have shown that beaver dams have a detrimental population-level effect on salmonids (Pollock et al 2003).	An in-depth review of the ecological benefits of beaver dams and potential delays to migration at each site should be conducted before management action in the project area.
	Farm road crossings (three structures)	Crossing	No	Potential	Access is restricted, and barrier evaluations have not been completed (as of 2013).	Modifications to structures for fish passage in this reach of the San Joaquin River depend on whether restoration flows are routed through the reach.
	San Joaquin River headgates	Control	Yes	Total	The structure is located at the confluence of the San Joaquin River and the Sand Slough Connector. The gates are not operational and completely block passage on the San Joaquin River. All flow from the San Joaquin River is directed down the Sand Slough Connector (through the Sand Slough Control Structure) to the Eastside Bypass. However, restoration flows of up to 4,500 cfs in this reach are being planned by the SJRRP depending on the site-specific project alternative. Modifications at the headgates and Sand Slough Control Structure are needed to enable routing of restoration flows into the San Joaquin River (Reach 4B) (U.S. District Court 2006). The structure is also referred to as the “Reach 4B Headgates” by the SJRRP.	The Sand Slough Control Structure was evaluated when stop logs were not in place and was determined not to be a barrier. Modifications at both structures should be considered simultaneously. This structure is part of a larger SJRRP project alternative, and modifications will be required if restoration flows are routed into Reach 4B.
	Sack Dam	Dam	No	Partial	Flows are diverted from the San Joaquin River into the Arroyo Canal, which is located just upstream of Sack Dam. The diversion dam is a concrete structure with wooden flap gates. The current fish ladder does not meet passage criteria.	USBR has completed the final environmental assessment/initial study for fish passage modification. Proposed designs target salmonid and sturgeon passage.
	Mendota Dam	Dam	No	Total	Mendota Dam distributes water deliveries from the Delta-Mendota Canal into several canals that connect to the Mendota Pool upstream of the dam and downstream into the San Joaquin River for deliveries to the Arroyo Canal. The	USBR is conducting a study to determine passage modifications.

Table 2. Channel-wide Structures Affecting Fish Migration in the Upper San Joaquin River Conservation Planning Area

Migratory Corridor	Structure Name	Structure Type	Part of SPFC?	Barrier Status[a]	Mechanism of Structural Impediment	Additional Assessment Needs or Notes
					Mendota Pool elevation is controlled by stop logs that are inserted into the dam during deliveries. The current fish ladder does not meet passage criteria.	
	San Joaquin River Control Structure	Control	Yes	Partial	The San Joaquin River and Chowchilla Bypass Control Structures manage the division of San Joaquin River flow into the bypass system. The San Joaquin River Control Structure contains four radial gates that are operated primarily during flood flows to divert water into the Chowchilla Bypass. Gate operations that close the gates block fish passage, and the structure's trash rack can potentially impede passage.	Dependencies between the San Joaquin River and Chowchilla Bypass Control Structures should be considered simultaneously in development of passage improvement alternatives.
	Donny Bridge	Crossing	No	Partial	The bridge foundation, which does not extend across the entire width of the channel, constricts flow. Thus, water velocities may exceed passage criteria at a range of flows until the bridge is overtopped. Flows that overtop the bridge may also present a passage impediment; however, future data collection and model refinement are required to make this determination.	Requires evaluation at flows greater than 2,500 cfs.
	Lost Lake Rock Weir #1 (Lower)	Miscellaneous	No	Partial	The structure is a human-made rock weir located downstream of Friant Dam in Lost Lake Park. Passage may be impeded at the site at flows of less than 900 cfs. Passage using jumping capabilities may be possible between 100 and 900 cfs. A one-dimensional hydraulic model was used to assess passage, but the model could be calibrated only when the weir was overtopped.	Requires further monitoring for model refinement. Two-dimensional modeling may be needed. Evaluation during lower flows is needed for model calibration.
Mariposa Bypass	Mariposa Bypass Control Structure	Control	Yes	Total	The Mariposa Bypass Control Structure is located just upstream from the Eastside Bypass Control Structure, at the head of the Mariposa Bypass. The structure was modeled assuming that gates are closed and that only the bays without gates have flow. Passage criteria were not met within the modeled flow range. Passage conditions were not evaluated when the gates are partially open and may be needed depending on structure operations.	Dependencies between the Eastside Bypass and Mariposa Bypass Control Structures should be considered simultaneously in development of passage improvement alternatives.
	Mariposa Bypass Drop Structure	Control	Yes	Total	The structure is located in the Mariposa Bypass, at the confluence of the Mariposa Bypass and the San Joaquin River. The weir prevents fish migration from the San Joaquin River into the Mariposa Bypass. Attraction flows to the Mariposa Bypass are present during flood events when flows	The Mariposa Bypass is part of a SJRRP project alternative and may have restoration flows if that alternative is selected. In that case, structures in the

Table 2. Channel-wide Structures Affecting Fish Migration in the Upper San Joaquin River Conservation Planning Area

Migratory Corridor	Structure Name	Structure Type	Part of SPFC?	Barrier Status[a]	Mechanism of Structural Impediment	Additional Assessment Needs or Notes
					are routed into the Mariposa Bypass from the Eastside Bypass.	Mariposa Bypass would require modification or replacement.
Eastside Bypass	Eastside Bypass Rock Weir	Weir	Yes	Partial	The structure is composed primarily of large concrete rubble. Passage is impeded, and there is potential for stranding at flows of less than 200 cfs. The passage impediment is related to debris that appears to be in place for maintaining a certain water surface elevation for operation of equipment.	
	Eastside Bypass Control Structure	Control	Yes	Partial	The Eastside Bypass Control Structure is located on the Eastside Bypass, just downstream of the Mariposa Bypass Control Structure. Passage is impeded below 700 cfs under a gates-fully-open scenario and when stop logs are in place (boards-in) at the structure's inlet, which is the current condition. Gate closure would cause this structure to be a total barrier. Further evaluation is required when the gates are being operated to ensure that the depth and velocities do not exceed passage criteria.	Dependencies between the Eastside Bypass and Mariposa Bypass Control Structures should be considered simultaneously in development of passage improvement alternatives. Information on gate operations and further evaluation are needed to determine impediment frequency.
	Dan McNamara Road Crossing	Crossing	No	Partial	This low-flow crossing is located upstream of the Eastside Bypass bifurcation structures. Crossing hydraulics are affected by a boards-in scenario at the Eastside Bypass and would be affected by gate closure. Depth constraints at the site may impede passage at flows of less than 600 cfs. The existing culvert impedes passage, and stranding on the road is a major concern at this location.	This is part of a SJRRP project alternative, and concepts for passage are being considered for implementation.
	Merced Refuge Weir #1 (Lower)	Weir	No	Partial	The Merced Refuge weirs are located on the Eastside Bypass in the Merced National Wildlife Refuge. This weir is located downstream the Merced Refuge Weir #2. The weir, when operated with boards in place, allows the refuge to divert Eastside Bypass flows into the Merced National Wildlife Refuge for irrigation. Merced Refuge Weir # 1 appears to impede passage at flows of less than 3,000 cfs during the migration period when boards are in. Boards typically are removed during flood flows.	When boards are out, there is risk of injury to fish that attempt passage by jumping at flows less than 100 cfs. The weirs are operated by U.S. Fish and Wildlife Service employees.
	Merced Refuge Weir #2 (Upper)	Weir	No	Partial	The Merced Refuge weirs are located on the Eastside Bypass in the Merced National Wildlife Refuge. This weir is located upstream of the Merced Refuge Weir #1. The weir,	Currently, this weir would be completely submerged when boards are in at the Lower

Table 2. Channel-wide Structures Affecting Fish Migration in the Upper San Joaquin River Conservation Planning Area

Migratory Corridor	Structure Name	Structure Type	Part of SPFC?	Barrier Status[a]	Mechanism of Structural Impediment	Additional Assessment Needs or Notes
					when operated with boards in place, allows the refuge to divert Eastside Bypass flows into the Merced National Wildlife Refuge for irrigation. Merced Refuge Weir # 2 exceeds passage criteria at flows less than 700 cfs when boards are in. Boards typically are removed during flood flows.	Merced Refuge Weir and would become unimpeded. In addition, passage is unimpeded when stop logs are removed.
	Avenue 21 County Bridge	Crossing	No	Total	The Avenue 21 county bridge is located on the Eastside Bypass in Madera County. This area of the Eastside Bypass is subject to subsidence. As a result, the channel is incised downstream from the bridge because of a headcut. Repairs to the channel have been completed by adding a support wall downstream from the bridge and a significant amount of riprap at the headcut and under the bridge to prevent erosion. This results in an approximately 10-foot difference in channel elevation under the bridge to the channel downstream. The bridge does not span the entire channel, so velocities may impede passage at high flows, which may be the typical hydrologic condition because the bypass is activated during floods.	Modifications for fish passage to the structure would need to consider the long-term effects of subsidence.
	Avenue 18-1/2 County Bridge	Crossing	No	Partial	The Avenue 18-1/2 county bridge is located on the Eastside Bypass in Madera County. This area of the Eastside Bypass is subject to subsidence. As a result, the channel is incised downstream from the bridge because of a headcut. Repairs to the channel have been completed by adding a support wall downstream from the bridge and a significant amount of riprap at the headcut and under the bridge to prevent erosion. This results in a nearly 15-foot difference in channel elevation under the bridge to the channel downstream. The bridge does not span the entire channel, so velocities may impede passage at high flows, which may be the typical hydrologic condition because the bypass is activated during floods.	Modifications for fish passage to the structure would need to consider the long-term effects of subsidence.
	Pipeline Crossing	Crossing	No	Partial	The pipeline crossing is located on the Eastside Bypass just upstream from the confluence with Ash Slough. It is assumed that the pipe is used to deliver irrigation (ditch water) for agricultural use based on the presence of gated structures located east and west of the bypass levees, and that it is in line with the pipe that feeds the irrigation canals. The circular concrete pipe is exposed with riprap at the base, and it extends the width of the low-flow channel. The pipe is raised	

Table 2. Channel-wide Structures Affecting Fish Migration in the Upper San Joaquin River Conservation Planning Area

Migratory Corridor	Structure Name	Structure Type	Part of SPFC?	Barrier Status[a]	Mechanism of Structural Impediment	Additional Assessment Needs or Notes
					on fill and riprap that is approximately 7 feet higher than the average channel bed elevation. A fish in good condition is assumed to be able to jump the structure at flows greater than 1,300 cfs.	
	Eastside Bypass Drop 2 (Upper)	Drop structure	Yes	Total	The drop structure is located on the Eastside Bypass, upstream of the confluence with the Fresno River. The weir is a concrete structure with an earthen levee that extends to connect to the bypass levees with the structure, so the weir cannot be bypassed. A hydraulic jump of more than 1 foot is present at the structure throughout the range of flood flows that are typical when the bypass is in operation. In addition, high water velocities may prevent passage after the weir is overtopped.	Dependencies between Eastside Bypass Drop Structures 1 and 2 should be considered simultaneously in development of passage improvement alternatives.
	Eastside Bypass Drop 1 (Lower)	Drop structure	Yes	Partial	The drop structure is located on the Eastside Bypass, downstream of the confluence with the Fresno River. The weir is a concrete structure with an earthen levee that extends to connect to the bypass levees with the structure, so the weir cannot be bypassed. A fish in good condition is able to pass when flows are greater than 800 cfs by jumping. Fish should be able to swim over the weir after flows are approximately 3,000 cfs.	Dependencies between Eastside Bypass Drop Structures 1 and 2 should be considered simultaneously in development of passage improvement alternatives.
Chowchilla Bypass	Chowchilla Bypass Control Structure	Diversion	Yes	Partial	The San Joaquin River and Chowchilla Bypass Control Structures are located at the junction of the San Joaquin River and Chowchilla Bypass. These two structures manage the division of San Joaquin River flow into the bypass system. Flows into the Chowchilla Bypass are controlled by the four radial gates of the Chowchilla Bypass Control Structure. Gate operations can potentially impede passage.	Dependencies between the San Joaquin River and Chowchilla Bypass Control Structures should be considered simultaneously in development of passage improvement alternatives.

Key: cfs = cubic feet per second; SJRRP = San Joaquin River Restoration Program; SPFC = State Plan of Flood Control; USBR = U.S. Bureau of Reclamation.

Notes:

[a] Barrier Status (within the modeled flow ranges for San Joaquin River modeled flow: 25–4,500 cfs; and for Chowchilla/Mariposa/Eastside Bypasses modeled flow: 25–8,500 cfs): Total = Impassable to the upstream migration of adult Chinook salmon during modeled flow range. Partial = Impassable to the upstream migration of adult Chinook salmon during a range of modeled flow. Potential = Unknown passage status

See DWR (2012a) for specific unimpeded flow ranges.

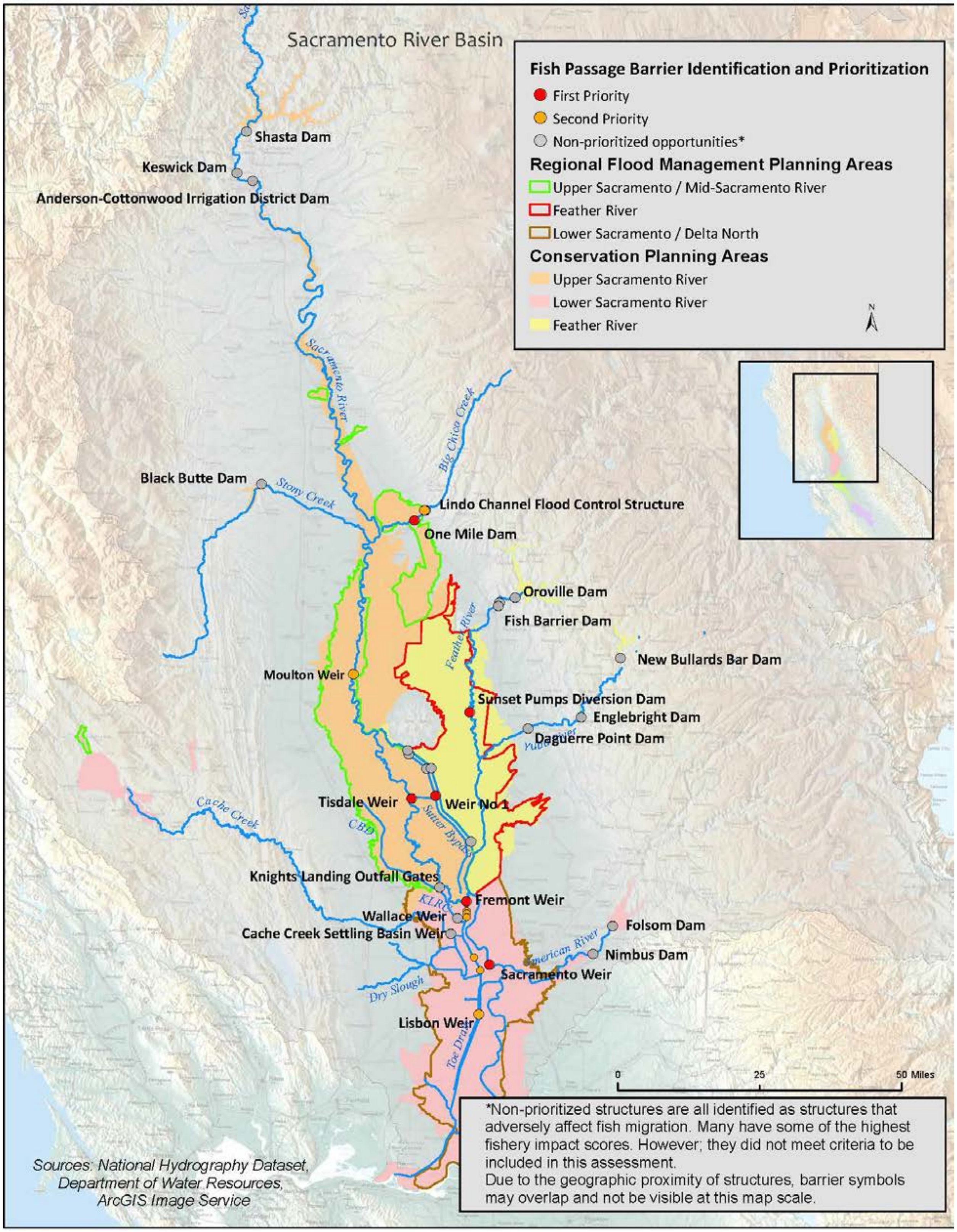

Figure 1. Sacramento River Basin Barrier Identification and Priority

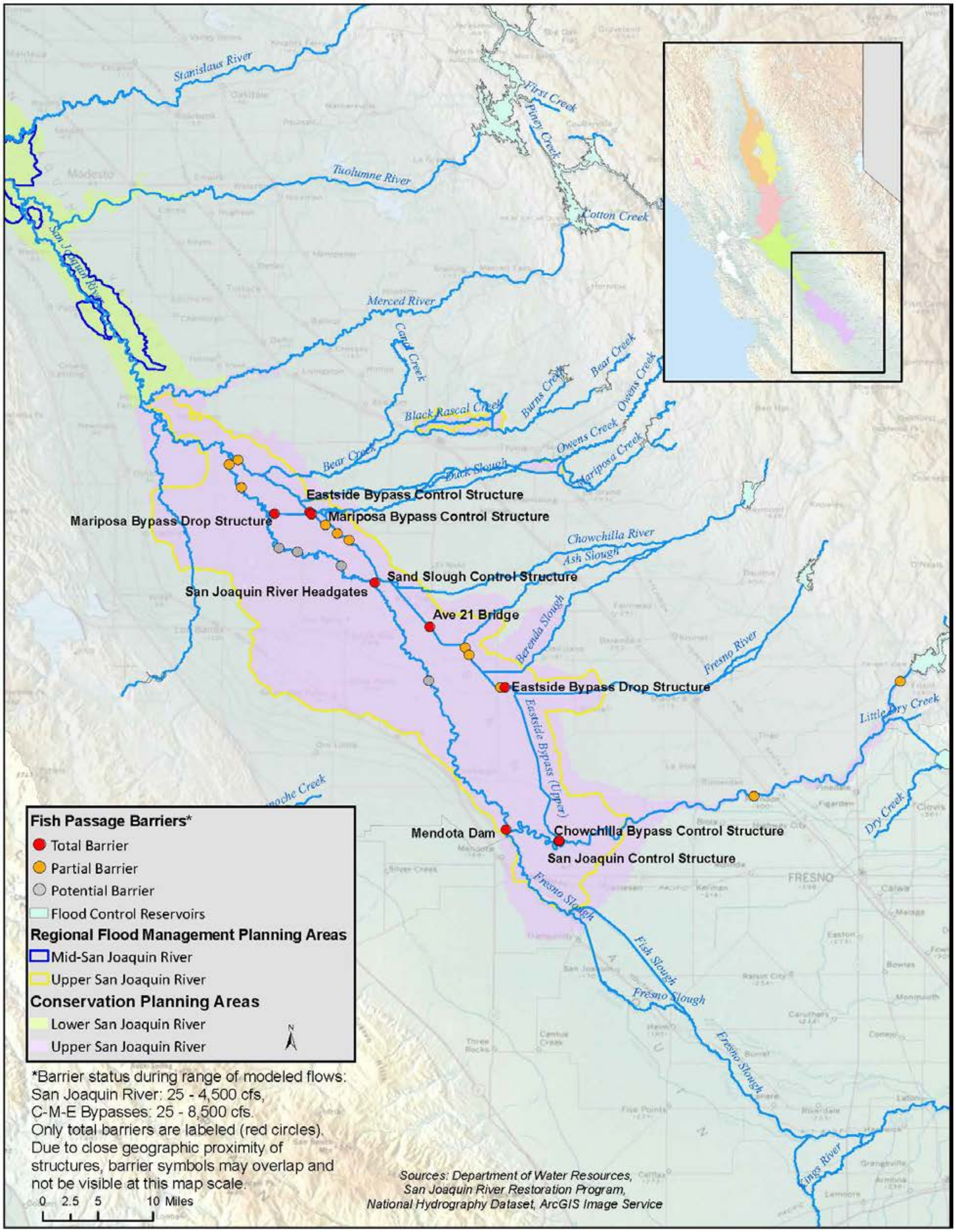

Figure 2. Upper San Joaquin River Conservation Planning Area Barrier Identification

Table 3. Fish Migration Improvement Opportunities Category Key

Category Number	Category Description
1	Provide access to suitable areas that benefit fish seasonally along migratory corridors (e.g., floodplains) and ensure that fish have an outlet back to a suitable migration route.
2	Eliminate access to structural features or areas where fish will be injured or die (see 2a–2c).
2a	Modify structures to eliminate engineered features that trap fish by improving aquatic connectivity.
2b	Create barriers or operate existing structures to keep fish from straying into dead-end canals, toward pumps, or into other types of detrimental environments (applicable to areas that are not considered suitable migratory routes or that lead to unsuitable areas).
2c	Implement strategies to reduce fish stranding in project construction, operation, and maintenance.
3	Provide efficient passage at structures in identified migration corridors that would otherwise block fish access to upstream or downstream habitat. This can be accomplished by removing or modifying structures, installing a seminatural fishway (e.g., a rock ramp or bypass channel), or constructing a more technical fishway (e.g., fish ladders). In all cases, downstream passage at the structure should be considered and optimized to reduce or eliminate the effect of the structure on juvenile or adult emigration.

Table 4. Fish Migration Improvement Opportunities at Specific Locations

Migration Corridor (Waterway)	Structures	Relative Priority	FMIO Category (see Table 3)
Lower Sacramento River Conservation Planning Area			
Yolo Bypass	Lisbon Weir	2	3
	Yolo Bypass Road Crossings (5)	2	3
	Wallace Weir	–	2b
	Fremont Weir*	1	1, 2a, 2b, 3
Cache Creek	Cache Creek Settling Basin Weir	–	3
Sacramento Bypass	Sacramento Weir*	1	1, 2a, 2b, 3
Feather River Conservation Planning Area			
Lower Feather River	Sunset Pumps Diversion Dam	1	3
	Oroville-Thermalito Complex (3)	–	3
Upper Sacramento River Conservation Planning Area			
Colusa Basin Drain Canal	Knights Landing Outfall Gates	–	2b
Sutter Bypass	Multiple (5) structures	*–	3
	Weir No. 1	1	3
Tisdale Bypass	Tisdale Weir*	1	1, 2a, 2b, 3
Butte Basin Overflow Area	Moulton Weir*	2	2a, 3
Big Chico Creek (lower)*	One-Mile Dam	1	3
	Big Chico Creek Flood Control Structure (Five-Mile Dam)	**–	–
Lindo Channel*	Lindo Channel Flood Control Structure	2	3

Table 4. Fish Migration Improvement Opportunities at Specific Locations

Migration Corridor (Waterway)	Structures	Relative Priority	FMIO Category (see Table 3)
Lower San Joaquin River Conservation Planning Area			
Comprehensive evaluation was not performed in all canals and waterways connecting the San Joaquin River to the Delta, although Categories 1–2c apply to BWFS-proposed Paradise Cut configurations and proposed system improvements in additional Lower San Joaquin River CPA locations.			
Upper San Joaquin River Conservation Planning Area			
San Joaquin River	Beaver dams	–	**
	Farm road crossings (3)	–	**
	San Joaquin River Headgates	–	3
	Sack Dam	–	2b, 3
	Mendota Dam	–	2b, 3
	San Joaquin River Control Structure	–	3
	Donny Bridge	–	3
	Lost Lake Rock Weir #1 (Lower)	–	3
Mariposa Bypass	Mariposa Bypass Control Structure	–	2b or 3
	Mariposa Bypass Drop Structure	–	2b or 3
Eastside Bypass	Eastside Bypass Rock Weir	–	2a, 2c, 3
	Eastside Bypass Control Structure	–	3
	Dan McNamara Road Crossing	–	2c, 3
	Merced Refuge Weir #1 (Lower)	–	1 or 2b, 3
	Merced Refuge Weir #2 (Upper)	–	1 or 2b, 3
	Avenue 21 County Bridge	–	3
	Avenue 18-1/2 County Bridge	–	3
	Pipeline Crossing	–	3
	Eastside Bypass Drop 2 (Upper)	–	3
	Eastside Bypass Drop 1 (Lower)	–	3

Key: BWFS = Basin-Wide Feasibility Study; CPA = conservation planning area; FERC = Federal Energy Regulatory Commission; FMIO = Fish Migration Improvement Opportunities; SPFC = State Plan of Flood Control.

Notes:

– = Not prioritized. For the Thermalito-Oroville Complex, in relation to the Oroville Dam FERC relicensing, a Habitat Expansion Agreement was signed in lieu of providing passage to the upper Feather River watershed for 50 years (DWR and PG&E 2010). Regarding the Knights Landing Outfall Gates and Wallace Weir, the prioritization method was limited to structures that adversely affect passage by impeding access; however, the Knights Landing Outfall Gates structure and Wallace Weir could potentially be operated to reduce straying into the Colusa Basin Drain. Therefore, they could not be prioritized using this method, although the stranding issue in the Colusa Basin Drain is significant. The San Joaquin River structures are not prioritized for the purposes of the Conservation Strategy but may be able to be prioritized in coordination with the San Joaquin River Restoration Program, dependent on the preferred alternative and chosen restoration flow path.

* SPFC weirs were ranked relative to each other in each CPA except the Fremont Weir because of multiple structures downstream of Fremont Weir in the Tule Canal (see FMIO draft report, Appendix D). The Lindo Channel Flood Control structure was ranked relative to Big Chico Creek structures because Lindo Channel is an associated bypass route.

** = Not enough available information.

6.0 Recommendations and Planning Guidelines

Collectively, the information presented in this synthesis report can be used to reduce the effects of proposed flood risk management projects, current projects, and system operations and maintenance on targeted anadromous fish species. Planning guidelines can be used to efficiently integrate FMIO into flood improvement projects.

6.1 Strategies to Reduce Fish Stranding

Strategies to reduce fish stranding with potential feasibility in SPFC bypasses could be integrated into floodway expansion planning and ongoing maintenance activities (e.g., sediment removal) (Table 3, Category 2c). Before implementation, these strategies should be evaluated in the context of flood conveyance requirements, site-specific feasibility, and impacts on potentially beneficial habitat. Strategies to reduce stranding include the following:

- **Provide Fish Passage at SPFC Weirs**. Provide a fishway at each weir to reduce stranding incidence downstream of the weir by providing volitional passage. Fish are rescued periodically from several SPFC weir stilling basins. It is possible for fish to enter stilling basins by swimming over the weir or by swimming upstream to the weir as a result of attraction flows coming from the bypass.

- **Manipulate Topography to Improve Drainage**. Contour topography during sediment removal activities or bypass expansion to improve drainage from the bypasses into perennial low-flow channels (e.g., toe drains) situated parallel to the bypasses. Evaluate whether stranding areas provide ecological benefits (e.g., floodplain meadows) that outweigh the adverse effects of stranding events before manipulating habitat.

- **Construct and Maintain Bypass Low-Flow Channel Connectivity**. Extend low-flow channels to parallel the length of the bypass and connect to perennial channels. Maintain the connectivity of low-flow channels by removing deposited sediments and maintaining functional connectivity below road crossings, as needed.

- **Rescue Fish**. Potential fish-stranding areas should be monitored, and interim fish rescues may need to be conducted at stranding locations until sustainable solutions are implemented.

- **Prevent Access**. Where necessary, create physical or behavioral barriers at canal intakes to keep fish from straying into undesirable areas and becoming stranded. At some locations, water diversions or releases could be timed to avoid peak periods of juvenile emigration or adult immigration. Timing diversions or releases may reduce entrainment potential or attraction flows.

6.2 Passage Improvement Planning Guidelines

The success of passage improvement projects is critically dependent upon consideration of landscape and local physical and ecological processes, passage and habitat requirements of targeted species in various life stages, migration beginning and end points, attraction flows affecting migratory route selection and migration delays, sound technical analyses, and a design process that involves quality checks and interdisciplinary expertise. The following guidelines were developed based on a synthesis of literature and can be used to improve decision making and guide passage improvement planning:

- Set quantitative passage efficiency goals for each passage improvement project, considering the site location in the river network (e.g., spatial proximity to habitat, cumulative effects of multiple barriers and fishways on bioenergetic cost), landscape and reach-scale processes that could affect fishway efficiency, the spatial relationship of the barrier to other structural impediments and adjacent habitat types, and the multidirectional (upstream and downstream) migration and habitat needs of multiple species. Monitor to determine whether goals are met.

- Identify external factors affecting project selection and prioritization (e.g., infrastructure improvements, impacts on flood risk/conveyance, actions to improve overall ecosystem functioning of a waterway, and others). Determine feasibility based on species biological requirements and habitat needs, planned infrastructure improvements at the site, structure purpose, existing use, and flood system constraints.

- Target optimal upstream and downstream passage at each barrier for all native anadromous species by considering natural, seminatural, and technical migration improvement alternatives in subsequent order (see DWR 2014 for a description of these). At a minimum, all improvements should provide volitional passage, eliminate the potential for fish to be trapped, and reduce management response (e.g., fish rescues, maintenance). Fishways are preferred that require less maintenance and allow transport of material and a wide range of aquatic organisms (see DWR 2014, Table 2.4.4).

- In cost-benefit analyses, include the costs of no action alternatives in terms of management response (e.g., fish rescue costs), regulatory compliance costs, and implications of future species listing under the federal and state Endangered Species Acts.

- Promote restoration of natural fluvial processes and ecological functioning in channels (upstream or downstream) affected by structures. This restoration should take into consideration effects that are observed close to a structure but that also occur over a broader geographic area and temporal period (see Marschall et al. 2011).

- Design fishways to accommodate passage of the most limited life stages of the most limited species.

- Consider habitat restoration opportunities that may be pursued near structures to provide refuge or resting areas.

- Consider the influence of attraction flow (e.g., origin, amount) on migratory route selection and potential migration delays.
- Consider the project life cycle and long-term maintenance requirements, and identify opportunities to increase project sustainability according to DWR's Environmental Stewardship Policy and the Envision Sustainable Infrastructure Rating System.
- Closely coordinate and align San Joaquin River flood planning, and structure modifications that may affect fish migration, with the SJRRP.

7.0 References

Cannon, T. 2013. Colusa Basin Drain Fish Stranding and Rescues: Workshop Notes and Comments. California Sportfishing Protection Alliance. Available at http://calsport.org/news/wp-content/uploads/2013/07/TC-Colusa-Basin-Drain-Fish-Stranding-1.pdf. Accessed 1 November 2013.

[DWR] California Department of Water Resources. 2012a. Task 2 Draft Technical Memorandum: Evaluation of Partial Fish Passage Barriers. July. Division of Integrated Regional Water Management, South Central Region Office, Fresno, California. Available at http://restoresjr.net/flows/data-reporting/2012/2012_PartialFishBarrier_Reporting.pdf.

[DWR] California Department of Water Resources. 2012b. Public Draft 2012 Central Valley Flood Protection Plan, Attachment 9C: Fish Passage Assessment. Sacramento, California. June. Available at http://www.water.ca.gov/cvfmp/docs/2012CVFPP_Att9C_June.pdf.

[DWR] California Department of Water Resources. 2014. Draft Central Valley Flood System Fish Migration Improvement Opportunities. FloodSAFE Environmental Stewardship and Statewide Resources Office (FESSRO). Environmental Restoration and Enhancement Branch, Fish Passage Improvement Program.

[DWR and PG&E] California Department of Water Resources and Pacific Gas and Electric Company. 2010. Habitat Expansion Agreement for Central Valley Spring-Run Chinook Salmon and California Central Valley Steelhead: Final Habitat Expansion Plan. November. Sacramento, California. Available at http://www.water.ca.gov/environmentalservices/hea_home.cfm.

[DWR and USBR] California Department of Water Resources and U.S. Bureau of Reclamation. 2012. Yolo Bypass Salmonid Habitat Restoration and Fish Passage Implementation Plan. September. Available at http://www.water.ca.gov/fishpassage/docs/yolo2.pdf.

Golder Associates, Ltd. 2012. Lower Columbia River [CLBMON #42(A)] and Kootenay River Fish Stranding Assessments: Annual Summary (April 2011 to April 2012). Golder Report

No. 10-1492-0042 and 10-1492-0100. Prepared for BC Hydro, Columbia Power Corporation, and FortisBC, Castlegar, British Columbia.

Gough, P., P. Philipsen, P. P. Schollema, and H. Wanningen. 2012. From Sea to Source: International Guidance for the Restoration of Fish Migration Highways. Regional Water Authority Hunze en Aa's, The Netherlands. Available at http://www.fromseatosource.com/.

Heise, G. 2013. Assessment of the Colusa Basin Drain Gate Structure at Knights Landing for Potential Passage of Adult Chinook Salmon from the Sacramento River into the Colusa Basin Drain. California Department of Fish and Wildlife, Sacramento, California.

Hendrick, M., and B. Swart. 2013. Colusa Basin Drain Watershed Fish Stranding Tour Concept Paper. National Marine Fisheries Service, Sacramento, California.

Johnson, J., and R. Vincik. 2012. Fish Rescue behind Tisdale Weir. California Department of Fish and Wildlife, North Central Region, Rancho Cordova, California.

Marschall, E., M. Mather, D. Parrish, G. Allison, and J. McMenemy. 2011. Migration delays caused by anthropogenic barriers: modeling dams, temperature, and success of migrating salmon smolts. Ecological Society of America 21(8):3014–3031.

Nagrodski, A., G. Raby, C. Hasler, M. Taylor, and S. Cooke. 2012. Fish stranding in freshwater systems: Sources, consequences, and mitigation. Journal of Environmental Management 103:133–141.

National Marine Fisheries Service. 2009. Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project. Available at http://swr.nmfs.noaa.gov/ocap.htm.

National Marine Fisheries Service. 2014. Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-Run Chinook Salmon and Central Valley Spring-Run Chinook Salmon and the Distinct Population Segment of Central Valley Steelhead. July. California Central Valley Area Office, Sacramento, California.

Pollock, M., M. Heim, and D. Werner. 2003. Hydrologic and Geomorphic Effects of Beaver Dams and Their Influence on Fishes. American Fisheries Society Symposium 37:1–21.

Quinn, T. 1997. Homing, straying, and colonization. In W. Grant (Editor), Genetic Effects of Straying of Non-Native Hatchery Fish into Natural Populations: Proceedings of the Workshop. National Oceanic and Atmospheric Administration Technical Memo NMFS-NWFSC-30.

[SJRRP] San Joaquin River Restoration Program. 2012. Framework for Implementation. Third Party Working Draft. Available at http://www.restoresjr.net/download/program-documents/program-docs-2012/20120619_SJRRP_Framework_for_ImplDRAFT.pdf.

[SJRRP] San Joaquin River Restoration Program. 2015. Revised Framework for Implementation. July. Available at http://www.restoresjr.net/wp-content/uploads/Revised-Framework_Final_20150729.pdf.

Thomas, M. J., M. L. Peterson, N. Friedenberg, J. P. Van Eenennaam, J. R. Johnson, J. J. Hoover, and A. P. Klimley. 2013. Stranding of spawning run green sturgeon in the Sacramento River: Post-rescue movements and potential population-level effects. North American Journal of Fisheries Management 33(2):287–297. Available at http://dx.doi.org/10.1080/02755947.2012.758201.

U.S. District Court. 2006. Notice of Lodgment of Stipulation of Settlement, CIV S-88-1658 LKK/GGH. Eastern District of California (Sacramento Division).

Vogel, D. 2011. Insights into the Problems, Progress, and Potential Solutions for Sacramento River Basin Native Anadromous Fish Restoration. April. Red Bluff, California. Prepared for Northern California Water Association and Sacramento Valley Water Users.

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES