8 Aquatic Resources and Fisheries

The following sections describe the existing fisheries and aquatic resources in the Yolo Bypass and adjacent areas of the Sacramento River as well as the areas of the Sutter Bypass and Sacramento-San Joaquin Delta (Delta) that could be affected by implementation of the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project (Project).

8.1 Environmental Setting/Affected Environment

8.1.1 Study Area

The study area for aquatic resources and fisheries consists of the Sacramento River from the vicinity of Fremont Weir (near river mile [RM] 83) to about Rio Vista near RM 12, the Sutter Bypass, the Yolo Bypass, and the Delta (Figures 8-1a and 8-1b). Although the Yolo Bypass is the primary region expected to be affected by the Project, changes in the frequency, duration, and volume of water spilling into the Yolo Bypass from the Sacramento River could affect aquatic resources and fisheries in the Sacramento River, the Sutter Bypass, and the Delta. Each of these regions is described in detail below.

8.1.1.1 Sacramento River

The Sacramento River is California's largest river, with an average annual runoff of 22,000,000 acre-feet. The headwaters of the Sacramento River, along with the Pit and McCloud rivers, drain into Shasta Lake about 12 miles north of the City of Redding. Flows released from Shasta Lake flow downstream for about 10 miles to Keswick Reservoir, which functions as a reregulating reservoir. Keswick Dam (RM 302) represents the upstream extent of anadromous fish.

The segment of the Sacramento River located within the study area extends from Fremont Weir (about RM 83) downstream to just above Rio Vista near RM 12. The Sacramento River within the study area is heavily channelized and leveed. It is bordered by agricultural land and the City of Sacramento and surrounding areas. This segment of the Sacramento River is characterized primarily by slow-water glides and pools, is depositional in nature, and has lower water clarity and habitat diversity relative to the upper portion of the river.

Over 30 fish species are known to occur within the Sacramento River. Many of these are anadromous, including both native and non-native species. Anadromous species include Chinook salmon (winter-run, spring-run, fall-run, and late fall-run), steelhead, green sturgeon, white sturgeon, Pacific lamprey, river lamprey, American shad, and striped bass.

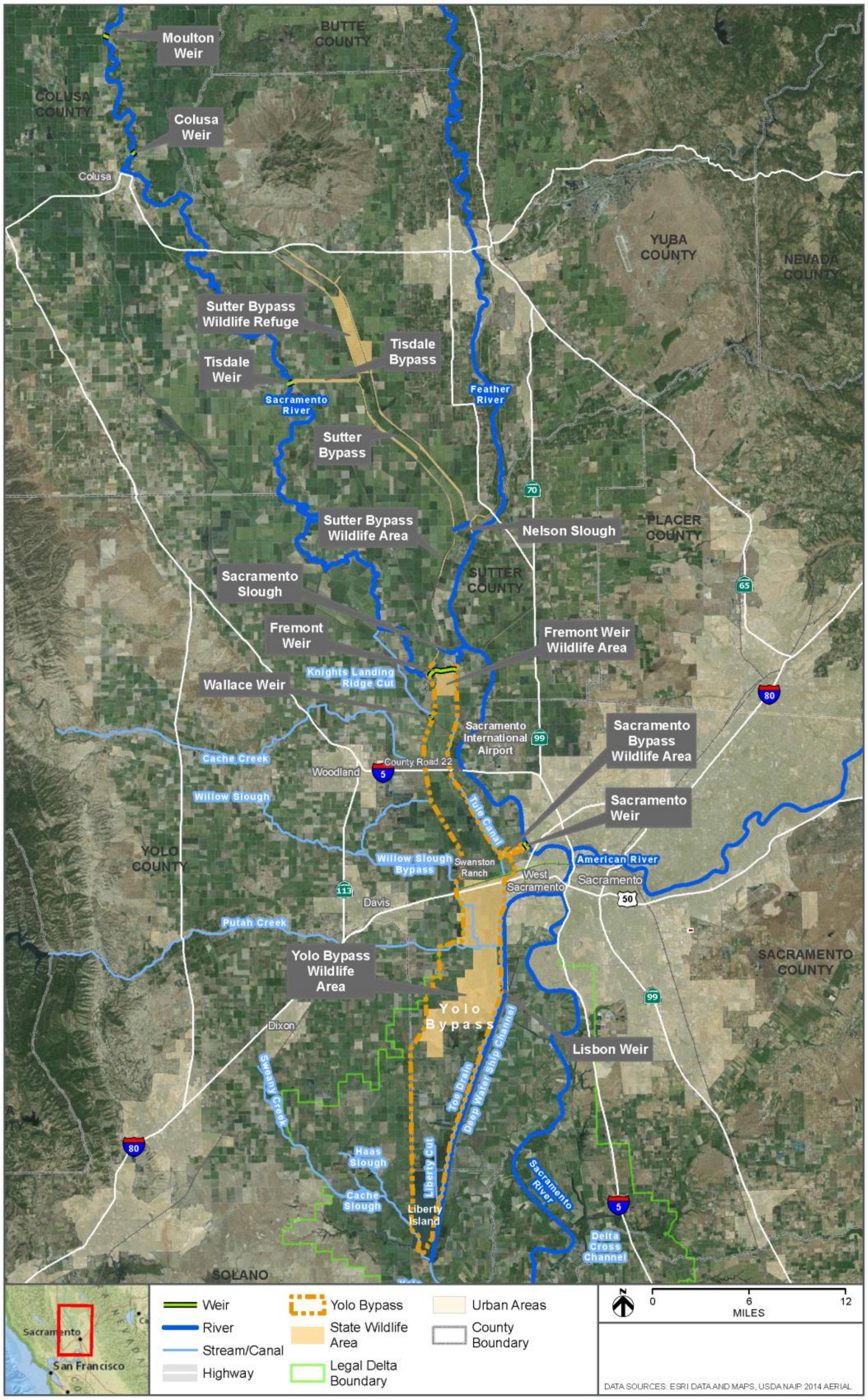

Figure 8-1a. Overview of the Northern Portion of the Aquatic Resources and Fisheries Study Area

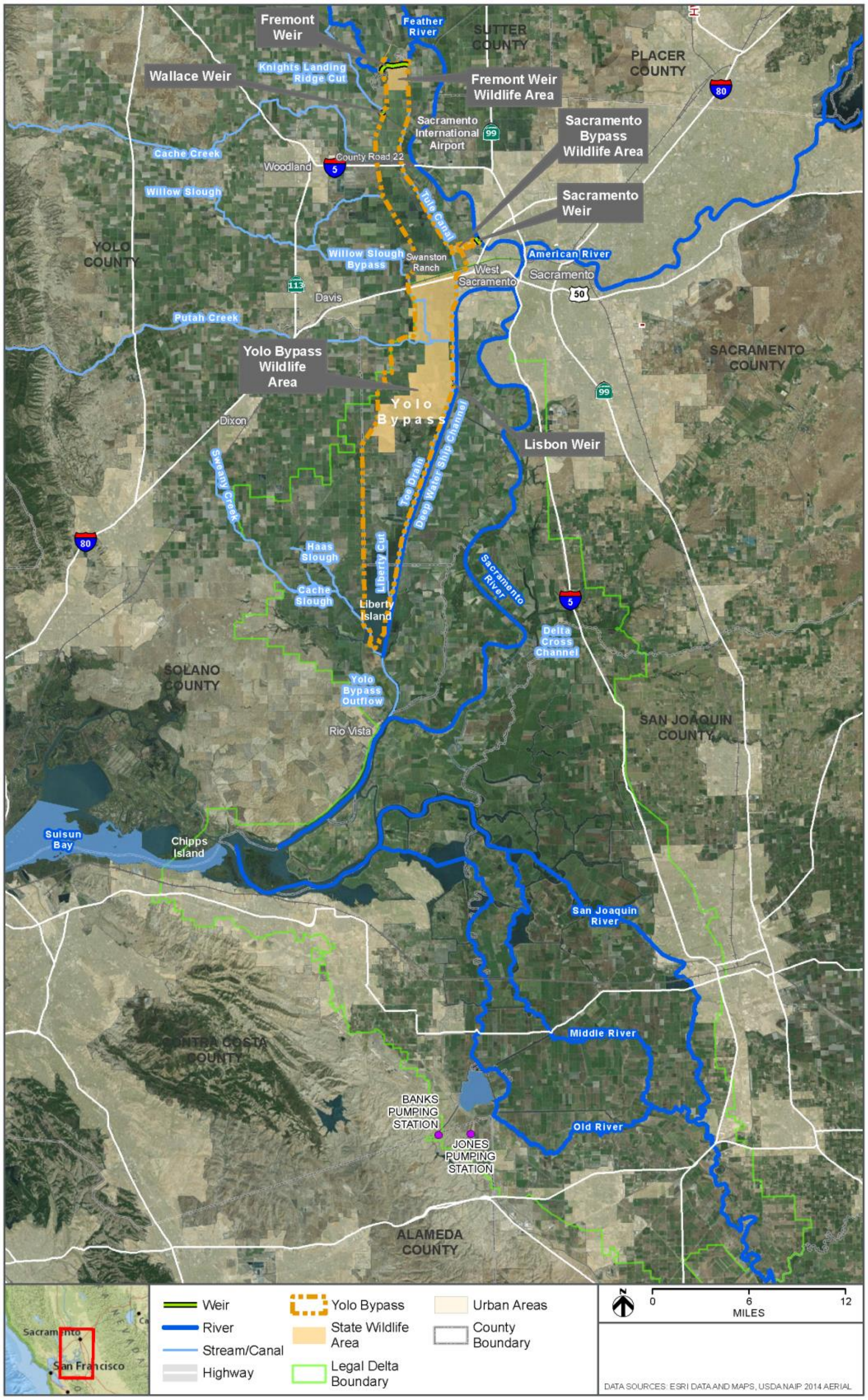

Figure 8-1b. Overview of the Southern Portion of the Aquatic Resources and Fisheries Study Area

Most anadromous salmonid spawning in the Sacramento River occurs upstream of the study area (National Oceanic and Atmospheric Administration National Marine Fisheries Services [NMFS] 2009; United States Bureau of Reclamation [Reclamation] 2015). Most Chinook salmon spawning occurs upstream of Red Bluff Diversion Dam (RBDD) (NMFS 2009; California Department of Fish and Game [CDFG] 1998; California Department of Fish and Wildlife [CDFW] 2017a). However, some Chinook salmon, particularly fall-run Chinook salmon, have been observed to also spawn in the reaches downstream of RBDD to Princeton (CDFW 2017a). Steelhead spawning in the mainstem Sacramento River likely is limited to the area upstream of RBDD although specific information regarding steelhead spawning within the mainstem Sacramento River is limited (NMFS 2009).

Green sturgeon spawning habitat has been confirmed within a 58-mile reach of the Sacramento River, extending from upstream of RBDD to downstream of RBDD, ranging from approximately RM 207 to 265 (Poytress et al. 2011; 2013). Although exact spawning locations are unknown, white sturgeon are reported to likely spawn between Knights Landing (RM 90) and upstream of Colusa (RM 143) (Kohlhorst 1976; Moyle 2002).

Downstream from the City of Red Bluff, the Sacramento River provides a migration corridor and rearing habitat for salmonids as well as spawning and rearing habitat for a variety of other native fish species such as Sacramento splittail and Sacramento pikeminnow.

During high flow events, water from the Sacramento River spills out at several locations into the Sutter Bypass or basins draining into the Sutter Bypass to minimize the potential for unintentional flooding along the Sacramento River.

8.1.1.2 Sutter Bypass

The Sutter Bypass is a wide flood control channel that carries excess Sacramento River flood waters to the Feather River and back to the Sacramento River near its confluence with the Feather River. The Sutter Bypass is approximately 30 miles long and 3,600 to 4,000 feet (ft) wide upstream of Nelson Slough and about 6,000 ft wide downstream of Nelson Slough[1]. During high flow events, water from the Sacramento River spills at several locations, which eventually drain into the Sutter Bypass, including at the Colusa and Moulton weirs into the Butte Basin and at the Tisdale Weir through the Tisdale Bypass.

The Moulton and Colusa weirs are overtopped when Sacramento River flows exceed 60,000 and 30,000 cubic feet per second (cfs), respectively (California Department of Water Resources [DWR] 2010). The Tisdale Weir is overtopped when Sacramento River flows exceed 23,000 cfs (DWR 2010). Each of these weirs is a concrete structure that passes floodwaters by gravity once the Sacramento River reaches the elevation at which flow overtops the weir. The Sacramento River also overtops the east bank at several locations when flows are above 90,000 cfs at Ord Ferry (southwest of Chico) (DWR 2010).

The Sutter Bypass has been reported to be an important nursery area for anadromous salmonids of Butte Creek and the upper Sacramento River and its tributaries, particularly during wetter water years (United States Fish and Wildlife Services [USFWS] 2000). Flooded lands of the

[1] Distances are based on estimated measurements taken in ArcGIS.

Sutter Bypass are also reported to be an important spawning and nursery area for Sacramento splittail (USFWS 2000) and have also been found to support Chinook salmon, lamprey, Sacramento pikeminnow and other (non-native) cyprinids, American shad, threadfin shad, inland silverside, channel catfish, largemouth bass, and bluegill and other sunfish species (Feyrer et al. 2006a). Other anadromous fish species also may potentially utilize the bypass for rearing (i.e., steelhead and sturgeon).

Water flowing through the Sutter Bypass reaches the northern side of the Sacramento River to the north of Fremont Weir. During flood events, water from the Sutter Bypass flows into the Sacramento River and the Yolo Bypass (Figure 8-2).

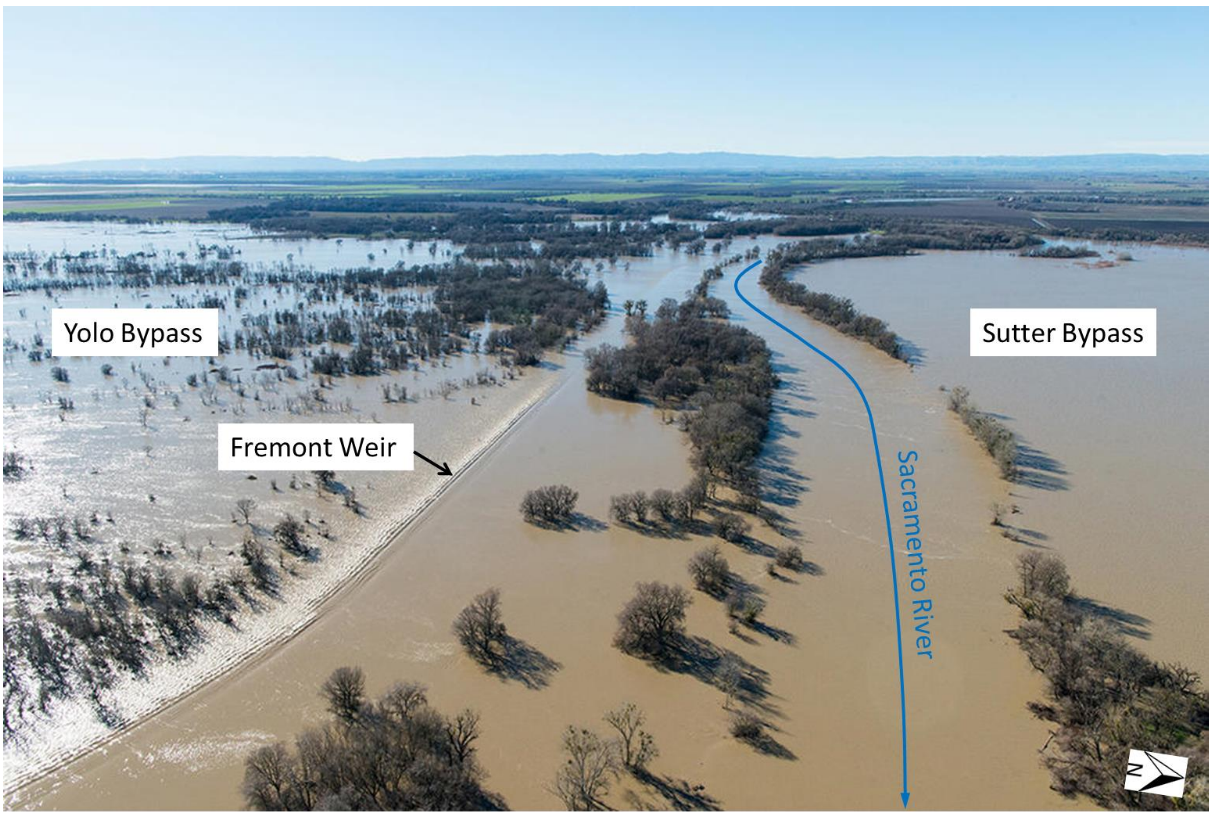

Figure 8-2. The Sutter and Yolo Bypasses and the Sacramento River

8.1.1.3 Yolo Bypass

The Yolo Bypass is an engineered floodplain located about five miles west of Sacramento. Floodwater from the Sacramento River passing over Fremont Weir initially flows through the Toe Drain before overflowing onto the floodplain when flows in the Toe Drain are greater than 3,500 cfs (Sommer et al. 2001b). The Toe Drain is a perennial, tidally influenced riparian channel running along the eastern edge of the Yolo Bypass and is the primary source of perennial water in the bypass during drier periods. Floodwaters from the Yolo Bypass re-enter the Sacramento River through Cache Slough.

The Yolo Bypass supports multiple aquatic habitats, including stream and slough channels, as well as flooded shallow water. These diverse habitats provide opportunities for fish migration, spawning, and rearing (CALFED Bay-Delta Program [CALFED] 2000). The Yolo Bypass is inundated to some extent about 70 percent of all years when total flow in the Sacramento River exceeds about 56,270 cfs (Yolo Bypass Working Group et al. 2001). The Yolo Bypass has inundated as early as October and as late as June (Yolo Bypass Working Group et al. 2001), but the typical period of inundation has been between January and March (Sommer et al. 2001a). When flows within the Yolo Bypass are greater than about 75,000 cfs, the floodplain is considered fully wetted (Sommer et al. 2001b). However, even at a flow rate of 6,000 cfs, hydraulic modeling indicates that approximately 21,500 acres of the floodplain would be inundated, the majority of which would consist of low-velocity (average of 1.26 feet per second [ft/s]) and shallow (average of 2.6 feet deep) habitat (Reclamation and DWR 2012). Williams et al. (2009) identified a flow of 8,000 cfs to fully activate the floodway width of the Yolo Bypass.

When flooded, the Yolo Bypass provides up to about 59,300 acres of shallow floodplain habitat, ranging from about 1.2 to 6 miles wide over it's approximately 40-mile length, and has a typical mean depth of 6.5 feet or less (Sommer et al. 2008a).

Flow over the Fremont Weir is the primary flow input to the Yolo Bypass in the north, conveying floodwaters from the Sacramento River, Feather River, and the Sutter Bypass. The Fremont Weir is a concrete overflow levee extending parallel to the Sacramento River for about 9,120 ft (DWR 2010). During major storms (i.e., greater than 177,000 cfs), additional water enters the Yolo Bypass from the east via Sacramento Weir, including water from the Sacramento and American rivers (DWR 2010). In contrast to the Moulton, Colusa, Tisdale and Fremont weirs, the Sacramento Weir requires manual operation to allow flow past the weir (DWR 2010).

Flow also enters the Yolo Bypass from several west-side streams, including Cache Creek, the Willow Slough Bypass, and Putah Creek. During high-flow conditions, flow also enters the Yolo Bypass through the Knights Landing Ridge Cut, which is a manmade canal that drains agricultural water and ephemeral streams in the Colusa Basin (CDFW 2016a). These tributaries can add substantial flow to floodwaters in the Yolo Bypass and provide localized floodplain inundation prior to Fremont Weir spilling. During periods when no flow enters the Yolo Bypass from the Fremont Weir, substantial short-term (e.g., one to three weeks) flooding can occur from these tributaries (Sommer et al. 2014).

Liberty Island, an inundated island encompassing 5,209 acres, is the southern outlet of the Yolo Bypass (CALFED 2005). In 1998, Liberty Island's levees were breached for the last time during high flows through the Yolo Bypass, flooding the island. It has remained flooded since that time, and provides nearly 20 acres of riparian habitat, 55 acres of herbaceous wetlands, and over 800 acres of freshwater tidal and emergent marsh (CALFED 2005).

The Yolo Bypass is an important migratory pathway for downstream migrating Chinook salmon, steelhead, and other native, anadromous fish during wet years. Although many species are presumed to spawn in the Yolo Bypass (Harrell and Sommer 2003; Sommer et al. 2004), most of these are thought to spawn in deeper channels, such as the Toe Drain or in upstream tributaries to the Yolo Bypass. However, within the Sacramento River Basin, the Yolo Bypass is one of the most important known spawning areas for Sacramento splittail, along with the Sutter Bypass; the Cosumnes River floodplain may be their most important spawning habitat in the eastern Delta (Moyle et al. 2004). A comparison of indices of juvenile Sacramento splittail abundance within the Estuary showed an average abundance index of 5 during years when the Yolo Bypass was flooded for less than three weeks, compared to an average abundance index of 39 during years when the Yolo Bypass was flooded for more than three weeks (Sommer et al. 1997), leading to the belief that Sacramento splittail are spawning successfully within the flooded bypasses.

Sommer et al. (2001c) found that seasonal floodplain habitat within the Yolo Bypass also provided better rearing conditions for outmigrating anadromous salmonids than nearby Sacramento River sites because of the increased area, the complexity of suitable habitat, and increased food resources. This study concluded that these conditions allowed juvenile Chinook salmon to grow substantially faster in the Yolo Bypass, primarily because of a greater abundance of invertebrate prey in the inundated floodplain (Sommer et al. 2001c).

Analysis of beach seine fish catch data in the Yolo Bypass during a wet year (2011) and a dry year (2012) indicates that although non-native fish species dominate the fish assemblage in the Yolo Bypass, native fishes were more widely distributed during the wet year (Frantzich et al. 2013). Based on the increase in the proportion of bluegill catches during 2012, low flows may provide more suitable conditions for the spawning and recruitment of centrarchids upstream of Lisbon Weir (Frantzich et al. 2013). Table 8-1 lists fish species found in the Yolo Bypass.

Table 8-1. Fish Species Commonly Found in the Yolo Bypass

Common Name	Scientific Name	Common Name	Scientific Name
American shad	*Alosa sapidissima*	Redear sunfish	*Lepomis microlophus*
Bigscale logperch	*Percina macrolepida*	River lamprey*	*Lampetra ayresii*
Black bullhead	*Ameriurus melas*	California roach*	*Hesperoleucus symmetricus*
Black crappie	*Pomoxis negromaculatus*	Sacramento blackfish*	*Orthodon microlepidotus*
Bluegill	*Lepomis macrochirus*	Sacramento pikeminnow*	*Ptychocheilus grandis*
Brown bullhead	*Ameriurus nebulosus*	Sacramento sucker*	*Catostomus occidentalis*
Channel catfish	*Ictalurus punctatus*	Shimofuri goby	*Tridentiger bifasciatus*
Chinook salmon*	*Oncorhynchus tshawytscha*	Smallmouth bass	*Micropterus dolomieusalmoides*
Common carp	*Cyprinus carpio*	Sacramento splittail*	*Pogonichthys macrolepidotus*
Delta smelt*	*Hypomesus transpacificus*	Spotted bass	*Micropterus punctulatus*
Fathead minnow	*Pimephales promelas*	Steelhead*	*Oncorhynchus mykiss*
Golden shiner	*Notemigonus crysoleucas*	Striped bass	*Morone saxatilis*
Goldfish	*Carassius auratus*	Threadfin shad	*Dorosoma petenense*
Green sunfish	*Lepomois cyanellus*	Threespine stickleback*	*Gasterosteus aculeatus*
Green sturgeon*	*Acipenser medirostris*	Tule perch*	*Hysterocarpus traski*
Hardhead*	*Mylopharodon conocephalus*	Wakasagi	*Hypomesus nipponensis*
Sacramento hitch*	*Lavinia exilicauda*	Warmouth	*Chaenobryttus gulosus*
Inland silverside	*Menidia beryllina*	Western mosquitofish	*Gambusia afinis*
Largemouth bass	*Micropterus salmoides*	White catfish	*Ameiurus catus*
Pacific lamprey*	*Entosphenus tridentatus*	White crappie	*Pomoxis annularis*
Pacific staghorn sculpin*	*Leptocottus armatus*	White sturgeon*	*Acipenser transmontanus*
Prickly sculpin*	*Cottus asper*	Yellowfin goby	*Acanthogobius flavimanus*
Red shiner	*Cyprinella lutrensis*		

* Native Species
Source: Modified from Sommer et al. 2001a

8.1.1.4 Delta

The San Francisco Bay/Sacramento-San Joaquin River Delta Estuary (Estuary) is the largest intact estuary on the west coast of the United States (United States Environmental Protection Agency [USEPA] 2003). The upstream portion of this Estuary, the Delta, is a triangular area comprising 700 miles of sloughs, waterways, and islands located near the confluence of the Sacramento and San Joaquin rivers (Water Education Foundation 2016). The Delta covers a surface area of about 75 square miles. Relatively high-salinity waters of the San Joaquin River dominate the southern Delta, whereas the lower-salinity waters of the Sacramento River dominate the northern Delta. Delta hydrology is driven primarily by tides, river inflows, in-Delta agricultural diversions, and water export operations of the Central Valley Project (CVP) and the State Water Project (SWP) (Delta Stewardship Council 2013).

The portion of the Delta in the study area consists primarily of the Sacramento River and associated waters located downstream of the Yolo Bypass outlet near Rio Vista (see Figure 8-1). Characteristics of this area include leveed river channels, subsided and flooded leveed islands, and sloughs. Salinities are typically higher than in upstream areas because of the tidal influence of the Estuary. Estuarine fishes occurring in this area include delta smelt and longfin smelt, which use these areas depending on seasonal and diel (i.e., daily) salinity gradients. Additionally, many non-native warm water fish species spawn and rear in this area, whereas Chinook salmon, steelhead, sturgeon, and lamprey use this area primarily for migration and rearing.

8.1.2 Species Evaluated in the EIS/EIR

8.1.2.1 Methodology

Fish species considered in this Environmental Impact Statement (EIS)/Environmental Impact Report (EIR) include those that are Federally or State of California (State)-listed as threatened or endangered, species that are proposed for Federal or State listing as threatened or endangered, species classified as candidates for future Federal or State listing, Federal species of concern, or State species of special concern. Special-status fish species (i.e., fish species designated under one or more of the aforementioned categories) potentially occurring in the study area were identified by using the online NMFS species list (NMFS 2017) and the CDFW special animals list (CDFW 2017b). Additional fish species considered in this EIS/EIR include non-listed native species that are known to inhabit the study area and that could affect special-status species (e.g., native predators of listed anadromous salmonids). Non-native fish species of commercial or recreational importance are also included. Table 8-2 lists fish species of focused evaluation in this EIS/EIR.

Table 8-2. Fish Species of Focused Evaluation in the Project Area

Common Name	Status
Sacramento River winter-run Chinook salmon ESU	Federal and State endangered
Central Valley spring-run Chinook salmon ESU	Federal and State threatened
Central Valley fall-/late fall-run Chinook salmon ESU	Federal species of concern State species of special concern
Central Valley steelhead DPS	Federal threatened
Southern DPS of North American green sturgeon	Federal threatened; State species of special concern
Delta smelt	Federal threatened; State endangered
Longfin smelt	Federal candidate[a]; State threatened
White sturgeon	State species of special concern
River lamprey	State species of special concern
Pacific lamprey	State species of special concern
Sacramento splittail	State species of special concern
Hardhead	State species of special concern
Sacramento hitch	State species of special concern
Sacramento pikeminnow	Native predatory species
American shad	Recreational importance
Striped bass	Recreational importance; non-native predatory species
White catfish	Recreational importance; non-native predatory species
Warm water game fishes	Recreational importance; non-native predatory species

[a] Federal candidate status applies to the San Francisco Bay-Delta DPS of longfin smelt.
Key: DPS = distinct population segment; ESU = evolutionarily significant unit

8.1.2.2 Special-Status Fish Species

8.1.2.2.1 Chinook Salmon

Chinook salmon are the most important commercial anadromous fish in California. The species has evolved a broad array of life history patterns that allow them to take advantage of diverse riverine conditions throughout the year. These life history patterns generally fall into two main generalized freshwater life history types (Healey 1991):

- "Stream-type" adult Chinook salmon enter freshwater months before spawning, and juveniles of this type can reside in freshwater for a year or more prior to emigrating.
- "Ocean-type" adult Chinook salmon spawn soon after entering freshwater and juveniles typically migrate to the ocean as young-of-the-year.

Both winter-run and spring-run Chinook salmon tend to enter freshwater in a sexually immature state and delay spawning for months while holding in freshwater. Fall-run Chinook salmon enter freshwater at an advanced stage of maturity and generally spawn within a few days or weeks of freshwater entry (Healey 1991).

Spawning occurs in gravel substrate in relatively fast-moving, moderately shallow riffles or along banks with relatively high-water velocities. Embryos and alevins (newly hatched fish with the yolk sac still attached) require adequate water movement through the substrate; however, this movement can be inhibited by the accumulation of fines and sand.

Eggs develop in the gravel in about 40 to 60 days where they remain for another four to six weeks until the yolk sac is completely absorbed. Emergence occurs from mid-June through mid-October. 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).

During the Chinook salmon juvenile rearing and downstream movement life stage, salmonids prefer stream margin habitats with sufficient depths and velocities to provide suitable cover and foraging opportunities. Juvenile Chinook salmon reportedly use river channel depths ranging from 0.9 to two feet and most frequently use water velocities ranging from zero to 1.3 ft/s (Raleigh et al. 1986). Ephemeral habitats, such as floodplains and the lower reaches of small streams are also very important to rearing Chinook salmon (Maslin et al. 1997; Sommer et al. 2001c). These areas can be more productive than the main channel and provide refuge from predatory fishes. However, side channels and low-gradient floodplains also can strand and isolate juveniles when high flows subside quickly (NMFS 1997).

Adult Chinook salmon enter the Yolo Bypass from the south, often straying from the adjoining Sacramento River in response to tidal exchange or substantial flow pulses coming from the Yolo Bypass. While adults have been documented in the Yolo Bypass each month that sampling has occurred, the majority have been caught between October and December. Although juvenile Chinook salmon are in the Sacramento River throughout the year, they can only access the Yolo Bypass floodplain following a Fremont Weir overtopping event. Juveniles have been observed between December and July, with peak presence occurring between February and April (DWR 2016, as cited in DWR and Reclamation 2017). Juvenile Chinook salmon that use the Yolo Bypass are reported to be primarily fall-run; the extent to which other runs use the Yolo Bypass is not well understood (Opperman et al. 2017). In Suisun Marsh, Chinook salmon fry tend to remain close to the banks and vegetation, near protective cover, and in dead-end tidal channels (Moyle et al. 1986).

Major factors that limit the range and abundance of Chinook salmon are flow, water temperature, barriers to upstream migration, habitat quality and quantity, entrainment in water diversions, and ocean conditions (NMFS 2014). Climate change and associated impacts on water temperature, hydrology, and ocean conditions are generally considered likely to have substantial effects on Chinook salmon populations in the future (NMFS 2014).

Four principal life history variants are recognized in the Central Valley and named for the timing of their adult spawning runs (i.e., time of freshwater entry): winter-run, spring-run, fall-run, and late fall-run. Discussions of each of these runs are provided below.

Sacramento River Winter-run Chinook Salmon ESU

The Sacramento River winter-run Chinook salmon evolutionarily significant unit (ESU) is listed as endangered under both the Federal Endangered Species Act (ESA) and the California Endangered Species Act (CESA).

Since the construction of Shasta Dam, winter-run Chinook salmon spawning has been confined to the mainstem Sacramento River below Keswick Dam. In 1993, critical habitat for winter-run Chinook salmon was designated to include:

1. The Sacramento River from Keswick Dam (RM 302) to Chipps Island (RM 0) at the westward margin of the Delta
2. All waters from Chipps Island westward to the Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait
3. All waters of San Pablo Bay westward of the Carquinez Bridge
4. All waters of San Francisco Bay north of the San Francisco-Oakland Bay Bridge (58 Federal Register [FR] 33212)

NMFS' 2016 five-year status review of winter-run Chinook salmon concluded that the overall viability of the ESU had worsened since the 2010 assessment. Specifically, a reduction in the population growth rate over the past 10 years (2005 through 2014) and an increase in the proportion of hatchery fish comprising the spawning population have increased the risk of extinction of the ESU (NMFS 2016a).

Primary spawning and rearing habitats for winter-run Chinook salmon are confined to the coldwater areas between Keswick Dam and RBDD (NMFS 2014). The lower reaches of the Sacramento River, the Delta, and San Francisco Bay serve as migration corridors for the upstream migration of adult and downstream migration of juvenile winter-run Chinook salmon.

According to NMFS (2009; 2014), adult winter-run Chinook salmon immigration (upstream spawning migration) in the Sacramento River occurs from November through July. Most of the run passes the RBDD from January through May, with the peak passage occurring in mid-March (Hallock and Fisher 1985 as cited in NMFS 2009). Adults prefer to hold in deep cold pools until they are sexually mature and ready to spawn during spring or summer.

Winter-run Chinook salmon spawn primarily between mid-April and mid-August, with peak spawning generally occurring during June (Vogel and Marine 1991). Winter-run Chinook salmon embryo incubation in the Sacramento River can extend into September during wet water years (Vogel and Marine 1991).

Winter-run Chinook salmon fry in the upper Sacramento River exhibit the greatest abundance during September. Fry and juvenile emigration past the RBDD occurs as early as mid-July and extends as late as the end of March (NMFS 1997 and Vogel and Marine 1991, both as cited in NMFS 2014). Juvenile emigration past Knights Landing occurs primarily between September and March and peaks in the months of December and January, with some emigration continuing through May during some years (Snider and Titus 2000). Winter-run Chinook salmon juveniles have been observed emigrating from the Sacramento River in large numbers during the first increase in flows from storm events in late fall or early winter (Vogel and Marine 1991; Poytress et al. 2014). Based on analysis of rotary screw trap (RST) data at Knights Landing and Delta fish survey data, a large pulse of juvenile winter-run Chinook salmon have been observed to emigrate past Knights Landing and into the Delta during and shortly after the first large fall storm event where flows reach approximately 14,000 cfs at Wilkins Slough (del Rosario et al. 2013).

Although juvenile Chinook salmon are in the Sacramento River throughout the year, they can only access the Yolo Bypass floodplain following a Fremont Weir overtopping event. Juveniles have been observed in the Yolo Bypass between December and July, with presence peaking between February and April (DWR 2016, as cited in DWR and Reclamation 2017).

According to NMFS (2014), juvenile winter-run Chinook salmon can occur in the Delta primarily from November through early May, based on size-at-date criteria from trawl data in the Sacramento River at West Sacramento (RM 57) (USFWS 2001, as cited in NMFS 2014). Juveniles reportedly remain in the Delta until they reach a fork length (FL) of about 118 millimeters (mm) and are from five to 10 months old. Emigration to the ocean begins as early as November and continues through May (Fisher 1994 and Myers et al. 1998, both as cited in NMFS 2014). In the Suisun Marsh, Chinook salmon fry tend to remain close to the banks and vegetation, near protective cover, and in dead-end tidal channels (Moyle et al. 1986). In the intertidal zone, mudflats and tule marshes become important habitat for juveniles during high tides.

Central Valley Spring-run Chinook Salmon ESU

The Central Valley spring-run Chinook salmon ESU was listed as a threatened species under both the ESA and the CESA because of the reduced range and small size of remaining spring-run Chinook salmon populations (64 FR 50393). Critical habitat was designated on September 2, 2005 and includes the mainstem Sacramento River from Chipps Island (RM 0) to Keswick Dam, and tributary reaches, including the Feather and Yuba rivers; Big Chico, Butte, Deer, Mill, Battle, Antelope, and Clear creeks; and portions of the northern Delta (70 FR 52488).

Spring-run Chinook salmon are known to use the Sacramento River as a migratory corridor to spawning areas in upstream tributaries. Historically, spring-run Chinook salmon did not use the mainstem Sacramento River downstream of Shasta Dam except as a migratory corridor to and from headwater streams (CDFG 1998). However, construction of Shasta and Keswick dams blocked passage to upstream areas, limiting potential spawning habitat to areas downstream of the dams.

Spring-run Chinook salmon enter the Sacramento River between mid-February and July. The peak of the migration reportedly occurs in May (CDFG 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 (CDFG 1998). Spring-run Chinook salmon spawning occurs during September and October, depending on water temperatures (NMFS 2009). Embryo incubation has been reported to occur primarily during September through mid-February (DWR 2004b; Moyle 2002; Vogel and Marine 1991).

Spring-run Chinook salmon fry emerge from the gravel from November to March (Moyle 2002) and can have highly variable emigration timing based on various environmental factors (NMFS 2009). Some juveniles begin emigrating soon after emergence from the gravel, whereas others over-summer and emigrate as yearlings with the onset of intense fall storms (CDFG 1998). The emigration period for spring-run Chinook salmon can extend from November to early May, with up to 69 percent of the young-of-the-year fish outmigrating through the lower Sacramento River and Delta during this period (CDFG 1998 as cited in NMFS 2009). As described by NMFS (2009), juvenile spring-run Chinook salmon emigration at the RBDD occurs primarily from November through January. Peak movement of yearling spring-run Chinook salmon in the Sacramento River at Knights Landing occurs in December and again in March and April for young-of-the-year juveniles (NMFS 2009).

Central Valley Fall-/Late Fall-run Chinook Salmon ESU

Central Valley fall-run and late fall-run Chinook salmon are considered by NMFS to be the same ESU (64 FR 50394). NMFS determined that listing this ESU as threatened was not warranted (64 FR 50394) but subsequently classified it as a species of concern because of specific risk factors, including population size and fish hatchery influence (69 FR 19975). The Central Valley fall-run and late fall-run Chinook salmon ESU also is listed as a State species of special concern (CDFW 2016b). The ESU includes all naturally spawned populations of fall-run Chinook salmon in the Sacramento and San Joaquin river basins and their tributaries east of Carquinez Strait. Because the Central Valley fall-run and late fall-run Chinook salmon ESU is not listed as threatened or endangered, no critical habitat has been designated.

The Central Valley fall-/late fall-run Chinook salmon ESU has displayed broad fluctuations in adult abundance. Between 1959 and 1970, escapement of fall-run Chinook salmon in the mainstem Sacramento River exceeded 100,000 fish every year except for one year (1967). Since 1970, escapement in the mainstem Sacramento River generally has not exceeded 100,000 (Reclamation 2008).

Although Central Valley fall-run and late fall-run Chinook salmon are part of the same ESU, because they differ in life stage-specific timing, they are discussed and considered separately below.

Fall-run Chinook Salmon

In the Central Valley, fall-run Chinook salmon are the most numerous of the four salmon runs and continue to support important commercial and recreational fisheries.

Adult fall-run Chinook salmon enter the Sacramento and San Joaquin rivers from July through December (Reclamation 2008). Migration of adult fall-run Chinook salmon into the Sacramento River basin reportedly begins in July, peaks in October, and ends in December (Vogel 2011). Unlike spring-run Chinook salmon, adult fall-run Chinook salmon do not exhibit an extended over-summer holding period. Rather, they stage for a relatively short period before spawning. Fall-run Chinook salmon generally spawn from October through December (Reclamation 2008; Vogel 2011).

In general, the fall-run Chinook salmon spawning and embryo incubation period extends from October through March (Vogel and Marine 1991). In the Sacramento River basin, fall-run Chinook salmon juvenile emigration occurs from January through June (Moyle 2002; Vogel 2011; Vogel and Marine 1991). Juvenile fall-run Chinook salmon emigration past RBDD begins as early as December, peaks in January and February during winter flow events, decreases through the spring, and extends to as late as June or July (Gaines and Martin 2001 as cited in USFWS and CDFG 2012).

Juvenile fall-run Chinook salmon habitat requirements are similar to those described for winter-run Chinook salmon.

Late Fall-run Chinook Salmon

Central Valley late fall-run Chinook salmon escapement is dominated by spawners in the Sacramento River above the RBDD and fish hatchery production from Coleman National Fish

Hatchery on Battle Creek, with varying numbers of spawners in the Sacramento River downstream of the RBDD and relatively few spawners in Battle Creek (CDFW 2017a).

Adult immigration of late fall-run Chinook salmon in the Sacramento River generally begins in late October and extends through March (USFWS and CDFG 2012). Spawning has been suggested to occur in tributaries to the upper Sacramento River (e.g., Battle, Cottonwood, Clear, Big Chico, Butte, and Mill creeks) and the Feather and Yuba rivers although these fish do not make up a large proportion of the late fall-run Chinook salmon population (USFWS 1995). Late fall-run Chinook salmon spawning generally occurs from January through April in the mainstem Sacramento River, primarily from Keswick Dam to RBDD (Moyle 2002; Vogel and Marine 1991).

Late fall-run Chinook salmon embryo incubation can extend from January through June (USFWS and CDFG 2012; Vogel and Marine 1991). Post-emergent fry and juveniles rear and disperse from their spawning and rearing grounds in the upper Sacramento River and its tributaries during April through December, with low rates of emigration occurring from July into the fall although fall and winter freshets (i.e., pulses of flow during storm events) can increase emigration rates (Vogel 2011; Vogel and Marine 1991). According to USFWS and CDFG (2012), juvenile late fall-run Chinook salmon rear in the upper Sacramento River from late April through the following winter before emigrating to the Estuary. Late fall-run Chinook salmon yearlings can use flow events as migration cues during the late fall and winter, and some individuals could continue to spend another seven to 13 months in the Sacramento River before entering the Delta and ocean (Moyle 2002).

8.1.2.2.2 Central Valley Steelhead DPS

Steelhead are the anadromous form of rainbow trout (McEwan 2001). NMFS originally listed the Central Valley steelhead DPS as threatened under the ESA on March 19, 1998 (64 FR 14517), and listing was reaffirmed on January 5, 2006 (71 FR 834). Designated critical habitat for the Central Valley steelhead DPS includes all river reaches accessible to steelhead in the Sacramento and San Joaquin rivers and their tributaries in California (70 FR 52488). This includes major tributaries to the Sacramento River, such as the American and Feather rivers, as well as smaller and intermittent streams (McEwan 2001). NMFS' 2016 status review found that the DPS continues to be at a high risk of extinction (NMFS 2016b). Steelhead in the Feather and American rivers are supported by the Feather and Nimbus fish hatcheries, respectively.

Adult steelhead immigration into Central Valley streams typically begins in August, continues into March or April (McEwan 2001; NMFS 2014), and generally peaks during January and February (Moyle 2002). Adult steelhead immigration can occur during all months of the year, with upstream migration occurring primarily during September and October (NMFS 2009). However, in Mill and Deer creeks, adult steelhead immigration has been reported to occur from October through June, with peak migration occurring from October through mid-March (NMFS 2009).

Steelhead reportedly spawn in small streams and tributaries from December through April, with peaks from January through March (NMFS 2009). The preferred range of water depths for spawning steelhead has been observed most frequently between 0.3 and 4.9 feet (Moyle 2002). The reported preferred water velocity for steelhead spawning is 1.5 to 2.0 ft/s (USFWS 1995).

Eggs usually hatch within four weeks, depending on stream temperature (CDFG 1996). The yolk sac fry remain in the gravel after hatching for another four to six weeks (CDFG 1996). Steelhead fry and fingerlings rear and move downstream in the Sacramento River year-round although most steelhead smolts reportedly emigrate from January through June (McEwan 2001). Based on CDFW sampling at Knights Landing, juvenile steelhead emigration occurs primarily from January through May, with peaks during March and April (Snider and Titus 2000).

After fry emerge, they inhabit shallow areas along the stream margin and seem to prefer areas with cobble substrates (CDFG 1996). As they grow and develop, juveniles use a greater variety of habitats (CDFG 1996). Juvenile Central Valley steelhead typically migrate to the ocean after spending from one to three years in freshwater (CDFG 1996).

Generally, juvenile steelhead migrate downstream during most months of the year, but the peak period of emigration occurs in spring, with a much smaller peak in fall (Hallock et al. 1961). The emigration period for naturally spawned 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).

Adult and juvenile steelhead can be present in the Yolo Bypass year-round although their presence often coincides with high flow events during the fall through spring. Adult steelhead have been observed in the Yolo Bypass between October and April, with peaks in January and February, and juveniles have been observed between January and June, peaking in March (DWR 2016, as cited in DWR and Reclamation 2017). However, the Yolo Bypass does not appear to be important habitat for steelhead (Opperman et al. 2017).

8.1.2.2.3 Southern DPS of North American Green Sturgeon

NMFS listed the southern DPS of North American green sturgeon as threatened in 2006 (71 FR 17757). On October 9, 2009, NMFS designated critical habitat for the southern DPS of North American green sturgeon. In the Central Valley, critical habitat for green sturgeon includes the Sacramento River downstream of Keswick Dam, the Feather River downstream of Oroville Dam, the Yuba River downstream of Daguerre Point Dam, portions of the Sutter and Yolo bypasses, the Sacramento-San Joaquin Delta, and the San Francisco Estuary (74 FR 52300). In 2015, NMFS issued an updated status review in which the threatened status was confirmed (NMFS 2015).

Based on surveys of sites where adult green sturgeon aggregated in the upper Sacramento River from 2010 through 2014, the total number of adults in the Southern DPS population was estimated to be 1,348 ± 524 (pers. comm. with Ethan Mora, University of California at Davis [UC Davis], May 6, 2015, as cited in NMFS 2015). The principal factor in the decline of the Southern DPS of green sturgeon is the reduction in historical spawning habitat (NMFS 2015). The population also is threatened by insufficient flows in spawning areas, elevated water temperatures, entrainment and stranding in water and flood diversions, indirect effects of invasive species, potential poaching, and exposure to contaminants (NMFS 2015).

Green sturgeon adults in the Sacramento River are reported to begin their upstream spawning migrations into freshwater during late February, prior to spawning between March and July, with peak spawning believed to occur between April and June (Adams et al. 2002). NMFS (2009) reports that based on recent data gathered from acoustically tagged adult green sturgeon, they migrate upstream as far as the mouth of Cow Creek on the Sacramento River. Poytress et al.

(2012) reported that green sturgeon spawning habitat has been confirmed within a 58-mile reach of the Sacramento River, extending from about RM 207 to RM 265. Heublein et al. (2009) observed that green sturgeon enter San Francisco Bay in March and April and migrate rapidly up the Sacramento River to the region between the Glenn Colusa Irrigation District (GCID) Hamilton City Pumping Plant and Cow Creek. Brown (2007) suggested that spawning in the Sacramento River can occur from April to June but may extend from late April through July, as indicated by RST data at the RBDD from 1994 to 2000. Green sturgeon spawning also has been documented in the Feather River (Seesholtz et al. 2015).

After spawning, some green sturgeon adults hold over in the upper Sacramento River between the RBDD and the GCID Hamilton City Pumping Plant until November (Klimley et al. 2007), whereas some adult green sturgeon rapidly leave the system following their suspected spawning activity and re-enter the ocean in early summer (Heublein 2006).

Little is known about the occurrence of green sturgeon in the Yolo Bypass although; at times their presence is known to coincide with that of white sturgeon (DWR 2016, as cited in DWR and Reclamation 2017). During flood flows in the Sacramento River system, upstream migrating adult green sturgeon are attracted by high flows in the Yolo and Sutter bypasses. Adults may become stranded behind the Fremont, Sacramento and Tisdale weirs, in splash basins, and in various scour pools downstream of the weirs as flows subside (Beccio 2016; Thomas et al. 2013). Although agency biologists conduct rescues when fish become stranded behind the weirs (CDFG 2011b; CDFW 2016c), monitoring of green sturgeon has shown that some of the rescued individuals appear to abort their spawning migrations (Thomas et al. 2013; CDFG 2011b; CDFW 2016c). Recurring stranding events might have substantial population-level impacts on green sturgeon (Thomas et al. 2013). Green sturgeon have never been observed in the 18-year history of DWR fyke trap operation in the Toe Drain of the Yolo Bypass downstream of Lisbon Weir (DWR 2016, as cited in DWR and Reclamation 2017).

Juvenile green sturgeon have been caught in traps at the RBDD and the GCID diversion in Hamilton City primarily during May through August, with peak counts reported during June and July (68 FR 4433). Juvenile emigration can reportedly extend through September (Environmental Protection Information Center et al. 2001). Juveniles appear to spend one to four years rearing in fresh and estuarine waters (Beamesderfer and Webb 2002; Moyle et al. 1995). The Yolo Bypass does not appear to be important habitat for juvenile green sturgeon (Opperman et al. 2017).

8.1.2.2.4 White Sturgeon

White sturgeon are a recreationally important species in the Central Valley. White sturgeon are regulated by CDFW through sport fishing regulations and designated as a California Species of Special Concern (CDFW 2016b). The number of adults within annual age classes is highly variable and appears to be the result of successful recruitment to the juvenile life stage; the adult population is dominated by a few strong year classes associated with high spring outflows (Moyle 2002).

White sturgeon reside in the brackish portions of estuaries of large rivers for much of their lives (Kohlhorst et al. 1991). Apparently triggered by photoperiod (Israel et al. 2011) and increases in river flow (Schaffter 1997), adult white sturgeon initiate their upstream migration into the lower Sacramento River from the Delta during late fall and winter (Kohlhorst and Cech 2001). Some mature adult white sturgeon move up the Sacramento River until they are concentrated near Colusa from March through May (Kohlhorst et al. 1991 as cited in Kohlhorst and Cech 2001).

Spawning typically occurs between February and June when water temperatures are 46 to 66 degrees Fahrenheit (°F) (Moyle 2002). White sturgeon typically spawn every three to four years; only a small percentage of the adult population spawns each season. It is believed that adults broadcast spawn in the water column in areas with swift current. Fertilized eggs sink and attach to the gravel, cobble, or bedrock substrates. Eggs reportedly hatch after four days at 61°F (Beer 1981) but can take up to two weeks at lower water temperatures (Pacific States Marine Fisheries Commission 1992).

Although exact spawning locations are unknown, white sturgeon are reported to likely spawn between Knights Landing (RM 90) and Colusa (RM 143) (CDFG 2002b and Shafter 1997, both as cited in Beamesderfer et al. 2004; Kohlhorst 1976; Moyle 2002), or several kilometers upstream of Colusa (Miller 1972, Kohlhorst 1976, and Schaffter 1997, all as cited in Israel et al. 2011). Vogel (2008) sampled adult sturgeon near the GCID Hamilton City Pumping Plant between 2003 and 2006 and sampled white sturgeon as far upstream as RM 165.

Recently hatched sturgeon larvae begin swimming in a vertical position, making them more susceptible to being carried downstream to the estuary (Wang 2010). Juvenile rearing and downstream movement can occur year-round. Juvenile presence in the Yolo Bypass has been observed in low abundances from December through February, with some presence coinciding with Fremont Weir overtopping (DWR 2016, as cited in DWR and Reclamation 2017).

Adult white sturgeon have been observed to migrate into the Yolo Bypass when there was no flow overtopping Fremont Weir, preventing them from reaching their upstream spawning grounds (Harrell and Sommer 2003). White sturgeon have been rescued from both the Tisdale and Fremont weirs and from the Tule Pond by CDFW personnel (CFDW 2016b). CDFW documented dead sturgeon in the Oxbow Pond in October 2016; these fish likely were stranded during the March 2016 Fremont Weir overtopping event.

DWR fyke trap efforts in the Toe Drain of the Yolo Bypass have observed adult white sturgeon presence from January through August, with peak presence between March and April (DWR 2016, as cited in DWR and Reclamation 2017).

8.1.2.2.5 Delta Smelt

The USFWS listed delta smelt as a threatened species under the ESA in March 1993 (58 Code of Federal Regulations 12854), and critical habitat for delta smelt has been designated within the Delta, Suisun Bay and several sloughs connected to the west Delta and Suisun Bay. In response to a petition to elevate the status of delta smelt from threatened to endangered under the ESA (Center for Biological Diversity et al. 2006), on April 7, 2010, USFWS ruled that the change in status from threatened to endangered was warranted but was precluded by other higher-priority listing actions (75 FR 17667). Delta smelt were listed as threatened under the CESA in 1993. In 2009, their status was elevated to endangered under CESA.

Delta smelt are endemic to the Estuary. Delta smelt are small, slender-bodied fish with a typical adult size of two to three inches (Moyle 2002). Delta smelt are euryhaline fish (can tolerate wide-ranging salinities) but rarely occur in waters with salinities greater than 7 parts per thousand (ppt) (Baxter et al. 1999); however, delta smelt have been documented in water with a salinity of up to 19 ppt and even seawater for short durations (Moyle et al. 2016). Similarly, delta smelt tolerate a wide range of water temperatures (observed at water temperatures from 42.8 to 82.4°F) (Moyle 2002). Delta smelt are typically found in Suisun Bay and the lower reaches of the Sacramento and San Joaquin rivers although they are occasionally collected within the Carquinez Strait and San Pablo Bay.

During the late winter and spring, delta smelt migrate upstream to spawn. Delta smelt spawning reportedly occurs from February through May, with embryo incubation extending through June (Wang 1986). They are thought to spawn in shallow fresh or slightly brackish waters in tidally influenced backwater sloughs and channel edgewaters (Wang 1986). Although most delta smelt spawning seems to take place at 44.6 to 59°F, gravid delta smelt and recently hatched larvae have been collected at 59 to 71.6°F (Moyle 2002). Females generally produce between 1,000 and 2,600 eggs (Bennett 2005), which adhere to vegetation and other hard substrates. Larvae hatch in 10 to 14 days (Wang 1986) and are planktonic (float with water currents) as they are transported and dispersed downstream into the low-salinity areas in the western Delta and Suisun Bay (Moyle 2002).

Delta smelt grow rapidly, with most smelt living only one year. Most adult smelt die after spawning in the early spring although they are capable of spawning multiple times during a season (Bennett 2005; Brown and Kimmerer 2001; Moyle 2002) and will continue to spawn if water temperatures remain favorable (Damon et al. 2016). Delta smelt initially feed entirely on zooplankton and may consume mysids and amphipods when they are larger (Slater and Baxter 2014; Feyrer et al. 2003). For the majority of their one-year lifespan, delta smelt inhabit areas in the western Delta and Suisun Bay characterized by salinities of about two ppt. Delta smelt occur in open surface waters and shoal areas (Moyle et al. 1992). Because delta smelt typically have a one-year lifespan, their abundance and distribution have been observed to fluctuate substantially within and among water year types. Delta smelt abundance appears to be reduced during either unusually dry years with exceptionally low outflows (e.g., 1987 through 1991), or unusually wet years, with exceptionally high outflows (e.g., 1982 and 1986).

Delta smelt populations have shown a long-term decline in the upper Estuary (the Delta and Suisun Bay), beginning with an abrupt decline in 1982 (Kimmerer 2002a) and extremely low abundance in recent years as part of the pelagic organism decline (Baxter et al. 2010; Sommer et al. 2007). The low abundance of delta smelt since the early 1980s is attributed to many interacting factors. These include larvae being swept downstream during high flows in the winter and spring of 1982 and 1983 (Kimmerer 2002a), the prolonged drought from 1987 to 1992 (Baxter et al. 2010), the extreme drought from 2013 through 2015 (USFWS 2017), entrainment in water diversions (Kimmerer 2008), declines in salinity and increases in water clarity for juveniles (Nobriga et al. 2008) and maturing individuals (Feyrer et al. 2007; Thomson et al. 2010), predation and competition from non-native species (Bennett 2005), and a decline in food resources (Miller et al. 2012).

Fisheries surveys indicate that delta smelt abundance has declined substantially in the Estuary since the 1970s and has been relatively low during most years since 2004 (CDFW 2016d). The 2016 delta smelt abundance index was the second-lowest in the history of the annual survey, which began in 1967 (CDFW 2016d).

Delta smelt have been captured during DWR’s Yolo Bypass sampling efforts primarily from January through June, with peaks in catch during February, March, May, and June

(DWR unpublished data). Most delta smelt captures occurred during RST surveys in the Tule Canal. Individuals captured averaged about 65 to 70 mm FL during January through March and about 40 to 55 mm during April through June (DWR unpublished data).

8.1.2.2.6 Longfin Smelt

Longfin smelt were listed as threatened under the CESA in 2009, and the San Francisco Bay-Delta DPS of longfin smelt was designated as a Federal candidate species by USFWS in 2012.

Longfin smelt are found in areas ranging from almost pure seawater upstream to areas of pure freshwater. In the Bay-Delta, they are most abundant in San Pablo and Suisun bays (Moyle 2002) and rarely observed upstream of Rio Vista in the Delta (Moyle et al. 1995).

Longfin smelt tend to inhabit the middle to lower portions of the water column and spend the early summer in San Pablo and San Francisco bays, generally moving into Suisun Bay in August. Most spawning occurs from February to April at water temperatures ranging from 44.6 to 58.1°F (Moyle 2002). Most longfin smelt live for up to two years although some age-three longfin smelt have been observed (CDFG 2009). Most adults die following spawning (CDFG 2009). Each female lays 5,000 to 24,000 adhesive eggs, a number that is considerably variable. Embryos hatch in about 40 days at 44.6°F (Moyle 2002). The buoyant newly hatched larvae (five to eight mm long) are swept downstream into the more brackish parts of the Estuary. High Delta outflow rates are thought to be positively correlated with longfin smelt survival as higher flows transport longfin smelt young to more suitable rearing habitat in Suisun and San Pablo bays (Moyle 2002).

Fisheries surveys indicate that longfin smelt abundance has declined in the Bay-Delta since the 1990s and has been relatively low during most years since 2001 (CDFW 2016d). The 2016 longfin smelt abundance index was the second-lowest in the history of the annual survey, which began in 1967 (CDFW 2016d).

Relatively few longfin smelt have been captured in DWR's Yolo Bypass sampling efforts, but they have been captured during January and April through June (DWR unpublished data).

8.1.2.2.7 River Lamprey

River lamprey are not listed under the ESA or the CESA although they are identified by CDFW as a California species of special concern (CDFW 2016b).

River lampreys generally have not been studied in California (Moyle 2002). Most of the available information on their life history is based on studies in British Columbia (UC Davis 2012).

Adult river lampreys migrate into freshwater during the fall and spawn during the winter or spring in small tributary streams although the timing and extent of their migration in California is poorly known (UC Davis 2012). Wang (1986) reported that adult river lampreys spawn from April to June in small tributary streams, whereas Moyle (2002) reported that river lampreys spawn during February through May. Adults create saucer-shaped depressions (redds) in gravel riffles in which to spawn (UC Davis 2012). River lampreys are semelparous (i.e., adults die after spawning).

River lamprey ammocoetes (i.e., larval lampreys) burrow into sandy or muddy substrates near river banks (Hart 1973 and Scott and Crossman 1973, both as cited in Wang 1986) and remain in silt-sand backwaters and eddies (UC Davis 2012). River lamprey ammocoetes also have been found in the Delta during dredging operations in the Stockton Deep Water Ship Channel and the Sacramento Deep Water Ship Channel (USACE 2012a). The ammocoete life stage is believed be about three to five years (Moyle 2002). During the final stages of metamorphosis, ammocoetes congregate immediately upriver from saltwater and enter the ocean during late spring (Moyle et al. 1995), which indicates that downstream migration of juveniles in the Sacramento River can occur during the winter through spring.

Based on studies of other lamprey species, presumably, adult river lampreys need clean gravel substrate in riffles in perennial streams for spawning, whereas the ammocoetes require sandy backwaters or stream edges in which to bury themselves where water quality is continuously good and water temperatures do not exceed 77°F.

The majority of river lamprey documented in the Yolo Bypass are juveniles caught in the RST during periods of high flow in the winter and spring. River lamprey have been observed in the Yolo Bypass between December and May, with peak presence in January (DWR 2016, as cited in DWR and Reclamation 2017).

8.1.2.2.8 Pacific Lamprey

Pacific lamprey are not listed under the ESA or the CESA although they are identified as a California species of special concern (CDFW 2016b). Pacific lamprey were petitioned for protection under the ESA in 2003, but USFWS determined that insufficient population information existed to warrant listing.

Adult Pacific lampreys typically migrate into freshwater streams between March and June (Moyle 2002), but upstream migrations have been observed during January and February (Entrix 1996 and Trihey and Associates 1996a, both as cited in Moyle 2002). Most upstream movement is reported to occur at night (Chase 2001 as cited in USFWS 2010; Moyle 2002).

Reportedly, spawning generally occurs between March and July (USFWS 2010). The spawning habitat requirements of Pacific lampreys have not been well studied, but it is believed that adults need clean gravel riffles to spawn successfully and have similar habitat requirements to those of salmonids (Moyle 2002; USFWS 2010). Moyle (2002) reported that, although historical spawning locations of Pacific lampreys are not known, they have been observed spawning in Deer Creek and likely could have migrated over 300 miles to spawn. Typically, spawning habitat is located near suitable ammocoete habitat, and low-to-moderate-gradient stream reaches with a mix of silt and cobble substrate are reported to be optimal spawning and rearing habitat (USFWS 2010).

Moyle (2002) reported that Pacific lamprey embryos hatch in about 19 days at 59°F. Eggs hatch into ammocoetes, spend a short time in the redd, and then drift downstream to suitable areas in sand, silt, or mud substrates (Moyle 2002; USFWS 2010). Typical ammocoete habitat includes areas of low velocity with muddy or sandy substrates into which they burrow where they can remain for about three to seven years. Although mostly sedentary during their freshwater residence, ammocoetes are reported to be able to move downstream when disturbed or during high-flow events (USFWS 2010).

Ammocoetes begin metamorphosis into macropthalmia (juveniles) when they reach 14 to 16 centimeters (cm) total length. Juveniles reportedly drift and swim downstream between late fall and spring (USFWS 2010). Others reported that downstream migration is associated with increased stream flows during the winter and spring (USFWS 2010 and the references therein). Based on RST survey data from water years 2004 through 2012 at the RBDD on the Sacramento River, the primary emigration period of Pacific lamprey macropthalmia ranged from November to May (Goodman et al. 2015). The median emigration date over the period of record was December 29 but ranged annually between December 4 and March 14 (Goodman et al. 2015). Juvenile life stages of lamprey (ammocoetes and macropthalmia) and adult lampreys are reported to stay close to the stream bottom during their migration periods. Juveniles also are reported to prefer low light conditions and migrate mostly during the night (Moursund et al. 2003 as cited in Chelan County Public Utility District 2006; Goodman et al. 2015).

Pacific lamprey have been observed in the Toe Drain of the Yolo Bypass between December and April, with peak presence occurring in February (DWR 2016, as cited in DWR and Reclamation 2017). Adults are occasionally found in the Yolo Bypass although the majority of RST catch is dominated by ammocoetes and macropthalmia during periods of increased flows in the winter and spring months (DWR 2016, as cited in DWR and Reclamation 2017).

8.1.2.2.9 Sacramento Splittail

USFWS removed Sacramento splittail from the list of threatened species on September 22, 2003 and did not subsequently identify it as a candidate for listing under the ESA. However, Sacramento splittail is identified as a California species of special concern (CDFW 2016b).

Sacramento splittail are native cyprinids (minnows) that occur in the Sacramento River and its major tributaries and are endemic to the Central Valley, with a range that centers on the San Francisco Bay Estuary. Sacramento splittail are adapted for living in estuarine waters with fluctuating conditions as well as in severe conditions that once occurred in alkaline lakes and sloughs on the floor of the Central Valley during droughts (Moyle 2002). Adults are normally found in relatively shallow water (less than 12 feet deep) in brackish tidal sloughs, such as Suisun Marsh, but can also occur in freshwater areas with either tidal or riverine flows (Moyle et al. 2004). Historically, Sacramento splittail were found as far up the Sacramento River as Redding yet today are largely absent from the upper parts of their historical range (Moyle 2002). It has been suggested that, during wet years, Sacramento splittail might migrate up the Sacramento River as far as the RBDD (Moyle 2002).

The normal lifespan of Sacramento splittail ranges from five to seven years (Caywood 1974; Meng and Moyle 1995). Adults can attain a length of over 300 mm (USFWS 1995).

Sacramento splittail spawning can occur anytime between late February and early July, but peak spawning occurs in March (Feyrer et al. 2006b). DWR (2004a) reported that Sacramento splittail spawning, egg incubation, and initial rearing in the Feather River occurs primarily during February through May. Sacramento splittail exhibit protracted gradual upstream migration in the winter to forage and spawn although some spawning activity has been observed in Suisun Marsh (Moyle 2002). Attraction flows are necessary to initiate migration onto floodplains where spawning occurs (Moyle et al. 2004). Spawning generally occurs in water with depths of three to six feet over submerged vegetation where eggs adhere to vegetation or debris until hatching (Moyle 2002; Wang 1986). Caywood (1974) reported that older fish are generally the first to spawn. Based on field observations and a review of Sacramento splittail thermal tolerance literature, DWR (2004a) concluded that water temperatures from 45 to 75°F are suitable for spawning.

Eggs normally incubate for three to seven days, depending on water temperature (Moyle 2002). After hatching, Sacramento splittail larvae remain in shallow weedy areas until water recedes, then they migrate downstream (Meng and Moyle 1995). The largest catches of Sacramento splittail larvae occurred in 1995, a wet year when outflow from inundated areas peaked during March and April (Meng and Matern 2001).

Juvenile Sacramento splittail prefer shallow-water habitat with emergent vegetation (Meng and Moyle 1995). Snorkel surveys conducted in a managed wetland in the Yolo Bypass found that young Sacramento splittail juveniles (mean 21 mm FL) were strongly associated with habitats located relatively close to the edge of wetland, emergent terrestrial vegetation, and submerged aquatic vegetation during the day (Sommer et al. 2008b). At night, young juveniles moved to deeper areas with submerged terrestrial vegetation and tule stands. Most larger juveniles (mean 41 mm FL) were observed in deeper offshore areas and exhibited benthic behavior at night (Sommer et al. 2008b). Sommer et al. (2002) reported that during wetter years juvenile Sacramento splittail are abundant in the Yolo Bypass floodplain in the shallowest areas of the wetland with emergent vegetation. Downstream movement of juvenile Sacramento splittail appears to coincide with drainage from the floodplains between May and July (Caywood 1974; Meng and Moyle 1995; Sommer et al. 1997).

Floodplain inundation in the Yolo Bypass during March and April appears to be the primary factor contributing to Sacramento splittail abundance. Moyle et al. (2004) reported that moderate-to-strong year classes of Sacramento splittail develop when floodplains are inundated for six to 10 weeks between late February and late April. Reportedly, when floodplains are inundated for less than a month, strong year classes are not produced (Sommer et al. 1997). Sommer et al. (1997) discussed the resiliency of Sacramento splittail populations and suggested that, because of their relatively long lifespan, high reproductive capacity, and broad environmental tolerances, their populations can recover rapidly even after several years of drought conditions. Despite downward trends in total population size during periods of drought, Moyle et al. (2004) reported that the ability of at least a few Sacramento splittail to reproduce under the least suitable hydrologic conditions ensures the population will persist.

Juvenile abundance in the Yolo Bypass peaks between May and June (DWR 2016, as cited in DWR and Reclamation 2017; Meng and Moyle 1995; Sommer et al. 1997).

8.1.2.2.10 Hardhead

Hardhead, a California species of special concern (CDFW 2016b), is a large, native cyprinid that is widely distributed throughout the Sacramento-San Joaquin river system although it is absent from the valley reaches of the San Joaquin River (Moyle 2002).

Hardhead generally occur in large, undisturbed low-to-mid-elevation rivers and streams of the region (Moyle 2002). Hardhead mature during their third year and often make spawning migrations into smaller tributary streams during the spring (Moyle 2002). Most hardhead spawning is reportedly restricted to foothill streams (Wang and Reyes 2007) primarily during April and May (Grant and Maslin 1999; Moyle 2002). However, spawning might occur into July in Sacramento River tributaries and into August in San Joaquin River tributaries (Wang and

Reyes 2007). Estimates based on juvenile recruitment suggest that hardhead spawn by May and June in Central Valley streams (Wang 1986). Spawning behavior has not been documented, but hardhead are believed to mass spawn in gravel riffles (Moyle 2002). Hardhead forage at the bottoms of deep pools for aquatic insects, occasionally taking drifting insects on the surface (Moyle 2002).

Although they occupy the Yolo Bypass, hardhead have not been consistently observed in substantial numbers in any of DWR's Yolo Bypass sampling efforts dating back to 1998 (DWR 2016, as cited in DWR and Reclamation 2017). They have only been observed in six of the years between 1998 and 2016, with eight individuals being the maximum number observed in a single year (2011). Hardhead are likely year-long residents in the Yolo Bypass as they have been documented in the Yolo Bypass every month that sampling occurs (DWR 2016, as cited in DWR and Reclamation 2017).

8.1.2.2.11 Sacramento Hitch

Sacramento hitch, a California species of special concern (CDFW 2016b), were historically found throughout the Sacramento and San Joaquin valleys in low elevation streams and rivers as well as in the Delta (Brown 2000). Although Sacramento hitch appear to be spread across much of their native range, populations are scattered relative to historical conditions and are only found in a few localities and in relatively low numbers (Moyle 2002; May and Brown 2002).

Sacramento hitch have high temperature tolerances; fish acclimated to 30 degrees Celsius (°C) can survive water temperatures up to 38°C for short periods of time although they are usually most abundant in waters cooler than 25°C during the summer (Moyle 2002). They most commonly inhabit warm, lowland waters, including clear streams, turbid sloughs, lakes, and reservoirs (Moyle et al. 2015). In streams, they are generally found in pools or runs among aquatic vegetation, and in lakes, adults occupy open waters (Moyle et al. 2015).

Spawning takes place over gravel riffles at temperatures ranging from 14 to 26°C, but spawning can also occur on aquatic vegetation (Moyle 2002). Spawning may begin in February, generally in response to an increase in flow associated with spring runoff, and may end as late as July (Moyle et al. 2015). Fertilized eggs sink into gravel interstices before absorbing water and then swell to become lodged in the gravel. Hatching takes place in three to seven days, and larvae become free-swimming in another three to four days (Moyle et al. 2015).

Relatively few Sacramento hitch have been caught in DWR's Yolo Bypass sampling efforts. The largest number of Sacramento hitch caught (52) in one year occurred in 2011 (DWR unpublished data). Most individuals captured appear to have been juveniles. Therefore, it is not expected that the Yolo Bypass is an important spawning area for Sacramento hitch.

8.1.2.2.12 Sacramento Pikeminnow

Although the native Sacramento pikeminnow is not considered a special-status or commercially important species, this species can prey on listed juvenile salmonids in the study area. Therefore, Sacramento pikeminnow is discussed below and included as a fish species of focused evaluation in this EIS/EIR.

Sacramento pikeminnow are large native predatory cyprinids found throughout the Sacramento-San Joaquin river system. They are most prevalent in low- to mid-elevation streams with deep pools, slow runs, undercut banks, and overhanging vegetation (Moyle 2002). Sacramento pikeminnow begin spawning as early as April and continue through July (Moyle 2002). Fish from large rivers or reservoirs usually move into small tributaries to spawn, whereas fish resident in small- to medium-sized streams typically move into the nearest riffle (Moyle 2002).

Sacramento pikeminnows are opportunistic predators, and their predation on juvenile salmonids appears to be correlated with human-made changes to a natural free flowing riverine channel. Obstructions that cause Sacramento pikeminnows to congregate in the presence of outmigrating juvenile salmonids appear to increase the incidence of predation. A study on the predation of juvenile salmonids at the RBDD found that juvenile salmonids were not a significant food source of Sacramento pikeminnows when the gates were configured to create a free-flowing riverine environment (Tucker et al. 1998). However, when the gates were in place at the RBDD, juvenile salmonids accounted for 66 percent of the total weight of stomach contents for Sacramento pikeminnows, more than twice the weight of other fish species (Tucker et al. 1998).

DWR’s Yolo Bypass sampling efforts have captured Sacramento pikeminnow primarily during January through June; with peaks in catch during February through April (DWR unpublished data).

8.1.2.3 Non-native Species

8.1.2.3.1 Overview of Non-native Fish Species in the Yolo Bypass

Discussed below are non-native fish species of focused evaluation that have been documented in the Yolo Bypass study area. These species include recreationally important non-native species and non-native species that are known to interact with juvenile salmonids and other native fish species through predation and/or competition.

8.1.2.3.2 American Shad

American shad occur in the Sacramento River, its major tributaries, the San Joaquin River, and the Delta. Because of its importance as a sport fish, American shad has been the subject of investigations by CDFW. American shad are native to the Atlantic coast and were planted in the Sacramento River in 1871 and 1881 (Moyle 2002).

Adult American shad typically enter Central Valley rivers from April through early July (CDFG 1986), with most immigration and spawning occurring from mid-May through June (CDFG 1987). Spawning takes place mostly in the main channels of rivers, and generally about 70 percent of the spawning run is made up of first-time spawners (Moyle 2002). When suitable spawning conditions are found, American shad school and broadcast their eggs throughout the water column. Based on the capture of juveniles, Harrell and Sommer (2003) suggested that American shad might spawn in the Toe Drain although a tidal slough is not believed to be preferred American shad spawning habitat (Harrell and Sommer 2003). Peak abundance of shad in the Yolo Bypass has been correlated with higher water temperature, which is generally linked to their upstream migration (Sommer et al. 2014), and might not necessarily indicate presence in the Yolo Bypass during high-flow events when juvenile salmonids might be present.

Water temperature is an important factor influencing the timing of spawning. American shad are reported to spawn at water temperatures ranging from 46 to 79°F (USFWS 1967) although optimal spawning temperatures are reported to range from 60 to 70°F (Leggett and Whitney 1972; Painter et al. 1979; Rich 1987). Eggs hatch in six to eight days at 62°F; at temperatures near 75°F, eggs reportedly hatch in three days (MacKenzie et al. 1985). Egg development and hatching, therefore, are coincident with the spawning period.

Some young shad move downstream into brackish water soon after hatching, but large numbers reportedly remain in freshwater through November when they are five to six months old (CDFG 2010a). Some juvenile American shad rear in estuaries for one to two years before migrating to the ocean, but most American shad migrate directly to the ocean after transforming from larvae to juveniles, which occurs about four weeks after hatching (UC Davis 2015). Juvenile American shad can occur in the Sacramento River year-round (Moyle 2002).

Concern has been expressed regarding the potential impacts of American shad on juvenile salmonid populations. Dietary overlaps between American shad and juvenile salmonids are the primary factor of concern and are cited as evidence of interspecific competition. However, American shad numbers have declined considerably from peak levels in the early 1990s (Stouder et al. 1997; CDFW 2016d).

8.1.2.3.3 Striped Bass

Striped bass occur in the Sacramento River, its major tributaries, and the Delta but spend most of their lives in the San Francisco Estuary. Because of its importance as a sport fish, striped bass has been the subject of investigations by CDFW. Substantial striped bass spawning and rearing occurs in the Sacramento River and Delta; however, striped bass can typically be found upstream as far as barrier dams (Moyle 2002). Striped bass are native to the Atlantic coast and were first introduced to the Pacific coast in 1879 when they were planted in the San Francisco Estuary (Moyle 2002).

Adult striped bass are present in Central Valley rivers throughout the year, with peak abundance occurring during spring (CDFG 1971; DeHaven 1979). The presence of striped bass in the Yolo Bypass has been documented from November through June (Harrell and Sommer 2003). Adult striped bass are reported to prefer water temperatures from 68 to 75.2°F (Emmett et al. 1991).

Striped bass spawn in water temperatures ranging from 59 to 68°F (Moyle 2002). Therefore, spawning can begin in April but peaks in May and early June (Moyle 2002). In the Sacramento River, most striped bass spawning is believed to occur between Colusa and the mouth of the Feather River. In years of higher flow, spawning typically occurs farther upstream than usual because striped bass continue migrating upstream while waiting for temperatures to rise (Moyle 2002). Adult and juvenile striped bass have been caught in the Yolo Bypass between November and June (Harrel and Sommer 2003; Sommer et al. 2014). Because of the high numbers of juveniles caught, it is suggested that adults might use the Toe Drain to spawn (Harrell and Sommer 2003).

Egg survival requires a sufficiently strong current to keep the eggs suspended in the water column. After fertilization, eggs hatch within two to three days, followed by a net movement of the larval fish to downstream, tidal portions of the river (Moyle 2002). Striped bass larvae are generally distributed in the Delta or Suisun Bay, depending on flow through the Estuary. During lower-flow years, striped bass eggs and larvae are generally found in the Delta, whereas during higher-flow years, eggs and larvae are transported downstream into Suisun Bay (Hassler 1988).

The number of striped bass entering Central Valley streams during the summer is believed to vary with flow levels and food production (CDFG 1986). Sacramento River tributaries can be nursery areas for young striped bass (CDFG 1971, 1986). Juvenile and sub-adult fish historically have been reported to be abundant in the lower American River and lower Yuba River during the fall (DeHaven 1977, as cited in DeHaven 1979). Optimal water temperatures for juvenile striped bass rearing have been reported to range from 61 to 71°F (Fay et al. 1983).

The predation impact of striped bass on juvenile salmonids has been well documented, as summarized below by CDFG (2011a):

> By virtue of their abundance, habits, and size, predation by striped bass has been implicated as a substantial contributor to the poor survival of young salmon used in experiments to estimate reach- and site-specific survival rates through the Delta and in the Sacramento River (see CDFW 2011a for references). By plausible extension, listed salmon (and steelhead) also suffer poor survival rates due to predation, including predation by striped bass.

Fisheries surveys in the Bay-Delta indicate that the abundance of juvenile (age 0) striped bass has declined since the 1970s and 1980s and has remained relatively low since 2002 (CDFW 2016d).

8.1.2.3.4 White Catfish

White catfish are native to the rivers of the Atlantic coastal states from Florida to New York. The species is found in sluggish, mud-bottomed pools, open channels, backwaters of small to large rivers and in lakes and impoundments. In rivers, white catfish prefer depths of greater than two meters during the day and move to shallow vegetated areas at night (UC Davis 2017). White catfish can be found in salinities of up to 14.5 ppt and prefer water temperatures above 20°C (68°F) (UC Davis 2017). White catfish spawn between June and September near vegetated or rocky areas when water temperatures are greater than 21°C (69.8F°) (UC Davis 2017).

White catfish have been collected year-round by the Yolo Bypass Fish Monitoring Program (Sommer et al. 2014) and are consistently the most abundant predatory fish collected during fyke trap operations in the Yolo Bypass (Mahardja et al. 2016). White catfish have been reported to predate on native fish species, including Chinook salmon, delta smelt, and Sacramento splittail (Grossman 2016).

8.1.2.3.5 Warm Water Game Fish

Largemouth Bass

Largemouth bass are not listed as threatened or endangered under the ESA or the CESA and are not a Federal species of concern or a State species of special concern. However, largemouth bass are a recreationally important species throughout California and are regulated by CDFW. Largemouth bass are a piscivorous species known to prey on juvenile salmonids in the Delta and portions of the Yolo Bypass.

Warm, shallow waters (less than six meters (m), or about 20 feet, deep) of moderate clarity and beds of aquatic plants are preferred habitat of largemouth bass (Moyle 2002). They are common in river backwaters and streams with large pools or ponds with dense aquatic vegetation. Stream populations are often maintained by continuous colonization from upstream sources, usually farm ponds or reservoirs (Moyle 2002). Optimal water temperatures for largemouth bass are 25 to 30°C (77 to 86°F) though largemouth bass can survive in a much wider range of temperatures.

Largemouth bass begin to spawn when water temperatures reach 15 to 16°C (59 to 61°F), which usually occurs from April through June (Moyle 2002). Nests are generally shallow depressions up to one m (3.28 feet) in diameter created by males in sand, gravel, or debris-littered bottoms at depths of 0.5 to two m (1.6 to 6.6 feet) (Moyle 2002).

Largemouth bass are solitary predators and exhibit both ambush and pursuit methods of capturing prey. Prey items are generally determined by size, with smaller juvenile bass feeding primarily on aquatic and terrestrial insects and small crustaceans and larger adult bass feeding on fish, frogs, and crayfish.

Smallmouth Bass

Smallmouth bass are not considered a special-status species. However, smallmouth bass are a recreationally important species throughout California and are regulated by CDFW. Smallmouth bass are a piscivorous species known to prey on juvenile salmonids.

Smallmouth bass are not native to California but have been introduced into suitable waters throughout the State. Smallmouth bass prefer streams with abundant cover, such as rocky bottoms and overhanging trees with water temperatures ranging from 20 to 27°C (68 to 81°F) (Moyle 2002). In streams, spawning takes place from May to July once water temperatures reach 13 to 16°C (55 to 61°F) (Moyle 2002). Males build nests or “beds” on rubble, gravel, or sandy bottoms at a depth of around one meter (Moyle 2002). Females deposit eggs within the nest, and fry emerge around one to two weeks later.

Smallmouth bass fry feed mainly on crustaceans and aquatic insects until they reach three to five centimeters (1.2 to two inches) total length when larger prey, especially crayfish and fish, start becoming more important. Larger prey rarely dominates the diet until the bass measure 10 to15 cm (four to six inches) total length (Moyle 2002).

Spotted Bass

Spotted bass are not considered a special-status species. However, spotted bass are a recreationally important species throughout California and are regulated by CDFW. Spotted bass are a piscivorous species that is known to prey on juvenile salmonids.

Spotted bass in streams are pool dwellers and avoid riffles and backwaters with heavy growth of aquatic plants (Moyle 2002). Spotted bass prefer slower and more turbid water than do smallmouth bass and favor faster water than do largemouth bass (Moyle 2002). Spawning and feeding characteristics are similar to those of smallmouth and largemouth bass, as discussed above.

8.1.3 Floodplain Processes and Ecology

8.1.3.1 River-Floodplain Ecological Frameworks

Generally, floodplains are low-gradient features adjacent to river channels that are subject to lateral inundation by high flows. Floodplains can provide conditions that support relatively higher biodiversity and productivity relative to conditions in river channels (e.g., Tockner and Stanford 2002; Junk et al. 1989; Opperman et al. 2009; Opperman et al. 2010; Jeffres et al. 2008; Killgore and Miller 1995).

Opperman et al. (2017) reviewed previously developed frameworks applicable to river-floodplain ecology, including the River Continuum Concept (Vannote et al. 1980), the Flood Pulse Concept (Junk et al. 1989), the Shifting Habitat Mosaic (Stanford et al. 2005), the Riverine Productivity Model, and the River Wave Concept. The River Continuum Concept suggests that productivity of large rivers is derived from upstream sources; confined rivers with minimal floodplains have been shown to conform relatively well to this concept, whereas rivers with extensive floodplains do not conform as well (Opperman et al. 2017).

Junk et al. (1989) developed the Flood Pulse Concept, which recognizes the absence of floodplains in the River Continuum Concept (Opperman et al. 2017) and proposes that periodic inundation and drought (flood pulse) is the driving force in the river-floodplain system. Junk et al. (1989) hypothesized that "*in unaltered large river systems with floodplains in the temperate, subtropical, or tropical belt, the overwhelming bulk of the riverine animal biomass derives directly or indirectly from production within the floodplains*." Opperman et al. (2017) described three ways in which river-floodplain connectivity increases production for organisms in the system under this concept: 1) during floodplain inundation, the expanding edge of the water allows for increased access to food resources in a larger area – referred to by Junk et al. (1989) as the “aquatic-terrestrial transition zone;” 2) when the floodplain is inundated for a sufficient period of time, the floodplain becomes a highly productive area due to autochthonous production[2] and from decomposition of terrestrial vegetation; and 3) the transportation of carbon, nutrients, materials and organisms from the floodplain back into the river as the floodplain drains. The Flood Pulse Concept has been verified in relatively natural large tropical river-floodplain systems (Junk 1982; Junk et al. 1989; Koponen et al. 2010). For example, the most productive fishery in the world, in the Mekong River Basin (Baran 2010), is dependent on processes associated with the seasonal flood pulse and inundation of a large floodplain lake (Koponen et al. 2010).

Some authors have noted that the Flood Pulse Concept proposed by Junk et al. (1989) has not been as thoroughly evaluated for highly altered temperate river systems (Schramm and Eggleton 2006; Alford and Walker 2013). For example, studies conducted in some altered temperate floodplain systems found that floodplain inundation increased productivity and abundance of some fish species but not others or that floodplain inundation increased population abundance of some fish species only under particular conditions (Schramm and Eggleton 2006; Alford and Walker 2013). However, although the application of some aspects of the Flood Pulse Concept

[2] Photosynthesis by plants such as phytoplankton (microscopic plants that inhabit upper layers of water bodies), periphyton (mixture of algae and other organisms attached to submerged surfaces), and aquatic macrophytes (aquatic plants that grow in or near water)

outside of tropical systems has been questioned, the general theory that the flood pulse provides an advantage to fish species has been confirmed in many temperate settings (e.g., Sommer et al. 2001c) (Opperman et al. 2017).

In an update to the concepts proposed by Junk et al. (1989), Junk and Wantzen (2004) noted that although the flood pulse is the driving force in river-wetland systems in humid tropical areas, there are additional driving forces that affect organisms and floodplain processes in the lower latitudes (Junk and Wantzen 2004). In temperate regions, the timing of the flood pulse and associated light and/or temperature regime may determine the associated biological effects (Junk et al. 1989; Junk and Wantzen 2004).

Similar to the Flood Pulse Concept, the Shifting Habitat Mosaic concept also focuses on floodplains but instead describes river ecosystems based on how hydrologic processes create, maintain and change diverse patches of habitat across longitudinal (upstream to downstream), lateral (channel and floodplain interactions), and vertical (groundwater and surface water exchange) dimensions on a floodplain (Stanford et al. 2005; Opperman et al. 2017). A conceptual model developed for Central Valley floodplains (Opperman 2012) includes aspects of both the Flood Pulse Concept (i.e., processes that occur during inundation events) and the Shifting Habitat Mosaic concept (i.e., processes that develop and maintain the floodplain) (Opperman et al. 2017).

The Riverine Productivity Model (Thorp and Delong 1994) states that even though the total ecosystem carbon is dominated by detritus from upstream sources, the riverine food webs are driven by local autochthonous production and direct inputs from the riparian zone, including periods outside of the inundation period (Opperman et al. 2017). Thorp and Delong (2002 as cited in Opperman et al. 2017) emphasized the role of autochthonous production by algae and de-emphasized the importance of riparian inputs.

The River Wave Concept (Humphries et al. 2014) proposed that previously developed frameworks, including the River Continuum Concept, the Flood Pulse Concept, and the Riverine Productivity Model, together can explain the source of organic matter and the characteristics of storage, conversion, and movement of material and energy in the river. The River Wave Concept also hypothesizes that each of the three frameworks is relatively more applicable during different hydrologic “waves” or phases—at the wave troughs (i.e., baseflow or low flows), local autochthonous and allochthonous[3] inputs are the primary sources of production (Riverine Productivity Model); on the ascending or descending limbs of waves (i.e., rising or falling hydrographs), the primary sources of production are upstream allochthonous inputs (River Continuum Concept); and as waves rise to crests (i.e., flood flows), increases in production are sourced from the floodplain (Flood Pulse Concept) (Humphries et al. 2014).

As summarized by Opperman et al. (2017), these river-floodplain conceptual frameworks all emphasize the importance of the hydrology and connectivity for maintaining flood processes and the ecosystem benefits provided by these processes.

[3] Sources of production from outside of the floodplain

8.1.3.2 Floodplain Productivity

8.1.3.2.1 Primary Production

Food webs[4] on the floodplain are supported by carbon produced by plants on the floodplain (autochthonous inputs) and from external (allochthonous) sources. Internal sources of carbon include phytoplankton, aquatic macrophytes, and emergent plants that grow on the floodplain following inundation (Opperman et al. 2017). External sources include material from the upstream river, floodplain forests, and other terrestrial vegetation that grows on or adjacent to the floodplain when it is not inundated (Opperman et al. 2017). For example, floodplains have been shown to contribute nutrients to the system by releasing nutrients deposited during previous flood events (Junk et al. 1989; Schonbrunner et al. 2012). The relative importance of algae and plant matter to the floodplain food web may shift, depending on flow and turbidity conditions, with detrital carbon becoming more important during periods of high flow and high turbidity (Opperman et al. 2017). However, in most floodplain systems, algae are the primary contributor to the food web, despite the dominant presence of living and detrital plant matter (reviewed by Opperman et al. 2017).

The productivity of algae is regulated by four primary factors—light, nutrients, grazing by zooplankton, and hydrology (Opperman et al. 2017). Algae production is generally greater during spring or summer due to higher light levels (and increased temperatures) and is stimulated by higher levels of dissolved nutrients in the water. Zooplankton grazing pressure can reduce the amount of phytoplankton on the floodplain under conditions that allow zooplankton to persist (when water velocities are low and residence time[5] is high) (Grosholz and Gallow 2006).

Flow is the most important variable that affects the algal community during an inundation event (Opperman et al. 2017). For example, fast growing and smaller species of phytoplankton that are adapted to higher velocity and turbid environments were found during the initial period of inundation of the Yolo Bypass; as flows decreased and residence time of the water increased, the species composition shifted to larger species (Sommer et al. 2004). In the Yolo Bypass and Cosumnes River floodplains, concentration of chlorophyll *a* (an indicator of phytoplankton productivity) was positively correlated with residence time of water on the floodplain (Schemel et al. 2004; Ahearn et al. 2006). In addition, phytoplankton biomass has been shown to be highest during the draining phase of the floodplain (i.e., after there is no longer inflow to the floodplain) as water velocity decreases and residence time, water temperature, and water clarity all increase (Ahearn et al. 2006; Grosholz and Gallo 2006; Sommer et al. 2004; Opperman et al. 2017). In the Yolo Bypass, residence time can range from five days to four weeks (Opperman et al 2017). Recent research indicates that aquatic macrophytes are relatively minor contributors to carbon in floodplain food webs, but they can provide shelter and structure for periphyton, invertebrates, and fish (Opperman et al. 2017).

Production of phytoplankton has been found to increase substantially in the Yolo Bypass when it is inundated compared to adjacent Sacramento River locations (Lehman et al. 2007). During the

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[4] A system of interconnected food chains (linear networks of organisms dependent on one another as a source of food)

[5] The rate at which water moves through the floodplain

summer and fall, agricultural discharge into the Yolo Bypass can result in increased productivity in the Toe Drain and downstream in the estuary, potentially improving food production for delta smelt (Frantzich and Sommer 2015).

8.1.3.2.2 Secondary Production

Zooplankton and other invertebrates are the primary linkages between primary productivity and fish (Kreckeis et al. 2003 as cited in Opperman et al. 2017). Zooplankton productivity has been shown to be determined by the availability of carbon from algae, even where carbon from detritus dominates the available carbon (Muller-Solger et al. 2002; Jassby et al. 2003). Grosholz and Gallo (2006) observed peaks in zooplankton biomass on the Cosumnes River floodplain two to three weeks after the floodplain disconnected from the river (i.e., during the draining phase). Zooplankton can be displaced from the floodplain during flood events but can apparently quickly recolonize afterward (see Opperman et al. 2017). Abundance of zooplankton on natural floodplains can be substantially higher relative to the adjacent river, as found in the Cosumnes River (Grosholz and Gallo 2006). However, in the Yolo Bypass, zooplankton abundance was not significantly different from that observed in the Sacramento River (Sommer et al. 2004).

The distribution of aquatic invertebrates is influenced by the floodplain's hydrologic characteristics, and their productivity has been found to be higher on floodplains than in adjacent rivers (see Opperman et al. 2017). Floodplains also provide various habitat features, such as floating and emergent plants, floating algal mats, and large wood, that can promote the abundance of invertebrates (Opperman et al. 2017).

Although zooplankton (mainly small crustaceans, including cladocerans and copepods) are an important food source for juvenile Chinook salmon in the Yolo Bypass (Sommer et al. 2001c), it is currently understood that juvenile Chinook salmon in the Yolo Bypass mainly consume insects belonging to the order Diptera (true flies), primarily within the family Chironomidae (non-biting midges) (Sommer et al. 2001c). However, juvenile Chinook salmon in an artificial flooded rice field in the Yolo Bypass primarily fed on zooplankton (Katz et al. 2017). Chironomid larvae are reported to be a particularly important food source for juvenile salmonids during the winter due to the scarcity of other food sources during this time (Sommer et al. 2001c) and have been found to be more abundant in the Yolo Bypass relative to the Sacramento River (Sommer et al. 2004). Chironomid larvae (as well as cladocerans) also are an important food source for larval and small juvenile Sacramento splittail (Moyle et al. 2004). Little currently is known about the feeding behavior of steelhead in the Yolo Bypass (Reclamation and DWR 2012), but chironomids and zooplankton have been found in the diets of post-yearling steelhead in other systems such as the Mokelumne River (Merz 2002).

Benigno and Sommer (2008) found that floodplain sediment is an important source of the initial peak of chironomic abundance in in the Yolo Bypass and that it took at least 14 days of inundation for dominant chironomid species in the Yolo Bypass to mature into the life stages that could be used as a food source for fish. However, Benigno and Sommer's (2008) observation was made under laboratory conditions and may not reflect the timing under actual conditions in the Yolo Bypass (Reclamation and DWR 2012). Also, Benigno and Sommer's (2008) field observations during the winter may not reflect actual temporal patterns because the dominant macroinvertebrate taxa may change over time after floodplain inundation (Benigno and Sommer 2008; Grosholz and Gallo 2006) and may differ based on hydrologic conditions (Reclamation and DWR 2012). For example, Sommer et al. (2004) reported that chironomids were less abundant in a drier year than in wetter years.

In an experimental flooded rice field in the Yolo Bypass, productivity was found to increase dramatically, producing up to 100 times more zooplankton and invertebrates than adjacent river channels (Katz et al. 2013). In another study, experimental agricultural fields in the Yolo Bypass had 150 times or greater zooplankton and cladoceran densities during the study period compared to the Sacramento River (Corline et al. 2017). However, flooded rice fields in the Yolo Bypass are unique compared to natural flooding events as they receive inundation water from highly productive agricultural canals and are inundated in the summer and winter (Corline et al. 2017).

8.1.3.2.3 Downstream Productivity

Flood pulses can result in increased productivity in the floodplain, which can be “exported” to downstream waterbodies (reviewed by Opperman et al. 2017). Despite this potential source of productivity, current conditions during major flood pulses in the Yolo Bypass may not be conducive to providing the maximum beneficial impact to downstream reaches of the Delta (Opperman et al. 2017).

In the Yolo Bypass floodplain, inundation results in increased wetted area and improved conditions for phytoplankton production (Schemel et al. 2004). However, substantial increases in phytoplankton production appear to be limited by inflows from tributary streams and on a larger scale by the hydrologic conditions of the draining period of the flood pulse cycle (Lehman et al. 2007; Schemel et al. 2002; Schemel et al. 2004). The importance of the draining period on productivity has been supported by several studies, which observed that chlorophyll *a* concentrations remained relatively low until Fremont Weir was no longer overtopping and the draining phase had begun (Lehman et al. 2007; Schemel et al. 2002; Schemel et al. 2004). These studies also concluded that chlorophyll *a* concentrations in the Yolo Bypass were higher than in comparable sampling locations in the Sacramento River. From January to June 2003, Lehman et al. (2007) concluded that 14 percent of the chlorophyll *a* in the lower Sacramento River originated from the Yolo Bypass, despite only accounting for three percent of the total flow re-entering the river at this point. Additionally, this increase in chlorophyll *a* was attributed to the accumulation of diatoms and green algae, the former of which serves as a high-quality food source for primary consumers in the aquatic food web (Lehman et al. 2007).

One limitation of these aforementioned studies is that contributions of chlorophyll *a* concentrations were inferred based on direction and percentage of flow from upstream sampling locations in the Yolo Bypass and Sacramento River. More recent studies provide evidence of the exportation of primary production in the Yolo Bypass to sampling locations in the lower Sacramento River. Specifically, Fall Low Salinity Habitat studies conducted in 2011 and 2012 included data from sampling locations in the Cache Slough Complex (CSC) and Sacramento River at Rio Vista where Yolo Bypass flood water is discharged (Frantzich and Sommer 2015). The Fall Low Salinity Habitat study measured a large phytoplankton bloom in the lower Sacramento River, following two agricultural flow pulses in the Yolo Bypass. The Cache Slough Complex and Yolo Bypass were determined to be the major source of the bloom, based on increased levels of chlorophyll *a* in both the CSC and Yolo Bypass and no observed increase in the Sacramento River upstream of Rio Vista (Frantzich and Sommer 2015). These flow pulses allowed for a real-time comparison of the movement of water through the Yolo Bypass and increased levels of chlorophyll *a* and productivity observed downstream at Rio Vista.

Water exiting the Yolo Bypass has been hypothesized to be an important source of nutrients for the estuary to increase food resources for estuarine fishes and other organisms. Jassby and Cloern (2000) estimated that, based on the relative amount of water discharging from the Yolo Bypass, effects of inundating the Yolo Bypass on Bay-Delta productivity are likely minor during the winter and negligible in other seasons, except potentially during wet years. However, even during wet winters, the effect of transporting organic matter downstream would be lessened due to shorter residence times through the Bay-Delta (Jassby and Cloern 2000). Under the existing infrastructure and hydrology of the Yolo Bypass, major inundation periods typically occur during the wet winter period when high flows in the Sacramento River result in overtopping at Fremont Weir and, in some extreme years, the Sacramento Weir (Sommer et al. 2001b). Consequently, high-flow conditions and low residence times in the lower Sacramento River lessen the beneficial impacts of primary and secondary productivity that is transported downstream from the Yolo Bypass (Jassby and Cloern 2000). Schemel et al. (2004) noted that although phytoplankton-rich water from the Yolo Bypass may be limited to brief periods of time during late winter and spring, these discharges may deliver food resources to nutrient-poor areas of the Delta. Moreover, multiple flooding and draining sequences within the Yolo Bypass may produce more phytoplankton for export to the Delta relative to a single flooding event (Schemel et al. 2004).

Based on a review of the available information relating to the exportation of phytoplankton and zooplankton from the Yolo Bypass to the Bay-Delta, Gray et al. (2014, p. 337) stated that "Our analysis shows no evidence that the open waters of the estuary receive a detectable subsidy of phytoplankton or zooplankton." However, Opperman et al. (2017, p.189) stated that "…active management of Bypass flooding – controlling timing, duration, and frequency of inundation – could greatly increase its contribution to downstream productivity. For example, managed flooding of the Bypass could promote a series of relatively short pulses with long draining times that would produce pulses of productivity to the Delta."

8.1.3.3 Fisheries Habitat and Productivity

8.1.3.3.1 Floodplain Habitat Utilization

Moyle et al. (2007) classified fishes found on the seasonal floodplain in the Cosumnes River and connected sloughs into six user groups: floodplain spawners, river spawners, floodplain foragers, floodplain pond fishes, inadvertent floodplain users, or floodplain nonusers. Descriptions of each group are summarized from Moyle et al. (2007) below.

Floodplain Spawners – Fish that use the floodplain for spawning and initial juvenile rearing; adults migrate onto the floodplain as water levels are rising or stable and spawn on flooded substrate, and juveniles leave the floodplain as it is draining. Floodplain spawners include obligate spawners[6] and opportunistic spawners[7]. Sacramento splittail is an obligate floodplain

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[6] Typically require floodplain-type habitat to successfully spawn

spawner; opportunistic floodplain spawners include common carp, goldfish, largemouth bass, and sunfishes. For floodplain spawners, the minimum duration of inundation must be sufficiently long to encompass spawning and juvenile rearing to a stage that allows them to leave the floodplain as it drains (Opperman et al. 2017).

River Spawners – Fish that spawn in rivers upstream of floodplains and can rear as juveniles on floodplains. The growth and survival advantage provided by floodplains to the juvenile life stage may vary, depending on the species, but the most abundant and persistent species likely benefit from juvenile rearing on floodplains. River spawners include Sacramento hitch, Sacramento pikeminnow, Sacramento sucker, Chinook salmon, prickly sculpin, and bigscale logperch.

Floodplain Foragers – Fish that move onto the floodplain to take advantage of food resources, typically later in the inundation period as water temperatures become warmer. These fish include the juvenile life stages of species that are residents in perennial waterbodies adjacent to floodplains and can include adults during prolonged flood events. Floodplain foragers include golden shiner, largemouth bass, black crappie, bluegill, and redear sunfish. These fish typically exhibit increased growth and survival on floodplains relative to mainstem rivers and appear to be able to avoid stranding as floodwaters recede (likely because their native habitat includes inundated floodplains).

Floodplain Pond/Lake Fishes – Fish that can reproduce in shallow floodplain ponds during most years and can dominate ponded areas due to high growth and survival rates. These fishes attract piscivorous birds and are often stranded in ponds that dry up. Species in California include inland silversides and western mosquitofish.

Inadvertent Users – Most of these fish species enter floodplains from adjacent perennial waterbodies but do not exhibit adaptations allowing them to necessarily benefit from using floodplain habitat. Larvae and juvenile life stages often drift into the floodplain and either pass through or become stranded. Large adults of these species also may become stranded on the floodplain, or move short distances onto the floodplain from perennial habitat to avoid being stranded. Inadvertent users include Pacific lamprey, rainbow trout/steelhead, American shad, threadfin shad, and catfishes.

Because fish species found on the floodplain have varying relationships with and dependence on floodplain habitat, physical habitat conditions can be important determinants of the timing, duration, and ecology of fish on a floodplain.

8.1.3.3.2 Fisheries Floodplain Habitat

Depending on the hydrology, characteristics of the river-floodplain connectivity, floodplain geomorphology, and anthropogenic discharges, fisheries habitat on the floodplain may include expansive seasonally inundated habitat, perennial waterways, and disconnected ephemeral ponds.

Typically, as high flows overtop the main channel and flow onto adjacent floodplains, velocities decrease and water temperatures increase on the floodplain (Ahearn et al. 2006). For example,

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[7] Do not require floodplain habitats to spawn but often exhibit improved reproductive success and increased juvenile growth and survival on floodplains

Sommer et al. (2001c) found that water temperatures during March of 1998 and 1999 were up to 5°C (9°F) higher in the Yolo Bypass than in the adjacent Sacramento River. Expansive areas of reduced velocities on the floodplain can provide substantially larger areas of suitable hydraulic habitat for small juvenile Chinook salmon and other fishes relative to the littoral area of the adjacent river. Lower velocities found in floodplain habitats also may potentially encourage increased growth in juvenile fishes because of a decrease in energy expended during foraging activities relative to the adjacent river (Sommer et al. 2001c).

The composition of the floodplain fish community appears to vary as the inundation season progresses in both the Cosumnes River and Yolo Bypass floodplains. Generally, native species, including juvenile Chinook salmon, adult Sacramento splittail, juvenile lamprey, juvenile white sturgeon, and juvenile Sacramento pikeminnow, are in greatest abundance during the earlier portion of the inundation period (January through April), and non-native species are heavily dominant during April through June (Sommer et al. 2004; Sommer et al. 2014; Moyle et al. 2007; DWR 2016, as cited in DWR and Reclamation 2017). However, juvenile Sacramento splittail can peak in abundance in the Yolo Bypass during May and June (DWR 2016, as cited in DWR and Reclamation 2017), and juvenile Chinook salmon can occur later in the season during wetter years (Moyle et al. 2007). In the Yolo Bypass, adult Sacramento splittail, white sturgeon, and Sacramento pikeminnow appeared to be associated with flood pulses early in the inundation season (Moyle et al. 2014). In the Cosumnes River floodplain, western mosquitofish, inland silverside, and other non-natives dominated catches in June and July; yearling and adult Sacramento sucker, juvenile pikeminnow, and in some years, adult Sacramento blackfish and Sacramento hitch, moved onto the floodplain in April and May (Moyle et al. 2007). Centrarchids also moved onto the Cosumnes River floodplain from ponds and sloughs during April and May if water temperatures exceeded 20°C (68°F) for an extended period (Moyle et al. 2007).

Physical habitat can be as important as flood pulse dynamics in structuring river–floodplain fish communities (Feyrer et al. 2006a). In the Cosumnes River floodplain, late season juvenile inhabitants (i.e., western mosquitofish, golden shiner, inland silverside, black crappie, and Sacramento blackfish) were found in shallow water associated with ponds, and common carp and Sacramento splittail were found in cooler, deeper water with submerged annual vegetation; young Sacramento sucker were found in clear and cold water early in the inundation season (Moyle et al. 2007). Yearling and adult non-native fish (i.e., black crappie, western mosquitofish, bluegill, and inland silverside) were associated with shallow ponds late in the inundation season. Because yearling Sacramento pikeminnows and golden shiners were present during early season flooding, they were associated with lower conductivity and lower water clarity (Moyle et al. 2007).

Crain et al. (2004) found that prickly sculpin and bigscale logperch larvae were associated with flooded terrestrial vegetation, Sacramento sucker and common carp larvae were associated with higher flows, and Sacramento splittail larvae were associated with higher flows and emergent vegetation. Larvae of non-native species, including inland silverside, crappie, and sunfish, showed an association with warmer temperatures and clay substrates in permanent floodplain ponds (Crain et al. 2004). Based on their observations, Crain et al. (2004) suggest that fields of annual vegetation on the floodplain may be very important habitat for larval rearing because of the abundance of food and cover, particularly for native species, including Sacramento splittail. Moreover, Jeffres et al. (2008) found that juvenile Chinook salmon experienced higher growth rates in seasonally inundated floodplain habitat with annual terrestrial vegetation relative to perennial ponded floodplain habitat.

Feyrer et al. (2006a) suggested that the fish communities in Yolo and Sutter bypasses appeared to be structured primarily by the habitat characteristics of each floodplain, most notably the water source of the perennial channels, and secondarily by the flood pulse dynamics. The upstream freshwater source of water in the Sutter Bypass led to a community of primarily freshwater species, and the downstream source of water for the Yolo Bypass led to a higher proportion of estuarine or anadromous fishes (Feyrer et al. 2006a). Physical habitat and land use in each floodplain was similar; however, the Sutter Bypass had a much higher proportion of its area covered with native terrestrial and riparian vegetation (over 50 percent of the area of Sutter Bypass, relative to about 12 percent of the Yolo Bypass) (Feyrer et al. 2006a). Differences in the littoral habitats of the perennial channels of the two floodplain systems also probably contributed to differences in the fish communities. The Toe Drain in the Yolo Bypass is a relatively simplified channel with little riparian complexity, whereas the perennial channels of the Sutter Bypass exhibit more channel and riparian habitat complexity, including riparian forests that are inundated under relatively low flows (Feyrer et al. 2006a). The Sutter Bypass also has substantial amounts of aquatic vegetation, which is generally not present in the Yolo Bypass and likely contributes to the relatively high abundance of non-native cyprinids and centrarchids in the Sutter Bypass (Feyrer et al. 2006a).

Rearing in shallow and well-vegetated areas on a seasonal floodplain is believed to reduce predation of juvenile fishes from predators (Sommer et al. 2001c; Swenson et al. 2001). Predation may have been reduced for juvenile Chinook salmon in the Yolo Bypass during a higher flow year due to a greater amount and duration of floodplain rearing area associated with higher and longer duration flows (Sommer et al. 2001c). Moyle et al. (2007) found very few adult predatory fish during flood events on the Cosumnes River floodplain; non-native predatory fish species were more frequently observed as yearlings, with occasional spawning by adults in temporary floodplain ponds late in the season. Similar results were found in the Willamette River in Oregon where non-native fishes were not found in floodplain habitats until water temperatures exceeded 20°C (68°F) (Colvin et al. 2009 as cited in Opperman et al. 2017).

Although floodplains can provide substantial benefits to fish, there are factors that may lower the ecological value of floodplains for fish, such as less suitable water quality (e.g., elevated water temperature, reduced dissolved oxygen); shallow water depths; and unfavorable timing, duration, and magnitude of inundation (CDFG 2010b). For example, increased water temperatures can be beneficial to fish by increasing growth rates when temperatures are near optimal levels, or temperatures can reduce growth rates or increase susceptibility of fish to predation if temperatures are well above optimum levels (CDFG 2010b). Elevated water temperatures reaching lethal levels on the floodplain also may lower dissolved oxygen concentrations and increase stress levels, which can increase the susceptibility of fishes to disease (CDFG 2010b). Ahearn et al. (2006) found that after the floodplain became disconnected after a previous inundation event, a subsequent flood event redistributed elevated amounts of algae on the floodplain, such that hypoxic zones (areas of low dissolved oxygen) were created, resulting in mortality of juvenile Chinook salmon confined to enclosures in a hypoxic zone (Jeffres et al. 2008). Shallow floodplains also may experience greater variation in water temperatures. Water depth (and instream cover) also influences the susceptibility of fishes such as young juvenile Chinook salmon to avian predators; piscivorous birds can consume large quantities of fish on a floodplain, particularly if they become stranded (Opperman et al. 2017), as observed in a flooded rice field in the Yolo Bypass (Katz et al. 2013). Therefore, the value of floodplains as avian predator avoidance refugia may depend on the presence of submerged vegetation or other cover elements. Inundation depths greater than approximately one foot also may reduce the risk of mortality due to avian predation (CDFG 2010b).

The presence of non-native fish species that predate on or compete with native fish species also is an important consideration in assessing the benefits of floodplain inundation. For example, Stoffels et al. (2014) found that reconnecting a river to its floodplain in southeast Australia increased abundances of native fish species but also substantially increased the abundance of an undesirable non-native fish species. Crain et al. (2004) found that the Cosumnes River floodplains are particularly important habitat for native fishes during February through April because warmer temperatures and lower flows later in the season provide more suitable habitat for non-native fish species. However, some non-native species, such as common carp, also benefit from early season flooding (Crain et al. 2004).

An additional phenomenon that may reduce the ecological value of floodplains is the occurrence of fish stranding as a floodplain is draining. However, fishes native to an area where stranding may occur have often been found to exhibit life history and/or behavioral adaptations to local hydrologic regimes that reduce the potential for stranding (Opperman et al. 2017). For example, some fish will leave the floodplain before becoming stranded based on a variety of cues, such as decreasing flow and/or water depth, increasing water temperature and/or clarity (Opperman et al. 2017), or decreasing dissolved oxygen levels (Henning et al. 2006). In wetland habitats on the Chehalis River floodplain in Washington, dissolved oxygen levels appeared to serve as cues to juvenile coho salmon to emigrate from the wetland to the main river channel (Henning et al. 2006). However, if the outlet channel connecting the wetland to the main river desiccated before dissolved oxygen concentrations fell below about 1.5 milligrams per liter (mg/L), the number of juveniles stranded was substantially higher (Henning et al. 2006).

Moyle et al. (2007) found that most fish stranded in isolated ponds after the Cosumnes River floodplain drained were non-native pond species. However, a rapid and/or unusually early disconnection between the river and its floodplain can lead to high levels of stranding of other species (Opperman et al. 2017). Fish concentrated in pools also can become more susceptible to predation (Moyle et al. 2007). Anthropogenic structures that interrupt natural drainage patterns, such as gravel pits, berms, and water control structures, create the greatest risk for stranding (Sommer et al. 2005).

As summarized by CDFG (2010b), the benefit of flood events to an aquatic system is highly variable, transient, and dynamic and is influenced by hydrologic, geomorphic, and biological conditions on the floodplain. Flood events can temporarily provide optimal fish habitat conditions, but these conditions may only occur for a particular species at specific times of the year and under particular hydrologic conditions or over particular types of terrain (CDFG 2010b).

In addition to periods of flooding, the Yolo Bypass may provide important habitat for juvenile salmonids and delta smelt during dry periods and during drought. Mahardja et al. (2015) found relatively high numbers of delta smelt during the recent drought years (2013 and 2014) when the Yolo Bypass had minimal floodplain inundation. During 2014, Goertler et al. (2015) found that despite the lack of flooding during an extreme drought, a relatively high number of juvenile

Chinook salmon were found occupying the Yolo Bypass (after moving upstream through Cache Slough). Based on drift invertebrates and zooplankton sampling in the Toe Drain, the Yolo Bypass may have been the most productive habitat available to juvenile Chinook salmon outmigrating from the Sacramento River during the drought (Goertler et al. 2015). Although water temperatures were elevated in the Yolo Bypass, higher prey levels may have allowed juvenile Chinook salmon to continue to rear there. In addition, the Yolo Bypass has more natural banks and riparian vegetation than the Sacramento River and is better connected to tidal wetlands than the Sacramento River (Goertler et al. 2015).

8.1.3.3.3 Fisheries Productivity

Increased spawning success, growth, or abundance of various fish species, such as black bass, sunfishes, blue catfish, common carp, Sacramento splittail, and Chinook salmon, on inundated floodplains relative to mainstem rivers has been documented in many temperate river-floodplain systems (Dutterer et al. 2013; Alford and Walker 2013; Baker and Killgore 1994; Schramm and Eggleton 2006; Crain et al. 2004; Grosholz and Gallo 2006; Jeffres et al. 2008; Feyrer et al. 2006b; Sommer et al. 1997). Opperman et al. (2017, p. 57) stated that "…there is likely to be a direct, positive relationship between total floodplain area connected to rivers and levels of productivity, biodiversity, and ecosystem services supported by floodplains." For example, production of Sacramento splittail in the Yolo Bypass exhibited a significant positive relationship with the amount of available floodplain habitat during the peak spawning and juvenile rearing period (Feyrer et al. 2006b). Authors also have reported that fisheries of temperate river floodplains have been lost or substantially reduced due in large part from the disconnection of rivers from productive floodplain habitats (Galat et al. 1998 as cited in Opperman et al. 2010).

Jeffres et al. (2008) reported that juvenile Chinook salmon grew faster in enclosures within floodplain habitats relative to enclosures in adjacent river habitats in the Cosumnes River; highest growth rates occurred in floodplain areas where the water had the highest residence time, presumably due to sufficient time to allow for primary and secondary production to increase food resources. Juvenile Chinook salmon collected from the Yolo Bypass also were significantly larger than individuals collected from the Sacramento River (Sommer et al. 2001c). Bioenergetics modeling suggested that feeding success was greater in the floodplain, despite increased metabolic costs of rearing in warmer floodplain water (Sommer et al. 2001c).

Similarly, during a recent study on an experimental flooded rice field in the Yolo Bypass, growth rates of juvenile Chinook salmon were found to be among the highest recorded in freshwater habitats in California (Katz et al. 2013; Katz et al. 2017).

The potential for increased juvenile fish growth rates resulting from highly productive floodplain habitat could be a critical component of improving the adult return rates of Chinook salmon populations. Larger sizes of juvenile salmonids emigrating to the ocean have been correlated with a higher probability of surviving a laboratory seawater challenge (Beakes et al. 2010) and a higher probability of returning to spawn as an adult (Bond et al. 2008). In addition to the increased juvenile growth, the use of floodplain habitat by Central Valley salmonids promotes life history diversity, which could increase the resiliency of Central Valley salmonids in response to varying ecological conditions (Carlson and Satterthwaite 2011).

Use of the floodplain by juvenile salmonids also can alter their ocean entry timing. Historically, Central Valley Chinook salmon juveniles reared for up to three months on inundated floodplains, growing rapidly prior to ocean entry (Sommer et al. 2001b). Following this period of rapid growth, juveniles would enter the ocean during the spring as the production of nutrients, zooplankton, and forage fish increase in the coastal ocean (Lindley et al. 2009). Based on ocean recovery rates of adult (age three) fall-run Chinook salmon released as smolts into the San Francisco Bay, Satterthwaite et al. (2014) found that marine survival was correlated with the timing of juveniles entering the ocean. However, separating out the relative influence of ocean entry timing and size of fish is difficult because these traits are often correlated (Satterthwaite et al. 2014). Although variable, the optimal juvenile release timing appeared to occur near the end of May and about 70 to 115 days after the spring transition date (Satterthwatie et al 2014). The spring transition date indicates when ocean upwelling begins, which is when ocean conditions begin to promote the production of zooplankton and small fish, increasing food availability for juvenile salmonids in the ocean.

8.1.4 Stressors in the Study Area

8.1.4.1 Habitat Availability

Prior to the construction of levees to prevent flooding of agricultural land and local cities, the Sacramento River floodplain occupied most of the valley floor, and seasonal flooding often filled much of the alluvial valley during the winter and spring (Sommer et al. 2001c). This seasonal flooding carried millions of juvenile Chinook salmon from upstream riverine habitats onto the wetted floodplains throughout the valley where they reared and grew rapidly before entering the ocean (Williams 2012).

Since 1900, approximately 95 percent of historical freshwater wetland habitat in the Central Valley floodplain habitat has been lost, typically through the construction of levees and draining for agriculture or residential uses (Hanak et al. 2011). The Yolo Basin historically contained an area of perennial wetland habitat that would have been larger than the existing area of the Yolo Bypass. The Yolo Basin currently contains about eight percent of the historical perennial wetland habitat and relatively higher amounts of seasonal wetland habitat (Whipple et al. 2012).

The remaining floodplain habitats in the valley are highly altered by upstream reservoirs and flow regulation (The Bay Institute 1998). Due to upstream flow regulation and the filling of reservoirs during the spring, the Sutter and Yolo bypasses receive muted flood pulses and are inundated less frequently and for shorter durations than prior to dam construction (Williams et al. 2009). The bypasses also are managed to minimize hydraulic roughness to promote drainage, further reducing residence time relative to historical conditions (Sommer et al. 2001a; Opperman et al. 2017). Reduced hydraulic connectivity between the floodplains and the Sacramento River, physical modifications of the floodplains, and reduced residence time of water moving through the floodplains has reduced primary and secondary productivity and associated ecological benefits to fish and aquatic resources.

The Central Valley now consists primarily of a mosaic of communities and agricultural lands that are protected by high, steep levees. This condition has disrupted the natural process of sediment and nutrient transport and fish connectivity between riverine and adjacent floodplain habitats and limited the ability of these processes to occur between upstream riverine and downstream estuarine habitats (Eisenstein and Mozingo 2013). The majority of the existing Central Valley floodplain habitat is inundated only during large floods.

In addition to floodplains adjacent to rivers along the valley floor, the Delta historically consisted of a mosaic of riverine, floodplain, and tidal marsh habitats. This mosaic of habitats enabled the Delta to support an exceptionally high level of biological productivity and influence food webs throughout the entire estuary (Jassby and Cloern 2000; Kimmerer 2004). Like many floodplain-riverine systems throughout the world, the Delta plays a critical role in supporting and shaping food webs for entire aquatic ecosystems. As with many of these systems, the Delta's ecological functioning has been severely altered and degraded by anthropogenic changes to the landscape (Strayer and Findlay 2010).

8.1.4.2 Hydrology

8.1.4.2.1 Yolo Bypass Attraction Flows

During overtopping events at Fremont Weir, increased flows into the Cache Slough area can increase the attraction of migrating anadromous fish species. It is well documented that these flows can result in adult Chinook salmon and sturgeon using the Yolo Bypass as an alternative upstream migration route (CDFW 2016c). Flows during flooding events in the Yolo Bypass can typically convey up to 80 percent of the Sacramento River flows. Due to a lack of hydraulic connectivity between the Sacramento River and Yolo Bypass, adults migrating up the Yolo Bypass can experience migratory delays and increased mortality relative to the Sacramento River migration corridor, as further described below (Section 8.1.4.4, *Upstream Migration Barriers and Stranding*).

Studies documenting the differential attraction of anadromous salmonids into the Yolo Bypass at various flow and inundation levels relative to the Sacramento River have not been conducted. However, because higher numbers of anadromous fish are rescued on the Fremont Weir apron (Figure 8-3) during higher-flow events, it is likely that increased flow through the Yolo Bypass results in increased attraction and subsequently increased stranding.

Photo Credit: U.S. Fish and Wildlife Service

Figure 8-3. Fremont Weir and Apron

8.1.4.2.2 Sacramento River

The Sacramento River from Colusa to Sacramento is constrained by levees. The altered channel morphology in this region has resulted in altered hydrology and reduced rearing opportunities for migrating anadromous salmonids and other fishes. The altered hydrology has transformed these lower river reaches from productive rearing habitats to primarily simplified migration corridors. Detailed discussion of Sacramento River hydrology is provided in Chapter 5, *Surface Water Supply*.

Reduced flow in the Sacramento River due to inundation of the Yolo Bypass is not likely to be limiting upstream or downstream fish migration in the Sacramento River because inundation of the bypass occurs during relatively high-flow events.

8.1.4.2.3 Delta

Diversions

There are about 2,200 water diversions in the Delta (Herren and Kawasaki 2001; Reclamation 2008). Although entrainment by agricultural diversions is not frequently identified as a factor in the decline of Delta fish species, most of these small diversions are not screened (Herren and Kawasaki 2001). Many of the diversions divert water to agricultural fields between April and August. The early part of this irrigation season coincides with the timing of spawning and larval development of Delta fish species. Because spawning and larval development are likely to occur in shallow shoreline locations with limited movement, entrainment of these life stages by agricultural diversions could be more substantial (Reclamation 2008).

Reverse Flows

The CVP and the SWP both divert water from Old River, a tidal slough that intersects the lower San Joaquin River (Figure 8-1). CVP and SWP diversions can cause the tidally averaged flow in the Old River, Middle River, and other adjacent channels in the southern Delta to reverse flow toward the diversions. These reverse flows contribute to the entrainment of numerous fish species, including migrating and spawning delta smelt and their offspring and migrating anadromous salmonids. Patterns of entrainment vary with life history and season as well as with food availability and water quality (Grimaldo et al. 2009). Pilot studies conducted to investigate the effect of Delta Cross Channel operations on the movement of juvenile Chinook salmon in the Delta indicate that yearling salmonids will move into the Delta Cross Channel during flood tides, and can be drawn into the channel after initially migrating past the channel gates (CALFED 2000).

CVP and SWP exports can influence the magnitude of flows into the Delta and the outflow from the Delta into Suisun Bay. Along with Delta inflow, Delta outflow is an important regulator of habitat quality and availability and of fish distribution, survival, and abundance (Baxter et al. 2010). Delta inflow and outflow are important for species residing primarily in the Delta (e.g., delta smelt and longfin smelt) (USFWS 2008) and for juveniles of anadromous species that rear in the Delta prior to ocean entry. CVP and SWP operations can increase fish entrainment, redirect fish into areas with higher risks of mortality, affect salinity, and degrade habitat conditions. The susceptibility of entrainment of fish into the Central Delta via the Delta Cross Channel is likely variable based at least in part on Sacramento River flow.

8.1.4.3 Water Quality

8.1.4.3.1 Yolo Bypass

Water quality in the Yolo Bypass is influenced by several sources, including the Sacramento, Feather, and American rivers via the Fremont and Sacramento weirs, along with the Knights Landing Ridge Cut, Cache Creek, Willow Slough, and Putah Creek. In addition, agricultural activities in the Yolo Bypass during non-inundated periods, discharge from the City of Woodland wastewater treatment plant, and urban runoff from nearby cities (i.e., Davis and Woodland), and major streets and highways (Interstate (I) 5 and I-80) can affect local water quality.

Although juvenile salmonids can survive a wide range of temperatures, their growth and overall fitness are maximized at levels well below upper survivable or tolerable water temperatures. The optimal growth rate might also vary based on the acclimation temperature of an individual fish. It is not uncommon for water temperatures in the Yolo Bypass to rise above 20°C (68°F) as the inundation season progresses (Frantzich and Sommer 2015), potentially making conditions less suitable for Chinook salmon growth, as suggested by Katz et al. (2013) in a flooded rice field, and more suitable for effective foraging by predators. Even in the deeper, cooler waters of the Toe Drain, water temperatures typically approach the incipient upper lethal temperature for salmonids by late April to early May (Reclamation and DWR 2012). As water temperatures increase, conditions might become more favorable to predators, such as centrarchids, which can compete with or predate on juvenile salmonids.

Dissolved oxygen might also be a stressor to fish species of focused evaluation in the Yolo Bypass. Reported optimal dissolved-oxygen levels for juvenile Chinook salmon are greater than nine mg/L at water temperatures below 50°F (10°C) and greater than 13 mg/L at water temperatures above 50°F (10°C). Allen and Hassler (1986) reported that juvenile Chinook avoided dissolved oxygen levels below 4.5 mg/L at temperatures of 61 to 77°F (16 to 25°C) and avoided dissolved oxygen levels below three mg/L at temperatures of 46 to 64°F (8 to 18°C). In cooler waters, steelhead can survive dissolved oxygen concentrations as low as 1.5 to two mg/L, but they require concentrations close to saturation for optimal growth (Moyle 2002).

Prolonged low dissolved oxygen concentrations also reduce the overall fitness of juvenile salmonids. For example, Colt et al. (1979, as cited in Reclamation and DWR 2012) found that juvenile coho salmon showed a marked decrease in food consumption and ultimately a loss of body mass as dissolved oxygen concentrations fell to two mg/L. It is likely that Chinook salmon and other salmonids exhibit a similar response. Overall, although it is unclear whether reduced dissolved oxygen concentrations are a major stressor to fish in the Yolo Bypass, dissolved oxygen might influence the movements and potential stranding of fish and affect growth rates on the floodplain (Reclamation and DWR 2012).

During much of the winter, suspended sediment levels are elevated in the Yolo Bypass, resulting in high levels of turbidity (Sommer et al. 2001b). Hydraulic residence times are generally greater in the Yolo Bypass than in the mainstem Sacramento River (Sommer et al. 2004) because floodwaters recede from the northern and western portions of the Yolo Bypass along low gradients (Sommer et al. 2007).

California's historical gold-mining practices have resulted in high concentrations of methylmercury in much of the Central Valley, including the Yolo Bypass. Methylmercury is formed from inorganic mercury by microscopic organisms that live in waterbodies and sediments. Inundation of sediments, such as on a floodplain, can increase the methylation of mercury. Domagalski (2001) found that mercury concentrations in the Yolo Bypass can exceed State standards. In 2011, the Central Valley Regional Water Quality Control Board (RWQCB) amended the *Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Methylmercury and Total Mercury in the Sacramento-San Joaquin River Delta Estuary* to identify allowable maximum concentrations of methylmercury in Delta and the Yolo Bypass waterways and established a control program to reduce current methylmercury levels to meet new standards by 2030 (Central Valley RWQCB 2016).

Methylmercury is a neurotoxin that bioaccumulates and biomagnifies in the aquatic food web (Davis et al. 2003). For example, Berntssen et al. (2003, as cited in Henery et al. 2010) showed that methylmercury can cause pathological damage and altered behavior in Atlantic salmon (*Salmo salar*). Henery et al. (2010) found that juvenile Chinook salmon reared on the Yolo Bypass floodplain displayed a more rapid accumulation of methylmercury and showed higher methylmercury levels by weight at outmigration than those reared in the Sacramento River. However, the observed levels of methylmercury in fish that spent one to 12 weeks rearing on the floodplain were reported to represent insignificant concentrations of methylmercury in the tissues of the eventual adult fish (Henery et al. 2010).

The primary source of water in the Yolo Bypass may affect the accumulation of mercury in fish. Henery et al. (2010) found that during the two years when Cache Creek was the primary source of floodwater, methylmercury accumulation in floodplain-reared fish exhibited a linear trend, increasing with duration of residence. In contrast, for two years when water in the Yolo Bypass was dominated by flood events from the Sacramento River, fish on the floodplain exhibited a quadratic pattern of methylmercury accumulation (methylmercury accumulation initially increased with residence time but stopped increasing for fish that remained on the floodplain) (Henery et al. 2010). Henery et al. (2010) indicated that methylmercury accumulation may have been greater in fish when Cache Creek was the dominant source of water in the Yolo Bypass due to lower flows and warmer water temperatures (relative to the higher flows and lower water temperatures that occur when Fremont Weir overtops), which could have increased the rates of mercury methylation.

Although bioaccumulation is more rapid on the floodplain, it is not known whether this is a function of the amount of methylmercury on the floodplain or of higher feeding rates of prey that have accumulated methylmercury, relative to the Sacramento River (Reclamation and DWR 2012).

8.1.4.3.2 Sacramento River

Water quality stressors in the Sacramento River include, but are not limited to, water temperature, urban and agricultural runoff, and methylmercury. A detailed discussion of water quality constituents in the lower reaches of the Sacramento River is provided in Section 6.1.3.2 of Chapter 6, *Water Quality*.

8.1.4.3.3 Delta

Anthropogenic and environmental toxins might adversely affect fish populations in the Delta (DWR and CDFG 2007). Although initial data on striped bass and delta smelt indicated high frequencies of liver lesions and other signs of disease indicative of toxic poisoning (Armor et al. 2005), subsequent studies have shown that acute contaminant toxicity is not likely the cause for population declines but could be a contributing factor (Baxter et al. 2010). Two liver-damaging toxins that have received notable attention are pyrethroid pesticides and *Microcystis* hepatotoxins.

Pyrethroid pesticides have been identified as a factor contributing to pelagic organism decline because of their increased use in recent years and their high toxicity to aquatic organisms. Although pyrethroids are readily absorbed into sediment, they can be mobilized during high-flow events and are highly toxic to zooplankton and fish (Werner and Moran 2008).

Microcystis is a colonial cyanobacteria that produces hepatotoxins that can affect both fish and humans. Blooms of *Microcystis* have become larger and more widespread during the summer than in the past. Reduced stream flow in the Delta seems to promote the growth of *Microcystis*, which is more abundant during drier water years (Baxter et al. 2010).

In addition to pyrethroid pesticides and *Microcystis*, contaminants, such as mercury, selenium, and herbicides, associated with agricultural production have been identified as potential stressors to fish and aquatic species in the Delta (Davis et al. 2003; Linville et al. 2002). Yolo Bypass outflow may introduce mercury and methylmercury to the Delta during high-flow events.

Delta salinity conditions are important determinants of habitat quality for Delta resident and some anadromous fish and aquatic species. Several fish species use a variety of behaviors to maintain themselves in open-water areas where water quality and food resources are favorable (Bennett et al. 2002). Delta smelt, longfin smelt, striped bass, and threadfin shad distribute themselves at different concentrations of salinity within the estuarine salinity gradient (Feyrer et al. 2007; Kimmerer 2002a), indicating that, at any point in time, salinity is a major factor affecting their geographic distributions. Because of the importance that salinity has on fish distribution in the estuary, the term low-salinity zone (LSZ) was created to define the area within the San Francisco Estuary where salinity is about 0.5 to six ppt. Located at roughly the center of the LSZ, X2 is defined as the location upstream from the Golden Gate Bridge where salinity near the bottom of the water column is about two ppt (Kimmerer 2002b).

Salinity between two and approximately 30 ppt is roughly linearly distributed between X2 location and the mouth of the Estuary (Monismith et al. 1996 as cited in Kimmerer 2002b). X2 location reflects the physical response of the Estuary to changes in flow and provides a geographic frame of reference for estuarine conditions (Kimmerer 2002b). Because the position of X2 depends on a variety of physical parameters, including river flows, water diversions, and tides, its position shifts over many kilometers on a daily and seasonal cycle. Over the course of a year, the location of X2 can range from San Pablo Bay (during high-river flow periods) to the Delta (during the summer).

The relationships between X2 location and the abundance of fish and aquatic species have been developed for many estuarine-dependent copepods, mysids, bay shrimp, and several fishes, including longfin smelt, Pacific herring, starry flounder, Sacramento splittail, American shad, and striped bass (Kimmerer 2002a). For example, Feyrer et al. (2007) reported that higher outflow that expands and moves delta smelt habitat downstream of the Delta is expected to improve conditions for delta smelt. Additionally, Kimmerer (2002a) found that distributions of fish species, including striped bass, Sacramento splittail, longfin smelt, delta smelt, and starry flounder, substantially overlapped with the LSZ.

According to CDFG (2010b), the available data and information indicate: 1) many fish and aquatic species' abundances are related to water flow timing and quantity (or the location of X2); 2) for many fish and aquatic species, more water flow translates into greater species production or abundance; 3) fish and aquatic species are adapted to use the water resources of the Delta during all seasons of the year, but, for many species, important life history stages or processes consistently coincide with increased winter and spring flows; and 4) the source, quality, and timing of water flows through the estuary influence the production of Chinook salmon in both the San Joaquin River and Sacramento River basins.

8.1.4.4 Upstream Migration Barriers and Stranding

The Yolo Bypass and Fremont Weir are a source of migratory delay and loss of adult Chinook salmon, steelhead, and sturgeon (NMFS 2009). The existing fish passage structure at Fremont Weir is inadequate to allow normal fish passage at most flows (NMFS 2009). As a result, adult salmonids and sturgeon migrating upstream through the Yolo Bypass are unable to reach upstream spawning habitat in the Sacramento River and its tributaries when there is insufficient flow through Fremont Weir (Harrell and Sommer 2003). Other structures in the Yolo Bypass, such as the Toe Drain, Lisbon Weir, and irrigation dams in the northern end of Tule Canal, can also impede migration of adult anadromous fish (NMFS 2009).

The existing agricultural road crossings and Lisbon Weir restrict the flow of water down Tule Canal, creating partial-to-complete barriers to adult fish passage, depending on flow. In addition, adult fish can become stranded in depressions within the Yolo Bypass, such as the Tule Pond or on the Fremont Weir apron, as flood flows recede. Upstream migrating adults also can become stranded at Sacramento Weir.

To hold back drainage water, the earthen Wallace Weir has been manually constructed annually at the terminus of Knights Landing Ridge Cut in the Yolo Bypass. However, winter storms often break the weir, allowing adult salmonids to stray into the Colusa Basin where they cannot re-enter the Sacramento River. Beginning in January 2014, CDFW installed a temporary fyke trap to rescue salmonids and sturgeon straying toward Wallace Weir; however, flow conditions compromised the fish rescue efforts (DWR and Reclamation 2017). In 2016, construction began to replace Wallace Weir with a permanent structure that includes a fish facility that can remain operational under low and high flows (DWR and Reclamation 2017).

8.1.4.4.1 Agricultural Road Crossings

Road crossings for agricultural use during the dry season are found along Tule Canal and the Toe Drain. These road crossings create barriers that might not have any substantial effect during high-flow events but could cause migration delays and increased mortality rates during low-flow periods. Many of these crossings were constructed to allow agricultural traffic (e.g., harvesting equipment) to cross the Tule Canal and Toe Drain and enter agricultural fields west of the Tule Canal and Toe Drain in the Yolo Bypass. During the spring, these agricultural road crossings are repaired due to damage from high winter and spring flow events. Four distinct road crossings have been identified for evaluation and removal and/or improvements, three of which are in the process of being modified to improve fish passage before this EIS/EIR is submitted and are not discussed further.

The first road crossing south of Fremont Weir, referred to as Agricultural Road Crossing 1, is being evaluated for improved fish migration. This crossing serves as a vehicle crossing and a water delivery feature. An earthen berm just upstream of the road crossing creates a cross canal that conveys water across the Yolo Bypass from Wallace Weir to two 36-inch culverts that pass through the east levee of the bypass. The culverts deliver water via gravity flow into the Elkhorn area for agricultural use.

The cross-canal berm is a flow barrier in the Tule Canal. The top of the berm has an elevation of about 21 feet (North American Vertical Datum of 1988), which backs up water into the forested area and Tule Pond when water flows over Fremont Weir during an overtopping event.

Additionally, the cross-canal leaks in some years, which provides water inflow to the wooded area and Tule Pond (see Figure 2-1).

8.1.4.4.2 Fremont Weir

The Fremont Weir is the primary migration barrier to adult Chinook salmon, steelhead, and green sturgeon migrating upstream through the Yolo Bypass. In 1966, a fish ladder was constructed toward the east end of the weir to provide adult fish passage for salmonids. This ladder is operated by CDFW after flows recede and Fremont Weir is no longer overtopping.

As flows decrease at the weir, a single fish ladder is inadequate because of varying elevations of the apron. When flows decrease, the east and west sides of Fremont Weir become disconnected, and fish isolated on the west side do not have access to the fish ladder and cannot return to the Sacramento River on their own. Fish stranded on the apron either may be unable to detect flows through the Fremont Weir fish passage structure or are unwilling to traverse long shallow sections of the weir basin to reach the fish passage structure, thus, remaining in deeper water at either end of the apron. Scouring that occurs beyond the downstream edge of the Fremont Weir apron creates various scour pools, scour channels, and swales, which create additional potential for stranding. Fish unable to re-enter via the fish ladder into the Sacramento River frequently become stranded in these scour pools.

Stranding of adult salmonids and sturgeon in the Yolo Bypass has been well-documented in recent years. Since 1955, CDFW has conducted 28 fish rescues at Fremont Weir and inundated features within the Fremont Weir Wildlife Area (CDFW 2016c). Over 10,000 fish, comprising 19 species, including four listed species (Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and southern DPS green sturgeon), have been captured and relocated during these rescue efforts (CDFW 2016c). Without these efforts, many of these fish would die from poor water quality, predation, or poaching.

In 2012, velocity baffles were removed from the fish ladder to help allow for sturgeon passage, but it is unlikely that this provided substantially improved passage for sturgeon. Because the fish ladder is currently considered somewhat ineffective for adult fish passage, a project to replace the ladder is being implemented. Reclamation and DWR are planning for completion of the fish ladder improvements before construction of a gated notch associated with this Project.

8.1.4.4.3 Sacramento Weir

Fish can be stranded in the Sacramento Weir’s stilling basin and various scour pools, scour channels, and swales when flows recede. Fish can also experience migration delays because of following attraction flows leaking through the flashboards at the weir. It is unknown whether adult sturgeon are able to pass the Sacramento Weir under any flow condition.

8.1.4.4.4 Lisbon Weir

Lisbon Weir is the southernmost agricultural impoundment that crosses the Toe Drain. The weir is a partial barrier to flow located about halfway down the Yolo Bypass. It helps maintain water levels upstream of the rock weir for both agricultural use and to support Yolo Bypass Wildlife Area during varying tidal cycles (Reclamation and DWR 2012). However, high tides flow over the top of the weir and through three flapgates. The flapgates allow incoming tidal flows to pass but are closed when water is higher upstream than downstream.

Lisbon Weir provides some adult fish passage at higher tides or higher net outflows. The weir is considered less of a barrier to migration than other features in the Yolo Bypass. Also, based on acoustic tagging of adult Chinook salmon and white sturgeon in the Toe Drain, the individuals that successfully passed upstream of Lisbon Weir were found to continue their upstream migration and did not attempt to migrate back downstream to Lisbon Weir (UC Davis 2013).

8.1.4.4.5 Sutter Bypass

The Sutter Bypass has not been studied as extensively as the Yolo Bypass but also contains impediments and barriers to adult fish upstream migration. Although the Sacramento River overflows Tisdale Weir during most years, it is unlikely that upstream passage at the weir occurs during flood events due to the dimensions of the weir and prohibitive hydraulic conditions below and above the weir (Reclamation and USFWS 2016). Adult and juvenile Chinook salmon, steelhead, green sturgeon, white sturgeon, and Sacramento splittail have been found in Tisdale Weir's stilling basin after flood recessions. CDFW conducts rescue efforts at Tisdale Weir to relocate stranded individuals. Rescued fish that have been tagged have been observed migrating to spawning grounds and have been found in carcass surveys in the Sacramento River and Butte Creek. Isolated pools in the Tisdale Bypass also can strand fish (Reclamation and USFWS 2016). Efforts to improve fish passage at Fremont Weir will be used to inform potential future efforts to provide for fish passage at Tisdale Weir (Reclamation and USFWS 2016).

Moulton and Colusa weirs also can prevent fish from re-entering the Sacramento River, and juvenile Chinook salmon have been observed stranded at Moulton Weir (USRMPWT 2017). However, because Moulton Weir is relatively small and spills infrequently, fish stranding does not appear to be as significant as at the other weirs (USRMPWT 2017).

Weir No. 1, located on the west side of Sutter Bypass just north of Tisdale Bypass, has a degraded fish ladder and non-operable weir structure that impedes fish passage during critically dry water years (Reclamation and USFWS 2016).

Two weirs that were recently fish passage impediments in the Sutter Bypass include Weir No. 2 and Willow Slough Weir, which impound water in the East Borrow Canal to maintain surface water elevations for irrigation diversions. Although both weirs have fish ladders, the weirs and fish ladders deteriorated and were no longer providing reliable fish passage. The culverts and fish ladder at Willow Slough Weir were replaced in 2010, and Weir No. 2 and its fish ladder were replaced in 2013, such that both facilities could provide more reliable fish passage at a much larger range of flows.

8.1.4.5 Downstream Migration and Stranding

Juvenile salmonids have been documented in the Yolo Bypass after weir overtopping events and have been found to benefit from inhabiting floodplains during rearing stages (Sommer et al. 2001b). However, stranding on floodplains also is known to occur for various reasons (Henning et al. 2006). Although the Yolo Bypass is generally well-graded and well-drained, there are many scour ponds and channels in the northern portion of the bypass, which could potentially strand juveniles as flood waters recede. Sommer et al. (2005) found that a relatively low proportion of juvenile Chinook salmon would likely be stranded in the Yolo Bypass. However, due to the hydrologic variability on floodplains, stranding losses might cause excessive mortality in some years; however, the risks may be offset by increased rearing habitat and food resources in other years (Sommer et al. 2001c). Sommer et al. (2005) also found that, when stranding occurred in the Yolo Bypass, there were significantly higher stranding rates in the concrete weir splash basins than in the downstream scour ponds, pools, and swales, suggesting that artificial water control structures can create unnatural hydraulics that promote stranding. Due to the predominance of private land in the Yolo Bypass and the occurrence of avian predation on juvenile salmonids in isolated ponds, documentation of precise rates of stranding under varying conditions in the Yolo Bypass are unknown and difficult to estimate.

8.1.4.6 Predation

Predation on special-status fish species in the Sacramento River and the Yolo and Sutter bypasses is influenced by anthropogenic factors, the presence of non-native fish species, altered physical habitat, and hydrology. Marine mammals, such as sea lions, are also known to predate on adult salmonids in the lower Sacramento River and the Yolo Bypass, and river otters have been observed preying on salmonids at Wallace Weir.

High rates of predation have been known to occur at diversions and locations where rock revetment has replaced natural river bank vegetation (NMFS 2009 as cited in Reclamation 2015). Chinook salmon fry, juveniles, and smolts are more susceptible to predation at these locations because Sacramento pikeminnow and striped bass congregate in areas that provide predator refuge (Tucker et al. 2003; Williams 2006). Non-native centrarchids, such as largemouth bass and spotted bass, will opportunistically feed on juvenile salmonids, particularly in the presence of human-made structures and altered habitat.

8.1.4.7 Structural Habitat

Many of the levees in the lower Sacramento River between Fremont Weir and Rio Vista use rock revetment to armor the bank from erosive forces. The effects of channelization and revetment include the alteration of river hydraulics, cover along the bank, and changes in bank configuration and structural features (Stillwater Sciences 2006 as cited in NMFS 2009). These changes affect the quantity and quality of near-shore habitat for juvenile fishes (Garland et al. 2002, Schmetterling et al. 2001, and USFWS 2000, all as cited in NMFS 2009).

Simple slopes protected with rock revetment generally create near-shore hydraulic conditions characterized by greater depths and faster, more homogeneous water velocities than those that occur along natural banks. These changes in hydraulic conditions result in reduced habitat complexity. Additionally, higher water velocities typically inhibit deposition and retention of sediment and woody debris. These changes generally reduce the range of habitat conditions typically found along natural shorelines, particularly by eliminating the shallow, slow-velocity river margins used by juvenile fish as refuge and escape from fast currents, deep water, and predators (Stillwater Sciences 2006 as cited in NMFS 2009). In addition, the armoring and revetment of stream banks tends to narrow rivers, reducing the amount of habitat per unit of channel length (Sweeney et al. 2004).

In addition to direct effects of levees on aquatic habitat and fishes, riparian vegetation is substantially reduced on rock revetment leveed banks, reducing overhanging vegetation and future woody debris sources (Reclamation 2008). Large woody debris provides valuable habitat to fish such as salmonids (Reclamation 2008).

8.1.4.8 Food Web

Historically, the Delta food web was supported primarily by wetlands. Currently, the Delta relies on smaller amounts of carbon inputs, primarily from tributaries (Jassby and Cloern 2000; Jassby et al. 2003). Secondary sources of carbon in the Delta include phytoplankton production and agricultural drainage (Jassby and Cloern 2000). Only carbon resulting from tributary inputs and phytoplankton production are consistently important sources in most seasons and water year types (Jassby and Cloern 2000).

Other sources include wastewater treatment plant discharges and exports from tidal marsh areas. Much of the land in the Yolo Bypass has been converted to agricultural production or is managed for waterfowl habitat, which has led to a reduction of carbon and nutrients being exchanged through tidal action and exported to the Estuary.

8.2 Regulatory Setting

This section provides the regulatory setting for aquatic resources, including potentially relevant Federal, State, and local requirements applicable to the Project.

8.2.1 Federal Plans, Policies, and Regulations

Federal laws, policies, and regulations pertaining to aquatic resources and fisheries are discussed below.

8.2.1.1 Federal Endangered Species Act

The ESA requires that both USFWS and NMFS maintain lists of threatened and endangered species. An endangered species is defined as "… any species which is in danger of extinction throughout all or a significant portion of its range." A threatened species is defined as "… any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" (Title 16 United States Code [USC] Section 1532). Section 9 of the ESA makes it illegal to "take" (i.e., harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in such conduct) any endangered species of fish or wildlife, and regulations contain similar provisions for most threatened species of fish and wildlife (16 USC 1538).

The ESA also requires the designation of critical habitat for listed species. 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 a species' 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 (USFWS and NMFS 1998).

Section 7 of the ESA requires all Federal agencies to ensure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of designated critical habitat. To ensure against jeopardy, each Federal agency must consult with USFWS or NMFS, or both, if the Federal agency determines that its action might affect listed species. NMFS jurisdiction under the ESA is limited to the protection of marine mammals, marine fish, and anadromous fish. All other species are within USFWS' jurisdiction.

If an activity would result in the take of a Federally listed species, one of the following is required: 1) an Incidental Take Permit issued as part of an approved Habitat Conservation Plan under Section 10(a) of the ESA or 2) an Incidental Take Statement issued pursuant to Federal interagency consultation under Section 7 of the ESA. The Incidental Take Statement typically requires various measures to avoid and minimize species take.

Where a Federal agency is not authorizing, funding, or carrying out a project, take that is incidental to the lawful operation of a project may be permitted pursuant to Section 10(a) of the ESA through approval of a Habitat Conservation Plan.

8.2.1.2 Long-term Central Valley Project and State Water Project Operations Biological Opinions

8.2.1.2.1 USFWS Biological Opinion

The 2008 USFWS biological opinion (BO) concurred with Reclamation's determination that the coordinated operations of the SWP and CVP are not likely to adversely affect listed species, except for delta smelt (USFWS 2008). USFWS concluded that the coordinated operations of the SWP and CVP, as proposed, were likely to jeopardize the continued existence of delta smelt and destroy or adversely modify delta smelt critical habitat. Consequently, USFWS developed a reasonable and prudent alternative, consisting of several components and actions to avoid the likelihood of jeopardizing the continued existence or the destruction or adverse modification of critical habitat for delta smelt.

8.2.1.2.2 NMFS Biological Opinion

The NMFS BO (NMFS 2009) concluded that the SWP and CVP operations are likely to jeopardize the continued existence of the following species:

- Sacramento River winter-run Chinook salmon
- Central Valley spring-run Chinook salmon
- Central Valley steelhead
- Southern DPS of North American green sturgeon
- Southern resident killer whale

NMFS (2009) also concluded that CVP and SWP operations are likely to adversely modify the designated critical habitats of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley steelhead, and green sturgeon. Consequently, NMFS developed a reasonable and prudent alternative, consisting of several components and actions to avoid the likelihood of jeopardizing the continued existence or the destruction or adverse modification of critical habitat for these species, including restoration actions to increase juvenile salmonid access to the Yolo Bypass and improve adult migration through the Yolo Bypass.

8.2.1.3 Magnuson-Stevens Fishery Conservation and Management Act

The Magnuson-Stevens Fishery Conservation and Management Act, as amended by the Sustainable Fisheries Act (Public Law 104 to 297), requires that all Federal agencies consult with NMFS on activities or proposed activities authorized, funded, or undertaken by that agency that could adversely affect Essential Fish Habitat (EFH) of commercially managed marine and anadromous fish species. EFH includes specifically identified waters and substrate necessary for fish spawning, breeding, feeding, or growing to maturity. EFH also includes all habitats necessary to allow the production of commercially valuable aquatic species, support a long-term sustainable fishery, and contribute to a healthy ecosystem (16 USC 1802[10]).

The Pacific Fishery Management Council (2004) has designated the Delta, the Sacramento River, and tributaries as EFH to protect and enhance habitat for Chinook salmon. Because EFH applies only to commercial fisheries, all Chinook salmon habitats are included but not steelhead habitat.

8.2.1.4 Recovery Plan for Sacramento-San Joaquin Delta Native Fish Species

Since the *Recovery Plan for Sacramento-San Joaquin Delta Native Fishes* was released in 1996 (USFWS 1996), new information regarding the status, biology, and threats to Delta native species has emerged (CDFG 2008). Ongoing revision of the plan will review the new information and develop a strategy for conserving and restoring Delta native fish by identifying recovery actions that specifically address the threats to their existence. Species covered by this plan include delta smelt, longfin smelt, Sacramento splittail, and Sacramento perch.

The basic goal of the plan is to establish self-sustaining populations of the species of concern that will persist indefinitely (USFWS 1996). The plan stated that a variety of actions could be needed to achieve this goal, but the actions are not mandated by statute or policy.

8.2.1.5 Recovery Planning for Salmon and Steelhead in California

The public draft *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* was released in October 2009. The final plan was released in July 2014 (NMFS 2014). A recovery plan for green sturgeon will be developed in the future by NMFS. As defined in the draft recovery plan, the California Central Valley Recovery Domain extends from the upper Sacramento River Valley to the northern portion of the San Joaquin River Valley (NMFS 2014). For the Central Valley Chinook salmon ESUs and the steelhead DPS to achieve recovery, each diversity group must be represented, and population redundancy within the groups must be met to achieve diversity group recovery. The following priority recovery actions to address specific limiting factors were identified by NMFS (2014) to help meet recovery objectives:

- Protect and restore watershed and estuarine habitat complexity and connectivity.
- Improve understanding of life stage survival through focused research and monitoring.

- Establish at least two additional populations of winter-run Chinook salmon that are spatially diverse and secure from natural and human-made threats.
- Develop more-effective and efficient Federal and State mechanisms to correct already documented threats to listed salmonids.
- Collaboratively balance water supply and allocation with fisheries' needs through improving criteria for water drafting, storage and dam operations, water rights programs, development of passive diversion devices and/or offstream storage, elimination of illegal diversions in priority watersheds and streams, and other such opportunities.
- Screen appropriate water diversions and provide adequate downstream flows.
- Provide outreach to Federal action agencies regarding ESA Section 7(a)(1) and carry out programs to conserve and recover Federally listed salmonids.
- Identify and treat point and non-point source pollution to streams from wastewater, agricultural practices, and urban environments.

8.2.1.6 Fish and Wildlife Coordination Act (16 USC Section 651 et seq.)

The Fish and Wildlife Coordination Act gives the United States Secretary of the Interior the authority to assist Federal, State, public, or private agencies in developing, protecting, rearing, or stocking all wildlife, wildlife resources, and their habitats (16 USC 661). Under this act, whenever waters of any stream or other water body are proposed to be impounded, diverted, or otherwise modified by any public or private agency under a Federal permit, that agency must consult with USFWS and, in California, CDFW (16 USC 661–667e, March 10, 1934, as amended 1946, 1958, 1978, and 1995).

8.2.1.7 Clean Water Act

The Clean Water Act (CWA) is a comprehensive set of statutes aimed at restoring and maintaining the chemical, physical, and biological integrity of the nation's waters. The CWA is the foundation of surface water quality protection in the United States (USEPA 2010). Initial authority for implementing and enforcing the CWA rests with USEPA. However, this authority can be exercised by states with approved regulatory programs. In California, this authority is exercised by the State Water Resources Control Board (SWRCB) and the RWQCBs.

The CWA contains a variety of regulatory and non-regulatory tools to significantly reduce direct pollutant discharges into waters of the United States, finance municipal wastewater treatment facilities, and manage polluted runoff. These tools (e.g., Section 303[d] List of Impaired Waters and Section 404 permitting process) are used to achieve the broader goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters so that they can support "the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water."

8.2.1.7.1 Constituents of Concern Listed under Clean Water Act Section 303(d)

Section 303(d) of the Federal CWA requires states to identify water bodies that do not meet water quality standards and are not supporting their designated beneficial uses. These waters are placed on the Section 303(d) List of Impaired Waters. This list defines low-, medium-, and high-priority pollutants that require immediate attention by Federal and state agencies. Placement on this list triggers development of a Total Maximum Daily Load (TMDL) Program for each water body and associated pollutant and/or stressor on the list. The Central Valley RWQCB is responsible for implementing the TMDL Program in California. Completed or ongoing TMDLs in the Delta region include chlorpyrifos and diazinon, dissolved oxygen, mercury and methylmercury, pathogens, pesticides, organochlorine pesticides, salt and boron, and selenium (Central Valley RWQCB 2010). For further information about TMDLs in the Delta region, refer to Chapter 6, *Water Quality*.

8.2.1.7.2 Clean Water Act Section 404

Section 404 of the CWA authorizes USACE and USEPA to issue permits to regulate the discharge of "dredged or fill materials into waters of the United States" (33 USC 1344). Should activities such as dredging or filling of wetlands or surface waters be required for project implementation, then permits obtained in compliance with CWA Section 404 would be required for the project applicant(s).

8.2.1.7.3 Clean Water Act Section 401

Section 401 of the CWA specifies that states must certify that any activity subject to a permit issued by a Federal agency (e.g., USACE) meets all state water quality standards. In California, the SWRCB and the RWQCBs are responsible for certifying activities subject to any permit issued by USACE pursuant to Section 404 of the CWA or pursuant to Section 10 of the Rivers and Harbors Act of 1899.

8.2.1.8 River and Harbors Act of 1899

The Rivers and Harbors Act of 1899 makes it unlawful to excavate, fill, or alter the course, condition, or capacity of any port, harbor, channel, or other areas within the reach of the act without a permit. Under Section 10 of the Rivers and Harbor Act, USACE regulates all structures and work in navigable waters.

8.2.1.9 Executive Order 11990, Protection of Wetlands

Executive Order 11990 calls for each Federal agency, in carrying out its ordinary responsibilities, to take actions to minimize the destruction, loss, or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands. Federal agencies must avoid undertaking new construction located in wetlands unless no practicable alternative is available and the action includes all practicable measures to minimize harm to wetlands.

8.2.1.10 Central Valley Project Improvement Act

The Reclamation Projects Authorization and Adjustment Act of 1992 (Public Law 102-575) includes Title 34, the Central Valley Project Improvement Act (CVPIA). The CVPIA amends the authorization of the CVP to include fish and wildlife protection, restoration, and mitigation as project purposes of the CVP having equal priority with irrigation and domestic uses of CVP water and elevates fish and wildlife enhancement to a level having equal purpose with power generation. Among the changes mandated by the CVPIA was dedication of 800,000 acre-feet annually to fish, wildlife, and habitat restoration. The United States Department of the Interior's October 5, 1999, Decision on Implementation of Section 3406(b)(2) of the CVPIA provides the basis for implementing upstream and Delta actions for fish management purposes. Implementation of Section 3406(b)(2) includes curtailing exports at Jones Pumping Plant for fishery management protection based on USFWS' recommendations.

8.2.1.11 Central Valley Project Improvement Act 3406(b)(2) Account

According to the 1992 CVPIA, the CVP must:

> … dedicate and manage annually 800,000 acre-feet of Central Valley Project yield for the primary purpose of implementing the fish, wildlife, and habitat restoration purposes and measures authorized by this title; to assist the State of California in its efforts to protect the waters of the San Francisco Bay/Sacramento–San Joaquin Delta Estuary; and to help meet such obligations as may be legally imposed upon the CVP under federal or state law following the date of enactment of this title, including but not limited to additional obligations under the federal ESA.

Dedication of CVPIA 3406(b)(2) water occurs when Reclamation takes a fish and wildlife habitat restoration action based on recommendations of USFWS (and in consultation with NMFS and CDFW), pursuant to Section 3406(b)(2). This dedicated and managed water (i.e., (b)(2) water) is water USFWS, in consultation with Reclamation and other agencies, has at its disposal to use to meet *Water Quality Control Plan* fishery objectives and helps meet the needs of fish listed under the ESA as threatened or endangered since the enactment of the CVPIA (Reclamation 2008). To supplement the *Water Quality Control Plan* requirements, (b)(2) water may be used to augment river flows and curtail pumping in the Delta.

8.2.1.12 Anadromous Fish Restoration Program

An important goal identified to meet the fish and wildlife purposes of the CVPIA is the broad goal of restoring natural populations of anadromous fish (e.g., Chinook salmon, steelhead, green sturgeon, white sturgeon, American shad, and striped bass) in Central Valley rivers and streams to double their recent average abundance levels. The Anadromous Fish Restoration Program strives to achieve this goal by directing the United States Secretary of the Interior to develop and implement a program to ensure the sustainability of anadromous fish in Central Valley rivers and streams.

8.2.2 State Plans, Policies, and Regulations

State laws, policies, and regulations pertaining to aquatic resources and fisheries are discussed below.

8.2.2.1 California Endangered Species Act

CESA (Fish and Game Code Sections 2050 to 2089) establishes various requirements and protections regarding species listed as threatened or endangered under State law. California's Fish and Game Commission is responsible for maintaining lists of threatened and endangered species under CESA. CESA prohibits the "take" of listed and candidate (petitioned to be listed) species (Fish and Game Code Section 2080). "Take" under California law means to "… hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch capture, or kill …" an individual of a listed or candidate species (Fish and Game Code Section 86). The State definition does not include "harm" or "harass," as the Federal definition does. As a result, the threshold for take under CESA is typically higher than that under ESA. In accordance with Section 2081 of the California Fish and Game Code, a permit from CDFW is required for projects that could result in the incidental take of a wildlife species that is State-listed as threatened or endangered.

8.2.2.2 California Fish and Game Code Section 1602, Lake and Streambed Alteration Program

Diversions, obstructions, or changes to the natural flow or bed, channel, or bank of any river, stream, or lake in California that supports wildlife resources are subject to regulation by CDFW, pursuant to Section 1602 of the California Fish and Game Code. The regulatory definition of a stream is a body of water that flows at least periodically or intermittently through a bed or channel having banks and supports wildlife, fish, or other aquatic life. This includes watercourses having a surface or subsurface flow that supports or has supported riparian vegetation. CDFW's jurisdiction within altered or artificial waterways is based on the value of those waterways to fish and wildlife.

8.2.2.3 California Fish and Game Code Sections 5901 and 5931

Section 5901 of the California Fish and Game Code states that it is unlawful to construct or maintain any device in a stream which prevents, impedes, or tends to impede the passing of fish upstream and downstream. Section 5931 allows CDFW to require a fishway to be constructed to provide passage over or around a dam.

8.2.2.4 Salmon, Steelhead Trout, and Anadromous Fisheries Program Act

Enacted in 1988, the Salmon, Steelhead Trout, and Anadromous Fisheries Program Act was implemented in response to reports that the natural production of salmon and steelhead in California had declined dramatically since the 1940s, primarily because of lost stream habitat in many streams in the State. This act declares that it is the policy of the State of California to increase the State's salmon and steelhead resources, and it directs CDFW to develop a plan and program that strives to double the salmon and steelhead resources (Fish and Game Code Section 6902[a]). It is also the policy of the State that existing natural salmon and steelhead habitat shall not be diminished further without offsetting the impacts of lost habitat (Fish and Game Code Section 6902[c]).

8.2.2.5 Sacramento Valley Salmon Resiliency Strategy

The California Natural Resources Agency released a plan in June 2017 to address near-term and long-term needs of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon and California Central Valley steelhead. The plan relies on the NMFS (2014) Central Valley recovery plan, and incorporates conceptual models of factors affecting Chinook salmon population dynamics. Goals and objectives of the plan relate to the CVPIA salmonid doubling goals and NMFS ESU/DPS recovery criteria. Recommended actions to improve the viability and resiliency of listed salmonid species in the Central Valley include the following.

- Restoration actions in Battle Creek
- Implementation of the McCloud River reintroduction pilot plan in the upper Sacramento River Watershed
- Increasing flows in Mill, Deer, Antelope and Butte creeks
- Restoring fish passage and habitat in Mill and Deer creeks
- Restoration of instream habitats in the upper Sacramento River
- Improving fish passage at Sunset Pumps Rock Dam on the Feather River
- Restoration of rearing and migratory habitats in the Sacramento River
- Completion of fish screen construction on major diversions along the Sacramento River
- Improvement of Sutter Bypass and associated infrastructure to facilitate adult fish passage and improvement of stream flow monitoring
- Improvement of Yolo Bypass adult fish passage
- Increasing juvenile salmonid access to Yolo Bypass and increasing duration and frequency of Yolo Bypass floodplain inundation
- Construction of a permanent Georgiana Slough non-physical barrier
- Restoration of tidal habitat in the Delta

8.2.3 Regional and Local Plans, Policies, and Regulations

8.2.3.1 Yolo County 2030 Countywide General Plan

The *Yolo County 2030 Countywide General Plan* (County of Yolo 2009) includes a conservation and open space element containing goals and policies designed to protect natural resources in perpetuity for the benefit of current and future residents. These resources include water, woodlands, soils, lakes, rivers, fisheries, wildlife, and minerals. The conservation and open space goals and policies provide management guidance for biological resources that may occur in unincorporated lands within the project area.

8.2.3.2 Yolo County Habitat Conservation Plan/Natural Communities Conservation Plan

The Yolo Habitat Conservancy (YHC), a Joint Powers Agency consisting of the County of Yolo and the cities of Davis, West Sacramento, Winters, and Woodland, formed in 2002 to begin drafting a habitat conservation plan/natural community conservation plan (HCP/NCCP) (Yolo Habitat Conservancy 2017). The Yolo County HCP/NCCP will provide the YHC with long-term permits under the federal ESA and the California Natural Community Conservation Planning Act to cover a wide range of public and private activities in Yolo County. Although the Yolo County HCP/NCCP does not directly address fish species, it does include goals and policies related to protecting and improving habitat conditions in the Yolo Bypass, which could indirectly benefit fish resources (Yolo Habitat Conservancy 2017).

8.3 Environmental Consequences

This section describes the impacts of the Alternatives on fisheries and aquatic resources, including the methodology applied to evaluate impacts of the Project Alternatives. Potential impacts of the Alternatives are described relative to the regulatory baseline conditions (California Environmental Quality Act [CEQA] Existing Conditions and National Environmental Policy Act [NEPA] No Action Alternative).

Both quantitative and qualitative assessments were conducted to evaluate potential impacts to fisheries and aquatic resources that could occur as a result of the alternatives. Primarily qualitative assessments were carried out to evaluate potential impacts associated with construction- and maintenance-related activities. Assessment of operations-related impacts included both qualitative and quantitative methodologies.

Hydrologic, hydraulic, fish behavior, and fish population modeling was performed to provide a quantitative basis from which to assess potential operations-related impacts of the alternatives on fish species of focused evaluation and aquatic habitats. Specifically, the modeling analyses were utilized to simulate data intended to represent operational conditions that would occur due to implementation of the alternatives (e.g., Alternative 1 scenario), which were compared to modeled data intended to represent operational conditions that occur under Existing Conditions (i.e., Existing Conditions scenario) and under future conditions (i.e., the No Action Alternative scenario). The methodologies used to simulate comparative operational scenarios under the alternatives relative to the basis of comparison are described in the model-specific technical memoranda.

The impact assessment for fisheries and aquatic resources considered five primary types of potential impacts, including: 1) permanent impacts associated with the construction and operation of infrastructure, 2) temporary and localized impacts associated with construction of infrastructure, 3) ongoing impacts associated with maintenance of infrastructure, 4) short-term hydrologic changes associated with the construction of infrastructure, and 5) long-term hydrologic and aquatic habitat changes associated with the operations of the alternative. The analytical framework used to assess the potential impacts of each component of the alternatives evaluated in this EIS/EIR is described below. Detailed descriptions of the alternatives evaluated in this section are provided in Chapter 2, *Description of Alternatives*.

8.3.1 Methods for Analysis

This section describes the methodologies that the Lead Agencies implemented to evaluate the potential effects of the alternatives on fish species of focused evaluation and their aquatic habitats. In addition to generally qualitative methods for assessing potential construction- and maintenance-related impacts, impact assessment methodologies relied on simulated changes in hydrology, water temperature, water quality, and fisheries habitat parameters under the alternatives relative to the basis of comparison.

8.3.1.1 Construction- and Maintenance-related Impacts

Assessment of construction-related impacts in the project area addressed all of the alternative-specific components, which are described in more detail in Chapter 2. For each infrastructure component evaluated, the assessment was based on several considerations, including the duration and extent of construction-related activities and the proximity of construction-related activities to the Sacramento River and the Tule Canal or other waterways in the Yolo Bypass. Potential construction-related impacts could include: 1) changes in erosion, sedimentation, and turbidity in waterways; 2) potential for hazardous materials or chemicals to enter waterways; 3) changes in aquatic habitat quantity and quality, including riparian vegetation; 4) increases in hydrostatic pressure waves, noise, and vibration; 5) impediments to fish passage; 6) stranding and entrainment; 7) increases in predation risk of fish species of focused evaluation; and 8) direct harm or mortality of fish species of focused evaluation.

The potential for construction-related impacts to affect fisheries and aquatic resources is dependent on the location and type of infrastructure component to be constructed and the potential for construction-related activities to directly harm individuals and/or remove, damage, or alter onsite habitat conditions within and adjacent to the construction footprints for a given alternative.

The impact assessment took into consideration the potential for general effects to occur and the potential for construction activities to affect a particular fish species that may be present in or adjacent to the construction footprint. Depending on the specific activity evaluated, the impact assessment considered either all, or a combination of, the elements listed below, as feasible and appropriate:

- Visual inspection of conditions within the immediate construction footprint and surrounding areas to determine habitat conditions and the potential for disturbance-related effects on aquatic habitat
- Review of available maps and aerial photography to determine the proximity of the construction footprint to adjacent receiving waters
- Evaluation of the sequencing, timing, extent (e.g., long-term or short-term duration), intensity, and severity of disturbance activities resulting from construction-related activities and the use of construction equipment
- Determination if there is a potential for construction activities to adversely modify habitat or appreciably diminish the value of designated or proposed critical habitat

- Identification of avoidance measures and/or mitigation measures to minimize or mitigate for potential construction-related impacts on sensitive life stages of fish species that may be present during construction activities

Maintenance-related impacts were evaluated in the Yolo Bypass and Sacramento River associated with sediment removal within and near the intake facilities; vegetation removal in the intake channel; inspection and maintenance of the headworks facilities; and maintenance of the transport, intake, outlet, and bypass channels.

Conducting fully quantitative analyses of potential impacts on fisheries and aquatic resources associated with construction and maintenance activities requires information specific to each construction activity that often is not available at the time of environmental documentation. Much of the information required to conduct quantitative analyses becomes available as design documents progress to final design stages and as contractors are selected to construct the facilities. Design and specific equipment information can then be used to conduct subsequent analyses for use in permitting processes, including ESA and CWA permitting processes.

The requirements for conducting analyses under CEQA and NEPA include utilizing the best available information to conduct impact assessments. In the absence of final design and equipment specifications, environmental documents often rely on the use of qualitative analyses, which rely on an understanding of potential impact mechanisms, general construction activities and timing, and a detailed understanding of species habitat utilization and life history characteristics. These qualitative analyses focus on the types of impacts that could occur on a species that could be present at a general location during a general time of year.

Although most potential construction- and maintenance-related impacts were evaluated qualitatively, aquatic habitat modification was assessed quantitatively, as discussed below.

The evaluation of altered habitat conditions along the Sacramento River considers the principles of the Standard Assessment Methodology, which has been used to evaluate the value of aquatic habitat as it pertains to life stage responses of focus fish species in the Sacramento River (USACE 2004; USACE 2012b). Although the specific models were not used for assessment in this document, the principles and concepts of habitat alteration associated with the alternatives were used in the evaluation of potential impacts to fish species of focused evaluation.

To the extent feasible, habitat variables considered include structural features (bank slope, substrate size, instream woody material [IWM], riparian vegetation, and instream object cover), hydraulics, riparian habitat/overhanging shade/cover, and associated predation potential. USACE (2012b) examined the extent to which life stages of Chinook salmon, steelhead, green sturgeon, and delta smelt are sensitive to changes in key Sacramento River shoreline parameters, including bank slope, floodplain inundation, bank substrate size, instream structure (IWM), aquatic vegetation, and overhanging shade. Generally, only the juvenile life stages are expected to exhibit sensitivities to changes in physical habitat (USACE 2012b). Specifically, juvenile salmonids are expected to be the most sensitive to habitat variable changes along the Sacramento River (USACE 2012b). Therefore, this impact assessment focused on potential impacts to structural habitat conditions for juvenile anadromous salmonids.

To determine the magnitude of potential disturbance and/or removal of aquatic and riparian habitat (e.g., shaded riverine aquatic[8] [SRA]) habitat associated with construction of the alternative-specific facilities and channels along the Sacramento River and in the Yolo Bypass waterways, the total amount of available aquatic, riparian, and grassland habitat within the construction footprint was calculated for each alternative. According to the USFWS, the amount of available SRA habitat can be quantified through length and width measurements (i.e., L x W). For this impact assessment, habitat areas temporarily and permanently impacted by the alternatives were quantified using ArcGIS.

8.3.1.2 Operations-related Impacts

Potential operations-related impacts to fish species of focused evaluation and aquatic habitat associated with the alternatives would primarily occur in the Yolo Bypass and Sacramento River downstream of Fremont Weir due to changes in the magnitude, duration, and frequency of flow entering the Yolo Bypass over or through Fremont Weir. Operations of structures in the Yolo Bypass also have the potential to affect passage and predation of fish species of focused evaluation. In addition, changes in flow in the Sacramento River and the Yolo Bypass have the potential to affect habitat conditions in the Delta and downstream estuarine waterbodies. Although not expected to substantially affect fisheries habitat conditions, there also would be potential for the alternatives to result in re-operations of the SWP/CVP system and affect fisheries habitat conditions in Shasta, Oroville, Folsom, and San Luis reservoirs and in the upper Sacramento, lower Feather, and lower American rivers.

8.3.1.2.1 Analytical Tools

The fisheries and aquatic habitat impact assessment relied on hydrologic, hydraulic, water temperature, and fisheries modeling to provide a quantitative basis from which to assess the effects of the alternatives on fish species of focused evaluation and aquatic habitats in the project area relative to the basis of comparison. Models and other tools applied in the evaluation of alternatives are summarized below.

- Mean monthly hydrologic (CalSim II) and water temperature modeling (Reclamation Water Temperature Model) to address potential changes in reservoir operations and instream conditions in the Sacramento River and other areas of the SWP/CVP system, including the Delta
- Hydrologic Engineering Center River Analysis System (HEC-RAS) hydraulic modeling within facilities and in transport, intake, and outlet channels in the Yolo Bypass and Sacramento River to estimate hydraulic conditions for use in evaluating adult fish passage
- Yolo Bypass Passage for Adult Salmonids and Sturgeon (YBPASS) tool (a compilation of files generated in Microsoft Excel for water years 1997 through 2012) to evaluate modeled water depths and velocities to assess adult fish passage performance through planned facilities at the Fremont Weir

[8] The nearshore aquatic area occurring at the interface between a river (or stream) and adjacent woody riparian habitat

- Sedimentation and River Hydraulics – Two Dimensional modeling (SRH-2D) along the Fremont Weir section of the Sacramento River to predict the hydrodynamics under the influence of various Fremont Weir notch configurations
- Eulerian-Lagrangian Agent Method (ELAM) modeling at the Fremont Weir and proposed notches in the weir based on hydraulic modeling and acoustically tagged fish movement to evaluate the proportion of juvenile Chinook salmon predicted to be entrained into the Yolo Bypass at particular flows
- Critical streakline analysis to evaluate entrainment potential of various notch locations based on modeling of hydraulic conditions and acoustically tagged fish tracks
- Yolo Bypass Juvenile Entrainment Evaluation Tool (a spreadsheet tool generated in Microsoft Excel for water years 1997 through 2012) to evaluate estimated entrainment into the Yolo Bypass at the Fremont Weir that utilizes empirical juvenile Chinook salmon catch data and assumes that entrainment of fish is proportional to the volume of flow diverted
- Daily hydrodynamic Two-Dimensional Unsteady Flow modeling (TUFLOW) in the Yolo Bypass and Sacramento River downstream of Fremont Weir to evaluate hydraulic conditions in the Yolo Bypass and Sacramento River associated with changes in Sacramento River flows entering the Yolo Bypass at Fremont Weir
- Salmon Benefits Model (SBM) to simulate changes in annual size, size variation, ocean entry timing variation, and survival of juvenile Chinook salmon emigrating through the Yolo Bypass and lower Sacramento River and Delta and resulting changes in adult returns by run

CalSim II

CalSim II is the application of the Water Resources Integrated Modeling System software to the SWP and CVP. This application was jointly developed by Reclamation and DWR for planning studies relating to SWP/CVP operations.

CalSim II is used to simulate system operations for an 82-year (water years 1921 through2002) period using a monthly timestep. The model assumed that facilities, land use, water supply contracts, and regulatory requirements were constant over this period, representing a fixed level of development (LOD) (e.g., 2005, 2030). Major Central Valley rivers, reservoirs, and SWP/CVP facilities are represented by a network of arcs and nodes. Flows were simulated as monthly averages, and reservoir storages are simulated as end-of-month storages. Descriptions of the assumed regulatory standards and operations criteria used in CalSim II for the alternative and baseline scenarios are provided in Appendix E.

The hydrologic analysis conducted for this Draft EIS/EIR used CalSim II models with 2030 and 2070 hydrology from the California Water Commission Climate Change Water Supply Improvement Project modeling to approximate system-wide changes in storage, flow, salinity, and reservoir system re-operation associated with the alternatives. Reclamation's CalSim II modeling of the Existing Conditions scenario and the alternatives under existing LOD assumed a 2030 hydrology. Future conditions in the CalSim II modeling for the No Action Alternative and the alternatives under future LOD assumed a 2070 hydrology, including estimates of climate change and sea level rise.

Hydrologic simulation results from CalSim II provided a quantitative basis to assess the effects of the alternatives and coordinated SWP/CVP operations on flows spilling over Fremont Weir into the Yolo Bypass, flows in the Sacramento River downstream of the Fremont Weir, and hydrologic and salinity conditions in the Delta. Simulated reservoir storages provided a quantitative basis to assess potential changes in fisheries habitat in Shasta, Oroville, Folsom, and San Luis reservoirs and as indicators of potential changes in hydrologic conditions in the upper Sacramento, lower Feather, and lower American rivers under the alternatives relative to the basis of comparison (i.e., Existing Conditions and No Action Alternative scenarios).

Although water temperatures would not be expected to substantially change in the project area under the alternatives, the Lead Agencies used CalSim II simulated flows as inputs to Reclamation's water temperature model for the lower Sacramento River to simulate mean monthly water temperatures over the water years 1922 to 2003 simulation period.

YBPASS Tool and HEC-RAS Modeling

Using hydraulic criteria developed by Yolo Bypass Fisheries and Engineering Technical Team (FETT), DWR developed the YBPASS tool to compare HEC-RAS modeled water depths and velocities in the alternative-specific intake structures and transport channels to compare against adult Chinook salmon and sturgeon fish passage criteria.

SRH-2D

SRH-2D is a 2D depth-averaged hydrodynamic model for river systems developed by Reclamation (Lai 2008; 2010). Flow hydrodynamics were modeled using SRH-2D near Fremont Weir to support the ELAM modeling of fish movement within the Sacramento River and through the Fremont Weir to evaluate the effectiveness of different notch configurations (Lai 2017).

The SRH-2D model domain encompasses the approximately 18-kilometer (km) (10.8-mile) reach along the Fremont Weir section of the Sacramento River extending from Knights Landing downstream to the Verona gage station. Inflows from the Feather River, Sacramento Slough, and Natomas Cross-Cut (located between the Feather River confluence and Verona gage station) also were included in the model domain. For notch configuration prediction, 2015 bathymetric data were used in conjunction with local terrain modifications associated with the placement and configurations of each notch. Hydrology from December 2014 to January 2015 was used to generate the flow hydrodynamics, which included both low and high flows. Model input parameters were the same for all notch configurations except for the terrain and geometry modifications associated with the notch to allow for relative comparisons to be made among the notch configurations. Refer to Lai (2016; 2017) for a detailed description of the SRH-2D modeling conducted.

ELAM

The ELAM model is a mechanistic representation of individual fish movement that accounts for local hydraulic patterns represented in computational fluid dynamic models. As described in Appendix G1, Smith et al. (2017) used simulated hydraulics from the SRH-2D model and observed fish movement along the Fremont Weir to estimate entrainment of juvenile Chinook salmon into the Yolo Bypass using an ELAM model. Hydrodynamic information generated at discrete points was interpolated to locations anywhere within the physical domain where fish may be, which allowed the generation of directional sensory inputs and movements in a reference framework similar to that perceived by real fish.

The SRH-2D model was integrated with landscape topography (LiDAR [light detection and ranging]), bathymetry, and basic notch designs. The model approach was informed by 2D observations of hatchery late fall-run and winter-run Chinook salmon collected during a telemetry study on the Sacramento River at Fremont Weir (Steel et al. 2016). Individual fish telemetry tracks were not modeled directly, but rather statistical properties of the measured tracks were used to develop model coefficients. Because actual entrainment estimates into the evaluated notch configurations are unknown, the entrainment estimates using ELAM should not be viewed as absolute numbers and should be used as relative entrainment rates to highlight differences across scenarios (Smith et al. 2017).

One key limitation of the ELAM modeling is that it is based on movement of relatively large hatchery-produced juvenile Chinook salmon (mean FL of 145 mm for late fall-run and 103 mm for winter-run). Because the behavior of fry-sized juveniles may be different than that of smolt-sized juveniles, the probability of fry being entrained into a notch may differ from the probability of smolts being entrained into a notch. The probability of hatchery-produced smolts being entrained into a notch also may be different than the probability of naturally produced smolts being entrained into a notch. The ELAM modeling also could produce different entrainment results under flow conditions in the Sacramento River near Fremont Weir, which differ from the flows observed during the telemetry study used in the ELAM model. Refer to Smith et al. (2017) for a detailed description of the methods, data inputs, and limitations of the ELAM modeling.

Critical Streakline Analysis

The critical streakline analysis used hydraulic modeling and acoustically tagged juvenile Chinook salmon tracks to identify the number of juvenile Chinook salmon that would be entrained into the various notch locations based on the location of the critical streakline (Blake et al. 2017; Appendix G2). The critical streakline is the cross-stream dividing line upstream of the proposed notch that separates water that will go into the notch from water that will continue to go down the Sacramento River. Past studies have found that evaluating the movement of fish based on the cross-stream location of the critical streakline relative to the cross-stream location of a fish immediately upstream of a junction has been found to be a good predictor of a fish's movement within the junction and a good predictor of aggregate entrainment rates when predictions were summed over a group of fish (DWR 2012, 2015, 2016, all as cited in Blake et al. 2017; Appendix G2).

The cross-stream location of the critical streakline upstream of the notch was estimated from the cross-stream distribution of bathymetry and discharge immediately upstream of the notch, which was overlaid with the fish spatial distributions to estimate entrainment rates for each notch. Abundance and temporal distributions of juvenile Chinook salmon were developed from the Knights Landing RST catch data from water years 1997 through 2011. Fish tracks were developed based on acoustically tagged juvenile late fall-run Chinook salmon from Coleman National Fish Hatchery during 2016.

The largest source of uncertainty in the critical streakline analysis is that the simulation is based on a limited sample of fish tracks from hatchery-origin late fall-run Chinook salmon. Therefore, the simulation does not account for the potential differences in physiology and behavior between hatchery-produced and naturally produced juveniles (Blake et al. 2017; Appendix G2). The simulation also does not account for behavioral differences between the large (smolt-sized) juveniles used in the simulation and smaller juveniles. Additional limitations include the use of a limited range of Sacramento River backwater conditions represented in the 2016 fish track data set and the possibility that modifications to Fremont Weir could alter the hydrodynamics in the study area (Blake et al. 2017; Appendix G2). Refer to Appendix G2 for a detailed description of the methods, data inputs, and limitations of the critical streakline analysis.

Yolo Bypass Juvenile Entrainment Evaluation Tool

The FETT requested that a tool be developed that could evaluate the entrainment potential of various project alternatives using empirical juvenile salmon catch data and the corresponding Sacramento River stage and flow data. This tool needed to be capable of easily incorporating changes to alternatives as they became more refined and needed to produce a result quickly without undergoing lengthy model runs.

DWR designed the Juvenile Entrainment Evaluation Tool (DWR 2017a; Appendix G3) to incorporate juvenile salmon catch data from water years 1997 through 2011 from CDFW RSTs located approximately 5.5 miles upstream of the Fremont Weir near Knights Landing. The daily proportion of Sacramento River flow that would be diverted through alternative-specific notches and onto the Yolo Bypass was generated using TUFLOW. These flow splits were used to determine the proportion of juvenile Chinook salmon (by run) present near the Fremont Weir that would be entrained onto the Yolo Bypass. The Juvenile Entrainment Evaluation Tool was used to estimate the total annual average proportion of juvenile Chinook salmon (by run) that would be entrained into the Yolo Bypass for each Alternative and the total annual average proportion of smaller (i.e., <80 mm) juvenile Chinook salmon by run that would be entrained into the Yolo Bypass for each Alternative. Smaller fry-sized fish presumably would experience the greatest benefit because of being entrained onto the Yolo Bypass to rear (DWR 2017a; Appendix G3).

One limitation of this tool is that entrainment onto the Yolo Bypass is assumed to equal the proportion of flow diverted onto the floodplain from the Sacramento River. Entrainment through alternative-specific structures was compared to estimated entrainment for the period of record under current conditions (i.e., fish brought onto the floodplain during periods where the Sacramento River stage exceeded the crest of the Fremont Weir and spilled onto the Yolo Bypass). The product of this tool is the relative increase in entrainment from Existing Conditions for each alternative, rather than an absolute number of fish entrained.

TUFLOW

To better characterize spills into the Yolo Bypass and hydraulic conditions and inundation of the Yolo Bypass on a daily timestep, the Lead Agencies developed a 2D hydrodynamic model (TUFLOW) to compare alternatives. The 2D capabilities of the TUFLOW model allow for the comparison of the spatial distribution of flow, velocity, and depth with or without assumed future hydraulic features. The TUFLOW model extends along the Sacramento River from RM 118 to RM 12 (near Rio Vista) and includes the entire Yolo Bypass. Historical flows from the year 1997 to 2012 were simulated for several channel and weir configurations on a five- to 10-second timestep as a part of the initial alternatives evaluation (see Appendix D for detailed information on the TUFLOW modeling).

Salmon Benefits Model

The Lead Agencies used simulated daily flows overtopping Fremont Weir and flows through the proposed notches as well as modeled depths and velocities in the Yolo Bypass and Sacramento River from TUFLOW as inputs to the SBM. The SBM tracks key Chinook salmon life history stages from freshwater emigration in the lower Sacramento River (just upstream of the Yolo Bypass) to numbers of returning adults. Specifically, the SBM quantifies effects of changes in flows entering the Yolo Bypass on the size distribution of juvenile Chinook salmon emigrating to the ocean and on abundance of returning adults for each year of the simulation period (Hinkelman et al. 2017). The SBM accounts for the timing and duration of inundation of the Yolo Bypass as well as modeled depths and velocities with respect to juvenile Chinook salmon habitat suitability criteria. The SBM uses data and assumptions to determine the proportion and abundance of juveniles entrained into the bypass, the timing and duration of juvenile rearing, the timing and duration of emigration through the bypass, amount of accessible suitable habitat, and growth and survival of juveniles daily from October through May for each year of the 15-year (water years 1997 through 2011) simulation period. The SBM uses the “proportion of flow” approach such that the number of juveniles assumed to be entrained into the Yolo Bypass is proportional to the amount of Sacramento River flow diverted into the Yolo Bypass. Specifically, the SBM uses the proportion of each Chinook salmon run estimated to be entrained using the proportion of flow approach based on all size classes of each run (i.e., it is not limited to the entrainment of smaller juveniles).

Hinkelman et al. (2017) reported that although all the effects examined in the SBM have the potential to influence the fish benefit results of the alternatives, there is a particularly strong interactive effect of the rearing rule and rearing survival value. Hinkelman et al. (2017) recommended that the rearing rule and rearing survival assumptions be targets for additional investigations. Detailed information on the methodology, limitations, and results of the SBM is provided in Appendix G4, *Salmon Benefits Model* (Hinkelman et al. 2017).

8.3.1.2.2 Application of Model Output

The Lead Agencies used computer simulation models and post-processing tools to assess changes in hydrology and water quality and associated changes in habitat conditions and fish populations that could occur under the alternatives, relative to the basis of comparison. The Lead Agencies used model assumptions and results for comparative purposes, rather than for absolute predictions, and focused the analysis on differences in the results among comparative scenarios. The assumptions are generally the same for both the with-project and without-project model runs, except for assumptions associated with the different alternatives themselves, and the focus of the analysis is the differences in the results.

The models used in the analyses, although mathematically precise, should be viewed as having inherent uncertainty because of limitations in the theoretical basis of the models and the scope of the formulation and function for which each model is designed. Nonetheless, models developed for planning and impact-assessment purposes represented the best available information with which to conduct evaluations of the alternatives on fisheries and aquatic resources in the project area.

Figure 8-4 displays the linkages between the models applied, the model outputs used, and the species that were evaluated.

Riverine Flows

The Lead Agencies assessed effects on fish species of focused evaluation by evaluating hydrologic model outputs to identify changes in aquatic habitat that could affect fish species of focused evaluation. Specific types of model output used to assess changes in fisheries habitat conditions are summarized below.

Post-processing tools use monthly output to calculate the average monthly flows that would occur over the respective simulation periods under the alternatives and the basis of comparison. The Lead Agencies used monthly average simulated flows by water year type to compare differences between the basis of comparison and the alternatives. Presented in tabular format, the data tables for the average flows by month over the entire simulation period, and the monthly average flows by water year type, demonstrate the changes that could occur with the alternatives, relative to the basis of comparison.

The Lead Agencies developed monthly flow probability of exceedance distributions (or curves) from monthly outputs for the entire simulation periods. These curves illustrate the distribution of simulated flows with the alternatives and the basis of comparison. Exceedance distributions generally represent the monthly flow output for a given month sorted by magnitude for the entire period of record. In general, flow exceedance distributions represent the probability, as a percentage of time, that modeled flow values would be met or exceeded at a specific location during a certain period. Therefore, exceedance distributions demonstrate the cumulative probabilistic distribution of flows for each month at a given river location under a given simulation. Exceedance distributions also allow a comparison of flow output among model scenarios without attributing unwarranted specificity to changes between model years.

Because changes in river flows associated with the alternatives are expected to occur primarily in the Sacramento River downstream of Fremont Weir, life stages of fish species of focused evaluation that could potentially be affected would generally be restricted to adult and juvenile migration and juvenile rearing. For the purposes of this impact assessment, changes in flow of 10 percent or greater are used to indicate potential substantial changes in simulated mean monthly flows. Although there is no direct biologic rationale to indicate that flow changes of 10 percent or more would substantially affect fish species or aquatic habitat, a change in monthly flow of 10 percent or greater has been previously identified by various environmental documents as an appropriate criterion to evaluate flow changes, including the *Trinity River Mainstem Fishery Restoration Draft EIS/EIR* (USFWS et al. 1999), the *San Joaquin River Agreement EIS/EIR* (San Joaquin River Group Authority 1999), the *Freeport Regional Water Project Draft EIR/EIS* (Reclamation and Freeport Regional Water Authority 2003), the *Yuba Accord EIR/EIS* (YCWA et al. 2007), the *Sites Reservoir Project Draft EIR/EIS* (Sites Project Authority and Bureau of Reclamation 2017), and the *Substitute Environmental Document in Support of Potential Changes to the Water Quality Control Plan for the San Francisco Bay-Sacramento/San Joaquin Delta Estuary* (SWRCB 2016).

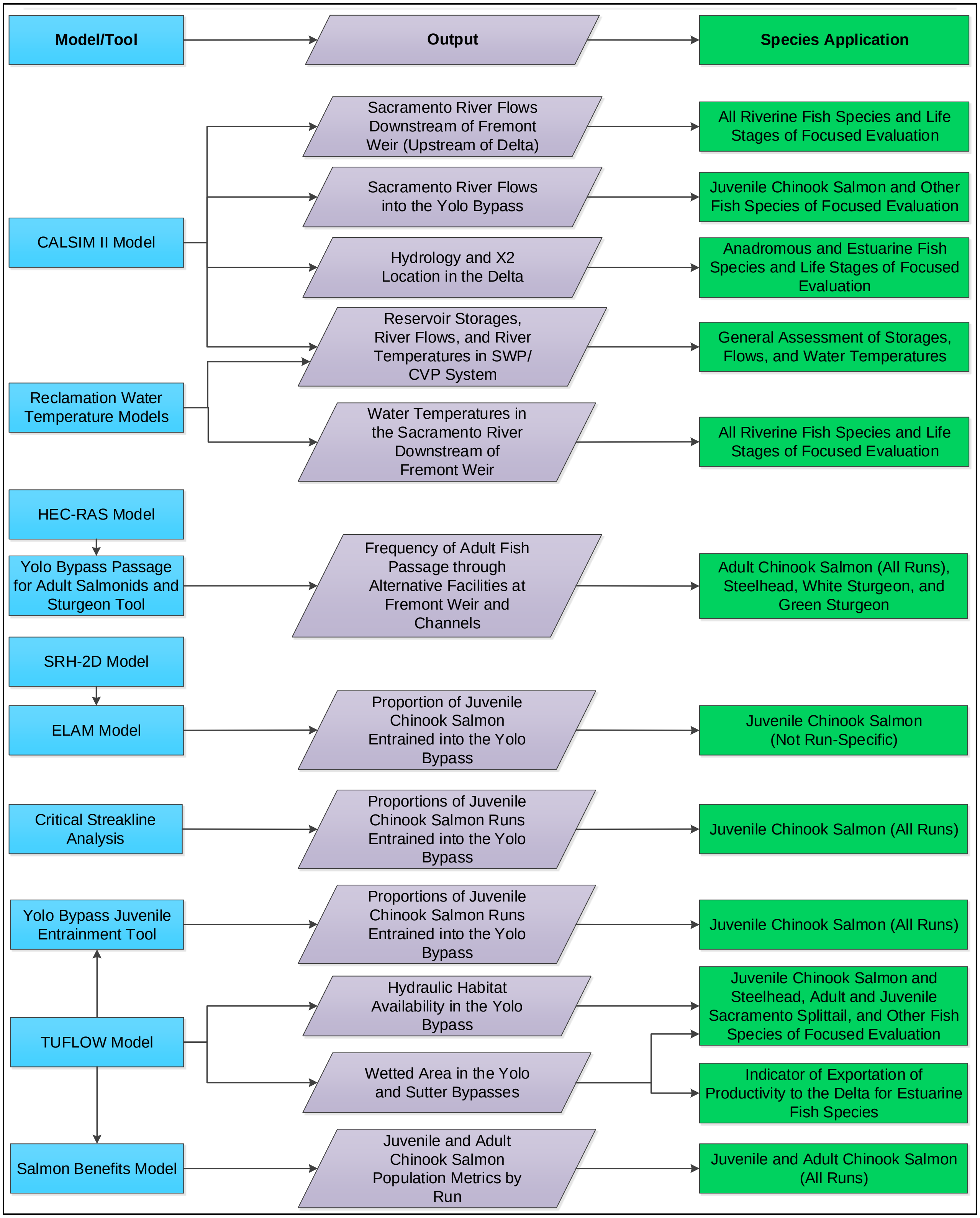


Figure 8-4. Linkages between Models/Tools, Outputs, and Species Evaluations

As suggested by previous environmental documents, a change of 10 percent or more was selected because it is assumed to be high enough to reveal a potentially significant change to a condition while a lesser amount of change could be due to errors or uncertainties in the various analytical and modeling techniques. Therefore, a change of 10 percent provides a conservative qualitative basis to evaluate whether adverse effects to sensitive species at the population level could occur (SWRCB 2016).

Because it is not expected that changes in flows under relatively high-flow conditions would adversely affect fish species of focused evaluation in the lower Sacramento River, this impact assessment specifically evaluated changes during low-flow conditions (e.g., flows for critical and dry water year types). This is consistent with previous environmental documents, such as SWRCB (2016), which determined that flow reductions of 10 percent or more over the highest 50 percent distribution of flows would not adversely affect anadromous salmonids or other fish species of focused evaluation. Recent and current hydrologic modeling of the SWP/CVP included an 82-year period of record for evaluation (water years 1922 to 2003) of which 30 years (37 percent) are classified as dry or critical according to the Sacramento Valley (40-30-30)[9] Index. Recent regulatory and environmental documents evaluating fisheries in the Central Valley, including the Reclamation (2008) biological assessment on the continued long-term operations of the SWP and CVP and the NMFS BO (NMFS 2009) on the long-term operations of the SWP and CVP evaluated flows and/or fisheries indicators of potential impact by water year type. In accordance with the selected flow criteria described above, a change in flow generally encompassing dry and critical conditions (i.e., the lowest 40 percent of monthly flows over the flow exceedance probability distributions) of 10 percent or greater under an alternative, relative to the basis of comparison, was used as an indicator of potential impact. Specifically, net changes in flow of 10 percent or more were calculated to determine if flow increases by 10 percent or more with higher frequency or if flow decreases by 10 percent or more with higher frequency (i.e., the percentage of the time that flow increases by 10 percent or more minus the percentage of time that flow decreases by 10 percent or more). The net change in flow of 10 percent or more was evaluated monthly for the lowest 40 percent of the distribution of monthly flows.

Riverine Water Temperatures

The Lead Agencies developed monthly water temperature exceedance distributions (or curves) from Reclamation's monthly water temperature model output for the entire simulation period for the Sacramento River at Freeport to identify whether simulated water temperatures would exhibit substantial differences under the alternatives relative to the basis of comparison. In general, water temperature exceedance distributions represent the probability, as a percentage of time, that modeled water temperature values would be met or exceeded at a specific location during a certain period. Monthly water temperature exceedance distributions were compared under the alternatives relative to the basis of comparison in the lower Sacramento River to determine whether potential impacts to fish species of focused evaluation may occur. An initial evaluation was conducted by comparing the differences in the probability of exceeding water temperature index values for fish species of focused evaluation, including Chinook salmon, steelhead, green

[9] 40-30-30 refers to the coefficients used in the calculation of the index (i.e., 0.4*Current April-July runoff + 0.3*Current October-March runoff + 0.3*Previous Year's Index)

sturgeon, white sturgeon, and Pacific and river lamprey, under the alternatives relative to the basis of comparison. Water temperature index values evaluated and supporting information are provided by Sites Project Authority and Bureau of Reclamation (2017). More detailed evaluations would be conducted for this impact assessment if substantial differences in water temperatures would be expected to occur at other locations in the SWP/CVP system under an alternative relative to the basis of comparison.

Potentially substantial changes in water temperature suitability were identified based on changes in the frequency of exceeding species and life stage-specific water temperature index values of 10 percent or more under an alternative relative to a basis of comparison. A change in frequency of exceedance of 10 percent was assumed to be high enough to reveal the potential for a substantial change yet minimizes the potential for identifying a change due to error or uncertainty in the analytical methodologies and modeling (SWRCB 2016).

Delta Hydrologic and Water Quality Conditions

CALSIM II was used to simulate mean monthly hydrologic and water quality conditions in the Delta to assess species and life stage-specific impacts under the alternatives relative to the basis of comparison. Parameters modeled included flows at Rio Vista, Delta outflow, X2 location, water temperature at Freeport, and Old and Middle River (OMR) flows. Modeled variables were evaluated using probability of exceedance distributions to compare the frequency with which modeled conditions were within ranges of life stage-specific suitabilities or exceeded thresholds of life stage-specific suitability previously identified by regulatory agencies or in scientific studies (e.g., SWRCB 2010), as applied by Sites Project Authority and Bureau of Reclamation (2017). The following modeled parameters were evaluated for particular life stages of fish species of focused evaluation expected to occur in the Delta:

- Delta smelt (adult, egg, larval, and juvenile life stages)
  - Water temperature, X2 location, OMR flows, and Delta outflow
- Longfin smelt (adult and larval/juvenile life stages)
  - OMR flows, X2 location
- Chinook salmon (juvenile life stage; all Central Valley runs)
  - OMR flows, Delta outflow, Rio Vista flows
- Chinook salmon (San Joaquin River Basin adults)
  - OMR flows
- Steelhead (juvenile life stage)
  - OMR flows, Delta outflow, Rio Vista flows
- Striped bass and American shad (egg and larval life stages)
  - X2 location

Potentially substantial changes in Delta flows were identified based on changes in flow of 10 percent or more occurring 10 percent or more of the time during a month (based on the monthly flow exceedance distributions). Changes in average monthly flow of 10 percent or more over the entire simulation period and by water year type also were considered potentially substantial changes under an alternative relative to the basis of comparison.

In addition to evaluating the Delta parameters above, an assessment was conducted to determine whether the alternatives could cause substantial changes in fish salvage and entrainment at the Skinner Fish Protection Facility (part of the SWP) and the Tracy Fish Collection Facility (part of the CVP) by comparing mean monthly total water export volumes from the SWP and CVP export facilities relative to the basis of comparison. More detailed evaluation of fish salvage and entrainment loss for fish species of focused evaluation would be conducted if substantial (i.e., greater than 10 percent) changes in average monthly exports over the entire simulation period and by water year type would occur under an alternative, relative to the basis of comparison.

Juvenile Entrainment into the Yolo Bypass

A key objective of the Project is to increase the entrainment of juvenile Chinook salmon into the Yolo Bypass. Multiple methods were applied by the Lead Agencies to assess and evaluate the proportion of emigrating juvenile Chinook salmon that could be entrained into the Yolo Bypass associated with different Fremont Weir notch configurations and different notch flow capacities, as described below.

Proportion of Flow Approach

One method to estimate entrainment of juvenile fish into the Yolo Bypass was to assume that juveniles are equally distributed across the wetted channel and throughout the water column in the Sacramento River at Fremont Weir; therefore, juveniles would enter the Yolo Bypass at Fremont Weir in proportion to the total volume of flow passing through and over Fremont Weir (DWR 2017a; Appendix G3). Similar dispersion assumptions have been used to evaluate juvenile salmon entrainment into the central Delta using particle tracking (Kimmerer and Nobriga 2008). However, it should be noted that tagged juvenile hatchery late fall-run and winter-run Chinook salmon exhibited a non-uniform distribution within the channel near Fremont Weir, with a tendency to use area along the outer bend more frequently than the inner bend (Steel et al. 2016).

DWR (2017a) used the proportion of flow approach to estimate the daily and seasonal average annual proportion of juvenile Chinook salmon by run entrained onto the Yolo Bypass for each alternative. Under the proportion of flow approach, Alternatives 1, 2, and 3 were assumed to entrain the same proportion or number of juvenile Chinook salmon because they have the same flow capacity (6,000 cfs) and are designed to function and entrain the same volume of water at a given Sacramento River stage (DWR 2017a; Appendix G3). Although this method does not account for behavior of juvenile salmonids (or potentially variable behaviors of different size classes at different flows), it provides a consistent methodology for comparing potential differences in entrainment of juvenile salmonids, including smaller juveniles (i.e., <80 mm FL), into the Yolo Bypass. The SBM and the Juvenile Entrainment Evaluation Tool both utilized this methodology to estimate the proportion and number of juvenile Chinook salmon entrained into the Yolo Bypass.

ELAM

The Lead Agencies used simulated 2D hydraulics as inputs to the ELAM to estimate entrainment of juvenile Chinook salmon into the Yolo Bypass under each of the six alternatives (see Appendix 1 of Smith et al. 2017). Estimates of entrainment percentages for each alternative were made over a range of Sacramento River stages at Fremont Weir (20.23 to 28.83 feet), which correspond to Sacramento River flows ranging from 14,952 to 24,640 cfs at Fremont Weir (Appendix G1). For the purposes of this impact assessment, ELAM simulation results were used to inform the relative difference in proportion of juvenile Chinook salmon expected to be entrained through the alternative-specific notch configurations at specific modeled flows.

Critical Streakline Analysis

The critical streakline analysis was performed for six scenarios corresponding to different alternative notches and variations of the alternatives (Blake et al. 2017; Appendix G2). Scenarios modeled were intended to represent Alternative 3 (Scenario 1), Alternative 4 (Scenario 2), and Alternative 6 (Scenario 3). No scenarios were modeled near the central or eastern portions of Fremont Weir corresponding to the proposed locations of Alternatives 1, 2, and 5. Therefore, relative differences in estimated entrainment rates were compared among the notch configurations of Alternatives 3, 4, and 6.

Flow-Dependent Habitat Availability

Flow-dependent habitat availability refers to the quantity and quality of habitat available to individual species and life stages for a particular flow. The project objectives include improving access to and area of seasonal floodplain fisheries habitat for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley steelhead. Improving access to and area of floodplain habitat also could improve conditions for Sacramento splittail and Central Valley fall-run/late fall-run Chinook salmon. Therefore, this impact assessment evaluates changes in hydraulic (i.e., water depth and velocity) habitat availability for these species. It should be recognized that the suitability of floodplain habitat for a given species and life stage may be affected by factors other than water depth and velocity, including substrate type, the presence and type of instream cover, water temperature, and dissolved oxygen levels. Therefore, the modeled areas of hydraulic habitat availability may overestimate actual habitat availability.

Because there is relatively more information and modeling available for Chinook salmon, and because improving habitat conditions for juvenile Chinook salmon is a key objective of the Project, modeled hydraulic habitat availability for juvenile Chinook salmon was used as a surrogate for hydraulic habitat availability for other fish species and life stages with similar habitat suitability criteria (described below).

Chinook Salmon

Habitat suitability criteria for Sacramento River juvenile Chinook salmon (USFWS 2005) were used to define suitable floodplain rearing habitat for fry (<70 mm FL) and smolts (≥70 mm FL) in the SBM (Hinkelman et al. 2017). Suitable habitat for fry (or pre-smolts) was characterized as 0.39 to 4.0 feet deep, with velocities less than 1.6 ft/s, and for smolts as 0.39 to 8.0 feet deep, with velocities less than 1.6 ft/s (USFWS 2005). This impact assessment compared the period of record average and average by water year type daily hydraulic habitat availability for the pre-smolt and smolt life stages in the Yolo Bypass for winter-run, spring-run, fall-run, and late fall-run Chinook salmon under the alternatives relative to the basis of comparison. Due to the potential masking effect of comparing average values, this impact assessment also compared daily hydraulic habitat availability values over the entire period of record (using probability of exceedance distributions) for each Chinook salmon run and juvenile life stage (pre-smolt and smolt) under the alternatives relative to the basis of comparison. Consistent with previous environmental documentation (e.g., SWRCB 2016), changes in area of potential habitat of 10 percent or more were identified under the alternatives relative to the basis of comparison.

Steelhead

Juvenile steelhead are not as likely to utilize floodplain habitat in the Yolo Bypass to the extent of juvenile Chinook salmon and are not frequently caught in the Yolo Bypass. The juveniles that have been caught in the Yolo Bypass were smolt-sized (DWR unpublished data). Nonetheless, because steelhead smolts likely can utilize similar ranges of depths and velocities as Chinook salmon smolts on the Yolo Bypass, the relative difference in modeled hydraulic habitat availability for Chinook salmon smolts was used as an indicator for evaluating differences in hydraulic habitat availability for juvenile steelhead.

Sacramento Splittail

Based on information and studies on Sacramento splittail (Moyle et al. 2004; Sommer et al. 2002; Moyle et al. 2007; Young and Cech 1996; Feyrer et al. 2005; Sommer et al. 2008b), Merced Irrigation District (2013) developed consensus-based habitat suitability curves for juvenile and spawning adult Sacramento splittail in consultation with NMFS, USFWS, and CDFW. For juveniles, depths corresponding to optimal suitability (i.e., a Habitat Suitability Index of 1.0) ranged from 0.5 to 3.0 feet, and velocities corresponding to optimal suitability ranged from zero to about 1.4 ft/s. For adult spawning, depths corresponding to optimal suitability ranged from 1.0 to 6.0 feet, and velocities corresponding to optimal suitability ranged from 0.4 to 1.37.

Because the ranges of depths and velocities corresponding to optimal suitability for juvenile Sacramento splittail are similar to those used to define Chinook salmon pre-smolt hydraulic habitat availability (i.e., 0.39 to 4.0 feet; <1.6 ft/s), relative differences in modeled hydraulic habitat availability for Chinook salmon pre-smolts were used as an indicator for evaluating relative differences in hydraulic habitat availability for juvenile Sacramento splittail. Because the ranges of depths and velocities corresponding to optimal suitability for adult spawning Sacramento splittail are similar to those used to define Chinook salmon smolt hydraulic habitat availability (i.e., 0.39 to 8.0 feet; <1.6 ft/s), relative differences in modeled hydraulic habitat availability for Chinook salmon smolts were used as an indicator for evaluating differences in hydraulic habitat availability for adult spawning Sacramento splittail.

Other Fish Species of Focused Evaluation

Although the alternatives are not expected to substantially affect hydraulic habitat availability for fish species other than those described above, potential changes in hydraulic habitat availability were assessed for other fish species of focused evaluation. As an indicator of potential change in habitat availability, changes in modeled hydraulic habitat availability for Chinook salmon pre-smolts and smolts, and changes in modeled wetted area (i.e., the area with a water depth greater than zero) would encompass the range of potential changes in hydraulic habitat availability for the other fish species of focused evaluation that may occur in the Yolo Bypass. As an indicator of a potentially substantial difference in hydraulic habitat availability, changes in area of potential habitat of 10 percent or more were identified under the alternatives relative to the basis of comparison using probability of exceedance distributions over the entire simulation period and averages over the entire simulation period and by water year type.

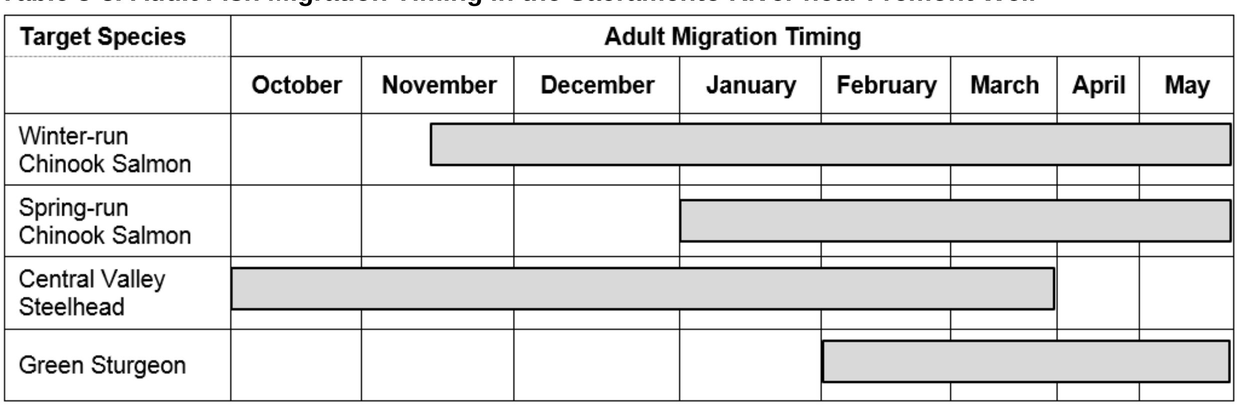
Sutter Bypass Inundation

Because the Alternatives would result in increased flows entering the Yolo Bypass from the Sacramento River at Fremont Weir at reduced Sacramento River flows, the alternatives could result in some reduction in wetted extent and duration in the area of the Sutter Bypass north of the Sacramento River at Fremont Weir. The TUFLOW model extent includes the Sutter Bypass north of the Sacramento River at Fremont Weir upstream to the area just south of where East Canal/Nelson Slough cross the Sutter Bypass. Therefore, changes in the number of days when this area of the Sutter Bypass would be wetted under the alternatives was compared relative to Existing Conditions as an indicator of changes in hydraulic habitat availability for fish species of focused evaluation.

Adult Fish Passage through the Yolo Bypass

Adult fish passage at the Fremont Weir for the target fish species (i.e., winter-run Chinook salmon, spring-run Chinook salmon, steelhead, and green sturgeon) was evaluated over the expected migration periods in the Yolo Bypass (Table 8-3) (DWR 2017b; Appendix G5).

Table 8-3. Adult Fish Migration Timing in the Sacramento River near Fremont Weir



Source: DWR 2017b; Appendix G5

Based on these migration timings, the target fish species could be present near Fremont Weir from October through May. However, the Fremont Weir notch gates are not proposed to be operational in October and May under the alternatives. In addition, because flow conditions at Fremont Weir are generally too low to allow for fish migration between the Sacramento River and the Yolo Bypass (DWR 2017b; Appendix G5) and because project operations are unlikely to affect flow conditions at Fremont Weir during May, the evaluation period selected for adult fish passage at Fremont Weir extends from November through April.

The YBPASS Tool analyzes adult fish passage potential under two different operational ranges due to differences in operations between the November 1 through March 15 period and the March 16 through April 30 period. During the November 1 through March 15 period, the gated notch would be potentially in operation to allow flow through Fremont Weir up to the alternative-specific capacity. During the March 16 through April 30 period, most alternatives would allow for flows up to 1,000 cfs to pass through the gated notch to continue to allow for fish passage through the gated notch and transport channel without increasing inundation of the Yolo Bypass (DWR 2017b; Appendix G5).

The YBPASS Tool incorporates adult fish passage criteria for depth, velocity, and width for anadromous salmonids and sturgeon, including a minimum of three feet of depth at fish passage structures (i.e., gated notch/short channel transitions) and five feet of depth in project channels greater than or equal to 60 feet long (i.e., transport channels) to facilitate sturgeon passage (DWR 2017b; Appendix G5). Although adult anadromous salmonids can migrate through shallower depths (e.g., one foot), meeting the sturgeon passage depth criteria is expected to provide a positive behavioral response for both sturgeon and salmonids, which are likely to avoid shallow channels (DWR 2017b; Appendix G5). Velocity criteria also differ among target species. To avoid passage impedance due to excessive velocities for both adult salmonids and sturgeon, the FETT (2015, as cited in DWR 2017b) recommended a maximum velocity criterion of six ft/s at fish passage structures and four ft/s in project channels greater than or equal to 60 feet long. The width criterion applied for fish passage structures and channels was based on allowing sturgeon to make a complete directional change within the structure or channel. Therefore, a minimum width of 10 feet was used to evaluate the width of the gated notch and the downstream transport channel for each alternative (DWR 2017b; Appendix G5).

To compare adult fish passage performance among alternatives, the YBPASS tool relies on modeled velocity and depth from the HEC-RAS modeling that was developed to inform the dimensions of the proposed alternatives. For each alternative, water depth and velocity were measured as a function of the invert elevation at the weir, the bottom width, and the side slopes. HEC-RAS modeling determined corresponding channel configurations necessary to achieve the proposed discharge rates, and velocities were determined by modeling upstream and downstream water surface elevations associated with the alternatives (DWR 2017b; Appendix G5).

As described by DWR (2017a), to determine the operational range for each alternative, the TUFLOW-modeled stage must meet the minimum depth criterion and not exceed the maximum velocity criterion established for adult fish passage. The minimum stage input for depth represents the lower threshold for passage, and the maximum stage input for velocity represents the upper threshold for passage. If the stage input for depth is greater than the stage input for velocity, the depth criterion for passage is not met before the velocity criterion is exceeded. This results in an inoperable range for fish passage. In addition, if the stage input for velocity is greater than the stage input for discharge, the discharge criterion supersedes the velocity criterion. Therefore, stage inputs for depth, velocity, and discharge correspond to an operational fish passage window for each alternative.

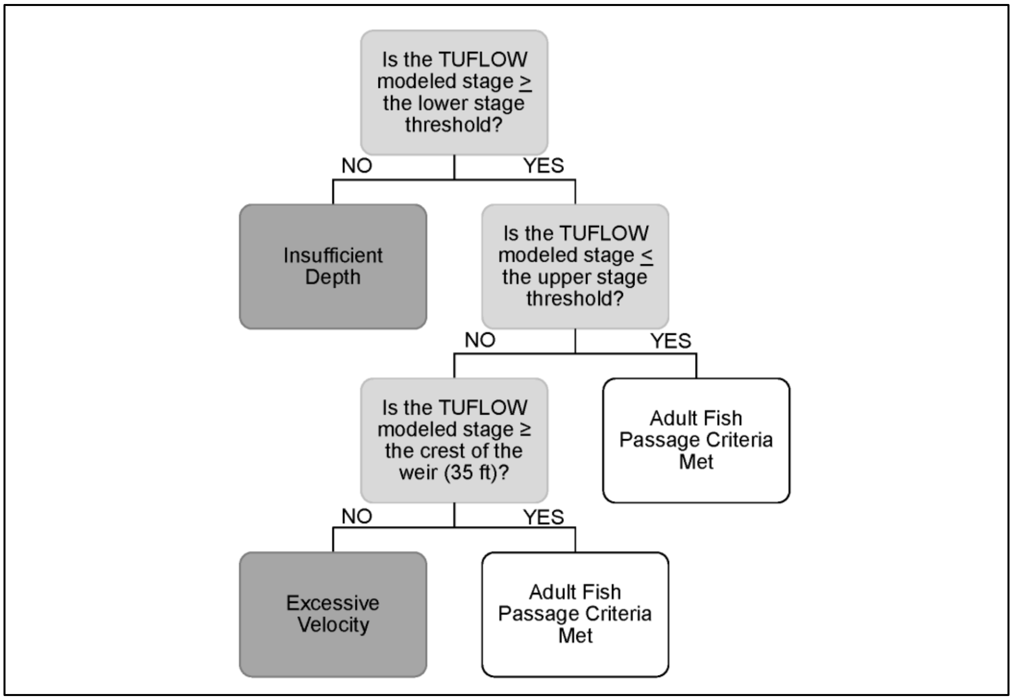
However, operational ranges exist for each component of an alternative, including the gated notch, transport channel, and benches (if included). To consolidate the ranges into one operational range for all components of an alternative, ranges must overlap. In other words, the transport channel's operational range is limited by the gated notch. Flows that exit the gated notch cannot exceed the criterion for the transport channel without causing a delay in passage. If benches are proposed, operational ranges must be within the operational range of the gated notch to meet criteria for passage. By overlapping the operational ranges, the alternative would have one operational range for the gated notch and transport channel. If benches are proposed, an additional operational range for benches can exist if it falls within the operational range of the gated notch. If a gap is present between the operational ranges for the transport channel and bench(es), passage delay is attributed to the TUFLOW-modeled stage exceeding the velocity criterion (DWR 2017b; Appendix G5).

Alternatives 1 through 4 were modeled using HEC-RAS to determine the operational range for adult fish passage through the gated notch, transport channel, and bench (DWR 2017b; Appendix G5). The operational range corresponds to passage windows for the transport channel and bench. For Alternatives 5 and 6, HEC-RAS modeling determined the operational ranges for the gated notch and transport channel. The upper stage threshold of the operational ranges (November 1 through March 15) for Alternatives 1, 2, and 6 do not include the maximum stage input for the design discharge because the stage input for the design discharge exceeded the stage input for the velocity criterion. Alternative 6 does not have an operational range after March 15 due to a velocity barrier once stage reaches the lower stage threshold for fish passage. Therefore, when the Alternative 6 TUFLOW-modeled stage is less than 21.12 feet, depth is a barrier to passage, and when the modeled stage is greater than or equal to 21.12 feet, velocity is a barrier to passage (DWR 2017b; Appendix G5).

For each water year, the effects of both depth and velocity criteria on adult fish passage were evaluated to determine their individual and combined impact on passage. Compliance with depth and velocity criteria was determined through a series of if-then statements as summarized in Appendix G5 (Figure 8-5)**.**

For each alternative, data were summarized for each water year to include the number of days depth caused a barrier to passage, the number of days velocity caused a barrier to passage, the number of days and percent of season the alternative met the criteria, and the last date the alternative met the criteria. Each summary statistic was averaged across water years and includes standard deviation.

In addition to the evaluation of fish passage at the gated notches and transport channels for each alternative, a similar evaluation also was conducted specifically for Alternative 4, which includes two water control structures in the Tule Canal and a sturgeon bypass channel constructed around each of the water control structures. Evaluation of adult fish passage through the bypass channels and at the water control structures was conducted qualitatively.



Source: DWR 2017b; Appendix G5

Figure 8-5. Schematic Diagram Depicting YBPASS Tool's Series of If-Then Statements used to Determine Adult Fish Passage through Project Alternatives

In addition to assessment of fish passage hydraulic (depth and velocity) criteria, this impact assessment also considers guidelines identified in the California Salmonid Stream Habitat Restoration Manual (Flosi et al. 2010) and other literature regarding potential impacts of alternative-specific structures and channels on adult fish passage and other life stages in the Yolo Bypass.

Viable Salmonid Population Parameters

The viable salmonid population (VSP) concept (McElhany et al. 2000) was developed as a conceptual framework for use in assessing salmonid population viability and ESU viability to facilitate establishment of ESU-level delisting goals and assist in recovery planning. The VSP framework identifies four key parameters related to population viability, including: 1) abundance, 2) productivity, 3) diversity, and 4) spatial structure. Because the SBM simulates habitat use and population-related metrics, the VSP parameters serve as a useful framework for presenting and describing changes in the SBM metrics under the alternatives relative to Existing Conditions.

Abundance (i.e., population size of a given life stage) and trends in abundance reflect extinction risk—small populations are generally at greater risk of extinction than large populations (McElhaney et al. 2000). Productivity over the entire life cycle (i.e., population growth rate), life stage-to-life stage-specific productivity (e.g., abundance of outmigrant juveniles relative to the number of spawning adults), and factors that affect productivity provide information on how well a population is "performing" in the habitats occupied during the life cycle of the species

(McElhaney et al. 2000). Diversity reflects the various life histories, sizes, ages, fecundity, run timing, and other traits expressed by individuals within a population and the genetic variation that allows a species to use a variety of environments, respond to short-term changes in the environment, and survive long-term environmental change (McElhaney et al. 2000). Spatial structure refers to the distribution of individuals in a population of a given life stage among the potentially available habitats and associated habitat-forming processes (McElhaney et al. 2000).

The SBM provides simulated output that was used in this impact assessment to qualitatively evaluate changes in the VSP parameters for Chinook salmon species and runs under the alternatives relative to Existing Conditions, as further described below. Population parameters were compared using period of record average and average by water year type tables and probability of exceedance distributions over the entire simulation period.

Abundance and Productivity

Spawner abundance measured over time (e.g., abundance over multiple generations) is the most fundamental population viability metric (NMFS 2016c). Productivity is calculated as the trend in abundance over time. Therefore, productivity is an indicator of a population’s performance in response to its environment, and environmental change and variability. Because the SBM simulates changes in adult returns under the alternatives over a 15-year simulation period, potential changes in abundance and productivity of winter-run, spring-run, fall-run, and late fall-run Chinook salmon were qualitatively evaluated in this impact assessment under the alternatives relative to Existing Conditions.

Diversity

The broad array of juvenile Chinook salmon life history types observed in the Yolo Bypass relative to the Delta suggest that the Yolo Bypass supports a greater diversity of migratory phenotypes and could play a role augmenting the juvenile life history portfolio for the larger Central Valley Chinook salmon population (Takata et al. 2017). For example, fry, parr, and smolt migratory stages were consistently observed emigrating from the Yolo Bypass floodplain, whereas unmarked juvenile Chinook salmon outmigrants in the Delta are often dominated by fry and smolt-sized juveniles (Takata et al. 2017). Therefore, increasing the entrainment of juveniles onto the Yolo Bypass may support the diversity and resilience of Chinook salmon populations.

The SBM simulates annual changes in variation of size (length) of juvenile Chinook salmon and variation in estuary (Chipps Island) entry timing over a 15-year simulation period. Therefore, simulated change in size variation and estuary entry timing were used as indicators of increases in phenotypic diversity for winter-run, spring-run, fall-run, and late fall-run Chinook salmon under the alternatives relative to Existing Conditions.

Spatial Structure

Spatial structure encompasses the geographic distribution of a population as well as the processes that generate or affect that distribution (McElhaney et al. 2000). Spatial structure depends fundamentally on habitat quality, spatial configuration, dynamics, and the dispersal characteristics of individuals in the population (McElhaney et al. 2000). Because the SBM allows for evaluating the annual number of emigrating juveniles that reared on the Yolo Bypass, the annual number of juveniles rearing on the Yolo Bypass was used as an indicator of changes in spatial structure for juvenile winter-run, spring-run, fall-run, and late fall-run Chinook salmon under the alternatives relative to Existing Conditions.

SWP/CVP System

As indicators of potential changes in fisheries habitat conditions in Shasta, Oroville, Folsom, and San Luis reservoirs and in the upper Sacramento, lower Feather, and lower American rivers, simulated changes in end-of-month storages in Shasta, Oroville, Folsom, and San Luis reservoirs were evaluated under the alternatives relative to the basis of comparison. If substantial (i.e., greater than 10 percent) changes in average end-of-month reservoir storage occur or if reductions in end-of-month storage of 10 percent or more occur over 10 percent or more of the simulation period, then more detailed evaluations would be conducted to assess potential impacts on fish species of focused evaluation in the applicable reservoirs and downstream rivers. It is assumed that relatively minor changes in reservoir storage would not substantially impact coldwater or warmwater fisheries habitat conditions or substantially affect instream flows or water temperatures downstream of the reservoir, particularly outside of the period of April through November.

The focus of this impact assessment was on fish species targeted by the project objectives—winter-run Chinook salmon, spring-run Chinook salmon, steelhead, and green sturgeon. However, this impact assessment also addresses the other fish species of focused evaluation with the potential to occur in the project area, with emphasis on species and life stages most likely to occur in the Yolo Bypass and the lower Sacramento River during periods when the alternatives would generally impact them. Construction-related impacts would occur from April through October, operations-related impacts would occur primarily from November through March or April, and maintenance-related impacts could potentially occur year-round. Species-specific spatial and temporal distributions and relative use of the project area used to inform this impact assessment are summarized in Section 8.1.2.

8.3.2 Significance Threshold – CEQA

The thresholds of significance for impacts are based on the environmental checklist in Appendix G to the State CEQA Guidelines, as amended, and were modified based on thresholds used for other projects and conservation plans in the region (e.g., the Bay Delta Conservation Plan/California WaterFix). These thresholds also encompass the factors considered under NEPA to determine the significance of an action in terms of its context and the intensity of its impacts. An impact resulting from the implementation of an alternative would be significant if it would:

- Have a substantial adverse effect, either directly or through habitat modifications, on any fish species identified as a candidate, sensitive, or special-status species in local or regional plans, policies, or regulations, or by the CDFW, the USFWS, or NMFS. An effect would be substantial if it would result in a substantial permanent reduction in area and quality of suitable habitat for special-status fish species.
- Interfere substantially with the movement of any native resident or migratory fish species.
- Conflict with the provisions of an adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other approved local, regional, or state habitat conservation plan.

8.3.3 Effects and Mitigation Measures

This section provides an evaluation of the direct and indirect effects on fisheries and aquatic resources associated with implementing the Project alternatives. This evaluation is organized by Project alternative, with specific impact topics numbered sequentially under each alternative.

The operations-related impact determinations described below apply to each Alternative under the existing LOD relative to Existing Conditions as well as to each alternative under the future LOD relative to the No Action Alternative.

The quantitative modeling described below represents each alternative under the existing LOD relative to Existing Conditions because all modeling conducted for the Project is available for this comparison. Only mean monthly flow (using CalSim II) and mean monthly water temperature (using Reclamation water temperature models) modeling were conducted for the alternatives under the future LOD and the No Action Alternative. However, potential changes to fisheries habitat conditions under each alternative under the future LOD relative to the No Action Alternative would be similar to the changes described for each alternative under the existing LOD relative to Existing Conditions. Although the frequency of spills into the Yolo Bypass from the Sacramento River would increase from January through March under the future LOD scenarios relative to the existing LOD scenarios, the assumptions under each Alternative with an existing LOD are the same as the assumptions used for the Existing Conditions scenario (with the exception of the Project), and the assumptions used for each Alternative with a future LOD are the same as the assumptions used in the No Action Alternative scenario (with the exception of the Project). Therefore, relative differences described for each Alternative under the existing LOD relative to Existing Conditions would be similar to the relative differences expected to occur under each Alternative under the future LOD relative to the No Action Alternative.

8.3.3.1 No Action Alternative

Both NEPA and CEQA require the evaluation of a No Action or No Project Alternative, which presents the reasonably foreseeable future conditions in the absence of the project. As previously discussed (see Chapter 2, *Description of Alternatives*), for the purposes of this EIS/EIR, the CEQA No Project Alternative and NEPA No Action Alternative are represented as the same scenario, referred to hereafter as the No Action Alternative.

Under the No Action Alternative, no construction activities would occur to increase seasonal floodplain inundation in the lower Sacramento River Basin or improve fish passage throughout the Yolo Bypass. The Yolo Bypass would continue to be inundated when Sacramento River levels overtop Fremont Weir. Juvenile fish would continue to enter the Yolo Bypass only when Sacramento River flows overtop the Fremont Weir. Continued stranding and mortality of adult green sturgeon and white sturgeon would occur in the Yolo Bypass after cessation of overtopping events of the Fremont Weir. CDFW rescue operations may continue, but rescued sturgeon would still undergo considerable stress and potential injury during capture, which may result in delays in spawning migrations and reduced spawning success.

The No Action Alternative assumes reasonably foreseeable actions that could occur in the project area in the future and do not rely on approval or implementation of the action alternatives, including actions with current authorization, secured funding for design and construction, and environmental permitting and compliance activities that are substantially complete. These reasonably foreseeable actions, in addition to changes in regulatory conditions and water supply demands, would result in differences in flows on the Sacramento River and in the Delta under the No Action Alternative. Possible changes include the following:

- Sea level rise and climate change
- Implementation of the California WaterFix
- Full implementation of the Grassland Bypass Project
- Implementation of the South Bay aqueduct improvement and enlargement project
- San Joaquin River Restoration Program Full Restoration Flows

8.3.3.1.1 Construction- and Maintenance-related Impacts – Evaluation of Substantial Adverse Effects on Fish Species of Focused Evaluation and their Habitat and Movement

Impacts FISH-1 through FISH-8: Potential Disturbance to Fish Species or their Habitat from Construction and Maintenance Activities due to 1) Erosion, Sedimentation, and Turbidity; 2) Hazardous Materials and Chemical Spills; 3) Aquatic Habitat Modification; 4) Hydrostatic Pressure Waves, Noise, and Vibration; 5) Stranding and Entrainment; 6) Predation Risk; 7) Fish Passage; or 8) Direct Harm

No construction- or maintenance-related impacts would occur under the No Action Alternative relative to Existing Conditions on aquatic resources and fisheries. Therefore, there would be no impacts related to: 1) erosion, sedimentation, and turbidity; 2) hazardous materials and chemical spills; 3) aquatic habitat modification; 4) hydrostatic pressure waves, noise, and vibration; 5) stranding and entrainment; 6) predation risk; 7) fish passage; or 8) direct harm associated with construction-related activities or ongoing maintenance-related activities.

CEQA Conclusion

The No Action Alternative would result in no change to fisheries and aquatic resources in the study area relative to Existing Conditions, would not substantially adversely affect any fish species of focused evaluation or their habitat, and would not interfere with the movement of any native resident or migratory fish species. Therefore, the No Action Alternative would have **no impact**.

8.3.3.1.2 Operations-related Impacts – Evaluation of Substantial Adverse Effects on Fish Species of Focused Evaluation and their Habitat and Movement

Operations-related impacts under the No Action Alternative were evaluated for the Yolo Bypass as well as for the Sacramento River downstream of Fremont Weir, the Delta and downstream habitats, and the SWP/CVP system. Modeling results indicate that mean monthly flows spilling into the Yolo Bypass from the Sacramento River at Fremont Weir under the No Action Alternative relative to Existing Conditions indicate that flows would be lower in November, substantially higher (i.e., higher by 10 percent or more) from January through March, and similar under both scenarios over the remainder of the year (see Appendix G6). Increases in flows entering the Yolo Bypass from the Sacramento River primarily would be due to increases in flows from the Sutter Bypass and Feather River. Overall, it is expected that juvenile salmonids and potentially other fish species would be more likely to be entrained into the Yolo Bypass during the winter months under the No Action Alternative. Overall impacts of the No Action Alternative in relation to the impact discussions below were generally evaluated by Reclamation and DWR (2015).

Impact FISH-9: Impacts to Fish Species of Focused Evaluation and Fisheries Habitat Conditions due to Changes in Flows in the Sacramento River

Modeling results indicate that average monthly flows in the Sacramento River downstream of Fremont Weir would be lower in April and May and from July through November; higher from January through March and June; and generally similar in December under the No Action Alternative relative to Existing Conditions (see Appendix G6). During relatively low-flow conditions (i.e., lowest 40 percent of flows over the cumulative monthly probability of exceedance distributions), net increases in flow of 10 percent or more would occur in October, June, and August, whereas net decreases in flow of 10 percent or more would occur in November, July, and September (see Appendix G6). Changes in mean monthly flows under the No Action Alternative relative to Existing Conditions primarily would be due to implementation of California WaterFix, assumptions related to future climate change and water demands under the future level of development.

CEQA Conclusion

The No Action Alternative would result in substantial hydrologic changes in the study area relative to Existing Conditions; therefore, the No Action Alternative could have a **significant impact**. However, mitigation is not applicable to the No Action Alternative.

Impact FISH-10: Impacts to Fish Species of Focused Evaluation and Fisheries Habitat Conditions due to Changes in Water Temperatures in the Sacramento River

Comparison of simulated mean monthly water temperatures in the Sacramento River at Freeport to species and life stage-specific water temperature index values indicates that water temperature conditions would be substantially less suitable due to increases in water temperature in October, April, May, and September for most of the applicable migration and rearing life stages of fish species of focused evaluation (see Appendix G7).

CEQA Conclusion

The No Action Alternative would result in substantial changes to water temperatures relative to Existing Conditions; therefore, the No Action Alternative could potentially have a **significant impact**. However, mitigation is not applicable to the No Action Alternative.

Impact FISH-11: Impacts to Fish Species of Focused Evaluation and Fisheries Habitat Conditions due to Changes in Delta Hydrologic and Water Quality Conditions

Evaluation of simulated mean monthly Delta hydrologic and water quality parameters with respect to species and life stage-specific time periods indicates that habitat conditions in the

Delta would be substantially more suitable for some life stages during some months and substantially less suitable during other months.

CEQA Conclusion

The No Action Alternative would result in substantial changes to habitat conditions for fish species of focused evaluation in the Delta and potentially downstream areas relative to Existing Conditions; therefore, the No Action Alternative could potentially have a **significant impact**. However, mitigation is not applicable to the No Action Alternative.

Impact FISH-12: Impacts to Fisheries Habitat Conditions due to Changes in Flow-Dependent Habitat Availability in the Study Area (Yolo Bypass/Sutter Bypass)

Modeling results indicate that flows entering the Yolo Bypass from the Sacramento River at Fremont Weir would substantially increase more often from January through March. The simulated increase in flows in the Sacramento River at Fremont Weir is primarily from the Feather River and Sutter Bypass. Therefore, inundation extent and/or duration of the Yolo Bypass and Sutter Bypass would increase during these months, potentially providing for increased hydraulic habitat availability for fish species of focused evaluation, particularly juvenile salmonids and adult and juvenile Sacramento splittail. Overall impacts of the No Action Alternative are generally evaluated by Reclamation and DWR (2015).

CEQA Conclusion

Based on increased mean monthly flows entering the Yolo Bypass, greater extent and/or duration of inundation of the Yolo Bypass under the No Action Alternative is expected to result in more suitable habitat conditions for fish species of focused evaluation in the Yolo Bypass; therefore, the No Action Alternative could potentially have a **beneficial impact**.

Impact FISH-13: Impacts to Fisheries Habitat Conditions due to Changes in Water Quality in the Study Area

Modeling results indicate that flows entering the Yolo Bypass from the Sacramento River at Fremont Weir would substantially increase more often from January through March. Therefore, increased flows and the potential for increased wetting and drying of the Yolo Bypass could increase the amount of methylmercury and other contaminants in the Yolo Bypass and in fish prey. Increased concentrations of contaminants in the Yolo Bypass could result in an increase in the exportation of contaminated water to the Delta. However, for juvenile Chinook salmon rearing in the Yolo Bypass, increased concentrations of accumulated methylmercury were reported to be insignificant in the tissues of the eventual adult-sized fish (Henery et al. 2010). Effects of increased methylmercury accumulation could be more substantial on resident fish species such as largemouth bass. Overall impacts of the No Action Alternative on the Yolo Bypass are generally evaluated by Reclamation and DWR (2015).

CEQA Conclusion

Based on higher mean monthly flows entering the Yolo Bypass, increased concentrations of methylmercury and other contaminants may occur in the Yolo Bypass and the Delta. However, the potential for increased concentrations of contaminants is not expected to substantially affect fish species of focused evaluation; therefore, the No Action Alternative would have a **less than significant impact**.

Impact FISH-14: Impacts to Aquatic Primary and Secondary Production in the Study Area

Modeling results indicate that the No Action Alternative would result in increased flows through the Sutter and Yolo bypasses relative to Existing Conditions. An increase in frequency and duration of inundation of shallow-water habitat in the Yolo Bypass would be expected to increase primary production in the Sutter and Yolo bypasses (Lehman et al. 2007). Increased primary and associated secondary production could potentially be exported to the Delta downstream of the Yolo Bypass.

CEQA Conclusion

Based on higher mean monthly flows entering the bypasses, increased primary and secondary production may occur, which could increase prey resources for fish species of focused evaluation; therefore, the No Action Alternative would have a **beneficial impact**.

Impact FISH-15: Impacts to Fish Species of Focused Evaluation due to Changes in Adult Fish Passage Conditions through the Yolo Bypass

Modeling results indicate that flows entering the Yolo Bypass from the Sacramento River at Fremont Weir would substantially increase more often from January through March. Therefore, the duration of potential adult fish passage from the Yolo Bypass into the Sacramento River could potentially increase for late fall-run Chinook salmon, spring-run Chinook salmon, winter-run Chinook salmon, steelhead, green and white sturgeon, and Pacific and river lamprey, which could provide for increased spawning success in the Sacramento River and reduced potential for mortality or migration delay in the Yolo Bypass. In addition, under the No Action Alternative, the Fremont Weir Adult Fish Passage Modification Project would be implemented, which would improve passage of the adult life stage of fish species of focused evaluation from the Yolo Bypass into the Sacramento River at Fremont Weir.

CEQA Conclusion

Increased duration of potential adult fish passage opportunity from the Yolo Bypass into the Sacramento River under the No Action Alternative is expected to result in improved upstream spawning success and less potential for mortality or migration delay for fish species of focused evaluation; therefore, the No Action Alternative could potentially have a **beneficial impact**.

Impact FISH-16: Impacts to Fish Species due to Changes in Potential for Stranding and Entrainment

The No Action Alternative would not include the construction of any facilities that would alter the potential for stranding or entrainment of fish species of focused evaluation. Overall impacts of the No Action Alternative are generally evaluated by Reclamation and DWR (2015).

CEQA Conclusion

No changes in the potential for fish stranding or entrainment are expected under the No Action Alternative relative to; therefore, the No Action Alternative would be expected to have a **less than significant impact**.

Impact FISH-17: Impacts to Fish Species due to Changes in Potential for Predation

The No Action Alternative would not include the construction of any facilities that would alter the potential for predation of fish species of focused evaluation. Overall impacts of the No Action Alternative are generally evaluated by Reclamation and DWR (2015).

CEQA Conclusion

No changes in the potential for predation of fish species of focused evaluation are expected under the No Action Alternative relative to Existing Conditions; therefore, the No Action Alternative would be expected to have a **less than significant impact**.

Impact FISH-18: Impacts to Chinook Salmon Species/Runs due to Changes in Viable Salmonid Population Parameters

Because the No Action Alternative could improve habitat conditions for juvenile Chinook salmon in the Yolo Bypass, VSP parameters, including abundance, productivity, diversity, and spatial structure, may potentially be improved for Sacramento River Chinook salmon species. However, passage of adult and juvenile fish between the Yolo Bypass and the Sacramento River would still be dependent on existing hydrologic conditions (i.e., Sacramento River stage relative to Fremont Weir). In addition, highly variable changes in habitat conditions in the lower Sacramento River and Delta may result in a combination of positive and negative impacts to fish species of focused evaluation in these areas under the No Action Alternative. Overall, it is not expected that the No Action Alternative would substantially affect Chinook salmon VSP parameters. Overall impacts of the No Action Alternative are generally evaluated by Reclamation and DWR (2015).

CEQA Conclusion

Potential changes in VSP parameters for Chinook salmon spawning in the Sacramento River Watershed are not expected to be substantially affected under the No Action Alternative relative to Existing Conditions; therefore, the No Action Alternative would be expected to have a **less than significant impact**.

Impact FISH-19: Impacts to Fish Species of Focused Evaluation and Fisheries Habitat Conditions due to Changes in Hydrologic Conditions in the SWP/CVP System

Simulated mean monthly storages in Trinity, Shasta, Oroville, and Folsom reservoirs indicate that storage would be lower or substantially lower during most months of the year. Therefore, reservoir and instream habitat conditions in the Sacramento, Feather, and American rivers may be substantially changed under the No Action Alternative relative to Existing Conditions. Mean monthly storage in San Luis Reservoir would be lower during portions of the fall and winter and higher or substantially higher more often from late winter through summer. Both warmwater and coldwater fisheries habitat conditions in San Luis Reservoir likely would be similar or more suitable under the No Action Alternative relative to Existing Conditions. Overall impacts of the No Action Alternative are generally evaluated by Reclamation and DWR (2015).

CEQA Conclusion

Due to substantial changes in mean monthly storages in the North-of-Delta SWP/CVP reservoirs, fisheries habitat conditions in the reservoirs and instream habitat conditions below the reservoirs may be changed under the No Action Alternative relative to Existing Conditions; therefore, the No Action Alternative could potentially have a **significant impact**. However, mitigation is not applicable to the No Action Alternative.

Impact FISH-20: Conflict with Adopted Habitat Conservation Plan; Natural Community Conservation Plan; or Other Approved Local, Regional, or State Habitat Conservation Plan

Although the Yolo County HCP/NCCP does not directly address fish species, it does include goals and policies related to protecting and improving habitat conditions in the Yolo Bypass, which could indirectly benefit fish resources (Yolo Habitat Conservancy 2017). Because projects assumed to potentially occur under the No Action Alternative would be expected to mitigate for any significant impacts to fisheries and aquatic resources in the study area, it is not expected that the No Action Alternative would conflict with HCPs, NCCPs, or other relevant habitat conservation plans.

CEQA Conclusion

The No Action Alternative is expected to have a **less than significant impact** relative to Existing Conditions.

8.3.3.2 Alternative 1: East Side Gated Notch

Alternative 1, East Side Gated Notch, would allow increased flow from the Sacramento River to enter the Yolo Bypass through a gated notch on the east side of Fremont Weir. The invert of the new notch would be at an elevation of 14 feet, which is approximately 18 feet below the existing Fremont Weir crest. Alternative 1 would allow up to 6,000 cfs to flow through the notch during periods when the river levels are not high enough to go over the crest of Fremont Weir to provide open channel flow for adult fish passage. See Section 2.4 for more details on the alternative features.

Therefore, the operations-related (as well as construction- and maintenance-related) impact determinations identified below would be the same for Alternative 1 relative to the No Action Alternative.

8.3.3.2.1 Construction- and Maintenance-related Impacts – Evaluation of Substantial Adverse Effects on Fish Species of Focused Evaluation and their Habitat and Movement

Construction of Alternative 1 would likely begin in 2020 or early 2021 and is estimated to last 28 weeks. All project components are expected to be completed in one season (April 15 through November 1). Construction of the components of Alternative 1 would begin with the demolition of a portion of the existing concrete Fremont Weir.

Maintenance-related activities would include sediment removal within and near the intake facilities; vegetation removal in the intake channel; inspection and maintenance of the headworks facilities; and maintenance of the transport, intake, and outlet channels.

Impact FISH-1: Potential Disturbance to Fish Species or their Habitat due to Erosion, Sedimentation, and Turbidity

Increased erosion in the Sacramento River and the Yolo Bypass could potentially occur during construction activities associated with Alternative 1 during the construction period of mid-April through October, whereas maintenance activities would primarily occur during the dry season. Construction activities with the potential to increase erosion or sedimentation include grading and excavation activities; use of staging, storage, and disposal areas; and construction-related traffic on access routes. The estimated excess amount of spoils to be excavated during construction would be about 266,000 cubic yards (CY). The estimated additional annual amount of sediment removal required in the area between Fremont Weir and Agricultural Road Crossing 1 due to increased flows into the Yolo Bypass under Alternative 1 is 37,800 CY. This corresponds to an estimated total annual amount of sediment removal required of 334,350 CY under Alternative 1 relative to 296,550 CY under Existing Conditions. However, local deposition patterns would depend on the specific design of downstream facilities.

Increased erosion also could occur indirectly due to removal of vegetation associated with construction activities along the Sacramento River and in the Yolo Bypass. Increased erosion could increase sedimentation and siltation, resulting in increased turbidity in the Sacramento River and in the Tule Canal or other waterways in the Yolo Bypass as well as in downstream waterbodies. The magnitude of potential impacts on fish would be dependent upon the timing and extent of sediment loading, flow conditions in the Sacramento River, and inundation or saturation of the Yolo Bypass during and immediately following construction. Excavation activities conducted under “wet” conditions would be expected to increase localized turbidity in the Yolo Bypass and the Sacramento River, which would occur from late May through early July.

In addition to potential sedimentation and turbidity within the construction footprint, there is the potential for increased sedimentation and turbidity to occur in waterbodies near the sediment disposal site.

Although most fish are highly migratory and capable of moving freely throughout the study area, a sudden localized increase in turbidity may potentially affect some juvenile fish by temporarily disrupting normal behaviors that are essential to growth and survival such as feeding, sheltering, and migrating. Behavioral avoidance of turbid waters may be one of the most important effects of suspended sediments on salmonids (Birtwell et al. 1984; DeVore et al. 1980; Scannell 1988). Salmonids have been observed moving laterally and downstream to avoid turbidity plumes

(Lloyd 1987; McLeay et al. 1984; Scannell 1988; Servizi and Martens 1991; Sigler et al. 1984). Juvenile salmonids tend to avoid streams that are chronically turbid, such as glacial streams or those disturbed by human activities, except when the fish need to traverse these streams along migration routes. Additional turbidity-related effects associated with behavioral alteration include disruption of feeding behaviors, which increases the likelihood that individual fish would face increased competition for food and space and experience reduced growth rates or possibly weight loss. Potential turbidity increases also may affect the sheltering abilities of some juvenile salmonids and may decrease their likelihood of survival by increasing their susceptibility to predation. Newly emerged salmonid fry could be particularly vulnerable to even moderate amounts of turbidity (Bjornn and Reiser 1991).

Although fish species of focused evaluation could be temporarily adversely affected physiologically or due to avoidance of preferred habitats, implementation of Mitigation Measure MM-WQ-2: Implement a Stormwater Pollution and Prevention Plan and MM-WQ-3: Develop turbidity monitoring program would be expected to minimize the potential for substantial adverse effects to fish species and their habitats. MM-WQ-2 would include measures related to timing of construction, stabilization of grading spoils, site stabilization, staging materials, minimizing soil and vegetation disturbance, and installation of sediment barriers (see Chapter 6 for more information). MM-WQ-3 would include the development and implementation of a turbidity sampling plan to ensure that turbidity limits are not exceeded during construction activities (see Chapter 6 for more information).

CEQA Conclusion

Erosion, sedimentation, and turbidity impacts would be **significant** because construction and maintenance activities would result in temporary increases in sedimentation and turbidity in the Sacramento River and the Yolo Bypass and could temporarily adversely affect all fish species of focused evaluation.

Development and implementation of Mitigation Measure MM-WQ-2: Implement a Stormwater Pollution and Prevention Plan and Mitigation Measure MM-WQ-3: Develop Turbidity Monitoring Program would reduce this impact to **less than significant**.

Impact FISH-2: Potential Disturbance to Fish Species or their Habitat due to Hazardous Materials and Chemical Spills

Construction- and maintenance-related activities have the potential to result in the release of hazardous materials or chemicals into adjacent aquatic habitats or waterbodies, including the Tule Canal and other waterbodies in the Yolo Bypass and the Sacramento River. The accidental release of contaminants into the environment could occur anytime during the construction period of April 15 through October and, although with lesser probability, during other times of the year when future maintenance-related activities are required. Activities with the highest likelihood of introducing contaminants into the environment would include excavation and construction activities in wet conditions from late May through early July in the Yolo Bypass and the Sacramento River.

Accidental discharge of hazardous materials and chemicals could potentially affect fish that may be present in the immediate vicinity and downstream of the construction area by increasing physiological stress, altering primary and secondary production, causing direct mortality, and reducing biodiversity.

Although contaminants could be accidentally released into aquatic habitats during construction- and maintenance-related activities and adversely affect fish species of focused evaluation, implementation of Mitigation Measure MM-WQ-1: Prepare and Implement a Spill Prevention, Control, and Countermeasure Plan is expected to minimize the potential for any chemical spills or seepage to occur. For example, the plan will specify that all maintenance materials (i.e., oils, grease, lubricants, antifreeze and similar materials) will be stored away from construction activities at offsite staging or storage areas and all construction vehicles and equipment will have regular maintenance performed to ensure they are in working order throughout the construction period.

CEQA Conclusion

Hazardous materials and chemical spills impacts would be **significant** because construction and maintenance activities could potentially result in the release of contaminants to aquatic habitats in the Sacramento River and the Yolo Bypass and could adversely affect all fish species of focused evaluation.

Development and implementation of Mitigation Measure MM-WQ-1: Prepare and Implement a Spill Prevention, Control, and Countermeasure Plan would reduce this impact to **less than significant**.

Impact FISH-3: Potential Disturbance to Fish Species or their Habitat due to Aquatic Habitat Modification

Ground-disturbing activities within the Yolo Bypass would have the potential to disturb floodplain vegetation, substrate, and the hyporheic zone (i.e., area where there is mixing of surface water and groundwater). Removal and disturbance of aquatic and riparian vegetation also would occur along the Sacramento River near the intake channel and headworks facility and in the Yolo Bypass near the outlet and transport channels. Potential effects on fish species of focused evaluation and aquatic habitat could include reduced refuge for fry and juveniles, altered macroinvertebrate production, altered biodiversity, altered exchange of nutrients between surface and subsurface waters and between aquatic and terrestrial ecosystems, and reduced potential for benthic invertebrate re-colonization of disturbed substrates.

Construction of the intake channels and other alternative elements could potentially require the removal of SRA and IWM from the Sacramento River channel and the Yolo Bypass floodplain, potentially reducing native fish refugia from predators and high flows and causing reductions in pool-forming structures and sediment and organic matter storage capacity. IWM is important to healthy riverine ecosystems and may be the most important structural component promoting stable fisheries resources. Because IWM has a key role in maintaining habitat complexity and refugia, potential loss of IWM could reduce available habitat quantity and quality.

Existing bank slope and substrate conditions in the affected areas adjacent to the Sacramento River for constructing the temporary cofferdam, headworks facility, and the intake channel would be primarily altered through grading activities and the placement of rock along the length of the intake channel from the Sacramento River to the headworks facility. The placement of rock along the lengths of the outlet and transport channels also would alter existing substrate conditions in the Yolo Bypass. The use of rock revetment in streams has been shown to affect natural river processes and functions through the following mechanisms (USFWS 2004):

- Halting new accretion of point bars and other deposition areas where riparian vegetation can colonize
- Halting meander migration which, over time, reduces habitat renewal, diversity, and complexity
- Incising the thalweg of the river adjacent to the rock revetment-lined area
- Filling in sloughs, tributary channels, and oxbow lake areas, causing loss of nearby wetland habitat and diversity
- Limiting lateral mobility of the channel, potentially reducing habitat complexity, including small backwaters and eddies
- Decreasing near shore roughness, causing stream velocity to increase at a high rate with increasing discharge, potentially causing accelerated erosion of earthen banks downstream
- Reducing the contribution of allochthonous material to the stream by inhibiting plant growth adjacent to the stream
- Reducing recruitment of IWM to the stream system, potentially resulting in a range of negative effects

Preliminary estimates based on calculations in ArcGIS indicate that a total of 28.9 acres (temporary impacts) and 47.1 acres (permanent impacts) of vegetated area would have the potential to be disturbed during Alternative 1 construction activities. Specifically, this includes 7.1 acres (temporary impacts) and 16.0 acres (permanent impacts) of riparian vegetation, which provides a potential source of IWM inputs to the Sacramento River or Yolo Bypass (Table 8-4 and Figure 8-6).

Table 8-4. Vegetation Communities Potentially Affected by Construction of Alternative 1

Vegetation Community					
	Grassland	**Freshwater Aquatic Vegetation**	**Freshwater Emergent Marsh**	**Riparian Forest/Woodland**	**Total**
Acres (Temporary)	17.9	0.9	3.0	7.1	28.9
Acres (Permanent)	19.3	3.1	8.7	16.0	47.1

CEQA Conclusion

Aquatic habitat modification adjacent to the Sacramento River and in the Yolo Bypass associated with construction and maintenance activities would be **significant** because aquatic and riparian habitat would be permanently affected. Although the temporary and permanent removal of riparian and aquatic habitat could adversely affect habitat availability and suitability for fish species of focused evaluation, particularly juvenile salmonids, temporarily affected habitats would be restored, including planting and seeding the aquatic and upland areas with plant species found in areas of suitable habitat on the Project site through implementation of Mitigation Measure MM-TERR-7: Restoration of Temporarily Disturbed Giant Garter Snake Aquatic and Upland Habitat. In addition, for areas of SRA habitat that are permanently removed, replacement of those habitats in adjacent areas would be conducted according to a restoration plan to be implemented after construction is completed as part of Mitigation Measure MM-FISH-1: Restore Degraded Riparian and SRA Habitat.

Mitigation Measure MM–FISH-1: Restore Degraded Riparian and SRA Habitat

As mitigation for loss of riparian and SRA habitat, degraded habitat would be restored to provide riparian and/or SRA habitat at or near the areas affected by construction of the intake facilities. Proposed restoration activities would include re-vegetation with native riparian species to provide SRA and/or riparian habitat. As a component of SRA habitat, riparian tree species, such as alders, cottonwoods, and willows, would be planted. In addition to habitat restoration actions, due to the importance of IWM to juvenile fishes in the Sacramento River (USFWS 2000), any IWM that is moved or altered by construction or maintenance activities would stay on site or be replaced with a functional equivalent to the extent practicable. Monitoring of restoration actions would be conducted for a specified number of years per the Mitigation Monitoring and Reporting Program (MMRP) to ensure that restored habitat is functioning as intended.

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Figure 8-6a. Vegetation Communities Potentially Affected by Construction of Alternative 1.

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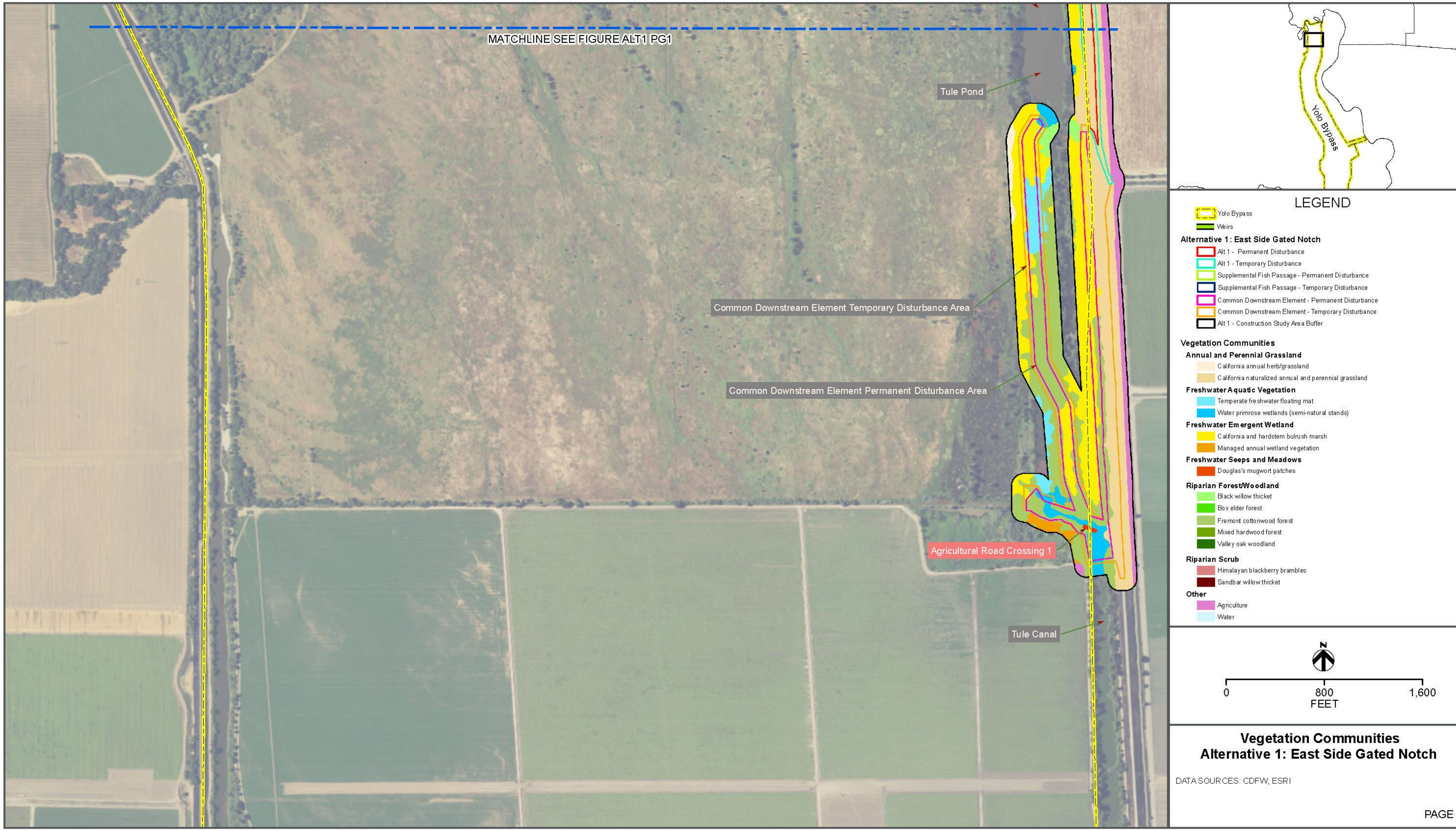

Figure 8-6b. Vegetation Communities Potentially Affected by Construction of Alternative 1.

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Implementation of Mitigation Measures MM-TERR-7 and MM-FISH-1 would reduce this impact to **less than significant**.

Impact FISH-4: Potential Disturbance to Fish Species or their Habitat due to Hydrostatic Pressure Waves, Noise, and Vibration

Alternative 1 would include pile driving to construct the headworks structure foundation and a temporary cofferdam around the headworks structure. Pile driving for the headworks structure would occur after the completion and dewatering of the temporary cofferdam such that the construction would be completed within the “dry” confines of the cofferdam.

Hydrostatic pressure waves and vibration generated by disturbance activities reportedly adversely affect all life stages of fish (NOAA 2016). Other studies (Fitch and Young 1948; Teleki and Chamberlain 1978; Yeleverton et al. 1975) suggest that adverse effects to fish resulting from hydrostatic pressure waves and vibration primarily are a function of species morphology and species physiology. Hydrostatic pressure waves could potentially rupture the swim bladders and other internal organs of all life stages of fish in the immediate construction area (NOAA 2016). Although understanding effects from pile-driving activities on fish is evolving, it remains problematic. There is evidence that lethal effects can occur from pile driving, but accurately analyzing and addressing these impacts as well as sublethal impacts (e.g., injury, temporary hearing threshold shifts, stress, and behavioral disturbance) is complicated by several factors. Sound levels and particle motion produced from pile driving can vary, depending on pile type, pile size, substrate composition, and type of equipment used.

The California Department of Transportation (Caltrans), in coordination with the Federal Highway Administration and the Departments of Transportation in Oregon and Washington established a Fisheries Hydroacoustic Working Group (FHWG) to improve and coordinate information on fishery impacts resulting from underwater sound pressure caused by in-water pile driving (Caltrans 2015). The FHWG also includes representatives from NMFS, USFWS, CDFW, and the USACE. In 2008, the FHWG developed an agreement on interim sound pressure criteria for injury to fish associated with pile driving. The criteria identify sound pressure levels of a peak of 206 decibels (dB) for all fish sizes, an accumulated sound exposure level (SEL) of 187 dB for fish larger than 2 grams, and an accumulated SEL of 183 dB for fish less than 2 grams (FHWG 2008). Although recent research summarized in Popper et al. (2014) suggested that cumulative SEL thresholds for fish injury may be well above 200 dB, until there is broad agreement on the use of higher thresholds, the thresholds from FHWG (2008) should be used (Caltrans 2015). These interim injury criteria identified in FHWG (2008) are considered to be protective of listed fish species (Caltrans 2015). It is important to recognize that these criteria were developed for impact pile driving only; they do not apply to vibratory pile driving or any other sound-generating activities (Caltrans 2015). The injury thresholds for impact pile driving are likely to be much lower than the injury thresholds for non-impulsive, continuous sounds produced by vibratory pile drivers (Caltrans 2015). Vibratory pile driving has been utilized in place of impact pile driving to minimize adverse effects on fish and other aquatic organisms (USFWS 2017).

Cofferdams that have been dewatered down to the mud line substantially reduce underwater pile driving sound, and although underwater noise cannot be eliminated due to energy transmitted through the ground, pile driving in a dewatered cofferdam is the best method for isolating underwater noise (Caltrans 2015). Therefore, sound pressure waves generated from construction activities within the confines of the cofferdam are expected to be attenuated to levels below which fish would be adversely affected.

Pile driving to construct the temporary cofferdam would be conducted over an approximate 3-week period in May and could occur in the "wet" (i.e., when the construction area is wetted) in the Sacramento River.

The cofferdam likely would be installed by driving interlocking sheet piles into the existing Fremont Weir with a pile driver, beginning at the upstream end of the cofferdam area and proceeding downstream until the cofferdam is complete. Based on existing information, it is expected that sheet pilings would be vibrated into place during construction of the cofferdam to minimize underwater pressure waves and subsequent impacts on fish. Specifically, if sheet pilings are vibrated into place during construction of the cofferdam, it is expected that resultant sound pressure waves would remain below the levels that would result in mortality or physical injury to fish (Caltrans 2015).

Construction and maintenance equipment noise sources, such as heavy diesel equipment (e.g., backhoes, graders, pavers, cranes), other earth-moving equipment, and stationary sources (e.g., compressors and generators), are not expected to produce sound pressure waves of sufficient magnitude to adversely impact fish species near construction and maintenance activities.

CEQA Conclusion

Impacts associated with construction noise would be **less than significant** if a vibratory pile driver can be used for the entire construction of the cofferdam. However, impacts associated with noise would be **significant** if impact pile driving was conducted in the Sacramento River, resulting in direct potential impacts to fish species of focused evaluation. If an impact pile driver is necessary to construct the cofferdam in the wet, Mitigation Measure MM-FISH-2: Implement an Underwater Noise Reduction and Monitoring Plan would be implemented to reduce the underwater noise, such as placing a bubble curtain system underwater.

Mitigation Measure MM-FISH-2: Implement an Underwater Noise Reduction and Monitoring Plan with Measures to Reduce Underwater Noise to Below Thresholds

If an impact pile driver is necessary to construct the cofferdam in the wet, mitigation measures would be implemented to reduce the underwater noise, such as placing a bubble curtain system underwater. This mitigation measure would also include underwater sound monitoring during impact pile-driving activities to minimize the potential for sound levels to exceed those which may adversely affect fish. Because both juvenile and adult life stages of fish species of focused evaluation may be present during pile driving in the Sacramento River, underwater noise thresholds to be applied include a peak level of 206 dB and an accumulated SEL of 183 dB (FHWG 2008).

Implementation of Mitigation Measure MM-FISH-2: Implement an Underwater Noise Reduction and Monitoring Plan would reduce this impact to **less than significant**.

Impact FISH-5: Potential Disturbance to Fish Species or their Habitat due to Stranding and Entrainment

Construction of the headworks structures adjacent to the Sacramento River could require dewatering of a temporary cofferdam, which may reportedly cause harm, injury, and mortality to fish species of focused evaluation by confining them to areas of increased water temperature, decreased dissolved oxygen concentration, and predation (Cushman 1985). Dewatering of channels in the Yolo Bypass and the Tule Pond associated with construction of facilities in the Yolo Bypass also could result in stranding or harm to fish species. The effects of stranding could include increased stress and direct mortality of individual fish. However, it is anticipated that impacts to fish species of focused evaluation would be minimized through implementation of a Fish Rescue and Salvage Plan (MM-FISH-3).

CEQA Conclusion

Stranding and entrainment impacts would be **significant** because fish species of focused evaluation could be entrained in the temporary cofferdam and could become stranded in the Yolo Bypass.

Implementation of Mitigation Measure MM-FISH-3: Prepare a Fish Rescue and Salvage Plan would reduce this impact to **less than significant**.

Mitigation Measure MM-FISH-3: Prepare a Fish Rescue and Salvage Plan

Implementation of a Fish Rescue and Salvage Plan would limit the number of fishes that may potentially be entrained and stranded during construction. A Fish Rescue and Salvage Plan would be prepared and approved by the Resource Agencies (CDFW, NMFS, and USFWS) and implemented before construction to minimize the number of fish stranded within the cofferdam during placement and removal and to minimize fish stranding associated with dewatering activities in the Tule Canal. It also is anticipated that this plan would stipulate that at least one resource agency biologist shall be on site to assist with fish rescue activities and ensure that cofferdam construction and removal procedures have been implemented according to resource agency standards and protocols. A list of approved equipment (e.g., dip nets, seines, backpack electrofishers, fyke nets) will be included in the Fish Rescue and Salvage Plan. Equipment used for the stranding event will be chosen at the discretion of the onsite biologist.

Impact FISH-6: Potential Disturbance to Fish Species or their Habitat due to Predation Risk

Construction activities have the potential to increase the risk of predation of fishes nearby and downstream of the construction footprints due to the potential for increased turbidity, hazardous spills, and vibration and pressure waves. Potential effects associated with construction activities that are not directly associated with predation risk are described above in the previous sections.

Temporary indirect effects associated with construction activities, such as increased turbidity, potential for hazardous spills, and increased underwater vibration and pressure waves, could result in fish species of focused evaluation moving from preferred habitats such that they could be more susceptible to predation. For example, it has been reported that behavioral avoidance of turbid waters reportedly may be one of the most important effects on fishes from suspended sediments (Birtwell et al. 1984; DeVore et al. 1980; Scannell 1988) although it also has been reported that increased turbidity could potentially decrease piscine predation on fish (Gregory and Levings 1998). Disorientation caused by noise associated with pile driving can temporarily disrupt normal fish behaviors, thereby increasing the risk of predation (Caltrans 2015). However, implementation of mitigation measures is expected to minimize the potential for fishes to be at increased risk of predation. Temporary instream structures, such as cofferdams, also may temporarily provide increased refugia to predatory species such as striped bass. This could potentially result in increased predation of fish species of focused evaluation such as juvenile salmonids. However, the temporary installation of these structures is not expected to substantially increase predation of fish species of focused evaluation.

CEQA Conclusion

Predation risk impacts would be **significant** because fish species of focused evaluation could be at increased risk of predation due to potential indirect effects of construction and maintenance activities.

Implementation of Mitigation Measures MM-WQ-2: Implement a Stormwater Pollution and Prevention Plan; MM-WQ-1: Prepare and Implement a Spill Prevention, Control, and Countermeasure Plan; MM-FISH-2: Implement an Underwater Noise Reduction and Monitoring Plan; and MM-FISH-3: Prepare a Fish Rescue and Salvage Plan would reduce this impact to less than significant.

Impact FISH-7: Potential Disturbance to Fish Species due to Changes in Fish Passage Conditions

Construction activities have potential to impair migration or passage of fishes nearby and downstream of the construction footprints due to the potential for increased turbidity, hazardous spills, and underwater noise. However, implementation of mitigation measures described above is anticipated to minimize potential passage impediments to fish species of focused evaluation in the Sacramento River and the Yolo Bypass associated with turbidity, potential hazardous spills, and underwater noise.

Installation of a cofferdam to facilitate construction of the intake facility could potentially physically impede migrating adults, limiting their ability to reach spawning areas, and could hinder migration of juveniles, potentially exposing them to increased predation and unsuitable aquatic habitat conditions. However, because most of the width of the cofferdam is expected to be in the dry, it is not expected to result in substantial changes to hydraulic conditions in the Sacramento River, which typically has a wetted width of 200 or more feet in the Project area. Therefore, it is not anticipated that the movement or survival of juvenile or adult fish species of focused evaluation would be substantially affected.

During construction activities associated with Agricultural Road Crossing 1, Tule Canal could be partially blocked to fish passage. However, most construction activities that could substantially affect Tule Canal would occur primarily from late June through mid-August. Because there would not be hydrologic connectivity between the Sacramento River and the Yolo Bypass at Fremont Weir, construction activities would not be expected to substantially affect large numbers of migratory fish. In addition, operation of the new fish collection facility at Wallace Weir could help to attract fish to Wallace Weir and away from construction areas near Tule Canal if flows in the Colusa Basin Drain and Knights Landing Ridge Cut are sufficient to create an attraction toward the weir. The potential for temporarily impeding passage of non-migratory fish species of focused evaluation in this area would not be expected to result in adverse impacts to those species because there would be habitat available downstream of and away from construction activities in Tule Canal.

CEQA Conclusion

Fish passage impacts would be **less than significant** because fish species of focused evaluation would either generally not be present near temporary fish passage blockages or would not be substantially affected by temporary blockages.

Impact FISH-8: Potential Disturbance to Fish Species or Their Habitat due to Direct Harm

Construction of the cofferdam, channels adjacent to the Sacramento River and Tule Canal, and Agricultural Road Crossing 1 have the potential to cause direct harm to fish species of focused evaluation if construction occurs in the wet.

Future ongoing maintenance-related impacts associated with expected maintenance activities at proposed facilities and channels in and adjacent to the Sacramento River and the Yolo Bypass could potentially occur because of direct contact between maintenance personnel or equipment and fish species of focused evaluation and potential effects associated with maintenance of project facilities and intake and transport channels, such as temporary increases in sedimentation and the potential for hazardous spills. Potential impacts associated with maintenance activities would generally be expected to be limited to the areas in the immediate vicinities of the infrastructure footprints and within and near the intake, outlet, and transport channels.

CEQA Conclusion

Direct harm impacts would be **significant** because fish species of focused evaluation could be directly harmed due to construction- and maintenance-related equipment, personnel, or debris. However, a qualified biologist would provide construction monitoring throughout all phases of the project. If possible, all fish species would be allowed to independently move away from the construction area. Fishes that become entrapped in any channel where construction work is taking place would be netted, transported to the river, and released according to the Fish Rescue and Salvage Plan (MM-FISH-3). General fish protection measures also would be implemented to minimize the potential for direct harm to fish species of focused evaluation (MM-FISH-4).

Mitigation Measure MM-FISH-4: General Fish Protection Measures

The construction contractor and operations and maintenance personnel shall implement the following general fish-protection measures during construction:

- Limit construction and maintenance activities to daylight hours.
- Construction activities will occur outside of the flood season (i.e., during April 15 through November 1).
- Confine clearing to the minimal area necessary to facilitate construction and maintenance activities.
- Clearly delineate the Project area limits by using fencing, flagging, or other means prior to construction activities.
- Keep construction equipment and materials as far away from suitable aquatic and riparian habitat as practicable.
- Retain a qualified biologist (approved by USFWS, NMFS, and CDFW) to be present or on call during construction and maintenance activities with the potential to affect sensitive biological resources. The biological monitor shall be on site during ground-disturbing activities occurring in the wet or adjacent to potential fish-bearing waterbodies. The biological monitor shall ensure that any construction barrier is maintained and construction activities allow for fish species in the vicinity to move away from the construction area on their own volition.

Implementation of Mitigation Measures MM-FISH-3 and MM-FISH-4: Implement General Fish Protection Measures would reduce this impact to **less than significant**.

8.3.3.2.2 Operations-related Impacts – Evaluation of Substantial Adverse Effects on Fish Species of Focused Evaluation and their Habitat and Movement

Implementation of the Alternatives would result in Sacramento River flows entering the Yolo Bypass more frequently. Changes in the frequency, magnitude, and duration of flow entering the Yolo Bypass from the Sacramento River could change fish passage conditions to and from the Sacramento River and the Yolo Bypass and fisheries habitat conditions in the Yolo Bypass, Sutter Bypass, and Sacramento River downstream of Fremont Weir relative to the basis of comparison. In addition, changes in the magnitude and timing of flows entering the Delta from the Yolo Bypass and the Sacramento River could change hydrology, water quality, and fisheries habitat conditions in the Delta, Suisun Bay, and other downstream estuarine habitats.

In addition to the potential for direct changes in Sacramento River and Delta hydrology and water quality associated with alternatives, changes in the frequency, magnitude, and duration of flow entering the Yolo Bypass could potentially result in re-operation of the SWP/CVP water export facilities and upstream reservoirs. Although Shasta, Folsom, and Oroville reservoirs would not be re-operated to inundate the Yolo Bypass, the increase in Sacramento River inflow to the Yolo Bypass would reduce flows in the Sacramento River between Fremont Weir and the Delta, which could affect water availability for diversion through the California WaterFix intakes under the alternatives with future LOD. A reduction in diversion through the California WaterFix intakes could affect storage in San Luis Reservoir, which could result in changes to operations of north-of-Delta reservoirs, such as Shasta, Folsom, and Oroville reservoirs.

Reoperation of north-of-Delta reservoirs has the potential to alter hydrologic and water temperature conditions in the Sacramento River below Keswick Dam, in the lower Feather River below the Fish Barrier Dam, and in the American River below Nimbus Dam because of the coordinated SWP/CVP operations between the Sacramento, Feather, and American rivers.

Operations-related impacts associated with Alternative 1 are evaluated in the Yolo Bypass, the Sacramento River at and downstream of the Fremont Weir, the Delta and downstream waterbodies, and the broader SWP/CVP system, as appropriate.

Impact FISH-9: Impacts to Fish Species of Focused Evaluation and Fisheries Habitat Conditions due to Changes in Flows in the Sacramento River

Simulated average monthly flows over the entire simulation period under Alternative 1 relative to Existing Conditions in the Sacramento River downstream of Fremont Weir indicate that flows generally would be the same or similar in most months and slightly (i.e., <5 percent) lower from November through March (see Appendix G6). During relatively low-flow conditions (i.e., lowest 40 percent of flows over the monthly probability of exceedance distributions), no changes in flow of 10 percent or more would occur during any month of the year (see Appendix G6). Therefore, migration and rearing conditions would be similar under Alternative 1 relative to Existing Conditions in the lower Sacramento River for fish species of focused evaluation, including winter-run, spring-run, fall-run, and late fall-run Chinook salmon, steelhead, green sturgeon, white sturgeon, river lamprey, and Pacific lamprey. In addition, there would be minimal potential for reduced flows in the Sacramento River to result in increased exposure of fish species of focused evaluation to predators or to higher concentrations of water quality contaminants and minimal potential to exacerbate the channel homogenization in the lower Sacramento River.

CEQA Conclusion

Alternative 1 would result in the same or similar flows in the Sacramento River downstream of Fremont Weir relative to Existing Conditions; therefore, Alternative 1 would have a **less than significant impact** due to changes in flows in the Sacramento River.

Impact FISH-10: Impacts to Fish Species of Focused Evaluation and Fisheries Habitat Conditions due to Changes in Water Temperatures in the Sacramento River

Modeling results indicate that mean monthly water temperatures in the Sacramento River at Freeport generally would not exceed species and life stage-specific water temperature index values more often under Alternative 1 relative to Existing Conditions (see Appendix G7). Therefore, migration and rearing thermal conditions would not be substantially affected for fish species of focused evaluation expected to occur in the lower Sacramento River, including winter-run, spring-run, fall-run, and late fall-run Chinook salmon, steelhead, green sturgeon, white sturgeon, river lamprey, and Pacific lamprey under Alternative 1 relative to Existing Conditions.

CEQA Conclusion

Alternative 1 would not result in substantial changes to water temperature suitability for fish species of focused evaluation relative to Existing Conditions; therefore, Alternative 1 would have a **less than significant impact** due to changes in water temperatures in the Sacramento River.

Impact FISH-11: Impacts to Fish Species of Focused Evaluation and Fisheries Habitat Conditions due to Changes in Delta Hydrologic and Water Quality Conditions

Evaluation of simulated mean monthly Delta hydrologic and water quality parameters with respect to species and life stage-specific time periods indicate that hydrologic and water quality metrics would not change under Alternative 1 relative to Existing Conditions. Therefore, habitat conditions in the Delta would be similar for all life stages evaluated. In addition, based on mean monthly Delta outflow, fisheries habitat conditions would be the same or similar in Suisun Bay.

CEQA Conclusion

Alternative 1 would result in the same or similar habitat conditions for fish species of focused evaluation in the Delta and in downstream areas relative to Existing Conditions; therefore, Alternative 1 would have a **less than significant impact** due to changes in Delta conditions.

Impact FISH-12: Impacts to Fisheries Habitat Conditions due to Changes in Flow-dependent Habitat Availability in the Study Area (Yolo Bypass/Sutter Bypass)

Average monthly hydraulic habitat availability over the entire simulation period for Chinook salmon pre-smolts in the Yolo Bypass would be substantially higher from December through March and similar for the remainder of the October through May evaluation period under Alternative 1 relative to Existing Conditions (Table 8-5). Average monthly hydraulic habitat availability by water year type would be substantially higher during most water year types from December through February and during dry and critical water year types in March.

Chinook salmon pre-smolt hydraulic habitat availability would increase under Alternative 1 relative to Existing Conditions over about 40 percent of the distribution (Figure 8-7). Over the exceedance distribution from November through March, daily hydraulic habitat availability would increase by 10 percent or more about 42 percent of the time and would never decrease by 10 percent or more under Alternative 1.

Table 8-5. Average Monthly Area of Pre-smolt Chinook Salmon Hydraulic Habitat in the Yolo Bypass from October through May based on TUFLOW Modeling (Water Years 1997 through 2012)

Alternative	Area (km^2) October	Area (km^2) November	Area (km^2) December	Area (km^2) January	Area (km^2) February	Area (km^2) March	Area (km^2) April	Area (km^2) May
Entire Simulation Period[1] (n=16)								
Alternative 1	20.0	21.5	38.8	55.6	56.1	52.3	37.0	27.0
Existing Conditions	19.8	21.2	31.1	47.6	43.7	46.9	36.9	27.2
Difference	0.2	0.3	7.7	8.0	12.4	5.4	0.1	-0.2
Percent Difference[2]	1.0	1.4	24.8	16.8	28.4	11.5	0.3	-0.7
Water Year Types[3]								
Wet (n=5)								
Alternative 1	20.0	22.2	55.7	58.5	69.5	72.1	58.3	31.6
Existing Conditions	19.8	21.1	37.7	48.5	56.9	68.7	58.3	31.8
Difference	0.2	1.1	18.0	10.0	12.6	3.4	0.0	-0.2
Percent Difference[2]	1.0	5.2	47.7	20.6	22.1	4.9	0.0	-0.6
Above Normal (n=3)								
Alternative 1	20.3	22.0	39.0	79.0	65.0	51.0	36.0	37.0
Existing Conditions	20.1	21.6	36.2	66.6	41.4	48.0	36.5	37.5
Difference	0.2	0.4	2.8	12.4	23.6	3.0	-0.5	-0.5
Percent Difference[2]	1.0	1.9	7.7	18.6	57.0	6.3	-1.4	-1.3
Below Normal (n=3)								
Alternative 1	19.9	21.3	28.9	53.6	50.7	43.8	26.8	20.9
Existing Conditions	19.7	21.2	25.1	45.4	41.8	40.0	26.6	21.0
Difference	0.2	0.1	3.8	8.2	8.9	3.8	0.2	-0.1
Percent Difference[2]	1.0	0.5	15.1	18.1	21.3	9.5	0.8	-0.5
Dry (n=4)								
Alternative 1	19.9	20.9	29.2	38.3	33.3	39.6	22.1	19.9
Existing Conditions	19.8	20.9	25.9	35.7	26.6	29.0	21.8	20.1
Difference	0.1	0.0	3.3	2.6	6.7	10.6	0.3	-0.2
Percent Difference[2]	0.5	0.0	12.7	7.3	25.2	36.6	1.4	-1.0
Critical (n=1)								
Alternative 1	19.8	20.9	21.6	45.7	69.8	32.8	22.4	20.2
Existing Conditions	19.7	20.7	21.4	39.9	57.7	27.6	22.2	20.5
Difference	0.1	0.2	0.2	5.8	12.1	5.2	0.2	-0.3
Percent Difference[2]	0.5	1.0	0.9	14.5	21.0	18.8	0.9	-1.5

[1] Based on modeled average daily values over a 16-year simulation period (water years 1997 through 2012)
[2] Relative difference of the monthly average
[3] As defined by the Sacramento Valley Index (DWR 2017c)
Key: km^2 = square kilometer

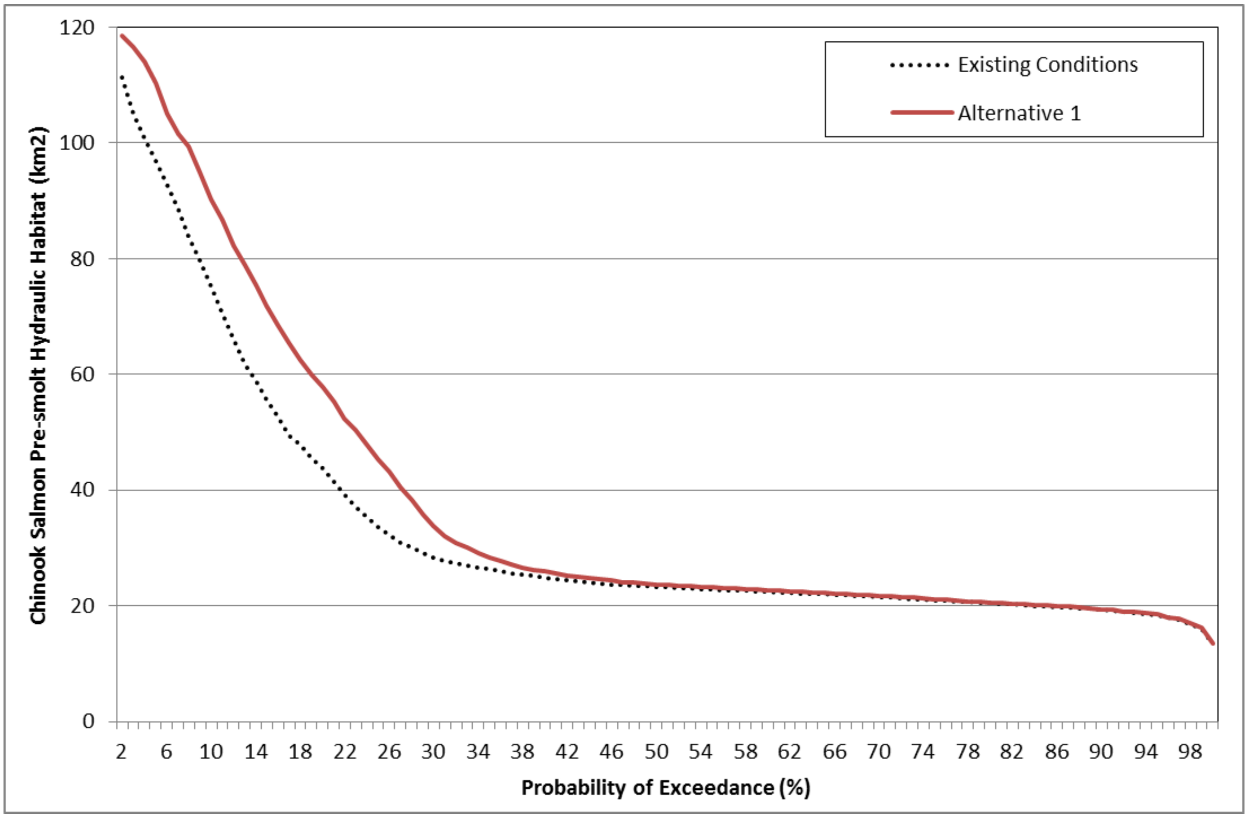

Figure 8-7. Simulated Chinook Salmon Pre-Smolt Hydraulic Habitat Availability Probability of Exceedance Distributions under Alternative 1 and Existing Conditions from October through May based on TUFLOW Modeling (Water Years 1997 through 2012)

Simulated average monthly hydraulic habitat availability over the entire simulation period for Chinook salmon smolts in the Yolo Bypass under Alternative 1 relative to Existing Conditions indicates that availability would be substantially higher (i.e., higher by 10 percent or more) from December through February, somewhat higher (i.e., higher by less than 10 percent) in March, and similar (i.e., change by less than 5 percent) for the remainder of the October through May evaluation period (Table 8-6). Average monthly hydraulic habitat availability by water year type would be substantially higher during most water year types in January and February, during wet and below normal water year types in December, and during dry and critical water year types in March.

Chinook salmon smolt hydraulic habitat availability would be higher under Alternative 1 relative to Existing Conditions over about 35 percent of the cumulative probability exceedance distribution (Figure 8-8). Over the exceedance distribution from November through March, daily hydraulic habitat availability would increase by 10 percent or more about 35 percent of the time and would never decrease by 10 percent or more under Alternative 1.

Table 8-6. Average Monthly Area of Chinook Salmon Smolt Hydraulic Habitat in the Yolo Bypass from October through May based on TUFLOW Modeling (Water Years 1997 through 2012)

Alternative	Area (km^2) October	Area (km^2) November	Area (km^2) December	Area (km^2) January	Area (km^2) February	Area (km^2) March	Area (km^2) April	Area (km^2) May
Entire Simulation Period[1] (n=16)								
Alternative 1	31.7	32.3	52.9	80.5	83.4	82.0	58.8	42.8
Existing Conditions	31.6	32.0	44.2	70.0	69.7	76.0	58.8	43.1
Difference	0.1	0.3	8.7	10.5	13.7	6.0	0.0	-0.3
Percent Difference[2]	0.3	0.9	19.7	15.0	19.7	7.9	0.0	-0.7
Water Year Types[3]								
Wet (n=5)								
Alternative 1	31.5	33.1	75.3	101.9	115.1	123.6	99.6	50.3
Existing Conditions	31.4	32.1	55.4	90.2	100.6	119.0	99.6	50.7
Difference	0.1	1.0	19.9	11.7	14.5	4.6	0.0	-0.4
Percent Difference[2]	0.3	3.1	35.9	13.0	14.4	3.9	0.0	-0.8
Above Normal (n=3)								
Alternative 1	32.1	33.0	53.0	100.0	93.0	80.0	50.0	54.0
Existing Conditions	32.1	32.9	48.3	82.4	68.3	76.6	50.4	54.6
Difference	0.0	0.1	4.7	17.6	24.7	3.4	-0.4	-0.6
Percent Difference[2]	0.0	0.3	9.7	21.4	36.2	4.4	-0.8	-1.1
Below Normal (n=3)								
Alternative 1	31.8	32.0	40.2	69.9	72.2	67.3	40.7	34.7
Existing Conditions	31.7	31.8	36.2	57.8	62.3	62.6	40.6	34.9
Difference	0.1	0.2	4.0	12.1	9.9	4.7	0.1	-0.2
Percent Difference[2]	0.3	0.6	11.0	20.9	15.9	7.5	0.2	-0.6
Dry (n=4)								
Alternative 1	31.7	31.5	39.9	52.7	44.7	52.2	34.1	33.1
Existing Conditions	31.6	31.5	36.6	48.9	37.9	41.0	33.9	33.4
Difference	0.1	0.0	3.3	3.8	6.8	11.2	0.2	-0.3
Percent Difference[2]	0.3	0.0	9.0	7.8	17.9	27.3	0.6	-0.9
Critical (n=1)								
Alternative 1	31.1	31.4	31.2	58.5	84.7	44.3	34.4	33.5
Existing Conditions	31.0	31.2	30.9	52.1	70.2	39.2	34.4	33.9
Difference	0.1	0.2	0.3	6.4	14.5	5.1	0.0	-0.4
Percent Difference[2]	0.3	0.6	1.0	12.3	20.7	13.0	0.0	-1.2

[1] Based on modeled average daily values over a 16-year simulation period (water years 1997 through 2012)
[2] Relative difference of the monthly average
[3] As defined by the Sacramento Valley Index (DWR 2017c)
Key: km^2 = square kilometer

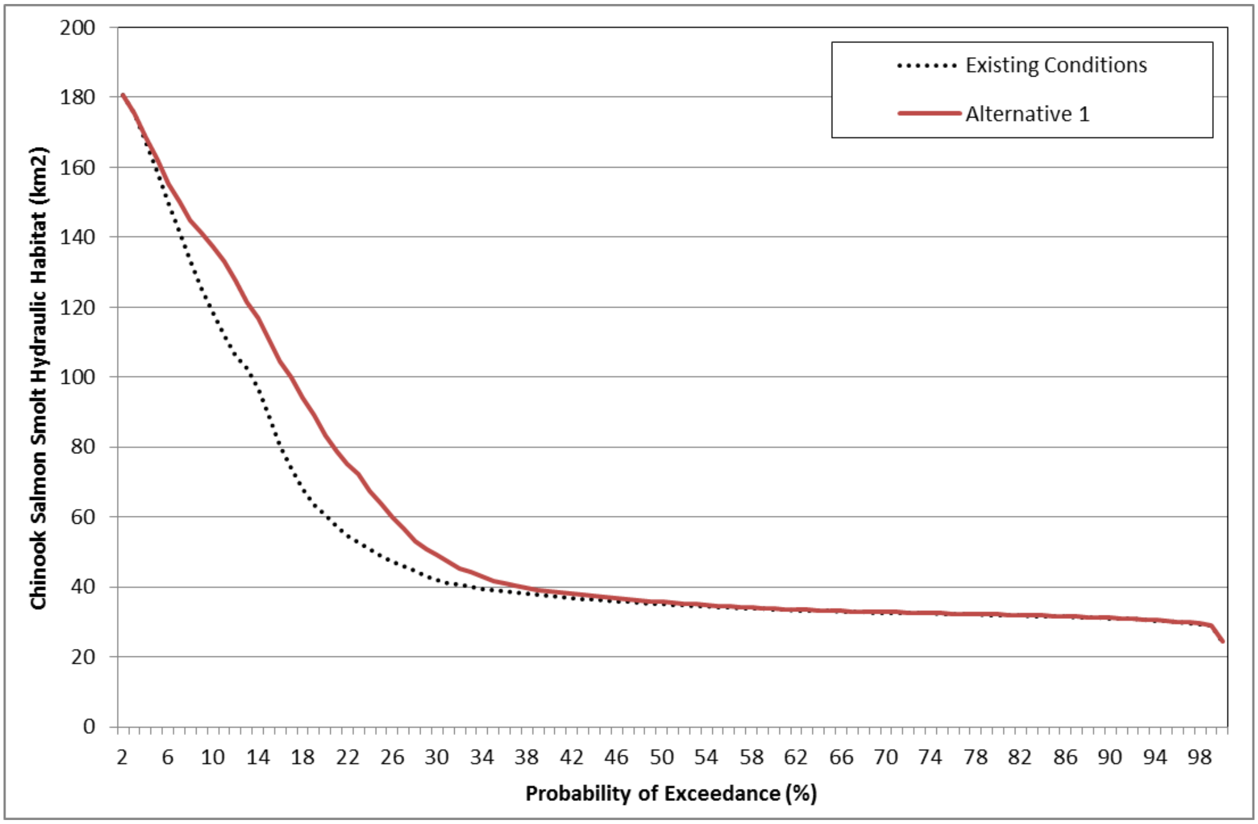

Figure 8-8. Simulated Chinook Salmon Smolt Hydraulic Habitat Availability Probability of Exceedance Distributions under Alternative 1 and Existing Conditions from October through May based on TUFLOW Modeling (Water Years 1997 through 2012)

As previously discussed, changes in estimated hydraulic habitat availability for Chinook salmon pre-smolts is expected to be generally representative of potential changes in hydraulic habitat availability for juvenile Sacramento splittail, and changes in estimated hydraulic habitat availability for Chinook salmon smolts is generally expected to be representative of potential changes in hydraulic habitat availability for adult spawning Sacramento splittail and juvenile steelhead.

To provide a more comprehensive range of potential changes in hydraulic habitat availability for other fish species of focused evaluation, simulated wetted extent (area with a water depth greater than 0.0 ft) was estimated for the Yolo Bypass under Alternative 1 relative to Existing Conditions. Average monthly wetted extent over the entire simulation period would be substantially higher from December through February, somewhat higher (i.e., higher by less than 10 percent) in March, and generally similar for the remainder of the October through May evaluation period under Alternative 1 relative to Existing Conditions. Average monthly wetted extent by water year type would be somewhat higher from December through February and substantially higher in December of wet water years, January of above normal and below normal water years, February of all water year types except for wet water years, and March in dry and critical water years (Table 8-7).

Table 8-7. Average Monthly Wetted Area in the Yolo Bypass under Alternative 1 from October through May based on TUFLOW Modeling (Water Years 1997 through 2012)

Alternative	Wetted Area (km^2) October	Wetted Area (km^2) November	Wetted Area (km^2) December	Wetted Area (km^2) January	Wetted Area (km^2) February	Wetted Area (km^2) March	Wetted Area (km^2) April	Wetted Area (km^2) May
Entire Simulation Period[1] (n=16)								
Alternative 1	48.0	48.9	73.3	115.6	121.2	114.7	85.9	63.8
Existing Conditions	47.8	48.4	64.1	105.0	106.4	107.5	85.9	64.1
Difference	0.2	0.5	9.2	10.6	14.8	7.2	0.0	-0.3
Percent Difference[2]	0.4	1.0	14.4	10.1	13.9	6.7	0.0	-0.5
Water Year Types[3]								
Wet (n=5)								
Alternative 1	47.8	49.9	100.1	166.6	176.8	169.0	145.3	77.1
Existing Conditions	47.6	48.6	78.9	154.3	161.7	163.4	145.3	77.5
Difference	0.2	1.3	21.2	12.3	15.1	5.6	0.0	-0.4
Percent Difference[2]	0.4	2.7	26.9	8.0	9.3	3.4	0.0	-0.5
Above Normal (n=3)								
Alternative 1	48.6	50.0	72.0	124.0	127.0	116.0	72.0	77.0
Existing Conditions	48.5	49.9	68.3	108.0	100.1	111.7	72.5	77.0
Difference	0.1	0.1	3.7	16.0	26.9	4.3	-0.5	0.0
Percent Difference[2]	0.2	0.2	5.4	14.8	26.9	3.8	-0.7	0.0
Below Normal (n=3)								
Alternative 1	48.1	48.2	58.2	91.2	102.6	94.9	59.6	52.0
Existing Conditions	47.9	47.9	53.9	79.2	91.7	89.6	59.6	52.3
Difference	0.2	0.3	4.3	12.0	10.9	5.3	0.0	-0.3
Percent Difference[2]	0.4	0.6	8.0	15.2	11.9	5.9	0.0	-0.6
Dry (n=4)								
Alternative 1	48.0	47.9	58.6	72.4	64.1	73.1	50.6	49.8
Existing Conditions	47.8	47.6	54.5	68.3	56.0	60.3	50.3	49.9
Difference	0.2	0.3	4.1	4.1	8.1	12.8	0.3	-0.1
Percent Difference[2]	0.4	0.6	7.5	6.0	14.5	21.2	0.6	-0.2
Critical (n=1)								
Alternative 1	47.2	46.9	47.0	81.8	111.0	64.8	51.1	50.6
Existing Conditions	46.9	46.7	46.6	74.4	95.7	58.1	51.1	50.9
Difference	0.3	0.2	0.4	7.4	15.3	6.7	0.0	-0.3
Percent Difference[2]	0.6	0.4	0.9	9.9	16.0	11.5	0.0	-0.6

[1] Based on modeled average daily values over a 16-year simulation period (water years 1997 through 2012)
[2] Relative difference of the monthly average
[3] As defined by the Sacramento Valley Index (DWR 2017c)
Key: km^2 = square kilometer

Wetted extent would be higher under Alternative 1 relative to Existing Conditions over about 30 percent of the middle to upper portion of the cumulative probability exceedance distribution (Figure 8-9). Over the exceedance distribution from November through March, daily wetted extent would increase by 10 percent or more about 34 percent of the time and would never decrease by 10 percent or more under Alternative 1.

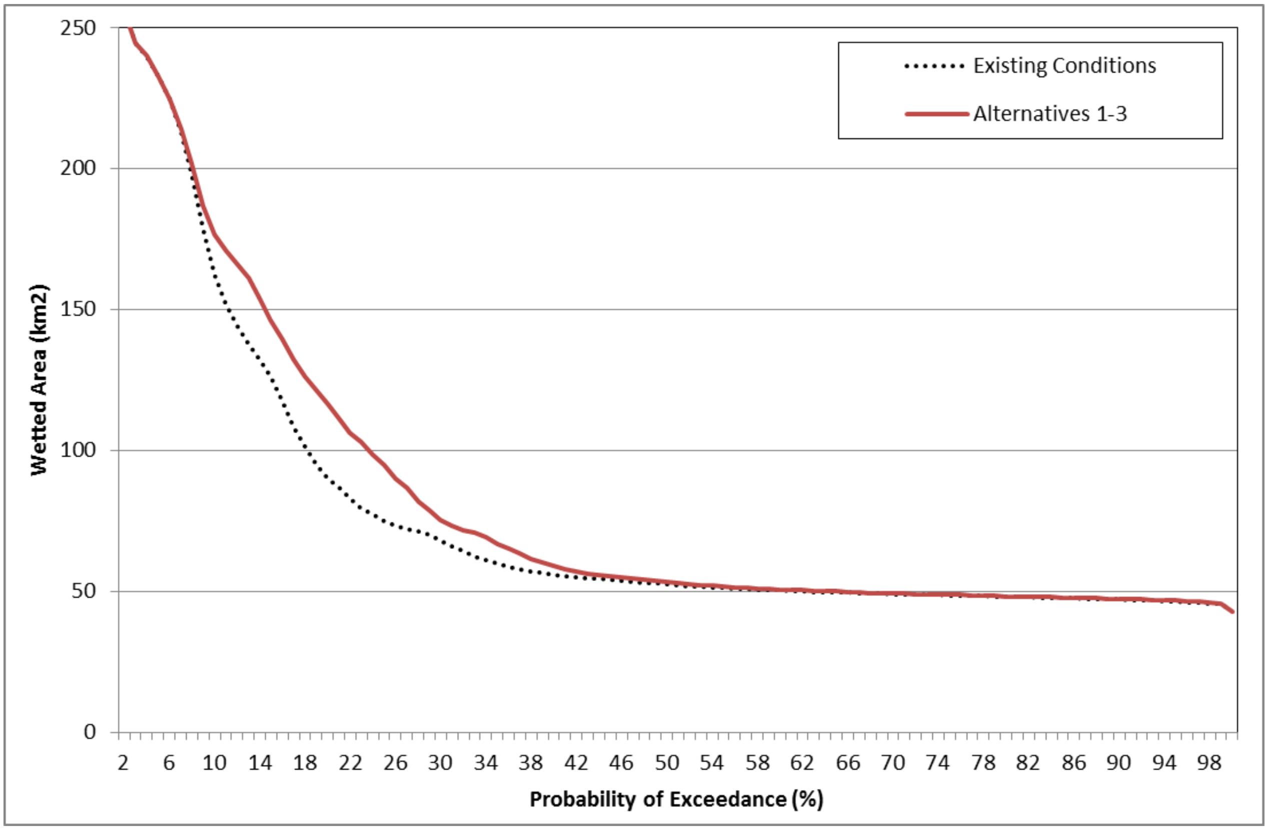

Figure 8-9. Simulated Wetted Area Probability of Exceedance Distributions under Alternative 1 and Existing Conditions from October through May based on TUFLOW Modeling (Water Years 1997 through 2012)

Average annual wetted days in the Sutter Bypass would decrease under Alternative 1 relative to Existing Conditions by approximately three to seven days in most of the area of Sutter Bypass between the Sacramento River and Sacramento Slough and by approximately one to three days over most of the Sutter Bypass between Sacramento Slough and Nelson Slough. This reduction in wetted area of the Sutter Bypass is due to less water from the Sacramento River spilling into the Sutter Bypass when Alternative 1 would be discharging water through the Fremont Weir and water is not overtopping Fremont Weir. During flood events when both the Sutter Bypass and the Yolo Bypass are inundated and water is spilling over Fremont Weir, Alternative 1 would not be expected to affect connectivity between the Sutter Bypass and the Sacramento River. Because migration impediments and barriers exist for fish moving upstream in the Sutter Bypass, minor reductions in connectivity between the Sutter Bypass and Sacramento River during non-inundation events is not expected to adversely affect fish species of focused evaluation.

CEQA Conclusion

In the Yolo Bypass under Alternative 1, increased hydraulic habitat availability for fish species of focused evaluation, particularly juvenile Chinook salmon and steelhead and adult and juvenile Sacramento splittail, is expected to result in more suitable conditions for these and other fish species of focused evaluation. Relatively minor reductions in the number of wetted days in the Sutter Bypass upstream of the Sacramento River at Fremont Weir would not be expected to substantially affect rearing or migration of fish species of focused evaluation; therefore, Alternative 1 would be expected to have a **beneficial impact** on flow-dependent hydraulic habitat availability in the Yolo Bypass and a **less than significant impact** on flow-dependent hydraulic habitat availability in the Sutter Bypass.

Impact FISH-13: Impacts to Fisheries Habitat Conditions due to Changes in Water Quality in the Study Area

Modeling results indicate that flows entering the Yolo Bypass from the Sacramento River at Fremont Weir would substantially increase more often from January through March under Alternative 1 relative to Existing Conditions (see Appendix G6). Therefore, increased flows and the potential for increased wetting and drying of the Yolo Bypass could increase the amount of methylmercury and other contaminants in the Yolo Bypass and in fish prey. Increased concentrations of contaminants in the Yolo Bypass could potentially result in an increase in the exportation of contaminated water to the Delta. However, for juvenile Chinook salmon rearing in the Yolo Bypass, increased concentrations of accumulated methylmercury were reported to be insignificant in the tissues of the eventual adult-sized fish (Henery et al. 2010). Effects of increased methylmercury accumulation could be more substantial on resident fish species such as largemouth bass. Increased flows in the Yolo Bypass also could temporarily increase turbidity levels in the Yolo Bypass.

CEQA Conclusion

Based on higher mean monthly flows entering the Yolo Bypass, increased concentrations of methylmercury and other contaminants may occur in the Yolo Bypass and the Delta. However, the potential for increased concentrations of contaminants is not expected to substantially affect fish species of focused evaluation; therefore, Alternative 1 would have a **less than significant impact**.

Impact FISH-14: Impacts to Aquatic Primary and Secondary Production in the Study Area

Modeling results indicate that Alternative 1 would result in increased frequency and duration of inundation of the Yolo Bypass relative to Existing Conditions. An increase in frequency and duration of inundation of shallow-water habitat in the Yolo Bypass would be expected to increase primary production in the Yolo Bypass (Lehman et al. 2007). Increased primary and associated secondary production in the Yolo Bypass would likely increase food resources for fish species of focused evaluation in the Yolo Bypass. More productive water in the Yolo Bypass also could potentially be exported to the Delta downstream of the Yolo Bypass, which could increase food resources for fish in the Delta.

Modeled wetted area of the Yolo Bypass under Alternative 1 relative to Existing Conditions was used as an indicator of relative changes in inundation and associated primary and secondary production. As described above, increases in average monthly wetted area would occur under

Alternative 1 relative to Existing Conditions, particularly from December through March, depending on water year type. Increased food resources in the Yolo Bypass during this period would be expected to improve growth and survival of some fish species of focused evaluation such as Chinook salmon and freshwater resident species. The potential for increased productivity downstream of the Yolo Bypass also could improve growth and survival of fish species of focused evaluation, particularly Delta resident species such as delta smelt.

Minor reductions in wetted area in the Sutter Bypass could reduce primary and secondary production in the Sutter Bypass. However, these reductions in wetted area are not expected to substantially affect primary or secondary production in the Sutter Bypass or substantially affect fish species of focused evaluation in the Sutter Bypass.

CEQA Conclusion

Based on increased wetted extent in the Yolo Bypass during the winter, increased primary and secondary production in the Yolo Bypass (and potentially in localized areas of the Delta) could increase food resources for fish species of focused evaluation. In the Sutter Bypass, slight reductions in wetted area could reduce primary and secondary production, but these reductions are not expected to be sufficient to substantially affect food resources for fish species of focused evaluation. Therefore, Alternative 1 would have a **beneficial impact** in the Yolo Bypass and a **less than significant impact** on the Sutter Bypass.

Impact FISH-15: Impacts to Fish Species of Focused Evaluation due to Changes in Adult Fish Passage Conditions through the Yolo Bypass

Modeling results indicate that flows entering the Yolo Bypass from the Sacramento River at Fremont Weir would substantially increase more often from January through March (see Appendix G6). Therefore, the duration of potential adult fish passage from the Yolo Bypass into the Sacramento River may potentially increase for late fall-run Chinook salmon, spring-run Chinook salmon, winter-run Chinook salmon, steelhead, green and white sturgeon, and Pacific and river lamprey, potentially providing for increased spawning success in the Sacramento River and its tributaries through reduced potential for mortality or migration delay in the Yolo Bypass. There is the potential that increased flows entering the Delta from the Yolo Bypass could attract more adult fish into the Yolo Bypass relative to the Sacramento River. However, adult fish passage would be provided at Fremont Weir more often relative to Existing Conditions.

Based on results of the YBPASS Tool, which applied fish passage criteria to modeled hydraulic conditions in the intake facility and transport channel under Alternative 1, adult salmon and sturgeon would be expected to successfully pass upstream through the transport channel and intake structure into the Sacramento River about 23 percent of the days from November through April over the water years 1997 through 2012 simulation period. The annual average date after which Alternative 1 would no longer meet the fish passage criteria would be April 2.

CEQA Conclusion

Increased duration of potential adult fish passage opportunity from the Yolo Bypass into the Sacramento River under Alternative 1 is expected to result in improved upstream spawning success and less potential for mortality or migration delay for fish species of focused evaluation; therefore, Alternative 1 would be expected to have a **beneficial impact** on adult fish passage conditions through the Yolo Bypass.

Impact FISH-16: Impacts to Fish Species due to Changes in Potential for Stranding and Entrainment

Project facilities constructed under Alternative 1, such as the transport and intake channels, would be graded to provide suitable passage conditions for fish, assuming sufficient water is present. Although Alternative 1 would allow for entrainment of juvenile fish at lower flows relative to Existing Conditions, the design of the transport channel to Tule Canal is expected to minimize the potential for stranding of juveniles. However, anthropogenic structures that interrupt natural drainage patterns, such as water control structures, create the greatest risk for stranding (Sommer et al. 2005). Therefore, there is some potential for increased juvenile stranding in the Yolo Bypass.

Because Alternative 1 would allow for adult migration into the Sacramento River during periods when adult migration is impeded or blocked at Fremont Weir under Existing Conditions, the potential for adult fish stranding in the Yolo Bypass would be expected to be reduced.

CEQA Conclusion

The potential for adult fish stranding would be expected to be reduced under Alternative 1 relative to Existing Conditions. Juvenile stranding may potentially increase under Alternative 1, but design of the project facilities is expected to minimize any increases in juvenile stranding. Therefore, Alternative 1 would be expected to have a **less than significant impact** on stranding and entrainment.

Impact FISH-17: Impacts to Fish Species due to Changes in Potential for Predation

Construction of the intake facility, supplemental fish passage facility, and intake and transport channels lined with rock could increase the potential for predation of fish species of focused evaluation under Alternative 1 relative to Existing Conditions by providing habitat for predatory fish species in these areas. However, the facilities on the Sacramento River are not expected to substantially increase the potential area of refugia for species such as striped bass relative to Existing Conditions. In the Yolo Bypass, increased flow pulses into the Yolo Bypass associated with Alternative 1 during the winter months (primarily December through March) could reduce the potential for predation of fish species such as juvenile salmonids by non-native fish species. For example, Sommer et al. (2014) found that increased connectivity to the Yolo Bypass would provide an overall benefit to native fish species, particularly during the winter, because it is prior to the spawning periods of non-native fish species in the spring. Frantzich et al. (2013) found that native fish species were more widely distributed during wetter years, and low flows may provide more suitable conditions for the spawning and recruitment of non-native centrarchids. Opperman et al. (2017) argued that flooding the Yolo Bypass from January through April would benefit native fish species. In addition, given the perennial nature of the Tule Canal and its ability to support non-native fish species under Existing Conditions, it is not expected that the proposed facilities under Alternative 1 would increase predation of fish species of focused evaluation above baseline levels in the Yolo Bypass. In addition, results of the SBM (evaluated under *Impact FISH-18*) account for predation associated with the estimated migration path and migration duration for juvenile Chinook salmon in the Yolo Bypass associated with Alternative 1.

CEQA Conclusion

Overall potential for predation of fish species of focused evaluation is not expected to substantially differ relative to predation rates under Existing Conditions; therefore, Alternative 1 would be expected to have a **less than significant impact** on predation.

Impact FISH-18: Impacts to Chinook Salmon Species/Runs due to Changes in Viable Salmonid Population Parameters

As previously discussed, model output from the SBM is used to evaluate the VSP parameters (abundance, productivity, diversity, and spatial structure) for fall-run, late fall-run, spring-run, and winter-run Chinook salmon.

Abundance and Productivity

Modeling results indicate that annual average adult returns under Alternative 1 relative to Existing Conditions would be higher over the entire simulation period and by water year type for fall-run and spring-run Chinook salmon (Table 8-8). Annual average adult returns would be similar or slightly lower for late fall-run Chinook salmon and similar or slightly higher for winter-run Chinook salmon under Alternative 1 relative to Existing Conditions. The simulated adult Chinook salmon returns probability of exceedance distributions under Alternative 1 relative to Existing Conditions would be similar for late fall-run and winter-run Chinook salmon and similar or slightly higher for fall-run and spring-run Chinook salmon (Figures 8-10 through 8-13).

Table 8-8. Average Annual Chinook Salmon Adult Returns under Alternative 1

Alternative	Entire Simulation Period[1]	Water Year Types[2]	Water Year Types[2]	Water Year Types[2]	Water Year Types[2]	Water Year Types[2]
		Wet	Above Normal	Below Normal	Dry	Critical
Fall-run Chinook Salmon						
Alternative 1	183,201	246,886	209,237	85,997	167,110	45,448
Existing Conditions	172,025	232,876	192,956	82,267	158,383	39,065
Difference	11,176	14,010	16,281	3,730	8,728	6,383
Percent Difference[3]	6	6	8	5	6	16
Late Fall-run Chinook Salmon						
Alternative 1	57,533	59,184	67,251	19,697	61,556	79,707
Existing Conditions	58,390	60,218	68,937	19,914	61,780	81,012
Difference	-857	-1,033	-1,686	-217	-224	-1,305
Percent Difference[3]	-1	-2	-2	-1	0	-2
Spring-run Chinook Salmon						
Alternative 1	6,391	9,652	6,049	2,345	5,094	4,385
Existing Conditions	5,960	8,803	5,821	2,174	4,884	4,031
Difference	431	849	228	171	210	354
Percent Difference[3]	7	10	4	8	4	9

Alternative	Entire Simulation Period[1]	Water Year Types[2]	Water Year Types[2]	Water Year Types[2]	Water Year Types[2]	Water Year Types[2]
		Wet	Above Normal	Below Normal	Dry	Critical
Winter-run Chinook Salmon						
Alternative 1	5,630	5,732	5,574	5,344	6,297	3,192
Existing Conditions	5,518	5,504	5,558	5,334	6,197	3,118
Difference	112	227	16	11	99	74
Percent Difference[3]	2	4	0	0	2	2

[1] Based on modeled annual values over a 15-year simulation period (water years 1997 through 2011)
[2] As defined by the Sacramento Valley Index (DWR 2017c)
[3] Relative difference of the annual average

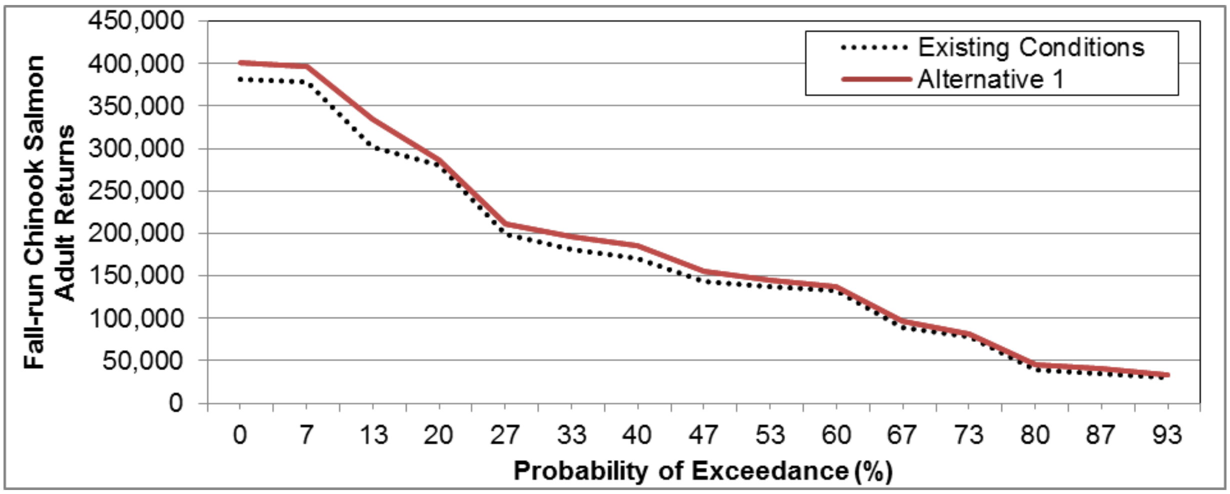

Figure 8-10. Simulated Adult Fall-Run Chinook Salmon Returns Probability of Exceedance Distributions under Alternative 1 and Existing Conditions

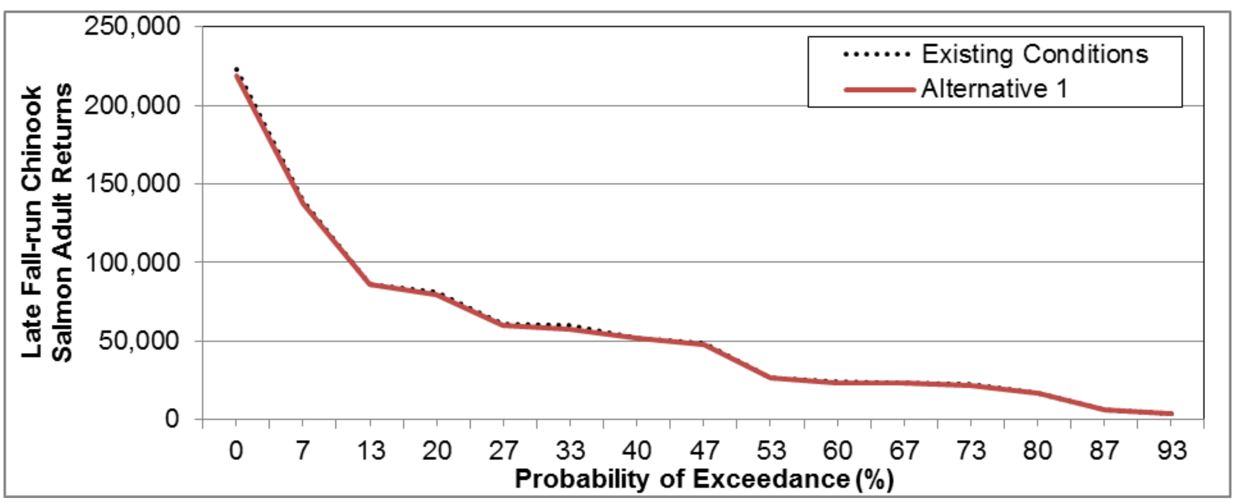

Figure 8-11. Simulated Adult Late Fall-Run Chinook Salmon Returns Probability of Exceedance Distributions under Alternative 1 and Existing Conditions

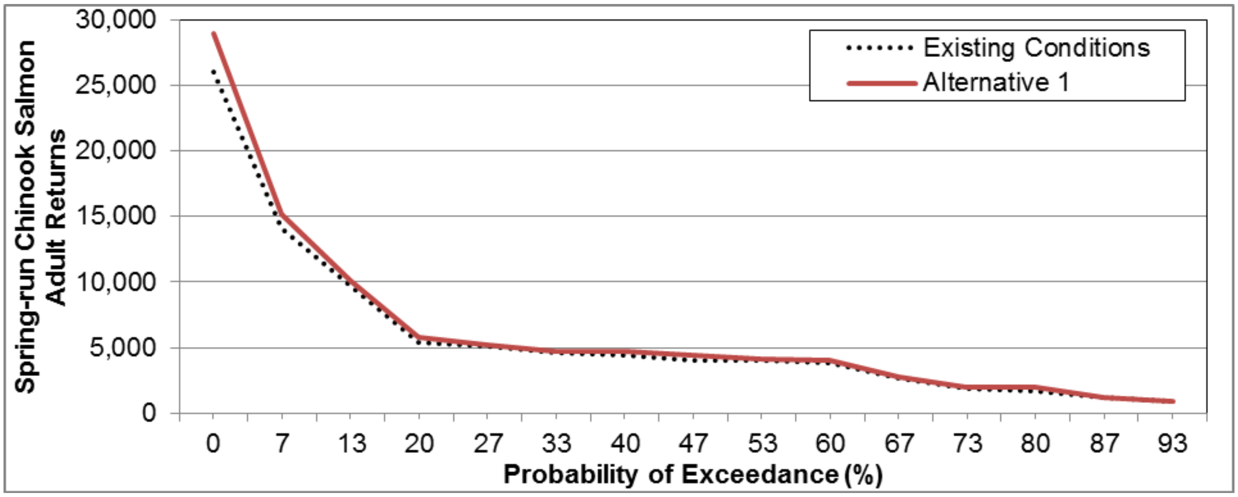

Figure 8-12. Simulated Adult Spring-run Chinook Salmon Returns Probability of Exceedance Distributions under Alternative 1 and Existing Conditions

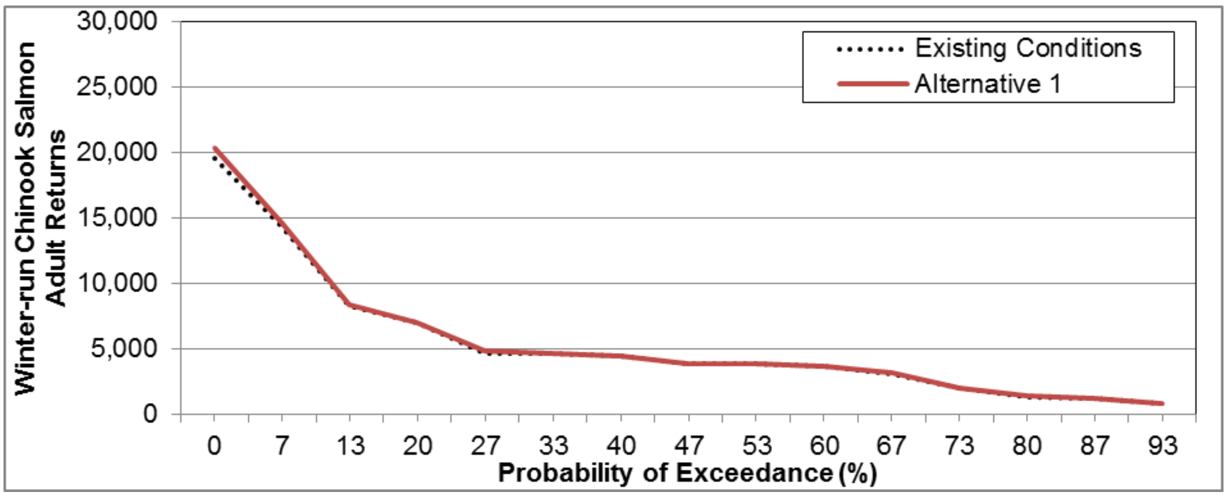

Figure 8-13. Simulated Adult Winter-run Chinook Salmon Returns Probability of Exceedance Distributions under Alternative 1 and Existing Conditions

Diversity

VARIATION IN JUVENILE CHINOOK SALMON SIZE

Modeling results indicate that annual average juvenile Chinook salmon coefficient of variation in size (FL) under Alternative 1 relative to Existing Conditions would be substantially higher (i.e., higher by 10 percent or more) over the entire simulation period and during most water year types for fall-run, spring-run, and winter-run Chinook salmon and similar for late fall-run Chinook salmon (Table 8-9). Similarly, the juvenile Chinook salmon coefficient of variation in size probability of exceedance distributions would be higher over the entire distributions under Alternative 1 relative to Existing Conditions for fall-run, spring-run, and winter-run Chinook salmon and would be similar for late fall-run Chinook salmon (Figures 8-14 through 8-17).

Table 8-9. Average Annual Juvenile Chinook Salmon Coefficient of Variation in Size under Alternative 1

Alternative	Entire Simulation Period[1]	Water Year Types[2] Wet	Water Year Types[2] Above Normal	Water Year Types[2] Below Normal	Water Year Types[2] Dry	Water Year Types[2] Critical
Fall-run Chinook Salmon						
Alternative 1	0.43	0.47	0.42	0.40	0.41	0.38
Existing Conditions	0.35	0.44	0.32	0.35	0.31	0.13
Difference	0.08	0.03	0.10	0.05	0.10	0.26
Percent Difference[3]	22	6	31	13	32	198
Late Fall-run Chinook Salmon						
Alternative 1	0.33	0.41	0.48	0.50	0.11	0.07
Existing Conditions	0.33	0.41	0.48	0.50	0.11	0.07
Difference	0.00	0.00	0.00	0.00	0.00	0.00
Percent Difference[3]	0	1	0	0	0	0
Spring-run Chinook Salmon						
Alternative 1	0.36	0.45	0.34	0.35	0.27	0.28
Existing Conditions	0.30	0.42	0.30	0.26	0.22	0.18
Difference	0.05	0.04	0.05	0.09	0.04	0.11
Percent Difference[3]	17	9	15	35	19	61
Winter-run Chinook Salmon						
Alternative 1	0.17	0.23	0.15	0.19	0.12	0.09
Existing Conditions	0.14	0.20	0.12	0.17	0.10	0.06
Difference	0.03	0.03	0.03	0.02	0.02	0.03
Percent Difference[3]	19	15	26	12	22	59

[1] Based on modeled annual values over a 15-year simulation period (water years 1997 through 2011)
[2] As defined by the Sacramento Valley Index (DWR 2017c)
[3] Relative difference of the annual average

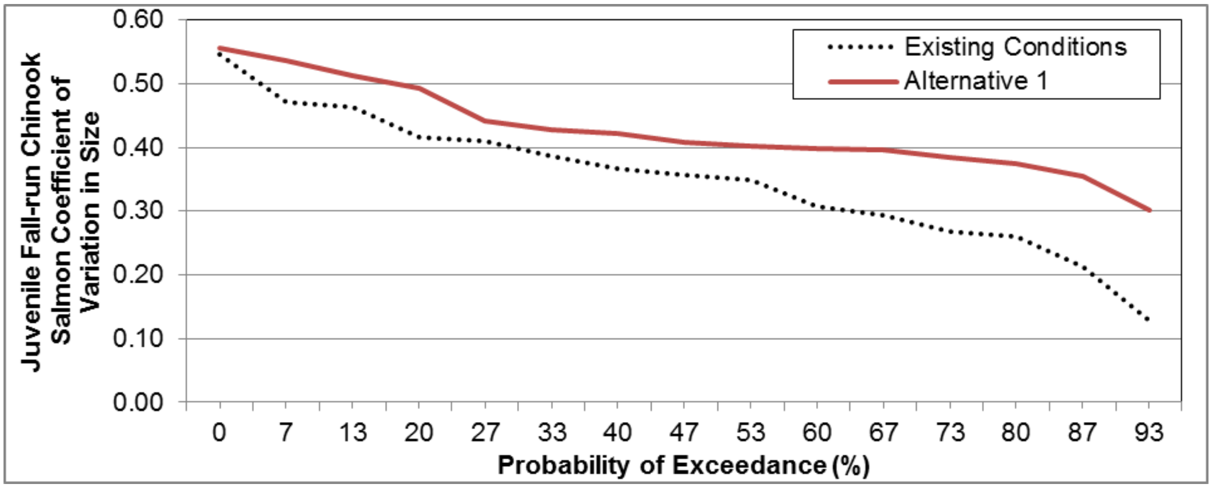

Figure 8-14. Simulated Juvenile Fall-run Chinook Salmon Coefficient of Variation in Size Probability of Exceedance Distributions under Alternative 1 and Existing Conditions

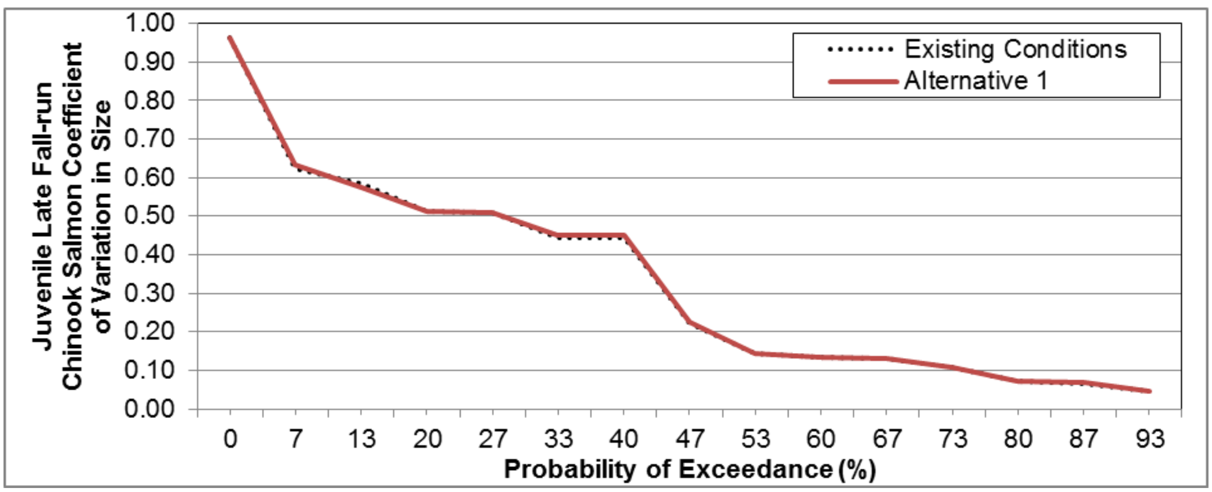

Figure 8-15. Simulated Juvenile Late Fall-run Chinook Salmon Coefficient of Variation in Size Probability of Exceedance Distributions under Alternative 1 and Existing Conditions

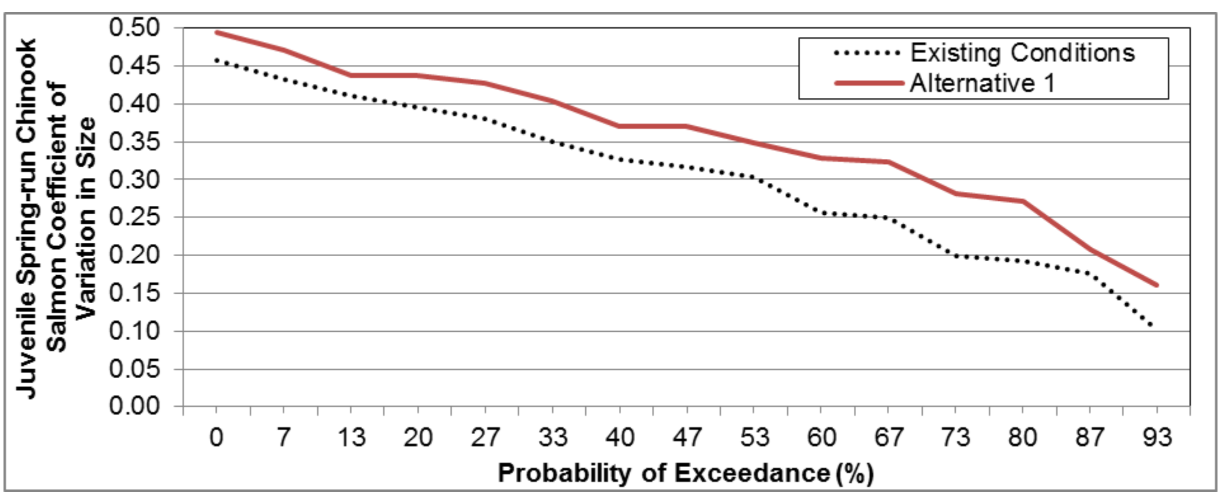

Figure 8-16. Simulated Juvenile Spring-Run Chinook Salmon Coefficient of Variation in Size Probability of Exceedance Distributions under Alternative 1 and Existing Conditions

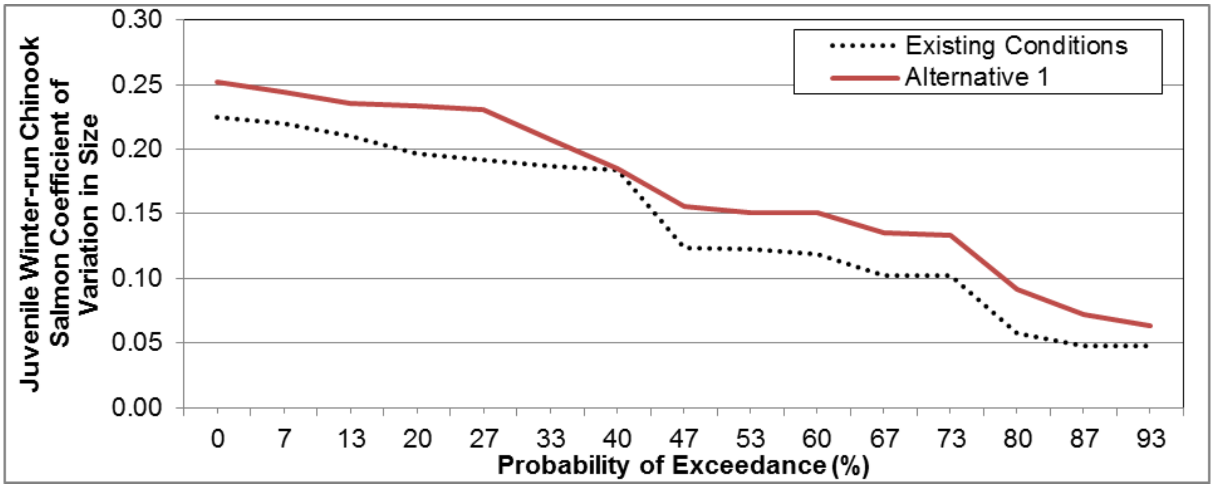

Figure 8-17. Simulated Juvenile Winter-run Chinook salmon Coefficient of Variation in Size Probability of Exceedance Distributions under Alternative 1 and Existing Conditions

Variation in Juvenile Chinook Salmon Estuary Entry Timing

Modeling results indicate that annual average juvenile Chinook salmon coefficient of variation in estuary entry timing under Alternative 1 relative to Existing Conditions would be slightly higher over the entire simulation period; similar during wet and below normal water years; and substantially higher during above normal, dry, and critical water years for fall-run Chinook salmon (Table 8-10). Annual average juvenile Chinook salmon coefficient of variation in estuary entry timing under Alternative 1 relative to Existing Conditions would be similar over the entire simulation period and during most water year types for late fall-run, spring-run, and winter-run Chinook salmon but would be substantially higher during critical water years for spring-run Chinook salmon.

The juvenile Chinook salmon coefficient of variation in estuary entry timing probability of exceedance distributions would be slightly higher over most of the distributions under Alternative 1 relative to Existing Conditions for fall-run, spring-run, and winter-run Chinook salmon and would be similar for late fall-run Chinook salmon (Figure 8-18 through Figure 8-21).

Table 8-10. Average Annual Juvenile Chinook Salmon Coefficient of Variation in Size under Alternative 1

Alternative	Entire Simulation Period[1]	Water Year Types[2]	Water Year Types[2]	Water Year Types[2]	Water Year Types[2]	Water Year Types[2]
		Wet	Above Normal	Below Normal	Dry	Critical
Fall-run Chinook Salmon						
Alternative 1	0.25	0.29	0.24	0.25	0.22	0.21
Existing Conditions	0.24	0.29	0.22	0.25	0.19	0.16
Difference	0.01	0.00	0.02	0.00	0.02	0.05
Percent Difference[3]	6	0	10	1	12	30

Alternative	Entire Simulation Period[1]	Water Year Types[2]	Water Year Types[2]	Water Year Types[2]	Water Year Types[2]	Water Year Types[2]
		Wet	Above Normal	Below Normal	Dry	Critical
Late Fall-run Chinook Salmon						
Alternative 1	0.33	0.44	0.32	0.21	0.29	0.15
Existing Conditions	0.33	0.44	0.33	0.21	0.29	0.15
Difference	0.00	0.00	0.00	0.00	0.00	0.00
Percent Difference[3]	-1	-1	-1	0	0	-1
Spring-run Chinook Salmon						
Alternative 1	0.30	0.39	0.28	0.28	0.24	0.21
Existing Conditions	0.29	0.38	0.28	0.26	0.23	0.18
Difference	0.01	0.00	0.01	0.02	0.01	0.03
Percent Difference[3]	3	1	3	8	3	14
Winter-run Chinook Salmon						
Alternative 1	0.28	0.39	0.23	0.31	0.22	0.13
Existing Conditions	0.28	0.38	0.22	0.30	0.21	0.12
Difference	0.01	0.01	0.01	0.01	0.01	0.01
Percent Difference[3]	3	2	4	2	3	7

[1] Based on modeled annual values over a 15-year simulation period (water years 1997 through 2011)

[2] As defined by the Sacramento Valley Index (DWR 2017c)

[3] Relative difference of the annual average

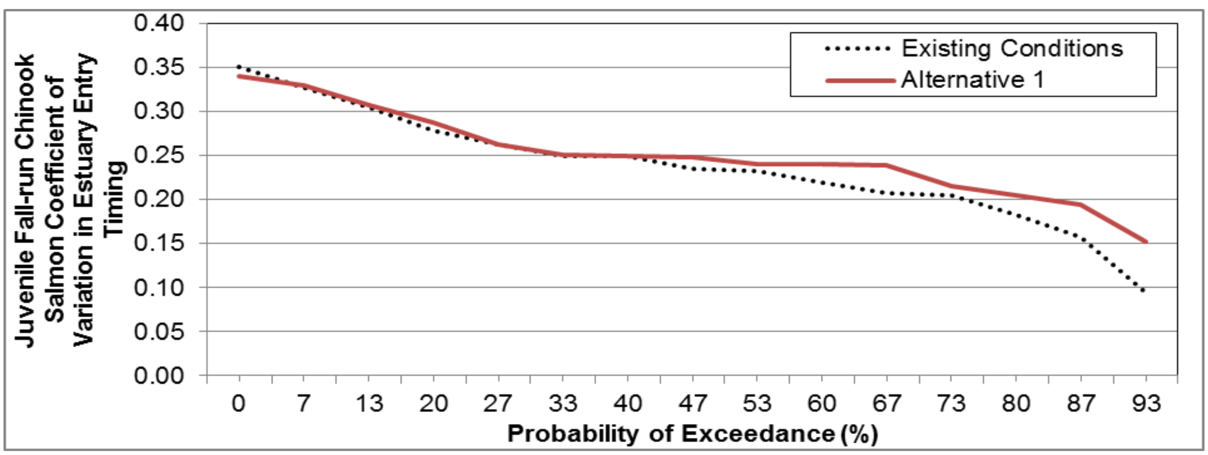

Figure 8-18. Simulated Juvenile Fall-run Chinook Salmon Coefficient of Variation in Estuary Entry Timing Probability of Exceedance Distributions under Alternative 1 and Existing Conditions

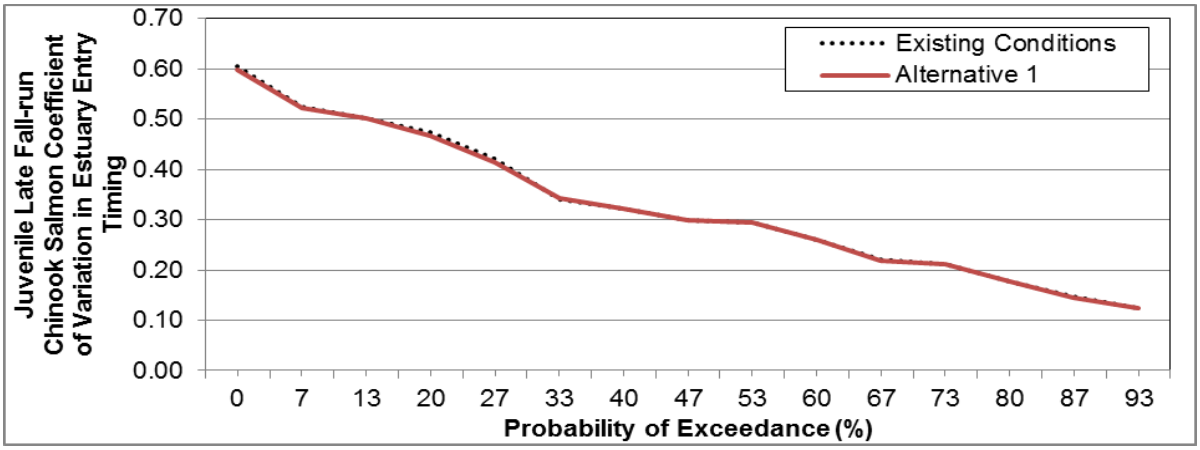

Figure 8-19. Simulated Juvenile Late Fall-run Chinook Salmon Coefficient of Variation in Estuary Entry Timing Probability of Exceedance Distributions under Alternative 1 and Existing Conditions

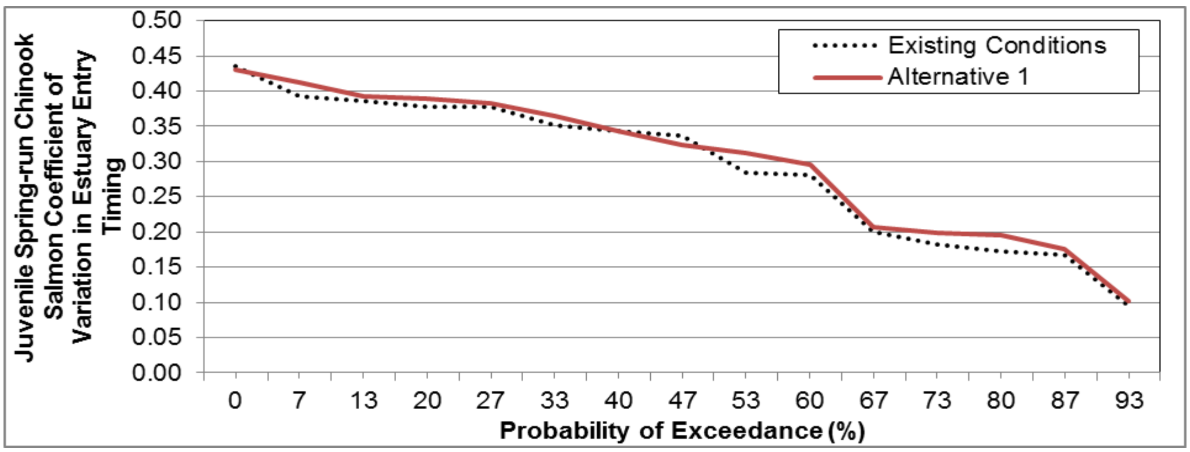

Figure 8-20. Simulated Juvenile Spring-Run Chinook Salmon Coefficient of Variation in Estuary Entry Timing Probability of Exceedance Distributions under Alternative 1 and Existing Conditions

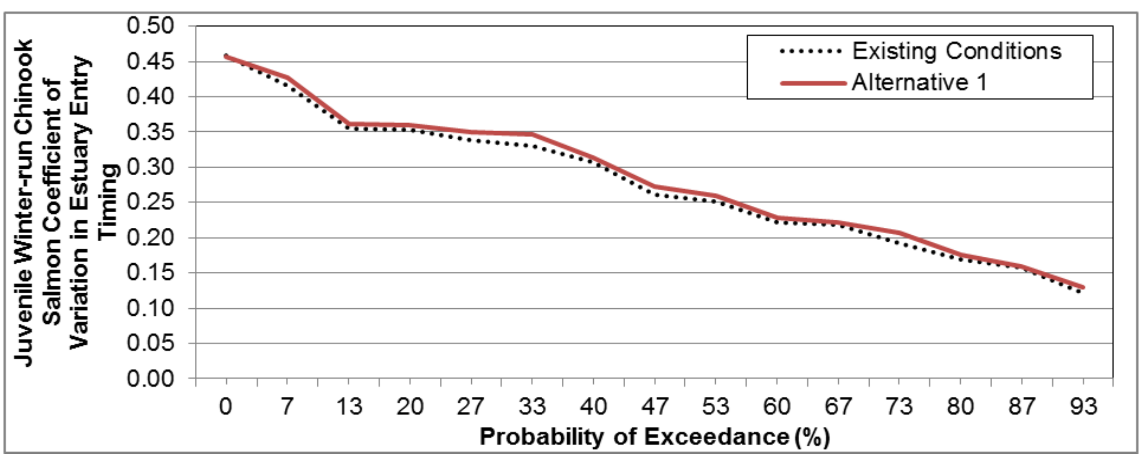

Figure 8-21. Simulated Juvenile Winter-run Chinook salmon Coefficient of Variation in Estuary Entry Timing Probability of Exceedance Distributions under Alternative 1 and Existing Conditions

Spatial Structure

Entrainment into the Yolo Bypass

Modeling results indicate that mean monthly flows spilling into the Yolo Bypass from the Sacramento River at Fremont Weir under Alternative 1 relative to Existing Conditions would be higher from November through March and similar over the remainder of the year (see Appendix G6). Mean monthly flows would be substantially higher (by 10 percent or more) during at least some water year types in November (wet water years), December (wet and above normal water years), January (above normal, below normal, and dry water years), February (above normal, below normal, dry, and critical water years), and March (above normal, below normal, and dry water years). Over the entire simulation period, net increases in flows of 10 percent or more would occur with substantially higher frequency (10 percent or more often) from December through March (see Appendix G6).

Based on increases in monthly flows from December through March, it is expected that juvenile salmonids and potentially other fish species would be more likely to be entrained into the Yolo Bypass from December through March under Alternative 1 relative to Existing Conditions.

The estimated average annual percentages of juvenile fall-run, late fall-run, winter-run, and spring-run Chinook salmon (all sizes) entrained into the Yolo Bypass using the proportion of flow approach would be 15.4, 5.9, 11.3, and 10.3 percent under Alternative 1, respectively, relative to 7.1, 2.6, 3.9, and 3.1 percent, respectively, under Existing Conditions (DWR 2017a; Appendix G3). For smaller juveniles (i.e., <80 mm), the percentages of fall-run, late fall-run, winter-run, and spring-run Chinook salmon entrained into the Yolo Bypass would be 15.3, 1.1, 7.1, and 10.6 percent, respectively.

The ELAM modeling for Alternative 1 indicates that at the highest Sacramento River stage modeled, up to about 14 percent of juveniles could be entrained into the Yolo Bypass (Smith et al. 2017; Appendix G1). The entrainment-Sacramento River stage relationship exhibits a positive trend as Sacramento River stage increases from 20.23 to 28.83 ft.

Juvenile Rearing in the Yolo Bypass for One or More Days

Modeling results indicate that annual average numbers of juvenile Chinook salmon rearing for one or more days in the Yolo Bypass under Alternative 1 relative to Existing Conditions would be substantially higher over the entire simulation period and during all water year types for fall-run, late fall-run, spring-run, and winter-run Chinook salmon (Table 8-11).

Similarly, the annual number of juvenile Chinook salmon rearing for one or more days in the Yolo Bypass under Alternative 1 relative to Existing Conditions would be higher over the entire exceedance distribution for fall-run, substantially higher over the entire distributions for spring-run and winter-run Chinook salmon, and higher about half of the time for late fall-run Chinook salmon (Figures 8-22 through 8-25). In addition, Alternative 1 would provide for juvenile rearing in the Yolo Bypass over about 20 percent of the distribution when no juvenile fall-run Chinook salmon would be rearing in the Yolo Bypass, over about 40 percent of the distribution when no juvenile late fall-run Chinook salmon would be rearing in the Yolo Bypass, and over about 30 percent of the distribution when few or no juvenile spring-run and winter-run Chinook salmon would be rearing in the Yolo Bypass under Existing Conditions.

Table 8-11. Average Annual Number of Juvenile Chinook Salmon that Reared in the Yolo Bypass for One or More Days under Alternative 1

Alternative	Entire Simulation Period[1]	Water Year Types[2]	Water Year Types[2]	Water Year Types[2]	Water Year Types[2]	Water Year Types[2]
		Wet	Above Normal	Below Normal	Dry	Critical
Fall-run Chinook Salmon						
Alternative 1	4,753,465	9,978,883	4,755,768	1,003,178	1,104,158	717,273
Existing Conditions	3,179,250	8,028,286	2,198,294	436,145	20,038	0
Difference	1,574,215	1,950,597	2,557,474	567,034	1,084,121	717,273
Percent Difference[3]	50	24	116	130	5,410	n/a
Late Fall-run Chinook Salmon						
Alternative 1	247,949	691,939	54,013	13,388	17,551	516
Existing Conditions	190,830	571,919	953	0	0	0
Difference	57,118	120,020	53,060	13,388	17,551	516
Percent Difference[3]	30	21	5,566	n/a	n/a	n/a
Spring-run Chinook Salmon						
Alternative 1	93,719	193,287	78,417	24,560	28,243	42,004
Existing Conditions	32,657	72,311	41,409	1,894	70	0
Difference	61,062	120,976	37,007	22,666	28,173	42,004
Percent Difference[3]	187	167	89	1,197	40,103	n/a
Winter-run Chinook Salmon						
Alternative 1	66,153	104,777	85,621	38,842	28,468	19,998
Existing Conditions	28,031	54,261	46,976	3,552	283	0
Difference	38,122	50,516	38,645	35,290	28,184	19,998
Percent Difference[3]	136	93	82	994	9,950	n/a

[1] Based on modeled annual values over a 15-year simulation period (water years 1997 through 2011)

[2] As defined by the Sacramento Valley Index (DWR 2017c)

[3] Relative difference of the annual average

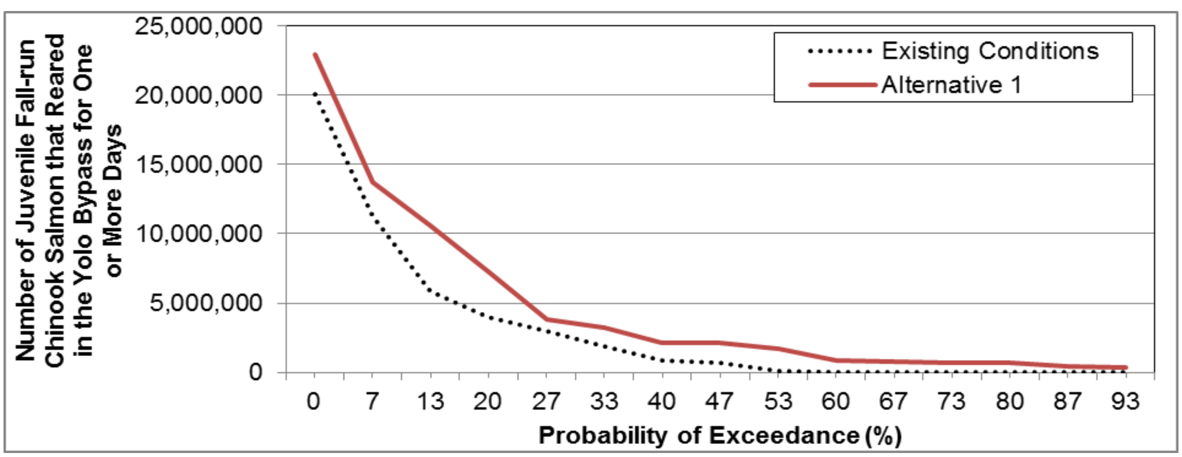

Figure 8-22. Simulated Number of Juvenile Fall-run Chinook Salmon Rearing for One or More Days in the Yolo Bypass Probability of Exceedance Distributions under Alternative 1 and Existing Conditions

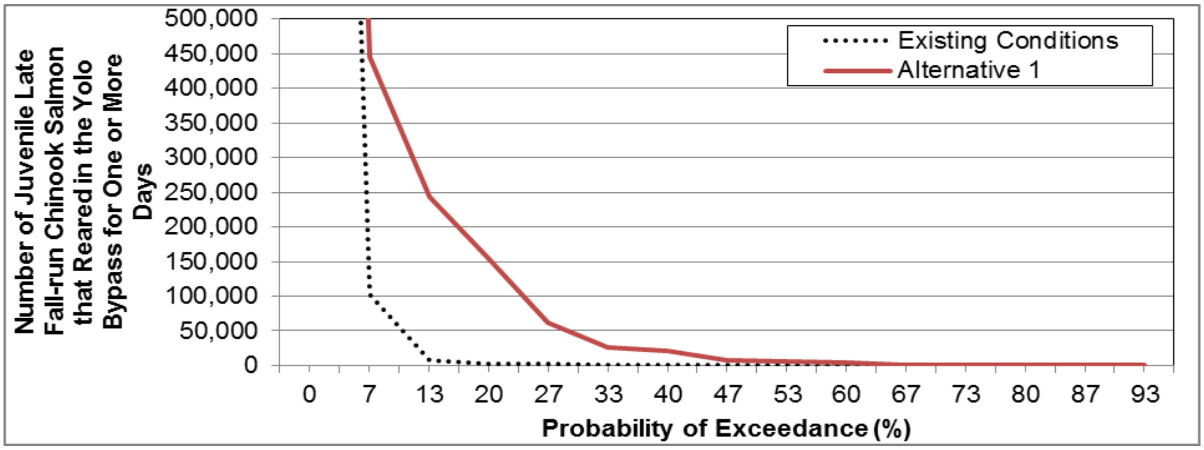

Figure 8-23. Simulated Number of Juvenile Late Fall-run Chinook Salmon Rearing for One or More Days in the Yolo Bypass Probability of Exceedance Distributions under Alternative 1 and Existing Conditions

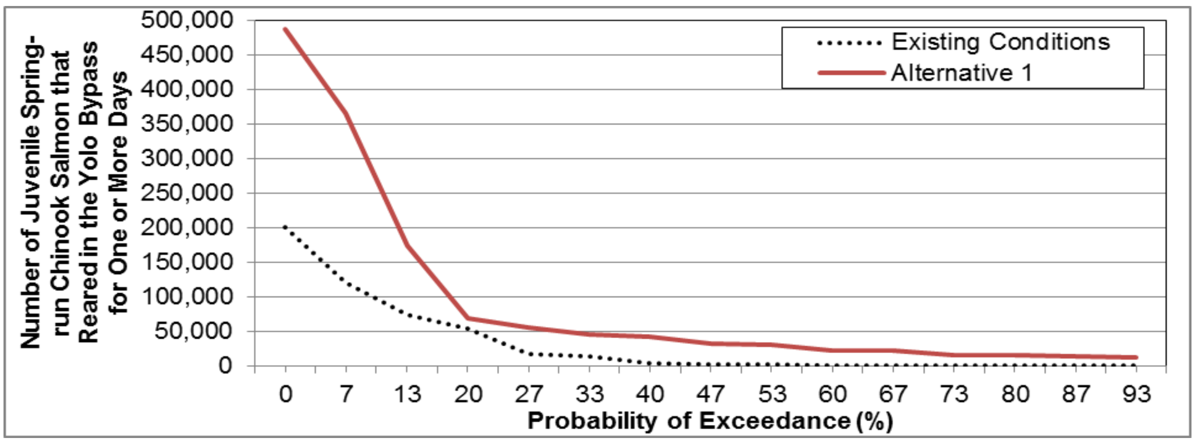

Figure 8-24. Simulated Number of Juvenile Spring-run Chinook Salmon Rearing for One or More Days in the Yolo Bypass Probability of Exceedance Distributions under Alternative 1 and Existing Conditions

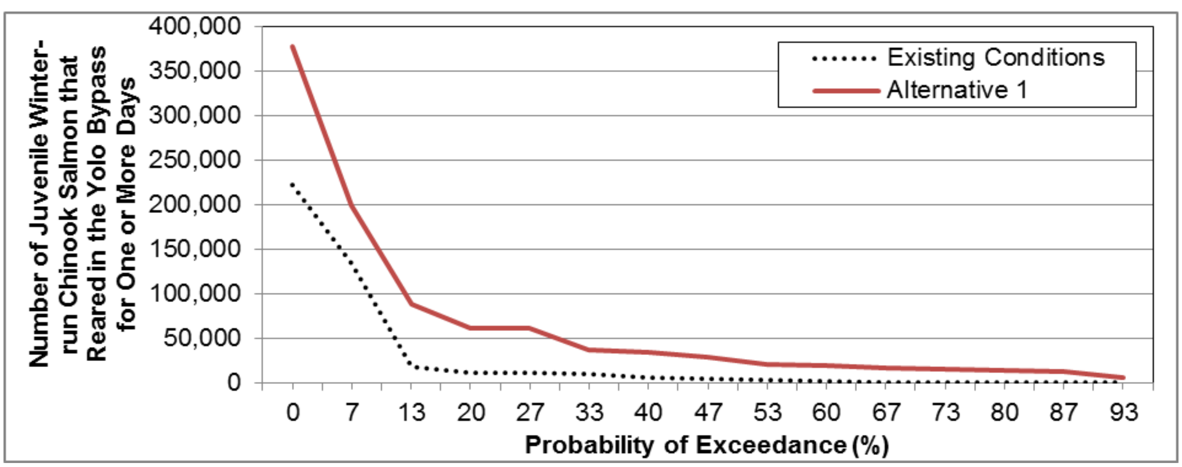

Figure 8-25. Simulated Number of Juvenile Winter-Run Chinook Salmon Rearing for One or More Days in the Yolo Bypass Probability of Exceedance Distributions under Alternative 1 and Existing Conditions

CEQA Conclusion

Simulated population metric indicators from the SBM were used to evaluate changes in the VSP parameters under Alternative 1 relative to Existing Conditions. Except for the abundance and productivity parameters for late fall-run and winter-run Chinook salmon and the diversity parameter for late fall-run Chinook salmon, which indicate generally similar conditions under Alternative 1 and Existing Conditions, the abundance, productivity, diversity, and spatial structure indicators would improve for fall-run, late fall-run, spring-run, and winter-run Chinook salmon under Alternative 1 relative to Existing Conditions.

Therefore, Alternative 1 would be expected to have a **less than significant impact** on VSP parameters.

Impact FISH-19: Impacts to Fish Species of Focused Evaluation and Fisheries Habitat Conditions due to Changes in Hydrologic Conditions in the SWP/CVP System

Modeling results indicated that mean monthly storage in Trinity, Shasta, Oroville, Folsom, and San Luis reservoirs would be the same or generally similar during all months of the year under Alternative 1 relative to Existing Conditions (see Appendix G6). Relative to the No Action Alternative, CalSim II modeling does indicate that there would be some changes in mean monthly storage of 10 percent or more in SWP/CVP reservoirs and changes of 10 percent or more in mean monthly flows in SWP/CVP system and Delta under Alternative 1, primarily because of assumed re-operations from other projects under the future LOD. However, the changes would be infrequent and would not occur over 10 percent or more of any monthly distribution. Therefore, changes under Alternative 1 relative to the No Action Alternative (and Existing Conditions) would not result in substantial adverse effects to fish species of focused evaluation and their habitats in the SWP/CVP system.

CEQA Conclusion

Due to similar modeled hydrology in the SWP/CVP system, Alternative 1 would be expected to have a **less than significant impact** on hydrologic conditions in the SWP/CVP system.

Impact FISH-20: Conflict with Adopted Habitat Conservation Plan; Natural Community Conservation Plan; or Other Approved Local, Regional, or State Habitat Conservation Plan

Although the Yolo County HCP/NCCP does not directly address fish species, it does include goals and policies related to protecting and improving habitat conditions in the Yolo Bypass that could indirectly benefit fish resources (Yolo Habitat Conservancy 2017). Because Alternative 1 would include mitigation for physical habitat impacts, Alternative 1 would not conflict with HCPs or NCCPs, including the Yolo County HCP/NCCP (Yolo Habitat Conservancy 2017).

CEQA Conclusion

Alternative 1 is expected to have a **less than significant impact** on habitat conservation plans.

8.3.3.3 Alternative 2: Central Gated Notch

Alternative 2, Central Gated Notch, would provide a similar new gated notch through Fremont Weir as described for Alternative 1. The primary difference between Alternatives 1 and 2 is the location of the notch; Alternative 2 would site the notch near the center of Fremont Weir. This gate would be a similar size but would have an invert elevation that is higher (14.8 feet) because the river is higher at this upstream location, and the gate would convey up to 6,000 cfs to provide open channel flow for adult fish passage. In addition, because hydraulic conditions upstream of the proposed Fremont Weir notch are not favorable to entraining juvenile Chinook salmon, Alternative 2 includes Sacramento River channel and bank improvements. These improvements include removing pilings in the Sacramento River and re-grading the Sacramento River channel and right bank. These improvements also are expected to fill in a scour hole near the pilings. See Section 2.5 for more details on the alternative features.

8.3.3.3.1 Construction-related Impacts – Evaluation of Substantial Adverse Effects on Fish Species of Focused Evaluation and their Habitat and Movement

The proposed construction schedule for Alternative 2 would be similar to the schedule described for Alternative 1. Construction- and maintenance-related activities evaluated for Alternative 2 are similar to those described for Alternative 1. However, Alternative 2 includes additional in-river activities just upstream of the proposed Fremont Weir notch. Activities include removing instream piles and re-grading the Sacramento River channel and right bank. In addition, future maintenance may be necessary to maintain the re-graded conditions in the Sacramento River channel and along the right bank to maintain hydraulic conditions that promote entrainment of juvenile Chinook salmon into the Fremont Weir notch.

Impact FISH-1: Potential Disturbance to Fish Species or their Habitat due to Erosion, Sedimentation, and Turbidity

Potential impacts due to erosion, sedimentation, and turbidity under Alternative 2 are expected to be similar to those described for Alternative 1. As an indicator of the extent of excavation that would occur under Alternative 2 in the Yolo Bypass, the estimated excess amount of spoils to be excavated during construction would be about 546,000 CY. As an indicator of maintenance-related impacts, the estimated additional annual amount of sediment removal required in the area between Fremont Weir and Agricultural Road Crossing 1 because of increased flows into the Yolo Bypass under implementation of Alternative 2 is 37,800 CY. This corresponds to an estimated total annual amount of sediment removal required of 334,350 CY under Alternative 2 relative to 296,550 CY under Existing Conditions. However, local depositional patterns will be dependent on the specific design of the downstream facilities. For example, although the total estimated increase in sediment deposition due to increased flows would be the same under Alternatives 1, 2, and 3, the additional lengths of channel connecting the intake facility to the Tule Pond under Alternatives 2 and 3 may result in the need for additional sediment removal under Alternatives 2 and 3 relative to Alternative 1.

CEQA Conclusion

Erosion, sedimentation, and turbidity impacts would be **significant** because construction and maintenance activities would result in temporary increases in sedimentation and turbidity in the Sacramento River and the Yolo Bypass and could temporarily adversely affect all fish species of focused evaluation.

Development and implementation of Mitigation Measure MM-WQ-2: Implement a Stormwater Pollution and Prevention Plan and Mitigation Measure MM-WQ-3: Develop Turbidity Monitoring Program would reduce this impact to **less than significant**.

Impact FISH-2: Potential Disturbance to Fish Species or their Habitat due to Hazardous Materials and Chemical Spills

Potential impacts associated with hazardous materials and chemical spills under Alternative 2 are expected to be similar to those described for Alternative 1.

CEQA Conclusion

Hazardous materials and chemical spills impacts would be **significant** because construction and maintenance activities could potentially result in the release of contaminants to aquatic habitats in the Sacramento River and the Yolo Bypass and could adversely affect all fish species of focused evaluation.

Development and implementation of Mitigation Measure MM-WQ-1: Prepare and Implement a Spill Prevention, Control, and Countermeasure Plan would reduce this impact to **less than significant**.

Impact FISH-3: Potential Disturbance to Fish Species or their Habitat due to Aquatic Habitat Modification

Potential impacts associated with aquatic habitat modification under Alternative 2 are expected to be similar to those described for Alternative 1, except as described below.

Preliminary estimates based on calculations in ArcGIS indicate that a total of 27.4 acres (temporary impacts) and 72.5 acres (permanent impacts) of vegetated area would have the potential to be disturbed during Alternative 2 construction activities. Specifically, 6.0 acres (temporary impacts) and 15.9 acres (permanent impacts) would be riparian vegetation and would be a potential source of IWM inputs to the Sacramento River or Yolo Bypass (Table 8-12 and Figure 8-26).

Table 8-12. Vegetation Communities Potentially Affected by Alternative 2

Vegetation Community					
	Grassland	Freshwater Aquatic Vegetation	Freshwater Emergent Marsh	Riparian Forrest/Woodland	Total
Acres (Temporary)	18.8	1.0	1.6	6.0	27.4
Acres (Permanent)	43.3	4.0	9.3	15.9	72.5

CEQA Conclusion

Aquatic habitat modification adjacent to the Sacramento River and in the Yolo Bypass associated with construction and maintenance activities would be **significant** because aquatic and riparian habitat would be permanently affected.

Implementation of Mitigation Measures MM-TERR-7 and MM-FISH-1 would reduce this impact to **less than significant**.

Impact FISH-4: Potential Disturbance to Fish Species or their Habitat due to Hydrostatic Pressure Waves, Noise, and Vibration

Potential impacts associated with hydrostatic pressure waves, noise, and vibration under Alternative 2 are expected to be similar to those described for Alternative 1.

CEQA Conclusion

Impacts associated with construction noise would be **less than significant** if a vibratory pile driver can be used for the entire construction of the cofferdam. However, impacts associated with noise would be **significant** if impact pile driving was conducted in the Sacramento River, resulting in direct potential impacts to fish species of focused evaluation.

Implementation of Mitigation Measure MM-FISH-2: Implement an Underwater Noise Reduction and Monitoring Plan would reduce this impact to **less than significant**.

Impact FISH-5: Potential Disturbance to Fish Species or their Habitat due to Stranding and Entrainment

Potential impacts associated with construction- and maintenance-related stranding and entrainment under Alternative 2 are expected to be similar to those described for Alternative 1.

CEQA Conclusion

Stranding and entrainment impacts would be **significant** because fish species of focused evaluation could be entrained in the temporary cofferdam or stranded in the Yolo Bypass associated with dewatering activities.

Implementation of Mitigation Measure MM-FISH-3: Prepare a Fish Rescue and Salvage Plan would reduce this impact to **less than significant**.

Figure 8-26a. Vegetation Communities Potentially Affected under Alternative 2

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Figure 8-26b. Vegetation Communities Potentially Affected under Alternative 2

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