INITIAL STUDY REPORT

APPENDIX C

UPPER TUOLUMNE RIVER BASIN
FISH MIGRATION BARRIERS STUDY
PROGRESS REPORT

This Page Intentionally Left Blank.

UPPER TUOLUMNE RIVER BASIN FISH MIGRATION BARRIERS STUDY PROGRESS REPORT

LA GRANGE HYDROELECTRIC PROJECT FERC NO. 14581

Prepared for:
Turlock Irrigation District – Turlock, California
Modesto Irrigation District – Modesto, California

Prepared by:
HDR, Inc.

February 2016

This Page Intentionally Left Blank.

Upper Tuolumne River Basin Fish Migration Barriers Study
Progress Report

TABLE OF CONTENTS

List of Figures

List of Tables

List of Attachments

List of Acronyms and Abbreviations

ac-ft .....acre-foot
BLM.....Bureau of Land Management
BOR .....Bureau of Reclamation
CCSF.....City and County of San Francisco
CDFG.....California Department of Fish and Game, now CDFW
CDFW.....California Department of Fish and Wildlife
cfs.....cubic feet per second
CG.....Conservation Group
Districts.....Turlock Irrigation District and Modesto Irrigation District
FERC.....Federal Energy Regulatory Commission
FLA .....Final License Application
FPA .....Federal Power Act
GIS .....geographic information system
ILP.....Integrated Licensing Process
ISR .....Initial Study Report
LGDD .....La Grange Diversion Dam
LP.....Licensing Participant
M&I.....municipal and industrial
MID.....Modesto Irrigation District
NMFS.....National Marine Fisheries Service
NPS .....National Park Service
O&M.....operation and maintenance
PAD.....Pre-Application Document
PSP.....Proposed Study Plan
QA/QC .....quality assurance/quality control
RM .....river mile
RSP .....Revised Study Plan
SD2 .....Scoping Document 2
SPD .....Study Plan Determination
TAF .....thousand acre-feet
TID.....Turlock Irrigation District
TM.....technical memorandum
USFWS .....United States Fish and Wildlife Service
USGS .....United States Geological Survey
USR.....Updated Study Report

1.0 INTRODUCTION

1.1 Background

The Turlock Irrigation District (TID) and Modesto Irrigation District (MID) (collectively, the Districts) own the La Grange Diversion Dam (LGDD) located on the Tuolumne River in Stanislaus County, California (Figures 1.1-1 and 1.1-2). LGDD is 131 feet high and is located at river mile (RM) 52.2 at the exit of a narrow canyon, the walls of which contain the pool formed by the diversion dam. Under normal river flows, the pool formed by the diversion dam extends for approximately one mile upstream. When not in spill mode, the water level upstream of the diversion dam is between elevation 294 feet and 296 feet approximately 90 percent of the time. Within this 2-foot range, the pool storage is estimated to be less than 100 acre-feet of water.

The drainage area of the Tuolumne River upstream of LGDD is approximately 1,550 square miles. Tuolumne River flows upstream of LGDD are regulated by four upstream reservoirs: Hetch Hetchy, Lake Eleanor, Cherry Lake, and Don Pedro. The Don Pedro Hydroelectric Project (Federal Energy Regulatory Commission [the Commission or FERC] No. 2299) is owned jointly by the Districts, and the other three dams are owned by the City and County of San Francisco (CCSF). Inflow to the La Grange pool is the sum of releases from the Don Pedro Project, located 2.3 miles upstream, and very minor contributions from two small intermittent streams downstream of Don Pedro Dam.

LGDD was constructed from 1891 to 1893 displacing Wheaton Dam, which was built by other parties in the early 1870s. LGDD raised the level of the Tuolumne River to permit the diversion and delivery of water by gravity to irrigation systems owned by TID and MID. The Districts' irrigation systems currently provide water to over 200,000 acres of prime Central Valley farmland and drinking water to the City of Modesto. Built in 1924, the La Grange hydroelectric plant is located approximately 0.2 miles downstream of LGDD on the east (left) bank of the Tuolumne River and is owned and operated by TID. The powerhouse has a capacity of slightly less than five megawatts. The La Grange Hydroelectric Project (La Grange Project or Project; FERC No. 14581) operates in a run-of-river mode. The LGDD provides no flood control benefits, and there are no recreation facilities associated with the Project or the La Grange pool.

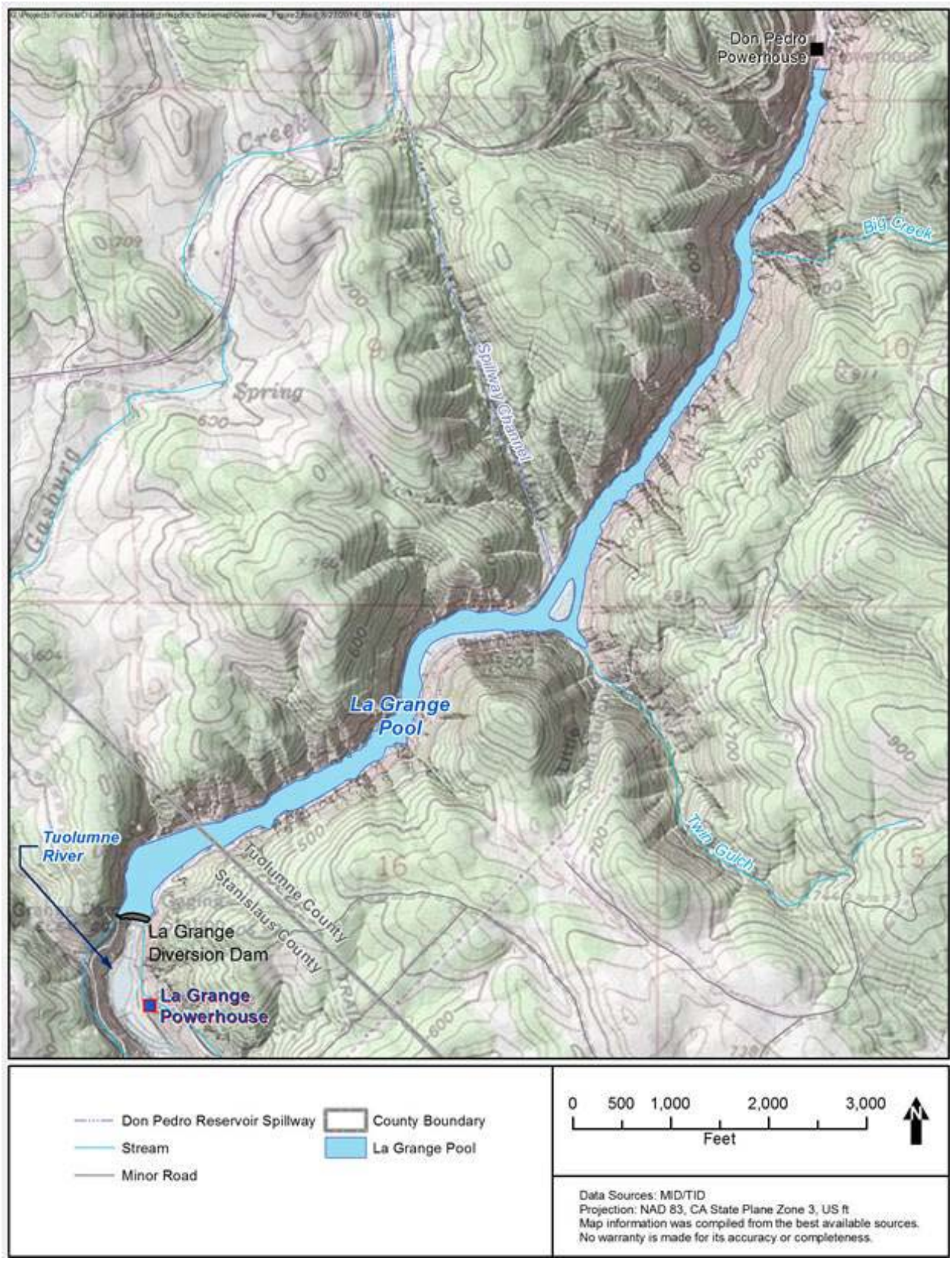


Figure 1.1-1. La Grange Hydroelectric Project location map.

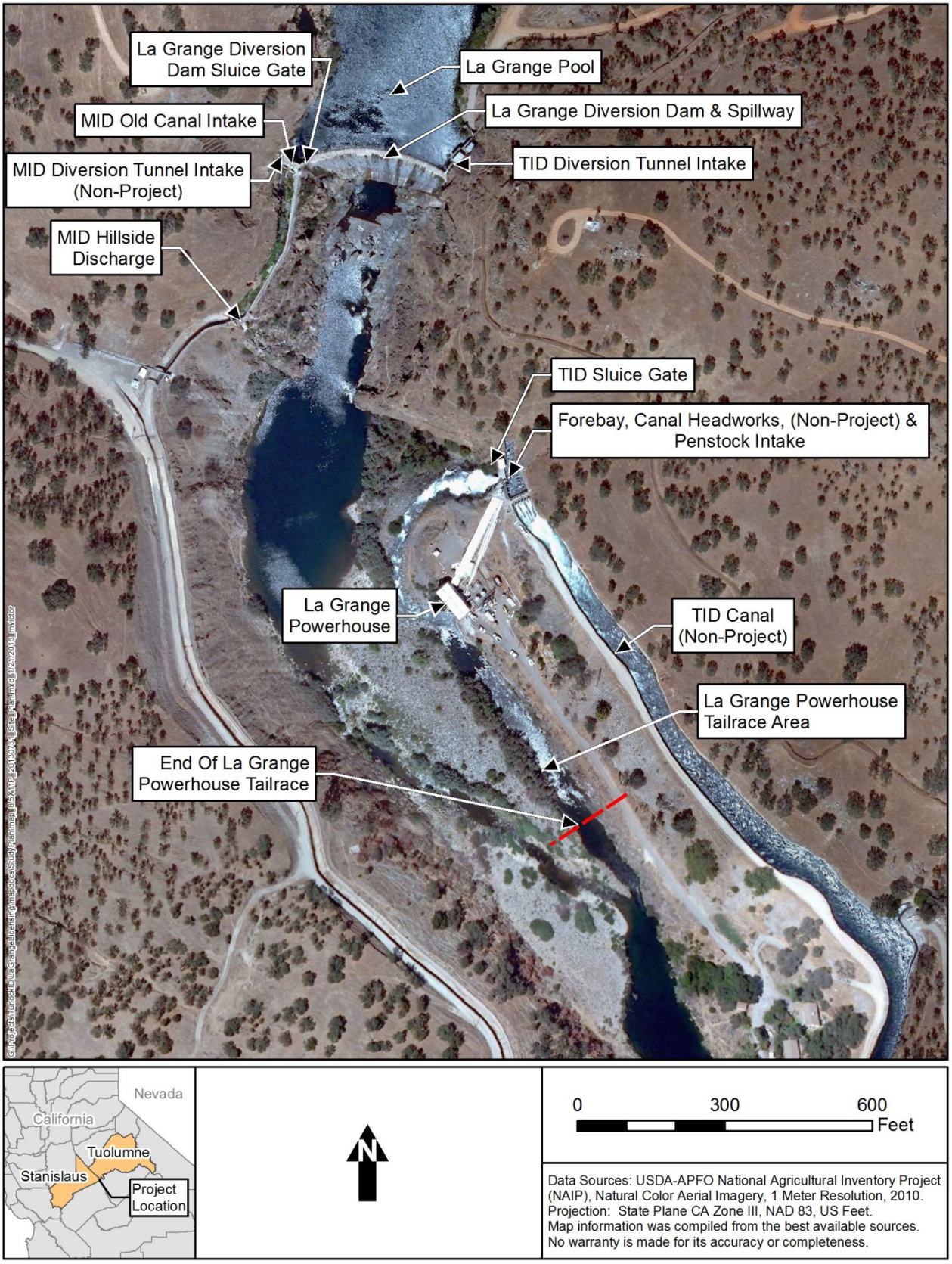


Figure 1.1-2. La Grange Hydroelectric Project site plan.

1.2 Licensing Process

On January 29, 2014, the Districts commenced the pre-filing process for the licensing of the La Grange Project by filing a Pre-Application Document (PAD) with FERC[1]. The Districts' PAD included descriptions of the Project facilities, operations, and lands as well as a summary of existing information available on Project area resources.

On September 5, 2014, the Districts filed their Proposed Study Plan (PSP) to assess Project effects on fish and aquatic resources, recreation, and cultural resources in support of their intent to license the Project. On October 6, 2014, the Districts held a PSP meeting at MID's offices in Modesto, California. Based on discussion at the PSP meeting, the Districts prepared an Updated Study Plan document that went to licensing participants (LP) for review and comment on November 21, 2014. On December 4, 2014, the National Marine Fisheries Service (NMFS), the Conservation Groups (CG), and the California Department of Fish and Wildlife (CDFW) filed comments on the PSP and/or Updated Study Plan.

On January 5, 2015, in response to comments from LPs, the Districts filed their Revised Study Plan (RSP) containing three study plans: (1) Cultural Resources Study Plan; (2) Recreation Access and Safety Assessment Study Plan; and (3) Fish Passage Assessment Study Plan[2]. Comments on the RSP were received from CDFW on January 16, 2015, and from NMFS, the CGs and the City of Modesto on January 20, 2015.

On February 2, 2015, FERC issued the Study Plan Determination (SPD), approving or approving with modifications six studies (Table 1.2-1). Of those six studies, five had been proposed by the Districts in the RSP. The Districts note that although FERC's SPD identified the Fish Passage Barrier Assessment, Fish Passage Facilities Alternatives Assessment, and Fish Habitat and Stranding Assessment below La Grange Diversion Dam as three separate studies, all three assessments are elements of the larger Fish Passage Assessment as described in the RSP. The sixth study approved by FERC, Effects of the Project and Related Activities on the Losses of Marine-Derived Nutrients in the Tuolumne River, was requested by NMFS in its July 22, 2014 comment letter. Of the eight studies requested by LPs, FERC approved only the NMFS study noted above.

Although FERC's SPD did not require the Districts to undertake the Upper Tuolumne River Basin Habitat Assessment studies contained in the RSP, the Districts are voluntarily conducting the Upper River Barriers Study and the Water Temperature Monitoring and Modeling Study. Regarding the third component of the Upper Tuolumne River Basin Habitat Assessment, the ongoing upstream habitat characterization work being completed by NMFS, the Districts anticipate the results of this work becoming available for consideration in this licensing proceeding.

[1] On December 19, 2012, Commission staff issued an order finding that the La Grange Hydroelectric Project is required to be licensed under Section 23(b)(1) of the Federal Power Act. Turlock Irrigation District and Modesto Irrigation District, 141 FERC ¶ 62,211 (2012), aff'd Turlock Irrigation District and Modesto Irrigation District, 144 FERC ¶ 61,051 (2013). On May 15, 2015, the U.S. Court of Appeals for the District of Columbia Circuit denied the Districts' appeal and affirmed the Commission's finding that the La Grange Hydroelectric Project requires licensing. Turlock Irrigation District, et al., v. FERC, et al., No. 13-1250 (D.C. Cir. May 15, 2015).

[2] The Fish Passage Assessment Study Plan contained a number of individual, but related, study elements.

Table 1.2-1. Studies approved or approved with modifications in FERC's Study Plan Determination.

No.	Study	Approved by FERC in SPD without Modifications	Approved by FERC in SPD with Modifications
1	Recreation Access and Safety Assessment		X
2	Cultural Resources Study		X
3	Fish Passage Barrier Assessment		X[1]
4	Fish Passage Facilities Alternatives Assessment		X
5	Fish Habitat and Stranding Assessment below La Grange Dam		X
6	Effects of the Project and Related Activities on the Losses of Marine-Derived Nutrients in the Tuolumne River	X[2]	

[1] Page A-1 of Appendix A of FERC's SPD states that FERC approved with modifications the Fish Passage Barrier Assessment. However, the Districts found no modifications to this study plan in the SPD and page B-7 of the SPD states that "no modifications to the study plan are recommended."

[2] FERC directed the Districts to conduct the study plan as proposed by NMFS.

In addition to the six studies noted in Table 1.2-1, the SPD required the Districts to develop a plan to monitor anadromous fish movement in the Project's powerhouse draft tubes and to determine the potential for injury or mortality from contact with the turbine runners. Per the SPD, the Districts developed a study plan in consultation with NMFS and other LPs. The Districts filed the Investigation of Fish Attraction to La Grange Powerhouse Draft Tubes study plan with FERC on June 11, 2015, and on August 12, 2015, FERC approved the study plan as filed.

This progress report describes the objectives, methods, and preliminary results of the Upper Tuolumne River Basin Fish Migration Barriers Study (herein referred to as the Upper River Barriers Study) as implemented by the Districts in accordance with FERC's SPD. The Upper River Barriers Study is one of three study components of the Upper Tuolumne River Basin Habitat Assessment as described in the RSP. Documents relating to the Project licensing are publicly available on the Districts' licensing website at www.lagrange-licensing.com/.

1.3 Study Plan

The Recovery Plan for the Evolutionary 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 (herein referred to as the Recovery Plan) (NMFS 2014) identifies the Tuolumne River above Don Pedro Reservoir as a candidate area for reintroduction of Central Valley steelhead and spring-run Chinook salmon. Recovery actions proposed in the Recovery Plan include a feasibility evaluation of a steelhead and spring-run Chinook passage program for La Grange and Don Pedro dams. The Recovery Plan states, "The program should include feasibility studies, habitat evaluations, fish passage design studies, and a pilot reintroduction phase prior to implementation of the long-term reintroduction program." However, little information exists to reliably assess the current quantity and quality of suitable habitat for the adult, juvenile, fry, and egg life stages of these salmonid species in the upper Tuolumne River watershed. NMFS requested information on upstream fish migration barriers

and water temperatures in the upper basin to inform its decision making in the context of potential Federal Power Act (FPA) Section 10(j) recommendations and Section 18 fishway prescriptions as well as Endangered Species Act consultation.

In the RSP, the Districts proposed to conduct an Upper Tuolumne River Basin Habitat Assessment, of which there are three components: (1) a two-year phased assessment of physical barriers in the upper Tuolumne River; (2) a two-year phased assessment of water temperatures in the upper Tuolumne River; and (3) a summary of data from the upper Tuolumne River habitat evaluation being conducted by NMFS and identification of additional information needs following completion of upper Tuolumne River studies. FERC's SPD did not recommend that the Districts conduct the proposed Upper Tuolumne River Basin Habitat Assessment because potential anadromous fish habitat in the upper Tuolumne River above the Don Pedro Project is not affected by operation of either the La Grange or Don Pedro projects and, consequently, there is no nexus between the project operations and effects on anadromous fish habitat in the upper Tuolumne River. Nonetheless, to more fully support LPs in their development of information to supplement the fish passage studies approved by FERC in the SPD, to provide further useful information, to document river conditions between CCSF's Early Intake and the upstream end of the Don Pedro Reservoir, and to foster collaboration among all parties, the Districts decided voluntarily to conduct Items (1) and (2) above.

On July 2, 2015, the Districts circulated the draft Upper Tuolumne River Basin Habitat Assessment – Fish Migration Barriers Component Study Plan to LPs for a 21-day review and comment period. Comments were received from the California Sportfishing Protection Alliance and NMFS. The Districts reviewed the comments and made revisions to the study plan. On July 31, 2015, the Districts filed the final study plan with FERC.

The Upper River Barriers Study Progress Report describes progress on completing Item (1). Progress on Item (2) is presented in the Upper Tuolumne River Basin Water Temperature Monitoring and Modeling Study Progress Report (TID/MID 2016). Item (3) will be completed when the NMFS habitat evaluation results are available to LPs for review.

2.0 STUDY GOALS AND OBJECTIVES

The goal of this study is to assess barriers to the upstream migration of adult spring-run Chinook salmon and steelhead in the upper Tuolumne River basin from the upper end of the Don Pedro Reservoir to the CCSF Early Intake. Study objectives include:

- Compile results from any relevant prior studies and conduct field surveys to identify barriers (both complete and partial) to upstream anadromous salmonid migration in the mainstem Tuolumne River upstream of the Don Pedro Project Boundary and tributaries, including the North, Middle, and South forks of the Tuolumne River, Cherry Creek, and the Clavey River.
- Characterize and document the physical structure of each barrier under base flow and high flow (i.e., spring runoff) conditions.

3.0 STUDY AREA

The study area includes the following mainstem and tributary stream reaches of the Tuolumne River watershed (Figure 3.0-1):

- **Tuolumne River** – From approximate upstream limit of the Don Pedro Project at RM 81 (below the North Fork confluence) upstream to the first total fish passage barrier (as described in Section 4.3 below) and no farther upstream than Early Intake.
- **North Fork Tuolumne River** – From the confluence with the Tuolumne River upstream to the first total fish passage barrier.
- **South Fork/Middle Fork Tuolumne River** – From the confluence with the Tuolumne River upstream to the first total fish passage barrier.
- **Clavey River** – From the confluence with the Tuolumne River upstream to the first total fish passage barrier. Note that Reed Creek (a tributary to the Clavey River) may be included depending upon the presence/absence of a total fish passage barrier downstream of its confluence with the Clavey River.
- **Cherry Creek/Eleanor Creek** – From the confluence with the Tuolumne River upstream to the first total fish passage barrier.

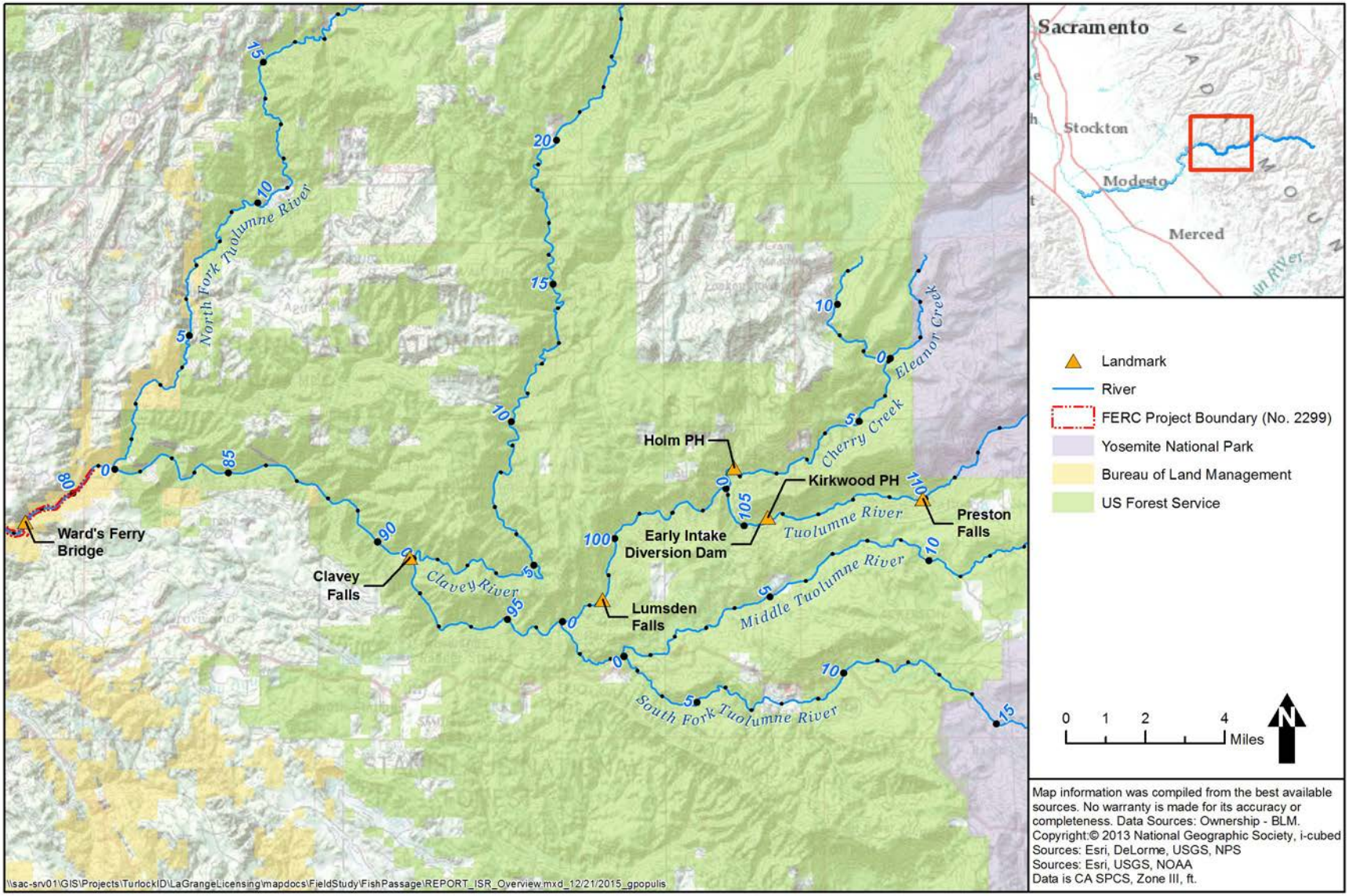


Figure 3.0-1. Overview map presenting the study area with notable rivers, tributaries and features.

4.0 METHODOLOGY

The Upper River Barriers Study included both desktop exercises and measurements in the field. Desktop exercises utilized topographic mapping software, aerial photographs, available hydrologic data, and other existing information to identify initial accounts of physical features that may potentially be barriers to the upstream migration of spring-run Chinook salmon and steelhead. Field investigations included visual observation and the collection of physical data to confirm site characteristics and draw conclusions regarding the ability of migrating anadromous fish to pass physical features that may potentially be barriers.

Features identified within the study area through desktop or field exercises which may or may not be impediments to fish passage are classified in the report as follows:

- Potential Barrier – A feature identified by the study team that may exhibit conditions which create an impediment to upstream fish passage of adult spring-run Chinook or steelhead on a partial, temporal, or intermittent basis but where conclusions have not yet been developed to establish the duration, range of flows, or conditions when or if the feature is passable.
- Partial Barrier – A feature which has been evaluated by the study team and conclusions have been developed to establish the duration, range of flows, or conditions when the feature is passable.
- Total Barrier – A feature which has been evaluated by the study team and found to be not passable by adult spring-run Chinook or steelhead throughout the range of flows when migration is anticipated.
- Passable Feature – A feature which has been evaluated by the study team and found to be passable by adult spring-run Chinook or steelhead throughout the range of flows when migration is anticipated.

The presence and/or absence of barriers to upstream passage and findings regarding the ability of fish to pass identified features employed a phased approach as described below.

- A list of potential barriers to upstream passage was initially developed based upon the information gathered by desktop methods described in Section 4.1;
- As described in Section 4.2, field surveys were performed to gather physical data at each feature and to characterize major elements which influence fish passage;
- A screening level barrier assessment was performed using the data from activities described in Section 4.1 and the field surveys described in Section 4.2;
- Each feature identified was classified as one of the following: (1) a “total barrier” to fish passage; (2) a “passable feature”; or (3) a “potential barrier” to fish passage. The initial classification was based upon screening criteria summarized in Section 4.3; and
- Potential barriers requiring additional field surveys, further evaluation, and final classification were identified and recommendations for activities to be performed in the 2016 field season were made.

In summary, the determination of fish passage and ultimate classification for each physical feature identified in this study was performed using the process outlined in Figure 4.0-1. Activities performed in 2015 focused on collection of data, performing the first field surveys, and conducting a screening level assessment of features identified in the field.

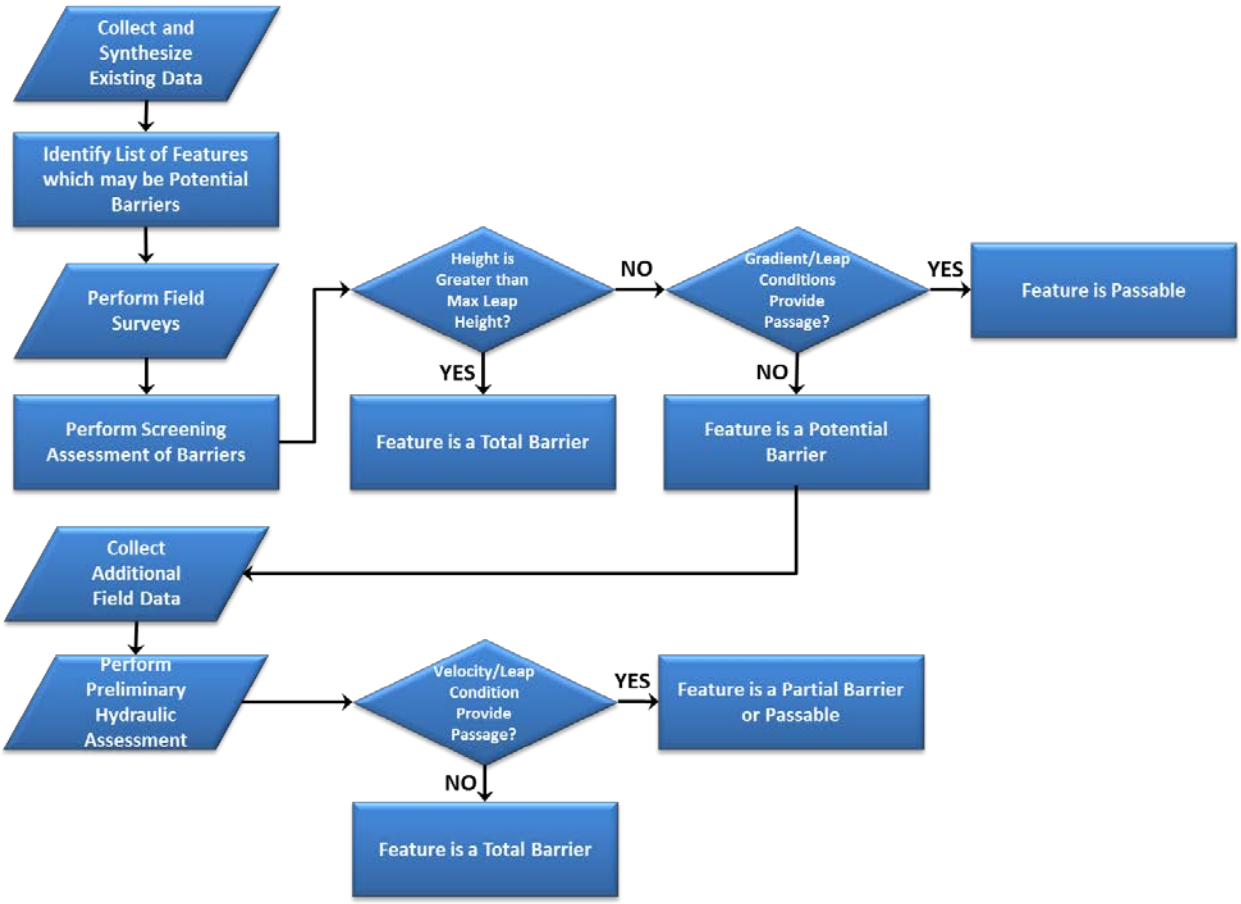


Figure 4.0-1. Process flow chart summarizing barrier study methodology.

4.1 Obtain and Review Existing Information

Existing data pertinent to the existence and classification of potential impediments to migration of anadromous salmonids within the study area were compiled and reviewed. Completion of this task included background research into multiple sources of data including habitat studies, recreational documentation (such as recreational boating maps and photos), ethnographic data, videos and photographs, newspaper records, historical accounts, and available geographic information system (GIS) data characterizing conditions in the upper Tuolumne River basin. This task also included requesting data from the Districts, federal and state agencies, and other entities that have performed work in the study area.

Data from the upper Tuolumne River LiDAR and hyperspectral remote sensing-based habitat evaluation being conducted by NMFS was not available for use in this study. According to NMFS' personnel, initial data are expected to be available in April 2016. Review and

incorporation of any relevant information from the NMFS study would occur upon this information becoming available.

4.2 Perform Field Surveys

Field surveys were performed on August 2 – 6 and October 26 – 27, 2015 to identify barriers in the mainstem Tuolumne, South Fork, and Middle Fork Tuolumne Rivers, as well as the Clavey River. A summary of locations, dates, and activities performed during the 2015 field season is provided in Table 5.2-1. Data and information gathered during the field surveys are presented in the following paragraphs and summarized by river. A photograph log containing images of each feature surveyed and an account of the data collected is provided in Attachment A.

Table 4.2-1. Summary of field surveys performed during the 2015 field season.

River or Tributary	RM or Feature	Activities Performed (Date(s))
Mainstem Tuolumne River	80 to 97	Performed via watercraft (August 2 – 4)
	97 to 103	Not surveyed
	103 to 104.3	Performed on foot (October 27)
	Lumsden Falls	Performed on foot (August 5 and 6)
North Fork	-	Not surveyed due to lack of flow (August 3)
South Fork	0 to 1.9	Performed on foot (August 5)
Clavey River[1]	0 to 2.05	Performed on foot (August 3)
Cherry Creek[1]	1.0 to 1.95	Performed on foot (October 26)
	0 to 1.0	Performed on foot (October 27)

[1] Results were unavailable at the time of reporting.

Conditions in August 2015 did not allow for adequate investigation of the North Fork Tuolumne River as the lower reach of the river had zero flow. A field survey was completed in October 2015 for the Cherry/Eleanor Creek watershed and the reach of the mainstem Tuolumne River from the Cherry Creek confluence upstream to Early Intake. The survey results obtained on potential Cherry Creek barriers are not presented in this document because there was inadequate time available to synthesize the data and develop conclusions at the time this document was published. Conclusions relative to barriers identified within Cherry and Eleanor creeks will be made available in the Updated Study Report (USR).

Watercraft was used primarily to transport personnel and equipment to the Clavey River and the North Fork Tuolumne River confluence with the mainstem Tuolumne River so that surveys could be conducted on foot in those tributaries. Qualitative observations of potential fish passage barriers were made while traveling along the mainstem Tuolumne River from the put-in at Meral's Pool to the take-out at Wards Ferry Bridge but in general it was not necessary to make additional stops while traveling along the mainstem to conduct barrier assessments. One stop was made at Clavey Falls to collect data and to conduct barrier surveys in the Clavey River.

Field surveys performed on foot were performed over very difficult terrain. Progress was slow and arduous even at low flow conditions. Challenges along the Clavey River and the South Fork Tuolumne River included frequent deep and shallow water crossings, bouldering, climbing, steep descents, and navigating through high levels of topographic diversity. In many cases, water portage through deep pools was required to avoid technical climbing requirements or traversing steep confined bedrock walls. Travel rates, excluding time required for surveying, were as slow

as two or three hours per mile in higher gradient areas. Given the difficult conditions, limited field gear was carried and in many cases abbreviated surveys were conducted given the constraint of safety protocols and available daylight. The following information was recorded at each identified feature during the field surveys:

- GPS coordinate points;
- Effective height of each barrier either measured in the field or through approximation of scaled features in photographs;
- Gradient/slope of the barrier (when applicable) measured with range finder and hand level;
- Notes describing leap conditions and presence of obstacles (e.g. overhanging ledges, shallow bedrock, dewatered, distance, boulder complex, etc.);
- An assessment and documentation of adjacent channel features that might be inundated at higher flows;
- Photograph of the barrier from one or more relevant photo-points; and
- Periodically flow and velocity measurements describing tributary flow and landing conditions at the feature crest.

The above list deviates slightly from the original elements defined in the original RSP. Three measurements were not consistently recorded: (1) maximum and average depth of plunge pools at the base of barriers; (2) water velocity measurements at the apex of the barrier; and (3) maximum and average depth of the landing zone on the upstream side of the barrier. These elements were not consistently recorded due to site-specific safety considerations, equipment requirements, time constraints, and the ability to measure using alternative desktop methods. Depth of the plunge pool below each barrier was difficult to evaluate on a quantitative basis for all sites and therefore the summary of results presented herein are based on field notes, photographs, and aerial photos available for each site. As conditions allowed, water velocities, depths, and landing conditions above the feature crest were sampled to characterize some features.

Existing information collected during activities summarized in Section 4.1 and field data collected as part of the field surveys in Section 4.2 were synthesized and a screening level fish passage assessment was performed to classify each selected feature as one of the following: (1) a total barrier to fish passage; (2) a passable feature; or (3) a potential barrier to fish passage. Barrier classifications were performed using the methods and criteria detailed in Section 4.3 below.

4.3 Barrier Classification and Rationale

The analysis and classification of barriers was performed by comparing fish swimming and leaping capabilities against the physical characteristics of each potential barrier identified and evaluated in the field. Swimming capabilities for spring-run Chinook salmon and steelhead were calculated using mathematical relationships outlined in Bell (1973), Power and Orsborn (1985), and Hunter and Mayor (1986). Calculated “sustained,” “prolonged,” and “burst” swim speeds

and durations were used to assess those situations where steep gradients create high velocity, turbulent conditions through chutes or cascades. The calculated burst speed for each fish species was also used to calculate the leaping capability using the mathematical relationships presented in Power and Orsborn (1985). Resulting calculations provided a series of leap angles, leap spans, and leap heights for specific size classes of adult fish. The combination of calculated swimming and leaping capabilities was used to identify whether or not a hydraulic feature (high velocity or leap condition) is passable.

The velocity and minimum leap conditions that a fish may experience can vary seasonally and are dependent upon the hydraulic regime occurring at the time a fish attempts to ascend a feature. The data gathered in the tributaries to Tuolumne River during the first field survey represented low-flow conditions; therefore, the first field survey focused on the identification of features exhibiting no opportunities for passage or those that would be classified as total barriers. Based upon the initial findings, collection of additional and more detailed information was recommended for a selected number of features to occur during the second field visit for those barriers that were found to be potential barriers to fish passage. Recommendations for further study are provided in Section 6.0 of this document.

Data and analysis presented by Bell (1973), Power and Orsborn (1985), and Hunter and Mayor (1986) speak generally of "Chinook" salmon or "steelhead" without clearly distinguishing between fall-run or spring-run. The swimming and leaping performance for either run can vary. Variations in ability are associated with the degree of maturation at the time of river entry, fish length, migration distance, the temperature and flow characteristics of the spawning site, and their actual time of spawning. The swimming and leaping capabilities developed for this study are therefore intended to characterize a representative population of spring-run Chinook and winter-run steelhead that are candidates for reintroduction into the upper Tuolumne River watershed according to NMFS' Recovery Plan.

4.3.1 Classification of Total Barriers

Features are classified as a total barrier if a feature exhibits a measured effective barrier height that is greater than the calculated maximum leap height of a spring-run Chinook salmon or steelhead. The maximum leap height is estimated for this study using the burst speed resulting from swimming capability data presented in Bell (1973) and Hunter and Mayor (1986) and the leap height relationships outlined in Powers and Orsborn (1985). Results from these calculations provided estimated leap heights and leap spans over a range of trajectory angles for spring-run Chinook and steelhead. The classification for total barriers used the maximum estimated leap height calculated for a trajectory of 85 degrees.

This study used a maturity coefficient, Cfc, of 0.75 to represent a fish in good condition (i.e., in the river a short time with spawning colors apparent, but still migrating upstream). The Cfc of 0.75 was applied to represent the expected general condition of spring-run Chinook salmon and steelhead by the time they have traveled upstream to the study area. Given that upstream migration requires travel over a significant distance (fish originate from the Bay-Delta and migrate up the San Joaquin River), this Cfc value is expected to be conservative and result in a higher swimming and leaping capability than fish that may reach the upper Tuolumne River.

The maximum leaping capability calculated for steelhead in good condition is provided in Figure 4.3-1. The maximum leaping capability calculated for spring-run Chinook salmon in good condition is provided in Figure 4.3-2.

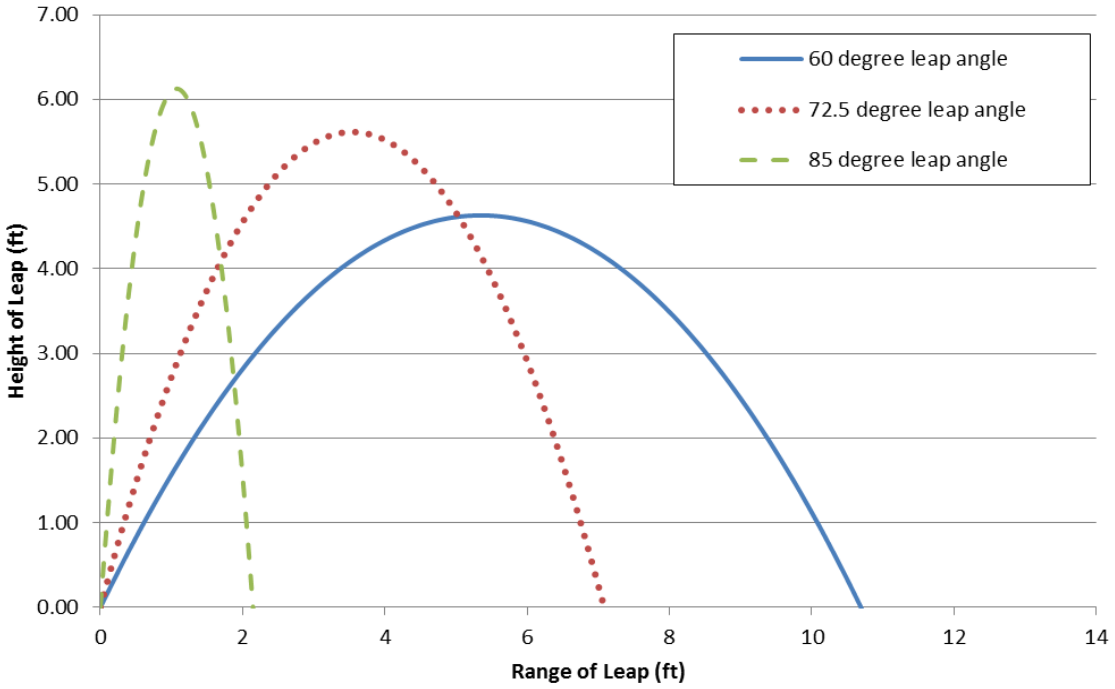


Figure 4.3-1. Maximum leaping capability calculated for steelhead in good condition, Cfc=0.75.

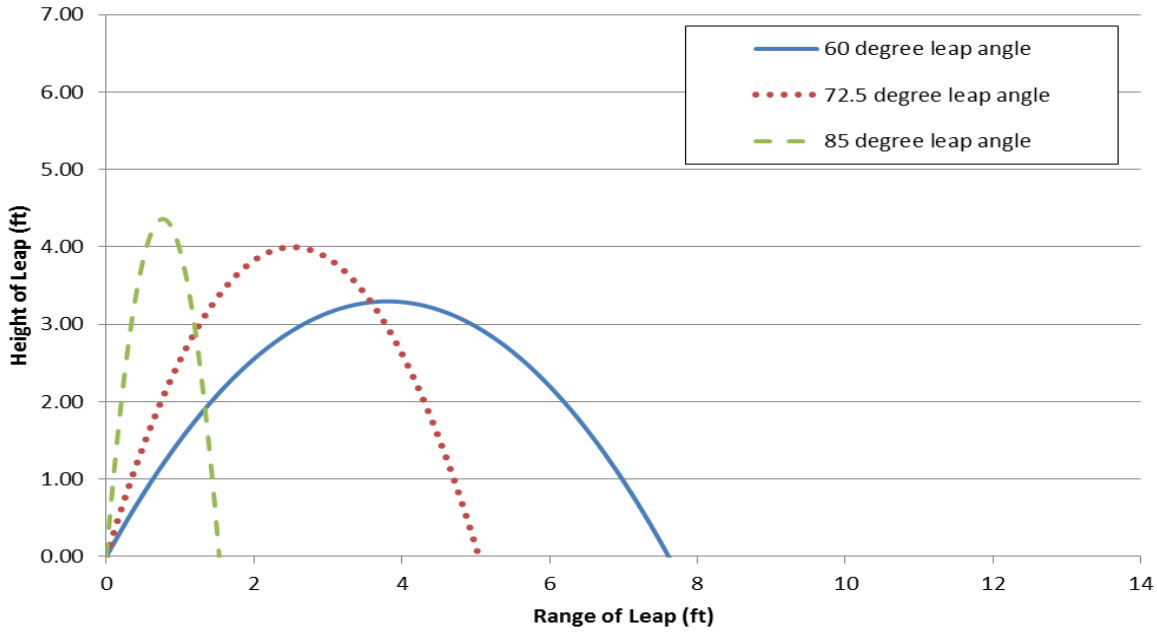


Figure 4.3-2. Maximum leaping capability calculated for spring-run Chinook salmon in good condition, Cfc=0.75.

The calculated maximum leap heights resulting from an 85 degree leap angle and a Cfc of 0.75 are estimated to be 6.12 feet for adult steelhead and 4.36 feet for adult spring-run Chinook salmon. Therefore, a feature with a measured effective height greater than 4.36 or 6.12 feet is classified as a total barrier, with respect to each individual species. One exception to this conclusion is if upon inspection it appeared that the effective leap height in question would be significantly influenced by higher flow regimes or alternative pathways. For example, if the cross-sectional geometry of the tailwater control is narrower than the crest height or landing area then such a feature may exhibit lower hydraulic differential conditions at higher flows, which may have implications upon feature classification. Features where multiple pathways appeared to be hydraulically connected at higher flows were also identified. If the study team determined that passable conditions could exist at different flow regimes, such features were classified as potential barriers and identified for further evaluation. Otherwise, the feature was documented as a total barrier and a recommendation for no further evaluation was made for that site.

4.3.2 Classification of Passable Features

A feature was classified as a passable feature if the feature exhibits a measured effective barrier height, potential leap span, and pool depth that fall within the calculated leaping capabilities estimated using the Powers and Orsborn (1985) methodology or if the average gradient of a feature meets the general requirements outlined in the U.S. Forest Service Handbook 2090.21 Adult Salmonid Migration Blockage (USFS 2001).

In this scenario, a number of leap trajectories, leap spans, and resulting leap heights were evaluated and compared to the barrier heights and leap spans measured in the field. If the measured field condition for a unique feature exhibits values lower than any combination of estimated leap trajectory, leap span, and leap height capability for each species, the feature was classified as passable for that individual species. If an apparent velocity impediment met the general gradient and length requirements outlined in USFS (2001), then the feature was classified as passable. Figure 4.3-1 and Figure 4.3-2 illustrate several potential leaping trajectory, span, and height combinations for adult steelhead and spring-run Chinook salmon in good condition. These values are summarized in Table 4.3-1. General criteria for average gradient and pool depth requirements as described by USFS (2001) are summarized in Table 4.3-2.

Table 4.3-1. Summary of leaping trajectory, span, and height capabilities for spring-run Chinook salmon and steelhead.

Species	Angle of Trajectory (degrees)	Height of Leap (ft)	Range of Leap (ft)
Steelhead	60.0	4.63	5.35
	72.5	5.62	3.55
	85.0	6.12	1.05
Spring-run Chinook Salmon	60.0	3.30	3.80
	72.5	4.00	2.50
	85.0	4.36	0.75

Table 4.3-2. Minimum pool depth and gradient criteria adapted from USFS (2001).

Metric	Criterion
Pool depth: A blockage may be presumed if pool depth is less than the values to the right.	1.25 x jump height, except that there is no minimum pool depth for falls: (a) <4 feet in the case of steelhead; and (b) <2 feet in the case of spring-run Chinook salmon
Steep Channel: A blockage may be presumed if channel steepness is greater than the following without resting places for fish.	>225 feet @ 12% gradient >100 feet @ 16% gradient >50 feet @ 20% gradient

Likewise with the classification of total barriers, if the measured conditions appear to exhibit values lower than any combination of estimated leap trajectory, leap span, flow velocity, and leap height capability for each species but the study team determined that conditions could exist at different flow regimes which were impassible, such features were classified as potential barriers and identified for further evaluation.

4.3.3 Classification of Potential Barriers

River hydraulics have a significant influence on upstream fish passage; the ability of a fish to pass a barrier is variable and can change seasonally. Higher seasonal flow events may increase plunge pool depths and reduce barrier heights when a certain species or portion of a fish population are present and actively migrating upstream. Run timing varies between spring-run Chinook salmon and steelhead. Spring-run Chinook salmon generally enter streams from the ocean coinciding with high flow events and generally hold for an extended period before spawning which may expose them to low flow periods with higher water temperatures. Steelhead enter streams from the ocean coinciding with higher spring flows, move high in the watershed, hold, and spawn during elevated flows (Moyle 2002). The extent to which either species would ascend upstream in the study area during elevated flows is an unknown factor that makes it difficult to determine at what flow a species would likely encounter a potential barrier[3].

Features classified as potential barriers that were identified by the study team exhibited conditions which create an impediment to upstream fish passage of adult spring-run Chinook or steelhead on a temporal or intermittent basis but additional data collection or observations are required to develop final conclusions whether the feature is a total barrier, partial barrier, or passable feature.

Specifically, features were classified as a potential barrier, rather than total barrier or passable feature, if one of the following conditions occurred:

- the identified feature exhibited measured effective barrier heights, horizontal leap distances, or flow velocities greater then the maximum leaping or swimming capability of spring-run

[3] Evaluation of partial barriers will include the identification of anticipated migration timing and potential flows experienced during migration in the Tuolumne River mainstem and tributaries. Flow periods and quantities should also account for the travel time needed for spring-run Chinook or steelhead to complete their upstream migration to the upper Tuolumne River basin. Because there are no spring-run Chinook or steelhead populations in the Tuolumne River, life stage periodicities are currently unknown and can only be inferred from other regional data sources. Additional input and collaboration with fisheries agencies has been requested on this subject. At the time of the ISR, there have been no responses by licensing participants on this issue.

Chinook or steelhead but conditions which may facilitate passage at some range of migration flows were apparent (e.g., alternative pathway or decreasing hydraulic differential with increasing flows); or

- the identified feature exhibited measured effective barrier heights, horizontal leap distances, or flow velocities less than the maximum leaping or swimming capability of spring-run Chinook or steelhead but possessed low pool depths, obstructions at the leaping or landing zones, or high levels of turbulence which may inhibit passage at some range of migration flows were apparent.

4.3.4 Feature Descriptions

Narratives describing findings of field observations for each feature were prepared using relative classifications of water depth (for both leaping and swimming), turbulence and flow velocity. For instance, high or low flow velocity is used in relation to fish swimming capabilities rather than in reference to high flow, low-frequency events. These terms are frequently referenced in the results section (Section 5.0) in qualitative terms such as shallow, moderate, deep, low and high. Although definitive measurements were not taken for all features during the first round of field surveys, these terms are used to refer to specific, quantitative ranges of conditions that influence the ability of adult salmonids to ascend each feature based upon the visual observations made in the field. The range of values and terms used in each narrative are assigned as shown in Tables 4.3-3 through 4.3-6.

Table 4.3-3. Water depth criteria for leaping.

Descriptor	Depth (feet)	Description
Shallow	< 2	Leaping potentially impaired by inadequate water depth.
Moderate	2 - 5	Sufficient water depth for shorter leaps (less than 1.25 times the pool depth) but impaired leaping for barriers greater than 1.25 times the pool depth (adapted from USFS 2001)
Deep	> 5	Likely no impediment to leaping features within leaping capability

Table 4.3-4. Water depth criteria for swimming.

Descriptor	Depth (feet)	Description
Shallow	< 1	Swimming impaired or delayed by inadequate water depth.
Deep	> 1	Water depth sufficient for swimming.

Table 4.3-5. Turbulence criteria.

Descriptor	Energy Dissipation Factor (ft-lb/ft^3/sec)	Description
Low	< 2	Laminar flow, little energy loss, few eddies or gyres. Conditions generally do not impede passage.
Moderate	2 - 6	Turbulent flow with some eddies, gyres, air entrainment, and energy loss. Conditions may impede swimming ability and cause some loss of locomotion.
High	> 6	Very turbulent flow with eddies, gyres, air entrainment and high energy loss. Conditions are difficult to navigate and likely impede swimming ability.

Table 4.3-6. Flow velocity criteria.

Descriptor	Swimming Speed[1]			Duration	Description
	Swimming Mode	Steelhead (ft/s)	Chinook Salmon (ft/s)		
Low	Sustained	0 - 4.6	0 - 3.4	> 200 min	Low water velocities where sustained swimming speeds can be maintained for long durations of time.
Moderate	Prolonged	4.6 - 13.7	3.4 - 10.8	15 sec to 200 min	Moderate water velocities where speed and/or duration are compromised; fish may be able to sustain prolonged swimming speeds for some duration, or swim at burst speeds for short durations.
High	Burst	13.7 - 26.5	10.8 - 22.4	Less than 15 sec	High water velocities where prolonged and burst swimming speed capabilities may be exceeded even for short durations of time.

[1] Powers and Orsborn 1985.

4.3.5 Final Feature Classifications and Collection of Additional Data

A second field survey and more quantitative assessment was recommended for a select number of features identified as a potential barrier to fish passage in this ISR. The purpose of a second field survey would be to collect additional data with which to refine assessments regarding the ability of fish to pass features initially classified as potential barriers to fish passage. Recommendations and the rationale for further study are provided in Section 6.0 of this document. No further data collection is recommended at features classified as a "total" barrier or as "passable" as further described in Section 6.0. Certain "partial" barriers are also proposed to need no further assessment for reasons described in Section 6.0.

Any additional information collected in 2016 will be used to calculate hydraulic characteristics for the feature over the anticipated range of potential migration flows. Leaping and swimming conditions will then be re-evaluated by comparing the leaping capabilities estimated with the Powers and Orsborn (1985) method or swimming capabilities estimated using equations by Hunter and Mayor (1986) with the calculated hydraulic conditions. In many cases, features resembling step-pool cascades composed of both leaping and velocity impediments may employ both leaping and swimming criteria to assess each potential flow pathway identified during the first and/or second field surveys. If the comparison finds that hydraulic conditions exceed any combination of potential leaping trajectories, heights, ranges, or velocities by the target fish species, that feature will be documented as a total barrier. If the comparison identifies a range of flows or a range of leaping or swimming conditions that meet the capabilities of the target fish species, that feature will be documented as a partial barrier for that specific species and the range of flows likely to be passable will be documented.

Details associated with the methods to be employed for the quantitative hydraulic assessment and final classification of features are provided in the original RSP for this study and will be incorporated in the USR.

5.0 RESULTS

The following section summarizes the study results obtained up to October 15, 2015. Activities performed during this time period included a desktop review of existing information and field surveys on the mainstem Tuolumne River from the upper extent of the Don Pedro Reservoir (RM 81) to Lumsden Falls (RM 97.3), Clavey River, and the South Fork Tuolumne River.

5.1 Review of Existing Information

A review of existing information regarding fish passage barriers in the upper Tuolumne River basin discovered five primary sources. Features which may potentially be barriers to fish passage identified in the literature are presented in Table 5.1-1 and discussed further in the paragraphs below.

Table 5.1-1. Fish passage barriers in the upper Tuolumne River basin, based on a review of existing information.

River/Tributary	Barrier Location	Description	Sources
Mainstem Tuolumne River	RM 90.0	Clavey Falls	Yoshiyama et al. 2001
	RM 97.3	Lumsden Falls	Tim Hutchins (personal communication, October, 13, 2015)
	RM 104.3	Early Intake	Visual observation August 2015
	RM 108.5	Preston Falls	Buckmaster et al. 2009, Yoshiyama et al. 2001
North Fork Tuolumne River	RM 1.0	12-foot waterfall	Buckmaster et al. 2009, Yoshiyama et al. 2001
South Fork Tuolumne River	No specific location given	Presumably not used by salmon – steep section at the mouth	Yoshiyama et al. 2001
	No specific location given	25-30 feet waterfall in the lower South Fork	Stanley and Holbek 1984
Clavey River	RM 0.2 - 0.7	Large magnitude falls (no size estimate given)	EA Engineering 1990
	RM 0.25	Barrier falls	Buckmaster et al. 2009, Yoshiyama et al. 2001
	RM 9 - 10	Large magnitude falls (no size estimate given)	EA Engineering 1990
Cherry Creek	Seven potential features within 2 miles of Holm Powerhouse	Visual cues exhibiting characteristics of hydraulic drops	Aerial photo review

Information presented in existing literature suggests that the mainstem Tuolumne River has at least two and possibly three natural barriers to fish passage. The first is Preston Falls located approximately four miles upstream of Early Intake (Yoshiyama et al. 2001, Buckmaster et al. 2009). The falls are approximately 15 feet high and present a complete barrier to fish migration

(Yoshiyama et al. 2001, Buckmaster et al. 2009). Additionally, Yoshiyama et al. (2001) identified several waterfalls just below the current Hetch Hetchy Reservoir that stop all fish that might have ascended to that point. Yoshiyama et al. (2001) also hypothesized that Clavey Falls (located on the mainstem Tuolumne River immediately downstream of the Clavey River confluence) could be a migration barrier at certain flows.

The North Fork Tuolumne River has one known potential barrier to fish passage. The feature is located approximately one mile upstream of the confluence with the mainstem Tuolumne River. Both Buckmaster et al. (2009) and Yoshiyama et al. (2001) identified this feature as a waterfall with a height approaching 12 feet.

According to Yoshiyama et al. (2001), the South Fork Tuolumne River has presumably never been used by salmon; Yoshiyama et al. (2001) hypothesized that the steep section near the mouth of the South Fork Tuolumne River likely obstructed salmon from moving further upstream. Additionally, Stanley and Holbek (1984) report that there is a 25 to 30 ft waterfall in the lower reach. However, the exact location of this falls was not provided.

The Clavey River has four barriers that were identified during the existing information review. EA Engineering (1990) found several large magnitude falls within the first mile of the confluence with the mainstem Tuolumne River. Buckmaster et al. (2009) and Yoshiyama et al. (2001) both identified river mile 0.25 as having a barrier to fish migration. EA Engineering (1990) also identified several large magnitude falls from RMs 9 through 10, and cascades and steep streambed at the mouth of Hunter Creek.

No information was found in the literature regarding fish passage barriers in Cherry Creek. A brief assessment of aerial photography using Google Earth imagery was performed to identify features which may require further field survey. The results of the aerial photography assessment revealed up to seven features within two miles upstream of Holm Powerhouse which exhibited visual characteristics consistent with hydraulic drops, e.g., large bedrock areas void of trees, confined channels, and areas of turbulence where hydraulic plunges or jets may be present. An example of such a feature is presented in Figure 5.1-1. The seven features identified through aerial photo review are provided in Figure 5.1-2.

Figure 5.1-1. Example feature exhibiting visual characteristics of a hydraulic drop which requires field verification.

Figure 5.1-2. Features within two miles of Holm Powerhouse which may require field verification to determine barrier classification.

5.2 Results of 2015 Field Investigations

The following section summarizes data obtained during the 2015 field investigations, discussion and interpretation of results, and barrier classifications for each feature. Barrier classification followed the methods outlined in Section 4.0.

5.2.1 Mainstem Tuolumne River

Field surveys were performed on the mainstem Tuolumne River via raft on August 2 – 4 and observed by land on August 5 and 6. Results from the field investigation identified two potential barriers to fish passage: Clavey Falls (RM 90) and Lumsden Falls (RM 97.3). The primary characteristics of each feature are presented in Table 5.2-1 and Table 5.2-2. A map summarizing the location of each feature is presented as Figure 5.2-1. A narrative description of each identified feature is provided in the following paragraphs. Each feature was observed at two flow conditions based upon releases from upstream hydropower facilities owned and operated by CCSF. Flows ranged from 400 to 600 cubic feet per second (cfs) during the evening to the morning and flows up to 1,200 cfs were observed during mid-day. Images and a data record of each feature are provided as Photos 1 through 12 in Attachment A.

Table 5.2-1. Summary of potential barriers identified on the mainstem Tuolumne River during field surveys.

Feature	River Mile	Description	Initial Classification
Clavey Falls	90	Cascade and steps	Passable
Lumsden Falls	97.3	Cascade	Potential Barrier

Table 5.2-2. Physical characteristics of potential barriers identified on the mainstem Tuolumne River during field surveys.

Feature	Total Height (ft)	Max Leap (ft)	Obstructed Launch or Landing	Leaping Depth	Swimming Depth	Turbulence	Velocity	Alternate Pathway Present?
Clavey Falls	12	3	Unobstructed	Moderate	Deep	Moderate	Moderate	Yes
Lumsden Falls	18	3-5	Unobstructed	Moderate	Deep	High	High	No

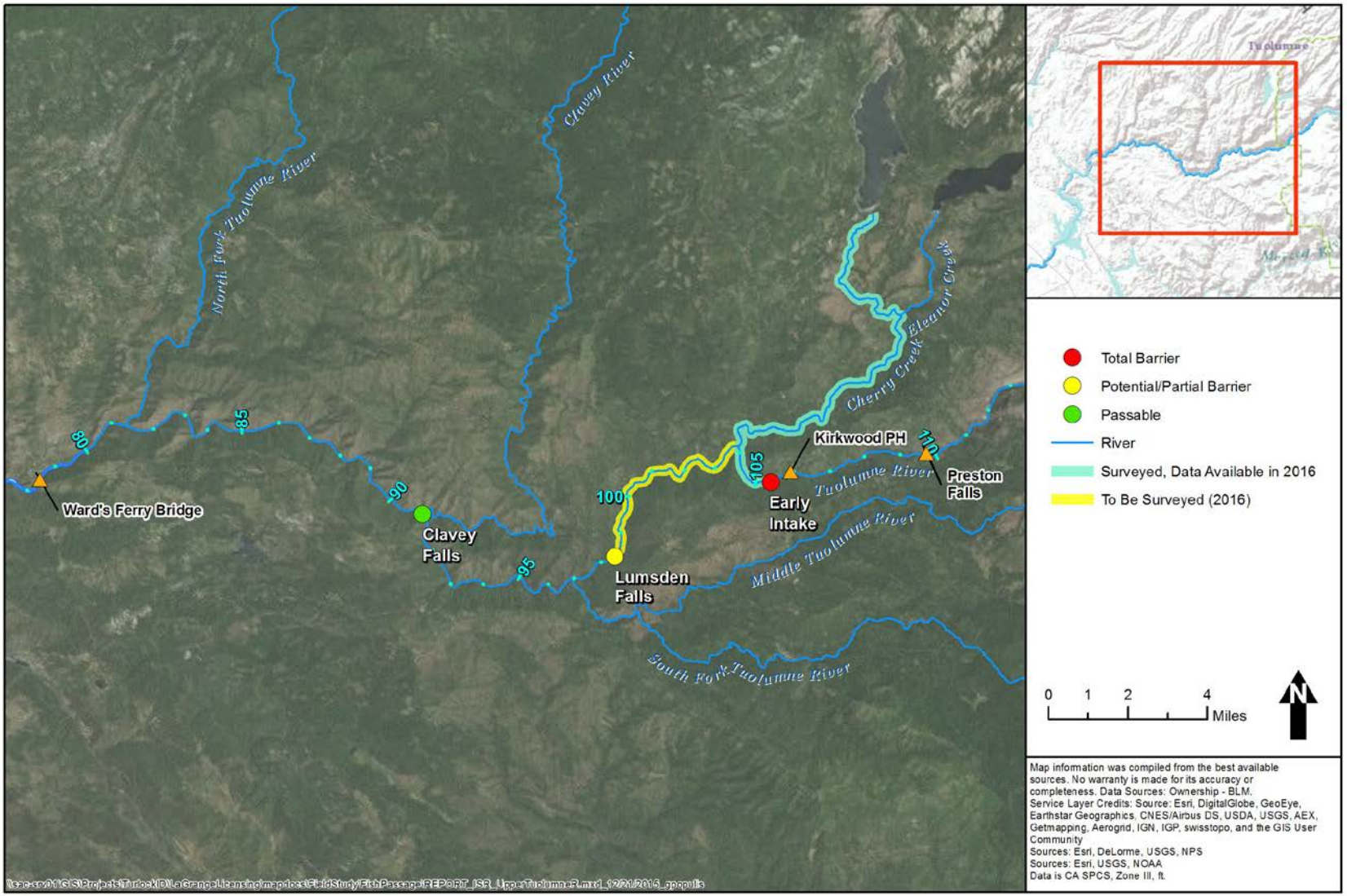


Figure 5.2-1. Summary of passage features and classification on the upper Tuolumne River.

5.2.1.1 Clavey Falls

Clavey Falls comprises a cascade sequence and several steps at RM 90 on the mainstem Tuolumne River. The downstream step is a constriction formed by a bedrock wall on river left and a large boulder (approximately 10 feet diameter) in the middle of the river (Attachment A, Photo 1). The main flow comprises a relatively smooth tongue on river left, with an approximately three-foot vertical drop. Both the launch and landing zones are deep and long (approximately 50 and 80 feet, respectively) with moderate velocity and turbulence. During observed on-peak flows, flow to the river right of the large boulder provides an alternative path, dropping approximately three vertical feet over a boulder-formed step. The launching pool has moderate depth and turbulence. The landing pool has moderate depth and low velocity. During observed flow conditions as low as 400 cfs, this pathway became too shallow to facilitate fish passage.

Upstream of the lower drop, there are several boulder-formed steps (each less than approximately two vertical feet; Attachment A, Photo 2). The steps occur within runs with moderate velocity and turbulence and without clear launching or landing pools. During higher on-peak flows, flow to the river right provides an alternative path with a lower gradient and low velocity; however, this pathway may be dewatered or too shallow for fish passage during lower flows.

Further upstream, the cascade sequence extends for approximately 70 feet, with an approximate vertical rise of 6 feet (Attachment A, Photos 3 through 5). The cascade sequence occurs within a series of boulders ranging from approximately two to five feet in diameter, with multiple drops and pathways; the flow has high turbulence through this area, particularly at higher (recreational) flows. Steps within the cascade range from approximately one to three feet in height, with high velocity, high turbulence, moderate depth launching and landing zones. During low flow conditions there is an alternate, lower gradient, moderate velocity and turbulence pathway on the river left, with one clear step (approximately one to two feet in height) with high turbulence and velocity launching and landing zones of moderate depths.

Information collected during the field survey suggests that this feature is passable at a wide range of flow conditions. The feature is likely a barrier at very low flows but generally exhibits conditions sufficient for passage throughout the range of flows observed. This feature is classified as passable given that multiple pathways exist which exhibit unobstructed leap heights within the leaping capabilities for both spring-run Chinook and steelhead calculated in Section 4.3.

5.2.1.2 Lumsden Falls

Lumsden Falls is a cascade feature located at RM 97.3 on the mainstem Tuolumne River (Attachment A, Photos 6 through 12). The flow takes multiple paths through a high gradient series of boulders confined by bedrock on river right. Boulders range in diameter from approximately 5 to 10 feet. During the August field survey, the flow had high turbulence throughout the length of the cascade at both recreational (1,200 and 950 cfs) and lower flow conditions (600 cfs). The main drop of the cascade is approximately 18 vertical feet over a distance of approximately 100 feet (18 percent gradient). A large, deep pool occurs at the bottom of the falls but has moderate turbulence, particularly at the presumed launching zone at

the base of the falls. Leaps with heights on the order of three to five feet taken in intermediate steps up the falls would have high turbulence and high velocity launching and landing zones of moderate depth. A boulder field forms the crest of the falls and also has high turbulence and velocity. Multiple pathways of flow occur throughout the falls, but a bedrock wall on river right and large boulders (10 to 20 feet diameter) on river left appear to confine the flow to the main channel, eliminating side channel development and therefore alternate fish passage pathways.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage based upon the definitions presented in Section 4.3.3. The primary impediments to fish passage include: high leap height, high velocity, high turbulence, high gradient, and high velocity launching and landing zones. Although individual leap heights appear to be within the range achievable by spring-run Chinook and steelhead, step pools exhibit a high turbulence and velocity with shallow or moderate step pool depths. No single passable pathway is readily apparent at the flows observed. The feature is likely a barrier at high flows and exhibits conditions sufficient for passage at low flows.

5.2.2 North Fork Tuolumne River

Conditions in August 2015 did not allow for adequate investigation of the North Fork Tuolumne River as the lower reach of the river had zero flow. Results for this field investigation will be made available in the USR.

5.2.3 South Fork Tuolumne River

A field survey of the South Fork Tuolumne River was performed on August 5, 2015. One total barrier and numerous potential barriers were identified within two miles of the confluence with the Tuolumne River. During this field survey, up to 17 individual features were documented. Features occurring within 0.5 miles of the total barrier identified during this study are closely interlinked with one another and represent a series or complex of rock features with no apparent separation from one to the next. Features are more sporadic and separated by longer reaches of river pools and glides as the gradient decreases near the confluence with the mainstem Tuolumne River. The primary characteristics of each feature are presented in Table 5.2-3 and Table 5.2-4. A map summarizing the location of each feature is presented as Figure 5.2-2. Narrative descriptions of each feature identified in the field are provided in the following paragraphs. Images and a data record of each feature are provided as Photos 26 through 44 in Attachment A. Flows on the day of the field survey measured five cfs.

Table 5.2-3. Summary of potential barriers identified on the South Fork Tuolumne River during field surveys.

Feature	River Mile	Description	Classification
ST-1	0.45	Split flow bedrock falls	Potential Barrier
ST-2	0.5	Step pool falls	Potential Barrier
ST-3	0.63	Split flow step pool falls	Potential Barrier
ST-4	0.67	Falls between boulders	Potential Barrier
ST-5	0.9	Split flow step pool falls	Potential Barrier
ST-6	0.95	Bedrock falls	Potential Barrier
ST-7	1.05	Bedrock falls	Potential Barrier
ST-8	1.15	Bedrock and boulder falls	Potential Barrier
ST-9	1.2	Bedrock and boulder step falls	Potential Barrier

Feature	River Mile	Description	Classification
ST-10	1.35	Boulder falls	Potential Barrier
ST-11	1.53	Split flow step falls	Potential Barrier
ST-12	1.57	Cascade	Potential Barrier
ST-13	1.6	Step pool falls	Potential Barrier
ST-14	1.62	Step pool falls	Potential Barrier
ST-15	1.65	Split flow step pool falls	Potential Barrier
ST-16	1.8	Bedrock falls	Potential Barrier
ST-17	1.85	Cascade	Potential Barrier
ST-18	1.9	Bedrock falls	Total Barrier

Table 5.2-4. Physical characteristics of potential barriers identified on the South Fork Tuolumne River during field surveys.

Feature	Total Height (ft)	Max Leap (ft)	Obstructed Launch and/or Landing	Leaping Depth	Swimming Depth	Turbulence	Velocity	Alternate Pathway Present?
ST-1	5-7	3-5	Unobstructed	Shallow	Deep	Moderate	Moderate	Yes
ST-2	3-4	3-4	Unobstructed	Shallow	Deep	Low	Low	Yes
ST-3	4-5	4-5	Obstructed	Shallow	Deep	Low	Low	Yes
ST-4	6	6	Obstructed	Shallow	Shallow	Low	Low	Yes
ST-5	3.5	3.5	Obstructed	Moderate	Deep	Low	Low	Yes
ST-6	11	4	Unobstructed	Shallow	Deep	Moderate	Moderate	Yes
ST-7	5	5	Unobstructed	Moderate	Deep	Low	Low	No
ST-8	6	6	Obstructed	Moderate	Deep	Low	Low	Yes
ST-9	16	3	Unobstructed	Shallow	Deep	Moderate	Moderate	Yes
ST-10	3-5	3-5	Obstructed	Shallow	Shallow	Moderate	Low	Yes
ST-11	3-5	3	Obstructed	Shallow	Shallow	Moderate	Moderate	Yes
ST-12	10	4	Obstructed	Shallow	Deep	Moderate	Moderate	No
ST-13	6-8	4-6	Obstructed	Deep	Deep	Low	Low	No
ST-14	14	6	Obstructed	Shallow	Deep	Moderate	Moderate	Yes
ST-15	3-4	1	Obstructed	Shallow	Deep	Moderate	Moderate	Yes
ST-16	5-6	5-6	Obstructed	Deep	Deep	Moderate	Moderate	No
ST-17	7	4	Obstructed	Shallow	Shallow	Moderate	Moderate	Yes
ST-18	32	32	Unobstructed	Deep	Deep	Low	Low	No

5.2.3.1 Feature ST-1

Feature ST-1 is a split flow falls over a bedrock outcrop located at RM 0.45 on the South Fork Tuolumne River (Attachment A, Photos 26 and 27). The flow is split roughly evenly, with river right flow down a continuously high velocity, high turbulence, high gradient chute, and river left flow down a bedrock-formed step-pool sequence. The total drop of the features is approximately five to seven vertical feet. The step-pool sequence contains two steps: a lower step that is at approximately three to five feet high, and an upper step that is approximately two feet high. The launching pool for the step is shallow with moderate turbulence but is unobstructed. The landing and launching pool in the middle of the step is set back somewhat from the drop and is shallow with moderate turbulence; the upper landing pool is also shallow, set back from the edge and has moderate turbulence and velocity. The two channels described represent the two alternative pathways present for fish passage.

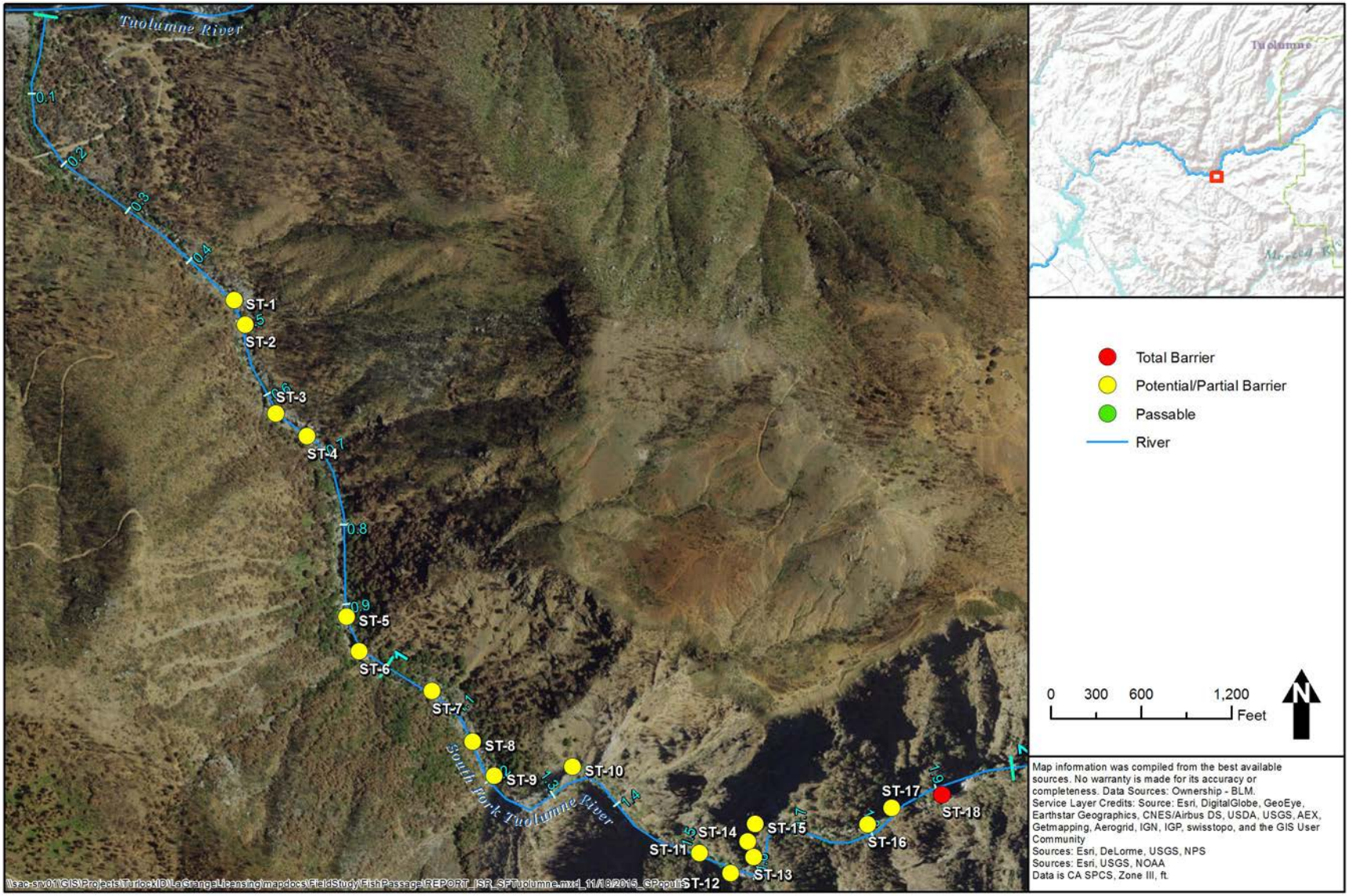


Figure 5.2-2. Summary of passage features and classification on the South Fork Tuolumne River.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage based upon the definitions provided in Section 4.3.3. The primary impediments to fish passage include: high leap height, high velocity, high gradient, and shallow and turbulent launching and landing zones. Although leap heights may be within the limits capable by spring-run Chinook and steelhead there is no defined launching pool and the chute identified along river right is not accessible until higher flows are present. The feature is likely a barrier at low flows and exhibits features which would create conditions sufficient for passage at high flows.

5.2.3.2 Feature ST-2

Feature ST-2 is a step pool falls located at RM 0.5 on the South Fork Tuolumne River (Attachment A, Photo 28). The falls forms between a bedrock outcrop on river left and a series of boulders (approximately two to four feet in diameter) on river right. The vertical height of the falls is approximately three to four feet. The launching and landing pools are small and shallow (approximately three feet long) but with low velocity and turbulence. During higher flow conditions, there is likely flow to the river right of the falls over a series of boulders but more information about the conditions in this portion of the channel during higher flows would be necessary to evaluate its viability as an alternative pathway for fish passage.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage based upon the definitions provided in Section 4.3.3. The primary impediment to fish passage is shallow launching and landing pool depth, which is an impediment to both spring-run Chinook and steelhead. However, the feature may exhibit better leaping conditions and alternative pathways along river right at higher flows. The feature is likely a barrier at low flows and exhibits features which would create conditions sufficient for passage at high flows.

5.2.3.3 Feature ST-3

Feature ST-3 is a split flow step pool falls located at RM 0.63 on the South Fork Tuolumne River (Attachment A, Photo 29). The falls forms over and between several boulders, ranging in diameter from two to five feet and has two distinct channels split by a boulder during the low flow conditions observed during the field survey. The vertical height of the falls is approximately four to five feet. The launching and landing pools are each about 15 feet long but are shallow and obstructed by boulders at or near the water surface. Flow may occur over and through the boulders on river left during higher flow conditions but more information about the conditions in this portion of the channel during higher flows would be necessary to evaluate its viability as an alternative pathway for fish passage.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage based upon the definitions provided in Section 4.3.3. Although the leap requirements are less than or equal to the leaping capabilities of spring-run Chinook and steelhead, the primary impediment to fish passage is low pool depth with the presence of obstructions. More favorable leaping conditions and alternative pathways may be exhibited along river right at higher flows. The feature is likely a barrier at low flows and exhibits features which would create conditions sufficient for passage at high flows.

5.2.3.4 Feature ST-4

Feature ST-4 is a falls located at RM 0.67 on the South Fork Tuolumne River (Attachment A, Photo 30). The falls forms between several large boulders (diameter approximately 10 to 12 feet). The vertical height of the falls is approximately six feet. The launching pool is obstructed by a boulder (approximately four feet in diameter) and shallow. The landing pool has low velocity and is unobstructed. Flow may occur over and through the boulders on river right during higher flow conditions but more information about the conditions in this portion of the channel during higher flows would be necessary to evaluate its viability as an alternative pathway for fish passage.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage based upon the definitions provided in Section 4.3.3. Although leap requirements exceed spring-run Chinook leaping capabilities and do not exceed steelhead leaping capabilities, the primary impediment to fish passage include a shallow and obstructed launching pool. Passage may only be possible at this feature when the larger boulders are hydraulically flanked on the right side which may offer passable conditions for both species at higher flows. The feature is likely a barrier at low flows and exhibits features which would create conditions sufficient for passage at high flows.

5.2.3.5 Feature ST-5

Feature ST-5 is a split flow step pool falls located at RM 0.9 on the South Fork Tuolumne River (Attachment A, Photo 31). The falls forms between several large boulders (diameter approximately 4 to 12 feet). The primary flow is at the center of the channel and drops approximately 3.5 feet. The launching and landing pools for this feature are long (at least 20 feet) and are unobstructed with low velocity, low turbulence, and moderate depth. There is a smaller portion of flow over several smaller boulders (diameter approximately two feet) on the river right. The launching pool for the river right pathway is the same as for the main pathway. However, the launching pool and overall trajectory for the river right pathway is obstructed by protruding boulders at the conditions observed with horizontal leap requirements exceeding spring-run Chinook and steelhead capability.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage based upon the definitions provided in Section 4.3.3. The primary impediments to fish passage include: high leap height and obstructed launching and landing pool. The feature is likely a barrier at low flows and exhibits features which would create conditions sufficient for passage at high flows.

5.2.3.6 Feature ST-6

Feature ST-6 is a bedrock falls located at RM 0.95 on the South Fork Tuolumne River (Attachment A, Photo 32). The falls forms in a channel between bedrock outcropping on both sides of the valley and comprises three smaller steps. The lowest step is approximately four feet high with flow splitting around a boulder, and with moderate turbulence and velocity and shallow depth in the launching and landing pools. The middle step is approximately three feet

high, with a moderate turbulence and velocity in the launching pool but a low velocity and turbulence in the landing pool. The uppermost step is approximately 4 feet high with long, low velocity and turbulence launching pools. However, the landing pools are partially obstructed on the river right side of the falls by shallow water depths over bedrock. During high flow conditions, water appears to flow over the bedrock to the river right of the falls features. Although more information is necessary to evaluate this alternative, it appears that flow may be shallow with high velocity over this feature. As flows increase, it appears that the low flow channel may be washed out and the streaming flow over the feature may become more dominant.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. Although the feature appears to exhibit hydraulic conditions that meet swimming and leaping capabilities of spring-run Chinook and steelhead at lower flows, visual evidence suggests that the feature may transition to a high velocity chute type feature at higher flows. The primary impediments to fish passage include: high leap height and potentially high velocities during periods when higher flows exist. The feature is likely a barrier at high flows and exhibits features which create conditions sufficient for passage at low flows.

5.2.3.7 Feature ST-7

Feature ST-7 is a bedrock falls located at RM 1.05 on the South Fork Tuolumne River (Attachment A, Photo 33). The falls forms in a channel between bedrock outcropping on both sides of the valley and has a total vertical height of approximately five feet at low flow conditions. The launching and landing pools are long with moderate depth and low turbulence and velocity. However, the falls itself is set back at an angle and would therefore require a substantial horizontal leap component to clear the crest of the falls. The bedrock outcrops confine the river on both the right and left banks, therefore eliminating the development of side channels and alternative fish passage pathways.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. The leap height appears to exceed the leaping capability of spring-run Chinook at low flow conditions but may be ascendable by steelhead. The horizontal jump requirement as well as the tailwater control hydraulics could be evaluated further to define the range of flows potentially passable by both species. The primary impediments to fish passage include: high leap height and shallow depths within the falls. The feature is likely a barrier at moderate flows and exhibits features which create conditions sufficient for passage at low or high flows.

5.2.3.8 Feature ST-8

Feature ST-8 is a falls located at RM 1.15 on the South Fork Tuolumne River (Attachment A, Photo 34). The falls form between a bedrock wall on the river left side and larger boulders (diameter approximately 6 to 15 feet) on river right. The total vertical drop is approximately 6 feet. The launching pool is long (over 20 feet, approximately) and unobstructed with moderate depth and low velocity and turbulence but the falls splits over and around several large rocks and exhibits an overhanging leap condition as well as obstructing the landing pool. An alternative pathway for fish passage may occur through the boulders on river right during higher flow

conditions. However, more information about the conditions in this portion of the channel during higher flows would be necessary to evaluate its viability as an alternative pathway for fish passage.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. The leap height appears to exceed the leaping capability of spring-run Chinook at low flow conditions but may be ascendable by steelhead. The horizontal jump requirement as well as the tailwater control hydraulics could be evaluated further to define the range of flows potentially passable by both species. The overhanging crest and formation of hydraulic nappe creates a difficult leaping condition. The primary impediments to fish passage include: high leap height and obstructed landing zone. The feature is likely a barrier at low flows and exhibits features which create conditions sufficient for passage at high flows.

5.2.3.9 Feature ST-9

Feature ST-9 is a bedrock and boulder step pool falls located at RM 1.2 on the South Fork Tuolumne River (Attachment A, Photo 35). The feature forms between a bedrock wall on the river left and a series of boulders (diameters ranging from approximately three to eight feet) on river right. The falls have a total vertical rise of approximately 16 feet over about 50 horizontal feet (gradient of approximately 32 percent) and comprise a series a smaller steps (approximately two to three feet high) separated by runs with moderate turbulence and velocity. The most downstream launching pool is approximately 20 feet long, narrow, with moderate depth, velocity and turbulence at low flows. Intermediate launching and landing pools are also have moderate turbulence and velocity with shallow depths at low flows. Alternative pathways for fish passage may occur through the boulders at river right during higher flow conditions. However, more information about the conditions in this portion of the channel during higher flows would be necessary to evaluate its viability as an alternative pathway for fish passage.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage. The high gradient exceeds the gradient criteria expressed in Table 4.3-2 of 20 percent for 50 feet at the observed low flow conditions but the presence of steps and potential for alternative pathways at higher flows may provide conditions sufficient for passage by spring-run Chinook and steelhead during some portion of the hydrograph. The primary impediments to fish passage include: high gradient, moderate velocity and turbulence in shallow launching and landing zones. The feature is likely a barrier at low and high flows but may exhibit conditions sufficient for passage at more moderate flows. Alternative pathways may be present at these moderate flows that could provide additional opportunities for passage.

5.2.3.10 Feature ST-10

Feature ST-10 is a split falls located at RM 1.35 on the South Fork Tuolumne River (Attachment A, Photo 36). The falls is split around boulders (approximately one to three feet in diameter) and vegetation and has a total vertical height of approximately three to five feet at low flow conditions. The launching and landing zones of the primary flow path are moderately turbulent, narrow, and shallow, and the falls itself is set back at an angle and would therefore require a

substantial horizontal component to successfully leap past the hydraulic crest. Additionally, this setback combined with shallow water depth at the top of the falls comprises an obstruction to the landing zone. Aerial photographs indicate that an alternative fish passage pathway may occur on the river left side through boulders during higher flow conditions. However, more information about the conditions in this portion of the channel during higher flows would be necessary to evaluate its viability as an alternative pathway for fish passage.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. Although the leap heights appear to be less than the leaping capabilities of spring-run Chinook and steelhead, insufficient leaping conditions create and impediment to passage at the observed low flow conditions. Further hydraulic assessment of this site would be necessary to determine if hydraulic conditions are sufficient for passage at various ranges of the hydrograph. The primary impediments to fish passage include: high leap height, horizontal leap distance, shallow and turbulent launching and landing zones, and obstructed landing zone. The feature is likely a barrier at low flows and exhibits features which create conditions sufficient for passage at high flows.

5.2.3.11 Feature ST-11

Feature ST-11 is a split flow step falls located at RM 1.53 on the South Fork Tuolumne River (Attachment A, Photo 37). The flow splits around a medial island, forming step pool falls on both the river right and river left sides of the channel. The river left channel in confined between a bedrock wall on the river left bank and boulders (diameter approximately two to four feet) on the right. The total vertical rise is approximately three to five feet over a series of steps separated by short runs. The bottommost launching pool is long (over 50 feet) with moderate depth and low velocity and turbulence, but the intermediate launching and landing pools are short (approximately less than 5 feet long) with shallow depth and moderate velocity and turbulence. The short pool configuration suggests that the flow regime will transition to a streaming flow scenario making this channel more of a chute feature as flows increase. The river right channel forms between several boulders (diameter approximately three to five feet) and has a total vertical rise of approximately three to five feet. The launching zone is obstructed by boulders, and the landing zone condition is unknown. The two channels described represent the two alternative pathways present for fish passage.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. Although the effective heights of these features are less than the leaping capability of spring-run Chinook and steelhead, hydraulic conditions at higher flows may be more complex creating velocity and turbulence conditions that my inhibit passage. The primary impediments to fish passage include: shallow, turbulent and obstructed launching and landing zones. The feature possesses multiple pathways that may provide sufficient conditions for passage at various ranges of the hydrograph. The feature is likely be a barrier at moderate flows but exhibits features which create conditions sufficient for passage at low flows and high flows.

5.2.3.12 Feature ST-12

Feature ST-12 is a complex of three cascades closely co-located near RM 1.57 on the South Fork Tuolumne River (Attachment A, Photo 38 which shows the middle series of steps). The series of cascades forms between bedrock walls on the river right and river left and large boulders in the channel center (diameters ranging from three to six feet). In each of the three sub-units flow spills over and around boulders for approximately 10 to 15 vertical feet each. With an approximate rise of 35 to 45 feet over a distance of 150 feet, the overall gradient of this complex is estimated to be 23 to 30 percent. Each major step identified in the three cascades appeared to have a vertical leaping component of three to four feet at the observed flow condition. In most cases, the launching and landing areas are short with moderate velocity and turbulence, and shallow depth. The bedrock outcrops confine the river on both the right and left banks, which appears to eliminate the development of side channels or additional pathways with the exception of the very top of the feature. The short pool configuration suggests that the flow regime will transition to a streaming flow scenario making this channel more of a turbulent chute feature as flows increase.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. Although the leap heights appear to meet the leaping capabilities of spring-run Chinook and steelhead at the observed flow conditions, short turbulent pools and the lack of alternative pathways may create an impediment to upstream passage at higher flows. The primary impediments to fish passage include: short turbulent and obstructed launching and landing zones. The feature is likely a barrier at high flows and exhibits features which create conditions sufficient for passage at low flows.

5.2.3.13 Feature ST-13 and ST-14

Features ST-13 and ST-14 represent a complex of step pool falls located at RM 1.6 on the South Fork Tuolumne River. ST-13 represents the most downstream step pool feature (Attachment A, Photo 39) which leads to Feature ST-14, comprising a longer complex of step pools (Attachment A, Photo 40). The falls at ST-13 flow over and between a series of large boulders (diameters approximately 6 to 15 feet) and into a large, deep pool (approximately 50 feet long) with low turbulence and velocity. The vertical rise at the falls is approximately six to eight feet, and the launching pool is obstructed by boulders. The landing pool is also set back somewhat from the edge of the falls creating a long horizontal leap component. The bedrock outcrops on both the left and right valley walls confine the river on both sides, therefore eliminating the development of side channels or alternative pathways.

Throughout Feature ST-14, the river flows over, around and through a series of boulders (ranging in diameter from two to eight feet) via multiple pathways and forms multiple steps and small pools. There are four distinct drops for a total 14 feet vertical drop. The most downstream drop is about 6 vertical feet with moderately turbulent flow over multiple protruding boulders which may obstruct leap paths. There is also a flow pathway to the river right of this feature with two shorter, steeper rises but shallow depth. At the top of the most downstream drop is a pool (approximately 10 feet long, depth unknown), followed by a short boulder-formed step (approximately 2 vertical feet), another pool (approximately 6 feet long), and another short

boulder-formed step (approximately 2 vertical feet). The most upstream step is approximately four vertical feet with split flow and both the launching and landing pools are partially obstructed by protruding boulders. The bedrock outcrops on both the left and right valley walls (visible in aerial photography) confine the river on both sides, therefore eliminating the development of additional alternative fish passage pathways.

The combined height of ST-13 and ST-14 is approximately 22 feet over a length of 115 feet which corresponds to a gradient of 19 percent.

Information collected during the field survey suggests that the ST-13 and ST-14 complex is a potential barrier to fish passage as defined in Section 4.3.3. Leap heights, obstructed landing and launching areas, and the overall horizontal leap requirement appear to exceed the leaping capability of spring-run Chinook and steelhead at the observed low flow condition. The primary impediments to fish passage include: high leap height, long horizontal leap component, and obstructed launching and landing zones. ST-13 and ST-14 are likely barriers to fish passage at low flows and exhibit features which create conditions sufficient for passage at high flows.

5.2.3.14 Feature ST-15

Feature ST-15 is a split flow step pool falls located at RM 1.65 on the South Fork Tuolumne River (Attachment A, Photo 41). The river flows over, around and through a series of boulders (diameters ranging from one to eight feet) in a channel confined by bedrock walls on both the left and right sides of the valley. The primary flow channel on the river left side comprises a low angle falls with a series of short, successive steps (one vertical foot) for an overall vertical rise of approximately three to four feet. Two smaller channels occur at river center and river right. The river right channel is similar to the river left channel, with a low angle falls comprising multiple small steps. The center channel is a steeper step falls. The bottom launching pool for each of the three pathways has low velocity and turbulence and shallow depth but intermediate landing and launching pools for the river right and river left channels are shallow with moderate turbulence and velocity. At higher flows, both channels on river right may transition into a streaming flow regime exhibiting high velocities and high levels of turbulence. The channel observed at river left may convey a smaller majority of flow and leaping conditions may improve as the tailwater control is backwatered. Bedrock outcrops on both the left and right valley walls confine the river on both sides, therefore eliminating the development of additional alternative fish passage pathways than the three observed at low flow.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. Leaping conditions on a portion of the feature may improve while velocities and turbulence may impede fish passage on other portions of the feature as flows increase. The primary impediments to fish passage include: high gradient, high velocity, and obstructed launching and landing zones which impede passage of both spring-run Chinook and steelhead. The feature is likely a barrier at low flows and exhibits features which create conditions sufficient for passage at high flows.

5.2.3.15 Feature ST-16

Feature ST-16 is a bedrock chute located at RM 1.8 on the South Fork Tuolumne River (Attachment A, Photo 42). The chute is formed in a narrow channel (approximately six feet wide) inset within a narrow canyon (approximately 30 feet wide). The total vertical rise is approximately 5 to 6 feet over a distance of approximately 40 feet (gradient 15 percent). The tailwater pool is deep and long (approximately 55 feet) but narrow with moderate turbulence and velocity at the approach to the first step. The entrance to the chute at low flow includes a series of short steps set back at an angle that would require a substantial horizontal leap component to clear the first crest. The bedrock canyon walls confine the river on both the right and left banks, therefore eliminating the development of potential side channels or alternative fish passage pathways. The narrow feature is likely overwhelmed easily and exhibits high velocities and high levels of turbulence as river flows increase.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. Although the leaping ability of spring-run Chinook and steelhead may facilitate passage at lower flows, it is apparent that the feature may exhibit much different hydraulic characteristics at higher flows which may impede passage. The primary impediments to fish passage include: high leap height, long horizontal leap distance, high velocity and obstructed launching and landing conditions. The feature is likely a barrier at high flows and exhibits features which create conditions sufficient for passage at low flows.

5.2.3.16 Feature ST-17

Feature ST-17 is a cascade located at RM 1.85 on the South Fork Tuolumne River (Attachment A, Photo 43). The river flows via multiple pathways over, around and through boulders (diameters ranging from two to six feet) creating small pocket pools and flowing over multiple steps. The downstream most step is approximately four vertical feet with flow tumbling over multiple protruding boulders. The launching and landing pools are shallow and small (approximately three feet in length, depth unknown) with moderate turbulence and velocity. Both the launch and landing are partially obstructed by boulders. The upstream step is approximately three vertical feet with flow tumbling over multiple protruding boulders. The launch pool is the same as the landing pool for the first step. Intermediate pools are turbulent, shallow and small, and the upper landing zone condition is unknown. Alternate pathways for fish passage exist within the cascade features but would need to be observed at different flow levels to asses their viability for fish passage.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. Spring-run Chinook and steelhead possess leaping capabilities that are greater than the effective heights measured at this feature, however, shallow, small launching pools and obstructed leap paths may impede passage during some portion of the hydrograph. The primary impediments to fish passage include: shallow, small, and obstructed launching and landing conditions. The feature is likely a barrier throughout a portion of the anticipated hydrograph but further hydraulic assessment would be required to determine the limits of passage.

5.2.3.17 Feature ST-18

Feature ST-18 is a bedrock falls located at RM 1.9 on the South Fork Tuolumne River (Attachment A, Photo 44). The bedrock ledge extends the full width of the channel and river flows down the bedrock face. The falls have a total vertical drop of approximately 32 feet. Flow plunges into a deep, large pool (approximately 100 feet long). The bedrock canyon walls confines the river on both the river right and river left, therefore eliminating the development of alternative fish passage pathways.

Information collected during the field survey suggests that this feature is a total barrier to fish passage as defined in Section 4.3.1. The effective height of this feature exceeds the leaping capability of spring-run Chinook and steelhead at all flows and there are no opportunities to alternative pathways at any range of flows. The primary impediment to fish passage is barrier height.

5.2.4 Clavey River

A field survey of the Clavey River was performed on August 3, 2015. One total barrier and two potential barriers were identified within two miles of the confluence with the Tuolumne River. The primary characteristics of each feature are presented in Table 5.2-5 and Table 5.2-6. A map summarizing the location of each feature is presented as Figure 5.2-3. Narrative descriptions of each identified feature are provided below. Images and a data record of each feature are provided as Photos 13 through 25 of Attachment A. Flow measurements taken near the mouth of the Clavey River indicate that observations occurred at a river flow near 4 cfs.

Table 5.2-5. Summary of potential barriers identified on the Clavey River during field surveys.

Feature	River Mile	Description	Classification
CR-1	0.2	Split flow bedrock falls	Potential Barrier
CR-2	1.15	Split flow falls with chute	Potential Barrier
CR-3	2.05	Boulder field	Total Barrier

Table 5.2-6. Physical characteristics of potential barriers identified on the Clavey River during field surveys.

Feature	Total Height (ft)	Max Leap (ft)	Obstructed Launch and/or Landing	Leaping Depth	Swimming Depth	Turbulence	Velocity	Alternative Pathway Present?
CR-1	12	5	Obstructed	Shallow	Shallow	Low	Low	Yes
CR-2	8	6	Obstructed	Shallow	Shallow	Moderate	Moderate	Yes
CR-3	7-13	7-13	Obstructed	Shallow	Shallow - Deep	Low	Low	No

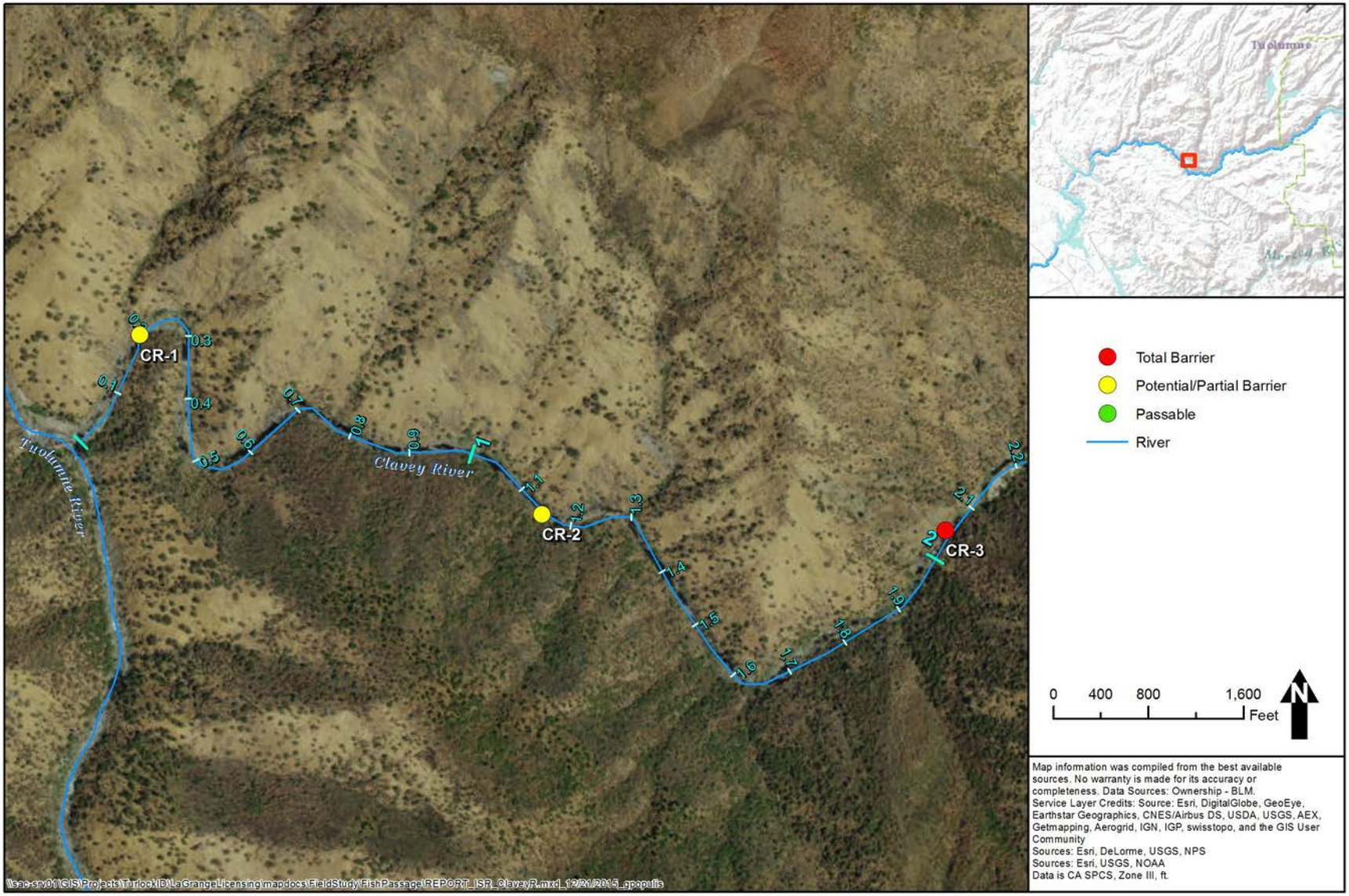


Figure 5.2-3. Summary of passage features and classification on the Clavey River.

5.2.4.1 Feature CR-1

Feature CR-1 is a split flow bedrock falls feature located at RM 0.2 on the Clavey River (Attachment A, Photos 13 and 14). During low flow conditions, flow occurs in two discrete channels down the face of a bedrock outcrop, with relatively more flow in the river right channel. The overall vertical drop is approximately 12 feet. The launching pools are shallow and partially obstructed by protruding rock at the base of both channels. The landing pools at the top of the falls are also shallow and set back from the maximum vertical relief. Neither channel has prominent intermediate launching/landing pools, although the river right channel has two shallow, sub-horizontal features located approximately one third and two-thirds of the way up the falls. The river left channel has two small, shallow, sub-horizontal features located near the top of the falls. A bedrock outcrop confines the river on the left banks, therefore eliminating the development of side channel. River right is less confined and a step pool side channel appears to be prominent which ties back to a pool further upstream. Passage at higher flows may be possible along this potential side channel.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage based upon the definitions provided in Section 4.3.3. The primary impediments to fish passage include: high leap height and shallow and obstructed launching and landing conditions. Although the required leap heights are greater than the capability of spring-run Chinook and steelhead, passage may be achievable through a side channel along the right bank during higher flows. The feature is likely a barrier at low flows and exhibits features which create conditions sufficient for passage at high flows.

5.2.4.2 Feature CR-2

Feature CR-2 is a split flow feature over large boulders and bedrock located at RM 1.15 on the Clavey River (Attachment A, Photos 15 through 18). During low flow conditions, the primary flow is on the river left down a bedrock chute. The overall vertical relief of the chute is approximately eight feet. After a small step (approximately one foot) from the launching pool, the lower portion of the chute comprises a high gradient but continuous chute feature, while the upper portion of the feature is a small falls (approximately three feet high) with high velocity launching and landing zones. In addition to the main flow feature active at low flows, two small channels also flow over boulders in the river center and to the river right. The vertical relief associated with the river right and center channels is approximately six feet. For the center and right to center channels, the launching pool is shallow and obstructed by boulders at the observed flow condition. Adequate launching zones are present approximately six to eight feet horizontally from the landing crest. The crest and landing zone is set back from the edge and thus obstructed. The river right channel flows over protruding rocks, which would require a more horizontal component for a leaping fish to clear. The launching pool has low velocity, but the landing zone is also set back from the edge and thus obstructed. Feature CR-2 is constrained by bedrock outcrops on both sides of the valley, but presence of a large boulder and rock accumulations along the right bank create a potential alternative pathway which may be hydraulically connected at slightly higher flows. If and when wetted, this alternative pathway may provide decreased leaping opportunities on the order of three to four feet.

Information collected during the field survey suggests that this feature is a potential barrier to fish passage as defined in Section 4.3.3. The primary impediments to fish passage include: high leap height, high velocity, and shallow and obstructed launching and landing conditions. The leaping opportunities at low flow conditions exceed the leaping capabilities of spring-run Chinook and steelhead; however, the presence of potential alternative pathways may provide passage at higher flow events. Further, tailwater control features downstream of the leaping pool potentially constrain hydraulics and thus higher flow conditions may backwater this feature and reduce overall leaping requirements. The feature is likely a barrier at low flows and exhibits features which create conditions sufficient for passage at high flows.

5.2.4.3 Feature CR-3

Feature CR-3 is a long boulder field feature located at RM 2.05 on the Clavey River (Attachment A, Photos 19 through 25). The boulder field extends for over 400 feet and spans the width of the valley floor with continuous, interlocking large boulders (approximately 5 to 40 feet in diameter). Flow through this reach weaves under, around, over and between boulders throughout the length of the feature with intermittent pools. At the crest of the boulder field, flow falls over a series of interlocking boulders with total vertical relief of approximately 7 to 13 feet. The launching pool is shallow and obstructed, and the landing zone is also obstructed by boulders. Multiple pathways for flow exist throughout the boulder field, but many are unsuitable for fish passage due to obstruction by large boulders, leap barriers, or hydraulic pathways flowing directly under boulders with inadequate clearance. No alternate pathways for flow or passage were observed at the boulder field or at the crest barrier. The boulder field appears to be remnants of a dip-slope bedrock landslide. The slide appears to be recent from a geological perspective and appears in aerial photography dated back to 1993.

Information collected during the field survey suggests that this feature is a total barrier to fish passage. Leaping or swimming opportunities meeting the maximum capabilities of spring-run Chinook or steelhead presented in Section 4.3.1 are not apparent. The primary impediments to fish passage include: high leap height, complete channel obstructions, and shallow and obstructed launching and landing conditions. The feature is therefore a barrier at high and low flow conditions.

5.2.5 Cherry/Eleanor Creeks

A field survey for the Cherry/Eleanor Creek watershed was completed October 2015. The survey results obtained on potential Cherry Creek barriers are not presented in this document because there was inadequate time available to synthesize the data and develop conclusions. Conclusions relative to barriers identified within Cherry and Eleanor creeks will be made available in the USR.

6.0 DISCUSSION AND FINDINGS

The work conducted in 2015 included a review of existing data, collection of field data, and analysis of all the resulting available data. Field surveys performed on foot were performed in very difficult terrain and required a high level of effort to collect an abbreviated dataset. For each of the studied tributaries (Clavey River and South Fork Tuolumne River), the 2015 work identified features generally consolidated together in the lower reaches of each tributary and a total barrier existing within two miles of the confluence of each tributary with the mainstem Tuolumne River. A summary of the features identified during the 2015 phase of work is provided in Table 6.0-1. As presented in the results section of this document, two potential barriers and one total barrier were identified on the Clavey River and 17 potential barriers and one total barrier were identified on the South Fork Tuolumne River. On both the Clavey and South Fork Tuolumne rivers, these barriers occurred within the lower two miles. As described in the results for each feature, potential barriers exhibited one of the following conditions:

(1) the identified feature exhibited conditions which exceeded the maximum leaping or swimming capability of spring-run Chinook or steelhead but conditions which may facilitate passage at some range of migration flows were apparent; or

(2) the identified feature exhibited conditions which were less than the maximum leaping or swimming capability of spring-run Chinook or steelhead but possessed elements which may inhibit passage at some range of migration flows.

For many of the features identified as potential barriers, it is noted in the results that hydraulic conditions favoring passage may occur at combinations of higher or lower flow conditions. These observations indicate that the lower two miles of both the Clavey River and the South Fork Tuolumne River are likely accessible by anadromous salmonids at certain flows other than the flows occurring during the field visit. Additional data collection and a more quantitative assessment of potential hydraulic conditions would be required to determine the range at which passable conditions may exist.

Survey results and subsequent analysis indicate that the limits of anadromy will be confined to the lower two miles of the Clavey River and South Fork Tuolumne River. However, even within these lower two miles of both tributaries, the habitat conditions observed by the survey team's fishery biologists indicate that the Clavey and the South Fork Tuolumne rivers lack sufficient amounts and/or patch sizes of spawnable sized gravel to provide significant spawning opportunities. The observations and measurements of spawning gravel were recorded by the team's fishery biologists. In the South Fork Tuolumne River downstream of the total barrier, less than 10 percent of habitat units observed had any gravel and there were no units which possessed sufficiently sized gravel patches for anadromous salmonid species. In the Clavey River downstream of the total barrier, less than 10 percent of units observed had gravel or adequately sized gravel patches and there was a very limited number of suitable low gradient riffles (i.e., habitat unit associated with spawning). Thermal conditions in the South Fork Tuolumne River appeared at best, considerably less than optimal for anadromous salmonids. In the Clavey River, summer temperature conditions below the total barrier appear to be lethal for anadromous salmonids. The Upper Tuolumne River Basin Water Temperature Monitoring and Modeling Study (TID/MID 2016) corroborates these field observations based upon past and

current (i.e., 2015 monitoring data) temperature datasets. At the South Fork Tuolumne River confluence, maximum daily temperatures routinely exceed 20ºC in July of 2010. In 2015, temperature data were similar to historical data where temperatures warm in the spring and remain warm throughout the summer. In the Clavey River, summer temperatures at the confluence exceeded 26ºC in 2009. Data collected in 2015 are generally consistent with historical data, recording warming through spring and reaching 25°C near the confluence during the summer.

Table 6.0-1. Summary of features identified within the upper Tuolumne River watershed which are impediments to anadromous fish passage.

Feature	River Mile	Current Classification
Mainstem Tuolumne River		
Clavey Falls	90.0	Passable
Lumsden Falls	97.3	Potential Barrier
Early Intake	104.3	Total Barrier
North Fork Tuolumne River		
Literature suggests that multiple barriers exist within the lower two miles of river. Currently, these features are classified as potential barriers.		
Clavey River		
CR-1	0.20	Partial Barrier
CR-2	1.15	Partial Barrier
CR-3	2.05	Total Barrier
South Fork Tuolumne River		
ST-1	0.45	Partial Barrier
ST-2	0.50	Partial Barrier
ST-3	0.63	Partial Barrier
ST-4	0.67	Partial Barrier
ST-5	0.90	Partial Barrier
ST-6	0.95	Partial Barrier
ST-7	1.05	Partial Barrier
ST-8	1.15	Partial Barrier
ST-9	1.20	Partial Barrier
ST-10	1.35	Partial Barrier
ST-11	1.53	Partial Barrier
ST-12	1.57	Partial Barrier
ST-13	1.60	Partial Barrier
ST-14	1.62	Partial Barrier
ST-15	1.65	Partial Barrier
ST-16	1.80	Partial Barrier
ST-17	1.85	Partial Barrier
ST-18	1.90	Total Barrier
Cherry Creek		
Multiple features identified through aerial photo assessment within two miles of Holm Powerhouse. Currently, these features are classified as potential barriers.		

Given the poor habitat quality conditions observed, the limited additional length of stream reach potentially available to anadromous fish below the identified total barrier, and the high cost required to quantitatively determine the range of passable conditions at each potential barrier, it is recommended that features initially classified as potential barriers in surveyed tributary reaches be given a final classification as partial barriers without further discretization of passable ranges of flow. Features with a final classification of either passable or total barrier would require no further study (see Section 6.1 for reach specific recommendations).

Two potential barriers to fish passage and one total barrier to fish passage were identified in the mainstem Tuolumne River. By inspection during the field visit, but subject to identifying any existing information to the contrary, Clavey Falls is classified as a passable feature. Early Intake is classified as a total barrier to fish passage and blocks anadromy further upstream. Lumsden Falls is initially classified as a potential barrier and exhibits complex hydraulic characteristics at low and high flow conditions. Observations at this site suggest that passable conditions may exist, but further study is warranted to discern the potential range of flows which may or may not be passable by anadromous salmonids.

Conclusions resulting from the information gathered and evaluated to date are summarized on a reach-by-reach basis in Table 6.0-2. A map illustrating the corresponding river reaches which are accessible by anadromous salmonids is provided in Figure 6.0-1. Conclusions suggest that the mainstem Tuolumne River is accessible by anadromous fish to Lumsden Falls at RM 97.3 and may potentially be accessible from Lumsden Falls to the Early Intake at RM 104.3. The lower two miles of the Clavey River are potentially accessible during adequate flow conditions. The Clavey River upstream of RM 2.05 is not accessible by anadromous fish. The lower two miles of the South Fork Tuolumne River are also potentially accessible during adequate flow conditions while the reach upstream of RM 1.9 is not accessible. The Middle Fork Tuolumne River originates upstream of RM 1.9 of the South Fork and therefore is also not accessible by anadromous fish.

Field observations and the resulting assessments have not been performed on the reach of the mainstem Tuolumne River from Lumsden Falls to the Cherry Creek confluence or the North Fork Tuolumne River. The Cherry/Eleanor Creek watershed and the mainstem Tuolumne River from Cherry Creek confluence upstream were surveyed in October 2015; however, results were unavailable at the time of reporting. Conclusions regarding access by anadromous fish for these areas will be made available no later than the USR.

Table 6.0-2. Summary of upper Tuolumne River reaches accessible by anadromous salmonids.

River/Tributary	River Mile	Current Classification
Mainstem Tuolumne River	Don Pedro Reservoir to 97.3	Accessible
	97.3 to 104.3	Potentially Accessible – to be surveyed in 2016
	104.3 and upstream	Not Accessible
North Fork Tuolumne River	To be surveyed in 2016	To be surveyed in 2016
Clavey River	0 to 0.2	Accessible
	0.2 to 2.05	Potentially Accessible
	2.05 and upstream	Not Accessible
South Fork Tuolumne River	0 to 0.45	Accessible
	0.45 to 1.9	Potentially Accessible
	1.9 and upstream	Not Accessible
Middle Fork Tuolumne River	All	Not Accessible
Cherry Creek	Surveyed in 2015 but results not available for this progress report. Findings will be provided in the USR.	Surveyed in 2015 but results not available in this progress report. Findings will be provided in the USR.

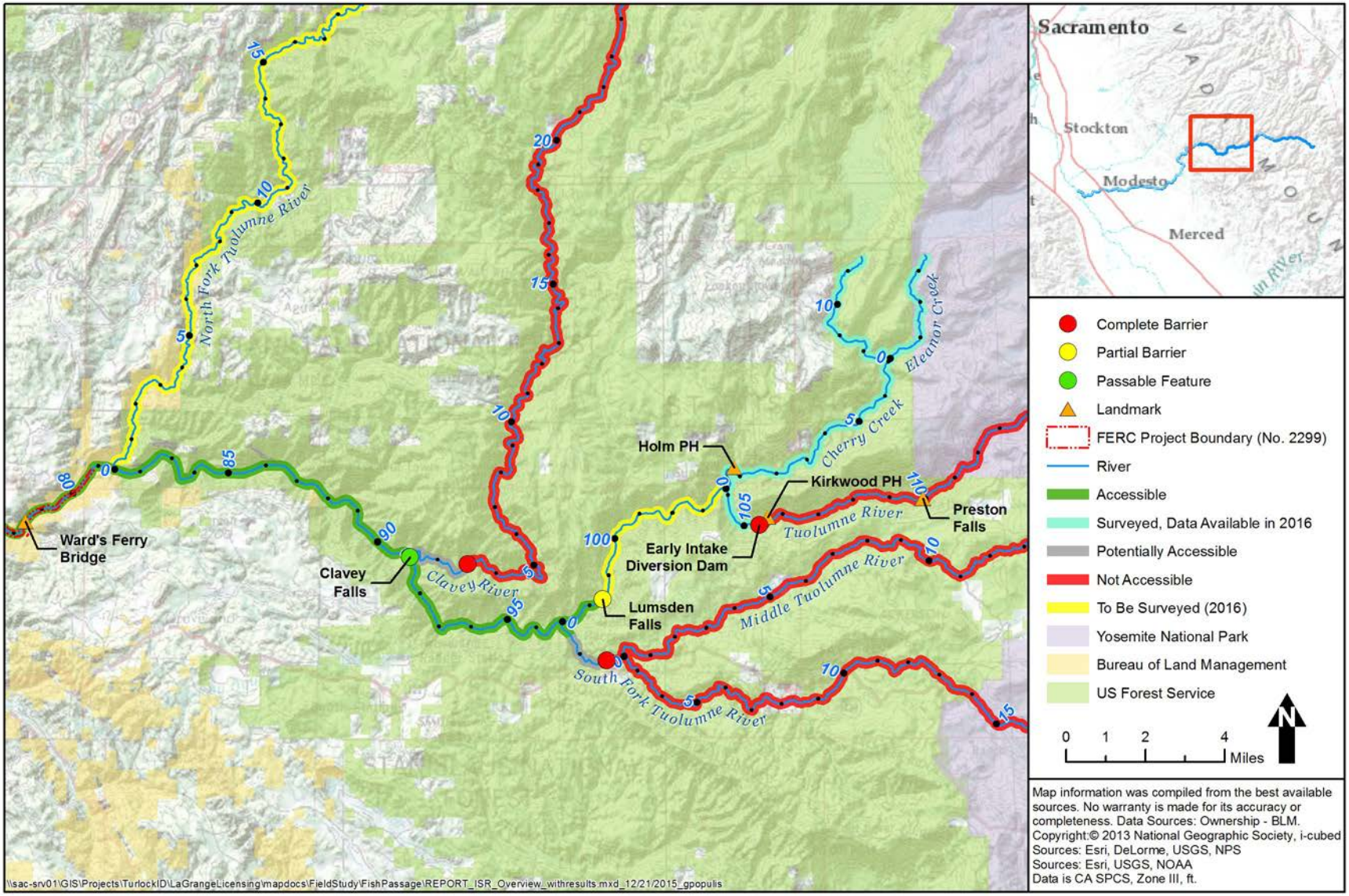


Figure 6.0-1 Overall conclusions and summary of river reaches accessible to anadromous fish based upon field surveys.

6.1 Recommendations for Further Study

Three field surveys are recommended for the 2016 phase of work and are summarized in Table 6.1-1. Surveys will be conducted on the mainstem Tuolumne River between RM 97.3 and 104.3, and on the North Fork Tuolumne River as these reaches were not surveyed in 2015. A more-detailed, second field survey will be conducted to collect additional data at Lumsden Falls. Upon collection of more detailed data at Lumsden Falls, a desktop analysis will be performed to determine whether passage is anticipated at various ranges of river flow conditions. Field data collected from the October 2015 surveys on the Cherry/Eleanor Creek watershed and the mainstem Tuolumne River from the Cherry Creek confluence upstream to Early Intake will be evaluated and assessed. Results, conclusions, and final barrier classifications for all barriers identified will be incorporated into the USR.

As experienced during the 2015 field investigations, performing surveys on foot within these tributaries is difficult and requires a high level of effort during periods when access into the water and around natural features is safe for field personnel. More importantly and as described in Section 6.0 above, habitat observations made during the barrier surveys in tributary reaches indicated that spawning conditions would not be suitable for anadromous salmonids, and that temperatures in the Clavey and South Fork significantly exceed thermal suitability as expressed in the U.S. Environmental Protection Agency (EPA) temperature water quality standards (EPA 2003). Given these observations and the resulting uncertainty of overall benefit, recommendations to perform additional surveys and hydraulic analysis in 2016 is reserved for only higher priority features that have the most profound influence on the potential limit of anadromy and access to quality habitat. No additional field surveys are proposed for other barriers in tributary reaches as identified in the 2015 results.

Table 6.1-1. Summary of recommendations for further study in 2016.

Feature or River Reach	Study Objective
Lumsden Falls	Perform a second field survey to collect additional site specific data. Perform a more detailed evaluation to determine whether passage is anticipated at various ranges of river flow conditions.
Mainstem Tuolumne River RM 97.3 to 104.3	Perform survey to determine if the potential barriers exist. Evaluate collected data and make initial classification.
North Fork Tuolumne River	Perform survey to determine if potential barriers exist. Evaluate collected data and make initial classification.
Cherry Creek	Field surveys were performed on October 26, 2015 but results are not presented in this progress report. Conclusions relative to barriers identified within Cherry/Eleanor Creeks will be made available in the USR.

7.0 STUDY VARIANCES AND MODIFICATIONS

Given the difficult conditions experienced while conducting the field surveys on foot, only limited field gear was carried for the purpose of collecting data and in many cases abbreviated surveys were obtained given the constraint of available daylight and personnel safety. To maintain collection of a consistent set of data an abbreviated list of information was collected. This list deviates slightly from the original elements proposed as part of the RSP based upon site-specific safety considerations, equipment requirements, time constraints, and ability to measure using alternative desktop methods. The three measurements not taken consistently were:

- maximum and average depth of plunge pools at the base of barriers;
- water velocity measurements at the apex of the barrier (if measurements could be made safely); and/or
- measured (or estimated if measurement is unsafe) maximum and average depth of the landing zone on the upstream side of the barrier.

Depth of the plunge pool below each barrier was difficult to evaluate on a quantitative basis for all sites and therefore the summary of conditions presented herein are based on field notes, photographs, and aerial photos available for each site. Water velocities, depths, and landing conditions above the feature crest were sampled on an intermittent basis to provide general characterization of some features. These factors will vary to some degree as flow quantity changes at each feature. The flows present during field observations created relatively poor launching and landing conditions for many of the features. These condition are apparent in many of the photographs taken at each feature and are discussed in Section 6.0.

As presented in Section 4.0, the recommendation to perform additional surveys in 2016 and further hydraulic analysis of tributary barriers identified during 2015 is reserved for features that would have the potential limit of anadromy and access to suitable habitat. The decision to proceed with additional data collection and analysis is based upon the anticipated level of benefit which may be achieved by performing such activities. In this progress report, it is recommended that further field surveys occur in 2016 at Lumsden Falls and for reaches that were not able to be in 2015. The ability to pass Lumsden Falls on the mainstem Tuolumne River will have a quantifiable impact on the quantity of habitat accessible by spring-run Chinook and steelhead.

For the remaining potential barriers identified in the Clavey and South Fork Tuolumne rivers, the study team recommends that no further data collection take place and that those features be classified as partial barriers (refer to Table 6.0-1) for reasons described in Section 6.0. By definition, partial barriers allow for the intermittent passage of both spring-run Chinook and steelhead during some range of flows.

8.0 REFERENCES

Bell, M.C. 1973. Fisheries Handbook of Engineering Requirements and Biological Criteria. Fisheries Engineering Research Program. U.S. Army Engineering Division. North Pacific Corps of Engineers. Portland, OR.

Buckmaster, Nicholas, A. Clause, T. Hatch, H. Jackson, A. Stephenson. 2009. Effects of unregulated tributaries on a regulated mainstem (Tuolumne River). University of California, Davis, Center for Watershed Sciences.

EA Engineering. 1990. Exhibit E (Report 3) of the Clavey River Project Administrative Draft FERC License Application.

Holbek, Lars and Chuck Stanley. 1984. A Guide to the Best Whitewater in the State of California. Sacramento: Friends of the River Books.

Hunter, Larry A. and Mayor, Lesley. 1986. Analysis of Fish Swimming Performance Data, Volume I.

Moyle, P.B. 2002. Inland Fisheries of California, 2nd Ed. University of California Press. Davis, CA.

National Marine Fisheries Service (NMFS). 2014. Recovery Plan for the Evolutionary Significant Units of Sacramento River Winter-Run Chinook Salmon and Central Valley Spring-Run Chinook Salmon and The Distinct Population Segment of California Central Steelhead. July 2014.

Powers, P.D. and J.F. Orsborn. 1985. Analysis of Barriers to Upstream Migration: An Investigation of the Physical and Biological Conditions Affecting Fish Passage Success at Culverts and Waterfalls. BPA Report No. DOE/BP-36523-1.

Turlock Irrigation District and Modesto Irrigation District (TID/MID). 2016. Upper Tuolumne River Basin Water Temperature Monitoring and Modeling Study Progress Report. Prepared by Watercourse Engineering, Inc. Attachment to La Grange Hydroelectric Project Initial Study Report. February 2016.

U.S. Environmental Protection Agency (EPA). EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards (2003). Available online at: http://www.epa.gov/region10/pdf/water/final_temperature_guidance_2003.pdf

U.S. Forest Service (USFS). 2001. Aquatic habitat management handbook. Chapter 20 – Fish and Aquatic Stream Habitat Survey, Forest Service Handbook 2090.21.

Yoshiyama, Ronald M., E. Gerstung, F. Fisher, P. Moyle. 2001. Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California. Contributions to the Biology of Central Valley Salmonids. Fish Bulletin 179: Volume 1.

UPPER TUOLUMNE RIVER BASIN
FISH MIGRATION BARRIERS STUDY
PROGRESS REPORT

ATTACHMENT A

PHOTOGRAPH LOG AND SUMMARY OF COLLECTED DATA

This Page Intentionally Left Blank.

	**Photo 1** **Waterbody:** Mainstem Tuolumne River **Feature:** Clavey Falls **River Mile:** 90 **Date:** 8/4/2015 **Time:** 10:54 **Image Name:** IMG_20150804_105404_-832109627.jpg **Coordinates:** 37.86466659, -120.11769261 **Total Vertical Height:** 3 feet **Description:** Recreational flows, looking upstream at constriction step. **Barrier:** Passable
	**Photo 2** **Waterbody:** Mainstem Tuolumne River **Feature:** Clavey Falls **River Mile:** 90 **Date:** 8/4/2015 **Time:** 10:54 **Image Name:** IMG_20150804_105459_1342125081.jpg **Coordinates:** 37.86467865, -120.11781715 **Total Vertical Height:** 2-3 feet **Description:** Recreational flows, looking upstream at boulder steps. **Barrier:** Passable
	**Photo 3** **Waterbody:** Mainstem Tuolumne River **Feature:** Clavey Falls **River Mile:** 90 **Date:** 8/4/2015 **Time:** 09:46 **Image Name:** IMG_20150804_094635_2064884884.jpg **Coordinates:** 37.86431125, -120.1178997 **Total Vertical Height:** 6 feet **Description:** Low flows, looking upstream at cascade. **Barrier:** Passable

	**Photo 4** **Waterbody:** Mainstem Tuolumne River **Feature:** Clavey Falls **River Mile:** 90 **Date:** 8/4/2015 **Time:** 10:57 **Image Name:** IMG_20150804_105707_1230910478.jpg **Coordinates:** 37.86418216, -120.11777968 **Total Vertical Height:** 6 feet **Description:** Recreational flows, looking upstream at cascade. **Barrier:** Passable
	**Photo 5** **Waterbody:** Mainstem Tuolumne River **Feature:** Clavey Falls **River Mile:** 90 **Date:** 8/4/2015 **Time:** 09:47 **Image Name:** IMG_20150804_094733_1267904529.jpg **Coordinates:** 37.86417511, -120.11785951 **Total Vertical Height:** 6 feet **Description:** Low flows, looking upstream close up at cascade. **Barrier:** Passable
	**Photo 6** **Waterbody:** Mainstem Tuolumne River **Feature:** Lumsden Falls **River Mile:** 97.3 **Date:** 8/5/2015 **Time:** 09:59 **Image Name:** IMG_20150805_095948_1451836945.jpg **Coordinates:** 37.84819453, -120.02996637 **Total Vertical Height:** 18 feet **Description:** Low flows, overview looking upstream at cascade. **Barrier:** Potential

	**Photo 7** **Waterbody:** Mainstem Tuolumne River **Feature:** Lumsden Falls **River Mile:** 97.3 **Date:** 8/6/2015 **Time:** 11:20 **Image Name:** IMG_20150806_112005_1245804360.jpg **Coordinates:** 37.84821225, -120.02995430 **Total Vertical Height:** 18 feet **Description:** Recreational flows, overview looking upstream at cascade. **Barrier:** Potential
	**Photo 8** **Waterbody:** Mainstem Tuolumne River **Feature:** Lumsden Falls **River Mile:** 97.3 **Date:** 8/5/2015 **Time:** 10:21 **Image Name:** IMG_20150805_102121_-648207368.jpg **Coordinates:** 37.84589793, -120.04109135 **Total Vertical Height:** 18 feet **Description:** Low flows, looking upstream at cascade. **Barrier:** Potential
	**Photo 9** **Waterbody:** Mainstem Tuolumne River **Feature:** Lumsden Falls **River Mile:** 97.3 **Date:** 8/6/2015 **Time:** 11:32 **Image Name:** IMG_20150806_113246_706160864.jpg **Coordinates:** 37.84830553, -120.02972330 **Total Vertical Height:** 18 feet **Description:** Recreational flows, looking upstream at cascade. **Barrier:** Potential

	**Photo 10** **Waterbody:** Mainstem Tuolumne River **Feature:** Lumsden Falls **River Mile:** 97.3 **Date:** 8/5/2015 **Time:** 10:25 **Image Name:** IMG_20150805_102537_1451836945.jpg **Coordinates:** 37.84842667, -120.02952527 **Total Vertical Height:** 18 feet **Description:** Low flows, looking upstream from mid-falls. **Barrier:** Potential
	**Photo 11** **Waterbody:** Mainstem Tuolumne River **Feature:** Lumsden Falls **River Mile:** 97.3 **Date:** 8/6/2015 **Time:** 11:46 **Image Name:** IMG_20150806_114406_-428109626.jpg **Coordinates:** 37.84853852, -120.02931625 **Total Vertical Height:** 18 feet **Description:** Recreational flows, looking upstream from mid-falls. **Barrier:** Potential
	**Photo 12** **Waterbody:** Mainstem Tuolumne River **Feature:** Lumsden Falls **River Mile:** 97.3 **Date:** 8/6/2015 **Time:** 11:47 **Image Name:** IMG_20150806_114742_2071543936.jpg **Coordinates:** 37.84843521, -120.02914996 **Total Vertical Height:** 18 feet **Description:** Recreational flows, looking upstream at falls crest. **Barrier:** Potential

	**Photo 13** **Waterbody:** Clavey River **Feature:** CR-1 **River Mile:** 0.2 **Date:** 8/3/2015 **Time:** 17:38 **Image Name:** IMG_20150803_173808_789570304.jpg **Coordinates:** 37.86620440, -120.11463213 **Total Vertical Height:** 12 feet **Description:** Looking upstream at split flow bedrock falls. **Barrier:** Partial
	**Photo 14** **Waterbody:** Clavey River **Feature:** CR-1 **River Mile:** 0.2 **Date:** 8/3/2015 **Time:** 17:39 **Image Name:** IMG_20150803_173949_-865758468.jpg **Coordinates:** 37.86618723, -120.11466690 **Total Vertical Height:** 12 feet **Description:** Looking downstream at tail water control pool. **Barrier:** Partial
	**Photo 15** **Waterbody:** Clavey River **Feature:** CR-2 **River Mile:** 1.15 **Date:** 8/3/2015 **Time:** 16:24 **Image Name:** IMG_20150803_162424_502621589.jpg **Coordinates:** 37.86219766, -120.10301435 **Total Vertical Height:** 8 feet **Description:** Looking upstream at split flow feature. **Barrier:** Partial

	**Photo 16** **Waterbody:** Clavey River **Feature:** CR-2 **River Mile:** 1.15 **Date:** 8/3/2015 **Time:** 16:05 **Image Name:** IMG_20150803_160556_1431754020.jpg **Coordinates:** 37.86201539, -120.10293057 **Total Vertical Height:** 8 feet **Description:** Looking upstream at river left flow feature over bedrock chute. **Barrier:** Partial
	**Photo 17** **Waterbody:** Clavey River **Feature:** CR-2 **River Mile:** 1.15 **Date:** 8/3/2015 **Time:** 16:08 **Image Name:** IMG_20150803_160818_1515502728.jpg **Coordinates:** 37.86202495, -120.10295292 **Total Vertical Height:** 8 feet **Description:** Looking upstream at river right flow features over boulders. **Barrier:** Partial
	**Photo 18** **Waterbody:** Clavey River **Feature:** CR-2 **River Mile:** 1.15 **Date:** 8/3/2015 **Time:** 16:00 **Image Name:** IMG_20150803_160000_1021997947.jpg **Coordinates:** 37.86205223, -120.10296322 **Total Vertical Height:** 8 feet **Description:** Looking upstream at feature crest. **Barrier:** Partial

	**Photo 19** **Waterbody:** Clavey River **Feature:** CR-3 **River Mile:** 2.05 **Date:** 8/3/2015 **Time:** 13:40 **Image Name:** IMG_20150803_134054_1556097379.jpg **Coordinates:** 37.86087502, -120.09213326 **Total Vertical Height:** not applicable **Description:** Looking upstream at 400 feet long boulder field. **Barrier:** Total
	**Photo 20** **Waterbody:** Clavey River **Feature:** CR-3 **River Mile:** 2.05 **Date:** 8/3/2015 **Time:** 13:28 **Image Name:** IMG_20150803_132843_1574218901.jpg **Coordinates:** 37.86150460, -120.09135843 **Total Vertical Height:** not applicable **Description:** Looking upstream at flow under boulder with inadequate clearance for fish passage. **Barrier:** Total

	**Photo 21** **Waterbody:** Clavey River **Feature:** CR-3 **River Mile:** 2.05 **Date:** 8/3/2015 **Time:** 13:15 **Image Name:** IMG_20150803_131516_139401152.jpg **Coordinates:** 37.86138223, -120.09151098 **Total Vertical Height:** not applicable **Description:** Looking upstream at flow through boulder field. **Barrier:** Total
	**Photo 22** **Waterbody:** Clavey River **Feature:** CR-3 **River Mile:** 2.05 **Date:** 8/3/2015 **Time:** 13:04 **Image Name:** IMG_20150803_130436_2021697091.jpg **Coordinates:** 37.86150460, -120.09135843 **Total Vertical Height:** not applicable **Description:** Looking downstream at flow through boulder field. **Barrier:** Total
	**Photo 23** **Waterbody:** Clavey River **Feature:** CR-3 **River Mile:** 2.05 **Date:** 8/3/2015 **Time:** 12:54 **Image Name:** IMG_20150803_125441_1710042233.jpg **Coordinates:** 37.86157972, -120.09111681 **Total Vertical Height:** not applicable **Description:** Looking uphill at hill slope slide area feeding into boulder field. **Barrier:** Total

	**Photo 24** **Waterbody:** Clavey River **Feature:** CR-3 **River Mile:** 2.05 **Date:** 8/3/2015 **Time:** 12:42 **Image Name:** IMG_20150803_124235_1273056850.jpg **Coordinates:** 37.86148716, -120.09138184 **Total Vertical Height:** 7-10 feet **Description:** Looking upstream at crest of boulder field. **Barrier:** Total
	**Photo 25** **Waterbody:** Clavey River **Feature:** CR-3 **River Mile:** 2.05 **Date:** 8/3/2015 **Time:** 12:50 **Image Name:** IMG_20150803_125009_144389114.jpg **Coordinates:** 37.86160869, -120.09119522 **Total Vertical Height:** 7-10 feet **Description:** Looking upstream at crest of boulder field. **Barrier:** Total
	**Photo 26** **Waterbody:** South Fork Tuolumne River **Feature:** ST-1 **River Mile:** 0.45 **Date:** 8/5/2015 **Time:** 19:13 **Image Name:** IMG_20150805_191358_-159393085.jpg **Coordinates:** 37.83525797, -120.04364120 **Total Vertical Height:** 5-7 feet **Description:** Looking upstream at split flow falls over bedrock. **Barrier:** Partial

	**Photo 27** **Waterbody:** South Fork Tuolumne River **Feature:** ST-1 **River Mile:** 0.45 **Date:** 8/5/2015 **Time:** 19:16 **Image Name:** IMG_20150805_191631_90572858.jpg **Coordinates:** 37.83530969, -120.04354825 **Total Vertical Height:** 5-7 feet **Description:** Looking upstream at river right falls over bedrock. **Barrier:** Partial
	**Photo 28** **Waterbody:** South Fork Tuolumne River **Feature:** ST-2 **River Mile:** 0.5 **Date:** 8/5/2015 **Time:** 19:06 **Image Name:** IMG_20150805_190643_2052653629.jpg **Coordinates:** 37.83469790, -120.04358405 **Total Vertical Height:** 3-4 feet **Description:** Looking upstream at step pool falls. **Barrier:** Partial
	**Photo 29** **Waterbody:** South Fork Tuolumne River **Feature:** ST-3 **River Mile:** 0.63 **Date:** 8/5/2015 **Time:** 18:50 **Image Name:** IMG_20150805_185040_68629034.jpg **Coordinates:** 37.83317976, -120.04269041 **Total Vertical Height:** 4-5 feet **Description:** Looking upstream at split flow step pool falls. **Barrier:** Partial

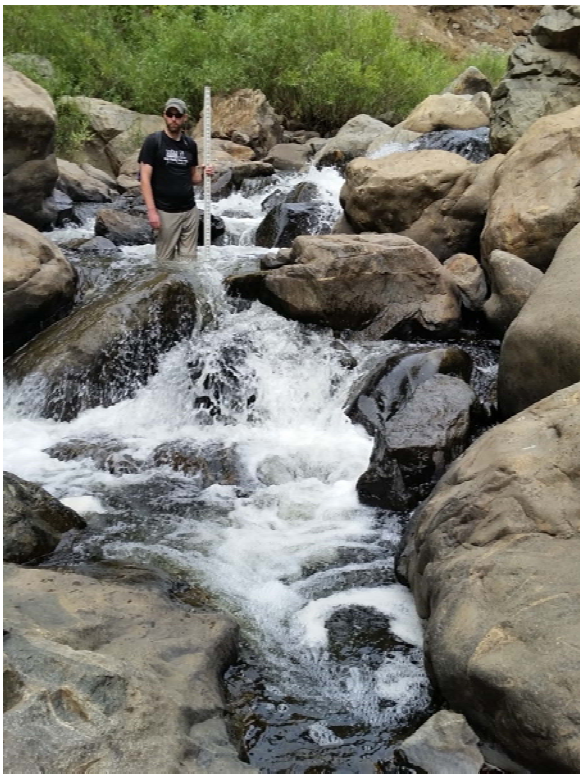
	**Photo 30** **Waterbody:** South Fork Tuolumne River **Feature:** ST-4 **River Mile:** 0.67 **Date:** 8/5/2015 **Time:** 18:44 **Image Name:** IMG_20150805_184426_1120698503.jpg **Coordinates:** 37.83276546, -120.04197991 **Total Vertical Height:** 6 feet **Description:** Looking upstream at falls between boulders. **Barrier:** Partial
	**Photo 31** **Waterbody:** South Fork Tuolumne River **Feature:** ST-5 **River Mile:** 0.9 **Date:** 8/5/2015 **Time:** 18:24 **Image Name:** IMG_20150805_182414_1616201536.jpg **Coordinates:** 37.82947237, -120.04108911 **Total Vertical Height:** 3.5 feet **Description:** Looking upstream at split flow step pool falls. **Barrier:** Partial
	**Photo 32** **Waterbody:** South Fork Tuolumne River **Feature:** ST-6 **River Mile:** 0.95 **Date:** 8/5/2015 **Time:** 18:17 **Image Name:** IMG_20150805_181720_1605778994.jpg **Coordinates:** 37.82883430, -120.04079654 **Total Vertical Height:** 11 feet **Description:** Looking upstream at bedrock falls. **Barrier:** Partial

	**Photo 33** **Waterbody:** South Fork Tuolumne River **Feature:** ST-7 **River Mile:** 1.05 **Date:** 8/5/2015 **Time:** 18:08 **Image Name:** IMG_20150805_180841_2002098336.jpg **Coordinates:** 37.82810769, -120.03913301 **Total Vertical Height:** 5 feet **Description:** Looking upstream at bedrock falls. **Barrier:** Partial
	**Photo 34** **Waterbody:** South Fork Tuolumne River **Feature:** ST-8 **River Mile:** 1.15 **Date:** 8/5/2015 **Time:** 17:57 **Image Name:** IMG_20150805_175753_1094997848.jpg **Coordinates:** 37.82718331, -120.03820443 **Total Vertical Height:** 6 feet **Description:** Looking upstream at falls between bedrock and boulders. **Barrier:** Partial
	**Photo 35** **Waterbody:** South Fork Tuolumne River **Feature:** ST-9 **River Mile:** 1.2 **Date:** 8/5/2015 **Time:** 17:50 **Image Name:** IMG_20150805_175027_481678163.jpg **Coordinates:** 37.82655809, -120.03770691 **Total Vertical Height:** 16 feet **Description:** Looking upstream at bedrock step falls. **Barrier:** Partial

	**Photo 36** **Waterbody:** South Fork Tuolumne River **Feature:** ST-10 **River Mile:** 1.35 **Date:** 8/5/2015 **Time:** 17:37 **Image Name:** IMG_20150805_173718_2036909888.jpg **Coordinates:** 37.82671097, -120.03590602 **Total Vertical Height:** 3-5 feet **Description:** Looking upstream at falls between boulders. **Barrier:** Partial
	**Photo 37** **Waterbody:** South Fork Tuolumne River **Feature:** ST-11 **River Mile:** 1.53 **Date:** 8/5/2015 **Time:** 17:15 **Image Name:** IMG_20150805_171534_1269685908.jpg **Coordinates:** 37.82512415, -120.03300482 **Total Vertical Height:** 3-5 feet **Description:** Looking upstream at split flow step falls. **Barrier:** Partial

	**Photo 38** **Waterbody:** South Fork Tuolumne River **Feature:** ST-12 **River Mile:** 1.57 **Date:** 8/5/2015 **Time:** 17:06 **Image Name:** IMG_20150805_170644_1217473234.jpg **Coordinates:** 37.82475480, -120.03229264 **Total Vertical Height:** 10 feet **Description:** Looking upstream at cascade. **Barrier:** Partial
	**Photo 39** **Waterbody:** South Fork Tuolumne River **Feature:** ST-13 **River Mile:** 1.6 **Date:** 8/5/2015 **Time:** 16:59 **Image Name:** IMG_20150805_165914_1249065127.jpg **Coordinates:** 37.82504767, -120.03175838 **Total Vertical Height:** 6-8 feet **Description:** Looking upstream at step pool falls. **Barrier:** Partial

	**Photo 40** **Waterbody:** South Fork Tuolumne River **Feature:** ST-14 **River Mile:** 1.62 **Date:** 8/5/2015 **Time:** 16:54 **Image Name:** IMG_20150805_165427_526436975.jpg **Coordinates:** 37.82533042, -120.03189472 **Total Vertical Height:** 14 feet **Description:** Looking upstream at step pool falls. **Barrier:** Partial
	**Photo 41** **Waterbody:** South Fork Tuolumne River **Feature:** ST-15 **River Mile:** 1.65 **Date:** 8/5/2015 **Time:** 16:48 **Image Name:** IMG_20150805_164822_208747719.jpg **Coordinates:** 37.82565017, -120.03171151 **Total Vertical Height:** 3-4 feet **Description:** Looking upstream at split flow step pool falls. **Barrier:** Partial
	**Photo 42** **Waterbody:** South Fork Tuolumne River **Feature:** ST-16 **River Mile:** 1.8 **Date:** 8/5/2015 **Time:** 16:29 **Image Name:** IMG_20150805_162930_1651167043.jpg **Coordinates:** 37.82563017, -120.02913378 **Total Vertical Height:** 5-6 feet **Description:** Looking upstream at bedrock falls. **Barrier:** Partial

	**Photo 43** **Waterbody:** South Fork Tuolumne River **Feature:** ST-17 **River Mile:** 1.85 **Date:** 8/5/2015 **Time:** 16:22 **Image Name:** IMG_20150805_162219_1883865277.jpg **Coordinates:** 37.82593146, -120.02857645 **Total Vertical Height:** 7 feet **Description:** Looking upstream at cascade. **Barrier:** Partial
	**Photo 44** **Waterbody:** South Fork Tuolumne River **Feature:** ST-18 **River Mile:** 1.9 **Date:** 8/5/2015 **Time:** 16:22 **Image Name:** IMGP0109.jpg **Coordinates:** 37.82616354, -120.02741986 **Total Vertical Height:** 32 feet **Description:** Looking upstream at bedrock falls. **Barrier:** Total