Appendix J
Engineering Feasibility Report

TISDALE WEIR REHABILITATION AND FISH PASSAGE PROJECT

Engineering Feasibility Report

Prepared for
California Department of Water Resources

January 2020

ESA

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Acronyms and Other Abbreviations

AACEI	Advancement of Cost Engineering International
ADCP	acoustic Doppler current profiler
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
cfs	cubic feet per second
CVFED	Central Valley Floodplain Evaluation and Delineation
CVFPB	Central Valley Flood Protection Board
CVFPP	Central Valley Flood Protection Plan
DPS	Distinct Population Segment
DWR	California Department of Water Resources
ESM	engineered streambed material
GIS	geographic information system
HEC-RAS	Hydrologic Engineering Center River Analysis System
IWG	Interagency Work Group
LWD	large wood debris
NEPA	National Environmental Policy Act
PG&E	Pacific Gas and Electric Company
SPFC	State Plan of Flood Control
SRFCP	Sacramento River Flood Control Project
SSJDD	Sacramento San Joaquin Drainage District
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation

TISDALE WEIR REHABILITATION AND FISH PASSAGE PROJECT

Engineering Feasibility Report

Executive Summary

This feasibility study and report was an initial step in developing, assessing, and identifying a recommended Project to rehabilitate the Tisdale Weir and also incorporate fish passage facilities that presently are not included in the weir. The study was intended to identify potential ways to rehabilitate the flood control structure, reduce fish stranding and provide fish passage for important fish species from the Tisdale Bypass to the Sacramento River, form a set of viable structural options, evaluate those options based on Project-specific evaluation criteria, and identify a recommended alternative for design progression and eventual implementation.

The feasibility study investigated and evaluated three structural options along with doing nothing (the no-action alternative). The three alternatives considered in the feasibility study support multiple goals and objectives from the Central Valley Flood Protection Plan (CVFPP) and its Conservation Strategy.

Based on cost, engineering feasibility, and operations and maintenance considerations, this feasibility report recommends an alternative that includes: rehabilitation of the weir surface; replacement of the north and south abutments of the weir (in kind); replacement of the energy dissipation basin with a multi-objective basin that also supports fish passage and reduces stranding; construction of a gated notch through the weir at its northern end and a connection channel to the west of the weir to significantly reduce fish stranding and facilitate passage of fish from the bypass to the river; and construction of various site improvements related to utilities, ancillary equipment for the gate, equipment access, and channel bed and bank scour protection.

1 Introduction

1.1 Overview

The Tisdale Weir is a critical, State-owned component of the State Plan of Flood Control (SPFC) located along the left bank of the Sacramento River about ten miles southeast of the town of Meridian in Sutter County, 4 miles west of the Sutter Bypass, and about 56 miles north of Sacramento (River Mile 119, as measured upstream from the Sacramento–San Joaquin Delta). The primary function of the Tisdale Weir is to “provide a means for release of excess overflow waters of the Sacramento River into Sutter Bypass” (USACE, 1955). The weir is a fixed-elevation, ungated overflow structure that was originally designed to spill and convey up to

38,000 cubic feet per second (cfs) of excess Sacramento River floodwaters into the Tisdale Bypass, a four-mile-long channel flowing eastward to connect with the Sutter Bypass.

The current Tisdale Weir was built by the U.S. Army Corps of Engineers (USACE) in 1932 with a 50-year life expectancy and is now well beyond its original design life. Because of the structure's age and frequent use, it has sustained damage that, if not rehabilitated, could eventually result in failure of the weir, with subsequent flooding, damage to property, and possibly loss of lives. Also, when flowing, the weir's height and design of the energy dissipation basin makes it difficult for fish to pass over the weir to reach the Sacramento River, and when flows over the weir cease, fish may be left stranded in the weir's energy dissipation basin.

The multi-benefit Tisdale Weir Rehabilitation and Fish Passage Project (Project) will construct needed structural repairs to the weir and will modify the weir to add fish passage facilities to allow for passage from behind the weir to the river. The Project will improve public safety by rehabilitating the flood structure that conveys excess floodwaters from the river to the bypass system while also reducing historical fish-stranding issues at the weir. Of key concern are ongoing historical losses to Chinook salmon (*Oncorhynchus tshawytscha*) and North American green sturgeon (*Acipenser medirostris*), both of which have races listed as threatened or endangered under either the California or federal Endangered Species Act. Post-construction adaptive management methods will be applied to monitor weir flood operations and fish passage, and, if necessary, make additional refinements to Project operations and maintenance practices based on field observations and scientific analysis.

This Project is a part of the Tisdale Weir and Bypass Program (Program). The Program includes: proposed Project 1 (this Project), which is composed of weir rehabilitation and fish passage improvements, and a potential Project 2, which would evaluate a reconfiguration of the downstream Tisdale Bypass and consider development of an accompanying Multi-Benefit Management Plan.

1.2 Study Purpose and Scope

The purpose of this feasibility study is to identify, evaluate, and recommend to decision-makers a feasible solution to identified problems and opportunities associated with the Project.

The scope of this feasibility study is limited to the formulation and evaluation of design alternatives and the identification of a recommended alternative. Further details of the design of any proposed Project would be provided in a separate Basis of Design report that would document specific design objectives and assumptions, design criteria, design details (including design plan sheets), and constructability considerations.

This feasibility study report provides documentation of the existing problems, opportunities, and constraints; formulation of alternatives to alleviate the problems; and selection of a recommended alternative. The alternatives screening process documented in this report seeks to balance Project goals and objectives (California Department of Water Resources [DWR], 2014a) with engineering considerations associated with construction cost, durability, costs and considerations for operations and maintenance (O&M), and any mitigation requirements.

1.3 Report Format

This feasibility study report generally follows a process described in DWR (2014a) guidance that provides a rational framework for decision-making and references the USACE (2018) feasibility report guidance. This report is organized by the following sections:

Executive Summary

Section 1 – Introduction

Section 2 – Background

Section 3 – Problems, Opportunities, and Constraints

Section 4 – Planning Goals and Objectives

Section 5 – Existing and Future Conditions

Section 6 – Formulation of Alternatives

Section 7 – Evaluation of Alternatives

Section 8 – Recommended Alternative

This report also includes five appendices:

Appendix A-1, Fish Passage Analysis Technical Memorandum – A technical memorandum that describes a hydrologic analysis, hydraulic modeling, and assessment of fish passage potential for existing conditions and various Project condition alternatives.

Appendix A-2, Tisdale Weir Historical Fish Passage and Stranding Technical Memorandum – A technical memorandum that summarizes information on documented historical fish stranding and passage of listed fish species at the Tisdale Weir and Tisdale Bypass in the Sacramento River Basin.

Appendix B, Large Wood Debris at Tisdale Weir Technical Memorandum – A technical memorandum that describes the data, methods, and results related to the mapping of historical large wood debris (LWD) deposits at the Tisdale Weir to support assessment of the future risk of LWD recruitment along the weir in relation to potential notch locations and maintenance considerations.

Appendix C, Sediment Budget Analysis Technical Memorandum – A sediment budget analysis considering existing and potential with-Project conditions relative to incoming sediment supply, transport and deposition, and related physical conditions and maintenance considerations.

Appendix D, Feasibility-Level Alternatives Cost Estimates – A line-item cost estimate providing a feasibility-level opinion on costs for three alternatives.

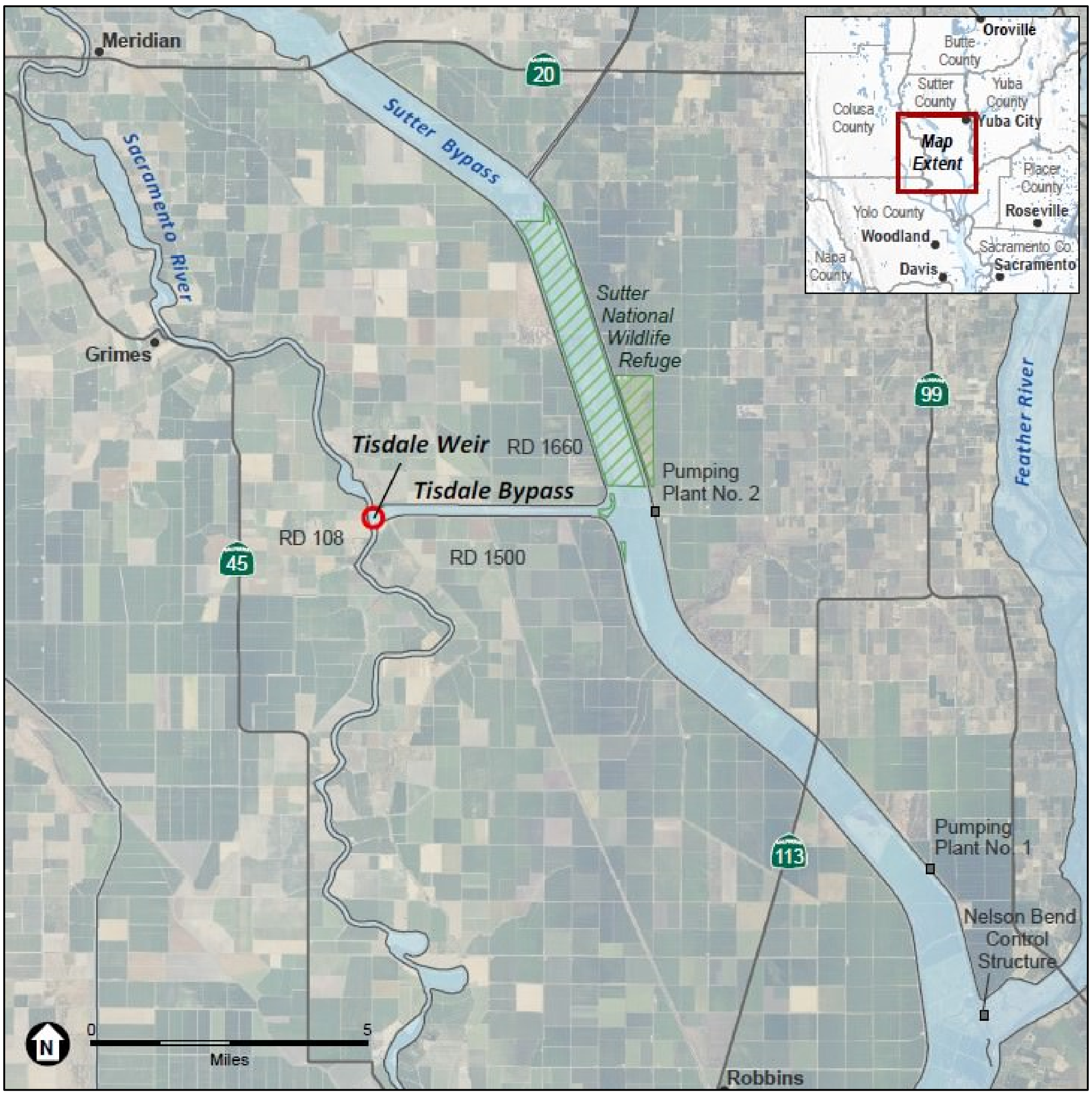
Appendix E, Tisdale Weir Alternatives Evaluation Matrix – A multi-criteria alternatives analysis conducted using evaluation criteria to identify a recommended alternative.

The information in these appendices supported the alternatives evaluation process by addressing key issues and supporting the objectives identified in the feasibility report.

2 Background

2.1 Project Site and Vicinity

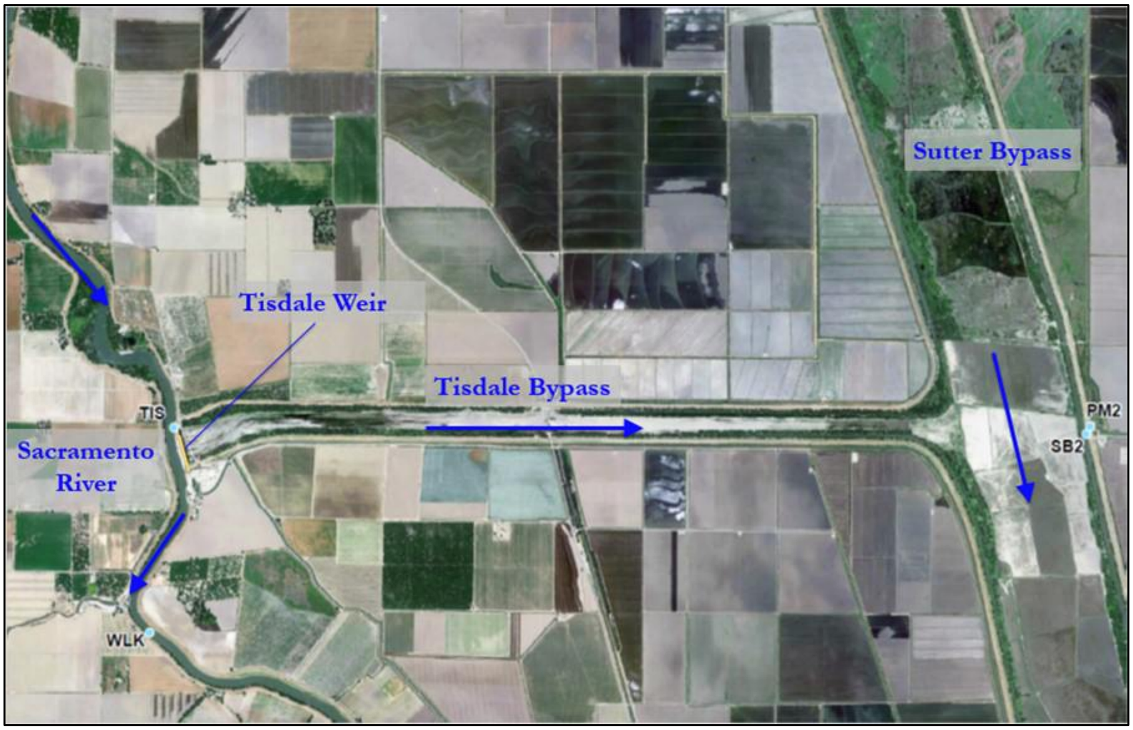
The Project site is located on the left bank of the Sacramento River, approximately ten miles southeast of the town of Meridian in Sutter County, California, about 56 miles north of Sacramento (River Mile 119, as measured upstream from the Sacramento–San Joaquin Delta) (**Figure 1**).



Tisdale Weir Rehabilitation and Fish Passage Project

Figure 1
Tisdale Weir and Bypass Vicinity Map

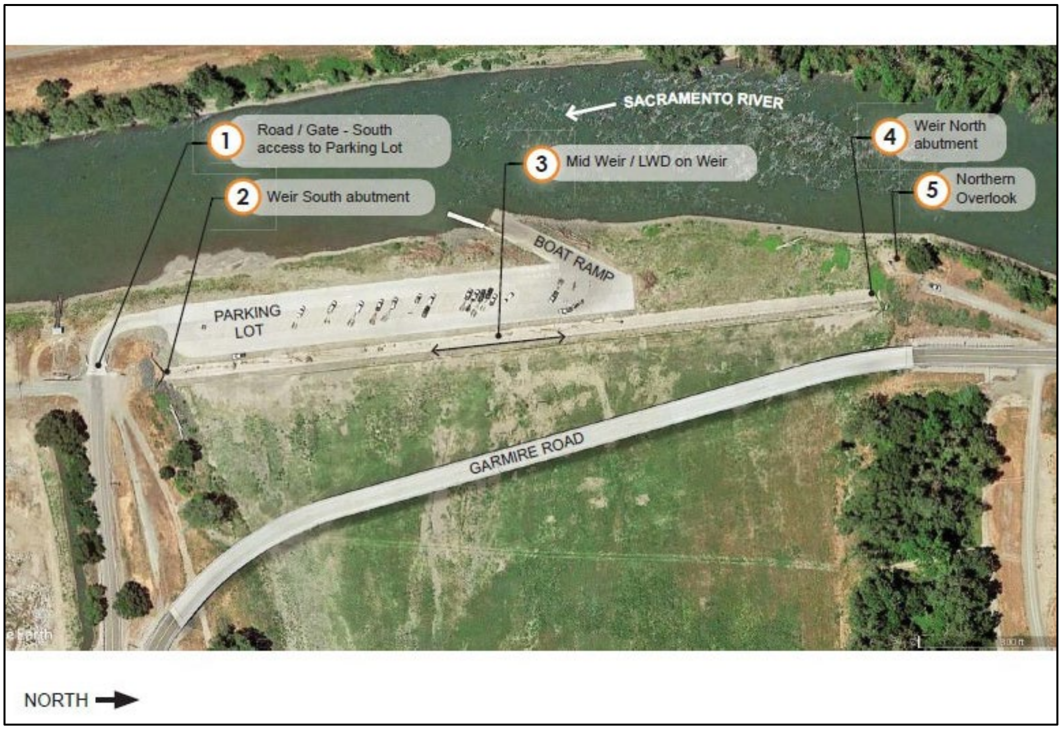
The Tisdale Weir is one of five major overflow weirs in the Sacramento River Flood Control Project (SRFCP), including: the Sacramento Weir, built in 1916; Fremont Weir, built in 1924; and Moulton, Tisdale, and Colusa Weirs, built between 1932 and 1934 (USACE, 1955). During flood events, the Tisdale Weir is generally the first weir to overflow and the last to stop flowing. The weir is a 1,150-foot-long, fixed-elevation, ungated overflow structure that was originally designed to overflow and convey up to 38,000 cfs of excess Sacramento River floodwaters into the Tisdale Bypass, a 1,000-foot-wide, 4-mile-long channel flowing eastward to the Sutter Bypass (**Figure 2**). Levee heights along the Tisdale Bypass range from 15 to 25 feet above the landside ground surface. An irrigation ditch is located near the landside toe of the southern levee embankment.



Tisdale Weir Rehabilitation and Fish Passage Project

Figure 2
Tisdale Weir and Bypass

The western boundary of the general Project area is the Sacramento River immediately west of the existing Tisdale Weir and the Sutter County Tisdale Boat Launch Facility (which includes a two-lane launch ramp (32 feet wide and 152 feet long), a parking area slab (88 feet wide and 750 feet long, with 43 vehicle/trailer parking spaces), and an access road). The eastern boundary of the Project area is downstream of the Tisdale Weir and immediately east of the Garmire Road Bridge (**Figure 3**).



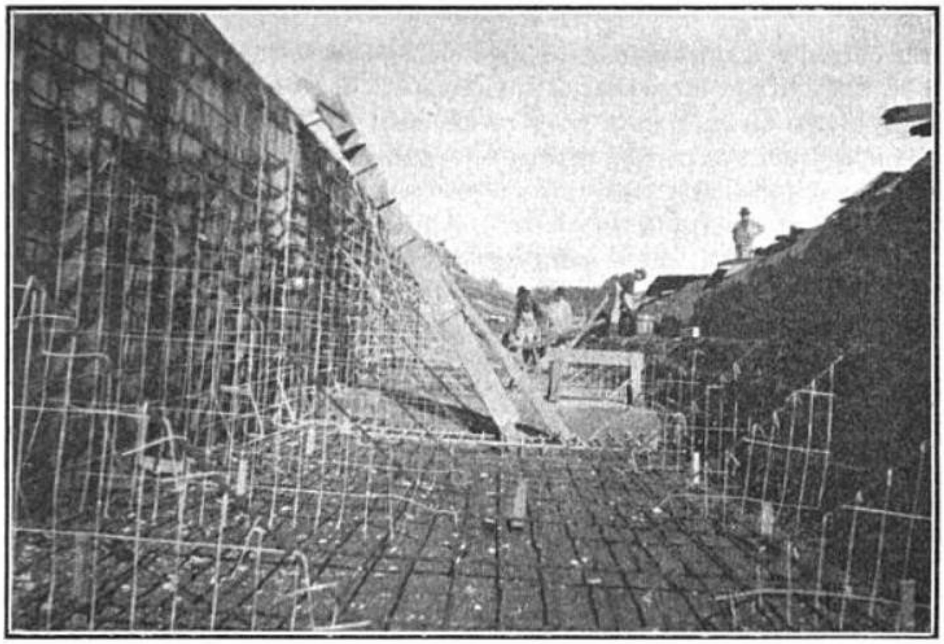
Tisdale Weir Rehabilitation and Fish Passage Project

Figure 3
Tisdale Weir Existing Condition

2.2 Historical Context

The Sacramento River Flood Control Project (SRFCP) was designed with the understanding that runoff from many of the storm events experienced in the Sacramento River watershed cannot be contained within the banks of the river, nor could this flow be fully contained within a levee system without periodically flooding adjacent property. Thus, the SRFCP was designed to occasionally spill through a system of weirs and flood relief structures into adjacent basins. These basins are designed to contain floodwaters and channel them downstream, to eventually be conveyed back into the Sacramento River near Knights Landing and Rio Vista. There are ten overflow structures in the SRFCP (six weirs, three flood relief structures, and an emergency overflow roadway) that serve a similar function as pressure relief valves in a water supply system. The weirs are essentially lowered and hardened sections of levees that allow flood flows in excess of the downstream channel capacity to escape into a bypass channel or basin.

An early form of the Tisdale Weir was built sometime around 1910 to 1919 by local interests. The current Tisdale Weir was built on top of this structure by the USACE between 1932 and 1934 (USACE, 1955) (**Figure 4**) with what would typically be a 50-year life expectancy, and it is now well beyond its original design life. The SRFCP was originally authorized by the Flood Control Act of 1917 and subsequently modified and extended by the Flood Control Acts of 1928, 1937, and 1941. The State adopted and authorized the SRFCP in 1953 by adding Section 12648 to the California Water Code regulations (USBR, 2019). The Sacramento River and Major and Minor Tributaries Project, initially authorized by the federal government in the Flood Control Act of 1944, as amended by the Flood Control Act of 1950, authorized the construction of revetment for the Tisdale Bypass levees (DWR, 2016a).



REINFORCING SCHEME TISDALE WEIR, SACRAMENTO RIVER.

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 4
Tisdale Weir Construction in 1932

Garmire Road was originally aligned along the Tisdale Weir, but accumulated LWD on the roadway piers proved to be a major maintenance challenge. In 2008, a new Garmire Road Bridge was built just east of the weir across the Tisdale Bypass and the older bridge was demolished.

Cracking and other signs of damage to the concrete and rebar are present throughout the weir structure. Because of the structure's age and frequent use, it has sustained damage that, if not rehabilitated, could eventually result in failure of the weir, with subsequent flooding, damage to property, and possibly loss of lives. Rehabilitation of the Tisdale Weir is intended to extend its design life by an additional 50 years or more.

2.3 Purpose and Need

This is a multi-benefit project intended to ensure that the Tisdale Weir will continue to serve its authorized purpose as a flood control facility, while meeting the State's goals for improving fish passage in the Sacramento River system. The Project was first envisioned in the 2012 CVFPP, as an opportunity to integrate ecosystem restoration with an existing flood risk reduction project. The Tisdale Weir is one of several locations within the SPFC system of weirs, bypasses, and other flood management facilities identified as a candidate to undergo modification or rehabilitation to improve aquatic habitat and facilitate natural flow routing (DWR, 2012). The primary purposes of the Project are to:

- Structurally rehabilitate the Tisdale Weir to extend its design life by an additional 50 years.
- Reduce fish stranding in the Tisdale Weir energy dissipation basin.
- Improve fish passage over a larger range of flows past the Tisdale Weir.

As expressed in the 2012 CVFPP (DWR, 2012): "DWR's goal in integrating ecosystem restoration and enhancement is to achieve overall habitat improvement, thereby reducing, or eliminating the need to mitigate for most ecosystem impacts."

2.4 Program Authority

The Tisdale Weir is a federally authorized structure for which the State, through the Central Valley Flood Protection Board (CVFPB) (formerly The Reclamation Board), has given assurances to the federal government to operate and maintain. The proposed Project will support DWR in meeting its Water Code Section 8361 responsibility to maintain and operate the SRFCP by extending the useful life of the weir. California Water Code Section 8361 addresses operation and maintenance responsibilities of the State for the Tisdale Weir and Bypass in clauses (d) and (o) as follows: "The department [DWR] shall maintain and operate on behalf of the state the following units or portions of the works of the SRFCP, and the cost of maintenance and operation shall be defrayed by the state: (d) The bypass channels of the Butte Slough Bypass, the Sutter Bypass, the Tisdale Bypass, the Yolo Bypass, and the Sacramento Bypass with all cuts, canals, bridges, dams, and other structures and improvements contained therein and in the borrow pits thereof; and, (o) The levees of Tisdale Bypass from Tisdale Weir 4.5 miles easterly to Sutter Bypass."

Title 33 of the Code of Federal Regulations, Section 208.10 (33 CFR 208.10) addresses local flood protection works and the maintenance and operation of structures and facilities. The regulation states: "The structures and facilities constructed by the United States for local flood protection shall be continuously maintained in such a manner and operated at such times and for such periods as may be necessary to obtain the maximum benefits." With regard to modification of flood protection works, the regulation states that no improvements should be made without prior determination by the District Engineer of the Department of the Army or the District Engineer's authorized representative that such improvement will not adversely affect the functioning of the protective facilities. The remainder of the regulation discusses the maintenance and operation requirements for levees, flood walls, drainage structures, closure structures, pumping plants, channels and floodways, and miscellaneous facilities.

As part of efforts to implement O&M activities in response to the 2017 CVFPP Update, the CVFPB passed Resolution No. 2018-06 for Acceptable Operation and Maintenance of the State Plan of Flood Control to fulfill its mandates pursuant to the California Water Code and its federal assurances (CVFPB, 2018).

2.5 Related Plans, Projects, and Programs

The following plans, projects, and programs directly discuss the need for this Project to rehabilitate the Tisdale Weir and/or improve fish passage at the weir and in the bypass:

- 2014 *Mid & Upper Sacramento River Regional Flood Management Plan* (Reclamation District 108, 2014) – "Generally Mid and Upper Sacramento River stakeholders are supportive of weir improvements that would reduce flood stage in the Sacramento River, and improve fish passage, and look forward to the reviewing the Basin-Wide Feasibility Study proposals for these facilities."

- 2014 *Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-Run Chinook Salmon and Central Valley Spring-Run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead* (NMFS, 2014) – A mainstem Sacramento River recovery action "providing and/or improving fish passage through the Yolo Bypass and Sutter Bypass allowing for improved adult salmonid re-entry into the Sacramento River."

- 2016 *CVFPP Conservation Strategy* (DWR, 2016b) – This study identified Tisdale Weir as a fish passage, stranding, and poaching problem location. Table 1 in Appendix K identifies "Channel-wide Structures Affecting Fish Migration in the Sacramento River Basin" and for the Tisdale Weir calls for identification of: "(1) passage alternatives aligned with flood management goals, (2) feasibility of low-flow channel connectivity, and (3) strategies to reduce stranding."

- 2017 update to the CVFPP (DWR, 2017a) – The plan update calls for the upgrade and modification of the Tisdale Weir associated with the Refinements to Physical and Operational Elements in the State Systemwide Investment Approach. Table 3.2 in the CVFPP 2017 update mentions the upgrade and modification of the Colusa and Tisdale Weirs for multi-benefit improvements.

- 2017 California Natural Resources Agency (CNRA) *Sacramento Valley Salmon Resiliency Strategy* (CNRA, 2017) – This strategy includes a proposed action to improve Sutter Bypass and associated infrastructure (Tisdale Weir) to facilitate adult fish passage and improved stream flow monitoring.

- 2018 *Water Quality Control Plan for the San Francisco Bay/Sacramento–San Joaquin Delta Estuary* (SWRCB, 2018) – Recommendation 10.xi(b) of the plan states, "Identify gravel pits, scour pools, ponds, weirs, diversion dams, and other structures or areas that harbor significant numbers of non-native fish and predatory fish that may currently reduce native fish survival."

- DWR Fish Passage Improvement Program (DWR, 2019a) – Rehabilitating the Tisdale Weir with the inclusion of fish passage is also encouraged through DWR's Fish Passage Improvement Program.

3 Problems, Opportunities, and Constraints

This feasibility study supports the formulation of alternatives that address flood management problems and fish passage issues at the Tisdale Weir. This section defines problems, opportunities, and constraints associated with the Project. In part, this information was developed through new technical work, communication, and engagement with involved agencies and stakeholders that included Interagency Work Group (IWG) meetings on November 6, 2018; November 30, 2018; December 18, 2018; January 14, 2019 (site reconnaissance); and March 5, 2019, and review and incorporation of existing, available information on known problems.

3.1 Problems

Problems are defined in terms of the major features and functions of the Project, including: the weir structure, fish passage, O&M, local infrastructure, and flood management. Opportunities and constraints associated with the problems are summarized in the following subsections.

3.1.1 Weir Structure

The current Tisdale Weir was built by the USACE in approximately 1932 with what would typically be a 50-year life expectancy, and it is now 37 years beyond its original design life. Existing problems with the weir structure were identified in a 2015 inspection (DWR, 2015), a 2017 inspection (DWR, 2017b), a 2018 inspection, and a site reconnaissance (DWR, 2018). These problems are summarized below.

1. Concrete surfaces – Spalling, scaling, and cracking and other signs of damage to the concrete and rebar are present throughout the structure. There are potentially internal voids in the existing weir due to missing annular space grouting. In the 2018 Structure Summary Report (DWR, 2018), concrete surfaces were the only item rated unacceptable by the DWR Flood Maintenance Office (FMO).

2. Weir structure – A 2015 Tisdale Weir Structure Assessment indicated that settlement of the weir has occurred. A review of field-surveyed elevations along the weir sill, as part of this feasibility study, indicates the crest elevation varies within approximately +0.1 foot from the documented 44.1-foot NAVD88[1] crest elevation, except for the northern end of the weir at the abutment where the elevation is approximately 0.1 foot below this elevation. This suggests the 2015 assessment was perhaps visual or was specific to the abutments or other smaller, isolated areas of the weir. Geophysical investigations were performed between November 27 and December 2, 2018 (AECOM, 2019), to identify the lateral extent of potential voids underlying the concrete crest slab and the potential presence of air-filled voids, and corresponding loss of the sub-slab support was identified along a portion of the weir.

3. Weir abutments – A 9-foot-long west segment of the south abutment wall is displaced out of plane and extensive horizontal and vertical cracks are visible (**Figure 5**). The wall of the north abutment has about a foot of missing concrete across the entire face with exposed rebar, and the concrete wing walls are falling apart. There is vertical and horizontal cracking throughout the walls. At the south end of the energy dissipation basin near the south abutment wall, there are large boulders and rocks covering the basin.

[1] Unless otherwise noted, all elevations reported herein are referenced to the North American Vertical Datum of 1988 (NAVD88).

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 5
Vertical and Horizontal Cracking of the South Abutment Wall

4. Weir sill – The weir sill concrete has eroded and exhibits exposed aggregate, spalls, cracks, and many patches; some locations show signs of exposed rebar. The cold joint above the energy dissipation basin (basin) wall appears to have some cracking and spalling along the entire length of the joint. The basin along the east side of the weir is badly damaged on the north end with concrete deterioration and exposed rebar, and a buttress wall is missing.

5. Energy dissipation basin – Numerous buttresses in the basin (40 short and 4 tall) are missing or badly damaged, and the basin concrete is showing signs of heavy erosion (**Figure 6**). Scour holes have routinely formed along the edge of the energy dissipation basin and require regular repair and maintenance. Sediment, including large rocks, and vegetation are present in the basin.

6. Revetment – The rock revetment adjacent to the top of the concrete weir sill is shown to be inconsistent throughout the length of the weir. The original rock revetment was comprised of small cobble and is routinely displaced during high flows causing scour holes that require annual maintenance. The revetment that is eroded away from the weir sill is transported over the weir and dispersed all around the lower area, including inside the dissipation basin.

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 6
Deterioration of Energy Dissipation Basin and Buttresses

3.1.2 Fish Passage, Stranding, and Rescue

The original purpose of the weir was for flood management and the design materials and O&M manual do not indicate consideration for fish passage. The weir presents a barrier to passage during many flow conditions for several listed species, including Chinook salmon, steelhead, and green sturgeon. Passage is sometime possible with deeper backwatering of the weir from the bypass (reducing the vertical height). Additional detail is provided in Appendix A. In sum, there are several problems at the weir related to limitations on fish passage and subsequent fish stranding:

1. Fish passage – The Tisdale Weir is a barrier to fish passage during most flood events. The greatest chance for fish to exit the bypass is when there is a backwatered condition and the Sacramento River stage is above weir crest. The backwater condition only occurs about 30 to 50 percent of the time when the Tisdale Weir is overflowing. During extremely large flood events, passage may be possible for a period, for many fish species, if the weir and Tisdale Bypass is backwatered from the Sutter Bypass. Extensive hydraulic analysis confirms that Tisdale Weir is a temporal barrier for: Chinook salmon, steelhead, and green sturgeon (Appendix A).

2. Fish stranding – Fish stranding occurs at the weir when flow over the weir ceases and those fish in the Tisdale Bypass are unable to pass upstream over the weir. Stranding occurs in the

energy dissipation basin or in multiple isolated residual pools elsewhere to east of the Tisdale Weir in the bypass after floodwaters recede.

3. Fish injury – As fish attempt passage over the weir, there is the potential for injury to occur as fish impact the weir sill and back face in the energy dissipation basin. Without timely rescue events fish stranded at the weir are eventually exposed to lethal water quality conditions (e.g., low oxygen, high water temperatures).

4. Fish poaching and predation – The concentration of fish within the energy dissipation basin provides opportunities for poaching by humans and predation by birds.

After some stranding events, fish rescues by the California Department of Fish and Wildlife (CDFW) have been conducted at the Tisdale Weir to rescue juvenile and adult salmon, steelhead, and sturgeon from the weir's existing energy dissipation basin (**Figure 7**). While trapped in the basin, fish are ultimately subject to lethal and sublethal conditions; their survival is dependent upon a timely fish rescue (i.e., removal and release). Additional information on fish stranding and rescues is provided in ESA (2019). Rescue efforts at this location have been limited to the weir apron and inundated areas immediately east of the weir.

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 7
Fish Rescue at Tisdale Weir

3.1.3 Operations and Maintenance

O&M requirements for weirs in the SPFC vary by location in the system. The Tisdale Weir and Bypass O&M problems are primarily associated with removal of sediment and LWD from the parking lot, weir crest, energy dissipation basin, and within the bypass. Previous inspection reports note that accumulations of sediment and large rocks in the basin and the deposition of LWD in the vicinity of the weir are recurring problems. These and other problems are summarized as follows:

1. LWD accumulation and removal – Since construction of the boat ramp and parking lot on the west side of the weir in 2009, the bulk of LWD accumulation has repetitively occurred on the parking lot surface, with additional accumulations on the weir itself and in the bypass (**Figure 8**). These accumulations create problems both for operations and for maintenance. For example, the gage at the north abutment records the stage on the Sacramento River and this stage information is then used to develop and maintain a stage-flow relationship (rating curve) over the weir and this is computed based on the assumption that the weir is clear of debris; however, LWD has been observed to obstruct and reduce flow over the weir in isolated locations, and this can result in variable flow across the weir, leading to inaccurate estimates of flow over the weir when debris is present. The physical removal of the LWD is a problem because the mass of debris requires cutting up large-diameter wood so it can be chipped and/or placed in trucks and hauled offsite.

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 8
Large Wood Debris Accumulation on Tisdale Weir – January 22, 2019

2. Sediment deposition and removal – DWR grades the bypass to level and fill scour holes and as necessary off-hauls any excess sediment near the weir. Downstream in the bypass, DWR has periodically conducted larger sediment removal in recent years, including: 240,000 cubic yards in 1984; 211,000 cubic yards in 1985; 1,301,000 cubic yards in 1986; 270,000 cubic yards in 1987; and, 1,712,800 cubic yards in 2007 (DWR, 2016c). The 2007 removal effort extended up to the back edge of the dissipation basin. Sediment (and LWD) removal from the existing energy dissipation basin is difficult given the current configuration of the buttresses in the basin, which preclude the use of a skid-steer tractor or other equipment to run through the existing basin and efficiently scoop out material. Instead, a small excavator or backhoe must be used to excavate material from the spaces in between these buttresses, which is very labor and time intensive.

3. Weir flow measurement – The existing stage recorder located at the northern end of the weir along the Sacramento River bank (**Figure 9**) is operated by the DWR North Region Office and requires maintenance to ensure proper operation. It does not measure lower Sacramento River stage elevations (below weir crest), which would be necessary to measure and record river stage for the range of stage elevations when any fish passage structure(s) constructed through the weir may be operating. Even with this single gage functioning properly, observations of differential flow over the weir due to LWD accumulations indicate that more than one stage measurement location may be helpful. For example, at least one additional gage could be installed at the south end of the weir, and ideally stage monitoring would occur at multiple locations across the weir in the direction of the overflow. Any future effort to establish a new stage-flow relationship across the weir with the installation of fish passage facilities(s) should also involve the conversion of all water surface elevation measurements (and reporting) from the existing USED vertical datum to the standard NAVD88 vertical datum.

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 9
Sacramento River Water Stage Recorder at the Northern End of Tisdale Weir

4. Vehicular access – Vehicular access to the weir is available from the boat ramp parking lot and maintenance staff also access the bypass at various locations from the bypass levees as evidenced by vehicle tracks observed on aerial imagery. Unauthorized vehicular access to the weir is a problem and DWR and Sutter County maintenance staff place LWD on the weir sill to serve as a vehicle barrier in an attempt to preclude vehicles from driving out of the parking lot and accidentally driving onto the weir (or worse, off the downstream side of the weir).

3.1.4 Local Infrastructure

Local infrastructure at and in the vicinity of the Tisdale Weir and Bypass include a variety of structures and features owned and operated by several entities. This infrastructure factors in the site's opportunities and constraints, as described below.

1. Parking lot and boat ramp – Since construction of the Sutter County Tisdale Boat Launch Facility in 2009, the LWD that has historically drifted over the weir (generally less to the north end and more to the south end, owing to flow patterns) tends to accumulate more on the elevated parking lot surface along the river than on the unpaved river bank to the north of the parking lot. The high-flow events in winter/spring 2019 scoured and undermined the east side of the roadway leading into the parking lot. Additionally, the non-paved area between the parking lot and the weir experienced erosion, as did the cutoff walls at the edge of the river.

2. Garmire Road Bridge piers – This Sutter County bridge runs across the bypass downstream of the weir, and LWD accumulates on the upstream (west) side of most of the bridge piers following extended periods of weir overflow. The 2017 weir inspection also noted scour pit development around some of the bridge piers.

3. Utility poles and power and communication lines – LWD also accumulates on the upstream (west) side of most of the utility poles (carrying Pacific Gas and Electric Company power lines and also a telecommunications line) that are located immediately west (upstream) of the Garmire Road Bridge following extended periods of weir overflow.

4. Water supply intakes – Two irrigation pump intakes (one associated with Oji Brothers Farm and one associated with the Sutter Mutual Water Company) are located on the east (left) bank of the Sacramento River and downstream of the weir. The Oji intake is located approximately 160 feet downstream from the south weir abutment and the Sutter Mutual Water Company Tisdale Pumping Plant is approximately 800 feet downstream.

3.1.5 Flood Management

The primary purpose of the Tisdale Weir is to divert flood flows from the Sacramento River into the Tisdale Bypass and route that flow on to the Sutter Bypass to reduce downstream Sacramento River flood stages. The primary flood management problem associated with the weir is the potential for failure of the weir given its deteriorating structural condition. Additional, related issues are summarized below.

- Flood risk – A high risk of flooding threatens life and public safety, property, and critical infrastructure throughout the areas protected by the flood management system. A single levee failure in the system can result in uncontrolled, rapid, and deep flooding (DWR, 2017c). Failure of the weir may lead to failure of the adjacent bypass levees if design flows are exceeded.

- Changing flood frequency – The flood system was designed with limited hydrologic data and, in many cases, the system is undersized for managing large floods. The SRFCP was designed to pass the known flood of record, which at the time of Congressional authorization (in the Flood Control Act of 1917) was the 1909 flood. The system has experienced much larger floods than those that guided the original design of the SRFCP. As historical hydrologic data have accumulated, the 1.0 percent and 0.5 percent annual chance of floods (flood size and frequency) are now known to be larger events than what was previously understood based on historical hydrology and flood events (DWR, 2017c). However, the authorized design capacity of the Tisdale Bypass exceeds these design events.

- LWD impacts on weir flow – Field observations and a historical assessment of LWD accumulations at the weir indicate that a majority of debris is deposited along the southern two-thirds of the weir, with the largest accumulations occurring in the parking lot area. This uneven pattern of deposition has been observed to induce an associated variation in flow depths from the north to the south ends of the weir (deep to shallow) (**Figure 10**), indicating that LWD can obstruct flow across the weir. LWD accumulations at the weir may also limit the ability of the weir to perform its authorized function/design capacity, forcing more water downstream in the Sacramento River, potentially increasing risk to the Sacramento River levees downstream.

- Bypass sedimentation – During weir overflow events, suspended sediment from the Sacramento River deposits in the Tisdale Bypass, and may affect the conveyance capacity of the bypass.

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 10
Weir Overflow Depth Variation on North (left) and South (right) – March 22, 2019

3.2 Opportunities

Based on field inspections, the existing energy dissipation basin and north and south abutment walls are not salvageable given the extent of the concrete deterioration, and the lack of information available in the existing as-built drawings inhibits the ability to assess the original design conditions. Thus, these weir features should be replaced. The top weir cap is visually in generally acceptable condition given its age; therefore, there may be an opportunity to conduct a simple rehabilitation of the weir cap by resurfacing the top of the weir cap to an acceptable finish thru the application of a thin restoration overlay.

The channel revetment in the bypass immediately east (downstream) of the existing energy dissipation basin is almost completely eroded and depleted. The as-built drawing (50-09-1286-1) shows cobble revetment extending approximately 24 feet into the bypass at a depth of 2 feet and flush with the top of the sill along the east side of the existing energy dissipation basin. Any new project should include scour protection in this area, and there is an opportunity to provide it in a reconfigured interface between the weir and the bypass that could be more easily maintained.

There are opportunities to incorporate multiple resource benefits with the flood management function of the weir by integrating features to improve fish passage. The existing single-purpose flood management structure can be easily re-designed and modified to install fish passage facilities. The DWR 2016 CVFPP Conservation Strategy identified general fish migration improvement opportunities at SPFC facilities (DWR, 2016b). These specific opportunities for the Tisdale Weir and Bypass are as follows:

1. Provide access to suitable areas that benefit fish seasonally along migratory corridors and ensure that fish have an outlet back to a suitable migration route.
2. Modify structures to eliminate engineered features that trap fish by improving aquatic connectivity.
3. Create barriers or operate existing structures to keep fish from straying into dead-end canals, toward pumps, or into other types of detrimental environments (applicable to areas that are not considered suitable migratory routes or that lead to unsuitable areas).
4. Provide efficient passage at structures in identified migration corridors that would otherwise block fish access to upstream or downstream habitat. This can be accomplished by removing or modifying structures, installing a semi-natural fishway (e.g., a rock ramp or bypass channel), or constructing a more technical fishway (e.g., fish ladder). In all cases, downstream passage at the structure should be considered and optimized to reduce or eliminate the effect of the structure on juvenile or adult emigration.

Since construction of the original weir, pneumatically operable gate technology has been successfully deployed at similar flood control structures to preserve the flood functions of a weir while also recognizing many of the above-stated fish passage opportunities through the structural modification of an existing weir structure. The removal of a portion of the weir to form a notch that is then fitted with gates is identified as a key opportunity at the site to simultaneously meet both flood management and fish passage needs. Similarly, the existing energy dissipation basin downstream of the weir is difficult to maintain and also traps fish. Reconstruction of a single, multi-purpose structure that can dissipate flow energy over the weir and can also support fish collection and passage through a notched weir is another significant opportunity.

3.3 Constraints

Planning constraints represent significant barriers or restrictions that limit the extent of the planning process and/or the range of alternatives that can be proposed. Study-specific planning constraints are statements of unique aspects of a planning study that alternative plans should avoid. Constraints provide limits on the planning process based on institutional, legal, and physical restrictions, among others. Constraints related to the existing weir structure, topography, habitats, and land uses may limit opportunities as well. Some of the major constraints affecting the alternative formulation process are summarized in the following subsections.

3.3.1 Weir Sill Elevation Constraint

The sill elevations of the existing weirs in the SPFC were originally set to achieve a balance between three competing needs (DWR, 2017c):

1. Keep as much flow in the main river channel as feasible, so that sediment is regularly scoured, thus maintaining the channel's flow capacity and navigability.
2. Release as much excess flow to the bypasses as necessary during major flood events, so that the channel capacity of the Sacramento River is not exceeded.
3. Limit the frequency of bypass channel inundation, so that the SRFCP bottom lands can be productively farmed.

The frequency and duration of flood flows over Tisdale Weir into the Tisdale and Sutter Bypasses is largely dependent upon the sill elevation of the Tisdale Weir relative to the Sacramento River channel, while the discharge capacity of the weir depends upon a number of factors, such as weir sill elevation, weir width, overflow depths, channel vegetation, and the effects of regional river and bypass water levels on the Tisdale Weir's efficiency.

For the purpose of this feasibility study, the existing weir sill elevation is considered to be an important constraint, because flood flow splits in the system are a critical component of the SPFC. For this reason, this feasibility study does not consider changing the Tisdale Weir sill elevation.

3.3.2 Structural Constraints

The Tisdale Weir is approximately 35 years past its design life, and recent inspections reveal multiple issues, especially with the existing energy dissipation basin, south abutment, and north abutment—all of which require reconstruction. While the north and south abutments have significant structural damage and are in need of replacement, the weir cap itself is generally in acceptable condition and shows no indication of requiring a complete replacement. The weir can receive structural repair and be resurfaced to extend the design life of the structure. However, all structural work must be done in a manner that does not change the existing weir geometry in any way which would inhibit the weir's ability to serve its authorized flood control purpose: i.e., maintain the overflow conveyance capacity of the structure and flow split at the weir.

3.3.3 Resource Constraints

Resource constraints are those associated with limits on knowledge, expertise, experience, ability, data, information, funding, and time (DWR, 2014a). Resource constraints associated with this feasibility study primarily involved the following:

1. The available as-built drawings of the weir (50-01-1814, 50-09-1286-1, and 50-09-1448) are not fully complete and are missing data on the length, rebar size and spacing, depths, heights, thickness, and elevations of weir features. As-Builts do not include any structural calculations or design assumptions.

2. Limited historical subsurface information is available for the Tisdale Weir. The historical information is limited to the subsurface information shown on the 1931 as-built drawings for the Tisdale Weir and the new Garmire Road Bridge foundation report.

3. Recent data on the characteristics of sediment transport are not available.

4. Data on the characteristics of sediment deposition are not available.

5. Data on the characteristics of LWD transport and accumulation patterns are not available.

6. The range of flow conditions at the weir that meet fish passage criteria for salmonids and green sturgeon—and the degree to which residual pools include stranded fish—are not certain, based on a review of available literature (ESA, 2019).

Given these information constraints, a series of technical investigations was conducted as part of this feasibility study to resolve these data gaps and reduce the associated constraints on alternative formulation (see Section 6.5, *Data Gap Assessments and Analyses*).

3.3.4 Regulatory and Legal Constraints

Legal and policy constraints are those defined by laws, applicable policies, regulations, and other types of guidance. The Project must follow all relevant federal, State, and local laws and regulations, including the National Environmental Policy Act (NEPA), the California Environmental Quality Act (CEQA), the Fish and Wildlife Coordination Act, the Clean Air Act, the Clean Water Act, the federal Endangered Species Act, the California Endangered Species Act, and the Magnuson-Stevens Fishery Conservation and Management Act.

The Sacramento–San Joaquin Drainage District (SSJDD) holds real property rights in the Tisdale and Sutter Bypasses in the form of flowage easements. The easements were acquired by compensating property owners for conveying to SSJDD the right to flow floodwater over portions of their real property. A flowage easement is a perpetual easement and right-of-way to flood, seep, pond, and overflow water over, through, or across a portion of real property (DWR, 2016a). Changes in the timing or maximum depth of flooding, or flowing water for purposes other than flood control, in these bypasses may require acquisition of additional easements.

3.3.5 Infrastructure Constraints

Infrastructure constraints in the vicinity of the Project include the Garmire Road and bridge, Pacific Gas and Electric Company (PG&E) poles and power lines, levees, the Sutter County parking lot and boat ramp, agricultural buildings, and water diversion, supply, and drainage facilities. Based on past sediment removal project s in the area, buried utilities are understood to not be present in the immediate Project area or where the ground is planned to be disturbed; however, to confirm, a utility locate will be performed as the Project progresses. The direct and indirect costs associated with removing or relocating infrastructure can range from modest to prohibitively expensive. The need to protect existing infrastructure while achieving site improvement objectives means that existing infrastructure can create financial, institutional, and temporal constraints (DWR, 2017c).

3.3.6 Bypass Topographic Constraints

Besides the major topographic constraint imposed on bypass flows by the weir sill elevation, topography in the bypass itself varies and there is, in effect, a “sill,” or “hinge point” at elevation 37 feet in the bypass located approximately 1,000–2,000 feet east of the weir sill (**Figure 11**). This elevation roughly corresponds to the water surface elevation in the bypass at which eastward flow through the bypass ceases, due to the elevation of this topographic “hinge point.” In other words, in the absence of the weir, the Sacramento River would not flow beyond this point in the Tisdale Bypass if the river water surface elevations were below this elevation.

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 11
Approximate Location of Tisdale Bypass “Hinge Point” Area

3.3.7 Flood Management Constraints

The USACE has prepared design water surface elevation profiles for much of the Sacramento River, San Joaquin River, and major tributaries of the flood management system. DWR operates SPFC facilities based on the design profiles rather than on design flows from the O&M manuals (USACE, 1969). For the SRFCP, USACE requires that channels pass design flood flows for stages at or below the 1957 Revised Profile Drawings (DWR, 2010a); therefore, flood elevations cannot exceed these stages, the flood flow split between the Sacramento River and the Tisdale Weir needs to be maintained, and the conveyance capacity of the Tisdale Bypass needs to be maintained.

3.3.8 Existing Land Use Constraints

Land use in the vicinity of the weir and in the Tisdale and Sutter Bypasses is predominantly agricultural; however, the location of the weir on the Sacramento River also attracts recreational boaters and angler. Constraints associated with these land uses are discussed briefly below.

- Agriculture – Existing agricultural practices within the downstream Sutter Bypass are compatible with the associated flood conveyance function. Most of the bypass lands are devoted to rice or row crops, which can accommodate winter flooding. Hence, the land in these areas offers minimal flow resistance to floodwaters. The integration of multiple benefits, including improved fish passage, could affect existing agricultural uses by changing the timing and/or duration of bypass flows. The effects of changes in land use associated with changes in channel configurations must be carefully assessed so that multiple resource benefits are achieved while impacts on existing land uses are minimized (DWR, 2017c).

- Recreational land uses – Land uses dedicated to recreation (e.g., public hunting areas and/or private duck clubs) may constrain or be affected by the Project. The Sutter County Tisdale Boat Launch Facility provides boaters with river access, and any construction of a notch and connecting channel will need to be designed to minimize impacts, and, if unavoidable, mitigate them.

- Recreation safety – The opportunities to improve fish passage at the weir will involve the construction of a notch and connecting channel that will present changed physical conditions along the east bank of the Sacramento River and associated changed hydraulic conditions. Recreational boaters and anglers will experience new localized flow conditions and temporary periods of high flow and velocity. The safety of humans and domestic animals should be considered.

3.3.9 Operations and Maintenance Constraints

Vehicular access to the weir for O&M will need to be maintained, and modifications to the weir for fish passage will need to accommodate this constraint. Access may require temporary or permanent crossings at any notch opening(s) and improved structural support if larger and heavier equipment is required for gate maintenance.

The weir and surrounding areas are readily accessible by pedestrians and off-road vehicles from Garmire Road or the Sacramento River. This accessibility of the weir to the public has led to instances of vandalism. Potential constraints may include vandalism, such as graffiti, theft, shooting, or other damage, to existing and proposed infrastructure.

4 Planning Goals and Objectives

The defined problems and opportunities led to a formulation of the study planning goals and objectives that are intended to guide the planning process by solving the problems and taking advantage of identified opportunities.

4.1 Project Goal and Objectives

The overall Project goal is to rehabilitate the Tisdale Weir to address structural deficiencies and address the fish passage and stranding issues at the weir.

The objectives for the feasibility study must be specific and measurable and should reflect the desired outcome of the Project and be aligned with DWR's commitment to Integrated Water Management (IWM), State interest, DWR policy directions, and any specific goals and objectives established by authorizing or appropriations language for the study (DWR, 2014a). Therefore, the objectives for this Project generally address the weir structure, fish passage, accompanying O&M, and flood management, and include the following (DWR, 2019b):

- Perform structural rehabilitation of the aging Tisdale Weir.
- Reduce stranding and delay of fish passage at the weir.
- Increase fish passage across the Tisdale Weir during more of the flood hydrograph.
- Facilitate maintenance of fish passage improvements, including sediment and debris removal.
- Maintain the conveyance capacity of the Tisdale Bypass and the flood flow split between the Sacramento River and the Tisdale Weir, so the Project will not change the flood control system's ability to serve its authorized purpose.
- Deliver a cost-effective, efficient, and sustainable Project within identified funding, design, and risk constraints.

In general, the initial concept is intended to provide passable velocities during high Sacramento River stages and to allow effective drainage and exit routes for fish as river stage recedes.

To provide a context for the Project goals and objectives, it is useful to compare them to broad statewide goals and objectives embodied in the Governor's Water Resilience Portfolio and the Central Valley regional goals embodied in the CVFPP.

4.2 Governor's Water Resilience Portfolio Strategies

The Governor's Water Resilience Portfolio, published in July 2020 in response to Executive Order N-10-19, identifies strategies that provide direct policy support to the proposed Project. Strategy 11.3 of the Portfolio supports "expansion of multi-benefit floodplain projects across the Central Valley…including projects that reduce flood risk and restore or mimic historical river and floodplain processes," and Strategy 25.1 calls for "implementation of the Central Valley Flood Protection Plan…[to] integrate natural systems into flood risk reduction projects." In addition, Strategy 10 calls for action to "reconnect aquatic habitat to help fish and wildlife endure drought and adapt to climate change," including a comprehensive program to improve fish passage (Strategy 10.2), and support of "climate change adaptation projects to prevent species decline" (Strategy 10.4). Finally, Strategy 9 calls for action to "help regions better protect fish and wildlife by quantifying the timing, quality and volume of flows they need," to which this Project also contributes.

4.3 CVFPP Goals

All CVFPP goals are identified in the 2017 CVFPP Update and the supporting Conservation Strategy. The 2012 CVFPP and 2017 CVFPP Update goals are entirely consistent with CWAP, although they are stated in somewhat different words. Its primary goal is to "Improve Flood Risk Management" with supporting goals to:

- Promote ecosystem functions.
- Promote multi-benefit projects.
- Improve O&M.
- Improve institutional support.

While not mentioning the Tisdale Weir specifically, the 2017 CVFPP Update does call for "Fish passage improvements at Tisdale Bypass, Colusa Bypass, and Deer Creek" (DWR, 2017a).

The proposed Project will support the primary goal of the CVFPP to improve flood risk management while achieving specific supporting goals. Noteworthy supporting goals to be achieved by the Program include improving O&M, promoting multi-benefit projects, promoting ecosystem functions including enhancing floodplain inundation, and addressing key stressors such as fish passage barriers.

The Program addresses all of the CVFPP Conservation Strategy Ecological Goals; more specifically, the Project reduces fish passage barriers. Importantly, the goals of the CVFPP are shaped by key regulatory drivers. For example, DWR, on behalf of the State of California and as required by California Water Code Section 8361, operates and maintains facilities of the State-federal flood protection system within the Sacramento Valley of California in accordance with assurances provided to the federal government by the State through the CVFPB (DWR, 2019c).

5 Existing and Future Conditions

The existing and future conditions for the Tisdale Weir and Bypass provide the basis for Project formulation.

5.1 Existing Conditions

Problems with the existing physical conditions of the weir structure and bypass were described in Section 3.1. The description of existing conditions in this section focuses on existing physical processes and operations. These existing conditions were documented from available reports and datasets and from direct reconnaissance of the weir and bypass on several occasions.

5.1.1 Weir Overflow

The Tisdale Weir is the first of the five weirs in the Sacramento River Flood Control System to overflow, and it continues to overflow for the longest duration. Under flood conditions, the Sacramento River flow overflows the Tisdale Weir when the river's stage reaches 44.1 feet, which corresponds to a Sacramento River flow of approximately 20,000–22,000 cfs. The Sacramento River is designed to contain 66,000 cfs upstream of the weir and only 30,000 cfs downstream, thereby diverting over half of the floodwater into the bypass system at this location. While there is significant variation in the annual and monthly weir overflow, weir overflow has been historically limited to the November to June time frame. (**Figure 12**).

The weir overflows about 43 days each year on average, or about 12 percent of the time, mostly consistently between January and March. Monthly averages for water years 1978–2017 show that the highest average flows and largest range in flows occur from December to March, with some variability in flows for November and May/June.

5.1.2 Energy Dissipation

The existing 12-foot-wide energy dissipation basin has effectively provided energy dissipation for a range of weir flows, however its effectiveness for higher flows has been limited and caused flow energy to impinge on the eastern wall of the basin and caused scour beyond in the bypass.

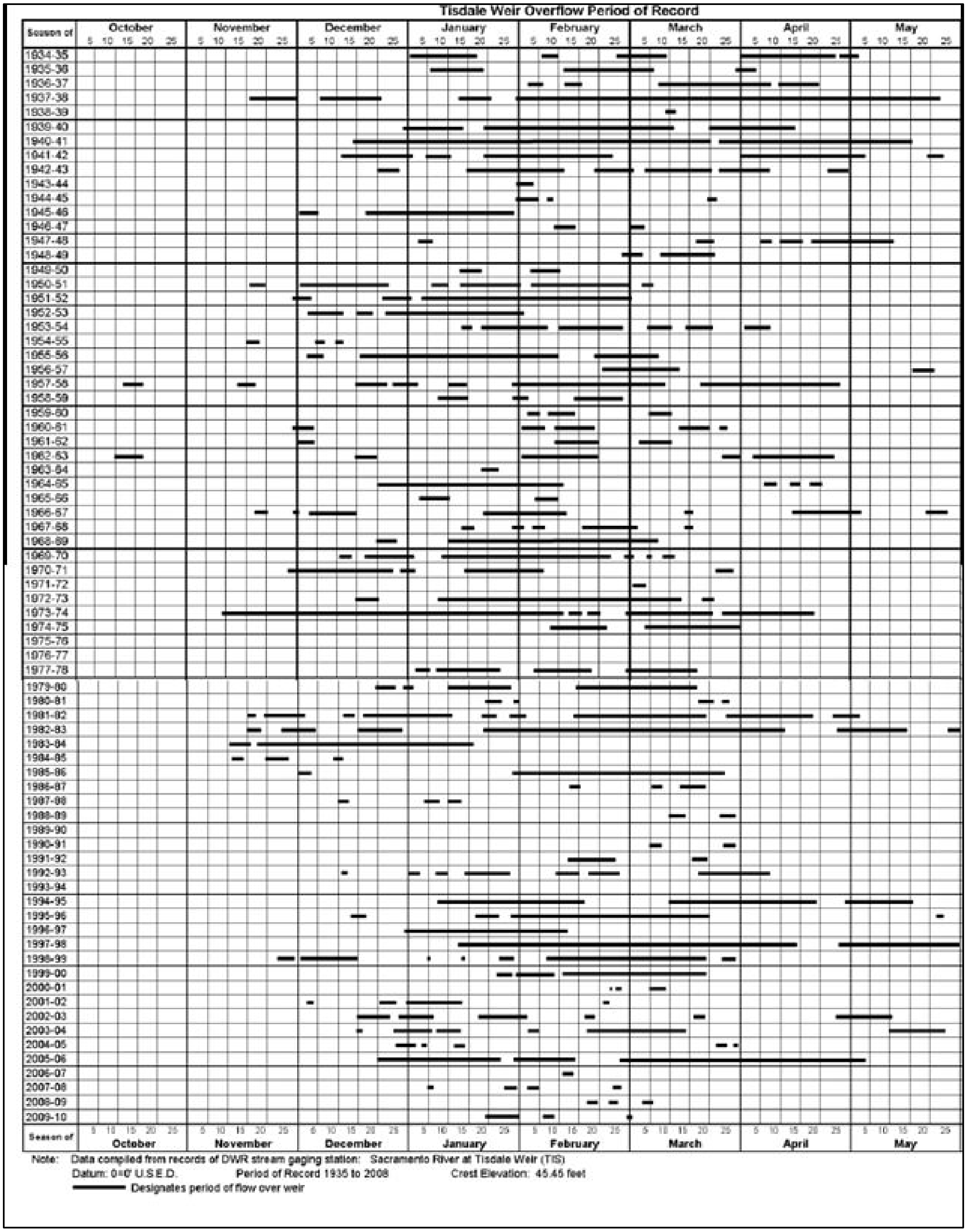
5.1.3 Bypass Hydraulics

The Tisdale Bypass provides flood protection to the Sutter and Colusa Basins, including the towns of Knights Landing, Meridian, and Robbins; Reclamation Districts 108, 1660, and 1500; and portions of State Routes 45 and 113. During high flows, the Tisdale Bypass fills up relatively quickly, with tailwater at the Tisdale Weir controlled by the normal depth of flow through the Tisdale Bypass or by backwater conditions in the Sutter Bypass. When the Tisdale Weir is overflowing, there is a backwatered condition about a third to half the time.

Flow velocities and elevations over the weir are complex due to the perpendicular orientation of the weir to the overflow from the river, and flow does not occur uniformly across the length of the weir. Hydraulic modeling of existing conditions performed as part of this feasibility study shows that during flood flows, the water surface elevation is super-elevated on the south side of the weir; there are lower velocities and a large eddy forms on the north end of the weir in the bypass.

5.1.4 Operations and Maintenance

The O&M manuals for the Tisdale Weir and Bypass system include SAC156 (Tisdale Weir) (USACE, 1955), SAC128 (East Levee of Sacramento River from Sutter Bypass to Tisdale Weir All Within Reclamation District 1500 [Mile 84.5 to 118.5]), and SAC129 (South Levee of Tisdale Bypass from the East Levee of Sacramento River to the West Levee of Sutter Bypass and West Levee Sutter Bypass Downstream to East Levee of Sacramento River) (DWR, 2016a). The maintaining agency is DWR, based out of the Sutter Maintenance Yard.



SOURCE: DWR, 2010b

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 12
Tisdale Weir Overflows, Water Years 1934–2010

The existing maintenance objectives for this facility aim to maintain flow design capacity, proper functioning of the structure, the facility's visibility and accessibility, and consistency with federal and State requirements, plans, and policies. As part of the proposed Project, adult fish passage would be added to the maintenance objectives for Tisdale Weir. This new objective may change the location, timing, and/or frequency of some existing maintenance activities, but the nature of the activities themselves would not differ substantially from existing practices.

In the Project area, DWR currently carries out a suite of existing maintenance activities for the Tisdale Weir structure, and specific portions of the Tisdale Bypass levees and Tisdale Bypass channel that lie inside the Project area. The following sections describe specific activities that are relevant to existing maintenance in the Project area.

Tisdale Bypass Levees

Vegetation Management

Levee vegetation must be managed appropriately. This work focuses on improving public safety by providing for levee integrity, visibility, and accessibility for inspections, maintenance, and flood-fighting operations, while also protecting important environmental resources. DWR's levee vegetation management efforts are, and will be, adaptive and responsive to:

- The results of ongoing and future research
- Knowledge gained from levee performance during high-water events
- Development of policy and guidance by the current and future iterations of the CVFPP and other related documents

DWR's approach to managing levees with vegetation is described in the levee vegetation management strategy presented in the 2012 CVFPP and CVFPP Conservation Framework:

- **Physical/Mechanical Treatments:** Physical/mechanical treatment methods include cutting, mowing, dragging, and grading.
- **Application of Herbicide:** Herbicide application involves selective application of contact pre-emergent and systemic herbicides.
- **Controlled Burning:** Prescribed burning involves the use of controlled fire to remove both vegetation and organic matter (such as thatch) from the ground surface, and to improve visibility along levee slopes for inspection and maintenance.

Erosion Repair

Erosion repair consists of stabilizing and, in some cases, reconstructing or reshaping the levee slope and other areas to prevent further erosion. Erosion repairs are often carried out along levees or levee toe roads where erosion or sloughing has occurred; around culverts and pipe penetrations; and alongside the abutments for bridges and structures (e.g., weirs).

Removal of Encroachments

Unauthorized encroachments that may cause a major detrimental impact on the Sacramento River Flood Control Project, or that interfere with inspection, operations, and maintenance or proper functioning of flood protection systems, must be removed, abandoned, or suitably modified. Types of encroachments vary widely and may include vegetation, landscaping, structures, pipes, and ditches. Vegetation encroachments are removed in a manner similar to that described previously for vegetation management on levees.

Tisdale Weir

DWR is responsible for maintaining the weir. Flood control weirs permit excess water to be diverted into a bypass channel during high river stages. They are designed to release additional flows through one or more overflow crests or a series of control gated to reduce stress on levee systems when needed. Proper operation of flood control weirs is considered vital to the safety of residential, industrial, and agricultural properties near and downstream of the facility. Typically, DWR's maintenance staff adheres to operational guidelines dictated by USACE and USACE documents that prescribe maintenance and operations. Typical maintenance activities include:

- Removing or leveling sediment deposits, debris, and undesirable vegetation between the channel and the structure. (For descriptions of vegetation management and sediment removal, see the *Tisdale Bypass Channel* section below.)
- Removing obstructions/debris from within the weir footprint to maintain the function of the weir. (For a description of obstruction/debris removal, see the *Tisdale Bypass Channel* section below.)
- Repairing erosion around the structure that can be caused by the depth and velocity of water during flow over the weir. (For a description of erosion repair methods, see *Erosion Repair* in the *Tisdale Bypass Levees* section above.)
- Repairing the weir structure. This may include removing and replacing broken, heaving, or deteriorated concrete; inspecting the concrete superstructure; annular grouting; and patching any cracks and spalls. Concrete is removed using a jackhammer and/or backhoe. This may also include light grading and form work to replace the concrete.
- Inspecting the weir. This requires constructing a cofferdam to block flows around the structure and/or lowering water levels in the low-flow channel.
- Removing sediment from around bridges, culverts/pipes and associated drainage ditches/ canals, road crossings, and the weir.

Tisdale Bypass Channel

Removal of Sediment or Debris/Obstructions

Sediment removal in the channel behind the Tisdale Weir occurs during dry conditions, except for rare and isolated areas where removal is required in a low-elevation area that may have residual ponded water. All work is done when there is no flow over the weir, outside of the flood season.

The width and depth of sediment excavation varies depending on existing topography, in-channel environmental features (e.g., riparian vegetation), and the gradient needed for drainage and restoration to the channel's original design capacity and configuration. Typical sediment removal and fill depths range from 1 to 6 feet and optimally are balanced on-site (cutting high areas to fill low areas). In most cases, the path of the existing low-flow channel in the bypass is retained and depth is restored to accommodate the 1957 design profiles for stage with required freeboard, and O&M manual flow requirements.

Debris in flood control channels has the potential to obstruct flow, reduce channel capacity, accelerate erosion, affect the proper functioning of the flood protection system, and damage structures or facilities; such debris can also be damaging to fish, wildlife, and the environment. Debris consists of trash, beaver dams, flood-deposited woody and herbaceous vegetation, downed trees and branches, and other items (e.g., vehicles, tires, refrigerators). Debris is typically removed using hand tools, tractors, truck-mounted cranes, bulldozers, backhoes, and excavators. Organic material is typically chipped or piled up and burned on-site. Non-organic materials such as trash, vehicles, and tires are hauled off-site to appropriate disposal sites. Debris removal work occurs year-round and generally takes 1 day to complete, although up to 1 week may be needed to clear debris after a high-water event at a specific location.

Vegetation Management

The intent of channel vegetation management is to reduce floodway roughness; maintain or restore floodway capacity; and reduce potential debris accumulation. Activities may include limbing of trees and mowing of grasslands or scrublands. Vegetation management may occur in wet or dry channels.

Vegetation management is guided by DWR's obligation to meet the objectives for channel capacity and proper flood protection system function established in USACE's operations and maintenance manuals and the 1957 design profiles for the Sacramento River Flood Control Project. The CVFPP Conservation Framework and DWR's Environmental Stewardship Policy also guide DWR vegetation management efforts.

Erosion Repair

Channel scour can create uneven ground surfaces caused by the erosive force of flowing water excavating material from the bed and banks and carrying it away. Channel scour can occur across large areas or as more localized depressions (e.g., around bridge foundations and weir structures). If left unrepaired, scour can grow and damage flood conveyance facilities, including through bank erosion and undermining of structures. Channel scour is repaired by grading, scraping, disking, filling, leveling, and regrading the ground surface. In the bypass channel, scour is typically repaired by dozing floodplain sediment into the scour area and leveling. On banks, repair of scoured areas through placement of 6-inch- to 24-inch-minus rock is generally used, depending on the size of scouring and expected velocities. These actions are similar to those described previously in the *Removal of Sediment or Debris/Obstructions* section and discussions regarding minor grading activities.

5.1.5 Fisheries Resources

At the Tisdale Weir and in the Sacramento River adjacent to the weir, four federally listed anadromous fish species may be present: Sacramento River winter-run Chinook salmon, California Central Valley spring-run Chinook salmon, California Central Valley Steelhead Distinct Population Segment (DPS), and Southern DPS of North American Green Sturgeon. The extent of the Tisdale Weir's impact on special-status fish species depends on its overflow frequency when fish are present in the system. During most years, there are multiple overflow events throughout fall, winter, and spring, with peak overflows during January through March.

Adult southern DPS green sturgeon enter San Francisco Bay in late winter through early spring and migrate to upper Sacramento River reaches to spawn from April through early July, often timing migration with peak flow events (Heublein et al., 2009; Poytress et al., 2011). Therefore, green sturgeon adult migration timing is aligned with Tisdale Weir overflow, making them especially susceptible to stranding in the Tisdale Bypass because of their presence in the system during times when the bypass is inundated. Spring-run Chinook salmon and steelhead adults are similarly susceptible to stranding in Tisdale Bypass, with upstream migration occurring from February to June, timed with increased run-off events (NMFS, 2011; Moyle et al., 2017). Upstream migration of winter-run Chinook salmon adults also overlaps with Tisdale Weir overflow events, with migration occurring from January through May and peaking in mid-March (Moyle et al., 2017).

Timing of Tisdale Weir overflow events occurring from November through June (DWR, 2014b) overlaps with the juvenile emigration period for all runs of Chinook salmon and steelhead, making a portion of each run susceptible to potential stranding depending on the annual overflow frequency and, because juveniles may pass downstream with flow, the recession hydrodynamics in the bypass downstream of the weir. The emigration timing of each salmonid run in the Sacramento River Basin varies, with winter-run and spring-run emigrating during September through January, spring-run and fall-run during December through May, and steelhead emigrating all year, with the majority during April through June (Voss and Poytress, 2017). Therefore, juvenile salmonids migrating downstream during the fall through spring may wash over the Tisdale Weir from the Sacramento River, with a portion potentially becoming stranded in the Tisdale Bypass as floodwaters recede.

For adult fish moving up the Tisdale Bypass seeking to gain access to the Sacramento River, the location of entry into the weir's existing energy dissipation basin has not been verified and no information regarding observations were identified. One potential scenario is confirmed by video footage showing an unidentified species being washed over the concrete weir sill during a weir flow event (DWR, 2014b). However, whether this is simply falling back into the bypass after attempting to pass the weir—or is a fish from the Sacramento River being washed from the river over the weir—is unknown. Another highly plausible scenario is that because of the split in Sacramento River flows during times of weir spill, fish at downstream locations are attracted to Sacramento River flows coming downstream in both the Sacramento River channel and in the Sutter Bypass. Thus, some fish are attracted into the Sutter Bypass, swim upstream through the Sutter Bypass and into the Tisdale Bypass, and ultimately cannot pass the weir to return to the Sacramento River and are found stranded in the existing energy dissipation basin (DWR, 2014b; Beccio, 2017).

5.1.6 Fish Passage

The weir presents a temporal barrier during most conditions for several listed species, including Chinook salmon, steelhead, and green sturgeon. Passage is easier with backwatering of the weir from the influence of the downstream Sutter Bypass forcing greater backwater in the Tisdale Bypass. The range of flow conditions at the weir which meet fish passage criteria for salmonids and green sturgeon was assessed in detail as described in work summarized in Appendix A.

Generally, passage is limited for all species at lower discharge over the weir (with commensurately low backwatering of the weir from backwater in the bypass). Salmonids may pass at higher discharge levels over the weir, though sturgeon appear to be challenged by the depths, velocities, and jump heights at almost all discharge levels.

5.2 Future without Project Alternative

The assumed "future without Project" alternative (or no-action alternative) is the benchmark against which over the weir alternative plans are evaluated, and it represents the most likely conditions expected to exist in the future, assuming a Tisdale Weir rehabilitation effort is not implemented and improved fish passage is not provided.

Future physical conditions associated with a without-Project alternative would result in continued structural degradation of the Tisdale Weir and delayed fish passage and stranding of fish at the weir. For the purpose of this feasibility study, future conditions are considered forecast to 2070, over the anticipated 50-year design life of the weir following rehabilitation.

Future socioeconomic conditions that may be pertinent to the Project include population growth as forecast by the California Department of Finance, regional economic growth, land use changes, and completion of other related flood management or fish passage projects with a high likelihood of implementation. Future environmental conditions that may be pertinent to the Project include changes in climate, wildfire, water quality, air quality, fisheries and wildlife habitat extent and quality, and recreational opportunities. Some of these future environmental conditions were estimated using the Cal-Adapt Climate Tools for the Sacramento River watershed tributary to Tisdale Weir, assuming that emissions will peak around 2040 and then decline (a scenario known as RCP 4.5, or Representative Concentration Pathway 4.5 in Cal-Adapt [2019]):

- Precipitation – The observed historical annual mean for 1950–2005 was 19.3 inches and the modeled projected annual mean for 2020–2070 is 20.7 inches.
- Total annual streamflow – The estimated historical average unimpaired flow for 1922–2014 for the Sacramento River near Red Bluff was 48,542 cfs and the modeled projected average unimpaired flow for 2020–2070 is 50,464 cfs.
- Wildfire risk – The observed average area burned by wildfires within the Sacramento River drainage area tributary to the weir for 1950–2004 was 1,280 annual mean hectares and the projection for 2020–2070 is 1,295 annual mean hectares.

Precipitation, streamflow, and wildfire risk are therefore estimated to slightly increase or remain unchanged over the next 50 years compared to historical data. This implies sediment and LWD loadings to the weir may remain similar in the future (and continue to be a constraint to achieving Project goals and objectives, as described further in this report).

6 Formulation of Alternatives

Alternatives were formulated to identify various ways to achieve the Project objectives, solve the problems, realize the opportunities, and avoid the constraints that are identified in the previous report sections. Each alternative consists of a system of structural and/or nonstructural management measures. A structural management measure involves a feature (e.g., facility improvement) that can be implemented to address one or more planning objectives. Nonstructural management measures are activities (e.g., incentives, regulations, land use changes, and emergency preparations) that can be implemented to address one or more planning objectives. The following subsections describe key stakeholder and agency input into the development of the alternatives. Subsequent subsections describe the measures that form the building blocks for the alternatives. A final subsection then summarizes the no-action alternative and three action alternatives.

6.1 Interagency Work Group

In November 2018, DWR formed an IWG to facilitate early engagement with resource and permitting representatives to discuss fish passage requirements and various design alternatives. IWG agencies included the U.S. Fish and Wildlife Service, National Marine Fisheries Service, USACE, CDFW, CVFPB, and others. During these IWG meetings and site visits, various notch locations, sizes, orientations, and combinations were considered for locations near the northern and southern weir abutments. Notch concepts were assessed using a geographic information system (GIS) algorithm that adapted fish passage criteria to the two-dimensional hydraulic model results to assess the efficacy of the design concepts in meeting the passage criteria for salmonids and green sturgeon. Analyses and model results were presented, refined, reviewed, and discussed over the course of four IWG meetings. DWR staff held three additional meetings with agency fisheries engineers and biologists to examine in greater detail the hydraulic modeling, analysis, and fish passage assessment.

6.2 General Concepts

This Project proposes to integrate structural rehabilitation of the Tisdale Weir along with installation of fish passage facilities to allow fish to enter the Sacramento River as flow to the bypass recedes. In addition to addressing flood risk concerns due to the aging weir, the proposed Project would address the issue of adult fish stranding. Fish passage facilities could include one or two notches through the weir, connection channels to the river, and one or more operable gates in each notch. Fish passage facilities would be designed to provide improved passage for upstream migrating fishes (salmonids and sturgeon) to exit the bypass and reach the Sacramento River. Weir rehabilitation/reconstruction and site improvements would be generally similar among alternatives with the primary differences associated with the notched opening(s) location(s).

6.3 Structural Management Measures

For this Project, given the fundamental need for rehabilitation of the weir sill and abutments, the structural management measure is common among all alternatives. Therefore, the assessment and screening of structural management measures pertains primarily to fish passage (i.e., the type of modification of the weir to provide fish passage and the location of the modification[s] along the weir to achieve the fish passage objective), and those fish passage structural and location considerations form the general basis of three action alternatives. Structural management measures for the rehabilitation of the energy dissipation/fish collection basin were also developed and these varied based on the location of the fish passage structural modifications.

Where optional methods or configurations of structural management measures were considered, screening was conducted to eliminate measures that would not be considered further. Screening was based on the planning objectives, constraints, and opportunities and problems.

6.3.1 Weir Rehabilitation

Structural management measures associated with the weir rehabilitation were limited, in that only certain measures could be taken to effectively rehabilitate the structural integrity of the weir. These measures included repairs related to the weir's north and south abutment, weir cap, energy dissipation basin, and scour protection through properly sized revetment.

Evaluation of the proposed structural measures at each of the key weir features included review of relevant geotechnical investigations, structural inspection information, as-built drawings, site reconnaissance, and discussion with DWR Flood Maintenance Office staff to understand past structural performance and develop feasible preliminary treatments/design concepts and cost estimates.

The as-built drawings that have been provided in Adobe Acrobat "PDF" file format (50-01-1814, 50-09-1286-1, and 50-09-1448) appear to be not fully complete or are of limited value for this feasibility effort. The as-built drawings are missing length, rebar size and spacing, depths, heights, thicknesses, and elevations.

Drawing 50-09-1448 shows the concrete construction of the north and south abutment walls, which are T-shaped walls constructed on piles. It appears that they were constructed after the construction of the original north/south wall abutments, top of weir and energy dissipation basin. On the drawing the original north/south wall abutments are called out in the set as "EXISTING ABUTMENT." The original top of weir, energy dissipation basin, and north and south abutments are understood to have been constructed first at some time prior to 1932. In 1932 the modification work was completed, consisting of the new top concrete cap and bridge over the weir as mentioned above in the background. From the as-built drawing, it is unclear how close the T-shaped walls are located to the existing abutment and for what purpose the T-shaped walls were designed and constructed. From a reconnaissance site visit, the existing abutment walls did not appear to be structurally salvageable.

Drawing 50-09-1286-1 shows the modification to the original weir consisting of a new concrete cap over the top of the original weir crest and a new bridge that was constructed in 1932. The original weir (weir cap and energy dissipation basin) is shown in the drawing set, but this drawing set is not the actual as-built set for the original weir construction. Therefore, the information for the construction of the original weir is limited to this set of drawings, which only shows the outline of the original weir. The original road bridge constructed over the weir in 1932, as shown in this drawing set, was removed in 2008 following the construction of the new Garmire Road.

For the purpose of presenting the findings and potential structural management measures associated with weir rehabilitation, Tisdale Weir is divided into segments consisting of the weir cap, the energy dissipation basin, the south abutment, the north abutment, and the revetment. The current condition, deficiencies, and measures considered for each segment are addressed below.

Weir Cap

The concrete weir cap is in relatively good condition. The cap's top surface elevation appears to be consistent throughout the length of the weir, without any signs of vertical or horizontal movements between the joints. At localized areas along the cap joints, some concrete spalling appears to be occurring, and light abrasion (evident thru exposed aggregate) is visible throughout the length of the weir's top surface. The recommendation is to repair and resurface the top of the weir cap with an epoxy or mortar grout to restore it to an acceptable finish.

Energy Dissipation Basin

The energy dissipation basin is in a badly deteriorated condition. The buttress walls on the upstream and downstream side of the energy dissipation basin are badly damaged throughout the basin. The concrete surface of the energy dissipation basin shows signs of heavy abrasion throughout, likely due to transport of cobbles in water overflowing the weir and impacting the surface of the basin. The top of the concrete downstream basin wall is badly damaged, with exposed rebar at the north end of the energy dissipation basin. Rocks and sediment build-up are evident throughout the inside of the basin, with more build-up present at the south end of the basin. Based on available information and a reconnaissance site visit, the existing energy dissipation basin is not salvageable, given the extent of the concrete damage and the lack of information from the as-built drawings pertaining to the existing construction. The recommendation is to totally replace and redesign the energy dissipation basin to perform both the requisite flood management function of energy dissipation of flood flows entering the bypass, and to support fish passage and, if possible, reduce the maintenance difficulty of clearing debris and sediment between the existing buttresses.

South and North Abutments

The south abutment wall is in a failed condition. Extensive vertical and horizontal cracking is visible throughout the south abutment wall, with full thickness cracks exhibiting rotation and translation, indicating a structural failure of the abutment. Concrete deterioration and spalling is present, exposing rebar to corrosion. The north abutment had vegetation present along the east and west side of the abutment wall during the site reconnaissance. That area of the wall was not viewed, but the area of the abutment that was viewed appeared to also be in a failed condition. At the bottom of the abutment wall near the energy dissipation basin, concrete appeared to be missing along the entire face of the wall, with exposed reinforcing. The bottom of the wall is experiencing some type of concrete failure as a result of the concrete deterioration and spalling present. Based on the available information and the reconnaissance site visit, the north and south abutment walls are not salvageable, given the extent of the concrete damage as mentioned above and the lack of information from the as-built drawings pertaining to the existing construction. The recommendation is to totally replace the north and south abutments.

Revetment

The revetment downstream of the energy dissipation basin is completely eroded away and depleted. The as-built drawing (50-09-1286-1) shows the as-designed cobble stone revetment to be approximately 24 feet wide and 2 feet deep and flush with the top of the downstream sill of the energy dissipation basin. The recommendation is to totally replace and redesign the revetment downstream of the energy dissipation basin, in coordination with the redesign of the basin.

6.3.2 Fish Passage Method

Fish passage options that were considered included the following:

1. A step-pool type of fish ladder up to the elevation of the weir crest – thus functional only when Sacramento River flows are above weir crest elevation
2. One or more notches constructed through the weir, with or without gates, with a connection channel leading west, daylighting on the left bank of the Sacramento River

The step-pool fish ladder option was deemed not applicable due to physical site constraints, the lack of functionality at stage levels in the Sacramento lower than weir crest elevation, and stringent hydraulic criteria required for green sturgeon passage. The notch concept was identified as appropriate for further consideration. A gate was preliminarily identified as desirable, owing to its ability to regulate the split of flood flows (e.g., close the gate during large floods) between the Sacramento River and the Tisdale Bypass, thus preserving the critical flood control function of this flow split.

Operation of a gate would generally involve the gate beginning in an upright, closed condition as the stage in the Sacramento River rises. A short time after the river stage exceeds the weir crest elevation, the gates would be fully opened to allow fish passage as water stages in the river-weir-bypass system fluctuate, and until the river stage falls below the invert elevation of the notch opening (and fish have passed from the bypass into the river), at which point the gates would be closed again. This cycle would repeat as necessary, triggered by the frequency of weir overflow events that occur in a given water year. Any gate operations would be further optimized during the design process.

6.3.3 Fish Passage Locations

Single and multiple locations for a gated notch were considered, the latter of which was at the request of stakeholder input (described previously in Section 6.1, *Interagency Work Group*). The potential notch location or locations would be adjacent to the north and/or south end of the weir to reduce construction costs (e.g., minimize the linear extent of control systems for the operable gates) and allow direct maintenance access from the respective weir abutments.

6.3.4 Energy Dissipation/Fish Collection Basin

Energy dissipation will be required for flows overflowing the weir and into the bypass, with considerations for the changed hydraulic conditions associated with a new notch opening(s) and other factors. Design objectives included:

1. Allow weir overflow and notch flows to enter the Tisdale Bypass without causing serious scour or erosion.
2. Facilitate drainage of the basin as flows recede in the Sacramento River.
3. Minimize fish stranding and facilitate passage.
4. Minimize maintenance needs; e.g., size the energy dissipation/fish collection basin in a way that: (a) will be large enough that anticipated sediment and debris are not issues for fish

passage back into the river, and (b) is configured such that, after the flood season or a particularly large event, equipment can easily clear any larger accumulations.

5. Facilitate constructability and minimize costs where possible.

The existing energy dissipation basin along the east side of the weir functions adequately as designed for clear water conditions, but it is a relatively narrow feature that can easily fill with sediment and, as flows recede and water stages lower, the confined space and potential for sediment blockages exacerbates fish standing, facilitates poaching of stranded fish, and increases the potential for lethal conditions related to increased water temperatures. While the introduction of a notch or notches in the weir will improve fish passage and reduce the duration of time that these detrimental conditions may occur, these problems may still persist if a narrow basin is maintained. Further, if a notch were included on the site, any structure to dissipate energy downstream of the weir sill would be coincident with the location where fish would converge toward the notch. Thus, if designed appropriately, there is an opportunity for a multiple-benefit structure that could support energy dissipation while also reducing stranding, poaching, and promoting passage.

Additionally, a wider energy dissipation/fish collection basin would enable fish passage around debris and sediment that may accumulate in this area, and a flat-bottomed surface to this basin would facilitate sediment and debris removal at the end of flood season.

6.3.5 Site Improvements

Structural management measures related to site features would involve improvements to existing features and the construction of new features, including the following:

- Utility pole relocation
- Elevated equipment access pad adjacent to notch(es)
- Permanent equipment access location (ramp[s])
- Bank scour protection
- Garmire Road Bridge pier scour protection

6.4 Nonstructural Management Measures

Nonstructural management measures are activities (e.g., incentives, regulations, land use changes, and emergency preparations) that can be implemented to address one or more planning objectives. Nonstructural management measures would primarily involve modified and additional O&M practices. Modified practices for sediment and debris removal would need to be developed to account for new flow patterns created with the addition of one or more notches through the weir. Additional practices would need to be included to service the operable gates and associated control systems and other infrastructure.

6.5 Data Gap Assessments and Analyses

Based on identified problems, opportunities, and constraints, and to support the development of management measures and facilitate alternative formulation and evaluation, a series of assessments and analyses was conducted – independently or as part of this feasibility study – to resolve resource constraints associated with key data gaps or to increase understanding. The following assessments and analyses were conducted:

1. *Tisdale Weir Historical Fish Passage and Stranding Technical Memorandum* (ESA, 2019; Appendix A-2) – This assessment was completed early in the problem identification stage of feasibility investigations. It summarizes available information related to: (a) historical information on fish stranding and passage of listed fish species at the Tisdale Weir; (b) fish rescues at the Tisdale Weir performed by CDFW; (c) the current knowledge of passage issues of listed fish species at the Tisdale Weir and within the Tisdale Bypass; and (d) key findings and remaining unknowns about fish passage concerns.
2. Field Data Collection – As a part of this feasibility study, hydrologic, hydraulic, and sediment data were collected, along with visual observations and documentation via photographs (aerial and ground-based).
3. Hydrologic and Hydraulic Analyses to Support Fish Passage Design (presented in Appendix A-1) – To establish an understanding of existing and potential future hydraulic conditions at the Project site, a series of hydrologic assessments and hydraulic modeling investigations was completed with the objective of understanding existing conditions (no action) and determining the feasibility and effectiveness of potential Project measures. These same analytical tools and assessments were progressed to a level adequate to support conceptual design.
4. *Fish Passage Analysis Technical Memorandum* (Appendix A-1) – The Project-developed hydraulic model (see above) was used to simulate existing and various with-Project conditions, and an automated, GIS-based approach to process the results of the model and assess the potential for fish passage from the bypass to the river was developed. Appendix A provides the details on the hydrologic analysis, the hydraulic modeling, and the methodology and results of the assessment of fish passage potential for existing conditions and various with-Project condition (with-notch/basin) alternatives.
5. Geotechnical Analysis – As a part of this feasibility study, initial geotechnical information was reviewed and collected to support assessment of existing conditions and understand opportunities and constraints for design of various structural measures.
6. *Large Wood Debris at Tisdale Weir Technical Memorandum* (Appendix B) – In support of this feasibility study, historical imagery (a combination of photographs, videos, and aerial imagery) that captures the location of LWD at the weir was collected and GIS mapping was performed to analyze trends in historic LWD debris deposition within the Project area. This information, along with field observations during water year 2019, form a basis of understanding of LWD transport and deposition at the site.
7. *Sediment Budget Analysis Technical Memorandum* (Appendix C) – To better understand contemporary sedimentation processes within the bypass, and how those may change as a result of potential measures, a suspended sediment budget for the Tisdale Bypass was calculated using two methodologies: topographic change detection and suspended sediment discharge estimates. The objective of the sediment budget is to: (1) estimate the annual amount of suspended sediment that deposits within the bypass under existing conditions, and (2) assess how the amount of suspended sediment deposition in the bypass may potentially change with potential Project implementation.
8. Flood Hydrologic and Hydraulic System Analysis– A hydraulic analysis at a feasibility level was performed during preparation of this study to identify potential changes to the performance of the overall SRFCP system that might result from implementation of various

alternatives. Specifically, a notch in the weir could affect the split of flood flows between the river and the bypass and this analysis was completed in part to understand the potential magnitude of these effects and consider potential constraints. Future focused analysis will be undertaken to support assessment and review by the USACE.

These assessments and analyses are described briefly in the following subsections.

6.5.1 Historical Fish Passage and Stranding Assessment

Historical information on fish stranding and passage of listed fish species at the Tisdale Weir and Tisdale Bypass were summarized to help inform future rehabilitation of the weir and bypass system (ESA, 2019; Appendix A-2). Key findings include the following:

1. Tisdale Weir has been shown to be a historical barrier to upstream migration for all targeted fish species. Some fish may be able to pass when the weir height is reduced by sufficient backwatering on the east side of the weir from backwater in the Tisdale Bypass.

2. Stranding occurs in the existing energy dissipation basin or in multiple isolated residual pools east of the Tisdale Weir created after floodwaters recede.

3. The adult life stages of green sturgeon, spring-run Chinook salmon, and winter-run Chinook salmon, and juvenile life stages of all salmonids are susceptible to stranding because their period of migration aligns with the peak period of Tisdale Weir flooding events.

6.5.2 Field Data Collection

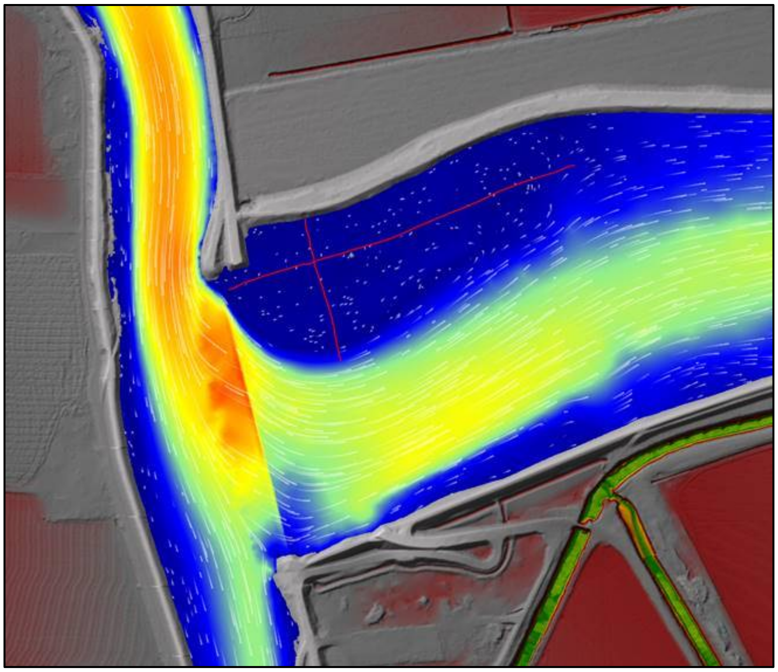
Field data collection involved the preparation and execution of applicable safety planning and documentation; field reconnaissance necessary to devise methods for installing/utilizing field monitoring equipment; and the subsequent collection of field data. Field data collection occurred before and through the flood season of water year 2019 and involved the following activities:

1. Visual observations – Reconnaissance and documentation of field conditions (e.g., scour, inundation, roughness, flow behavior, LWD transport and deposition) were made via photographs, video, drone video or imagery, and/or written observations. Observations were made from land and boat, based on conditions of flow in the Sacramento River and the Tisdale Bypass. Observations may use hydraulic measurement tools such as acoustic Doppler current profiler (ADCP), the Global Positioning System (GPS), and depth sounding equipment.

2. Topographic and bathymetric elevations – Measurement of the weir structure and the topography of the site were made during this feasibility study. Additionally, bathymetric data collection occurred in portions of the site, as applicable.

3. Water stage measurements – A stage recorder network (pressure transducers) was deployed to monitor/record water stages in the Sacramento River and Tisdale Bypass.

4. Discharge and velocity measurements – Discharge and velocity measurement data were collected in the Sacramento River and Tisdale Bypass and used to validate the hydraulic model (**Figure 13**). Hydraulic measurements were made using ADCP, GPS, and depth sounding equipment.



Tisdale Weir Rehabilitation and Fish Passage Project

Figure 13
Tisdale Weir and Bypass Hydraulic Model Showing Flow Velocities
(warmer colors are faster velocities)

5. Sediment sampling – Suspended sediment sampling was performed from a boat in the Sacramento River.

6. Sediment plates – Feldspar sedimentation plates were placed in the Tisdale Bypass to assess suspended sediment deposition characteristics.

These field data were used to support various work described in the remainder of Section 6.5.

6.5.3 Hydrologic and Hydraulic Analyses to Support Fish Passage Design

A hydrologic analysis (see Appendix A) was performed to understand the duration and frequency of Sacramento River flows and stages, including when water is overflowing from the Sacramento River into the Tisdale Bypass. On average, the weir overflows for approximately 43 days per year (about 12 percent of the time), and on a monthly basis, most weir overflow events occur in the December through March period, which corresponds to the months of the highest average and largest range of flows on the Sacramento River.

A hydraulic model was developed to analyze hydraulics conditions in relation to existing and potential conditions with fish passage, with the objective of determining the feasibility and effectiveness of the alternatives. The DWR Central Valley Floodplain Evaluation and Delineation (CVFED) one-dimensional Hydrologic Engineering Center River Analysis System (HEC-RAS) Sacramento River system model (Wood Rodgers, 2015), the Tisdale Bypass model (DWR, 2014c), and the DWR Integrated 1D-2D Sutter Bypass HEC-RAS model (CH2M, 2017) were updated with 2017 survey data of the bypass and bathymetry for the adjacent reach of the Sacramento River. From these models, a two-dimensional HEC-RAS model focused on the Project site was developed for this work and was used to simulate existing and proposed Project conditions. As described further in Section 6.5.4, *Fish Passage Analyse*s, below, an automated, GIS-based approach was developed to process the results of the model and assess the potential for fish passage from the bypass to the river.

The modeling shows that during overflow of the weir, the water surface elevation is super-elevated on the south side of the weir and there are lower velocities and a large eddy that forms on the north end of the weir in the bypass. Under a range of modeled flow conditions, at no point do all three conditions – the drop across the weir, the flow depth across the top of the weir, and the velocity over the weir – align to allow for fish passage across many portions of the weir.

When Sacramento River flow recedes back below the crest of the weir, most of the western half of the Tisdale Bypass (i.e., west of Reclamation Road) is either already drained or drains rather quickly (e.g., within a few hours). Once the water surface just east of the weir drops to an elevation of approximately 37 feet, the eastward flow of water within the bypass generally ceases; this 37-foot elevation in the bypass is referred to as the "hinge point."

Installing a notch in the weir, with an invert elevation well below the weir crest (e.g., 10 feet below), would allow Sacramento River water to flow into the bypass when the river's water surface elevation is both above and below the weir crest elevation. This would greatly enhance the opportunities for fish passage at the weir and substantially reduce fish stranding in the bypass.

Details on the hydrologic and hydraulic analyses conducted to evaluate fish passage conditions are provided in Appendix A.

6.5.4 Fish Passage Analyses

Fish passage performance was analyzed (see Appendix A-1) using the same general velocity, depth, and width criteria (see criteria provided in **Table 1**) as were developed for the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project (USBR and DWR, 2018). These criteria were further confirmed and vetted through a number of collaborative and informational interagency meetings. The same maximum velocities were used for salmon and sturgeon for short (< 60 feet) and long (60–200 feet) distances, but different minimum depths and widths were used for salmon and sturgeon. The majority of modeled notch and connection channel configurations (including the recommended configuration) were less than or equal to 200 feet long; therefore, only criteria for 200 feet or less were evaluated.

TABLE 1
SUMMARY OF FISH PASSAGE CRITERIA FOR FEDERALLY LISTED SPECIES WITHIN THE SACRAMENTO RIVER DEVELOPED FOR THE YOLO BYPASS SALMONID HABITAT RESTORATION AND FISH PASSAGE PROJECT

<table>
<tr><th>Species</th><th>Adult migration time</th><th>Minimum flow depth (short distance, <60 ft)</th><th>Minimum flow depth (long distance, 60–200 ft)</th><th>Minimum channel width</th><th>Maximum flow velocity (short distance, <60 ft)</th><th>Maximum flow velocity (long distance, 60–200 ft)</th></tr>
<tr><td>Adult sturgeon</td><td>Jan-May</td><td>3</td><td>5</td><td>10</td><td rowspan="2">6</td><td rowspan="2">4</td></tr>
<tr><td>Adult salmon</td><td>Nov-May</td><td>1</td><td>3</td><td>4</td></tr>
</table>

SOURCE: USBR and DWR, 2018

The one-dimensional criteria provided in Table 1 were adapted to the two-dimensional modeling to better account for spatial variation in flow velocity and depth within and near potential notch and connection channel configurations (e.g., flow separation, expansion/contraction) using a GIS algorithm. A summary of some key results is presented below.

1. For stages ranging from 37 feet to 48 feet, velocity is the limiting factor for passage across most of this range in Sacramento River flows, while depth becomes limiting as flows decrease toward the elevation of any assumed notch invert elevation.

2. For stages below approximately 37 feet, the hydraulic modeling results are not necessarily relevant; this is when the bypass is functionally higher than the river's water surface elevation, and thus, inundation behind the weir is not flowing east. As stage in the river decreases, the water in this area would slowly flow out to the Sacramento River. A river stage of approximately 37-feet roughly corresponds to the cessation of eastward flow through the bypass due to the elevation of the topographic "hinge point" in the bypass.

3. Stages above approximately 48 feet correspond to the 1957 design flood flows (USACE, 1957), and it is assumed that the proposed Project would not alter the hydraulics within this range because the gate would be closed. However, above this stage, the existing weir is predicted to be passable for both salmon and sturgeon because backwater in the bypass submerges the weir enough to allow for passage – and the velocities over the weir are not any higher than they are upstream or downstream of the weir during such a flood event.

4. Notch width and connection channel skew angle had the most prominent influence on passage performance. Other Project configurations and parameters were also assessed, though their relative influence on passage performance was not as significant.

A summary of salmon passability at existing conditions and for select notch configurations that subsequently became part of alternatives described in later sections of this report is provided in **Table 2**. In the table, red shading indicates conditions that are not passable, green shading indicates conditions that are passable at a long distance (< 200 feet), and green shading with an asterisk indicates conditions that are also passable, but only at a shorter distance (< 60 feet). Details on the fish passage analyses for both salmon and sturgeon are provided in Appendix A.

TABLE 2
SALMON PASSABILITY FOR EXISTING CONDITIONS AND SELECT NOTCH ALTERNATIVES

Sacramento River just upstream of the weir			Salmon Passability					
				Early notch alternative: 50-ft gate width, 0° skew angle, 31.5-ft invert elevation, 2:1 side slopes‡			Recommended notch alternative: north, 32.6-ft gate width, 45° south skew angle, vertical to 2:1 side slope transition, 34-ft invert elevation	
Stage (ft, NAVD88)†	Flow (cfs)	% exceedance	Existing conditions	North	South	North and south	Basin conform to 2017 bypass surface	Basin conform to uniform 37-ft elevation
48	47419	0.31		*				
47	41215	3.18	*	*				
46	27970	8.23				*	*	*
45	22525	10.60			*		*	*
44	19077	12.94		*			*	*
43	17684	14.07					*	*
42	16493	14.93					*	*
41	15226	16.01						*
40	14149	16.99						
39	13066	18.30						
38	11971	20.12						
37	10881	22.55	Basin drainage condition					
36	9875	24.68						
35	8974	25.47						
34	8072	25.47						
33	7172	25.47						
32	6286	25.47						

NOTES:
†Existing conditions, falling limb stage, which is higher than a stage under with-notch conditions given the decrease in downstream river flow and associated bypass backwater, due to notch discharge into the bypass.
‡The associated hydraulic model runs used a normal depth downstream boundary condition for the bypass, which did not differ significantly from the Sutter Bypass rating curve used in later runs with the recommended notch alternative.

KEY:

Passage category	Depth	Velocity	Continuous distance (ft) with these conditions
	> long distance min	< long distance max	<200
*	> short distance min	< short distance max	<60
	> short distance min	< short distance max	60-200
	< short distance min or:	> short distance max	<200

The above discussion applies to the intended functioning of the weir notch under normal gate operations. There is a chance that a malfunction or failure of the gate may occur. Because of the mechanical actuation of the gate, gate failure from mechanical or electrical problems would result in the gate "failing" (dropping) into a fully open position, without impacts on fish passage.

Floating debris may cause a gate to malfunction and/or fail. However, it is anticipated that the accumulation of floating debris in the notch opening would not be an impermeable obstruction and passage may still be viable. As necessary, inclusion of an equipment access area on the abutment adjacent to the notch and use of a crane or excavator may expedite the removal of debris, even during high-water conditions when human access would not be possible, thus limiting the duration of any potential impacts on passage.

6.5.5 Geotechnical Analysis

Limited historical subsurface information is available for the Tisdale Weir and energy dissipation basin. The historical information is limited to the subsurface information shown on the 1931 as-built drawings for the Tisdale Weir and bridge, and Garmire Road Bridge foundation report and boring information completed in 2002 by Sutter County Department of Public Works. These historical subsurface data will be used in developing appropriate design parameters, together with more recent geotechnical investigations to assess seepage and settlement potential, which are described below.

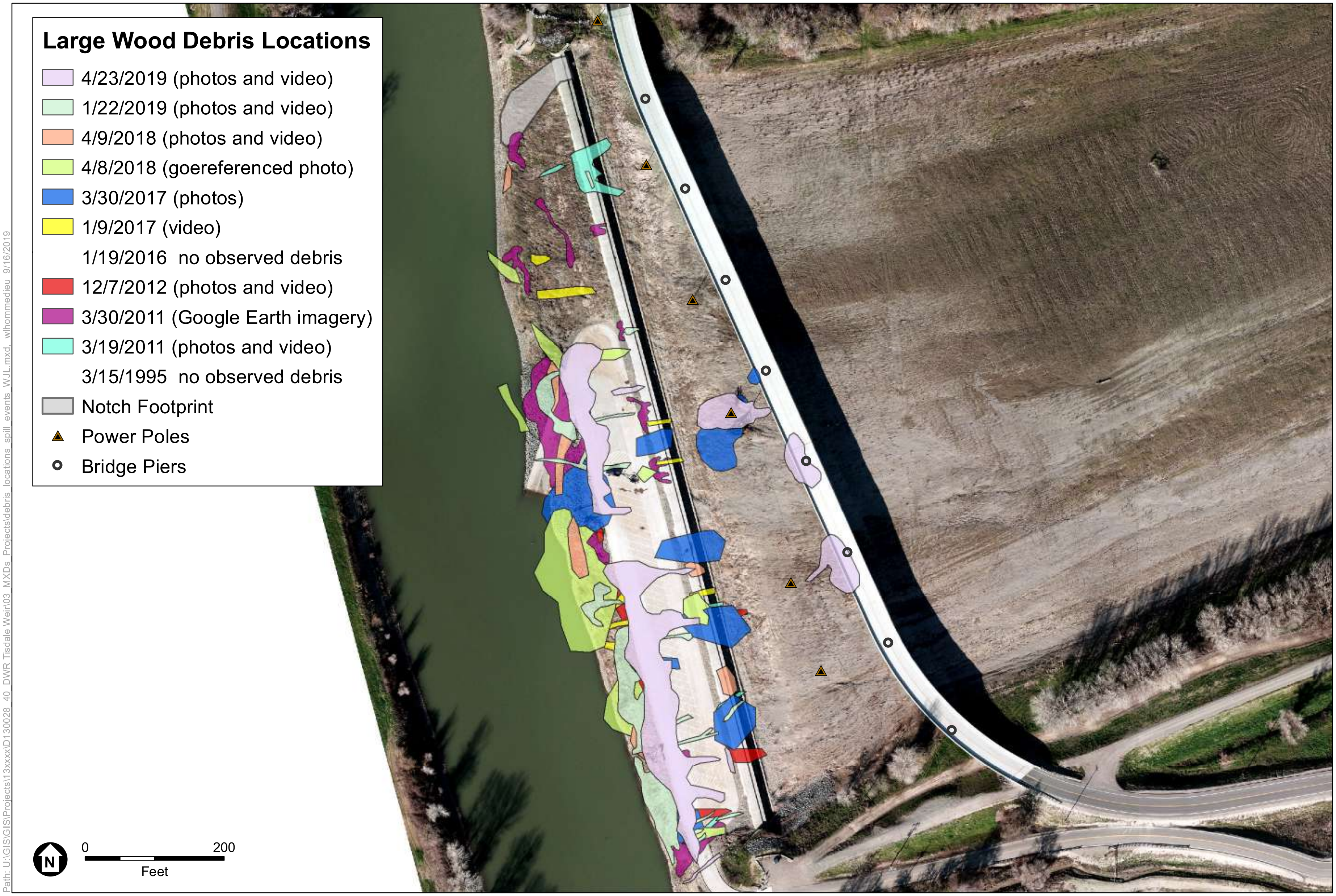
Between October 15 and October 19, 2018, DWR conducted five geotechnical borings adjacent to the Tisdale Weir structure to better characterize subsurface soil conditions. The borings were advanced between 36.5 and 61.5 feet below the existing ground surface and DWR performed a series of laboratory tests on the samples to evaluate hydraulic conductivity and shear strength properties of the site soils (Strahm, 2019).

As mentioned in Section 3.1.1, a geophysical investigation using ground-penetrating radar was performed between November 27 and December 2, 2018, to identify the lateral extent of potential voids underlying the concrete crest slab. The potential presence of voids and corresponding loss of the sub-slab support was identified along a portion of the weir.

6.5.6 Large Wood Debris Analysis

After a review of available debris routing models (all academic/research-oriented to date), it became obvious that debris routing models presented significant limitations for use in this feasibility study. Specifically, model codes are not yet developed to represent the hydrodynamics of the river to bypass bifurcation, and making these improvements would require significant cost and time. Additionally, debris routing is a highly stochastic process and it would be difficult to determine model validity. Therefore, engineering judgment was used to evaluate historic debris patterns. After reviewing actual field conditions during flood events through the winter of 2018–2019 and inspecting readily available historic photographic images, the pattern of LWD routing and accumulation is believed to be relatively well understood.

Mapped locations indicate that LWD deposits along the length of Tisdale Weir and in the area just west of the weir (including the parking area), excluding an area from the north bank of Tisdale Weir to approximately 70 feet south (see Appendix B). Mapped locations appear to indicate that the majority of the deposited LWD is located on or adjacent to the southern half of the weir, with the largest accumulations occurring in the parking lot area. Under existing conditions, most LWD is transported to the southern half of the weir (**Figure 14**).



NOTES: Large wood debris locations digitized from images and video of spill events

Tisdale Weir Rehabilitation and Fish Passage Project

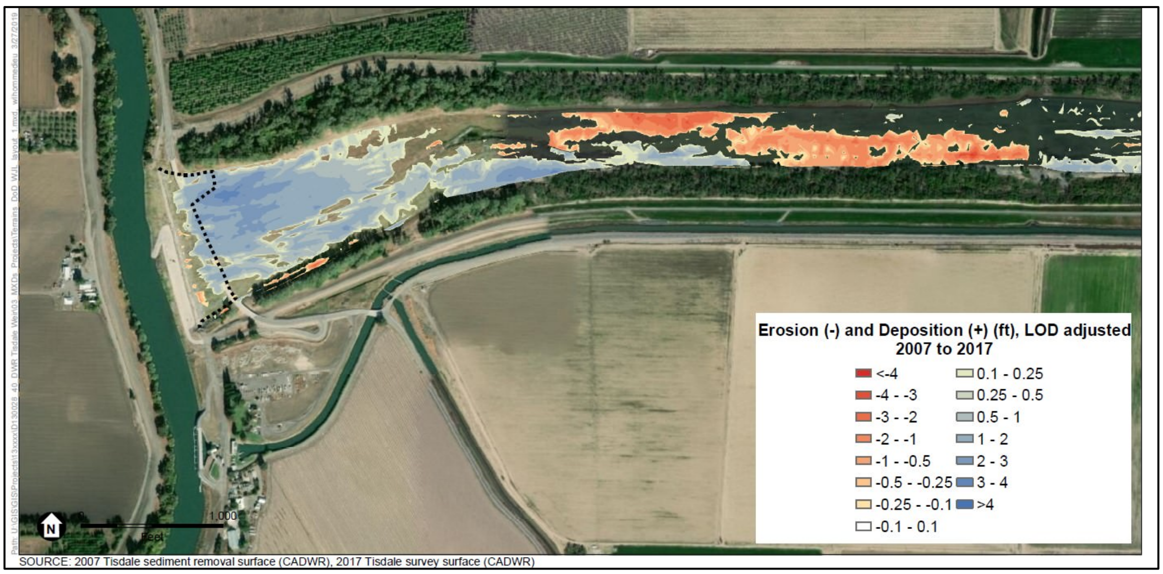
Figure 14
Large Wood Debris Locations During Spill Events

ESA

Given these findings, a weir notch located at the southern end of the weir would be more likely to rack LWD or entrain additional debris into Tisdale Bypass. A weir notch located at the northern end of the weir would alter the existing hydraulic conditions and may result in increased LWD transport to the northern portion of the weir; however, given the natural tendency for transport to the south, the risk of racking or entrainment at the northern notch is likely less than at the south. Appendix B provides more information about this assessment.

6.5.7 Sediment Budget Analyses

A sediment budget (see Appendix C) for the Project vicinity was developed to support greater understanding of the Project site and potential conditions if a Project were integrated into the weir. Surveys completed approximately 10 years after a 2007 sediment removal project in the bypass indicate that sand and finer sediment deposits in the bypass east of the weir, with some preferential deposition (deeper areas) seen in the area of the "northern eddy," which is generally described as the area along the north side of the bypass and just east of the Garmire Road Bridge alignment, with a length and width of about 1,500 and 600 feet, respectively (**Figure 15**).



Tisdale Weir Rehabilitation and Fish Passage Project

Figure 15
Tisdale Bypass Sediment Deposition and Erosion (2007 to 2017)

The sediment budget analysis was conducted to: (1) estimate the amount of suspended sediment that results in sediment deposition in the bypass under existing conditions and (2) assess how the amount of suspended sediment deposition in the bypass may potentially change with implementation of the proposed Project. The analysis involved a geomorphic change detection effort that calculated volumes associated with sediment deposition and erosion. The net change was estimated by differencing digital elevation models representing a 10-year period – November 15, 2007, to October 5, 2017 (the geomorphic change detection period) – immediately after the last major bypass sediment removal maintenance activity in 2007 (Figure 15).

The results indicate that 107,000 to 273,000 net cubic yards of sediment were deposited in the Tisdale Bypass between 2007 and 2017. Under proposed Project conditions, a notch or notches would allow flow to pass the weir at an increased depth in the river's water column, allowing more water and also water with a higher concentration of suspended sediment – and thus more suspended sediment – to enter the bypass. This increase in flow is anticipated to increase suspended sediment deposition volumes in the bypass based on the 2007 to 2017 existing-conditions flows.

6.5.8 Flood Impact Assessment

The operable gate of any notch would be closed during major flood events, so no impacts (increases in flood elevations in the Tisdale and Sutter Bypasses) would be anticipated. However, there is a possibility that an operable gate may fail (into the open position) during a flood event, and hydraulic modeling was performed as part of this feasibility study to assess flood impacts under this scenario.

Analysis was performed to identify potential changes to the performance of the overall SRFCP system that might result from an open-gate scenario. To anticipate potential implications resulting from a hypothetical condition, the gate was simulated in the fully open position for a full range of hydrologic loadings (2-year to 500-year events). This represents a worst-case condition and provides the most conservative estimate of the Project's potential impacts on the performance of the SRFCP system.

The flood impacts assessment was performed using the USACE's Common Features HEC-RAS model Release 5 (USACE, 2014). The hydraulic analyses were performed using HEC-RAS Version 4.2 (July 2013 Beta). Each of the storm events listed in the USACE's n-year events runs were modeled to consider a full range of hydraulic loadings. In addition to the 1957 authorized design flow, synthetic event hydrology was analyzed to assess impacts on the system for the 50, 10, 4, 2, 1, 0.5, and 0.2 percent annual chance exceedance events. This hydrology is based on the synthetic event hydrology prepared for the Sacramento–San Joaquin Rivers Comprehensive Study, with some changes to flood routing through Folsom Dam (USACE, 2014). Information from DWR's CVFED HEC-RAS model of the Sacramento River Basin (Wood Rodgers, 2015) was used to further update the Common Features model geometry to reflect the 2008 bridge improvements downstream of the weir at Garmire Road.

The modeling showed that flood elevations would increase, but by less than 0.01 foot during the 100-year event with the assumed gate failure. This negligible increase is reasonable when considering the relatively minor size of the weir opening compared to the overall weir length (i.e., initially assuming a 50-foot notch opening and 1,150-foot total weir length, one opening would represent approximately 4 percent of the total weir length) and significant tailwater conditions from the Sutter Bypass, which control the hydraulics at this location.

As part of the encroachment permit review process, the USACE (and in association with the CVFPB) typically assumes a negligible increase in flood risk if the maximum increase in flood stage is less than 0.1 foot. The USACE accepts this threshold because it is significantly less than the levee freeboard values incorporated into the design of the system and it mitigates the potential for significant cumulative effects (Kukas, 2014). Therefore, failure of the operable gate during a major flood event is assumed to not to result in a significant flood risk impact.

The current analysis is considered sufficient for screening the potential changes to the system performance that would result from implementation of the Project, and demonstrates that any reductions in assurance of the system design capacity would be negligible. Therefore, from a flood safety perspective, the Project will not be injurious to the public or affect the SRFCP's ability to meet its authorized purpose.

6.6 Summary of Alternatives

An alternative includes one or more management measures functioning together to achieve the planning objectives as described previously. Alternatives were developed in consideration of problems, opportunities, and constraints as well as study objectives. The driving concept is to creatively explore the range of possibilities, with an eye toward achieving multiple benefits while addressing problems. Alternatives were formulated through combinations of management measures, using screening criteria, to develop a focused array of alternatives for evaluation. The following subsections summarize the no-action alternative and three action alternatives.

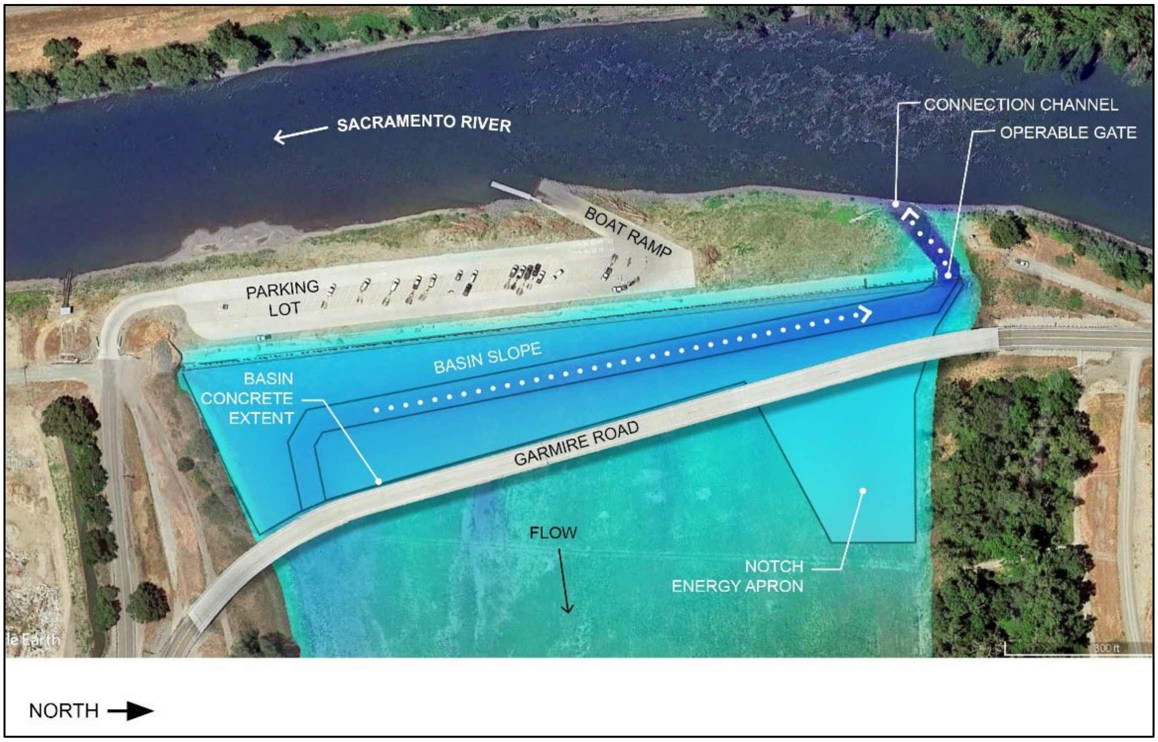
6.6.1 No-Action Alternative

The no-action alternative would involve no changes to the existing conditions described in Section 2.1, *Project Site and Vicinity*. The no-action alternative would not address the structural issues with the flood weir which may increase flood risk and the potential for life loss and property damage. Additionally, the no-action alternative would not improve or in any way address the existing fish stranding and passage problems.

6.6.2 Alternative 1 – North Notch

A single notch with an operable gate would be constructed at the northern end of the weir with a connection channel to the Sacramento River (**Figure 16**) (DWR, 2019b). An equipment pad would be constructed on the north abutment to place compressor and other mechanical and electrical equipment and to facilitate O&M of the gate. The energy dissipation basin would be extended farther east than the existing basin to accommodate energy dissipation for flows over the weir, and the basin would be reconstructed as a wide trapezoidal channel to provide passage for fish past debris and sediment deposits. The basin would be sloped to the north to facilitate drainage to the notch opening and facilitate fish passage through the weir as Sacramento River elevations decrease.

Potential erosion of the bypass channel from increased flows and velocities through a north notch would be mitigated by extending a concrete apron farther east than the energy dissipation basin itself. The apron would be slightly sloped to the west to support drainage toward the notch. Given the relatively close proximity of the north notch opening to the northern Garmire Road Bridge, additional scour protection would be provided at the northern bridge piers.

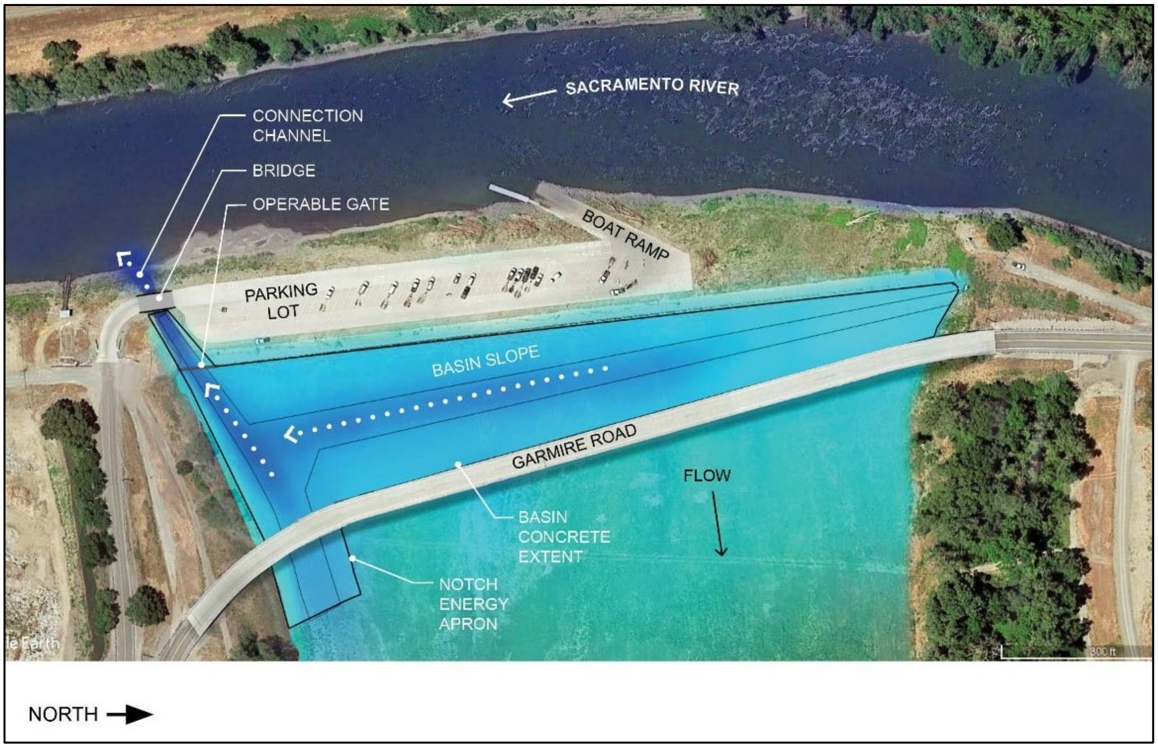


Tisdale Weir Rehabilitation and Fish Passage Project

Figure 16
Illustration of Alternative 1 – North Notch

6.6.3 Alternative 2 – South Notch

A single notch with an operable gate would be constructed at the southern end of the weir with a connection channel to the Sacramento River (**Figure 17**). An equipment pad would be constructed on the south abutment to place compressor and other mechanical and electrical equipment and to facilitate O&M of the gate. The energy dissipation basin would be extended farther east than the existing basin to accommodate energy dissipation and the basin would be reconstructed as a wide trapezoidal channel to provide fish passage past debris and sediment deposits. The basin would be sloped to the south to facilitate drainage to the notch opening and facilitate fish passage through the weir as Sacramento River elevations decrease.



Tisdale Weir Rehabilitation and Fish Passage Project

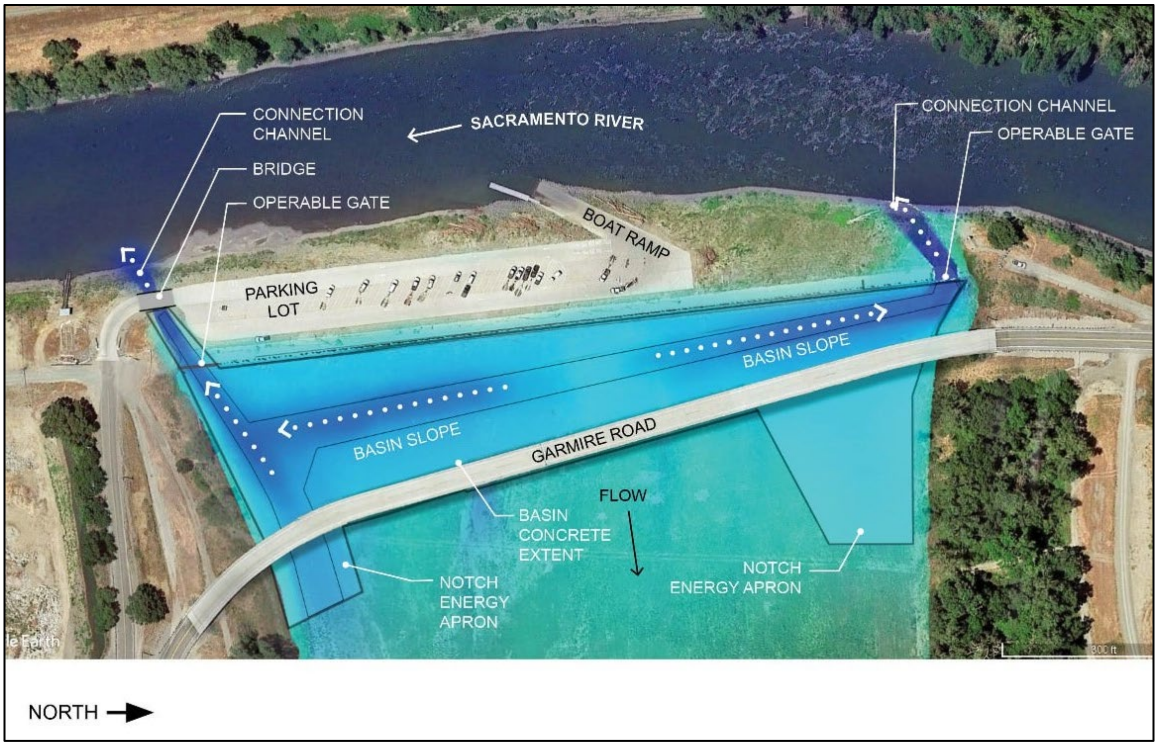
Figure 17
Illustration of Alternative 2 – South Notch

A bridge over the southern notch connection channel would be provided for vehicular access to the boat ramp parking lot. Because this crossing may have a high potential for collecting LWD, the bridge (and railings) would be designed such that it could be removed annually to reduce clogging of the channel and/or be removed for any required maintenance activities.

Potential erosion of the bypass channel from increased flows and velocities through a south notch would be mitigated by extending a concrete apron would farther east than the energy dissipation basin itself. Given the relative farther distance of the south notch opening from the Garmire Road Bridge than the north notch, additional scour protection would not be provided at the southern bridge piers unless deemed necessary.

6.6.4 Alternative 3 – North and South (Dual) Notches

Two notches with operable gates would be constructed at the northern and southern ends of the weir, with a connection channel to the Sacramento River (**Figure 18**) for each notch. Equipment pads would be constructed on both abutments to place compressor and other mechanical and electrical equipment and to facilitate O&M of the gates. The energy dissipation basin would be extended farther east than the existing basin to accommodate energy dissipation, and the basin would be reconstructed as a wide trapezoidal channel to provide fish passage past debris and sediment deposits. The basin would be sloped to the north and south from a high point approximately at the midpoint of the weir to facilitate drainage from across the width of the weir to the respective notch openings, facilitating fish passage through the weir as Sacramento River elevations fall.



Tisdale Weir Rehabilitation and Fish Passage Project

Figure 18
Illustration of Alternative 3 – North and South (Dual) Notches

A bridge over the southern notch connection channel would be provided for vehicular access to the boat ramp parking lot. Because this crossing may have a high potential for collecting LWD, the bridge (and railings) would be designed such that it could be removed annually to reduce clogging of the channel and/or be removed for any required maintenance activities.

Potential erosion of the bypass channel from increased flows and velocities through the notches would be mitigated by extending a concrete apron would farther east than the energy dissipation basin itself. Given the relative close proximity of the north notch opening to the northern Garmire Road Bridge, additional scour protection would be provided at the northern bridge piers.

6.7 Feasibility-Level Cost Opinions

Feasibility-level cost opinions were prepared for the three alternatives. The cost estimates are intended to be Class 4 according to the Association for the Advancement of Cost Engineering International (AACEI) (Cost Engineering, 2019), where the preliminary engineering is between 1 and 15 percent complete. The expected accuracy ranges for this class estimate are -15 to -30 percent on the low side and +20 to +50 percent on the high side.

This level of cost opinion is suitable for selecting and comparing conceptual alternatives and conducting feasibility evaluations. This estimate should *not* be used as a basis for final design or construction, or as an estimate of construction costs for construction planning or Project funding. Detailed strategic planning, business development, Project screening, alternative scheme analysis, and confirmation of economic and/or technical feasibility would be needed to improve the accuracy and level of detail of the cost estimate.

Cost opinions were developed for each budget line item by applying unit costs to quantities taken from the conceptual drawings, including plan and sections. Quantities were derived by using the estimated length, height, and depth of new facilities to be constructed. Budget line item costs and total costs are shown in 2019 dollars, with construction costs available from previous years escalated to 2019 values using the California Department of Transportation 2019 Highway Construction Price Index Report (Caltrans, 2019) or 20-city average annual *Engineering News-Record* Construction Cost Indices (ENR-CCI) (Engineering News-Record, 2019). **Table 3** shows the cost estimate summary for the three alternatives. Details of the assumed unit costs, quantities, and a further breakdown of the component costs are provided in Appendix D.

TABLE 3
FEASIBILITY-LEVEL OPINIONS OF COST FOR DESIGN ALTERNATIVES

Item No.	Component	Alternative 1 North Notch Cost	Alternative 2 South Notch Cost	Alternative 3 N&S Notches Cost
1	Site Coordination (Component 1)	$274,056	$279,056	$303,056
2	Site Improvements (Component 2)	$225,529	$225,529	$225,529
3	South Abutment (Component 3)	$183,343	$501,818	$414,008
4	North Abutment (Component 4)	$1,207,026	$888,551	$1,207,026
5	Connection Channel (Component 5)	$1,038,109	$2,134,578	$3,172,686
6	Weir Notch (Component 6)	$142,188	$142,188	$284,376
7	Operable Bottom Hinge Gates (Component 7)	$410,400	$410,400	$820,800
8	Weir Rehabilitation (Component 8)	$1,125,000	$1,125,000	$1,111,250
9	Energy Dissipation & Fish Basin (Component 9)	$14,345,348	$14,581,870	$15,133,756
10	Control Building (Component 10)	$98,086	$98,086	$196,172
11	Basin Access Ramps (Component 11)	$62,717	$62,717	$62,717
	Direct Item Subtotal	**$19,111,802**	**$20,449,793**	**$22,931,377**
	Contingency @ 30%	$5,733,541	$6,134,938	$6,879,413
	CA Sales and Use Tax Rate for Sutter County@ 7.25%	$1,385,606	$1,482,610	$1,662,525
	Construction Total	**$26,230,948**	**$28,067,341**	**$31,473,315**
	Planning, Engineering and Design @ 15%	$3,934,642	$4,210,101	$4,720,997
	Project Management and Administration @ 10%	$2,623,095	$2,806,734	$3,147,332
	Permitting and Legal @ 5%	$1,311,547	$1,403,367	$1,573,666
	Engineering During Construction @ 2%	$524,619	$561,347	$629,466
	Construction Management/Site Inspection @ 15%	$3,934,642	$4,210,101	$4,720,997
	Project Total	**$38,559,494**	**$41,258,991**	**$46,265,774**
	Low Estimate: -30%	**$26,991,646**	**$28,881,294**	**$32,386,042**
	High Estimate: +50%	**$57,839,241**	**$61,888,487**	**$69,398,660**

7 Evaluation of Alternatives

The four alternatives were evaluated for the purpose of identifying a recommended alternative.

7.1 Evaluation Criteria

The broader Program and Project goals and objectives described in Section 4.1 were used as a framework for the development of additional criteria to evaluate the three alternatives. These general goals and objectives were expanded to include more detailed criteria that are grouped into the categories of: CVFPP goals; general goals related to Project construction and success; weir rehabilitation objectives; fish passage objectives; O&M objectives; and flood management objectives. Supporting evaluation criteria to assess benefits and costs were identified for each objective. The criteria were developed to determine how well each alternative was able to achieve each individual objective through a direct comparison of their strengths, weaknesses, and tradeoffs. The evaluation criteria associated with each objective are listed in **Table 4**.

7.2 Multi-Criteria Alternatives Analysis

A multi-criteria alternatives analysis was conducted using the evaluation criteria to identify a recommended alternative. This was done by developing an alternatives evaluation matrix that considered a range of goals and objectives associated with the Project alternatives and provided a mechanism for scoring each alternative relative to each other. A summary of the decision matrix is provided in Table 4. The complete matrix, including weighting and scoring, is provided in Appendix E.

The relative importance (weighting) of each evaluation criterion, associated with each objective, was established by qualitatively assessing the relative importance of each criterion relative to all criteria, with weights based on a scale from 1 (less important) to 3 (more important). Each evaluation criterion was scored based on a scale from 0 (worst) to 3 (best) for each of the three alternatives and a no-action alternative. Rationales are provided to explain the scoring. Weighted scores were derived for each evaluation criterion and summed for each associated set of goals and objectives.

Weighted scores varied for each set of goals and objectives. All three alternatives scored similarly for the CVFPP goals. Alternative 1 scored higher for general Project goals and O&M objectives, tied with Alternatives 2 and 3 for fish passage objectives, and almost achieved a tie for weir rehabilitation objectives. The no-action alternative scored lower for all sets of goals and objectives, including flood management objectives, because the no-action alternative holds increased risk of failure of the structure absent any rehabilitation.

The final weighted scoring resulted in Alternative 1 scoring highest, followed by Alternative 2, then Alternative 3. Based on this analysis, Alternative 1, the northern gated notch alternative, is the recommended alternative.

TABLE 4
MULTI-CRITERIA ALTERNATIVES ANALYSIS

Goals and Objectives[1]	Evaluation Criteria[2]	Weighted Scores			
		No Action Alternative	Alternative 1 North Notch	Alternative 2 South Notch	Alternative 3 Dual Notches
CVFPP & CS Goals		6	37	37	35
Improves flood risk management	Improves public safety, preparedness, and emergency response (repairs aging infrastructure)	0	9	9	9
Promotes ecosystem functions	Integrates the recovery of key species into flood management system improvements	0	9	9	9
Promotes multi-benefit projects & reduces fish passage (stressor)	Contributes to broader integrated water management objectives; reduces stressor	0	9	9	9
Improves operations and maintenance	Reduces systemwide maintenance and repair requirements	6	4	4	2
Improves institutional support	Enables effective and adaptive integrated flood management	0	6	6	6
General Construction/Project Goals		3	26	21	13
Results in a Cost-Effective Project	Provides greater benefits for the associated cost	0	9	9	6
Results in a Constructible Project	More likely to be constructed on time and save the project money	0	6	4	2
Results in an Efficient Project	Can be operated and maintained with a lower cost	0	6	4	2
Results in a Sustainable Project	Supports the continuity of economic, social, institutional, and environmental aspects of human society and the environment	0	3	2	2
Results in a Safe Project	Maintains the welfare and protection of the general public at the weir	3	2	2	1
Weir Rehabilitation Objectives		0	21	18	18
Restores the Structural Integrity of the Weir Structure	Provide repairs to stop structural degradation	0	9	9	9
Extends the Design Life of the Weir Structure	Incorporate new engineering technologies/techniques in repairs to further extend design life	0	9	6	6
Fish Passage Objectives		**0**	**3**	**3**	**3**
Reduces Fish Passage Problems	Reduces passage barriers from flow depth, velocity, jump height, burst speed/distance	**0**	**21**	**21**	**21**
Increases passage during larger portions of the flood hydrograph Increase passage during larger portions of the flood hydrograph	Increases the total time available for passage across the weir	0	9	9	9
Reduces Fish Stranding and Delay Problems	Reduces the extent and timing of hydraulic disconnection of the bypass with the river	0	6	6	6

TABLE 4
MULTI-CRITERIA ALTERNATIVES ANALYSIS

Goals and Objectives[1]	Evaluation Criteria[2]	Weighted Scores			
		No Action Alternative	**Alternative 1 North Notch**	**Alternative 2 South Notch**	**Alternative 3 Dual Notches**
Operations & Maintenance Objectives		3	38	18	15
Reduces Operations Impacts from Large Wood Debris (LWD)	Reduces flow blockages and differential weir overflow and physical damages to operable gate from LWD	0	9	3	3
Facilitates Maintenance/Removal of LWD	Provides procedures/equipment to remove LWD throughout the year	0	6	2	2
Reduces Operations Impacts of Sediment Deposition	Reduces sediment impacts on gate operations and bypass flow conveyance	0	9	3	3
Facilitates Maintenance of Fish Passage Improvements (Sediment/Debris)	Provides procedures/equipment to remove sediment throughout the year	0	6	2	2
Facilitates Fish Rescue Efforts (if necessary)	Provides improved access for net rescue and wadeable conditions	0	6	6	4
Reduces incidents of and impacts from vandalism	Reduces opportunities for degradation of infrastructure	3	2	2	1
Flood Management Objectives		27	24	24	21
Maintains or Minimizes Flood Elevation Increases	Does not increase flood risk in the Tisdale Bypass or Sacramento River	9	9	9	9
Maintains the River/Weir Flood Split and Conveyance Capacity	Maintains CVFPP flood management functions	9	9	9	9
Maintains or Minimizes Flood Risk to downstream land uses	Does not increase inundation in Butte Slough and the Sutter Bypass for ag or waterfowl hunting	9	6	6	3
	Total Weighted Scores	**39**	**167**	**139**	**123**

NOTES:
1 The overall project goal is to rehabilitate the Tisdale Weir to address structural deficiencies and address the fish passage and stranding issues at the weir.
2 Criteria that describe multiple benefits and impacts.

7.3 Southern Notch Considerations

Although the three alternatives for the notch concept are similar in terms of their ability to meet the target fish passage hydraulics for passage from the bypass to the river, DWR has identified significant complications associated with the southern or dual-notch alternatives, including susceptibility to debris accumulation and potential risk of facility damage, equipment access, and complications with other existing infrastructure. Specifically, a southern notch would require construction at a location associated with the following complications:

1. Large Wood Debris Accumulation – The southern section of the weir is significantly prone to LWD accumulation as compared to the northern section. Heavy debris loading on the south end of the weir has been documented by the Sutter Maintenance Yard, supported by focused observations and forensic research performed as part of the feasibility study. Floating LWD from the Sacramento River is much more likely to block or damage a southern notch, as compared to a northern notch. Debris loading would also significantly increase maintenance costs for debris removal and increase maintenance crew exposure to potentially dangerous conditions, as compared to a northern location.
2. Existing Infrastructure – Design and construction of a southern notch would also be complicated and more costly because the existing Sutter County Boat Launch facility is located in front of and along the southern weir crest. DWR would need to mitigate any southern notch design to reduce impacts on the boat launch with additional elements, including a bridge (with removable deck to accommodate LWD and O&M) across the notch entrance channel to accommodate boat launch access and parking. DWR would need to explore and confirm existence of rumored sheet piles at the river side of the parking lot in this area, which could add design challenges and significant cost increases. Annual operations to remove and reinstall the bridge deck would also increase annual costs and removal of the bridge deck would close the boat launch through flood season, limiting recreational river access.
3. Construction Costs – A second notch would double the construction costs for the gate and related structural, mechanical, electrical, and control items.
4. Bypass Sedimentation – The sediment budget analysis indicates the construction of a single notch in the weir may increase suspended sediment volumes in the bypass by approximately 8 to 9 percent on average compared with existing conditions, based on the 2007 to 2017 existing-condition flows. This increases the amount of sediment that would need to be removed from the Tisdale Bypass to maintain conveyance. Though not explicitly analyzed, the construction of a second notch would intuitively further increase sediment deposition in the bypass and require increased maintenance.
5. Maintenance Access – Both the northern and southern locations would require an adjacent area to provide heavy equipment access and a gate control building. The southern site is partially occupied by the boat launch access road and would require extensive modifications or road relocation, while the northern area appears to provide all necessary space on State-owned land.
6. Redundancy – Any redundancy provided by a second notch in terms of pre-mitigating debris accumulations and blockage appear to be outweighed by the higher likelihood of debris accumulations in the notch itself, negating the perceived potential benefits.
7. Public Safety – The construction of a southern notch in the vicinity of the existing boat launch could increase the overall risk of accidents and injuries to recreational boaters.

Given that the fish passage assessment indicates that all alternatives would provide similarly suitable fish passage, these factors collectively establish that the southern notch and dual northern/southern notch concepts are likely to result in undesirable risks of impaired future performance by debris accumulation and associated structural damage. Those concepts also have associated increased costs for design, construction, operation, maintenance, and repair; complications from the existing parking lot/boat ramp; and may have public safety impacts on existing recreational river users.

8 Recommended Alternative

The recommended alternative involves an operable, gated notch located at the north end of the weir. This alternative is considered the best for achieving fish passage, providing maintenance access, avoiding Sutter County boat ramp access impacts, and minimizing the potential for damage and repairs/maintenance of the notch gate that may be caused by LWD. The recommended alternative consists of rehabilitation and reconstruction of the Tisdale Weir, installation of fish passage facilities, and associated Project site improvements. Each of these general actions comprise a number of Project components that are outlined and shown in **Figure 19** and described in more detail in the sections below.

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 19
Tisdale Project Components

8.1 Tisdale Weir Rehabilitation and Reconstruction

Weir rehabilitation and reconstruction would focus on addressing documented structural deficiencies in the existing weir. Some components would be rehabilitated with minor modifications to existing geometries, whereas others would require full reconstruction. Actions would generally consist of repairing the weir sill, reconstructing the two abutments (south and north), and reconstructing the energy dissipation basin (the latter is directly coupled with the proposed fish passage facilities). More specifically, weir rehabilitation and reconstruction would include:

- Removing and replacing the southern abutment in kind and providing scour countermeasures (e.g., sub-angular riprap) around the reconstructed abutment (Figure 19, Component 3).
- Removing and replacing the northern abutment with a taller structure to support an equipment pad to facilitate debris removal from the connection channel, notch, and operable gate (Figure 19, Component 4).
- Patching and sealing the existing concrete sill surface with an abrasion resistant overlay material (Figure 19, Component 8).
- Completing annular space grouting operations to fill potential internal voids in the existing weir structure and ensure consistent structural support for the slab. (Figure 19, Component 8).
- Removing and replacing the existing weir energy dissipation basin with a sloped basin that reduces negative impacts on fish species and other aquatic organisms (Figure 19, Component 9).

8.2 Fish Passage Facilities

The fish passage facilities constructed for the recommended alternative would include some components that would be specific to the objectives to pass fish and one that would also integrate flood management objectives – specifically the reconstructed energy dissipation and fish collection basin on the east side of the weir. Fish facilities also include installation of a notch, an operable gate (for flow regulation), and attendant facilities at the north end of the weir; and construction of a channel connecting the notch in the weir to the Sacramento River.

Fish passage facility implementation would include:

- Improving or reconstructing the entrance road off of Garmire Road on the north side of the weir (i.e., the entrance road to the equipment pad and control building location) (Figure 19, Component 4).
- Constructing an equipment pad above and north of the north abutment face to support notch and connection channel access from Garmire Road (Figure 19, Component 4).
- Installing a control building foundation and site utilities (i.e., power, communication, gate operation and power feed, and stormwater facilities) (Figure 19, Component 10).
- Constructing a control building to house electrical, mechanical, and communication equipment for the operable gate and scientific/monitoring equipment (Figure 19, Components 12, 13, and 14).

- Installing scour countermeasures (e.g., sub-angular riprap) extending from the north abutment into the bypass channel to provide scour protection for the water coming through the connection channel (Figure 19, Component 9.4).
- Constructing a tapering connection channel (approximately 27–32 feet wide by 10 feet deep) from the Sacramento River east to a proposed notch in the existing Tisdale Weir. The channel would have side slopes varying from approximately 2:1 at the Sacramento River and steepening to vertical at the location of the bottom-hinged, pneumatically actuated gate and remaining vertical to the downstream edge of the weir at the bypass confluence. The channel would be constructed with concrete to facilitate fish passage and draining of the basin, with sub-angular riprap placed on the river bank, up to a location where the channel concrete walls intercept the existing grade, to prevent scour of the river bank from flows entering or leaving the channel (Figure 19, Component 5).
- Installing a concrete weir notch structure 11 feet tall by approximately 32 feet wide to support an operable gate (Figure 19, Component 6).
- Installing an operable gate, including connections for electrical, mechanical, and monitoring controls. The gate would consist of a bottom-hinged, pneumatically actuated gate with inflatable air bladder controls to facilitate opening and closing the notch. The gate would be formed by two identical plates (bolted together) with nominal dimensions of 16 feet wide by 11 feet high and a gasket on each side to improve water sealing (Figure 19, Component 7).
- Removing and replacing the existing energy dissipation basin (Figure 19, Component 9.1) and filling existing scour holes and providing scour countermeasures (Figure 19, Component 9.2) and building a multi-purpose, concrete energy dissipation and fish collection basin (described in greater detail in Section 8.3, below) to: (1) provide energy dissipation of weir flood flows and a smooth transition to native ground, and (2) provide positive drainage of water back to the river as river stage recedes to minimize fish stranding. The concrete basin would transition on the downstream edge to scour countermeasures of some form of buried riprap (angular riprap, large cobble, and/or engineered streambed material [ESM]) to transition to native ground.
- On the north side/east edge of the basin (apron), excavating soil, removing vegetation (including trees, as necessary), and building a concrete apron (Figure 19, Component 9.4) with a scour countermeasure (e.g., sub-angular riprap) at the downstream edge as transition to native ground. This feature would provide scour protection and energy dissipation functions for flows focused through the connection channel when the operable gate is open.
- Installing a basin access ramp on the south side, providing access into the basin and bypass from the existing levee road to facilitate O&M activities (Figure 19, Component 11).

The fish passage facilities would focus on Chinook salmon and green sturgeon and be designed to provide passage for upstream migrating fish (salmon and sturgeon) from the Tisdale Bypass to the Sacramento River after river flows have overflowed the weir into the bypass. For a period of time during and after an overflow event, ranging from several days up to several weeks, the facility would be operated to maintain a connection between the bypass and the river and manage flow and water levels in a way conducive to allowing fish to move out (i.e., move upstream) of the bypass and into the Sacramento River.

8.3 Energy Dissipation and Fish Collection Basin

The existing basin on the east side of the weir would be removed and replaced to reduce fish impacts during overflow events. A multi-objective, concrete energy dissipation and fish collection basin would be constructed on the east side of the weir, extending across the entire downstream (eastern) edge of the weir. This concrete feature would comprise an area of approximately 8 acres (**Figure 20**).

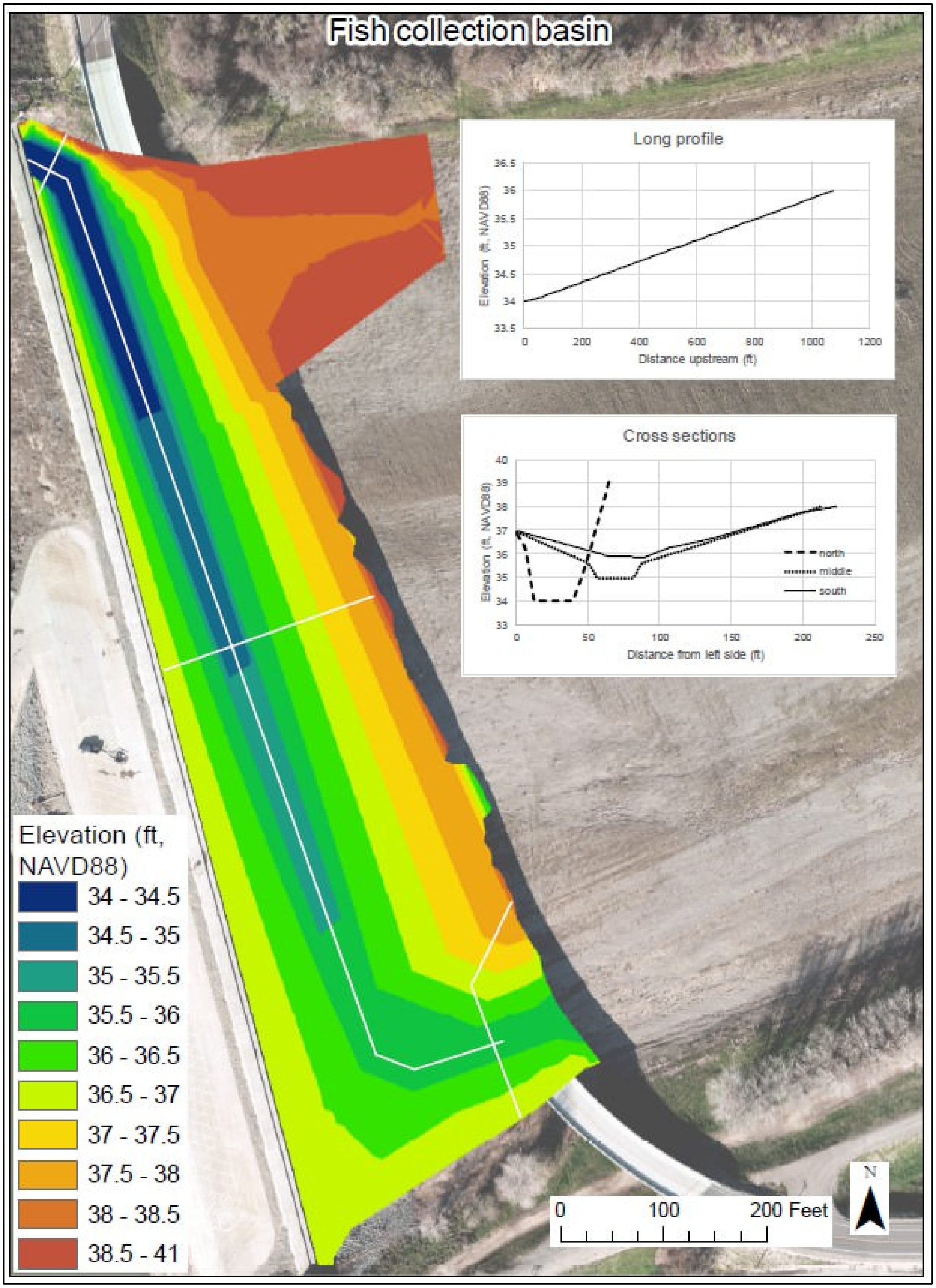
The basin would function to dissipate the flow of energy when the Sacramento River is overflowing the weir, and would provide a transition and pathway for migrating fish that can be efficiently maintained (e.g., cleared of debris and sediment). The basin would be designed such that when flow from the Sacramento River is no longer moving into the basin, the pool in the basin would “drain” or recede back toward the river, concurrent with the lowering of the river stage. This is understood to create a focused area of water that would collect fish, and the flow through the notch (or the deeper water in the northern/notch end of the basin, when river stage is lower than the hinge point) would encourage those fish to move to the notch and enter the river. The basin would contain a broad (at least 25-foot-wide) low-flow channel along its axis from roughly south to north.

Scour protection measures would be incorporated along the downstream edge of the basin at the transition from the basin to the bypass. Also, because the basin would extend near, or out to, the location of the bridge piers, some measure of scour protection would be afforded the piers. These scour countermeasures would consist of angular riprap, large cobble, and/or ESM. The low-flow channel through the basin would slope uniformly from the southern/upstream end (i.e., the transition to the bypass invert at the south, at an approximate elevation of 36 feet) to the inlet, which would be the point at which the basin would connect to the weir and notch (at an elevation of approximately 34 feet).

Permanent scour and erosion countermeasures would be designed and included on the north end of the basin. The concrete footprint of the basin would extend east of Garmire Road in the form of an apron that would contain higher velocity flow passing through the notch (Figure 19, Component 9.4). Further, large rock or riprap would be placed along the northern bank of the bypass just east of the proposed notch for scour protection, and limited grading would be implemented to facilitate rock placement.

8.4 Weir Notch and Operable Gate

A notch (i.e., the structural change in the weir to provide fish passage) would be installed in the north end of the weir (Figure 19, Component 6) to provide a connection between the Tisdale Bypass (and basin) and the Sacramento River via a connection channel. The concrete, rectangular notch opening would be just over 11 feet tall by approximately 32 feet wide and the invert (or bottom) of the notch would be at an elevation of 34 feet. When the water surface elevation of Sacramento River is at or above this level, a connection between the river and the Tisdale Bypass could be made.



Tisdale Weir Rehabilitation and Fish Passage Project

Figure 20
Alternative 1 Fish Collection Basin Configuration

Flow through the notch would be controlled by an operable, bottom-hinged, pneumatically actuated gate (Figure 19, Component 7) spanning the notch. The gate would be formed by two identical plates (bolted together) with nominal dimensions of 16 feet wide by 11 feet high and a gasket on each side to improve water sealing. This type of gate is raised and lowered by inflating or deflating, respectively, air bladders behind each plate.

8.5 Connection Channel

The connection channel (Figure 19, Component 5) would provide a hydraulically connected route for fish passage, connecting the notch in the weir to the Sacramento River. The connection channel would be excavated and installed within the east bank of the Sacramento River and tied in to the rectangular, approximately 32-foot-wide by 11-foot-tall concrete notch opening. From this tie-in point west (or upstream) to the Sacramento River, the connection channel would be angled southwest (or downstream) at approximately 45 degrees. The channel would be approximately 130 feet long and have an approximately 32-foot bottom width at the notch opening and an approximately 27-foot bottom width at its connection point to the Sacramento River. The side slopes of the connection channel would transition from 2:1 on the upstream (Sacramento River) end to vertical at the downstream end where the connection channel ties into the weir notch. The bottom elevation of the channel would start at the Sacramento River with an invert elevation of 33 feet, and it would slope slightly upward before terminating at the notch at an elevation of 34 feet. This slope and configuration would allow the basin to drain toward the Sacramento River at lower river stages.

Sub-angular riprap would be placed at the inlet to the proposed connection channel in the Sacramento River to prevent scour at the inlet. A coffer dam may be necessary during construction to isolate the connection channel construction site from the Sacramento River. The connection channel would be excavated to an average depth of 12 feet and would be constructed with scour resistant materials such as concrete, or angular or sub-angular riprap.

8.6 Entrance Road, Equipment Pad, and Control Building

Modifications at the north end of the weir would include installation or reconstruction of an entrance road, installation of an equipment pad, and installation of a control building for O&M purposes (Figure 19, Components 4 and 10).

An entrance road would be constructed or improved to provide large equipment (e.g., a crane or excavator) and vehicular access to the equipment pad and control building area at the north abutment.

An equipment pad would be constructed adjacent to the reconstructed northern abutment and would facilitate access to the notch primarily by emergency equipment (e.g., crane or excavator access to remove debris if deemed appropriate). The equipment pad would consist of concrete or compacted aggregate gravel and would be approximately 50 feet by 50 feet. The existing gravel vehicular access between Garmire Road and the north abutment would be repaired with additional gravel paving as necessary to support heavy equipment access.

An approximately 30-foot-by-30-foot control building would be installed at the north end of the weir (Figure 19, Component 10). The control building would house communication, electrical, scientific/monitoring, and mechanical equipment components relating primarily to operation of the gates. The building would be enclosed by modular fencing on the outside to protect the building and associated components. A concrete-encased duct bank would connect all electrical, communications/scientific, and air lines from the control building to the operable gates.

8.7 Site Improvements

Improvements to the Project site would facilitate weir rehabilitation and reconstruction and installation of fish passage facilities, and would provide enhanced protection of existing Project site features and reduce O&M. Project site improvements would include:

- Removing utility poles in the bypass channel and relocating power and communication lines to the Garmire Road Bridge in new conduit(s).
- Filling the scour holes north of the boat launch parking lot and south of the north abutment with scour resistant materials (riprap or large cobble, potentially with grout), while regrading the area to a smooth character to reduce wood debris impingement and facilitate equipment access to the south side of the connection channel (Figure 19, Component 2.3).
- Providing scour countermeasures around the Garmire Road Bridge piers.
- Stabilizing the existing cobble along the leading (upstream) edge of the weir (**Figure 21**) and/or replacing these cobbles with erosion protection measures (e.g., cobbles, riprap, concrete) to resist scour (Figure 19, Component 2.5).
- Constructing access ramps from the existing bypass channel berms to the proposed site improvement area downstream of the weir.

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 21
Existing Cobble Along the Western Edge of the Tisdale Weir

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Appendix A-1

Fish Passage Analysis Technical Memorandum

A copy of this appendix is included as Appendix F of this EIR.

Appendix A-2

Tisdale Weir Historical Fish Passage and Stranding Technical Memorandum

TISDALE WEIR HISTORICAL FISH PASSAGE AND STRANDING

Tech Memo

Prepared for
DWR Division of Flood Management

November 2019

ESA

TISDALE WEIR HISTORICAL FISH PASSAGE AND STRANDING

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November 2019

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TISDALE WEIR HISTORICAL FISH STRANDING AND PASSAGE

Tech Memo

1. Purpose and Organization

The purpose of this technical memo is to summarize historical information on fish stranding and passage of listed fish species at the Tisdale Weir and Tisdale Bypass in the Sacramento River Basin. Fish passage and stranding information will help inform future redesigns of the weir and bypass system. This memo is organized into five sections:

2. Background: describes the Tisdale Weir and Tisdale Bypass and associated hydrology and summarizes recent policy drivers for improving passage in the Tisdale Bypass.

3. Fish Stranding: summarizes historical information on fish stranding and fish rescues at the Tisdale Weir performed by California Department of Fish and Wildlife (CDFW).

4. Fish Passage: summarizes the current knowledge of passage issues of listed fish species at the Tisdale Weir and within the Tisdale Bypass.

5. Key Findings and Remaining Uncertainties: summarizes key findings and remaining unknowns about fish passage concerns in the Tisdale Bypass.

2. Background & Introduction

The Tisdale Weir, completed in 1932, is located along the left bank of the Sacramento River about ten miles southeast of the town of Meridian and about 56 miles north of Sacramento (River Mile 119, as measured upstream from the Sacramento–San Joaquin Delta). Its primary purpose is to release overflow waters of the Sacramento River into the Sutter Bypass via the Tisdale Bypass (DWR 2010). The fixed-crest, reinforced concrete weir is 1,150 feet long. The four-mile leveed bypass channel (Tisdale Bypass) connects the river to the Sutter Bypass. The crest elevation is 45.45 feet and the project design capacity of the weir is 38,000 cubic feet per second (cfs). Typically, the Tisdale Weir is the first of the five weirs in the Sacramento River Flood Control System to overtop, and continues to spill for the longest duration.

The north and south levee are turf-covered earthen structures, varying in height from approximately 16 ft. at the weir to approximately 21 ft. at the transition to Sutter Bypass (DWR 2014). The Tisdale Bypass provides flood protection to the Sutter and Colusa basins including the towns of Knights Landing, Meridian, and Robbins; Reclamation Districts 108, 1660, and 1500;

and portions of State Routes 45 and 113 (DWR 2014). Structures within Tisdale Bypass include Tisdale Weir at the head of the bypass and two bridge foundations (DWR 2014).

The Upper Sacramento weirs (Tisdale, Colusa, and Moulton) allow water to pass into their bypasses and into the Sutter Bypass (DWR 2014). The Sutter Bypass plays a critical role in conveying floodwater from the Upper Sacramento River and Feather River drainages into the Yolo Bypass and Lower Sacramento River (DWR 2014). The weirs are passive-gravity structures that overflow when Sacramento River stage exceeds the fixed weir elevation. Each weir (except Colusa Weir) consists of: (1) a fixed-level, concrete overflow section, followed by (2) a concrete, energy-dissipating basin with a downstream rock and/or concrete erosion blanket (usually riprap) across the channel beyond the energy dissipation basin, and (3) a pair of training levees that define the weir-flow escape channel (DWR 2014).

From 1991–2005, Tisdale Weir overflowed multiple times each year, except during 1994. Overflow events during those years were most common during January–March, but occurred as early as November and as late as June (DWR 2014). Major maintenance activities, including major erosion repairs and sediment removal are required periodically to maintain conveyance capacity. In 2007, approximately 1.7 million cubic yards of sediment were removed from below the weir and bypass (DWR 2014). During the 2016-2017 water year, Sacramento River flows overtopped Tisdale Weir six times totaling 114 days with a peak overtopping flow of 34,868 cfs on 22 February 2017 (Beccio 2017).

At the Tisdale Weir and Sacramento River four federally listed anadromous fish species may be present: Sacramento River winter-run Chinook salmon *Oncorhynchus tshawytscha*, Central Valley spring-run Chinook salmon *O. tshawytscha,* California Central Valley steelhead Distinct Population Segment (DPS) *O. mykiss*, and Southern DPS of North American Green Sturgeon *Acipenser medirostris*. Fish passage conditions for weir itself have not previously been formally investigated. Potentially passable conditions are different from conditions meeting fish passage criteria. This memorandum provides specific fish passage criteria for assessing passage success for each species addressed, including Green Sturgeon, which require the most stringent criteria among target listed species. Adult Chinook salmon, steelhead, sturgeon and other fish may become isolated and subsequently stranded in the Tisdale Bypass after overtopping of the Tisdale Weir (Beccio 2016). When flows recede below the top of the Tisdale Weir, these and other fish species can become stranded in the Tisdale Weir apron below the weir and in various residual pools (scoured holes and swales and existing channels at the toe of the levees) within the Tisdale Bypass (Beccio 2016).

Fish passage improvements at Tisdale Bypass have been identified as key priorities for Chinook salmon and Green Sturgeon recovery and resiliency in the Central Valley. The annual Work Plan for the Central Valley Project Improvement Act (CVPIA) includes improving access for spring-run Chinook salmon and Green Sturgeon through the Tisdale Bypass as a Core Team priority with the goal of reducing or eliminating stranding opportunities (CVPIA 2017). The NMFS (2014) Recovery Plan for Central Valley salmonids also includes an action (SAR 1.12) to implement short- and long-term solutions to minimize loss of Chinook salmon and Steelhead in the Sutter-Butte Basin. Lastly, the Sacramento Valley Salmon Resiliency Strategy (CNRA 2017) includes a Sutter Bypass improvements action (including Tisdale Weir modifications) to improve Chinook salmon passage as part of their suite of actions necessary to improve the immediate and long-term resiliency of Sacramento Valley salmonids.

3. Fish Passage

The Tisdale Weir is considered a temporal barrier to fish passage meaning that it may be passable under certain hydraulic conditions; nevertheless, passable conditions are limited (DWR 2014). During many flood events, the weir presents a significant barrier to upstream migration in terms of meeting fish passage criteria for federally listed anadromous fish species. Table 1 presents fish passage criteria developed for the Yolo Bypass Salmonid Habitat Restoration and Fish passage Project. It is unlikely that similar passage criteria at the Tisdale Weir is being met during many flood events as a result of the physical dimensions of the weir (11-ft high) and inadequate hydraulic conditions below and above the weir (DWR 2014). However, fish passage is likely possible during extremely large flood events, especially if the weir is backwatered on its downstream side because of deep inundation in the Sutter and Tisdale Bypasses (DWR 2014).

TABLE 1
SUMMARY OF FISH PASSAGE CRITERIA FOR FEDERALLY LISTED SPECIES WITHIN THE SACRAMENTO RIVER DEVELOPED FOR THE YOLO BYPASS SALMONID HABITAT RESTORATION AND FISH PASSAGE PROJECT

Species	Adult Migration Time	Minimum Depth of Flow (Short Distance)	Minimum Depth of Flow (Long Distance)	Minimum Channel Width	Maximum Velocity (Short Distance)	Maximum Velocity (Long Distance)
Adult Sturgeon	Jan-May	3 feet	5 feet	10 feet	6 feet/second*	4 feet/second
Adult Salmonids	Nov-May	1 feet	3 feet	4 feet		

NOTE:
* Short distance velocity is for a maximum length of 60 feet

Source: DWR 2017

Spring-run, fall-run, and winter-run Chinook salmon, Green Sturgeon, and Steelhead have been found trapped in Tisdale Weir's energy dissipation basin (DWR 2014; Beccio 2016). The bypass is maintained to efficiently convey water from the Sacramento River to the Sutter Bypass. These conditions do not necessarily provide many resting areas when water depth is adequate for upstream passage (DWR 2014). The method of entry into the weir's energy dissipation basin has not been verified. One potential scenario is confirmed by video footage showing an unidentified species being washed over the concrete weir overflow section from the Sacramento River (DWR 2014). Another possible scenario is that fish swim upstream from the Sutter Bypass through the Tisdale Bypass and cannot pass the weir to return to the Sacramento River (DWR 2014; Beccio 2017). ESA staff made a direct observation of a salmonid (likely a spring-run Chinook salmon) attempting to pass upstream at the northern end of the weir on March 30, 2017. Ultimately, the route of entry to the area of the Tisdale Bypass immediately downstream of the Tisdale Weir is irrelevant to addressing whether the weir meets fish passage criteria across a range of relevant flow conditions.

The extent of the Tisdale Weir's impact on special status fish species depends on its overflow frequency when fish are present in the system. During most years, there are multiple overflow events throughout fall, winter, and spring, with peak overflows during January through March. Adult Southern DPS green sturgeon enter San Francisco Bay in late winter through early spring and migrate to upper Sacramento River reaches to spawn from April through early July, often timing migration with peak flow events (Heublein et al. 2009; Poytress et al. 2011). Therefore, Green Sturgeon adult migration timing is aligned with Tisdale Weir overflow, making them especially susceptible to stranding in the Tisdale Bypass because of their presence in the system during times when the bypass is inundated. Spring-run Chinook salmon adults are similarly susceptible to stranding in Tisdale Bypass, with upstream migration occurring from February to June, timed with increased run-off events (NMFS 2011; Moyle et al. 2017). Upstream migration of winter-run Chinook salmon adults also overlaps with Tisdale Weir overflow events, with migration occurring from January through May and peaking in mid-March (Moyle et al. 2017).

Timing of Tisdale Weir overflow events occurring from November through June (DWR 2014) overlaps with the juvenile emigration period for all runs of Chinook salmon and steelhead making a portion of each run susceptible to stranding depending on the annual overflow frequency. The emigration timing of each salmonid run in the Sacramento River Basin varies, with winter-run and spring-run emigrating during September through January, spring-run and fall-run during December through May, and steelhead emigrating all year with the majority during April through June (Voss and Poytress 2017). Juvenile salmonids migrating downstream during the fall through spring may flow over the Tisdale Weir from the Sacramento River.

4. Fish Stranding & Rescues

Adult Chinook salmon, Steelhead, Sturgeon and other fish may become isolated and subsequently stranded in the Tisdale Bypass when migrating up the Sutter Bypass from the Sacramento River during overtopping of the Tisdale Weir (Beccio 2017). When flows recede below the top of the Tisdale Weir, these and other fish species become stranded in the Tisdale Weir splash basin and in inundated areas downstream of the weir. The most common location that fish become trapped is in the energy dissipation basin just below the weir (**Figure 1**).

Stranding potential is the greatest between Tisdale Weir and the Reclamation Road Bridge (CVPIA 2017). The Tisdale Bypass between the Reclamation Road Bridge and the Sutter Bypass has a low-flow channel on each side of the Bypass that connects to the West Borrow Canal of the Sutter Bypass (CVPIA 2017). However, the potential stranding areas closest to the weir are not connected to these low-flow channels (CVPIA 2017). In addition to the energy dissipation basin, stranding may also occur in multiple isolated residual pools throughout the Tisdale Bypass when floodwaters recede (**Figure 2**).

Notes: Screenshot is of the bypass between Tisdale Weir and the Reclamation Road Bridge. Imagery date is June 26, 2011.

SOURCE: Google Earth, 2011

Tisdale Weir Historical Fish Stranding and Passage

Figure 1
Photo C1-28 in DWR (2014) of the energy dissipation basin below Tisdale Weir.

Note: Photo was taken on April 17, 2012 at 10:30 a.m. Source: California Department of Fish and Wildlife

SOURCE: CDFW, 2012

Tisdale Weir Historical Fish Stranding and Passage

Figure 2
Photo C1-30 in DWR (2014) of multiple isolated residual pools that may cause stranding when floodwaters recede. Note that other pools likely occur downstream of Reclamation road.

A total of 17 fish rescue efforts were documented that captured salmonids or Green Sturgeon at the Tisdale Weir and Tisdale Bypass from 1986 through 2019 (see **Table 2**; Beccio 2016; Beccio 2017; Chris McKibbin, CDFW, Pers. Comm.). Rescue efforts at this location were limited to the weir apron and inundated areas immediately downstream of the weir (Beccio 2016). In total, 516 juvenile and 141 adult Chinook salmon were captured across the four runs for all 17 rescue events. In addition, 183 juvenile and one adult steelhead were captured during rescue events. During the 2017 rescue efforts, 9 adult Chinook salmon were found already dead (Beccio 2017). The depth and volume of water within the weir splash basin and downstream inundated area event prevented CDFW staff from conducting rescue efforts prior to the deterioration of water quality which likely resulted in the observed mortality of the salmon (Beccio 2017).

TABLE 2
CAPTURED FISH BY SPECIES AND LIFE STAGE DURING 17 RESCUE EFFORTS CONDUCTED BY CDFW.

	Chinook Salmon								Steelhead		Green Sturgeon	
	Spring-Run		Winter-Run		Fall/Late-Fall		Unknown run					
Date	Juv	Adult	Juv	Adult	Juv	Adult	Juv	Adult	Juv	Adult	Juv	Adult
5/15/2019					27		30					
5/08/2019		3		1								
5/03/2019		3		2				1			1	
4/26/2019	9			2	10				1		3	
4/25/2019				1							15	
5/12/2017		1		5				3				3
4/14/2016		21					81					
4/8/2016		19					168		2			
2/17/2016			13	1	4				60			
2/11/2016			3						1			
2/23/2015	7		25		3			4	119			
1/8/2015										1		
4/17/2012							120	9				
4/14/2011							14	53				11
3/6/2003								2				
4/26/1995							2	3				
4/21/1986								7				
Totals	**16**	**47**	**41**	**12**	**44**	**0**	**415**	**82**	**183**	**1**	**19**	**14**

A particularly large number of adult Green Sturgeon (11) were stranded at the energy dissipation basin at Tisdale weir in 2011 (Beccio 2016; Thomas et al. 2013). Thomas et al. (2013) evaluated the post-rescue movements and potential population effects of stranding. Success to the spawning ground for females stranded at Tisdale Weir was 80% (four out of five). Males stranded at the Tisdale Weir had similar migratory success to the spawning grounds as females (five of six, 83%). Looking at stranded Green Sturgeon at both Tisdale Weir and Fremont Weir on the Yolo Bypass, model projections over 50 years indicated that chronic stranding in flood control structures could have biologically significant impacts on the viability of the Sacramento River Green Sturgeon population. Simulations also suggested that monitoring and rescue operations could greatly reduce the impact of stranding on population viability. However, Thomas et al. (2013) suggest that rescue efforts should only be considered as a short-term management strategy to reduce population-level risks of stranding and that ultimately, major modifications to flood control structures will be necessary to prevent stranding risks of sturgeon species during their spawning migration.

5. Key Findings and Remaining Uncertainties

Key Findings:

- The range of flows at the weir which are potentially passable are different from conditions meeting fish passage criteria. Preliminarily, Tisdale Weir appears to be a barrier to upstream migration for all fish species under certain hydraulic conditions due to the height of the weir (11 ft.) and the potential for inadequate hydraulic conditions for passage below and above the weir. The exception appears to be when weir height is reduced by sufficient backwatering on the downstream side (in other words, Tisdale Bypass stage is equal to Sacramento River stage). This sufficient backwatering condition may be present only a portion of the time during which spill over the weir occurs.

- Stranding occurs in the energy dissipation basin or in multiple isolated residual pools downstream of the Tisdale Weir created after floodwaters recede. Stranding is caused by lack of continuous wetted habitat connecting to low-flow channels to the east of the Reclamation Road Bridge that would provide fish with an exit route back to Sutter Bypass.

- The adult life stages of Green Sturgeon, spring-run Chinook salmon, and winter-run Chinook salmon are particularly susceptible to stranding in Tisdale Bypass due to their early spring timing of migration that aligns with the peak period of Tisdale Weir flooding events.

- The juvenile life stages of all salmonids are susceptible to stranding in the Tisdale Bypass, with their emigration timing overlapping with the autumn-through-spring period of potential Tisdale Weir flooding.

- The route of entry for fish to the area of the Tisdale Bypass immediately downstream of the Tisdale Weir where passage is attempted is unknown, but is irrelevant to addressing whether the weir meets fish passage criteria across a range of relevant flow conditions.

Key Uncertainties Related to Planning and Design of Fish Passage Improvements.

- The range of flows at the Tisdale Weir which meet fish passage criteria for target listed species are unknown. These flow conditions should be determined and examined in relation to the timing, frequency and duration of flow conditions that do not meet fish passage criteria. This understanding should be used to guide planning and design of fish passage improvements.

- Anecdotally, fish have passed the weir at its northern end. It is unknown if flow and/or hydraulic conditions may develop preferential locations where fish tend to collect and attempt passage over the weir. If any such hydraulic preference exists, it should be factored into planning and design of fish passage improvements.

- The degree to which the residual pools in the bypass include stranded fish under various conditions is uncertain, as is the connectivity dynamics and habitat conditions in this pools.

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Appendix B

Large Wood Debris at Tisdale Weir Technical Memorandum

TISDALE WEIR REHABILITATION AND FISH PASSAGE PROJECT

Large Wood Debris Mapping at Tisdale Weir
Technical Memorandum

Prepared for
California Department of Water Resources

August 2019

TISDALE WEIR REHABILITATION AND FISH PASSAGE PROJECT

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TISDALE WEIR REHABILITATION AND FISH PASSAGE PROJECT

Large Wood Debris Mapping at Tisdale Weir

1. Introduction

The Tisdale Weir, completed in 1932, is located along the left bank of the Sacramento River about ten miles southeast of the town of Meridian and about 56 miles north of Sacramento (River Mile 119, as measured upstream from the Sacramento–San Joaquin Delta). Its primary purpose is to release overflow waters of the Sacramento River into the Sutter Bypass via the Tisdale Bypass. The fixed-crest, reinforced concrete weir is 1,150 feet long. The four-mile leveed bypass channel (Tisdale Bypass) connects the river to the Sutter Bypass. The crest elevation is 44.1 feet (NAVD88) and the project design capacity of the weir is 38,000 cubic feet per second. Typically, the Tisdale Weir is the first of the five weirs in the Sacramento River Flood Control System to overtop, and continues to spill for the longest duration.

As a part of the Tisdale Weir Rehabilitation and Fish Passage Project (Project), Environmental Science Associates is designing a fish passage notch in the Tisdale Weir. Under current conditions, large wood debris (LWD) accumulation in the area along Tisdale Weir and further downstream within Tisdale Bypass has been identified as an issue. The potential for the proposed notch in Tisdale Weir to rack LWD or entrain additional LWD into Tisdale Bypass was identified as a design consideration for the location of the proposed fish passage notch. GIS mapping was performed to analyze trends in historic LWD deposition within the project area (confluence of the Sacramento River and Tisdale Bypass). The objective of this mapping was to assess the risk of LWD accumulation along Tisdale Weir in relation to potential notch locations.

2. Methods

LWD mapping was performed using a combination of photographs, videos, and aerial imagery. LWD locations were mapped for weir overtopping events and during periods where wood debris was observed following overtopping events.

2.1 Data Sources

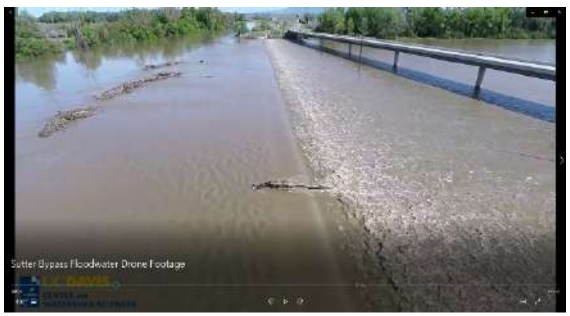
Table 1 lists the date of data acquisition, mapping method, weir overtopping condition, data source, and description of the data. **Figure 1** shows the photographs used for LWD mapping.

3/19/2011

12/4/2012

3/30/2017

4/9/2018



1/22/2019

4/23/2019

SOURCE: See Table 1

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 1

Photographs of LWD at Tisdale Weir

TABLE 1
SUMMARY OF WOOD DEBRIS MAPPING DATA SOURCES

Date	Source	Description	Weir Spill	Method
4/23/2019	ESA[1]	Drone photos and videos	Yes	Locations estimated from photos and video
1/22/2019	ESA[2]	Drone photos and videos	Yes	Locations estimated from photos and video
4/9/2018	UC Davis[3]	Drone video	Yes	Georeferenced screen capture from video
4/8/2018	Sacramento Valley[4]	Video taken from south bank	Yes	Locations estimated from video
3/30/2017	DWR[5]	Photograph taken from north bank	Yes	Locations estimated from photo
1/9/2017	Sutter County[6]	Drone video	Yes	Locations estimated from video
1/19/2016	Sutter County[7]	Video taken from south bank	Yes	No LWD observed in video
12/4/2012	Sutter County[8]	Video and photographs taken from south bank	Yes	Locations estimated from photos and video
3/30/2011	Google Earth[9]	Google Earth imagery	Yes	Delineated from historical aerial in Google Earth
3/19/2011	DWR[10]	Video and photographs taken from south bank	Yes	Locations estimated from photos and video
3/15/1995	DWR[11]	Helicopter video	Yes	No LWD observed in video
5/18/2017	Google Earth[12]	Google Earth imagery	No	Delineated from historical aerial in Google Earth
5/2/2013	Google Earth[13]	Google Earth imagery	No	Delineated from historical aerial in Google Earth
6/26/2011	Google Earth[14]	Google Earth imagery	No	Delineated from historical aerial in Google Earth
7/9/2010	Google Earth[15]	Google Earth imagery	No	Delineated from historical aerial in Google Earth
3/17/2010	Google Earth[16]	Google Earth imagery	No	Delineated from historical aerial in Google Earth
3/11/2009	Google Earth[17]	Google Earth imagery	No	Delineated from historical aerial in Google Earth

SOURCES: See Section 5, References, for sources.

2.2 Mapping

Mapping was performed using numerous types of input data: drone-based videos and photographs, georeferenced aerial photographs, and ground-based oblique videos and photographs. Due to the different types of input data, confidence in the accuracy of resultant LWD footprint mapping was variable. In Google Earth, LWD locations were visually identified and outlined on the georeferenced historical aerial images. For the drone video footage from 4/9/2018, a still image capture was georeferenced to an acceptable level to outline LWD footprints. For all other LWD mapping, locations and footprints were estimated using landmarks such as power poles, Garmire Road bridge piers, and the parking lot access road. Due to the uncertainty in estimating locations of LWD from non-georeferenced sources, the estimated LWD locations from these sources are inherently of slightly lower confidence than LWD locations mapped using Google Earth or other georeferenced images.

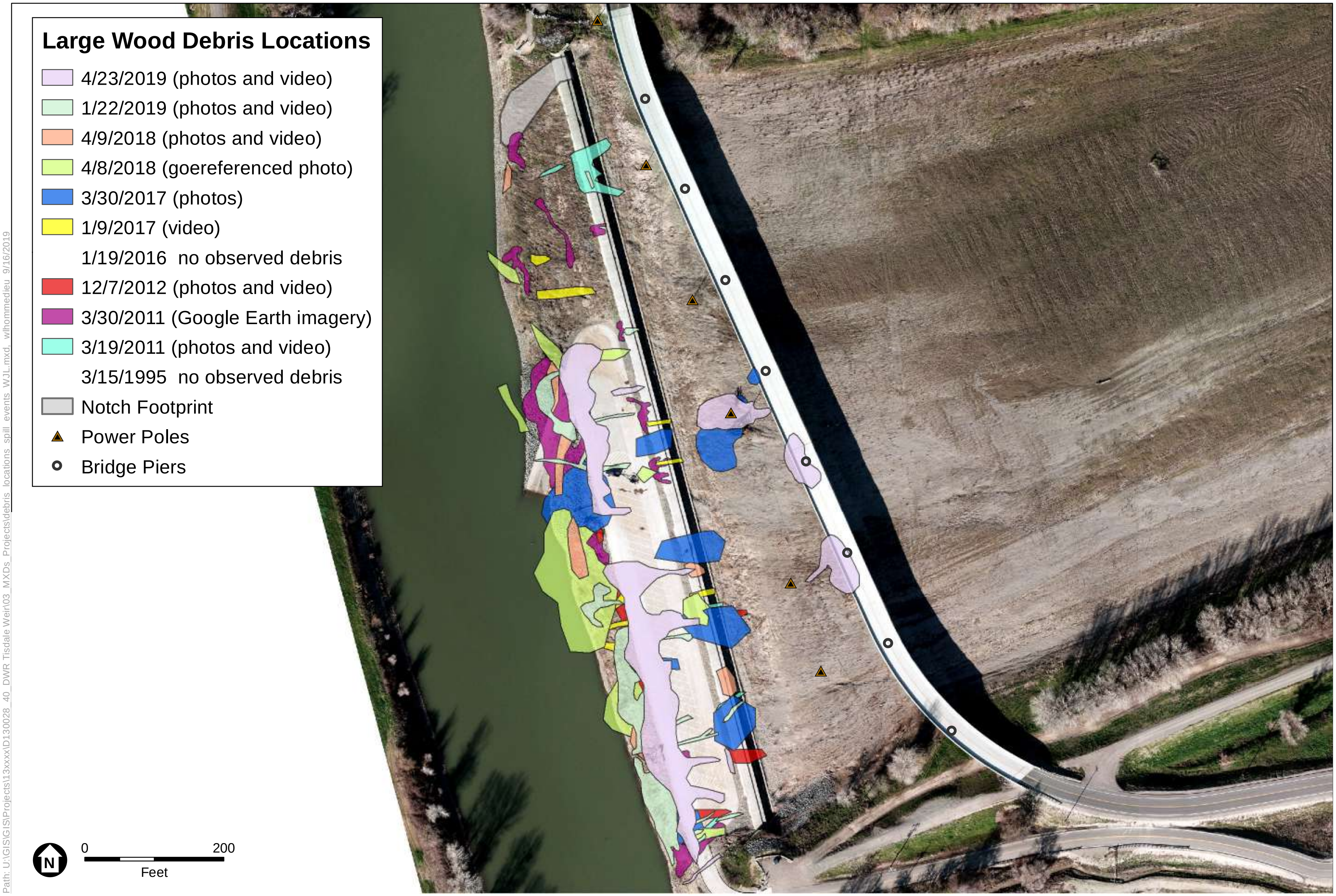
Mapping of LWD locations was performed using videos and images collected during overtopping events at Tisdale Weir and also following overtopping events. LWD locations mapped from images following overtopping events do not necessarily represent the location where LWD was deposited. Based on examination of LWD in images following overtopping events, it is apparent that some LWD has been moved, collected, and/or otherwise manipulated. However, LWD locations following overtopping events were mapped on the assumption that LWD would not be moved far from its original location and the mapped locations could serve as a close proxy for the original location of deposition.

3. Results

Figures 2 and **3** show the mapped LWD footprints for overtopping events and periods following overtopping events, respectively, as well as the current design location of the proposed weir notch, power poles within Tisdale Bypass, and Garmire Road bridge piers. Mapped locations indicate that LWD is primarily deposited along Tisdale Weir and in the area west of the weir (including the parking area). LWD was also observed in the area between the weir and Garmire Bridge, mostly clustered around power poles or bridge piers. There is an approximately 70-foot length of the weir starting from the north bank where no LWD was mapped, which includes the area of the proposed notch alternative. Mapped locations appear to indicate that the majority of LWD is deposited along the southern two thirds of the weir, with the largest accumulations occurring in the parking lot area.

4. Discussion

Under existing conditions, most LWD is deposited along the southern two thirds of the weir. Given these findings, a weir notch located at the southern end of the weir would be more likely to rack LWD and entrain additional LWD into Tisdale Bypass. A weir notch located at the northern end of the weir would alter existing hydraulic conditions by increasing flow through the northern portion of the weir and could potentially result in increased LWD recruitment to the north where LWD has been historically less frequently deposited. However, given the natural tendency for deposition to the south, the risk of LWD racking and entrainment at the northern notch is relatively low.

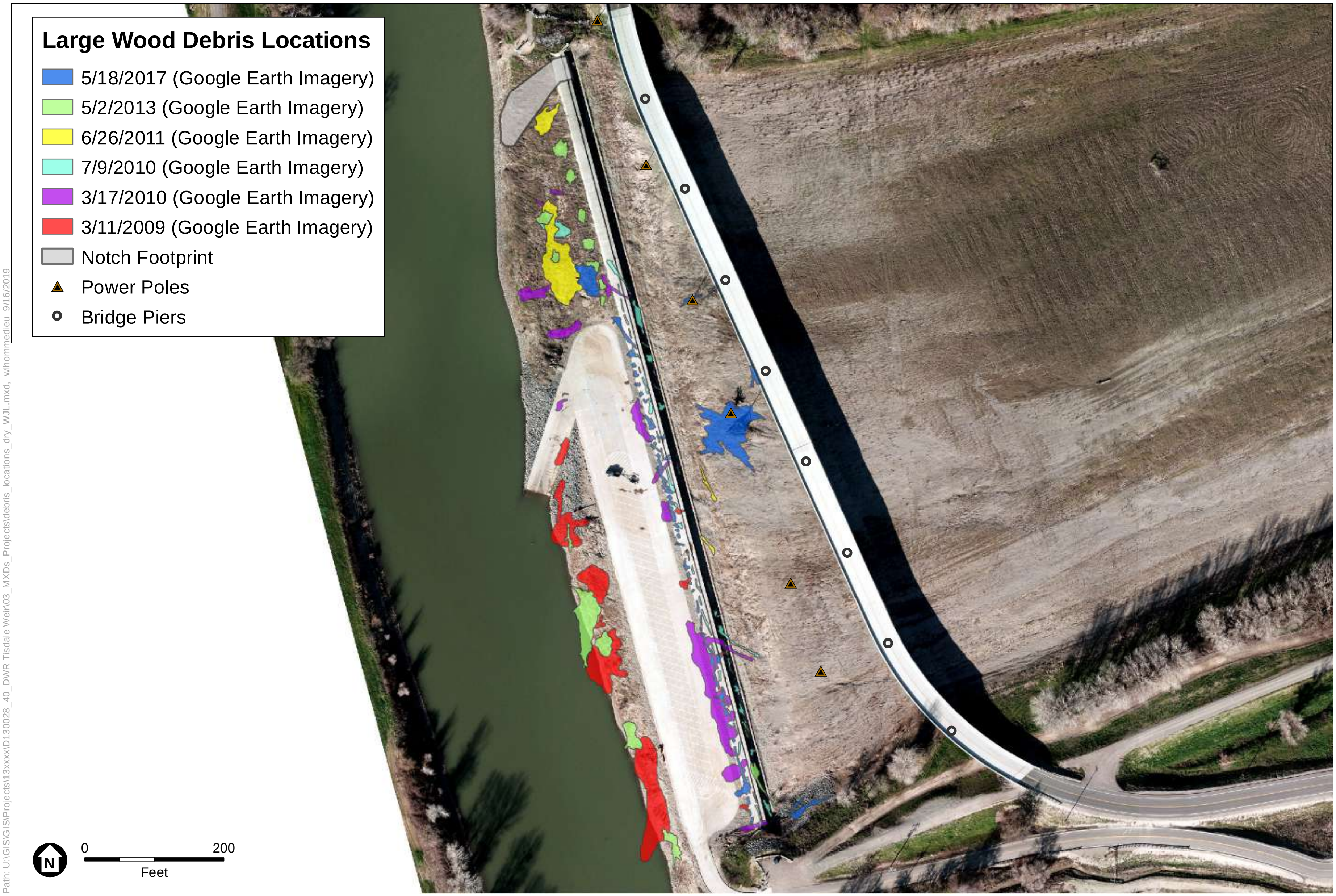


NOTES: Large wood debris locations digitized from images and video of spill events

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 2
Large Wood Debris Locations During Spill Events

ESA



NOTES: Large wood debris (LWD) locations digitized using Google Earth imagery during dry periods.

LWD locations reflect that debris has been moved and collected during maintenance following spill events.

Tisdale Weir Rehabilitation and Fish Passage Project

Figure 3
Large Wood Debris Locations After Spill Events

ESA

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Appendix C
Sediment Budget Analysis Technical Memorandum

A copy of this appendix is included in this EIR as Appendix H.

Appendix D
Feasibility-Level Alternatives Cost Estimates

TISDALE WEIR REHABILITATION AND FISH PASSAGE PROJECT - FEASIBILITY-LEVEL ALTERNATIVES COST ESTIMATES

Item No.	Item	Unit Price	Units	Alternative 1 North Notch		Alternative 2 South Notch		Alternative 3 North & South Notches	
				Quantity	Cost	Quantity	Cost	Quantity	Cost
1	**Site Coordination (Component 1)**								
	SPCC Plan	$2,500	LS	1	$2,500	1	$2,500	1	$2,500
	Mobilization & Demobilization	$0	LS	1	$185,000		$190,000		$214,000
	Temporary Traffic Control at Boat Launch & Roadways	$25,000	LS	1	$25,000	1	$25,000	1	$25,000
	Construction Fencing and Security/Lighting	$5,000	LS	1	$5,000	1	$5,000	1	$5,000
	Staging Area Clearing & Grubbing	$5,570	AC	1	$5,570	1	$5,570	1	$ 5,570
	Construction Area Clearing & Grubbing	$5,570	AC	4.6	$25,622	4.6	$25,622	4.6	$ 25,622
	Stripping	$3,340	AC	4.6	$15,364	4.6	$15,364	4.6	$ 15,364
	Post-Construction Road Improvements	$10,000	LS	1	$10,000	1	$10,000	1	$10,000
2	**Site Improvements (Component 2)**								
	Utility Pole Removal/Permits	$5,000	EA	1	$5,000	1	$5,000	1	$5,000
	Install power & fiber optic conduit on bridge	$10,000	EA	1	$10,000	1	$10,000	1	$10,000
	Plant with erosion resistant vegetation	$5,000	EA	1	$5,000	1	$5,000	1	$5,000
	Hydroseeding	$2,230	AC	3	$5,798	3	$5,798	3	$5,798
	Cobble Stabilizing Along Upstream Weir Edge	$145	CY	1,379	$199,731	1,379	$199,731	1,379	$ 199,731
3	**South Abutment (Component 3)**								
	South Abutment Demolition	$192	CY	83	$15,896	83	$15,896	83	$ 15,896
	South Abutment Reconstruction (Concrete)	$1,045	CY	83	$86,764	167	$174,573	83	$ 86,764
	South Abutment Scour Protection (RipRap)	$279	CY	289	$80,683	289	$80,683	289	$ 80,683
	Equipment / Crane Pad Construction	$20,000	LS		$0	1	$20,000	1	$ 20,000
	Earth Fill	$42	CY		$0	2,246	$94,291	2,246	$ 94,291
	Gravel Aggregate	$92	CY		$0	1,260	$116,374	1,260	$ 116,374
4	**North Abutment (Component 4)**								
	North Abutment Demolition	$192	CY	83	$15,896	83	$15,896	83	$ 15,896
	North Abutment Reconstruction (Concrete)	$1,045	CY	167	$174,573	83	$86,764	167	$ 174,573
	North Abutment Scour Protection (RipRap)	$279	CY	2,815	$785,891	2,815	$785,891	2,815	$ 785,891
	Equipment / Crane Pad Construction	$20,000	LS	1	$20,000		$0	1	$20,000
	Earth Fill	$42	CY	2,246	$94,291		$0	2,246	$ 94,291
	Gravel Aggregate	$92	CY	1,260	$116,374		$0	1,260	$ 116,374

TISDALE WEIR REHABILITATION AND FISH PASSAGE PROJECT - FEASIBILITY-LEVEL ALTERNATIVES COST ESTIMATES

Item No.	Item	Unit Price	Units	Alternative 1 North Notch		Alternative 2 South Notch		Alternative 3 North & South Notches	
				Quantity	Cost	Quantity	Cost	Quantity	Cost
5	**Connection Channel (Component 5)**								
	Excavation	$26	CY	3,222	$85,340	4,989	$132,141	8,211	$ 217,481
	Concrete	$1,045	CY	318	$332,421	350	$365,663	668	$ 698,085
	Base Rock	$115	CY	318	$36,713	350	$40,385	668	$ 77,098
	Rip Rap	$266	CY	688	$183,008	757	$201,362	1,445	$ 384,370
	Cofferdam Construction/Removal (sheet pile)	$1,903	LF	200	$380,627	200	$380,626.53	400	$761,253
	Fish Salvage & Dewatering Operation	$20,000	LS	1	$20,000	1	$20,000	2	$40,000
	South Notch Bridge & Road Work	$362	SF	0	$0	2,400	$869,400	2,400	$869,400
	Install South Notch Bridge with Safety Improvements	$125,000	LS	0	$0	1	$125,000	1	$125,000
6	**Weir Notch (Component 6)**								
	Weir Notch Concrete Demolition	$200	CY	404	$80,666	404	$80,666	808	$ 161,331
	Concrete	$1,045	CY	53	$55,404	53	$55,404	106	$ 110,807
	Base Rock	$115	CY	53	$6,119	53	$6,119	106	$ 12,238
7	**Operable Bottom Hinge Gates (Component 7)**								
	Operable Bottom Hinge Gates	$240,000	EA	1	$240,000	1	$240,000	2	$ 480,000
	Gate Air Supply	$46,000	EA	1	$46,000	1	$46,000	2	$ 92,000
	Freight FOB Shipping to Central California	$10,000	EA	1	$10,000	1	$10,000	2	$20,000
	Gate Installation and Air Pipes	$114,400	EA	1	$114,400	1	$114,400	2	$228,800
8	**Weir Rehabilitation (Component 8)**								
	Annular Grouting	$275,000	LS	1	$275,000	1	$275,000	0.95	$261,250
	Resurface Weir Cap with Epoxy/Mortar Grout	$2,000	CY	425	$850,000	425	$850,000	425.00	$850,000
9	**Energy Dissipation & Fish Basin (Component 9)**								
	Fish Salvage & Dewatering Operation	$20,000	LS	1	$20,000	1	$20,000	1	$20,000
	Excavation	$26	CY	12,380	$327,903	12,512	$331,399	12,902	$ 341,729
	Rip Rap	$266	CY	2,533	$673,778	2,833	$753,578	3,167	$ 842,422
	Base Rock	$115	CY	11,478	$1,325,139	11,610	$1,340,378	12,000	$ 1,385,404
	Concrete	$1,045	CY	11,478	$11,998,528	11,610	$12,136,515	12,000	$ 12,544,201

TISDALE WEIR REHABILITATION AND FISH PASSAGE PROJECT - FEASIBILITY-LEVEL ALTERNATIVES COST ESTIMATES

Item No.	Item	Unit Price	Units	Alternative 1 North Notch		Alternative 2 South Notch		Alternative 3 North & South Notches	
				Quantity	Cost	Quantity	Cost	Quantity	Cost
10	**Control Building (Component 10)**								
	Control Building Constructon (Foundation)	$1,045	CY	46	$48,086	46	$48,086	92	$ 96,172
	Control Building Structure	$50,000	LS	1	$50,000	1	$50,000	2	$ 100,000
11	**Basin Access Ramps (Component 11)**								
	Tree removal (>2" dbh) north bypass bank	$200	EA	100	$20,000	100	$20,000	100	$ 20,000
	South Basin Access Ramp (Gravel)	$115	CY	370	$42,717	370	$42,717	370	$ 42,717

	Alternative 1	Alternative 2	Alternative 3
Direct Item Subtotal	**$19,111,802**	**$20,449,793**	**$22,931,377**
Contingency @ 30%	$5,733,541	$6,134,938	$6,879,413
California Sales and Use Tax Rate for Sutter County@ 7.25%	$1,385,606	$1,482,610	$1,662,525
Construction Total	**$26,230,948**	**$28,067,341**	**$31,473,315**
Planning, Engineering and Design @ 15%	$3,934,642	$4,210,101.17	$4,720,997.31
Project Management and Administration @ 10%	$2,623,095	$2,806,734.11	$3,147,331.54
Permitting and Legal @ 5%	$1,311,547	$1,403,367.06	$1,573,665.77
Engineering During Construction @ 2%	$524,619	$561,346.82	$629,466.31
Construction Management / Site Inspection @ 15%	$3,934,642	$4,210,101.17	$4,720,997.31
Project Total	**$38,559,494**	**$41,258,991**	**$46,265,774**
Low Estimate: -30%	**$26,991,646**	**$28,881,294**	**$32,386,042**
High Estimate: +50%	**$57,839,241**	**$61,888,487**	**$69,398,660**

Appendix E
Tisdale Weir Alternatives Evaluation Matrix

TISDALE WEIR ALTERNATIVES EVALUATION MATRIX

Goals and Objectives	Evaluation Criteria	Relative Importance	Scoring (0 - 3 best)				Scoring Rationale	Weighted Scores			
		(Weighting 1-3 most imp.)	No Action	Alternative 1	Alternative 2	Alternative 3		No Action	Alternative 1	Alternative 2	Alternative 3
The overall project goal is to rehabilitate the Tisdale Weir to address structural deficiencies and address the fish passage and stranding issues at the weir.	Criteria that describe multiple benefits and impacts.	The weighting (relative importance) of each of the criteria using a common scale.	Alternative	North Notch	South Notch	Dual Notches		Alternative	North Notch	South Notch	Dual Notches
CVFPP Goals			**3**	**14**	**14**	**13**		**6**	**37**	**37**	**35**
Improves flood risk management	Improves public safety, preparedness, and emergency response (repairs aging infrastructure)	3	0	3	3	3	No action could result in weir failure; Alts 1-3 all equally improve flood risk management (ie, reduce risk of failure).	0	9	9	9
Promotes ecosystem functions	Integrates the recovery of key species into flood management system improvements	3	0	3	3	3	Species recovery (via fish passage) is equally achieved with all scenarios (e.g., fish passage analysis yielded the same results for the dual and single notch alternatives)	0	9	9	9
Promotes multi-benefit projects	Contributes to broader integrated water management objectives	3	0	3	3	3	All alternatives contribute to broader integrated water management objectives	0	9	9	9
Improves operations and maintenance	Reduces systemwide maintenance and repair requirements	2	3	2	2	1	Installation of operable gates will inherently increase O&M with single or dual notch alternatives over existing conditions	6	4	4	2
Improves institutional support	Enables effective and adaptive integrated flood management	2	0	3	3	3	Fish passage improvements lessen conflicting mandates between flood management and species recovery	0	6	6	6
General Construction Project Goals			**3**	**14**	**11**	**7**		**3**	**26**	**21**	**13**
Results in a Cost-Effective Project	Provides greater benefits for the associated cost	3	0	3	3	2	Measuring solely fish passage benefits, a dual notch may not pass twice as many fish for a higher cost of construction and additional O&M	0	9	9	6
Results in a Constructible Project	More likely to be constructed on time and save the project money	2	0	3	2	1	The south notch will require a bridge crossing and dual notches will require more construction time/risk	0	6	4	2
Results in an Efficient Project	Can be operated and maintained with a lower cost	2	0	3	2	1	The south notch and dual notches alternatives will likely require more O&M for sediment and large wood debris removal	0	6	4	2
Results in a Sustainable Project	Supports the continuity of economic, social, institutional, and environmental aspects of human society and the environment	1	0	3	2	2	Measuring solely fish passage benefits, the southern and dual notch alt.s are likely to have incrementally higher cost of construction and O&M as well as risk of damage and inoperability from sediment and large wood debris	0	3	2	2
Results in a Safe Project	Maintains the welfare and protection of the general public at the weir	1	3	2	2	1	Notch(es) and connecting channels may increase risks to boaters/fishers due to higher localized flow rates and velocities	3	2	2	1
Weir Rehabilitation Objectives			**0**	**9**	**8**	**8**		**0**	**21**	**18**	**18**
Restores the Structural Integrity of the Weir Structure	Provide repairs to stop structural degradation	3	0	3	3	3	The weir rehabilitation management measures are common for all alternatives.	0	9	9	9
Extends the Design Life of the Weir Structure	Incorporate new engineering technologies/techniques in repairs to further extend design life	3	0	3	2	2	The weir rehabilitation management measures are common for all alternatives; however, the south and dual notch alternatives may reduce the design life due to higher likelihood of damage and O&M needs	0	9	6	6
Provides Improved Monitoring of Weir Overflow	Augment single north flow gage with gages at south end and at weir sill	1	0	3	3	3	The weir rehabilitation will include instrumentation common to all alternatives	0	3	3	3
Fish Passage Objectives			**0**	**8**	**8**	**8**		**0**	**21**	**21**	**21**
Reduces Fish Passage Problems	Reduces flow depth, velocity, jump depth, burst speed/distance passage barriers	3	0	3	3	3	The installation of notches/gates will reduce barriers to fish passage across the weir	0	9	9	9
Increases passage during larger portions of the flood hydrograph	Increases the total time available for passage across the weir	3	0	2	2	2	All alternatives extend the duration of acceptable passage conditions; none are able to meet passage under all anticipated flood flow conditions	0	6	6	6
Reduces Fish Stranding and Delay Problems	Reduces the extent and timing of hydraulic disconnection in the bypass	2	0	3	3	3	The weir rehabilitation will include improvements common to all alternatives that modify the energy dissipation basin to help pass fish	0	6	6	6
Operations & Maintenance Objectives			**3**	**17**	**9**	**7**		**3**	**38**	**18**	**15**
Reduces Operations Impacts from Large Wood Debris (LWD)	Reduces flow blockages and differential weir overflow and physical damages to operable gates from LWD	3	0	3	1	1	LWD accumulations have been observed to increase from north to south along the weir	0	9	3	3
Facilitates Maintenance/Removal of Large Wood Debris (LWD)	Provides procedures/equipment to remove LWD throughout the year	2	0	3	1	1	Gate and bypass access to remove LWD would be common among all alternatives but dual south and notch alternatives may require more maintenance and complications with a bridge	0	6	2	2
Reduces Operations Impacts of Sediment Deposition	Reduces sediment impacts on gate operations and bypass flow conveyance	3	0	3	1	1	Sediment accumulations have been observed to increase from north to south along the weir	0	9	3	3
Facilitates Maintenance of Fish Passage Improvements (Sediment/Debris)	Provides procedures/equipment to remove sediment throughout the year	2	0	3	1	1	Maintenance access requires bridge for south notch and increased maintenance for dual notch alternative	0	6	2	2
Facilitates Fish Rescue Efforts	Provides improved access for net rescue and wadeable conditions	2	0	3	3	2	Basin design imporved ofor all alts; any rescue efforts with dual notches would be double the effort because the basin is split into two drainages and would result in double the effort for seining	0	6	6	4
Reduces incidents of and impacts from vandalism	Reduces opportunities for degradation of infrastructure and/or aesthetics (graffiti)	1	3	2	2	1	The dual notch alternative would increase the amount of infrastructure and exposed surface areas to vandalism	3	2	2	1
Flood Management Objectives			**9**	**8**	**8**	**7**		**27**	**24**	**24**	**21**
Maintains or Minimizes Flood Elevation Increases	Does not increase flood risk in the Tisdale Bypass or Sacramento River	3	3	3	3	3	All notch alternatives can be operated to maintain flood elevations similar to existing conditions	9	9	9	9
Maintains the River/Weir Flood Split and Conveyance Capacity	Maintains CVFPP flood management functions	3	3	3	3	3	All notch alternatives can be operated to maintain the flow split and conveyance similar to existing conditions	9	9	9	9
Maintains or Minimizes Flood Risk to downstream land uses	Does not increase inundation in Butte Slough and the Sutter Bypass for ag or waterfowl hunting	3	3	2	2	1	The increased magnitude and duration of flow through one or two notches will increase flows to downstream areas	9	6	6	3
		Total Scores >	**18**	**70**	**58**	**50**	**Weighted Scores >**	**39**	**167**	**139**	**123**