FINAL REPORT ◦ APRIL 2013

Lower Tuolumne River Instream Flow Study

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Cover photo: Tuolumne River upstream of Basso Bridge, summer 2011, 600 cfs.

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Acknowledgements

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1 INTRODUCTION

1.1 Project Description

Turlock Irrigation District (TID) and Modesto Irrigation District (MID) (collectively, the Districts) are the co-licensees of the 168-megawatt Don Pedro Project (FERC Project No. 2299) located at river mile (RM) 54.8 of the Tuolumne River in western Tuolumne County, in the Central Valley region of California.

Project facilities include Don Pedro Reservoir (2.03 million acre-feet capacity at normal maximum elevation of 830 feet), 580-foot-high Don Pedro Dam (completed in 1971), a four-unit powerhouse situated at the base of the dam, and related facilities. Downstream of the Don Pedro Project, at approximately RM 51.7, La Grange Dam diverts water into canals to the north and south that supply Modesto Irrigation District and Turlock Irrigation District, respectively.

Downstream of La Grange Dam, the lower Tuolumne River runs approximately 52 miles to its confluence with the San Joaquin River. Dry Creek, at RM 16, is the largest tributary to the lower Tuolumne River. All tributary inflows are highly seasonal, and none of them provide significant flow to the Tuolumne River on a year-round basis.

1.2 Background and Purpose

Pursuant to the Federal Energy Regulatory Commission (FERC or Commission) Order of July 16, 2009 (128 FERC ¶ 61,035), the Districts were required, in consultation with fishery resource agencies, to develop and implement an Instream Flow Incremental Methodology (IFIM) study. The Tuolumne River Instream Flow Studies Study Plan (Study Plan) (Stillwater Sciences 2009), including the development of an IFIM study, was filed with the Commission on October 14, 2009. The Study Plan was approved, pursuant to Ordering paragraphs (A) through (E) of the Commission's May 12, 2010 Order. A revised implementation schedule was approved under the July 21, 2010 FERC Order and a follow-up study extension request to file the Instream Flow Study Report on April 29, 2013 was approved under the December 5, 2011 FERC Order (FERC 2011).

Separate from the IFIM study component of the Study Plan, a Pulse Flow Study Report was submitted on June 18, 2012 (TID/MID 2012).

The purpose of the IFIM study under the July 16, 2009 Order (128 FERC ¶ 61,035) is "to determine instream flows necessary to maximize fall-run Chinook salmon *(Oncorhynchus tshawytscha)* and *O. mykiss* production and survival throughout their various life stages." This IFIM Study Report has been prepared both in fulfillment of Ordering Paragraph (D) of the May 12, 2010 Order modifying and approving Instream Flow and Water Temperature Model Study Plans, and in accordance with the revised implementation schedule approved by the December 5, 2011 Order, and provides detailed methods and results for the study (FERC 2011).

Two prior physical habitat simulation (PHABSIM) studies of the lower Tuolumne River have been conducted for the Don Pedro Project as part of the approved FERC Fisheries Study Plan. A 1981 study by the California Department of Fish and Game (CDFG) (now California Department of Fish and Wildlife [CDFW]) (TID/MID 1992a) was focused within a nine-mile reach (RM 50.5–42.0) extending from near the town of La Grange to near Turlock Lake State Recreation

Area. A reanalysis of the 1981 CDFG data was also completed by EA Engineering, Science, and Technology (EA) in 1991 on behalf of the Districts (TID/MID 1992b). Selected elements of the CDFG study are summarized in Table 1 below.

In 1992, the second PHABSIM study was conducted by the U.S. Fish and Wildlife Service (USFWS) (USFWS 1995), which is also briefly summarized in Table 1. The USFWS study reaches included the entire lower Tuolumne River from La Grange Dam (RM 52.2) downstream to the confluence with the San Joaquin River (RM 0.0), although the most extensive field efforts were focused in riffle and run habitats in the 21-mile reach upstream of Waterford (RM 31) that is most heavily utilized for spawning by salmonid species. Using the results of the USFWS study, the Districts previously responded to an August 2003 information request from FERC staff to develop a flow vs. habitat evaluation that incorporated water temperature effects on Weighted Usable Area (WUA) (Stillwater Sciences 2003).

Table 1. Selected instream flow model details for studies on the lower Tuolumne River in 1981 and 1992.

Study	Upper RM	Lower RM	Total transects	Calibration flows (approx. cfs)			Simulation range (cfs)
				Low	Mid	High	
CDFG reanalysis (TID/MID 1992b)	50.5	42.0	19	120	260	410	20–600
USFWS (1995)	52.2	0.0	25 (23 used)	250	600	1,050	25–1,200

Both prior studies included simulations for various life stages of *O. mykiss* and Chinook salmon. In addition to the previous IFIM studies and evaluations, the Districts have also produced flow-related reports on flow fluctuation and juvenile salmonid stranding analyses at flows up to 8,400 cfs (TID/MID 1992c and 1992d; TID/MID 2001, Report 2000-6; TID/MID 2005, Appendix E), as well as geographic information system (GIS) based mapping of overbank inundation surfaces at several flows within this range (TID/MID 2005, Appendix F). Additionally, as part of the Lower Tuolumne River Instream Flow Studies, a 2D assessment of temporarily inundated portions of Tuolumne River overbank areas was completed in 2012 (TID/MID 2012).

The current study described below is an independent, standalone investigation that is not dependent on data from the previous IFIM studies, although some prior data are presented for comparison purposes. The habitat results presented herein are a single, albeit important, consideration in the overall production of Chinook salmon and *O. mykiss* in the Tuolumne River. In addition to these results, information on geomorphic processes, water temperature, population dynamics, spawning area, and a variety of other factors are being considered in the evaluation of fish and flow management options for the lower Tuolumne River.

1.3 Study Plan Implementation and Agency Consultation

In accordance with Ordering Paragraph (D) of the May 12, 2010 FERC Order and as modified by Ordering Paragraph (A) of the July 21, 2010 FERC Order, the Districts developed the Study Plan and implemented the IFIM study through consultation with the National Marine Fisheries Service (NMFS), USFWS, and CDFW. As specified in the July 21, 2010 Order, the Districts held a series of workshops and meetings covering initial study planning, habitat typing, site selection and transect placement, habitat suitability criteria (HSC) development, and model calibration. Workshop summaries are provided in Appendices A through F.

An initial IFIM study progress report was filed with the Commission on December 10, 2010, detailing initial agency consultation activities and key decisions. A second progress report was filed on July 29, 2011 summarizing work performed by the Districts to implement the final study plan; it also requested a flow variance or study extension to address constraints created by high runoff conditions extending throughout water year 2011. A study extension was granted by FERC on December 5, 2011.

Pursuant to the requirements of the FERC Order, the Lower Tuolumne River Instream Flow Study Draft Report was circulated for a 30-day review period (February 28, 2013 – April 1, 2013) to the resource agencies, non-government organizations, and other interested parties. Following the 30-day review period, the USFWS provided comments on April 8, 2013, which have been addressed in this final report (Appendix K).

1.4 Relationship to Relicensing

Since initiation of the instream flow study, the Districts have started the relicensing process for the Don Pedro Project. A variety of studies are being conducted as part of relicensing, some of which are related to, or expecting to use, results of the ongoing instream flow study. Relicensing is a separate process (with a different schedule) from the FERC Order for the instream flow study, but it is the Districts' intent to integrate the instream flow study results (as they become available) into all relicensing studies and analyses where they are useful. An in-progress draft of this report was filed with FERC on January 17, 2013 as part of the Districts' Initial Study Report for relicensing of the Don Pedro Project (TID/MID 2013a). Subsequent to filing of this final report per the revised implementation schedule in the December 5, 2011 FERC Order, two additional tasks will be completed to address updated information being developed as part of the ongoing relicensing process for the Don Pedro Project (FERC No. 2299-075):

1. An evaluation of effective weighted usable area of affected salmonid life stages, which requires finalization of the current Lower Tuolumne River water temperature model (Study W&AR-16) being developed as part of relicensing. Completion of this analysis is anticipated by September 30, 2013.
2. Additional weighted usable area versus flow analyses for Sacramento splittail and Pacific lamprey, per FERC's December 22, 2011 relicensing Study Plan Determination letter and the habitat suitability criteria provided by the USFWS on April 8, 2013. The results of this analysis are expected to be available by July 30, 2013.

Any comments on the supplemental analyses identified above will be addressed in the Draft License Application.

2 METHODS

The instream flow assessment methodology (Bovee 1982) described below applies a mesohabitat and transect-based approach (commonly referred to as the 1-D method) for implementing the PHABSIM component of the USFWS Instream Flow Incremental Methodology to address flow-habitat relationships in the lower Tuolumne River. For this study, the RHABSIM (riverine habitat simulation) version of the model (Payne 1998) was applied using a one-flow velocity calibration approach, where transect and cell-specific data were derived from field survey data. The model calculates a habitat index that reflects the WUA based on simulation of river depths and velocities from the 1-D hydraulic models. Cross sections (transects) are used to represent the river, and habitat suitability criteria are applied which define the physical and hydraulic characteristics considered suitable for particular species and life stages of interest.

2.1 Habitat Mapping

In order to support appropriate reach segmentation and habitat representation of the lower Tuolumne River, habitat mapping data down to RM 29.0 below the City of Waterford were utilized to determine habitat composition and distribution (Figure 1). Mesohabitat delineation followed a geomorphic-based habitat mapping system (requested by the USFWS in their letter of October 5, 2009 [USFWS 2009]) using eight mesohabitat types: bar complex glides, bar complex pools, bar complex riffles, bar complex runs, flatwater glides, flatwater pools, flatwater riffles, and flatwater runs (Snider et al. 1992). Side channel habitat was originally proposed as a separate channel form (e.g., bar complex, flatwater), resulting in 12 potential habitat types; however, side channel was subsequently included as a separate feature during the study planning workshop and was mapped separately during field surveys to determine the total representation for transect selection purposes. The mesohabitat types selected by consensus[1] of the workgroup are described in Table 2. The study planning process was documented in the study planning workshop notes, included as Appendix A.

Habitat mapping was conducted from boats by teams of two individuals using low-elevation aerial photos of the river to delineate mesohabitat unit breaks. Mesohabitat units were numbered consecutively extending from the La Grange gage (RM 51.7) downstream to the existing rotary screw trap (RST) location near the City of Waterford (RM 29.0). Digital reference points at the upstream and downstream boundaries were recorded during the habitat mapping field survey. Distinct habitat units were defined when the unit length was at least equal to the active channel width or if the unit was otherwise distinctive. Additional habitat attributes described in Table 3 were recorded during the field survey. The relative abundance (i.e., frequency), percent composition, and total length of the mesohabitat units were calculated for use in PHABSIM modeling.

The percent composition of mesohabitat types in the study area are documented in Table 4 (La Grange gage at RM 51.7 to downstream of Waterford at RM 29).

[1] For purposes of this study, "consensus" is defined as the concurrence of all parties in attendance at the time and place that decisions were made.

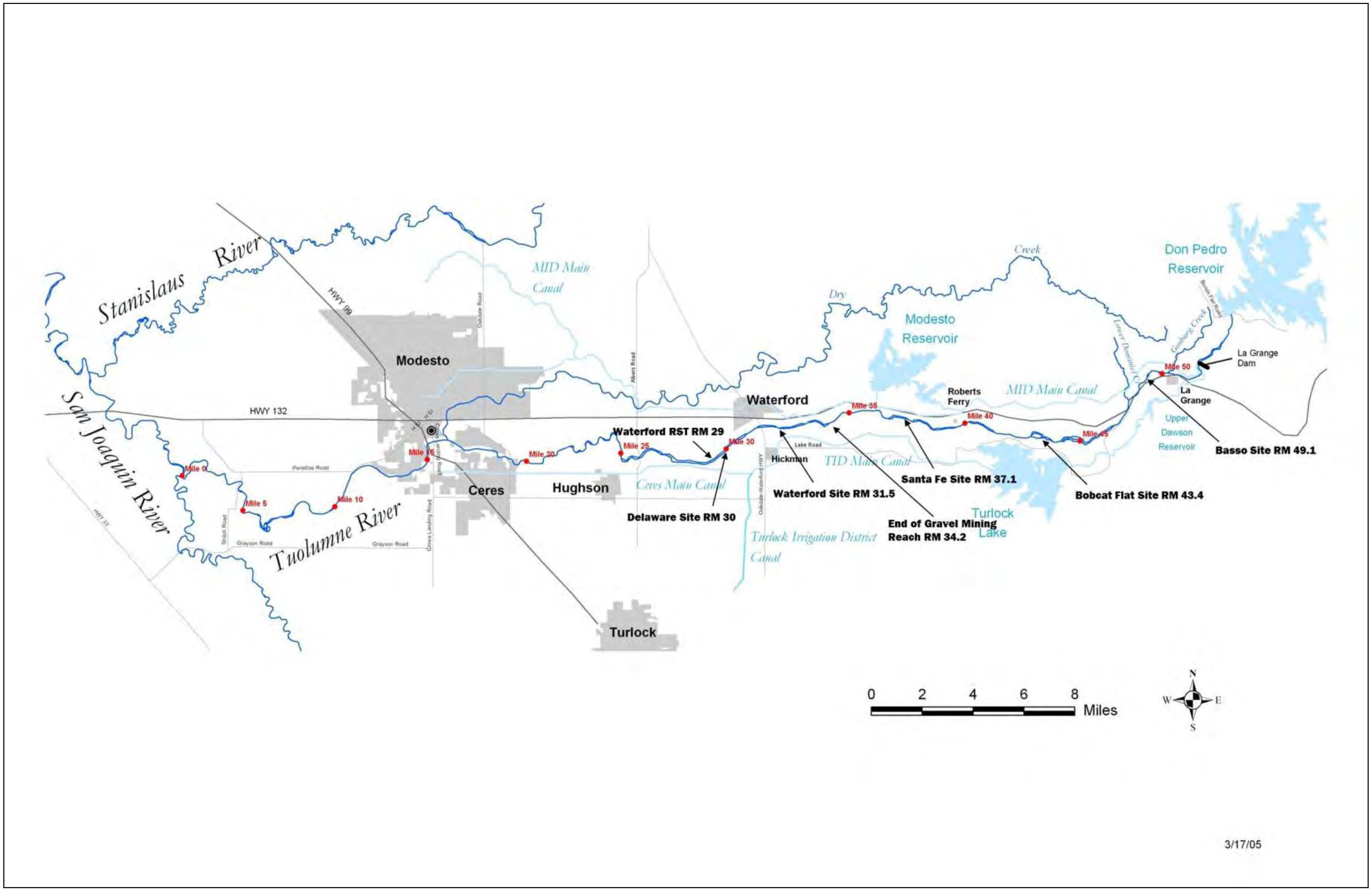

Figure 1. Vicinity map and study site locations for the lower Tuolumne River Instream Flow Study.

Table 2. Mesohabitat types used during instream flow surveys.

Channel form/ Habitat type	Description
Bar Complex	Submerged and emergent bars are the primary feature, sloping cross-sectional channel profile.
Flatwater	Primary channel is uniform, simple and without gravel bars or channel controls, fairly uniform depth across channel.
Pool	Primary determinant is downstream control - thalweg gets deeper going upstream from tail of pool. Fine and uniform substrate, below average water velocity, above average depth, tranquil water surface.
Glide	Primary determinants are no turbulence (surface smooth, slow and laminar) and no downstream control. Low gradient, substrate uniform across channel width and composed of small gravel and/or sand/silt, depth below average and similar across channel width (but depth not similar across channel width for Bar Complex Glide), below average water velocities, generally associated with tails of pools or heads of riffles, width of channel tends to spread out, thalweg has relatively uniform slope going downstream.
Run	Primary determinants are moderate turbulence and average depth. Moderate gradient, substrate a mix of particle sizes and composed of small cobble and gravel, with some large cobble and boulders, above average water velocities, usually slight gradient change from top to bottom, generally associated with downstream extent of riffles, thalweg has relatively uniform slope going downstream.
Riffle	Primary determinants are high gradient and turbulence. Below average depth, above average velocity, thalweg has relatively uniform slope going downstream, substrate of uniform size and composed of large gravel and/or cobble, change in gradient noticeable.

Table 3. Mesohabitat attributes assessed during habitat mapping surveys.

Attribute	Description
Stream width	Average wetted width of a unit calculated from GIS by dividing the unit area by unit length.
Stream depth	The maximum estimated depth of each habitat unit categorized into three groups: 1-4 feet deep; 4-10 feet deep, and >10 feet deep.
Channel confinement	Estimated ratio of width of active (wetted) channel to total stream channel (floodplain) width: • Confined – shallow = channel width confined and stream shallow (<4 ft) • Confined – deep = channel width confined and stream deep (>4 ft) • Moderate Confined = total channel width < 2 wetted channel widths • Unconfined = total channel width ≥ 2 wetted channel widths
Pool tail embeddedness	Percent in which gravel or larger substrates are vertically embedded in sand or smaller substrates at the downstream end of pool habitat.
Spawning gravel patch size	Estimates the largest patch of spawnable gravel within one unit (for salmonid species).
Tributary inflow	Estimate of the tributary inflow.

Table 4. Mesohabitat types and percent occurrence in the lower Tuolumne River Study Area from RM 51.7 to RM 29.0

Habitat type	No. of units	Total area (sq ft)	Percent of study reach
Bar Complex Glide	8	304,131	1.89
Bar Complex Pool	18	1,322,592	8.21
Bar Complex Riffle	57	2,259,617	14.04
Bar Complex Run	39	2,829,754	17.58
Flatwater Glide	14	484,716	3.01
Flatwater Pool	19	3,547,725	22.04
Flatwater Riffle	16	781,166	4.85
Flatwater Run	36	4,570,070	28.39
Totals	**207**	**16,099,772**	**100.0%**

2.2 Study Site Selection

Study sites were selected through a collaborative series of workshops with agency and non-governmental organization (NGO) representatives, using a collection of maps, aerial photos, gradient plots, habitat typing data, and other resources. The transect selection team targeted sampling of habitat types with a minimum of 5 percent occurrence, but with a reduced number of replicates/transects for those with less than 10 percent occurrence. The site selection process was documented in workshop notes included as Appendix B. A map of the study site locations is presented in Figure 1.

2.3 Transect Selection and Weighting

Initial habitat units for each site were randomly selected from either (1) key spawning riffles, or (2) other limited habitat unit types (e.g., bar complex spawning riffle), then selecting contiguous habitat units upstream or downstream from that habitat unit until the desired number and type of units for that river section were obtained. Units were typically contiguous unless an intervening unit was (1) not required for sampling and therefore skipped, or (2) exceptionally long and therefore effectively acted as a "boundary" to the local collection of transects.

Transect placement was determined during a field reconnaissance survey of each selected study site with representatives from CDFW and USFWS. Within each study site, transects were placed in each randomly selected habitat unit by professional judgment and on-site concurrence of the transect selection team. Transects were placed to capture the hydraulic variability within the randomly selected unit, while avoiding hydraulic anomalies or other features (e.g., re-circulating, vertical, or multi-directional flow, etc.) that cannot be accurately modeled.

A sufficient number of transects were established to model approximately three replicates of each major habitat unit type in the reach (e.g., runs, riffles, and pools), with the number of replicates dependent on the relative proportions of the major habitat unit types. Agency staff participating in the transect selection concurred on the number and placement of all transects. The transect selection process notes and list of transects are presented in Appendix B, along with documentation of agency concurrence and aerial photos of the transect locations.

For modeling purposes, individual transects were weighted to represent the proportion of their channel length and mesohabitat type (e.g., bar complex or flatwater glide, pool, riffle, and run) in the reach. These proportions were calculated based on habitat unit results from the habitat mapping data. Each habitat type was apportioned its respective length of the entire reach (e.g., bar complex riffles are 17.8% of the reach). Each transect in a habitat type was weighted equally based on the reach representation of the habitat type (e.g., each of 7 bar complex riffle transects would be weighted at 2.54% per transect if bar complex riffles represent 17.8% of the reach). A summary of transect weighting is provided in Table 5.

Table 5. Transect weighting used for lower Tuolumne River PHABSIM model.

Channel form	Mesohabitat type	Total Length (ft)	Total Length (%)	Number of transects	Weight per transect (%)	Weight per mesohabitat (%)
Bar Complex	Glide	2,085	1.73	2	0.86	1.73
Bar Complex	Pool	9,607	7.96	5	1.59	7.96
Bar Complex	Riffle	21,480	17.80	7	2.54	17.80
Bar Complex	Run	24,045	19.93	6	3.32	19.93
Flatwater	Glide	3,895	3.23	3	1.08	3.23
Flatwater	Pool	20,190	16.73	6	2.79	16.73
Flatwater	Riffle	6,660	5.52	2	2.76	5.52
Flatwater	Run	32,700	27.10	9	3.01	27.10
Totals		**120,662**	**100.00**	**40**		**100.00**

2.4 Calibration Flows

Model calibration flows were targeted based on extrapolation limits, log-scale considerations, and flows available during the field measurement surveys. Target calibration flows were selected to be relatively evenly spaced (on a log scale) and allow for simulated in-channel flows over a range of approximately 50–1,200 cfs, such that the lowest simulated flow would be no less than 0.4 of the lowest calibration flow and the highest simulated flow no more than 2.5 times the highest calibration flow. The proposed target calibration flows were as follows:

- low flow calibration: approximately 100 cfs;
- middle flow calibration: 250 cfs; and
- high flow calibration: 600 cfs.

The final calibration flows were reviewed in detail using all available data at each site, and agreed upon by consensus with agency representatives during the PHABSIM model workshop (Appendix C). Table 6 shows the final calibration flows used for this study.

Table 6. Calibration flows for lower Tuolumne River PHABSIM model.

Reach (site)	River Mile (approx.)	Calibration Flow (cfs)		
		Low	Medium	High
Basso	49.1	103	276	677
Bobcat Flat	43.4	99	282	682
Santa Fe	37.1	123	319	699
Waterford	31.5	120	308	710
Delaware	30.0	138	306	705

2.5 Hydraulic Data Collection

Hydraulic data collection and recording used standard procedures and guidelines for PHABSIM field studies (Trihey and Wegner 1981; Milhous et al. 1984; Bovee 1997). Independent elevation reference benchmarks were established for level control, as well as semi-permanent headpins and tailpins at each transect.

The local benchmarks established for each transect served as the reference elevations to which all elevations (streambed and water surface) were tied. The benchmarks were established at locations that will not change elevation over time, such as lag bolts driven into trees, painted bedrock points, or local infrastructure. Benchmark elevations were tied together for all sites, for efficient analysis, graphing, and QA/QC procedures.

Channel cross section profiles above the highest measured calibration flow were surveyed (to the nearest 0.1 foot) with a stadia rod and Topcon AT-G3 auto-level or total station to establish the overbank channel profile up to or beyond the water's edge at the highest flow to be modeled, with sufficiently close spacing of verticals to document changes in slope. In-channel profiles were calculated by subtracting the depth of water measured during the velocity measurements from the average water surface elevations (WSE). Additional topographic data collection for each transect included stage-of-zero-flow (SZF) elevation, which is the controlling elevation within or downstream of the transect line below which flow ceases.

Water surface elevations (i.e., stage) were measured using an auto-level and stadia rod along each transect at each calibration flow; WSE was typically measured near each bank (to the nearest 0.01 foot), and in mid-channel areas where a significant difference between the near-bank WSE existed. A level loop survey tied to the local benchmark was conducted at each calibration flow to ensure the accuracy of each survey. Benchmark and transect locations were recorded with a GPS, where feasible.

Temporary and permanent staff gage readings and time-of-day were recorded at the beginning and end of each transect measurement to check that the stage had not changed appreciably during the transect measurement, nor the calibration flow measurement for the entire study site.

Depths and mean column water velocities were measured across each transect at the middle calibration flow. The number of cells sampled for depth and velocity was based on a goal of retaining a minimum of 20–25 stations that would remain in-water at the low calibration flow. Discharge measurements were collected at each calibration flow following techniques outlined in Rantz (1982). These techniques include:

- cross section lies within a straight reach and streamlines are parallel to each other;
- velocities are greater than 0.5 ft/s and depths are greater than 0.5 ft;
- streambed is relatively uniform and free of numerous boulders and heavy aquatic growth; and
- flow is relatively uniform and free of eddies, slack water, and excessive turbulence.

Discharge measurements were made at each grouping of transects in hydrologically distinct areas, using either an existing habitat transect (if deemed suitable) or at some other suitable transect established solely for measuring discharge. These discharge measurements were used in conjunction with data from the La Grange gaging station (USGS No. 11289650) to determine more precisely the calibration flow and account for accretion, if any, within the study reach.

At transects that could be crossed by wading, velocities were measured using a Marsh-McBirney Flowmate 2000 flow meter and standard U.S. Geological Service (USGS) topset wading rod. Velocities were measured at six-tenths of the depth (0.6 depth) when depths were less than 2.5 feet, and at two-tenths (0.2 depth) and eight-tenths (0.8 depth) of the depth when depths were equal to or exceeded 2.5 feet, or when the expected velocity profile was altered by an obstruction immediately upstream. In instances of increased turbulence or obstructions, measurements were taken at all three depths (0.2, 0.6, and 0.8) and a weighted average calculated (Bovee and Milhous 1978). For transects where wading was not possible, a Teledyne RD Instruments Workhorse Rio Grande 1,200 kHz Acoustic Doppler Current Profiler (ADCP) with Ohmex Sonarmite depth sounder and Trimble R8 GNSS antenna mounted to a tethered OceanScience Riverboat was used to collect both velocity and channel bed elevation data. The ADCP was operated from a shore-based laptop through a wireless modem connection.

The ADCP transmits a series of short acoustic pulses and measures the change in frequency of acoustic energy reflected back (backscatter) from particles suspended in the water column. The ADCP software determines water velocity based on the principles of the Doppler effect, and water depth from pulse time delay of the reflected backscatter data. The ADCP depth and velocity data is resolved at a high frequency, approximately 1 ensemble or data point per second. An ensemble is analogous to a width cell or station in a traditional point-velocity discharge measurement, and represents a column of water along a measurement transect. The width of an ensemble is a function of the ADCP sampling rate and cross-stream ADCP velocity. One ensemble is divided into a number of discrete depth cells or bins whose depth range is set by the ADCP operator. Following the same assumptions as a traditional point-velocity discharge measurement, the ADCP discharge is computed as the product of cross-sectional area and mean water velocity perpendicular to cross-sectional area for each depth bin (Mueller and Wagner 2009). Total discharge is the sum of measured discharge, plus estimates of four unmeasured portions of each transect. The unmeasured portions of each transect are: top zone - instrument draft depth plus blanking distance at face of ADCP transducers, bottom zone of potential side lobe interference, and shallow areas at the start and end of transect. Velocity profile data was measured in the shallow unmeasured zones for each ADCP transect with the topset wading rod and flow meter.

Mean water column velocity and direction for each ensemble in an ADCP velocity calibration transect was exported from the ADCP software into GIS for processing. Due to the relatively high ADCP sampling frequency, the number of ensembles or stations across an ADCP velocity transect is much greater than a traditional point-velocity measurement. For purposes of providing input to the RHABSIM model, arbitrary stations were established at 2–3 foot intervals across transects and the mean water column velocity at each station was used.

Hydraulic field data were collected on the following dates:

- High Flows: July 26-29, 2011;
- Mid Flows: September 24-27, 2011; and
- Low Flows: June 25-29, 2012.

2.6 Substrate and Cover Data

Substrate data collection used a modified Wentworth Scale, with small cobble divided into two groups (3-4.5 in. and 4.5-6 in.), as agreed by the collaborative work group. The substrate scale is presented in Table 7.

Table 7. Modified Wentworth substrate scale used in the lower Tuolumne River PHABSIM model.

Description	Size (inches)
Organic	N/A
Silt	<0.1
Sand	0.1–0.2
Small Gravel	0.2–1.0
Medium Gravel	1–2
Large Gravel	2–3
Very Small Cobble	3–4.5
Small Cobble	4.5–6
Medium Cobble	6–9
Large Cobble	9–12
Boulder	>12
Bedrock	N/A

Fish cover recorded in the field included nine types, which were then collapsed into four categories for modeling purposes (in order to increase sample size and provide more meaningful results), as presented in Table 8. Cover was recorded in the field as a percent of area for each cover type, where the sum of all cover types present could sum to over 100 percent, as some areas may have overlapping types. For example, an evaluation area may have 100 percent turbulence cover with 50 percent overhead vegetation, and submerged large woody debris. The only restriction in assigning percentages is that no single cover type percentage can exceed 100 minus the area containing no cover. For example, if 60 percent of the evaluation area contained no cover, no individual type could exceed 40 percent.

Table 8. Fish cover types collected and used in the lower Tuolumne River PHABSIM model.

Cover Type	Category
No available cover	None
Cobble	Object Cover
Boulder	
Fine woody debris	
Large woody debris	
Overhanging vegetation	Overhead cover
Aquatic vegetation	
Undercut bank	
Rootwad	
Water surface turbulence (having entrained air)	
A combination of both overhead cover and object cover	Both

The four cover categories used in the model (object cover, overhead cover, both, or none) were based on presence/absence of the cover type. Cover presence/absence was evaluated in an area within 2 feet radius of a fish focal point, or within the PHABSIM transect cell (discussed in Section 2.5, *Hydraulic Data Collection*). The cover and substrate coding specifications were collaboratively developed with technical workgroup participants, and the process documented in workshop notes included as Appendix A.

2.7 Hydraulic Model Calibration

2.7.1 Stage and velocity calibration

Hydraulic data were calibrated using the HYDSIM module of RHABSIM v3.0 (Payne 1998). Stage-discharge relationships were developed from measured discharge and stage using both an empirical log/log formula (IFG4) and the Manning's channel conveyance procedure (MANSQ). Using either method, each transect is modeled independently of other transects. Based on review and consensus by agency participants, the most appropriate and accurate method was selected on a transect-by-transect basis (Appendix C).

The IFG4 method requires a minimum of three sets of stage-discharge measurements and an estimate of SZF for each transect. The SZF estimates were based on either the measured thalweg depth across a transect, or the measured thalweg depth of a downstream hydraulic control. The MANSQ procedure requires only a single stage-discharge measurement along with a SZF and uses a power function of the ratio of simulated discharge to observed discharge. The quality of the stage-discharge relationships was evaluated by examination of mean error and slope equation from the IFG4 results and the beta coefficient values from MANSQ. Using either method, mean errors should be less than 10%, with predicted water surface elevations within 0.1 feet of measured elevations. The MANSQ beta values should range between 0.0 and 0.5.

The one-flow velocity method, using a single set of velocities collected at the medium calibration flow, was used for all transects for velocity calibration. This technique uses a single set of measured velocities to predict individual cell velocities over a range of flows. Simulated velocities are based on measured data and a relationship between a fixed roughness coefficient (Manning's 'n') and depth. In some cases, roughness is modified for individual cells if substantial velocity errors are noted at the velocity calibration flows. Velocity adjustment factors (VAFs) were examined to detect any significant deviations and determine if cell velocities changed consistently with stage and total discharge.

2.7.2 Calibration metrics

Hydraulic calibration results of water surface elevation and velocity for the lower Tuolumne River model are shown in Table 9. Results show mean errors for all transects at less than 5.25%. The range of beta values for transects using MANSQ calibration was 0.045 to 0.479. Both the mean error and beta value metrics were in acceptable ranges.

Differences between observed and predicted water surface elevations ranged from 0.00 to 0.13 feet and averaged 0.02 feet. The VAF range at the calibration flow after adjustments to specific cell n-values was 0.8052 to 1.1905, with 77.5 percent (31 of 40) transects rated as "Good" and 22.5 percent (9 of 40) rated "Fair."

Table 9. Hydraulic calibration results for the lower Tuolumne River PHABSIM model.

Reach (site)	Transect	Method	Mean error (%)	Beta	Observed-predicted WSE			VAF	Rating
					Low	Mid	High		
Basso	40-24A-FG	Log-Log	5.243		0.02	-0.04	0.03	1.0008	Good
Basso	39-24B-FG	Log-Log	4.156		0.01	-0.03	0.02	0.9870	Good
Basso	38-25A-BR	MANSQ	0.393	0.045	0.00	-0.01	0.00	0.8166	Fair
Basso	37-25B-BR	Log-Log	2.254		0.01	-0.03	0.02	0.9849	Good
Basso	36-26A-BN	Log-Log	1.086		0.00	-0.01	0.01	0.8052	Fair
Basso	35-26B-BN	Log-Log	1.955		0.01	-0.02	0.01	1.0012	Good
Basso	34-28A-FN	Log-Log	1.870		0.01	-0.02	0.01	0.9059	Good
Basso	33-28B-FN	Log-Log	1.554		0.01	-0.02	0.01	0.8373	Fair
Basso	32-29A-FG	Log-Log	1.916		0.01	-0.02	0.01	0.9548	Good
Basso	31-30A-FR	Log-Log	0.766		0.01	-0.02	0.01	0.9309	Good
Basso	30-30B-FR	Log-Log	0.128		0.00	0.00	0.00	0.9474	Good
Bobcat	29-82C-FN	Log-Log	2.760		0.02	-0.05	0.04	0.9141	Good
Bobcat	28-83A-BN	Log-Log	1.410		0.01	-0.02	0.02	0.9521	Good
Bobcat	27-84A-FN	MANSQ	0.222	0.283	0.00	0.00	0.01	1.0146	Good
Bobcat	26-84B-FN	MANSQ	0.190	0.466	0.00	0.00	0.00	1.0080	Good
Bobcat	25-84C-FN	MANSQ	0.307	0.479	0.00	0.00	0.01	0.9530	Good
Bobcat	24-85A-BN	Log-Log	2.276		0.01	-0.03	0.02	0.9908	Good
Bobcat	23-86A-FP	Log-Log	1.841		0.01	-0.02	0.02	0.8091	Fair
Bobcat	22-86B-FP	Log-Log	1.756		0.01	-0.02	0.02	0.8286	Fair
Bobcat	21-86C-FP	Log-Log	2.885		0.01	-0.04	0.03	0.8573	Fair
Santa Fe	20-155A-BP	Log-Log	4.492		0.02	-0.05	0.03	1.0771	Good
Santa Fe	19-155B-BP	Log-Log	3.297		0.01	-0.03	0.02	0.9006	Good
Santa Fe	18-156A-BR	Log-Log	1.171		0.00	-0.01	0.01	0.8140	Fair
Santa Fe	17-156B-BR	MANSQ	1.465	0.283	0.02	-0.04	0.03	1.0021	Good
Santa Fe	16-159A-FN	Log-Log	0.886		0.00	-0.01	0.01	1.0162	Good
Santa Fe	15-159B-FN	Log-Log	2.052		0.01	-0.03	0.02	0.9157	Good
Santa Fe	14-159C-FN	Log-Log	1.994		0.01	-0.03	0.02	0.9753	Good
Santa Fe	13-160A-BR	Log-Log	3.359		0.01	-0.04	0.03	1.0022	Good
Santa Fe	12-160B-BR	Log-Log	3.223		0.01	-0.04	0.03	1.0244	Good
Santa Fe	11-161A-BN	Log-Log	3.833		0.02	-0.05	0.04	0.9371	Good
Santa Fe	10-161B-BN	Log-Log	3.239		0.01	-0.04	0.03	1.0773	Good
Santa Fe	9-162A-BR	MANSQ	4.971	0.085	0.00	-0.13	0.00	0.9864	Good
Santa Fe	8-163A-BP	Log-Log	4.340		0.02	-0.06	0.04	1.1905	Fair
Santa Fe	7-163B-BP	Log-Log	4.737		0.02	-0.06	0.05	0.8362	Fair
Santa Fe	6-163C-BP	Log-Log	4.525		0.02	-0.06	0.05	0.9346	Good
Waterford	5-205A-BG	Log-Log	0.849		0.00	-0.01	0.01	1.0591	Good
Waterford	4-205B-BG	Log-Log	0.980		0.00	-0.01	0.01	0.9443	Good
Delaware	3-225A-FP	Log-Log	1.301		-0.01	0.02	-0.02	1.0165	Good
Delaware	2-225B-FP	Log-Log	0.959		-0.01	0.02	-0.01	0.9041	Good
Delaware	1-225C-FP	Log-Log	2.355		-0.01	0.04	-0.03	1.0440	Good

2.7.3 Agency consultation

Calibration data and model details were reviewed and refined during a technical workshop that was attended by representatives from CDFW. Refinements to the model were made at that time, and are reflected in the calibration results reported above. The agency participants concurred that the model was suitably calibrated for subsequent use in the various analyses; notes from the model calibration workshop are presented in Appendix C.

2.8 Habitat Time Series

A Habitat Time Series (HTS) analysis was conducted to assess how habitat values for each species and life stage vary over time, under different water year type scenarios. Water year types selected for analysis were the five San Joaquin Basin 60-20-20 Index types: Critical, Dry, Below Normal, Above Normal, and Wet, as represented by Water Years 2008-2012 (the most recent years of these index types) and presented in Table 10.

Table 10. San Joaquin Basin 60-20-20 Index, corresponding water year types, and representative water years used for habitat time series analysis in the lower Tuolumne River instream flow study.

San Joaquin Basin 60-20-20 Index[1]	Water Year Type	Representative Water Year
2.06	Critical	2008
2.18	Dry	2012
2.73	Below Normal	2009
3.55	Above Normal	2010
5.59	Wet	2011

[1]In million acre-feet

Daily flow values for the lower Tuolumne River were obtained from the USGS gaging station at La Grange (No. 11289560) and were compiled for all Water Year types. No downstream adjustments for accretion or depletion were applied.[2] The associated WUA values were assigned based on the daily flows using a lookup table of WUA values from the PHABSIM results, interpolated to 5 cfs intervals.

For flows over the WUA extrapolation limit of 1,200 cfs, a variety of methods were considered for estimating WUA:

1) Extrapolating the downward trend of the WUA vs. flow relationship at the same slope that occurs between ~900-1,200 cfs. A drawback of this approach is that downward trends in WUA typically level off at some unknown, minimum level that would not be captured by this approach. In addition, overbank flooding effects would be expected to cause some less predictable inflection in the WUA vs. flow relationship when flows go out-of-channel.
2) Extrapolating upward trends at the same slope that occurs between ~900-1,200 cfs. This technique has a similar drawback to the one above, since upward trends will typically level off at some point and/or eventually descend at higher flows.
3) Do not extrapolate above 1,200 cfs. This method would preclude any estimate of WUA conditions that may exist during much of the spring season, when flows are highest and variability is greatest, and therefore compromise the utility of any HTS analysis.
4) Maintain WUA estimates for flows above 1,200 cfs at the 1,200 cfs level (e.g., “flatline” the WUA value). This approach assumes that in-channel WUA will not get significantly higher (or will get higher, then descend again) or lower (or go lower and rise again or level

[2] Accretion/depletion studies performed by the Districts suggest that flow changes along the study reach (which does not contain major tributaries) are relatively small compared to the scale of most HTS flows and the associated WUA reporting increments, and therefore the HTS results were not adjusted for these changes.

off) than where it was at 1,200 cfs. This is a more conservative approach, but it does have the drawback that all flows above 1,200 cfs will return the same WUA value and a depiction of potential variability at higher flows is lost.

For purposes of this analysis, method 4 was applied, and WUA values were maintained at the 1,200 cfs level (e.g., flatlined).

2.9 Effective Habitat

An "effective" WUA (eWUA) analysis will be conducted after current water temperature model data being developed as part of the relicensing studies become available. The eWUA analysis relates to summertime water temperature suitability for *O. mykiss*, and integrates both micro- and macro-habitat considerations. The results from the current water temperature model (in development) over a range of flows will be combined with the summer WUA results so that areas ("macrohabitats") with unsuitable water temperatures are excluded from the total WUA sum. In other words, if a given reach has 100,000 square feet of suitable habitat (i.e., WUA) based on hydraulic microhabitat conditions at flow 'X', but 30 percent of the reach at flow 'X' is above a critical temperature threshold for the species life stage of interest, the eWUA would be 70,000 square feet. This type of analysis was previously conducted, at a coarser level by Stillwater Sciences (2003), using a combination of the 1992 IFIM evaluation for the lower Tuolumne River (USFWS 1995) and the earlier SNTEMP model results (TID/MID 1992e).

2.10 Habitat Suitability Criteria

Use of the PHABSIM model requires application of HSC to the results of the hydraulic model in order to generate an index of habitat suitability (weighted usable area, or WUA) versus flow. Suitability criteria were developed from both existing published criteria and new site-specific data. The target species and life stages were:

- *O. mykiss:* adult, spawning, fry, and juvenile.
- Fall-run Chinook salmon: spawning, fry, and juvenile.

2.10.1 Existing habitat suitability criteria data

Existing HSC data were compiled for the target species and life stages, in collaboration with resource agencies and other interested parties, to create a database of curves that could be reviewed for applicability to the current study. Habitat suitability criteria from prior lower Tuolumne River studies (Tables 11 and 12) were included in the HSC database for consideration. The database of curves was reviewed in consultation with workgroup participants, and screening criteria applied as necessary to minimize the number of curves for further consideration. Screening criteria included the following, although no single criterion was used to qualify or disqualify a curve from further consideration.

- Minimum of 150 observations
- Clear identification of fish size classes
- Depth and velocity HSC
- Category II or III data (Bovee 1986)
- Comparable stream size and morphology (e.g., hydrology, stream width and depth, gradient, geomorphology, etc.)
- Source data from the lower Tuolumne River (or other Central Valley streams)

- Habitat availability data collected
- Data collected at high enough flow that depths and velocities are not biased by flow availability
- Availability of presence/absence data

Table 11. Habitat suitability criteria summary 1981 CDFG IFIM study (TID/MID 1992b).

Species	Life stage	Depth	Velocity	Substrate	Source [1]
Chinook	Spawning	Yes	Yes	Yes	CDFG site-specific[2]
Chinook	Fry	Yes	Yes	All suitable	USFWS (1985)
Chinook	Juvenile	Yes	Yes	All suitable	USFWS (1985)
Rainbow	Adult	Yes	Yes	Yes	Raleigh et al. (1984)
Rainbow	Juvenile	Yes	Yes	Yes	Raleigh et al. (1984)

[1] 1981 CDFG suitability criteria used are from the reanalysis performed in 1991 (TID/MID 1992b).
[2] Spawning depth criteria were modified for reanalysis in 1991 (TID/MID 1992b).

Table 12. Habitat suitability criteria summary from USFWS (1995) IFIM study.

Species	Life stage	Depth	Velocity	Substrate	Source
Chinook	Spawning	Yes	Yes	Combined Substrate / Embeddedness Code	CDFG site-specific[1]
Chinook	Fry	Yes	Yes	All suitable	USFWS (1988) site-specific (Tuolumne River)
Chinook	Juvenile	Yes	Yes	All suitable	USFWS (1990) site-specific (Stanislaus River 1989)
Rainbow	Adult	Yes	Yes	Combined Substrate / Embeddedness Code	Bovee (1978)
Rainbow	Juvenile	Yes	Yes	Combined Substrate / Embeddedness Code	Bovee (1978)

[1] Same criteria as used in the 1991 reanalysis of the 1981 CDFG IFIM study (TID/MID 1992b).

During a series of workshops with interested parties, applicable HSC curves were reviewed and discussed, and existing curves were selected and/or modified for use in the current study. Decisions were made for all of the target species and life stages identified, with the exception of Chinook fry depth criteria, and cover criteria. The workgroup decided to apply substrate criteria to spawning life stages only, and recommended cover data be collected during site-specific validation surveys (discussed below). The participants, notes, and results from the workshops are presented in Appendices D through F.

2.10.2 Site-specific habitat suitability criteria

Where existing curves for key species and life stages were considered potentially inadequate by the workshop participants, the Districts initiated efforts to validate existing HSC or develop site-specific HSC. These efforts involved making observations of Chinook salmon fry and juvenile life stages, and *O. mykiss* fry, juvenile, and adult life stages. In order to target the different life stages and to account for variation in habitat use under a variety of conditions, data were collected during multiple survey efforts (February 7-10, March 26-30, May 9-12, and July 11-13, 2012); covering a range of seasons (winter, spring, and summer); and a range of flow conditions (100 cfs, 350 cfs, and 2,000 cfs).

The existing site-specific criteria for Chinook salmon spawning, developed by CDFG (TID/MID 1992a), were found to be sufficient, and the workgroup expected the number of any site-specific observations of spawning *O. mykiss* to be insufficient to produce meaningful results. Therefore, additional site-specific spawning surveys were not conducted for either species.

2.10.2.1 Habitat suitability criteria study site selection

Site-specific HSC surveys were conducted in the lower Tuolumne River from just below La Grange Dam (RM 52) downstream to Waterford (RM 31). Survey locations were selected prior to each effort using a stratified random selection approach, where individual habitat units (based on the habitat mapping delineation described in Section 2.1, *Habitat Mapping*) between La Grange Dam and the city of Waterford were selected using a random number generator in Microsoft Excel, then sorted by habitat type. Randomly selected habitat units were included in the sampling based on equal distribution between the eight mesohabitat types. Additionally, under higher flow conditions, both floodplain and side-channel habitats were included. Individual survey locations, by season, are shown on Figure 2A–2D.

Within each sampled habitat unit, 3–5 10x10 m "cells" were selected using stratified random selection methods and a 10x10 m alpha-numeric grid overlay on the aerial photos (Figure 3). Randomly selected cells were included based on: (1) the likelihood of being within the wetted channel at the current flow; (2) stratified distribution within the head, body, and tail of each habitat unit, where applicable;[3] and (3) distribution across a range of shallow/deep water depths (i.e., </> 4 ft) and slow/fast velocities (i.e., </> 2 fps). Cells that were selected and only partially within the wetted channel were shifted to include a full 10x10 m area within the wetted channel. Because the wetted channel coverage area and depth/velocity criteria could not reliably be pre-determined in the office, pre-selected cells that were out of water were subsequently rejected in the field. Additionally, in an attempt to capture habitats with under-represented availability (e.g., > 4 ft deep with > 2 fps mean column velocity, or inundated floodplain habitat), cells containing those habitat attributes were directly targeted in place of pre-selected cells. Once cells were selected using the above criteria, each cell was subdivided into four 5x5 m quadrants during the field survey, each quadrant representing one potential habitat availability data point.

The selection process generally resulted in three cells, or 12 quadrants, per habitat unit surveyed, with multiple replicates of each habitat type surveyed during each effort. This approach was repeated for each field effort; however, the river reach length surveyed was reduced during the May and July efforts due to declining numbers of fish observations in downstream sections.

[3] Prior habitat mapping efforts delineated mesohabitat units into unit components, including head, body, and tail, where the component delineations were clear, such as a pool. These delineations were used during the placement of cells in order to better distribute sampling points within the selected habitat units.

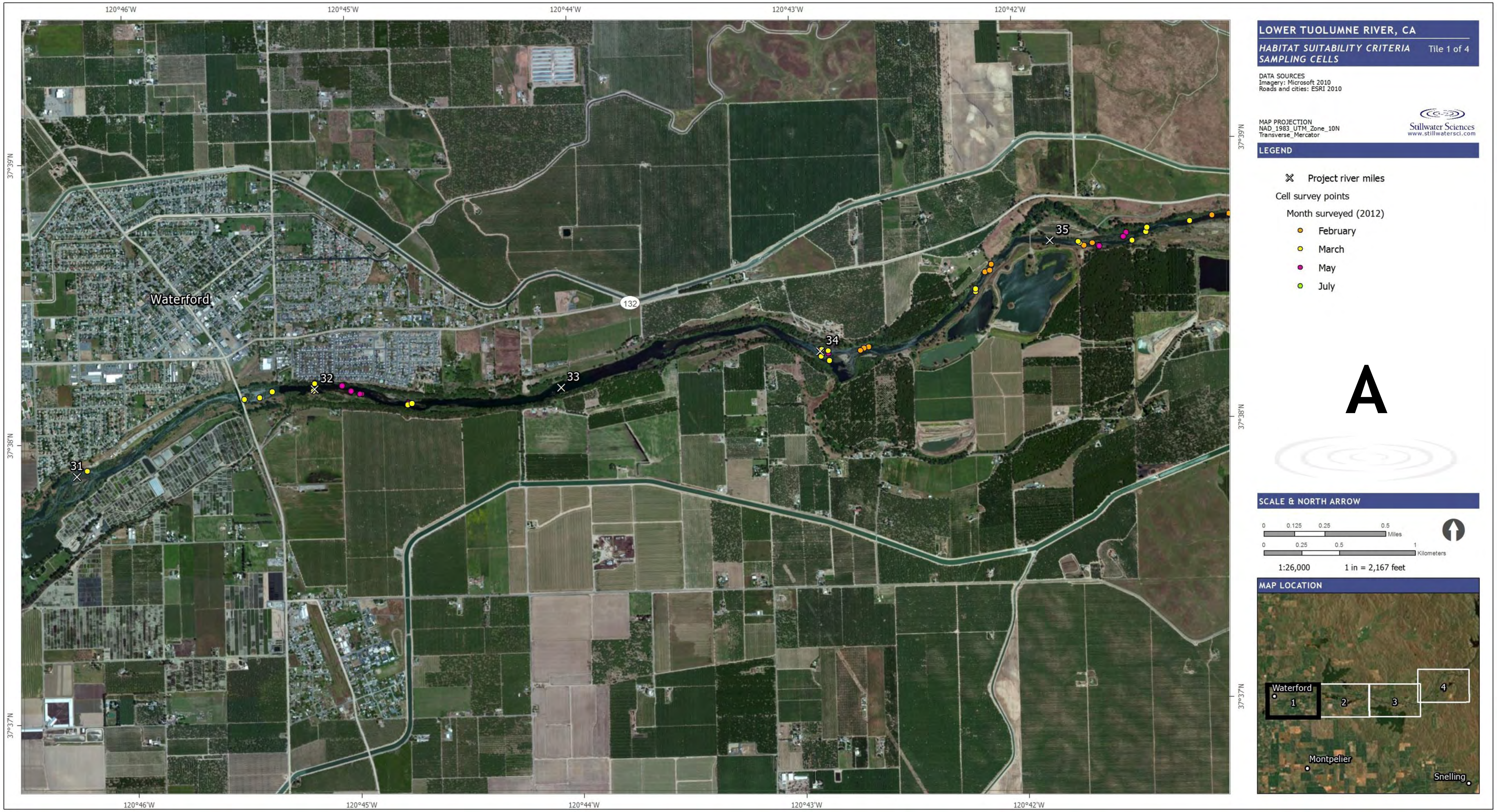

Figure 2A. Site-specific habitat suitability criteria survey locations in the lower Tuolumne River, 2012. (A) Tile 1: RM 31-35, (B) Tile 2: RM 35-40, (C) Tile 3: RM 41-46, and (D) Tile 4: RM 46-52.

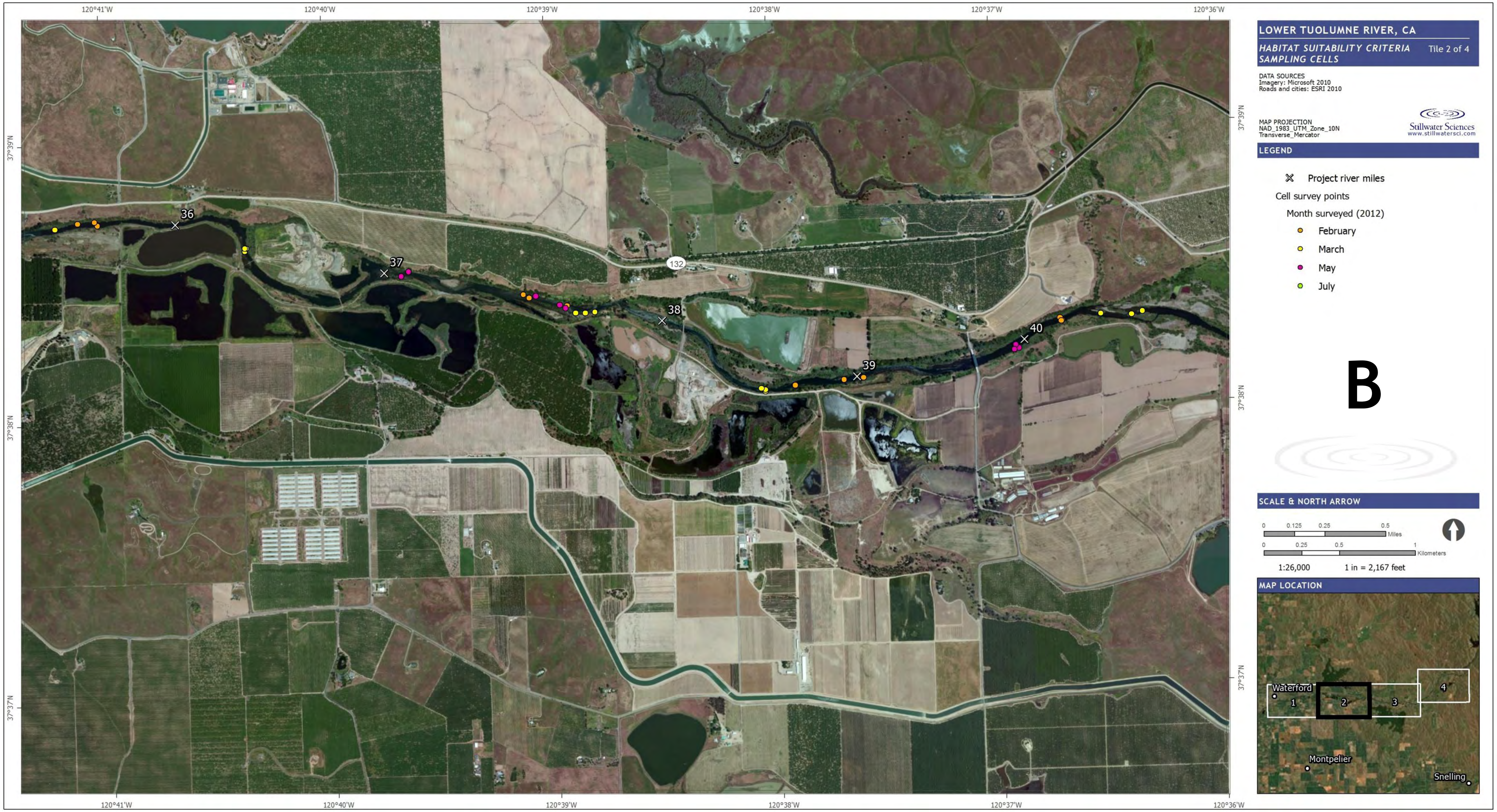

Figure 2B. Site-specific habitat suitability criteria survey locations in the lower Tuolumne River, 2012. (A) Tile 1: RM 31-35, (B) Tile 2: RM 35-40, (C) Tile 3: RM 41-46, and (D) Tile 4: RM 46-52.

Figure 2C. Site-specific habitat suitability criteria survey locations in the lower Tuolumne River, 2012. (A) Tile 1: RM 31-35, (B) Tile 2: RM 35-40, (C) Tile 3: RM 41-46, and (D) Tile 4: RM 46-52.

Figure 2D. Site-specific habitat suitability criteria survey locations in the lower Tuolumne River, 2012. (A) Tile 1: RM 31-35, (B) Tile 2: RM 35-40, (C) Tile 3: RM 41-46, and (D) Tile 4: RM 46-52.

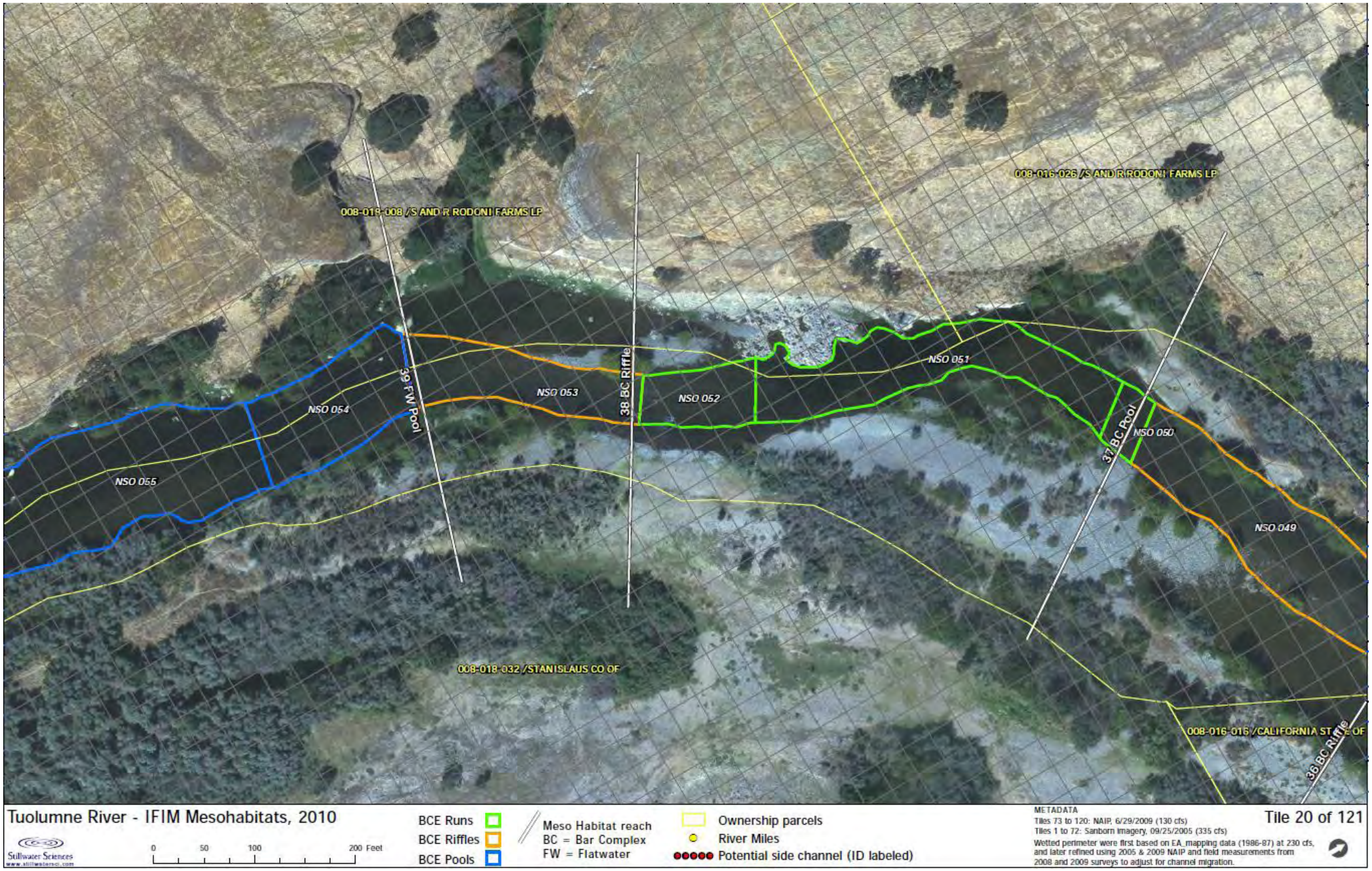

Figure 3. Example aerial photo showing grid used during random sampling site selection, and subdivision of pool into head, body, and tail.

2.10.2.2 Direct observation and field measurements

Once the sample cell was located in the field, two snorkelers entered the water from at least 20 ft downstream of the cell. Snorkelers were spaced at approximately one-third and two-thirds of the cell width (or in the middle of each lower quadrant) and moved uniformly in an upstream direction through the length of the cell to reduce the potential for fish disturbance. Each observation location was marked with a weighted flag so that site-specific measurements could be collected after snorkeling was complete, so to minimize disruptions to fish behavior.

Fish observation data included species name, number observed, total length (for individuals) or size range (for groups), focal depth, and activity (i.e., holding, feeding, roving, and spawning). Habitat observations included percent of fish cover and dominant and subdominant substrates (see Section 2.6, *Substrate and Cover Data*). After the snorkeling was completed, measurements were taken within each cell quadrant. Each observation point within occupied quadrants (quadrants with fish observations) included cell quadrant identification, water depth, mean column velocity, focal point water velocity, and adjacent water velocity (i.e., a potentially higher velocity within 2 ft of the focal point, in any direction). The same measurements and habitat observations, excluding focal depth, focal velocity, and adjacent velocity, were recorded at one representative location within each unoccupied and occupied quadrant of the cell in order to document habitat availability.

General site information was recorded, and included water temperature, water visibility (via secchi disk reading), discharge (based on USGS gage data for La Grange), GPS coordinates, and site photos.

2.10.2.3 Data analysis

All data were entered into a standardized database and checked against the field datasheets for quality assurance. Species life stages were determined based on total fish length, where fry included individuals measuring 50 mm or less; juveniles ranged from 51–150 mm, and adults included individuals greater than 150 mm. Fish cover identified during the field surveys was assessed for suitability using four categories: 1) no cover; 2) object cover, which includes cobble, boulder, fine woody debris, and large woody debris; 3) overhead cover, which includes overhanging vegetation, aquatic vegetation, undercut bank/rootwad, and water-surface turbulence; and 4) combined cover, which includes any combination of object and overhead cover types (Table 8).

Individual observations were assigned a frequency of one, regardless of the number of fish at that location (i.e., a fish observation could include a single fish, or a group of fish). The frequencies of occupied and unoccupied observations were plotted together as a histogram for each parameter (i.e., depth, velocity, and cover) for each of the target species and life stages. The combined frequency of occupied and unoccupied observations makes up habitat availability.

Habitat availability and occupied frequency were used to develop utilization and preference curves using methods described in Bovee (1986). Fish cover utilization values were developed based on the frequency of fish observations per habitat parameter increment divided by the total number of fish observations.

Utilization and preference indices for depth and velocity were plotted over occupied frequency histograms for ease of comparison and analysis. Because the sample sizes were limited for most life stages (e.g., $n<150$), these histogram estimates were quite "rough," with multiple peaks and valleys, which resulted in a non-normalized binning distribution of the raw data for most life stages. The suitability indexes subsequently required additional statistical treatment in order to generate continuous density functions of availability and utilization that would more fully represent actual fish habitat and behavior.

The first step in the statistical treatment is to express availability (A), utilization (U), and preference (P) in the form of probability density functions (PDFs). Doing so reflects the distribution of values of the habitat parameter, and the distribution of fish with respect to the habitat.

The PDFs are defined as follows:

$$A(x)dx \propto \Pr\begin{pmatrix}\text{a randomly chosen site will have a} \\ \text{parameter value between } x \text{ and } x + dx\end{pmatrix}$$

$$U(x)dx \propto \Pr\begin{pmatrix}\text{a randomly chosen site will have a} \\ \text{parameter value between } x \text{ and } x + dx \\ \text{if a fish is observed there}\end{pmatrix}$$

$$P(x)dx \propto \Pr\begin{pmatrix}\text{a fish will be observed at a site if the} \\ \text{parameter value is between } x \text{ and } x + dx\end{pmatrix}$$

Each PDF describes the relative likelihood of occurrence for a given parameter value. The probability of any given parameter value cannot exceed 1.

The next step is to relate A and U to P. According to basic probability theory, P is proportional to U/A, therefore we can express P as follows:

$$P_i = \frac{U_i}{A_i}$$

The last step in our statistical treatment is based on work by Bovee (1986) in which the PDFs for A and U are approximated by histograms. The histogram serves to divide the likelihood of a given habitat parameter value into intervals

$$x_0 < x_1 < \cdots < x_n$$

Where for each interval

$$I_i = [x_{i-1}, x_i],\ i = 1, \ldots, n:$$

$$A_i = \frac{\text{number of sites with } x \text{ in } I_i}{\text{total number of sites}}$$

$$U_i = \frac{\text{number of fish observed with } x \text{ in } I_i}{\text{total number of fish observed}}$$

This allows the preference function to also be approximated as a histogram

$$P(x) \doteq P_i \text{, where } x_{i-1} \leq x < x_i.$$

The kernel density estimation method was used to obtain smoother preference curves for depth and velocity indices. This method is widely used, and has a well-developed theory; standard references include Silverman (1986), Simonoff (1996), and Bowman and Azzalini (1997). A gaussian kernel was used, with Gasser and Müller boundary kernels, as described in Simonoff (1996), to account for the fact that depths and velocities should be non-negative. Smoothing parameters were chosen informally, with the goal of smoothing only enough to make the local behavior of the curves "reasonable" (e.g., the utilization and availability curves should be unimodal, and the preference curve at least close to unimodal). The calculations were carried out using the statistical programming language "R."

2.10.2.4 Adjacent velocity

Adjacent velocity analyses are sometimes used to assess whether fish are occupying lower velocity locations (presumably for energy conservation) while still positioning themselves near higher velocity "feeding lanes" for foraging. Such analyses can be useful for assessing water velocity "preferences" separate from water velocities typically occupied by the fish, particularly in higher gradient streams with a lot of boulder cover and the associated complex lateral variation in water velocity distributions. An assumption of such analyses is that habitat of a particular velocity and habitat suitability index value in close proximity to feeding lanes is of higher value than habitat with the same velocity that is not in close proximity to a feeding lane.

Adjacent velocities were first evaluated by comparing the mean column velocity at the focal location of the fish to the adjacent mean column velocity, using a paired t-test for each target species and life stage, in order to determine if there were any statistically significant differences that warranted further evaluation. In order to be evaluated further, adjacent velocities had to: 1) demonstrate a statistically significant difference from mean column velocities at the fish focal points, 2) be faster than the focal point mean column velocities, and 3) be in a velocity range with a lower suitability index (i.e., <0.5) than the velocity range where the fish were most frequently found (suggesting they were areas of brief feeding lane forays, rather than more continuously occupied areas).

3 RESULTS

3.1 Habitat Suitability Criteria

3.1.1 Habitat suitability criteria selection

The technical workgroup participants reviewed and selected Chinook salmon and *O. mykiss* criteria for the lower Tuolumne River as documented in the workshop notes (Appendices D–F), subject to validation of those HSC by site-specific studies.[4] Final HSC are included below, along with the validation results.

3.1.2 Site-specific habitat suitability criteria development and validation

Site-specific surveys were conducted during February, March, May, and July 2012, at 100 cfs, 350 cfs, and 2,000 cfs. Surveys were conducted within each habitat type, including side channel and overbank habitats. The stratified random sampling method was targeted at producing a similar level of sampling effort among each habitat and channel form combination, with each combination surveyed for a variety of deep/shallow and fast/slow hydraulic conditions. Not all deep/shallow and fast/slow conditions occur with sufficient frequency to allow for completely balanced sampling while still surveying sufficient area to collect enough fish observations (Table 13). Despite this limitation, a wide range of channel, habitat, and hydraulic conditions was sampled over a range of flows, thus minimizing the potential for any bias in the fish observation results.

In total, 4,616 Chinook salmon and *O. mykiss* were counted at 570 separate observation points among 763 sample quadrants (Table 14). The number of observations allowed for evaluation of each of the targeted species and life stages selected for validation (Chinook salmon fry and juvenile; *O. mykiss* fry, juvenile, and adult), and development of site-specific Chinook salmon fry suitability criteria.

[4] Subsequent to conclusion of the technical workshops on HSC selection, the Tuolumne River Conservancy withdrew their support for any decisions made by the technical workgroup regarding *O. mykiss*, as documented in the workshop notes.

Table 13. Summary of habitat suitability sample quadrants in the lower Tuolumne River during surveys conducted between February and July 2012.

Habitat		Velocity[1]	Deep (≥ 4 ft)	Shallow (< 4 ft)	Total Number of Sample Quadrants	
Glide	Bar Complex	Fast	0	3	20	68
		Slow	0	17		
	Flatwater	Fast	8	0	48	
		Slow	8	32		
Riffle	Bar Complex	Fast	13	41	120	197
		Slow	11	55		
	Flatwater	Fast	4	14	77	
		Slow	18	41		
Run	Bar Complex	Fast	16	17	112	222
		Slow	19	60		
	Flatwater	Fast	10	5	110	
		Slow	30	65		
Pool	Bar Complex	Fast	11	2	76	164
		Slow	18	45		
	Flatwater	Fast	2	5	88	
		Slow	42	39		
Side Channel	--	Fast	3	8	76	76
		Slow	4	61		
Overbank	--	Fast	0	8	36	36
		Slow	2	26		
Total			**219**	**544**	**763**	

[1] Fast water includes velocities ≥ 2 fps and slow water includes velocities < 2 fps.

Table 14. Summary of site-specific fish observation samples collected in the lower Tuolumne River during surveys conducted between February and July 2012.

Species	Life stage	Observations	Number of Fish Observed
Chinook salmon	fry	218	2,641
	juvenile	87	740
Chinook salmon Total		305	3,381
O. mykiss	fry	97	731
	juvenile	93	378
	adult	75	126
O. mykiss Total		265	1,235
Total		**570**	**4,616**

For purposes of this study, workgroup-selected HSC were considered “validated” if the HSC utilization curve developed from site-specific observations fell within the “envelope” of the workgroup-selected curve. Additional statistical comparisons of the resulting curves was not pursued, given the unavailability (or non-existence) of underlying empirical data for many of the workgroup-selected curves. No attempt was made to further restrict the range of the workgroup-selected curve based on the site-specific results, since in most cases the site-specific sample size does not clearly support such an adjustment. The following protocol was used to select the final curves used in the PHABSIM analysis:

- If the site-specific utilization and preference (in the case of Chinook fry) curves were within the workgroup consensus curve, then the consensus curve was considered validated and subsequently used in the PHABSIM analysis (seven curves).
- Where the workgroup consensus curve was closely spaced between the site-specific utilization and preference curves, the workgroup consensus curve was used based on the expectation that a larger sample size would likely push the site-specific results to look more like the workgroup consensus curve (one curve: *O. mykiss* adult velocity).
- If the site-specific utilization and preference curves both extended beyond the workgroup consensus curve, then the consensus curve was expanded to include the site-specific utilization curve data (two curves).

The workgroup consensus curves that were validated included:

- Chinook salmon juvenile velocity
- Chinook salmon fry depth and velocity[5]
- *O. mykiss* fry velocity
- *O. mykiss* juvenile depth and velocity
- *O. mykiss* adult depth and velocity

The curves that were expanded as a result of the site-specific surveys included:

- Chinook salmon juvenile depth
- *O. mykiss* fry depth

Previously developed Tuolumne River (Chinook spawning, depth and velocity curves) or published criteria (*O. mykiss* spawning, depth and velocity curves) were used in the model, as specified by the technical workgroup participants. No consistent and complementary cover criteria data from other sources were identified by the workgroup participants, and therefore site-specific cover data were developed from the Tuolumne River and were applied for life stages with a sufficient sample size.

The suitability criteria used in the model for all species and life stages are shown in Figures 4–20 at the end of this section, along with the most pertinent reference curves. Additional HSC reference data, curves, and curve coordinates are included in Appendix G.

The site-specific Chinook fry depth results (Figure 4) suggest that the workgroup-selected Tuol-Mod curve is appropriate (and matches the utilization data quite well), although the site-specific preference curve is much narrower. The differences between the site-specific utilization and preference curves appear to result primarily from a small sample size anomaly in the shallowest

[5] There was not final consensus on a single Chinook salmon fry depth curve within the technical workgroup participants, and three candidate curves remained under consideration. The curve selected for the PHABSIM model was the one that best matched the subsequently collected site-specific data.

locations, which tends to skew the calculation for the resulting preference curve. This sort of statistical anomaly is not uncommon, and overriding this anomaly through further statistical treatment or professional judgment would likely render a very similar result to the workgroup-selected curve.

The site-specific Chinook juvenile depth curve (Figure 7) indicates that fish are utilizing greater depths than covered by the workgroup-selected curve and, per the protocol described above, the final curve was expanded accordingly.

The site-specific Chinook juvenile velocity curve (Figure 8) suggests that the workgroup-selected curve is too broad. However, the sample size for the site-specific data is too small to justify a modification to the workgroup-selected curve at this point, since additional observations would likely result in greater convergence between the two data sets.

The site-specific *O. mykiss* fry depth curve (Figure 12) shows that fry are utilizing greater depths than covered by the workgroup-selected curve and, per the protocol described above, the final curve was expanded accordingly.

The site-specific *O. mykiss* juvenile velocity curve (Figure 15), like the Chinook juvenile velocity curve, suggests that the workgroup-selected curve is too broad. However, the sample size for the site-specific data is too small to justify a modification to the workgroup-selected curve without additional observations.

The site-specific *O. mykiss* adult depth curve (Figure 19) strongly indicates that the workgroup-selected curve extends to greater depths than Tuolumne River *O. mykiss* are utilizing. However, the sample size for the site-specific data is too small to justify a modification to the workgroup-selected curve without additional observations. Implications of this depth curve disparity are discussed further in Section 4, *Discussion*.

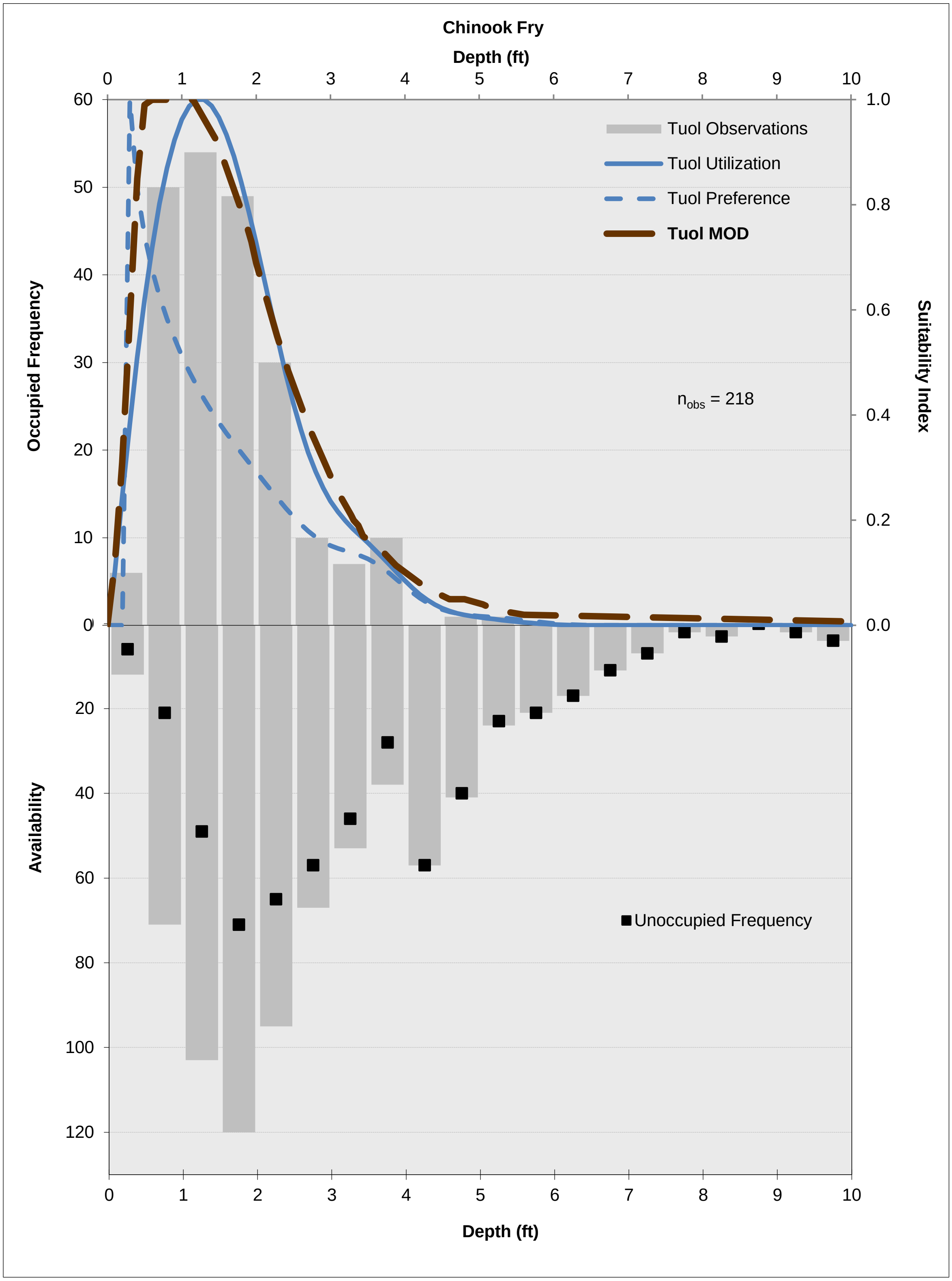

Figure 4. Chinook salmon fry depth suitability criteria for the lower Tuolumne River; curve applied in the PHABSIM model was Tuol MOD.

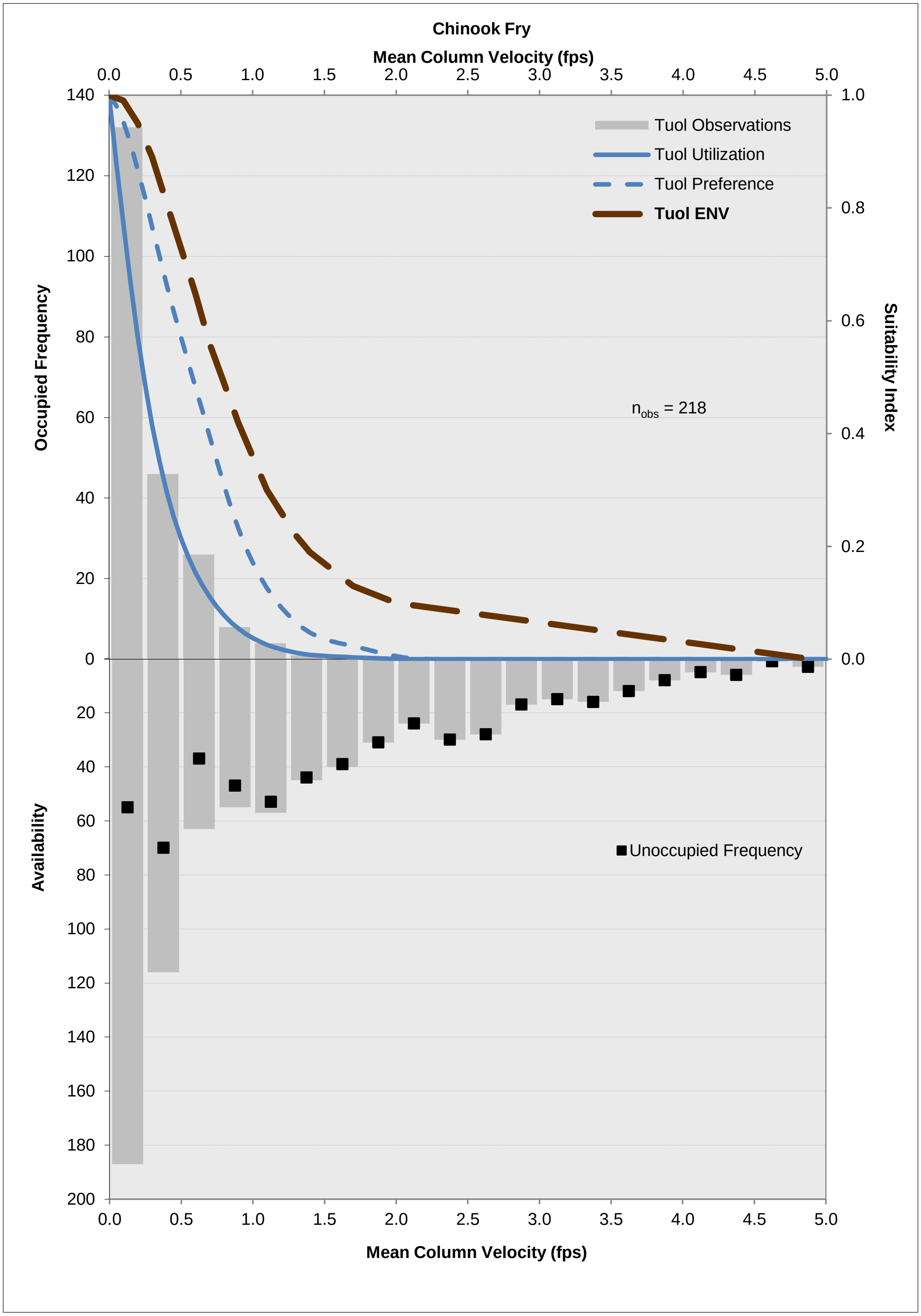

Figure 5. Chinook salmon fry velocity suitability criteria for the lower Tuolumne River; curve applied in the PHABSIM model was Tuol ENV.

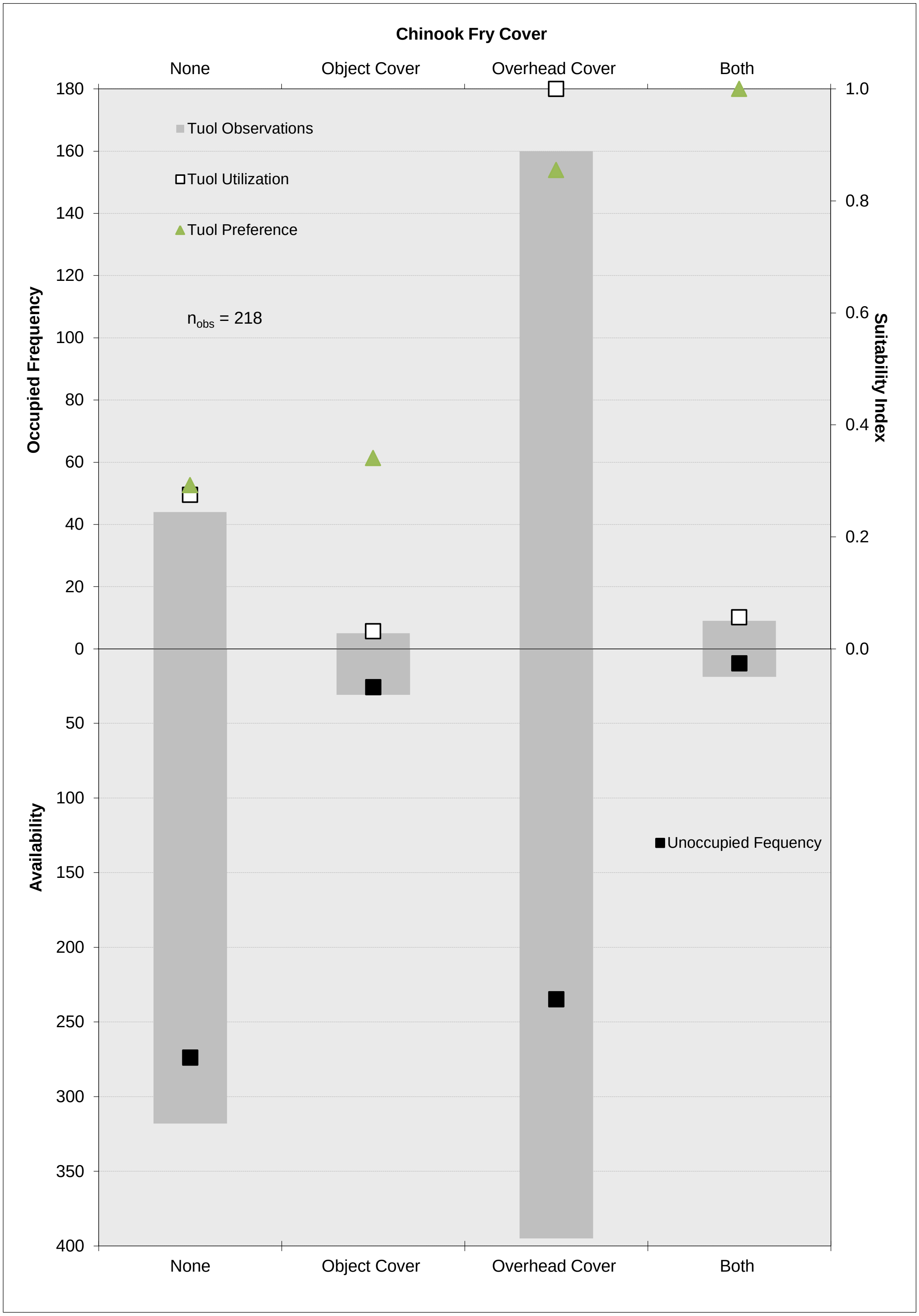

Figure 6. Chinook salmon fry cover suitability criteria for the lower Tuolumne River.

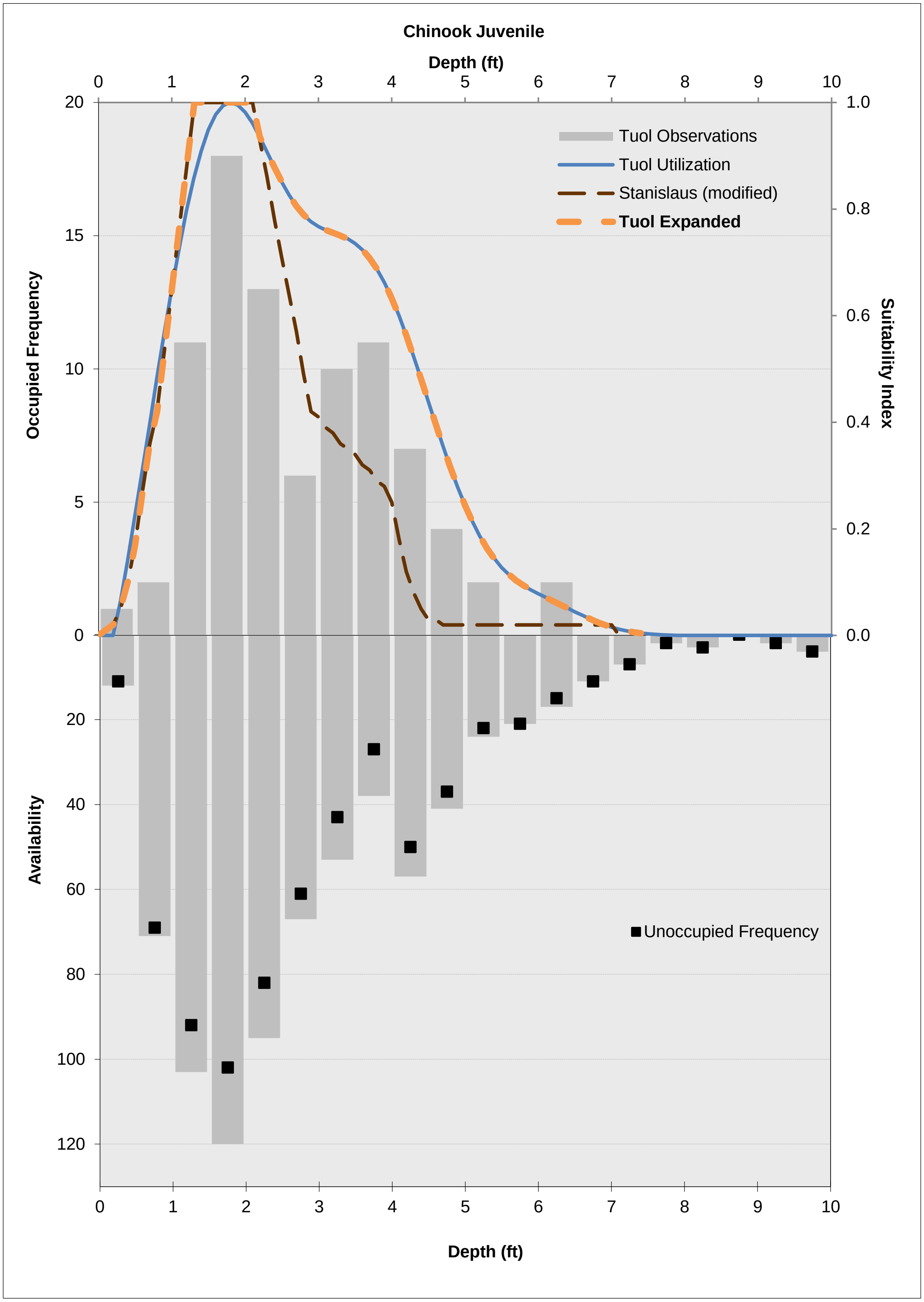

Figure 7. Chinook salmon juvenile depth suitability criteria for the lower Tuolumne River; curve applied in the PHABSIM model was Tuol Expanded.

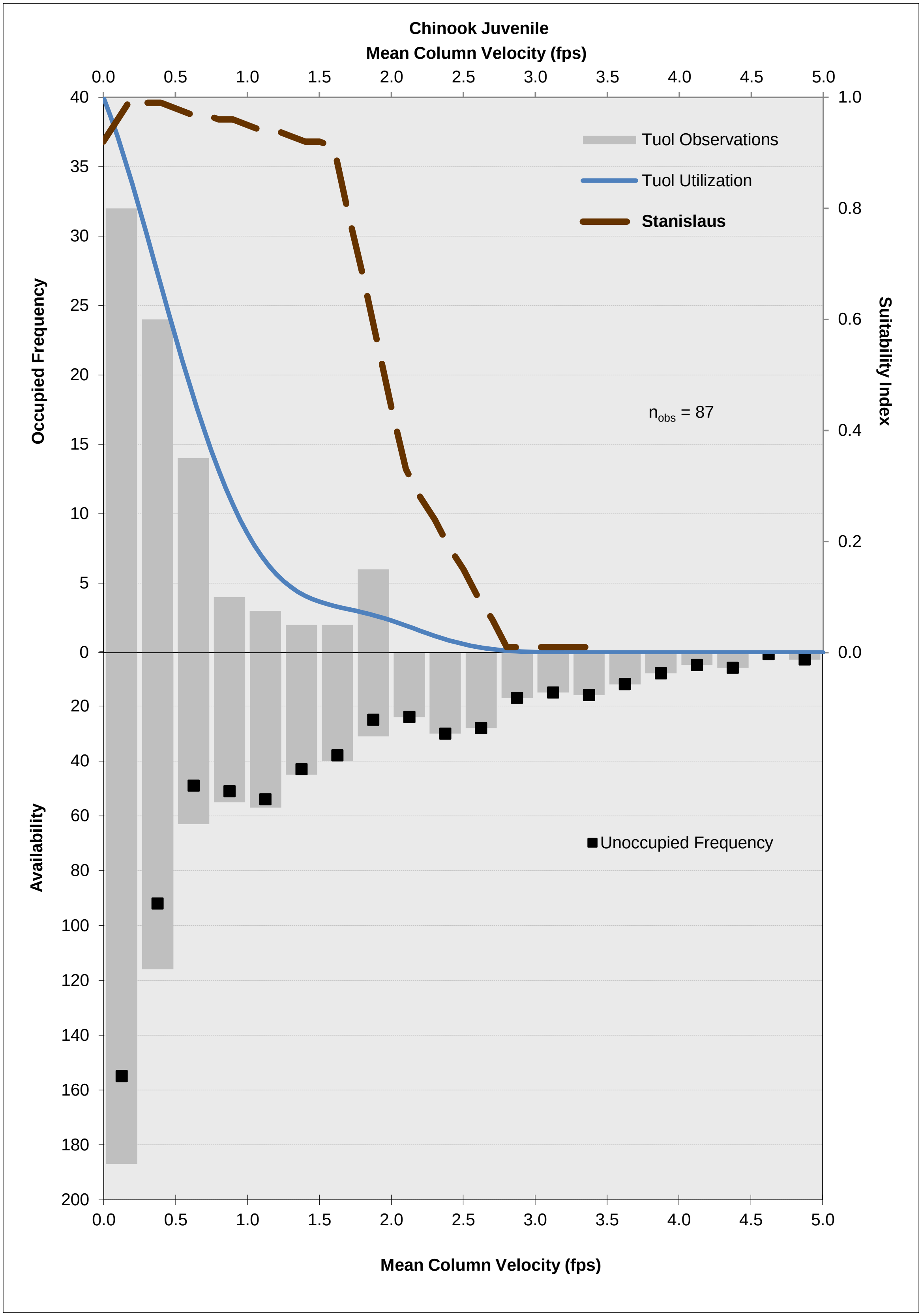

Figure 8. Chinook salmon juvenile velocity suitability criteria for the lower Tuolumne River; curve applied in the PHABSIM model was Stanislaus.

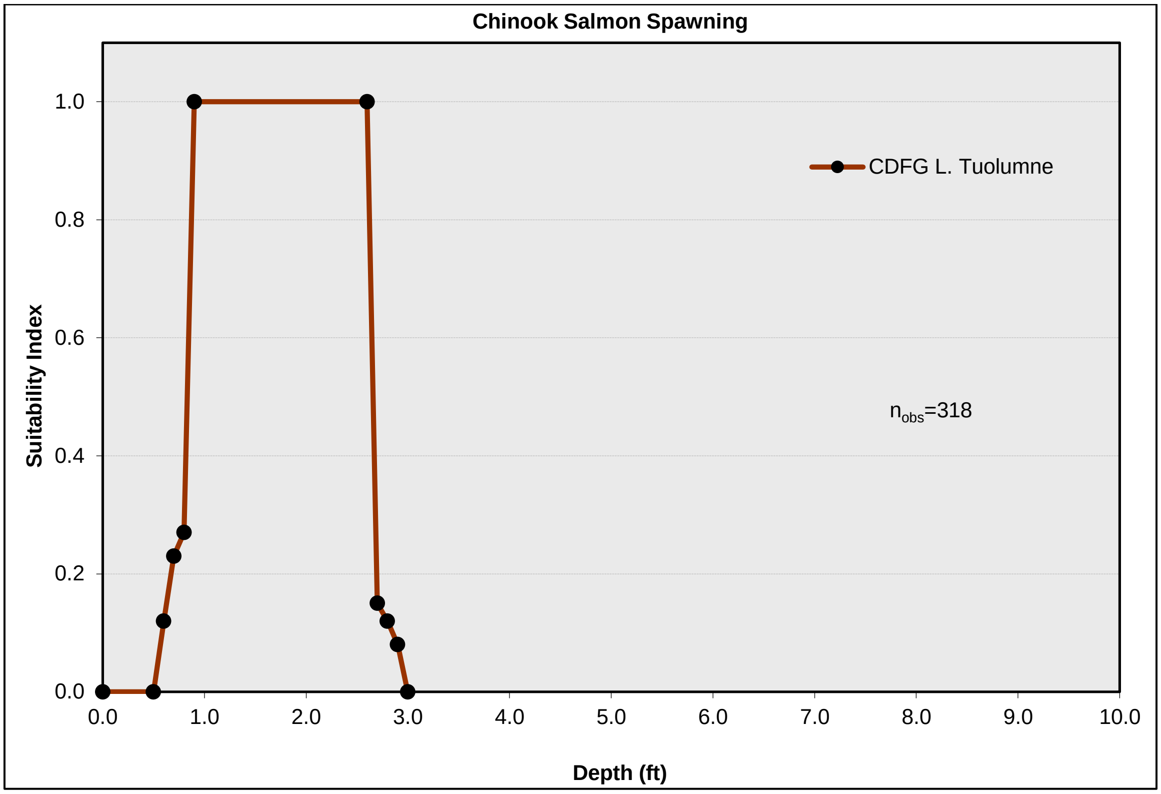

Figure 9. Chinook salmon spawning depth suitability criteria for the lower Tuolumne River.

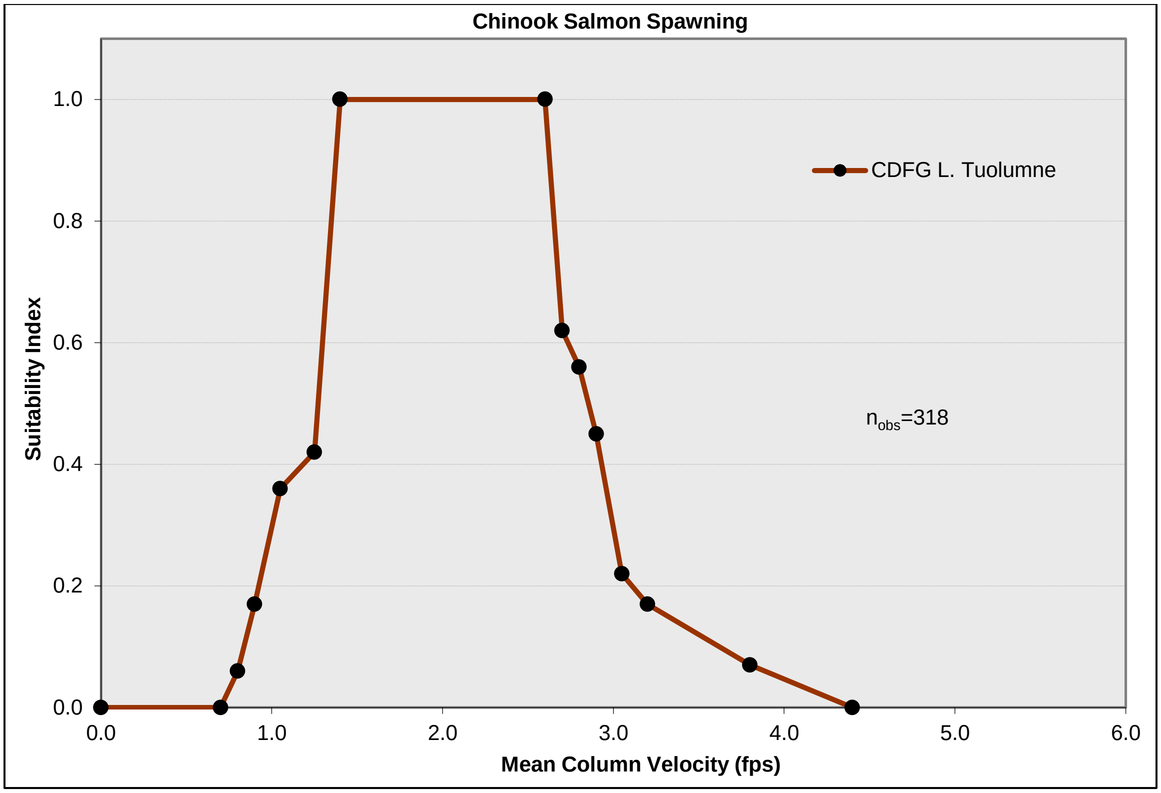

Figure 10. Chinook salmon spawning velocity suitability criteria for the lower Tuolumne River.

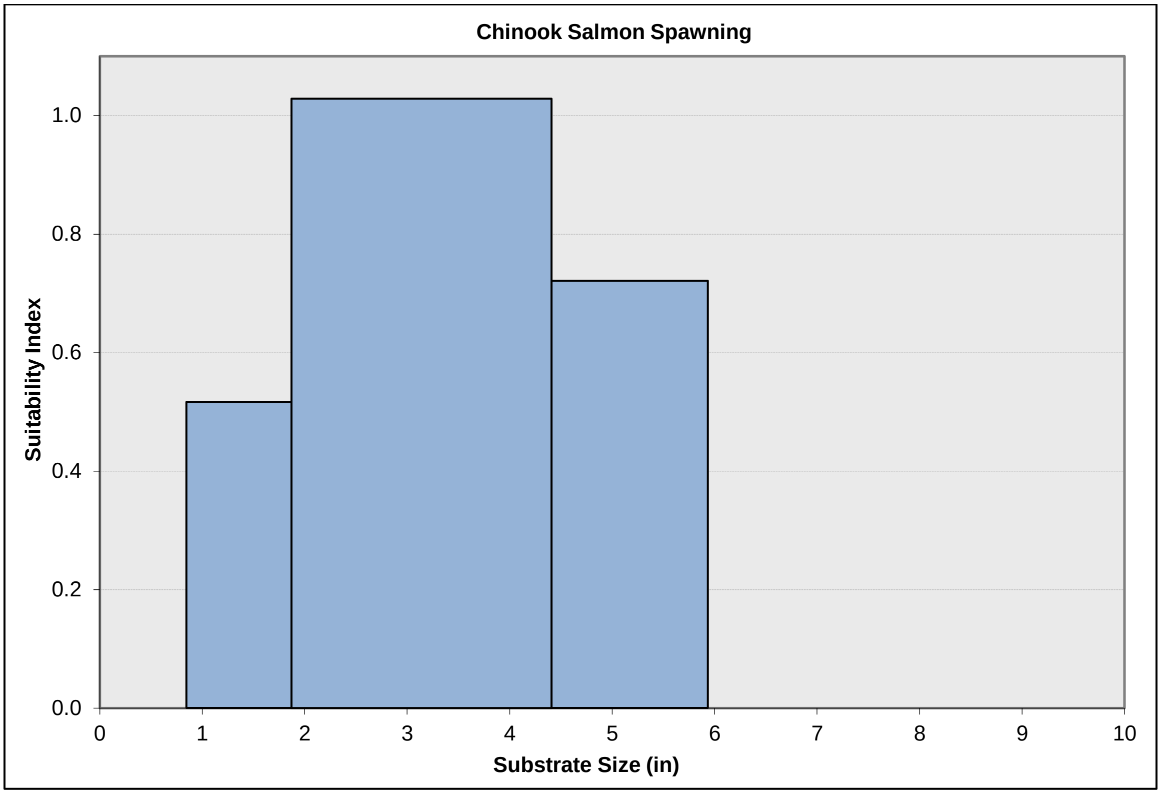

Figure 11. Chinook salmon spawning substrate suitability criteria for the lower Tuolumne River.

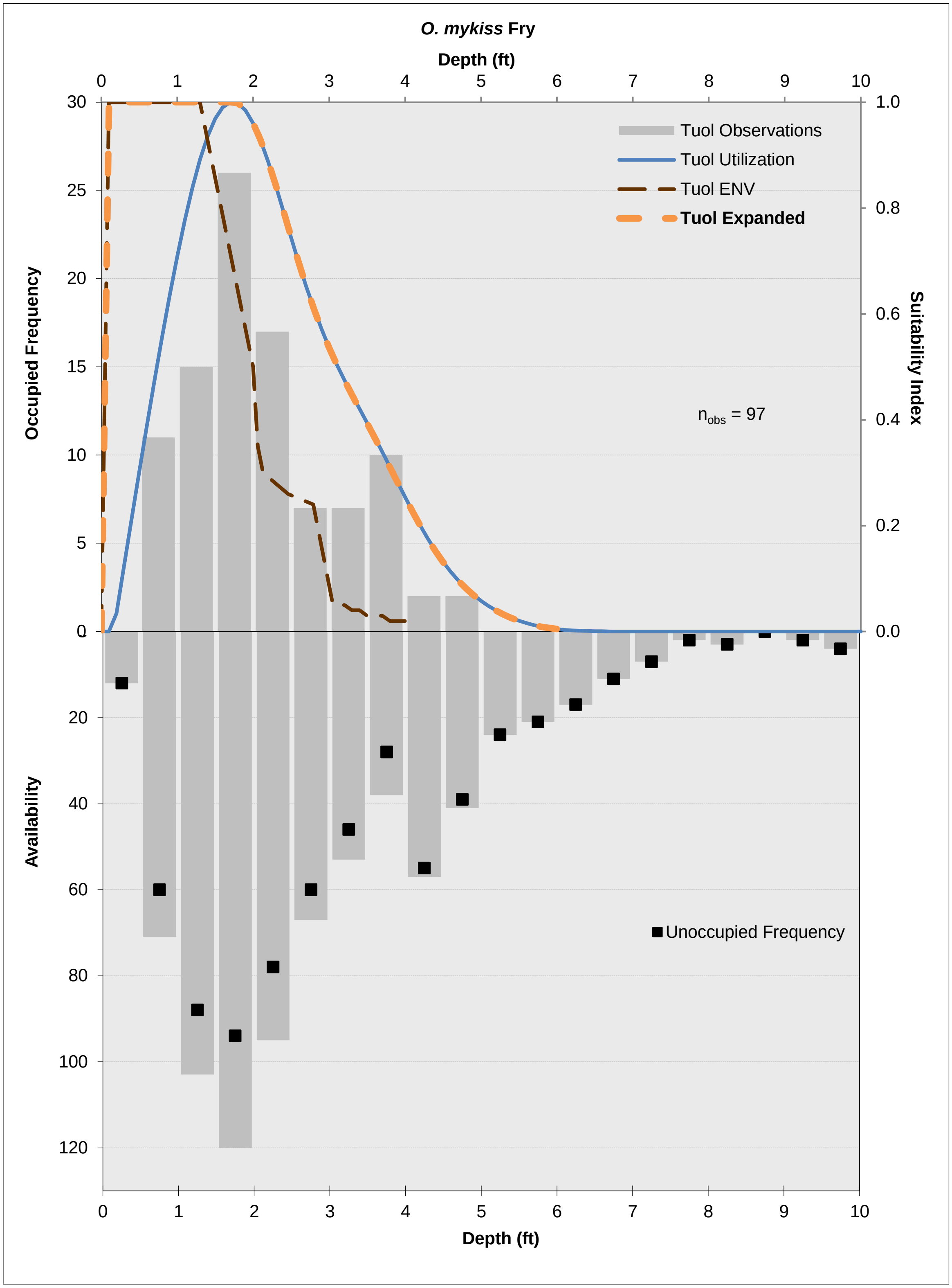

Figure 12. *O. mykiss* fry depth suitability criteria for the lower Tuolumne River; curve applied in the PHABSIM model was Tuol Expanded.

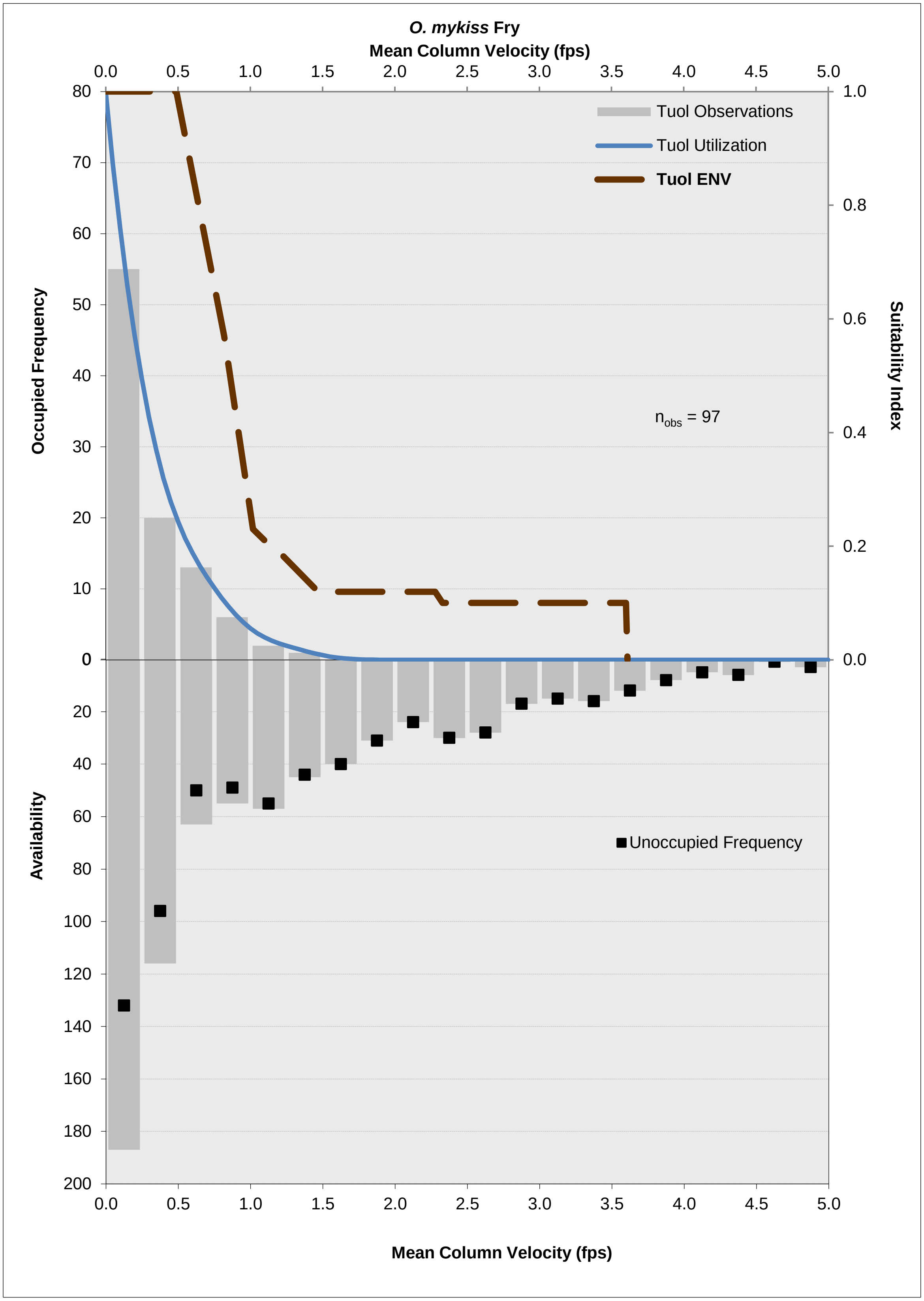

Figure 13. *O. mykiss* fry velocity suitability criteria for the lower Tuolumne River; curve applied in the PHABSIM model was Tuol ENV.

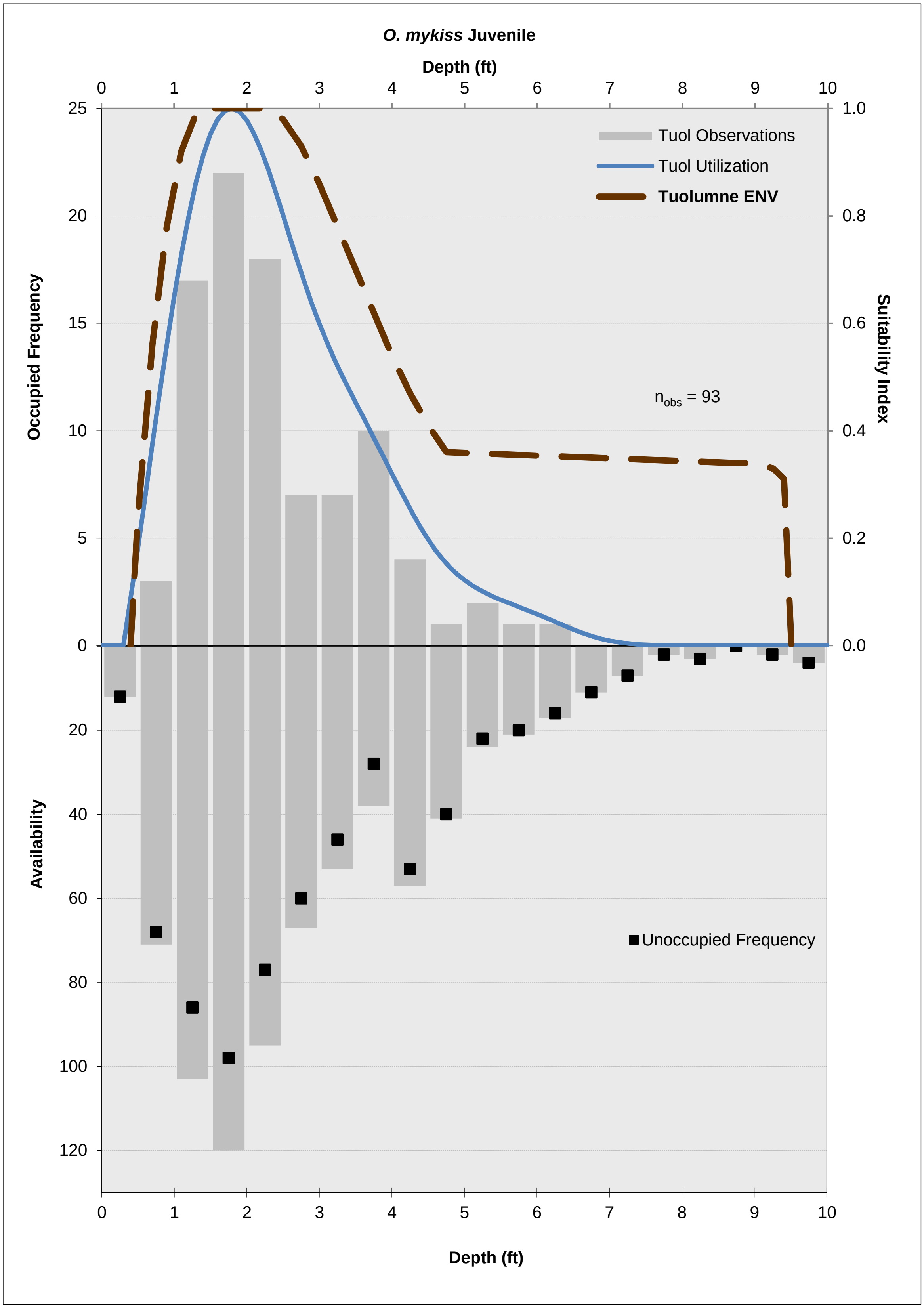

Figure 14. *O. mykiss* juvenile depth suitability criteria for the lower Tuolumne River; curve applied in the PHABSIM model was Tuol ENV.

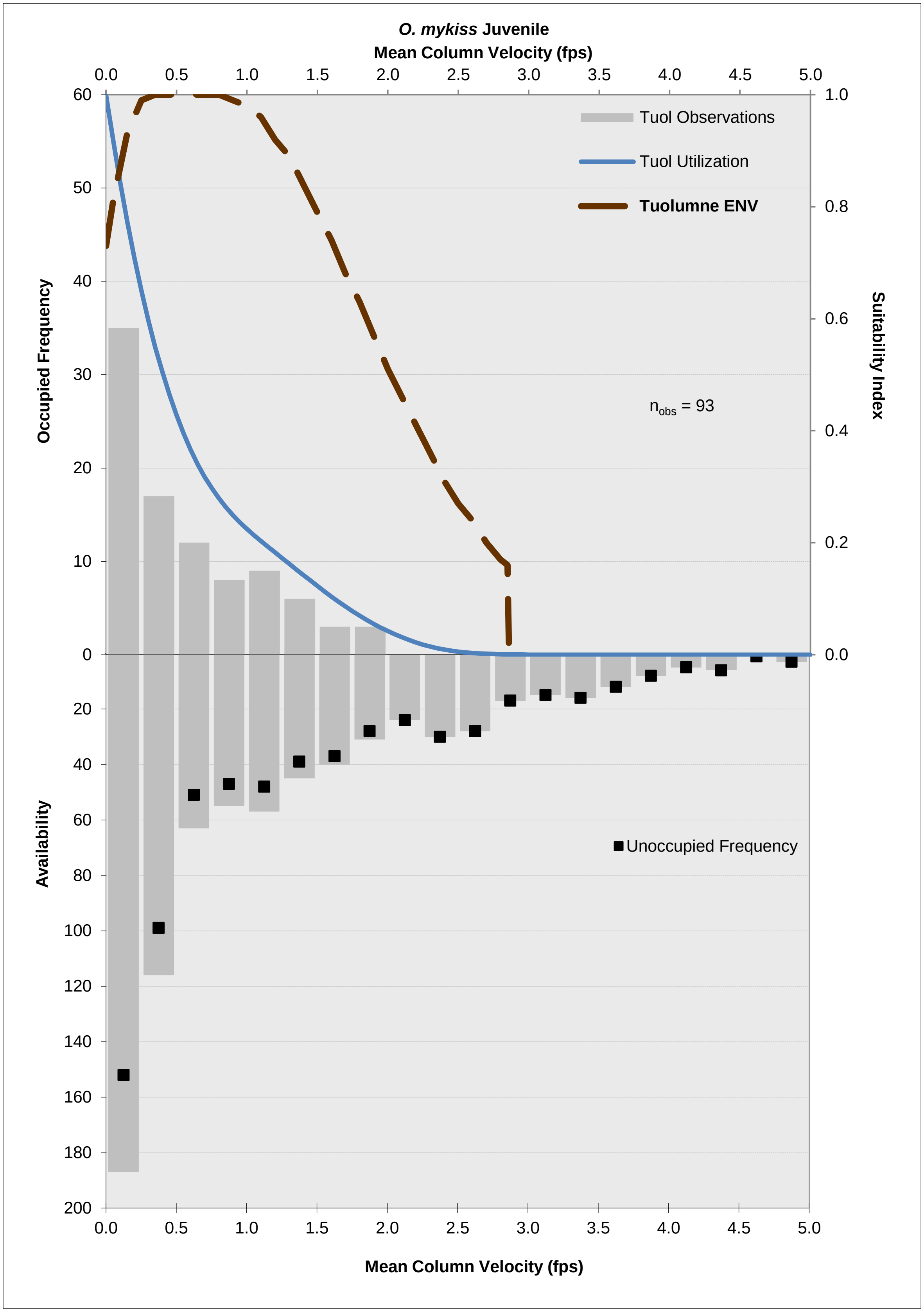

Figure 15. *O. mykiss* juvenile velocity suitability criteria for the lower Tuolumne River; curve applied in the PHABSIM model was Tuol ENV.

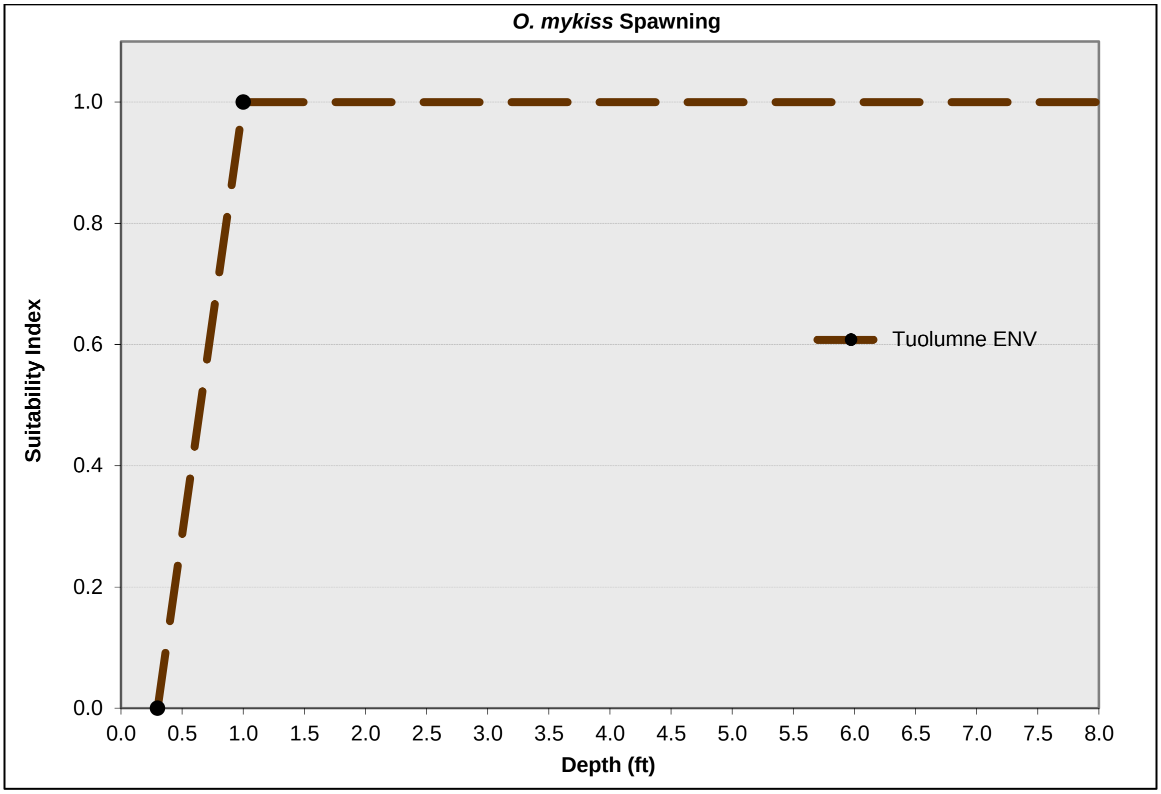

Figure 16. *O. mykiss* spawning depth suitability criteria for the lower Tuolumne River.

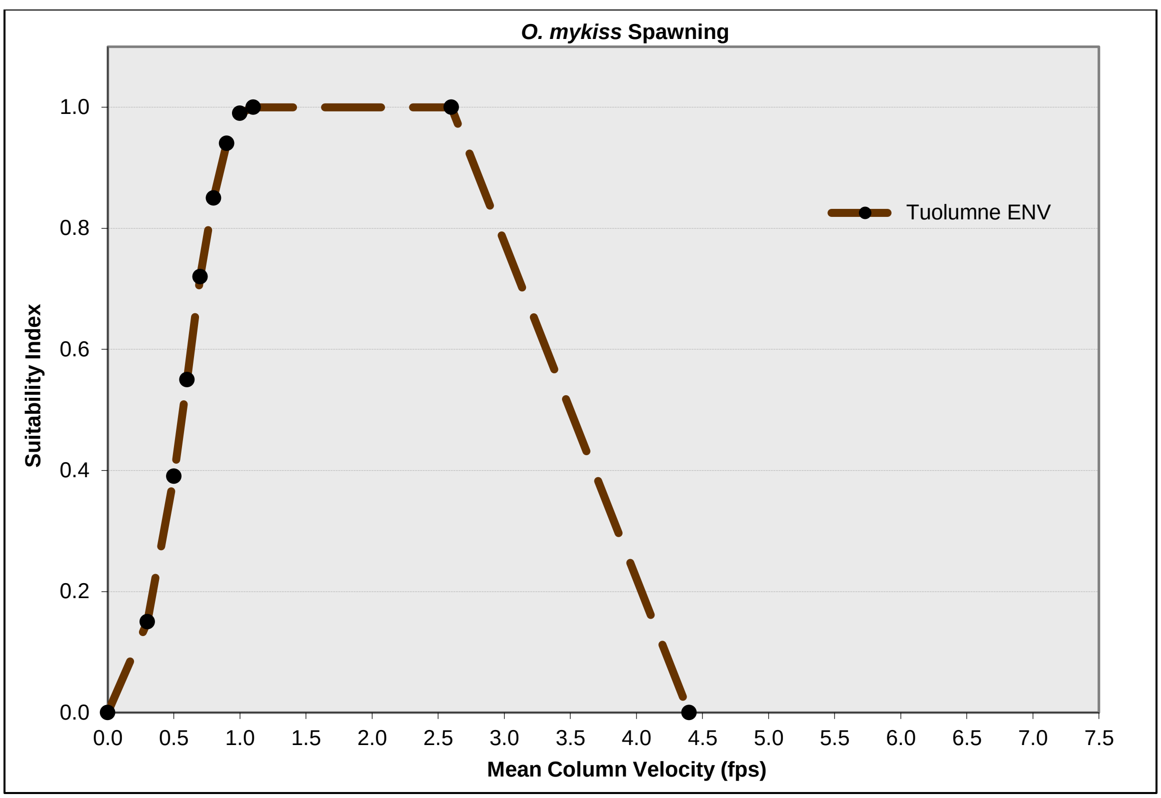

Figure 17. *O. mykiss* spawning velocity suitability criteria for the lower Tuolumne River.

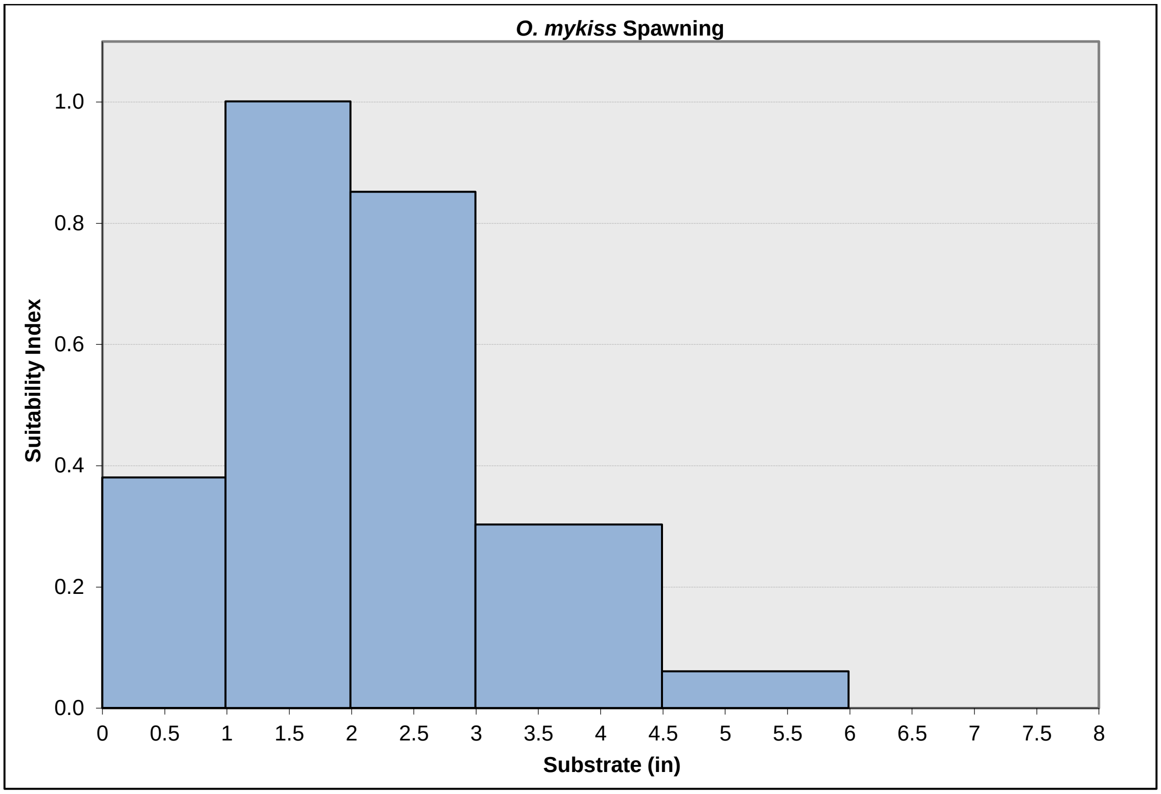

Figure 18. *O. mykiss* spawning substrate suitability criteria for the lower Tuolumne River.

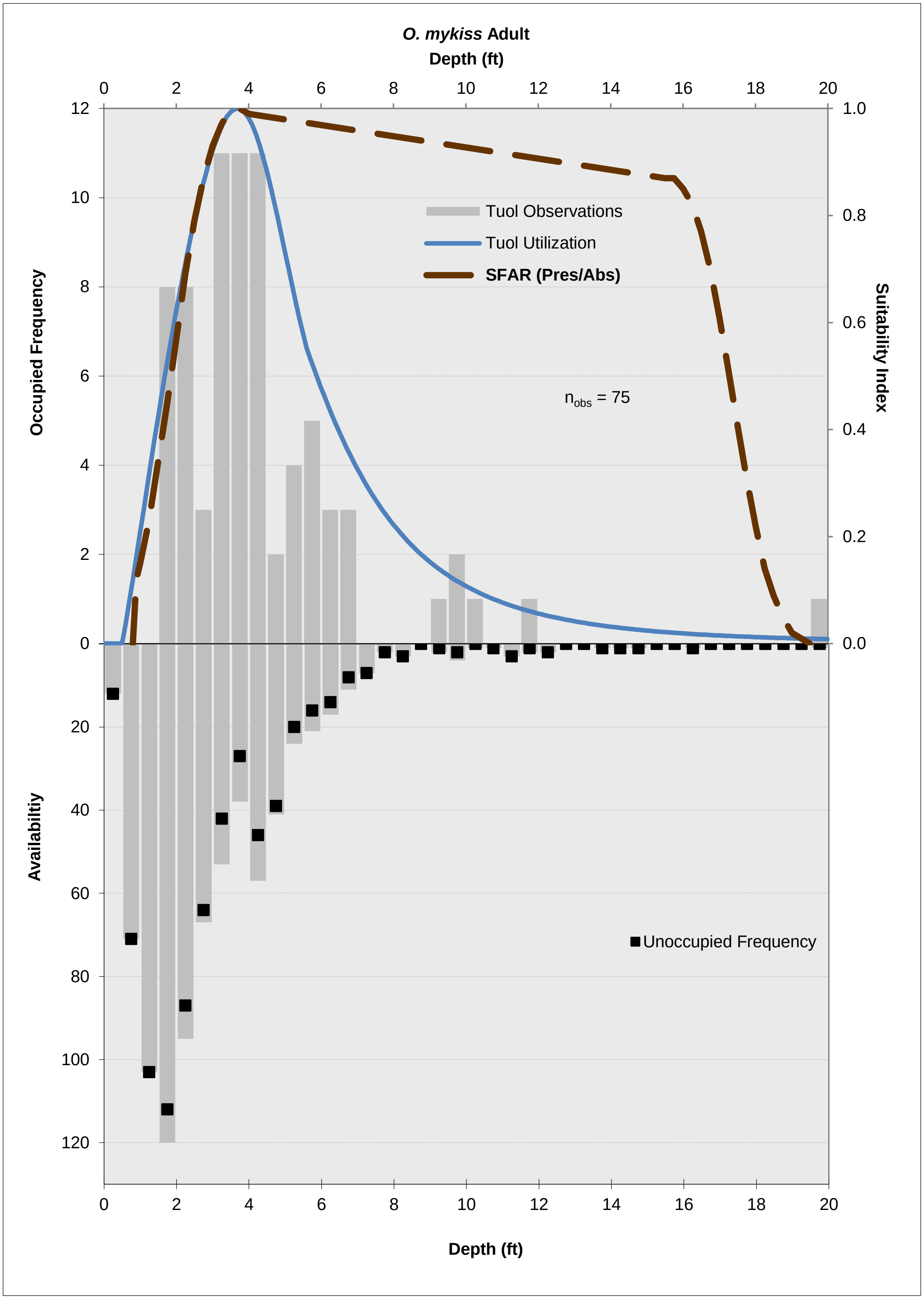

Figure 19. *O. mykiss* adult depth suitability criteria for the lower Tuolumne River; curve applied in the PHABSIM model was SFAR (Pres/Abs).

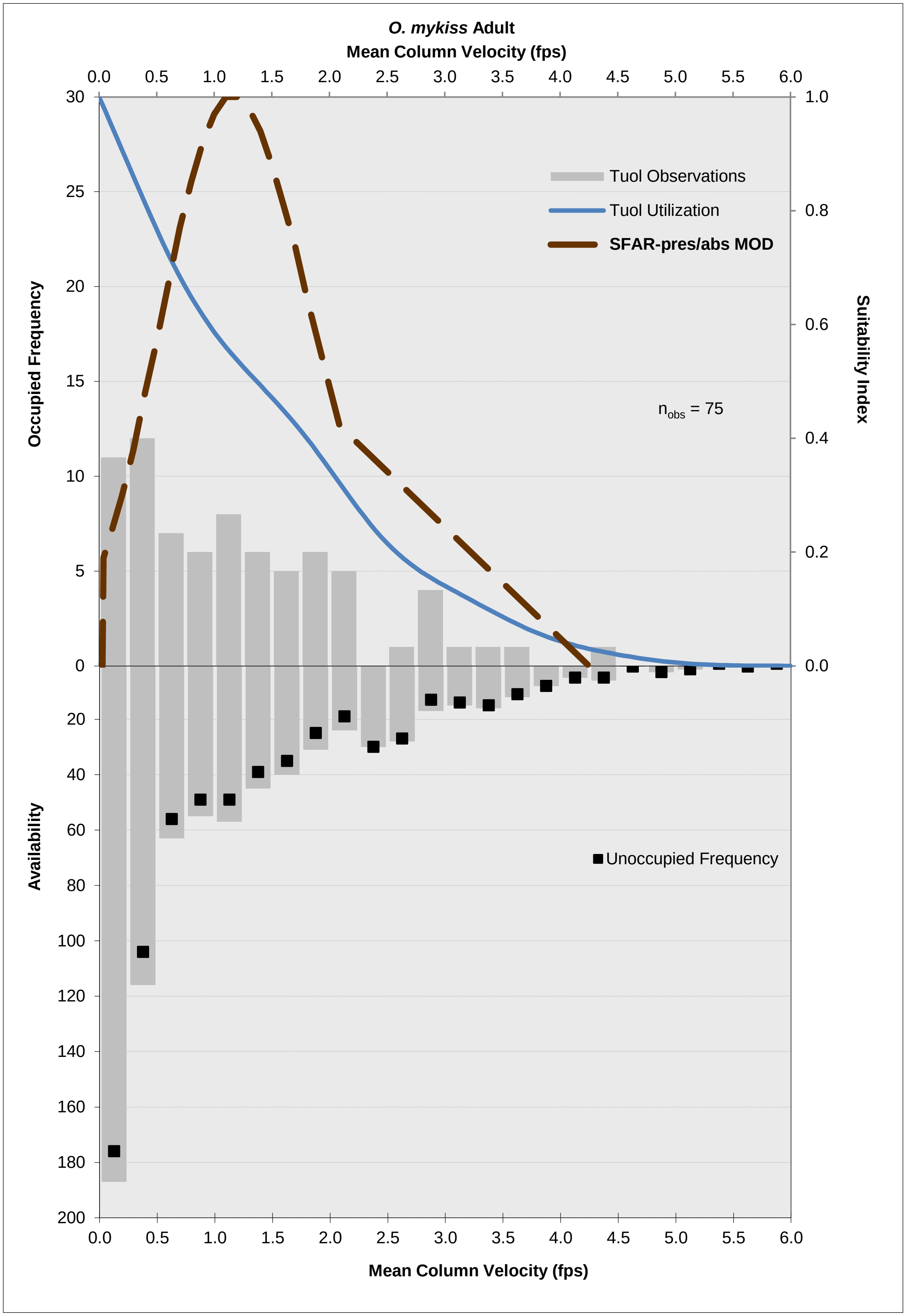

Figure 20. *O. mykiss* adult velocity suitability criteria for the lower Tuolumne River; curve applied in PHABSIM model was SFAR (pres/abs MOD).

3.1.3 Adjacent velocity

The results of the adjacent velocity analysis in the lower Tuolumne River are presented in Table 15. Adjacent velocities were significantly different ($p<0.05$) than fish observation point mean velocities for three of the five species and life stage combinations, although the fry life stage is not typically considered to use feeding lanes. However, the differences in mean column velocity were small (0.06 to 0.25 fps), suggesting limited use (or lack) of well-developed shear zones or feeding lanes (which is consistent with more homogenous morphological and hydraulic conditions observed in the Tuolumne or other large alluvial valley rivers). In addition, the magnitude of the adjacent velocities was well within the preferred velocity ranges (e.g., suitability indices of >0.5) for continuous occupation of the point location (i.e., the adjacent velocity was not in a much faster but less preferred location that was briefly and opportunistically used for feeding, but rather within a velocity range typical of positions more continuously occupied by the species and life stage). As a result, there appears to be limited application of adjacent velocity analytical methods to lower Tuolumne River conditions, and further analysis of adjacent velocities within the PHABSIM model was not warranted.

Table 15. Adjacent velocities observed during site-specific surveys in the lower Tuolumne River between February and July 2012.

Species	Life stage	Sample Size	Mean Column Velocity		Adjacent Velocity		Difference Between Averages	p[1]
			Average (fps)	Std. Dev.	Average (fps)	Std. Dev.		
Chinook salmon	fry	218	0.32	0.31	0.46	0.52	0.14	**0.000**
	juvenile	87	0.65	0.62	0.89	1.03	0.25	**0.001**
O. mykiss	fry	97	0.44	0.44	0.49	0.55	0.06	0.263
	juvenile	93	0.90	0.78	0.85	0.77	-0.06	0.431
	adult	75	1.58	1.10	1.79	1.31	0.21	**0.042**

[1] Statistically significant ($p<0.05$) values shown in bold.

3.2 Weighted Usable Area

Results of the PHABSIM analysis of WUA versus flow relationships for each species and life stage are presented in Figures 21 and 22. In order to facilitate comparison and analysis, the results are presented with a normalized y-axis scale representing "percent of maximum" WUA. Results presenting raw WUA values along the y-axis are provided in Appendix H, along with results of some ancillary analyses of substrate and cover. Photographs of each transect location at each measured flow are included in Appendix I.

Results for Chinook salmon fry show peak WUA values (e.g., ≥95% of maximum) at approximately 50-100 cfs, with relatively high WUA values (e.g., ≥80% of maximum) below 125 cfs (Figure 21). Results for Chinook salmon juveniles show peak WUA values at approximately 75–225 cfs, with relatively high WUA values below 400 cfs. Results for Chinook salmon spawning show peak WUA values at approximately 250–350 cfs, with relatively high WUA values from 175 to 475 cfs.

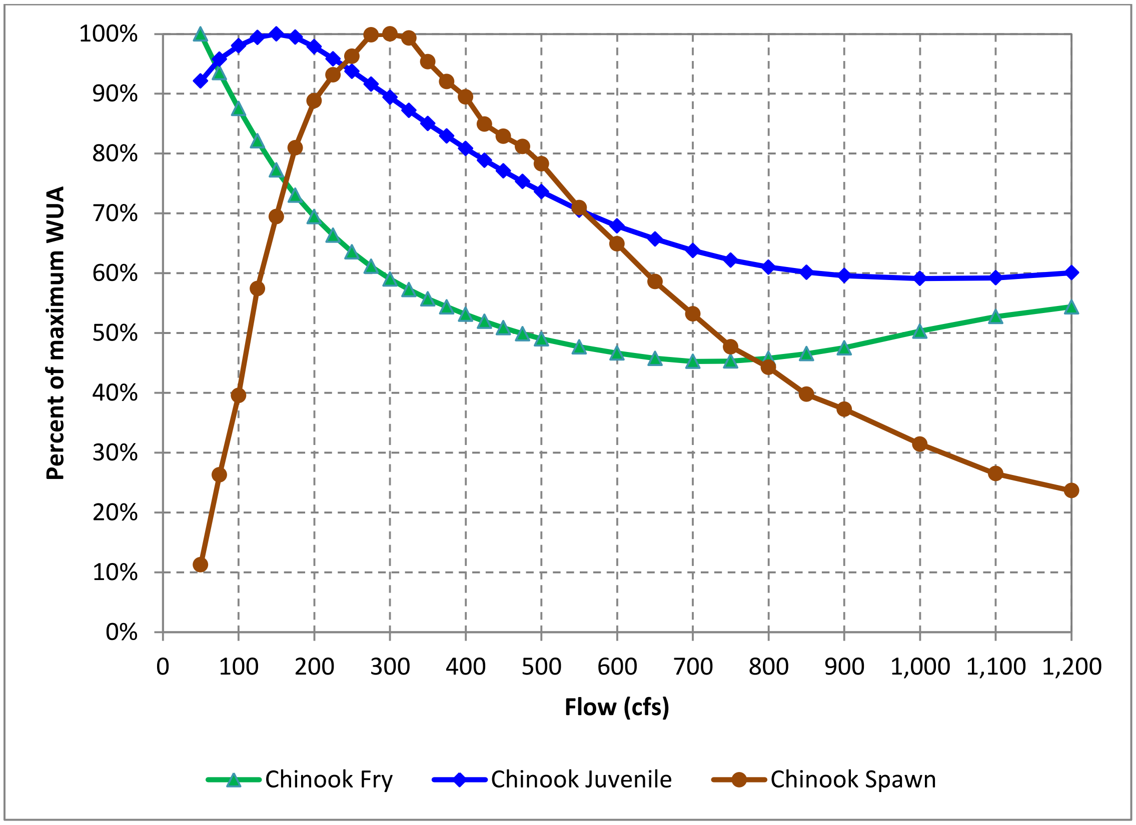

Figure 21. Chinook salmon WUA results for the lower Tuolumne River.

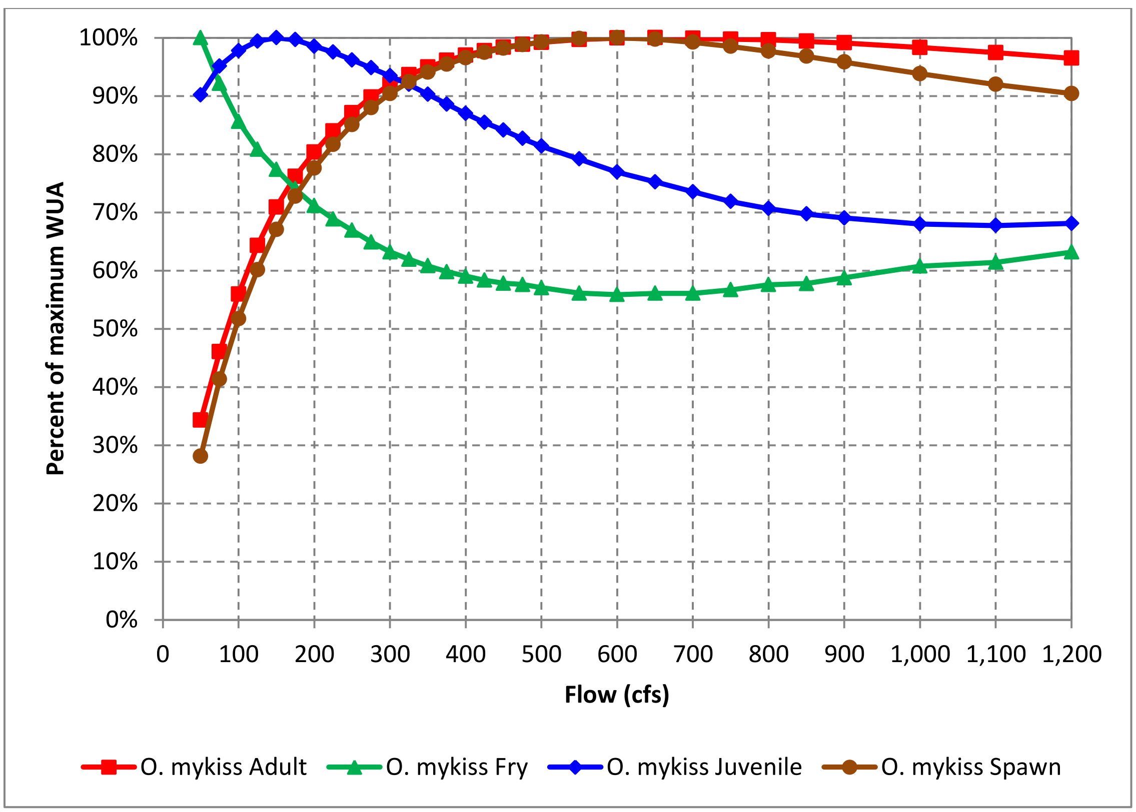

Figure 22. *O. mykiss* WUA results for the lower Tuolumne River.

Results for *O. mykiss* fry show peak WUA values below approximately 75 cfs, with relatively high WUA values at flows ≤125 cfs. Results for *O. mykiss* juveniles show peak WUA values at approximately 75–275 cfs, with relatively high WUA values at flows ≤500 cfs. Results for *O. mykiss* adults show peak WUA values at flows ≥350 cfs, with relatively high WUA values at flows ≥200 cfs. Results for *O. mykiss* spawning show peak WUA values at ≥375 cfs, with relatively high WUA values at flows ≥225 cfs.

3.3 Habitat Time Series

Habitat time series results for each of five water year types (using the San Joaquin River 60-20-20 Index) and five species and life stage combinations are presented in Figures 23 to 32. The time periods used in the habitat time series analysis when individual lifestages are most typically observed, or expected to be present, within the study reach are summarized in Table 16.

Under a Critical year scenario, Chinook salmon WUA values and flows stay relatively stable through the year, with two exceptions: 1) spawning habitat increases significantly in mid-October in association with a change in the spawning flow, and 2) fry and juvenile WUA drops in late spring in association with increased run-off or flood control releases (Figure 23). *O. mykiss* fry and juvenile WUA shows a similar pattern of WUA declines during spring flow peaks, but *O. mykiss* adults show a pattern of WUA changing in step with flows (i.e., higher when flows go up in the fall and spring, lower when they decline in summer) (Figure 24).

Under a Dry year scenario, a similar pattern to Critical years appears for Chinook salmon WUA, except that a relatively high spike in fall flows at the beginning of the spawning season actually depressed spawning WUA briefly (Figure 25). *O. mykiss* habitat for fry and juveniles declines with flow peaks in the spring and fall, and adult habitat varies up and down with flow (Figure 26).

Under a Below Normal year scenario, the same patterns as observed in drier years occur (Figures 27 and 28).

The Above Normal year exhibits an earlier and longer depression of Chinook salmon fry and juvenile WUA than drier years, in association with earlier and longer high spring flows or flood releases (Figure 29). *O. mykiss* WUA remains more stable (and higher for the adult life stage) than in other year types, except for drops in juvenile WUA in the spring (Figure 30).

The Wet year scenario creates stable, and lower, WUA areas for Chinook salmon fry and juveniles, with little change in spawning habitat (Figure 31). *O. mykiss* WUA is the most stable under Wet year flows, at higher WUA levels for adults and lower ones for fry and juveniles (Figure 32).

Figures 33 and 34 present HTS across all water year types for Chinook salmon and *O. mykiss*, respectively, and facilitate comparisons of patterns between water year types. Figure 33 documents that Chinook salmon WUA exhibits a similar pattern of annual fluctuation across all year types, except for juvenile and fry habitat that declines in wet years. Figure 34 shows that *O. mykiss* WUA displays a similar trend as Chinook salmon, although juvenile and fry WUA tends to be lower in both Above Normal and Wet water years. Adult *O. mykiss* WUA is typically higher and more stable in Above Normal and Wet years.

Table 16. Seasonal periodicity of Chinook salmon and *O. mykiss* life stages applied for the lower Tuolumne River habitat time series analysis.

		Fall			Winter			Spring			Summer		
Species	**Life stage**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**
Chinook salmon	Spawn												
	Fry												
	Juvenile												
O. mykiss	Spawn												
	Fry												
	Juvenile												

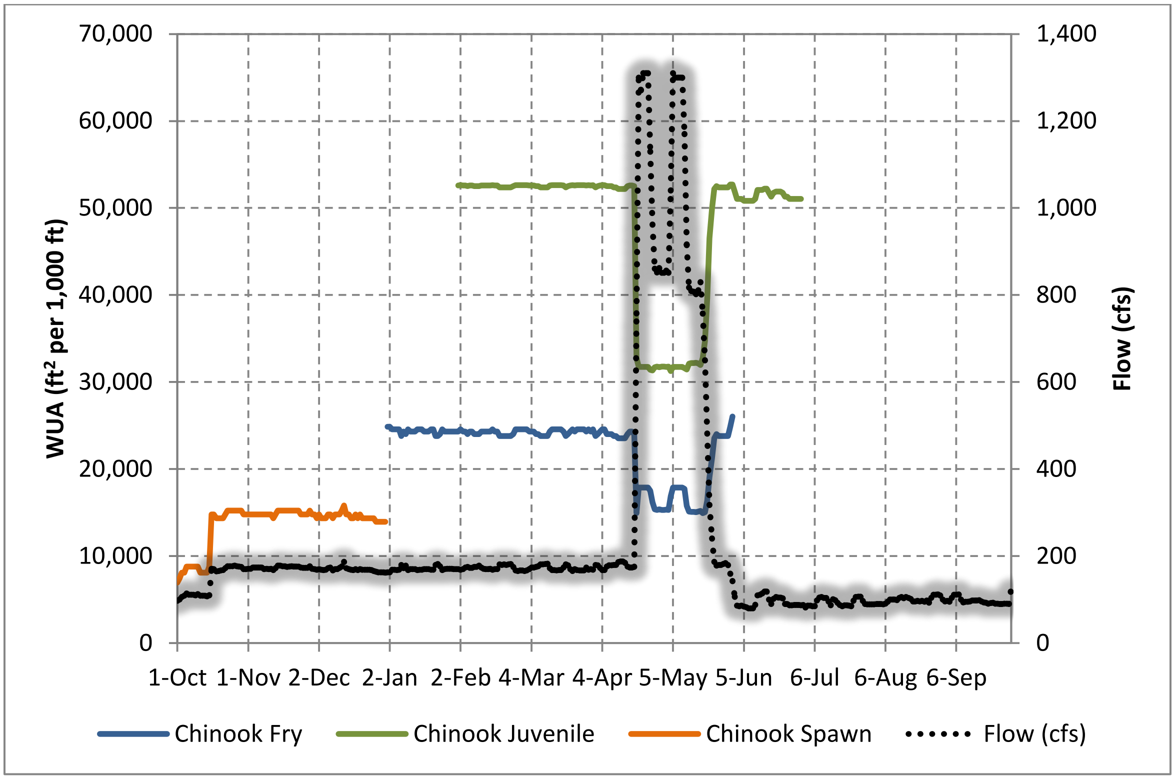

Figure 23. Habitat Time Series results for lower Tuolumne River Chinook salmon in a Critical water year (2008).

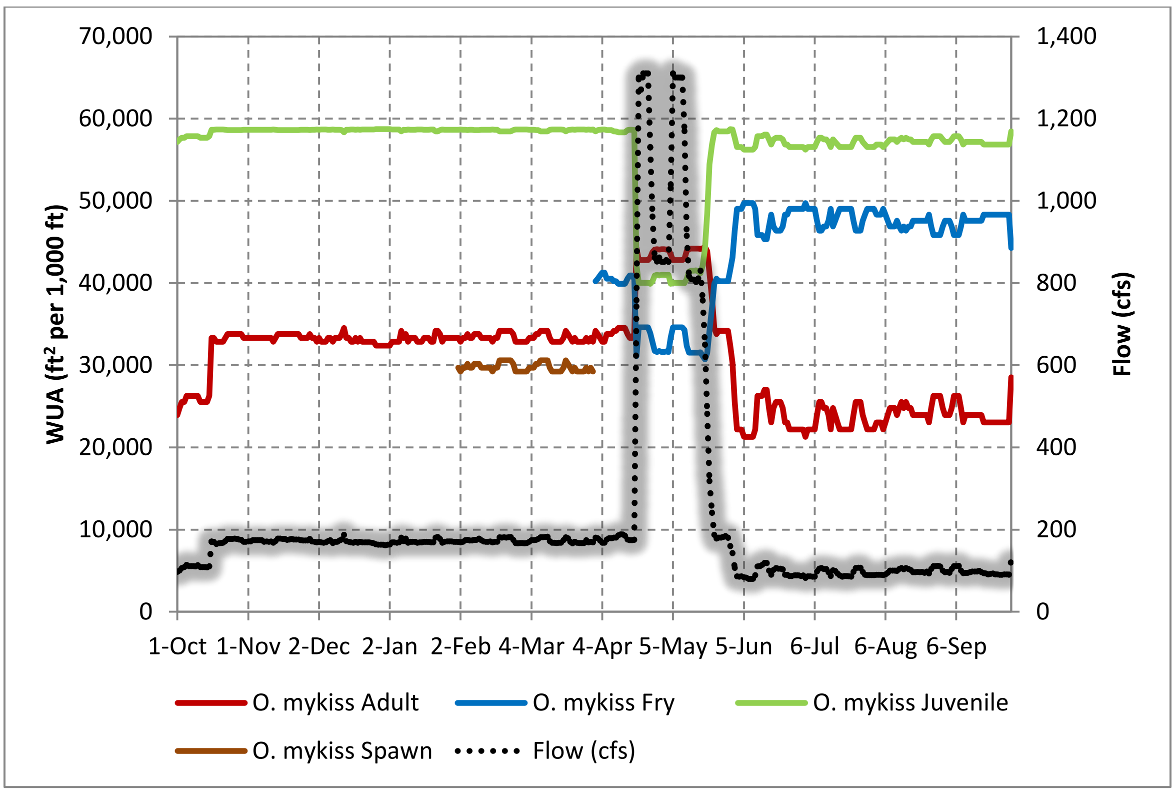

Figure 24. Habitat Time Series results for lower Tuolumne River *O. mykiss* in a Critical water year (2008).

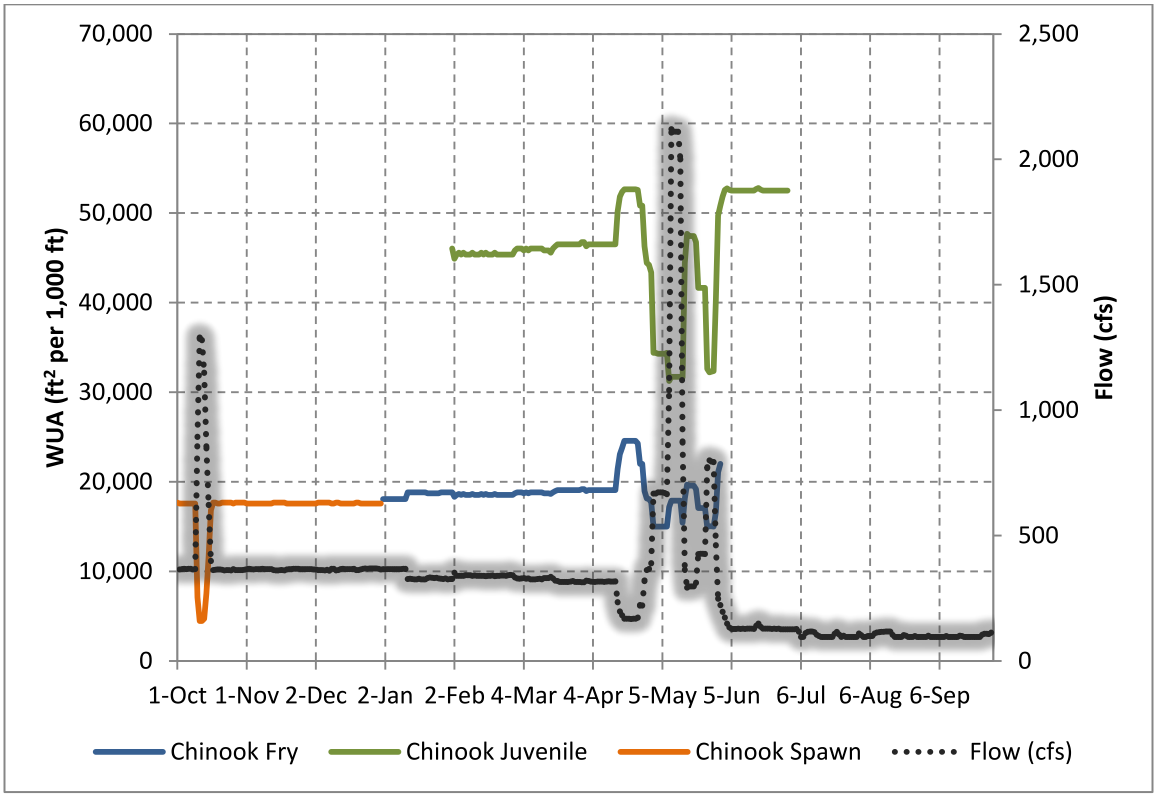

Figure 25. Habitat Time Series results for lower Tuolumne River Chinook salmon in a Dry water year (2012).

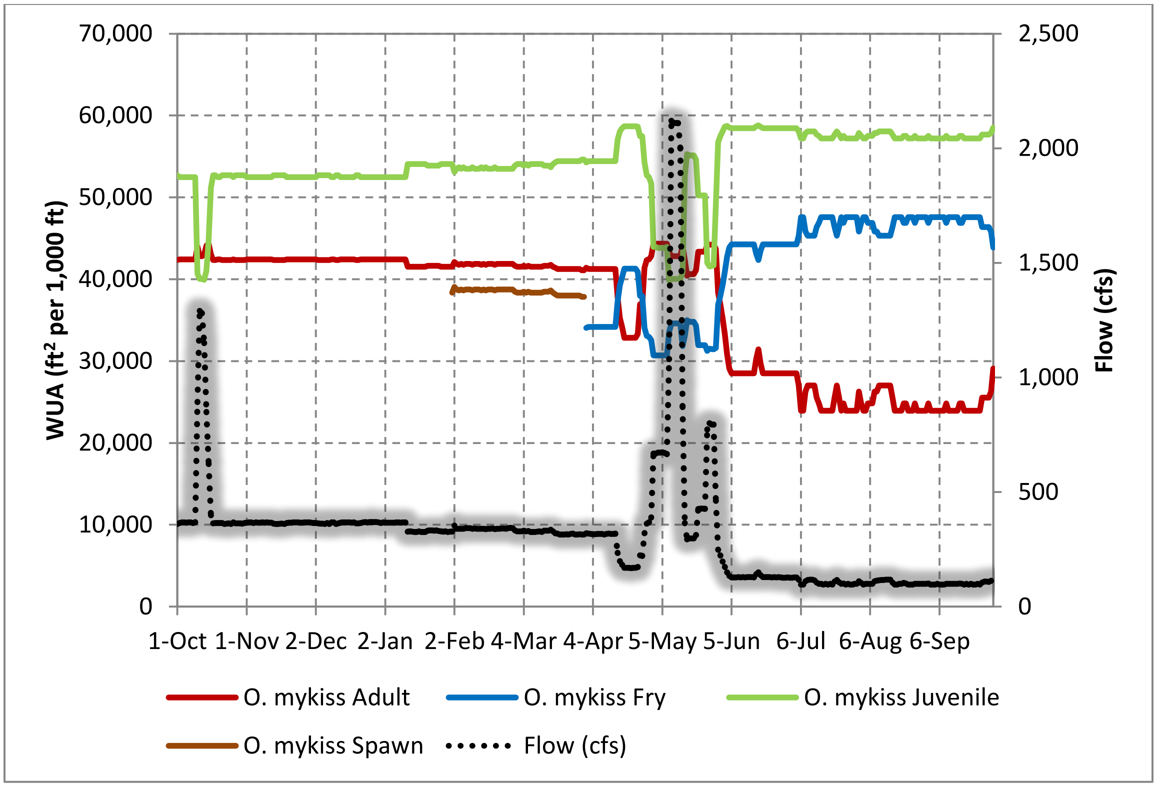

Figure 26. Habitat Time Series results for lower Tuolumne River *O. mykiss* in a Dry water year (2012).

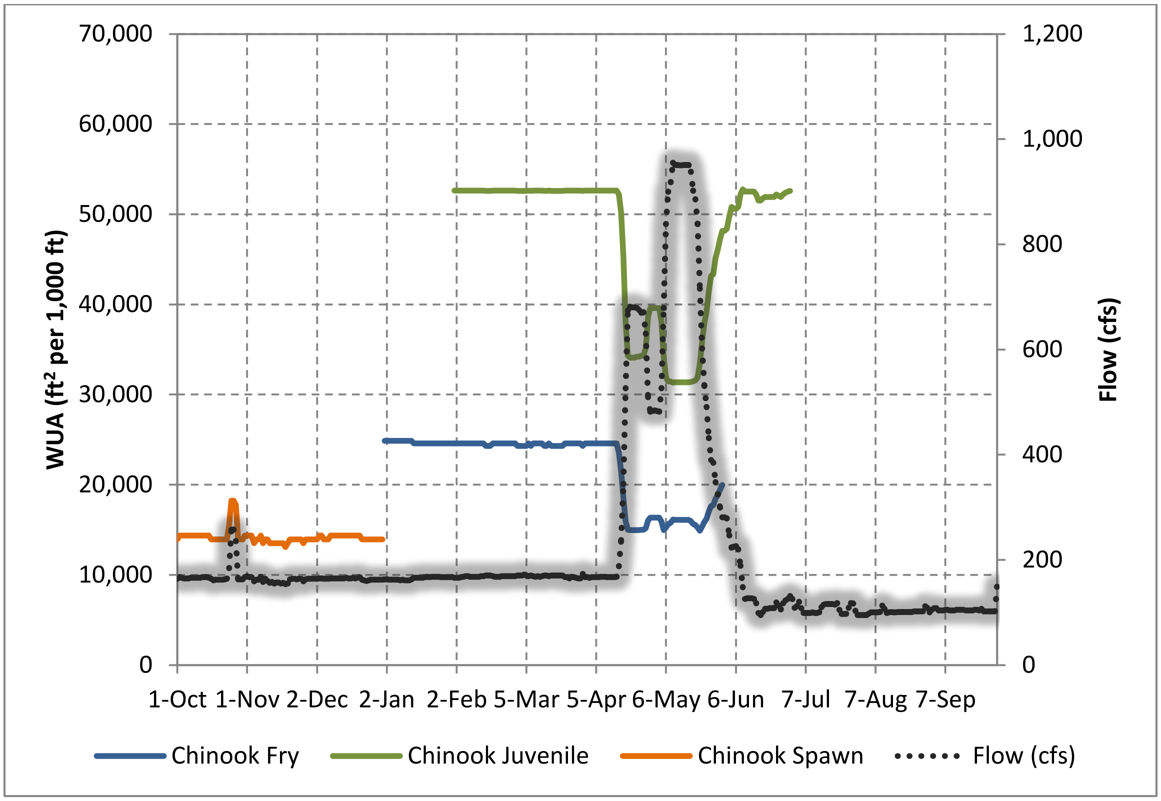

Figure 27. Habitat Time Series results for lower Tuolumne River Chinook salmon in a Below Normal water year (2009).

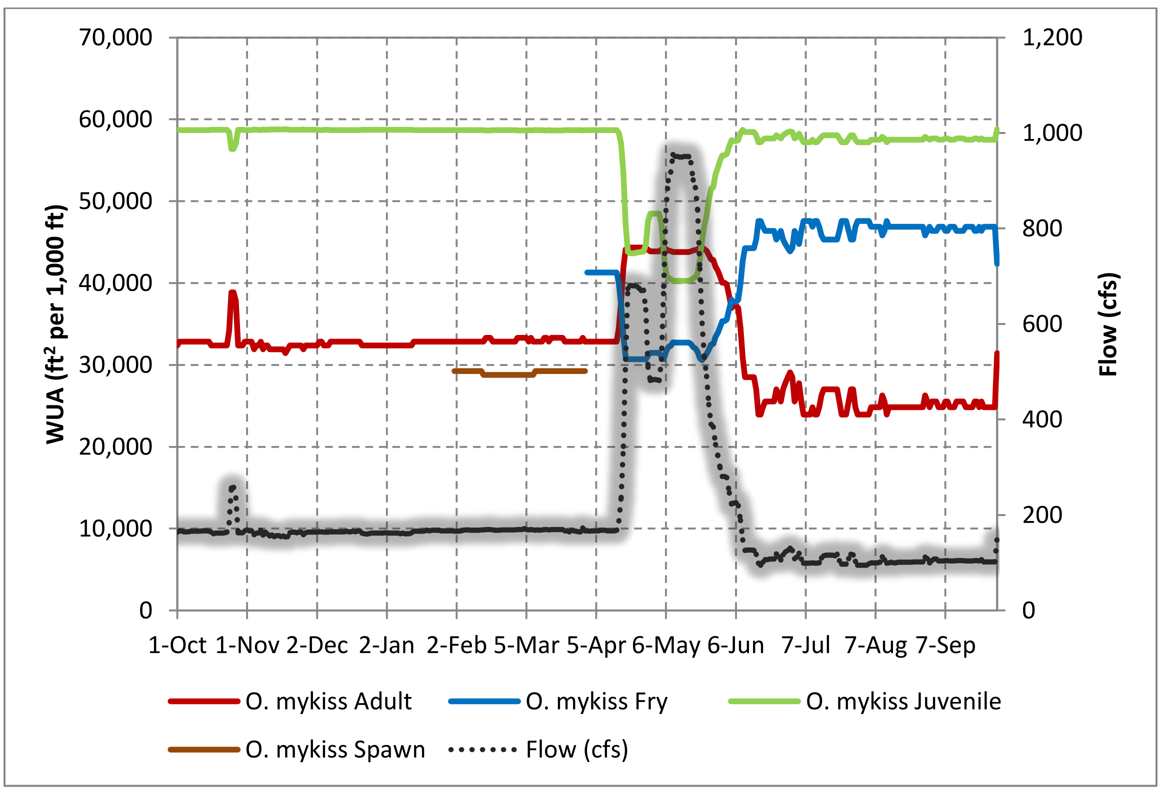

Figure 28. Habitat Time Series results for lower Tuolumne River *O. mykiss* in a Below Normal water year (2009).

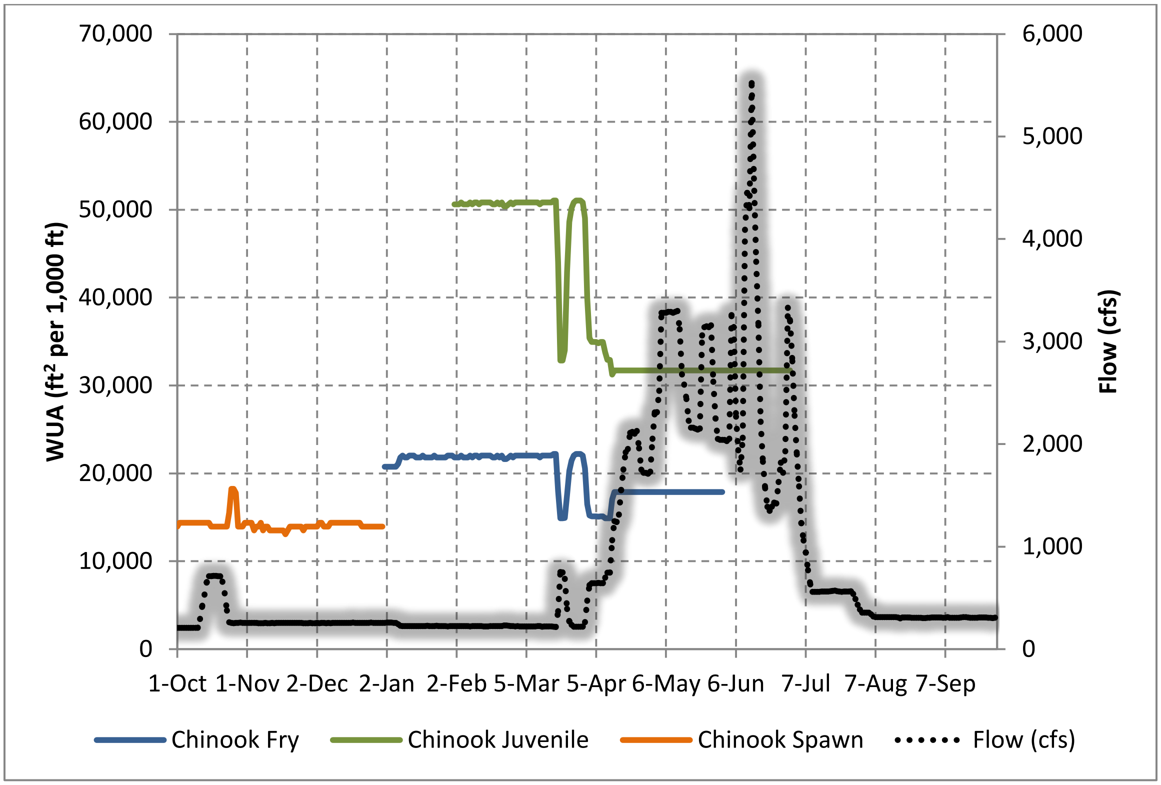

Figure 29. Habitat Time Series results for lower Tuolumne River Chinook salmon in an Above Normal water year (2010).

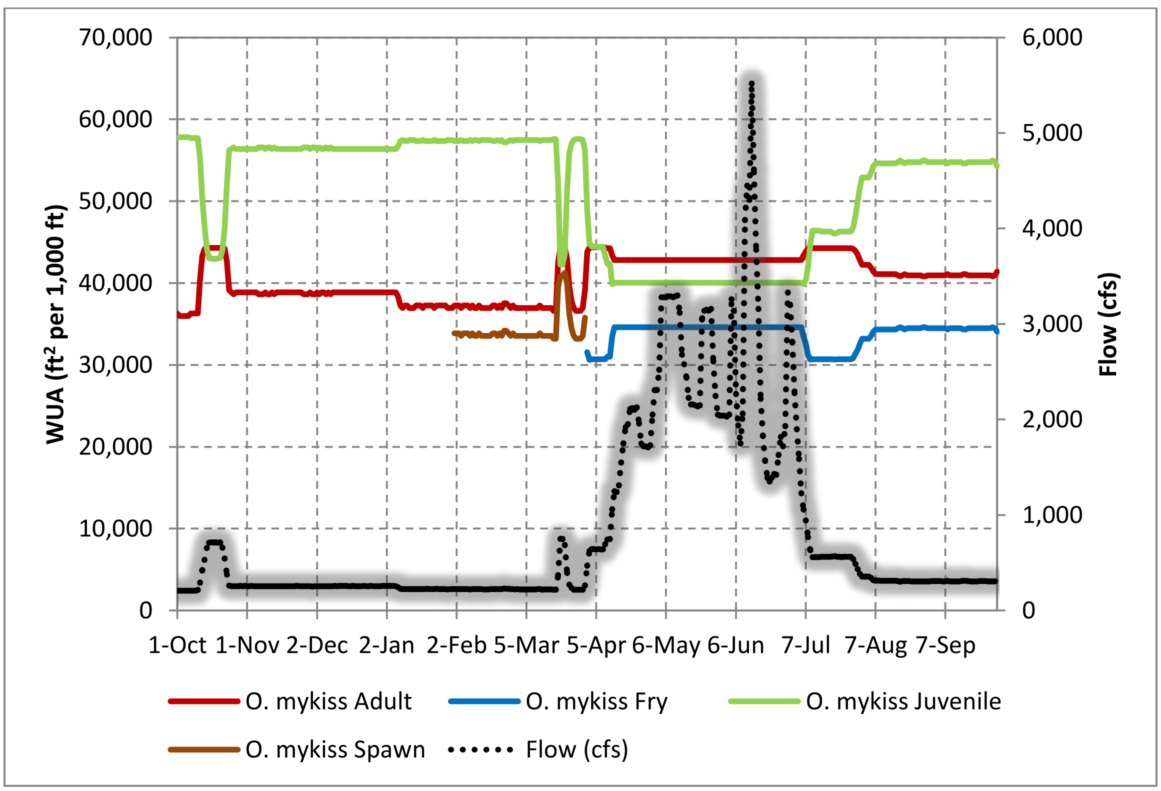

Figure 30. Habitat Time Series results for lower Tuolumne River *O. mykiss* in an Above Normal water year (2010).

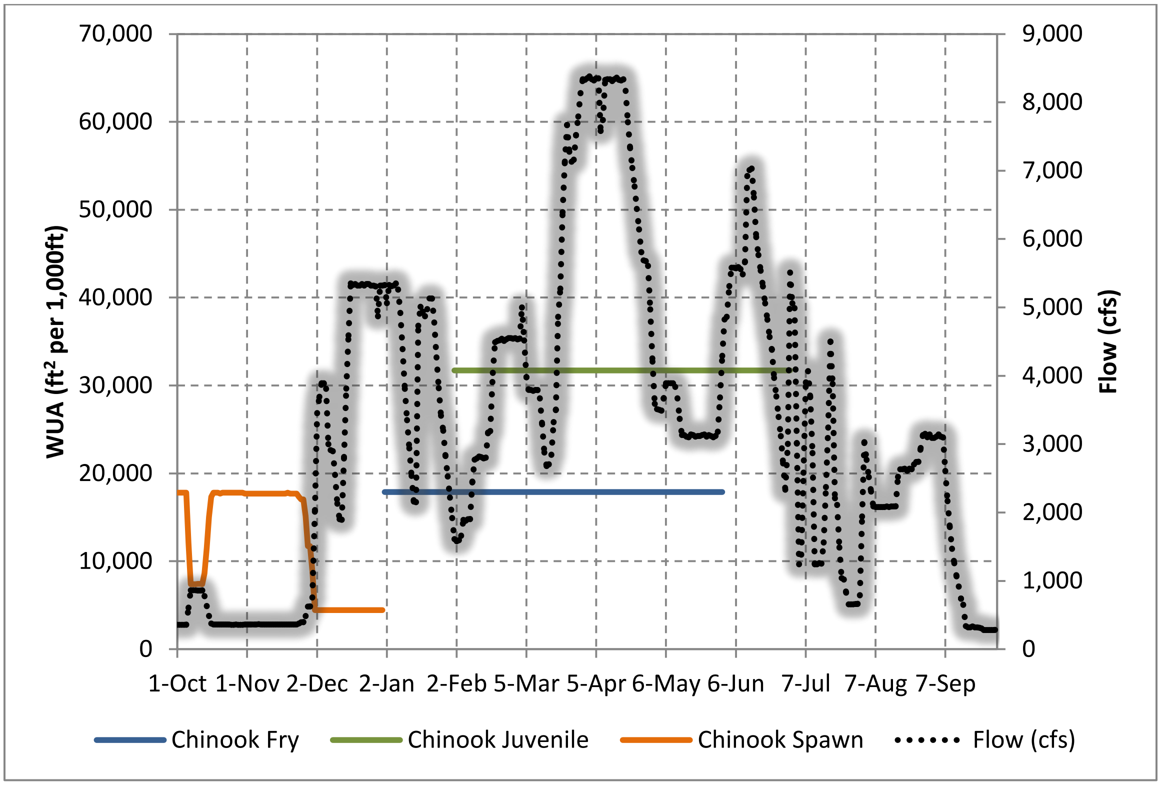

Figure 31. Habitat Time Series results for lower Tuolumne River Chinook salmon in a Wet water year (2011).

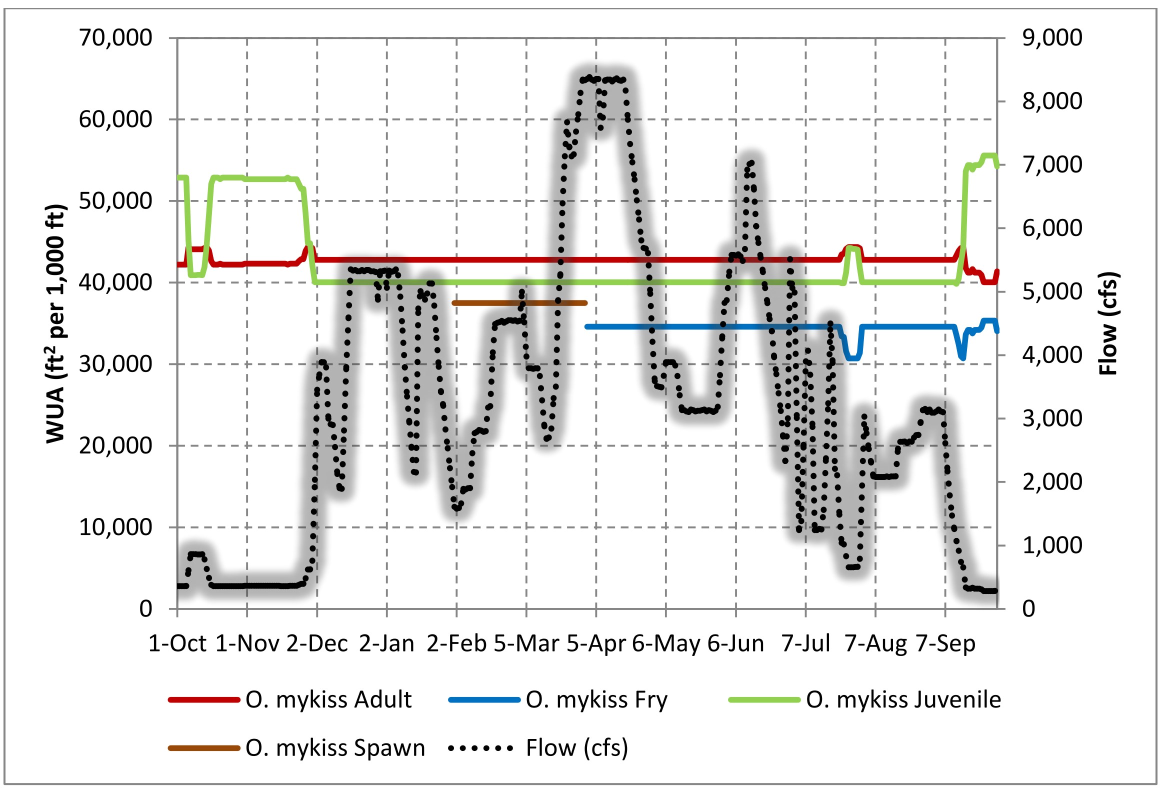

Figure 32. Habitat Time Series results for lower Tuolumne River *O. mykiss* in a Wet water year (2011).

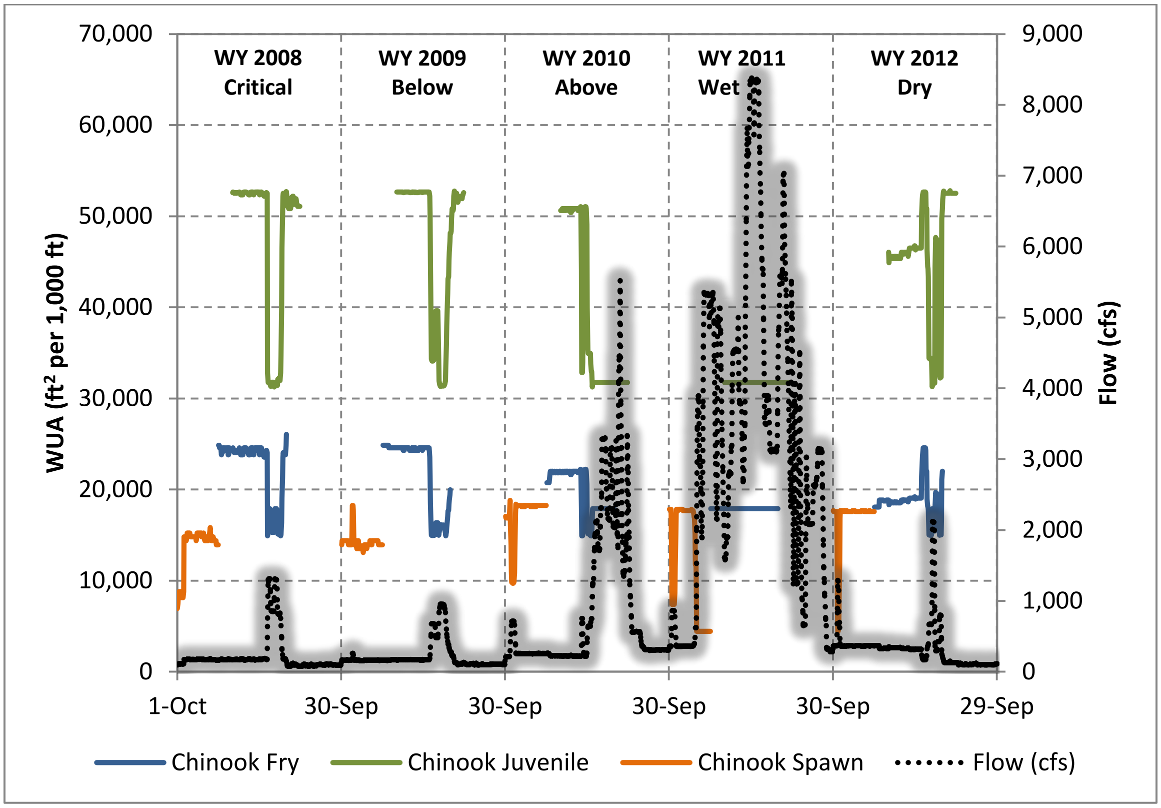

Figure 33. Habitat Time Series results for lower Tuolumne River Chinook salmon across all water year types.

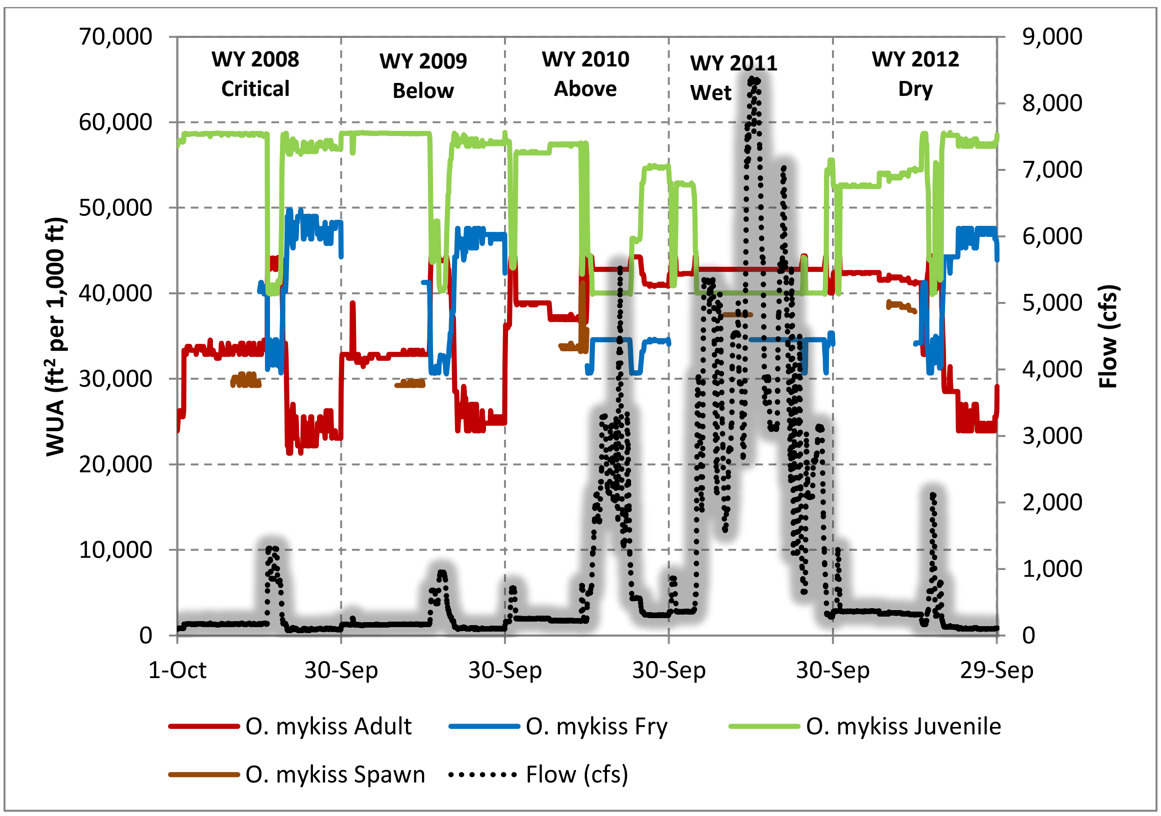

Figure 34. Habitat Time Series results for lower Tuolumne River *O. mykiss* across all water year types.

4 DISCUSSION

4.1 Habitat Suitability Criteria

4.1.1 Curve development

A variety of methods can be used for smoothing habitat suitability data and generating the resulting functions. The field data were collected in a manner that allows for alternative analytical techniques (such as logistic regression), as requested by technical workgroup participants and FERC. A primary advantage of the more traditional preference calculation methods from Bovee (1986) used here is that similar types of methods were used in the published studies that were included in the existing HSC data compilation and selection process. Thus, for validation purposes, the results calculated from the Tuolumne River site-specific data were most comparable to the other studies. Another advantage of the employed method is that it is non-parametric; the shape of the resulting preference curve is determined by the data, whereas the logistic regression approach (Guay et al. 2000) produces a parametric curve (a curve of a particular algebraic form, in this case 1/(1+exp(-P(substrate, velocity, depth))), where P is a polynomial) that may result in a less precise match to the underlying observations.

The kernel density approach used for this study is simply an implementation of the Bovee (1986) preference calculation method. The use of the kernel density estimation (versus an assessment using histograms) produces smooth curves instead of step functions, which is particularly helpful with small sample sizes (i.e., n<150).

4.1.2 Unlimited Depth Suitability

During the technical workgroup discussions of habitat suitability criteria, existing depth criteria for *O. mykiss* spawning and adults were selected that maintain maximum suitability to large or unlimited depths (Figures 16 and 19, respectively). Part of the reasoning behind these HSC is that, as a species that uses both riverine and lacustrine environments, *O. mykiss* are assumed to find any or most depths above some minimum to be suitable, as long as the velocities are sufficient. What is not known, or easily testable in the real world (because great depths with faster velocities rarely occur), is whether suitability is actually maximized at these greater depths, or whether deeper habitat is simply suitable at some lower index value.

In order to test the implications of this assumption, depth-limited criteria were applied to the *O. mykiss* adult and spawning life stages (and paired with existing velocity and substrate HSC, as applicable) to test whether a depth limitation substantively affected the WUA versus flow results. The depth-limited *O. mykiss* spawning HSC were from Bovee (1978), and adult depth HSC from an envelope curve drawn over a database from two dozen other studies (Appendix G, Figures 22 and 23).

The result of this comparison is presented in Figure 35. When depth limitations are applied, the spawning results for *O. mykiss* are significantly different, with a distinct WUA peak around 150 cfs (versus no distinct peak and maximum WUA at >350 cfs), a somewhat lower peak flow than observed for Chinook salmon spawning. Adult *O. mykiss* WUA peaks at 200-450 cfs versus >350 cfs without depth limitation.

These results suggest that if common depth limitations of alluvial rivers and the site-specific *O. mykiss* adult HSC data collected to date from the lower Tuolumne River are considered, the WUA versus flow relationship for the *O. mykiss* spawning and adult life stages are likely better represented by the results of this alternate analysis.

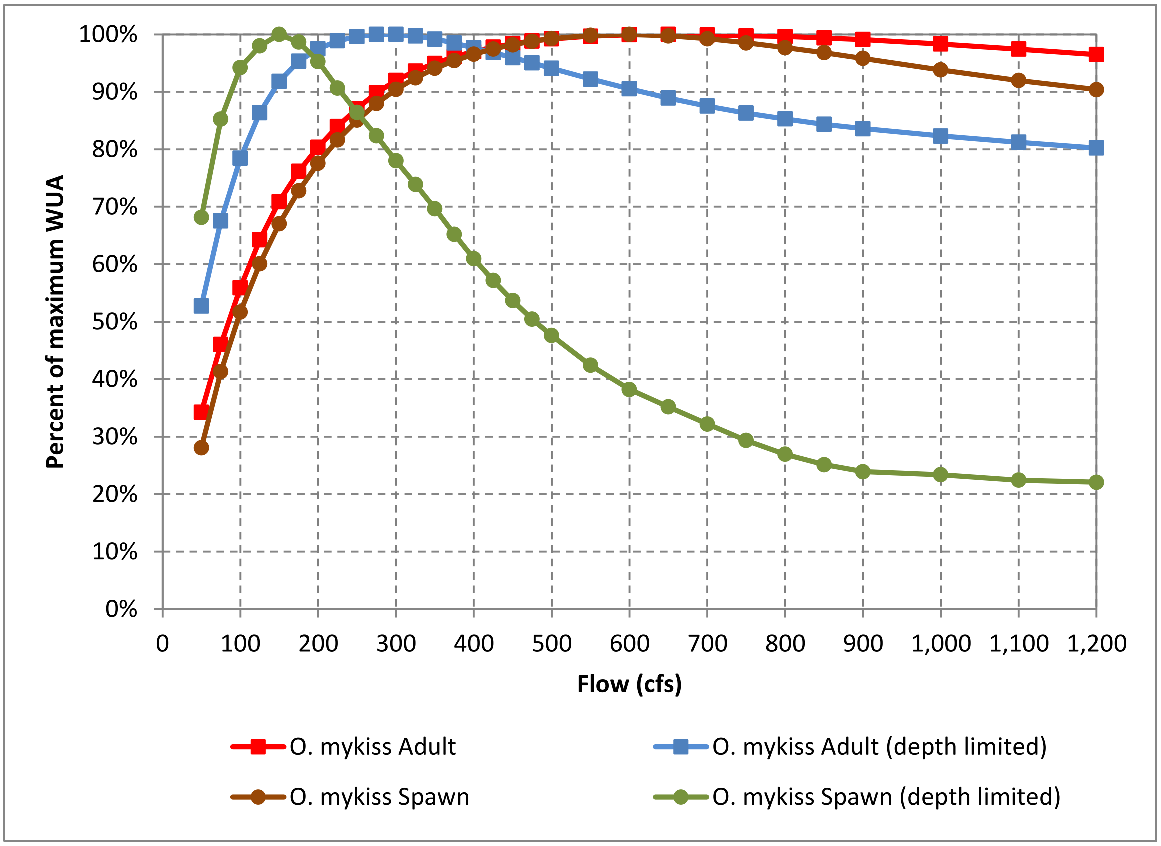

Figure 35. *O. mykiss* WUA results for the lower Tuolumne River using limited depth criteria.

4.1.3 Substrate and Cover Parameters

Both substrate (for spawning) and cover (for Chinook fry) parameters were included in the analysis. Use of a substrate parameter can sometimes give misleading results if the suitable substrate has a patchy distribution that is not well sampled with transect methods, leading to under-representation of available spawning substrate. To test for this scenario, the model was run with both substrate criteria and with "all substrates are suitable" criteria. The similarity of the results for Chinook salmon (Appendix H, Figure H-4) suggests that a lot of the sampled area with suitable hydraulic conditions for spawning also had suitable substrates; thus, the distribution of spawning gravels was not particularly patchy, and was well-sampled with transect methods. This is also consistent with the observations from other gravel mapping studies that document broad distribution of suitable Chinook spawning gravels in Tuolumne River riffle habitats (TID/MID 2013b). The larger disparity in results for *O. mykiss* spawning (Appendix H, Figure H-5) suggests that *O. mykiss* spawning gravels were less frequently encountered along the transects; however, the patchier distribution does not change the shape of the WUA versus flow relationship, but only its magnitude.

The importance of cover as a habitat parameter may vary considerably depending on the species, life stage, and river characteristics. In order to evaluate the effect of the cover parameter on the WUA results, the model was run both with and without cover for Chinook fry. The results presented in Appendix H (Figure H-3) suggest that cover has a relatively small influence in the magnitude of WUA, and no influence on the WUA versus flow relationship.

4.2 Comparison to Prior PHABSIM Study Results

Two prior instream flow studies of the lower Tuolumne River examined flow and habitat relationships for Chinook salmon and *O. mykiss*. Additionally, the current PHABSIM model was run using the same criteria included by USFWS in the 1995 study. Although the geographical extent, intensity of sampling, and habitat suitability criteria were different between the studies, a careful comparison of the results corroborates certain WUA versus flow relationships in the lower Tuolumne River (Table 17). See Appendix J for comparison graphics from these studies.

Results from all the studies indicate that WUA for the Chinook fry and juvenile is maximized at lower flows, with juveniles maintaining high habitat values up to around 300 cfs (Table 17). Similarly, there is agreement between the studies that Chinook salmon spawning WUA is maximized at flows between 175 and 400 cfs. There is more variation in the *O. mykiss* results; juvenile habitat is maximized in the 50-350 cfs range, and adult WUA is maximized in the 150-400 cfs range (Table 17 and Appendix J).

Although the current instream flow study is the most robust one to date, and uses current HSC, the results do not fundamentally conflict with those of prior studies.

Table 17. Lower Tuolumne River instream flow study result comparisons of maximum weighted usable area (WUA) results between 1981, 1995, and 2013.

Species/Life stage	TID/MID 2013	TID/MID 2013 (FWS 1995 HSC)[1]	FWS 1995[2]	CDFG 1981[3]
Chinook Fry	≤100 cfs	≤100 cfs	<75 cfs	40-280 cfs
Chinook Juvenile	50-300 cfs	50-400 cfs	75-225 cfs	80-340 cfs
Chinook Spawn	200-400 cfs	200-400 cfs	175-325 cfs	180-360 cfs
O. mykiss Fry	<125 cfs	--	--	--
O. mykiss Juvenile	50-350 cfs	100-300 cfs	50-170 cfs	40-140 cfs
O. mykiss Adult	>275 cfs	>200 cfs	50-425 cfs	140-280 cfs
O. mykiss Spawn	>225 cfs	--	--	--

[1] These results reflect the current PHABSIM model run with the HSC used in the FWS 1995 study.

[2] The USFWS 1995 study did not include *O. mykiss* fry and spawning criteria and limited the simulations for rainbow trout to 500 cfs, primarily as a means of evaluating summer conditions. Rainbow trout results were reported separately by habitat type only (i.e., riffle, run/glide, and pool) with significant habitat indicated as being primarily associated with riffle and run/glide types.

[3] The CDFG 1981 study simulated results to 600 cfs and did not include *O. mykiss* fry and spawning criteria. This study showed contrasting results for Chinook fry and juvenile between the two study reaches, with a 1991 reanalysis (TID/MID 1992b) documenting that the lower reach (Reach 2) results were disproportionally due to the influence of a single transect. As a consequence, only the results from Reach 1 are included above in order to maximize comparability of the data.

4.3 Effective Habitat

An "effective" habitat analysis was originally included in the study plan in order to examine the relationship between water temperature suitability and WUA.[6] The intent of the analysis was to

[6] "Effective Habitat" as discussed in Bovee (1982) often refers to an evaluation of habitat bottlenecks for particular life stages, and is applied as a type of population modeling exercise using habitat ratios. In this context, effective habitat is being used to refer to the moderating influence of water temperature on the WUA vs. flow relationship. For example, a longer reach of suitable temperature with a lower WUA value per unit length can have more "effective habitat" than a shorter reach with higher WUA. Since flow affects

better understand the tradeoffs between flow, WUA, and water temperature, since prior investigations and ongoing studies indicate that there may be an optimum balance between these parameters. For example, higher flows (presuming cold water releases) can push colder water temperatures further downstream, thereby increasing thermally suitable habitat area for salmonids. At the same time, WUA (which is largely based on hydraulics) for younger life stages typically decreases with higher flows, and can result in a net decrease in the combined hydraulic/thermal suitability of the habitat. Conversely, lower flows may provide higher WUA, but the combined hydraulic/thermal suitability can be compromised if the water temperature is unsuitable over too large a portion of the reach.

Study results to date provide the WUA information to pursue an effective habitat analysis. However, water temperature models of the lower Tuolumne River are currently being updated and reviewed for use in a variety of analyses. In order to use the most current temperature model (and a consistent one between studies) for the effective habitat analysis, further evaluations will be completed following the completion of the latest temperature model (relicensing Study W&AR-16). Completion of this analysis is anticipated by September 30, 2013, using the methods described in section 2.9.

4.4 Other Factors

Weighted usable area results are one consideration in the evaluation of factors affecting overall production of salmon and *O. mykiss* in the Tuolumne River. In addition to these results, numerous other factors such as geomorphic processes, water temperature, population dynamics, predation, spawning conditions, ocean harvest and other out-of-basin effects, and a variety of other factors affect fish and flow management options for the lower Tuolumne River. The most important in-river factors are the subject of detailed studies being conducted as part of the Don Pedro Project Relicensing process (TID/MID 2013a), which include:

- W&AR-4 Spawning Gravel Study
- W&AR-5 Salmonid Population Synthesis
- W&AR-6 Chinook Salmon Population Model
- W&AR-7 Predation Study
- W&AR-8 Salmonid Redd Mapping
- W&AR-10 *O. mykiss* Population Model
- W&AR-11 Chinook Salmon Otolith Study
- W&AR-12 *O. mykiss* Habitat Study
- W&AR-16 Temperature Model
- W&AR-20 *O. mykiss* Age Determination Study

These study results and other information will be used in developing recommendations for fish and flow management in the lower Tuolumne River as part of the relicensing process.

4.5 Next Steps

This report complies with requirements of the original July 16, 2009 FERC Order and subsequent directives to conduct a study "to determine instream flows necessary to maximize fall-run Chinook salmon (*Oncorhynchus tshawytscha*) and *O. mykiss* production and survival throughout their various life stages." The information provided herein can be used, along with other

both the WUA and temperature parameter suitability in opposing directions for some life stages, the effective habitat is moderated by the balance between these parameters.

information being developed as part of ongoing relicensing studies, to examine potential flow-related effects on these species and understand the implications of various flow regime management actions.

Observations during the conduct of this study, and results of prior studies, indicate that there are flow-related WUA and water temperature trade-offs at some times of the year for some life stages. This relationship will be examined as part of an effective habitat analysis described previously in section 4.3.

Additionally, FERC included an instream flow study requirement within the December 22, 2011 Relicensing Study Plan Determination, which expanded the scope of this study to include instream flow habitat relationships for Sacramento splittail and Pacific lamprey (if existing HSC are available). The results of that assessment, using HSC provided by the USFWS on April 8, 2013, are expected to be available by July 30, 2013.

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Appendices

Appendix A

Study Planning Workshop Summary
August 26, 2010

Lower Tuolumne River Instream Flow Study
Study Coordination Meeting #1 — NOTES
Thursday, August 26, 2010, 10 AM – 5 PM
Turlock Irrigation District
333 East Canal Drive, Room 152, Turlock, CA

Attendees:

Scott Wilcox (Stillwater)	Patrick Koepele (TRT)
Russ Liebig (Stillwater)	*Bob Hughes (CDFG) (Phone)*
Wayne Swaney (Stillwater)	Jenny O'Brien (CDFG)
Noah Hume (Stillwater)	Ramon Martin (USFWS)
Bill Johnston (MID)	Jennifer Vick (SFPUC)
Robert Nees (TID)	Jesse Raeder (TRT)
Ron Yoshiyama (CCSF-SF)	Jesse Roseman (TRT)
Allison Boucher (TRC) (phone)	Jarvis Caldwell (HDR|DTA)

[italicized names attended for part of the meeting]

Scott Wilcox provided a general overview of Instream Flow studies and some additional background on prior instream flow studies on the Tuolumne River.

The purpose of this meeting was to determine: (1) the study reach, and (2) habitat types to include in refined mapping for transect selection. Other objectives of the meeting included introducing the HSC curve possibilities and soliciting additional curves, if suitable, and reviewing potential pulse-flow study sites.

Study Area Segmentation:
Previously, MID/TID had recommended RM 34 as the lower extent of the study reach. CDFG had recommended RM 24 (below the in-channel mining reach). TID/MID provided a revised proposal for RM 29 near Waterford, or near the RST location (RM 29.5), based on: slope; channel configuration; dominant substrates; hydrology; biology; and flow-responsive habitat types. The group reviewed the channel characteristics below RM 34 and discussed where the most appropriate segment boundary may be.

DECISION:
The group decided to make the study reach between LaGrange Dam and RM 29. The group agreed to have one week to come back with comments on this decision. The group discussed using an existing hydraulic model at SRP9 (near RM 25.9) below RM 29, re-run with the current HSC, but the group postponed that decision

that until after we get into the field since it is not time critical for new data collection.

Habitat Mapping:
As a component of the study, the river needs to be re-delineated and the habitat types quantified. The river has already been mapped using different habitat mapping criteria. However, USFWS preferred a different set of habitat types, which FERC concurred with. The group discussed updating the current maps using the USFWS proposed mesohabitat types. The group preferred that side channels, though limited in the Lower Tuolumne, should be included in the mapping; however, they could be mapped as a component of a flatwater or bar-complex unit rather than a separate unit, since they would presumably occur off to the side of the main channel habitat unit.

DECISION:
Mapping will be based on two channel forms (flatwater and bar-complex) and 4 habitat types, as proposed by USFWS, with side channels as a subset of flatwater or bar complex (rather than its own channel form – e.g., bar complex, with side channel, pool). Run/glide habitat types may be lumped (resulting in 3 categories) following the field mapping if the mapping results show that one habitat would drop out of consideration based on frequency; this decision can be made after the mapping is complete. The group also noted that if there is representation of side channels, we will want to consider that channel characteristic during transect selection.

Transect Selection:
Transect selection will take place after the habitat mapping. There will be an office meeting prior to selection in the field. Dates for the meeting and field selection were discussed (listed below).

Habitat Suitability Criteria:
The group discussed Habitat Suitability Criteria (HSC), the proposed process, and the HSC development schedule. Curves will be required for: *O. mykiss* (adult, spawning, fry, and juvenile), and Chinook (spawning, fry, and juvenile). TID/MID initially proposed using existing curves. FERC ordered the use of existing curves and collection of some site-specific data. The proposed process relies on existing curves with additional field observations for validation.

Ramon Martin (USFWS) noted that they have steelhead curves for the Merced (recommended) and Lower American rivers that USFWS (or HDR|DTA) will provide.

The group reviewed cover types; Ramon Martin (USFWS) would like cover data collected.

The group reviewed substrate coding. Scott Wilcox reviewed an issue with the USFWS proposed substrate table (regarding overlapping categories and model complications). The group discussed the need to have something with "exclusive" categories. Jen Vick offered a more "standard" substrate classification (Wentworth scale) that she said she would e-mail to Scott. Bob Hughes (CDFG) suggested also doing a subdominant category in addition to the dominant substrate, and recommended the Bovee Code (Wentworth Scale as used on the Klamath).

DECISION:
HSC development is expected to take a considerable amount of time and the group did not select curves to be used during this meeting. It was requested that any curves that participants would like to have included for consideration (that are not currently included) should be sent to Scott Wilcox for discussion during the HSC development meetings.

The study will collect cover information using codes listed in Table 7a (see *Cover Codes* handout). If the group has any alternative cover type recommendations than those presented, they need to get it to Scott Wilcox within a week.

The group proposed to use the Wentworth Scale (for substrates) and split the Wentworth small cobble scale into two groups (3-4.5" and 4.5-6", per request of Allison Boucher). Any objections should be presented within the next week. Subject to confirmation, this scale is presented below.

Modified Wentworth Scale (adapted for the Tuolumne River)	
Description	**Size (inches)**
Organic	N/A
Silt	<0.1
Sand	0.1 – 0.2
Small Gravel	0.2 - 1.0
Medium Gravel	1 - 2
Large Gravel	2 - 3
Very Small Cobble	3 – 4.5
Small Cobble	4.5 – 6
Medium Cobble	6 – 9
Large Cobble	9 – 12
Boulder	>12
Bedrock	N/A

Pulse Flow Assessment Study Sites:

Noah Hume discussed the proposed Pulse Flow Study site locations (see *Pulse Flow Assessments* handout). The group identified 9 possibilities (5 were viewed as preferred [bolded]):

RM 49
RM 48.5
RM 44.5 broad floodplain with a side channel
RM 45.5 broad floodplain with a side channel
RM 43.5 (Bobcat restoration site) currently floods at 3,800, but will flood at 3,000 after summer 2011.
RM 37.8-38.3 (not a great option)
RM 34 closer to what a majority of the river looks like (riffle 46)
RM 26 restoration site
RM 5 (Big bend), no LIDAR

These sites will be visited and site-specific ground truthing information provided to the group.

There was also interest in the temperature study and combining the two studies (i.e., temperature monitors at the 2D sites).

Upcoming meeting dates:

Habitat Mapping Refinement Float Trip week of September 13 (3 days)
Site Selection Meeting, October 5, 2010
Site Selection in Field, October 6-7, and 8th if needed.
HSC development 1st meeting, September 20 in Davis.

Appendix B

IFIM Study Site Selection and Transect Placement Workshop Summaries
October 5 and November 18–19, 2010

Lower Tuolumne River Instream Flow Study
Site Selection Meeting Summary
Tuesday, October 5, 2010, 10 AM – 3 PM
Turlock Irrigation District
333 East Canal Drive, Room 152, Turlock, CA

Attendees:

Scott Wilcox (Stillwater)	Allison Boucher (TRC)
Russ Liebig (Stillwater)	Alison Willy (USFWS)
Wayne Swaney (Stillwater)	Bob Hughes (CDFG)
Noah Hume (Stillwater)	Jenny O'Brien (CDFG)
Robert Nees (TID)	Mark Gard (USFWS) phone

[italicized names attended for part of the meeting]

Scott Wilcox suggested an agenda and provided a general overview of the recent mesohabitat mapping results.

Target Habitat Types

The river was recently re-mapped using the new mesohabitat types recommended by USFWS. The habitat mapping results include percent occurrence (by length) of the various habitat types (see Attachment 1).

During the discussion of which habitat types to include in the model, the group discussed the minimum percent occurrence needed. Generally, the goal was to include habitat types with >10% occurrence, per the FERC-approved study plan. Mark Gard suggested a >5% occurrence with a lower number of transects in rare habitats (i.e., include habitat types down to 5% occurrence, but do not allocate as many transects to them).

Decision:

The group decided to sample habitat types with a minimum of 5% percent occurrence, but with a reduced number of replicates/transects for those less than 10%. This resulted in an initial selection of 13-15 replicate units (based on groupings listed below). The group also decided that it is desirable, where reasonably efficient, to divide transects allocated to a "single replicate" habitat type between two different units in order to encourage more heterogeneity in sampling (e.g., if only one Glide unit was to be sampled, try to divide the transects between two different Glide units if practical).

Glide (lumped between Bar Complex and Flatwater): 1 Replicate unit
Bar Complex Pool: 1 Replicate unit (e.g., 2 transects, one in middle, one in tail)

Bar Complex Riffle:	3 Replicate units (prioritize spawning riffles)
Bar Complex Run:	3 Replicate units
Flatwater Pool:	2 Replicate units
Flatwater Riffle:	1 Replicate unit (prioritize spawning riffles)
Flatwater Run:	3 Replicate units

Side Channel habitat (lumped between Bar Complex and Flatwater) included 2.9% occurrence and was therefore not included as a separate habitat type.

Proposed Habitat Units

The group discussed distributing the selected habitat units selected into four river sections based on the spawning survey data delineations, in order to spread the sites along the length of the study reach and encourage better representation of the entire reach:

Section 1: units 1-39
Section 2: units 40-106
Section 3: units 107-193
Section 4: units >193

Based on the 14 replicate units being targeted, and grouping of 3-5 units per "site", approximately 4-5 sites were anticipated.

Initial habitat units for each site were randomly selected by targeting either (1) key spawning riffles, or (2) other limited habitat unit types (e.g., bar complex spawning riffle) and then selecting contiguous habitat units upstream or downstream from that habitat unit until the desired number (~3 or more) and type of units for that river section were obtained. Units were typically contiguous unless an intervening unit was (1) not required for sampling and therefore skipped, or (2) exceptionally long and therefore effectively acted as a "boundary" to the local collection of transects.

"Backup" units were selected near the randomly selected sites (and were not required to be contiguous) in order to provide more options during field transect selection, in the event that an originally selected random unit was less acceptable for some reason (access, hydraulics, logistics, habitat characteristics, etc.). However, it was understood that during field transect selection the backup units and initially selected units would be equally acceptable, and the group would place transects (as appropriate) in whichever unit was reviewed first (to avoid backtracking).

"Extra" units were selected as candidates for transects for those habitat unit types that are only targeted for one replicate. Transects would be divided between the originally selected unit and the "extra" unit.

Decision:

Selected habitat unit replicates for the Lower Tuolumne River IFIM Study

Habitat Type*	No. of replicates	Units[1]	Backup	Transects/notes
Glide	1	**29**, 202[e]	24, 205	Possibly split transects between two units
BC Pool	1	**155**[e], **163**	92, 145	Possibly split transects between two units
BC Riffle	3	**25**, **81**, **160**	91, **162**	
BC Run	3	**26**, **85**, **161**	**83**	
FW Pool	2	**86, 196**	22, 225	Unit 22 was moved to a backup when the number of replicates was reduced from 3 to 2.
FW Riffle	1	**30**, 227[e]	197	Possibly split transects between two units
FW Run	3	**28**, **82**, **84**	198	Unit 82-potential overbank issues

* BC = Bar Complex, FW = Flatwater

[1] **Bold** signifies the randomly selected unit and adjacent contiguous units.

[e] Extra unit, which may be used to split transects between two replicates.

Habitat unit groupings for IFIM sites on the Lower Tuolumne River.

Site	Units		Backup	Section.
1	25-30	25-BC riffle; 26-BC run; 28-FW run; 29-glide; 30-FW riffle	22-FW pool; 24-glide	1
2	81-86	81-BC riffle; 82-FW run; 83-BC run; 84-FW run; 85-BC run; 86-FW pool	91-BC riffle; 92- BC pool	2
3	155[e], 160-163	155[e]-BC pool; 160-BC riffle; 161-BC run; 163-BC pool	145-BC pool; 162-BC riffle	3
4	196, 202[e]	196-FW pool; 202[e]-BC glide	197 FW riffle; 198-FW run; 205-BC glide	4
5	227[e]	227[e]-FW riffle	225-FW pool	4

[e] Extra unit, which may be used to split transects between two replicates.

<u>Transect Selection</u>
Site selection in field: Nov 17-18, 2010

<u>Action Items</u>
Wayne to make mapbook files available on the TRTAC website.
Russ to make meeting materials available as an attachment to this meeting summary.

Appendix B-1

Attachment 1

IFIM Study Site Selection Workshop Summary – October 5, 2010

Mesohabitat Mapping Data and Summary

Tuolumne River 2010 mesohabitat mapping summary

Chanel Form	Habitat	Count	Length (ft)	Percent
Bar Complex	Glide	8	2,085	1.73
Bar Complex	Pool	18	9,607	7.96
Bar Complex	Riffle	60	21480	17.80
Bar Complex	Run	40	24045	19.93
Flatwater	Glide	14	3,390	2.81
Flatwater	Pool	19	20,190	16.73
Flatwater	Riffle	17	6,660	5.52
Flatwater	Run	35	33,205	27.52
		211	120,662	100.00

MESOHABITAT	%
Pool	24.69
Riffle	23.32
Run/Glide	51.98
	100.00

Side channels with 20% of flow at 300 cfs

Chanel Form	Habitat	Count	Length (ft)	% SC
Side Channel	n/a	10	3490	2.9%

Mesohabitats mapped for IFIM									
RM	**ID**	**CHFORM**	**HABITAT**	**Length**	**Access**	**Group**	**Suggested**	**Notes**	**Reference**
51.68	1	Flatwater	Pool	610	poor	n/a		steep descent from powerhouse	
51.59	2	Flatwater	Pool	475	TID	A		split channel tail	
51.47	4	Flatwater	Riffle	660	TID	A			
51.05	5	Flatwater	Run	2225	TID	A			
50.96	6	Flatwater	Pool	450	TID	B	yes		
50.80	7	Flatwater	Run	850	TID	B	yes		
50.78	8	Flatwater	Glide	105	TID	B	"		
50.65	11	Flatwater	Riffle	710	TID	B	yes		snorkel RA7
50.49	12	Flatwater	Pool	855	TID	B			
50.44	13	Bar Complex	Glide	220	TID	B			
50.28	14	Bar Complex	Riffle	840	TID	B			
50.24	16	Bar Complex	Pool	230	TID	C	yes		
50.11	17	Bar Complex	Run	700	TID	C	yes		
50.07	18	Bar Complex	Riffle	230	TID	C	yes		
49.87	19	Bar Complex	Run	1005	TID	D			
49.82	20	Flatwater	Glide	285	TID	D			
49.71	21	Flatwater	Riffle	560	TID	D	yes		snorkel R2
49.64	22	Flatwater	Pool	410	TID	D	yes	Backup unit	
49.37	23	Flatwater	Run	1410	TID	D			
49.34	24	Flatwater	Glide	165	TID	D		Backup unit	
49.22	25	Bar Complex	Riffle	645	TID	E	yes	Selected	
49.16	26	Bar Complex	Run	320	TID	E	yes	Selected	snorkel R3B
49.12	27	Flatwater	Riffle	165	TID	F	yes		
49.10	28	Flatwater	Run	145	TID	F	yes	Selected	
49.07	29	Flatwater	Glide	120	TID	F	"	Selected	
48.87	**30**	**Flatwater**	**Riffle**	**1085**	**TID**	**G**		**Randomly Selected**	**R4A**
48.75	31	Flatwater	Run	625	TID	G	yes		
48.71	32	Flatwater	Glide	215	TID	G	"		
48.45	33	Flatwater	Riffle	1360	TID	H			R4B
48.33	34	Flatwater	Run	670	TID	H			
48.25	35	Flatwater	Glide	405	TID	H			
48.18	36	Bar Complex	Riffle	340	TID	H	yes		snorkel R5A
48.08	37	Bar Complex	Pool	530	TID	H	yes		
48.04	38	Bar Complex	Riffle	215	TID	H			R5B
47.31	39	Flatwater	Pool	3895	TID	H		long pool above/below Basso	
47.22	40	Flatwater	Glide	445	poor	n/a			
46.94	41	Bar Complex	Riffle	1490	poor	n/a			snorkel R7
46.88	43	Flatwater	Riffle	320	poor	n/a			
46.83	44	Flatwater	Run	260	poor	n/a			
46.81	45	Flatwater	Glide	120	poor	n/a			
46.76	46	Flatwater	Riffle	260	poor	n/a			
46.00	48	Flatwater	Run	4025	poor	n/a			
45.98	52	Bar Complex	Riffle	95	Zanker	n/a		complex channel, poor transects	
45.95	53	Bar Complex	Riffle	165	Zanker	n/a		complex channel, poor transects	
45.88	54	Bar Complex	Riffle	360	Zanker	n/a		complex channel, poor transects	
45.83	55	Bar Complex	Run	240	Zanker	n/a		complex channel, poor transects	
45.82	56	Flatwater	Riffle	40	Zanker	n/a		complex channel, poor transects	
45.76	57	Bar Complex	Riffle	330	Zanker	n/a		complex channel, poor transects	
45.71	58	Bar Complex	Run	285	Zanker	n/a		complex channel, poor transects	
45.68	59	Bar Complex	Riffle	135	Zanker	n/a		complex channel, poor transects	snorkel Zanker
45.65	60	Bar Complex	Run	160	Zanker	I			
45.59	61	Bar Complex	Riffle	310	Zanker	I	yes		
45.38	62	Flatwater	Run	1115	Zanker	I			
45.32	66	Flatwater	Pool	310	Zanker	I	yes	pool at Peaslee Creek confluence	
45.14	67	Flatwater	Run	970	poor	n/a			
45.06	69	Flatwater	Pool	420	poor	n/a			
44.99	70	Bar Complex	Riffle	385	poor	n/a			
44.94	71	Bar Complex	Pool	235	poor	n/a			

RM	ID	CHFORM	HABITAT	Length	Access	Group	Suggested	Notes	Reference
44.81	72	Bar Complex	Riffle	710	poor	n/a			
44.74	74	Bar Complex	Run	350	poor	n/a			
44.71	75	Bar Complex	Riffle	150	poor	n/a			
44.69	76	Bar Complex	Run	150	poor	n/a			
44.66	77	Bar Complex	Pool	130	poor	n/a			
44.62	78	Bar Complex	Run	225	poor	n/a			
44.58	79	Bar Complex	Riffle	190	poor	n/a			
44.54	80	Bar Complex	Run	240	poor	n/a			
44.45	81	Bar Complex	Riffle	470	poor	n/a		Selected	
44.36	82	Flatwater	Run	450	poor	n/a		Selected	
44.27	83	Bar Complex	Run	500	poor	n/a		Selected	
44.02	84	Flatwater	Run	1320	poor	n/a		Selected	
43.91	85	Bar Complex	Run	545	poor	n/a		Selected	
43.71	**86**	**Flatwater**	**Pool**	**1055**	**poor**	**n/a**		**Randomly Selected**	
43.51	87	Flatwater	Pool	1075	poor	n/a			
43.30	88	Bar Complex	Run	1140	poor	n/a			
43.23	89	Bar Complex	Riffle	335	poor	n/a			
43.05	90	Bar Complex	Run	965	Bobcat	G	yes		
43.00	91	Bar Complex	Riffle	240	Bobcat	G	yes	Backup unit	snorkel R21
42.96	92	Bar Complex	Pool	245	Bobcat	G	yes	Backup unit	
42.89	93	Bar Complex	Run	360	Bobcat	G	yes		
42.87	94	Bar Complex	Riffle	120	Bobcat	G			
42.68	95	Flatwater	Run	975	Bobcat	G	yes		
42.66	96	Bar Complex	Riffle	120	Bobcat	G			
42.40	97	Flatwater	Run	1360	TRR	H		currently no access, but potential	
42.35	98	Flatwater	Glide	275	TRR	H		currently no access, but potential	
42.31	99	Bar Complex	Riffle	215	TRR	n/a		side channel area, poor transects	snorkel TRR
42.29	101	Bar Complex	Run	100	TRR	n/a		side channel area, poor transects	
42.24	102	Bar Complex	Riffle	265	TRR	n/a		side channel area, poor transects	
42.19	103	Flatwater	Run	285	TRR	n/a		side channel area, poor transects	
42.15	104	Flatwater	Riffle	205	TRR	I		currently no access, but potential	
42.06	105	Flatwater	Run	455	TRR	I		currently no access, but potential	
42.02	106	Flatwater	Glide	205	TRR	I		currently no access, but potential	
41.92	107	Bar Complex	Riffle	560	TLSRA	J	yes		
41.74	108	Bar Complex	Run	935	TLSRA	J	yes		
41.67	109	Bar Complex	Riffle	360	TLSRA	J	yes		
41.43	110	Flatwater	Run	1255	poor	n/a			
41.17	111	Bar Complex	Pool	1410	poor	n/a			
41.10	113	Bar Complex	Glide	340	poor	n/a			
40.99	114	Bar Complex	Run	565	poor	n/a			
40.95	115	Bar Complex	Glide	250	poor	n/a			
40.90	116	Bar Complex	Riffle	260	poor	n/a			
40.40	118	Bar Complex	Run	2625	poor	n/a			
40.16	120	Bar Complex	Riffle	1265	poor	n/a			
39.86	121	Flatwater	Run	1605	poor	n/a			
39.77	122	Flatwater	Glide	475	poor	n/a			
39.67	123	Flatwater	Run	505	poor	n/a			
39.61	124	Bar Complex	Riffle	305	poor	n/a			
39.43	125	Bar Complex	Run	945	7/11	K	yes		
39.42	285	Bar Complex	Riffle	85	7/11	K			
39.26	286	Bar Complex	Run	825	7/11	L	yes		
39.20	126	Bar Complex	Riffle	350	7/11	L	yes		
38.89	127	Bar Complex	Pool	1607	7/11	L			
38.86	128	Flatwater	Riffle	170	7/11	L	yes		
38.77	129	Flatwater	Run	485	7/11	L	yes		
38.73	130	Flatwater	Pool	215	7/11	L	yes		
38.65	131	Flatwater	Run	415	7/11	M	yes		
38.63	132	Flatwater	Riffle	75	7/11	M			
38.58	133	Flatwater	Pool	265	7/11	M	yes		

RM	ID	CHFORM	HABITAT	Length	Access	Group	Suggested	Notes	Reference
38.55	134	Bar Complex	Glide	200	7/11	M	"		
38.47	135	Bar Complex	Riffle	400	7/11	M	yes		
38.33	137	Bar Complex	Run	740	7/11	M	yes		
38.26	138	Bar Complex	Pool	380	7/11	M	yes		
38.18	139	Bar Complex	Run	395	7/11	M			
38.12	140	Bar Complex	Riffle	310	7/11	N			snorkel 7/11
38.05	141	Bar Complex	Pool	415	7/11	N	yes		
37.93	142	Bar Complex	Pool	610	7/11	N	yes		
37.87	143	Bar Complex	Run	320	7/11	N	yes		
37.81	144	Bar Complex	Riffle	305	7/11	N	yes		
37.58	145	Bar Complex	Pool	1240	Sante Fe	O		Backup unit	
37.55	146	Bar Complex	Riffle	140	Sante Fe	O			
37.39	147	Flatwater	Run	850	Sante Fe	O	yes		
37.31	148	Bar Complex	Riffle	420	Sante Fe	P			
37.17	149	Bar Complex	Run	730	Sante Fe	P			
37.01	151	Bar Complex	Run	850	Sante Fe	P			
36.97	152	Bar Complex	Riffle	235	Sante Fe	P		Pit/Pool	snorkel Ruddy
36.91	154	Bar Complex	Pool	295	Sante Fe	n/a		Pit/Pool	
36.86	**155**	**Bar Complex**	**Pool**	**280**	**Sante Fe**	**Q**		**Randomly Selected Extra Unit**	
36.79	156	Bar Complex	Riffle	340	Sante Fe	Q			
36.62	157	Flatwater	Run	895	Sante Fe	Q	yes		
36.59	158	Bar Complex	Riffle	185	Sante Fe	R			
36.33	159	Flatwater	Run	1345	Sante Fe	R			
36.29	**160**	**Bar Complex**	**Riffle**	**225**	**Sante Fe**	**R**		**Randomly Selected**	
36.23	161	Bar Complex	Run	335	Sante Fe	R	yes	Selected	
36.18	162	Bar Complex	Riffle	235	Sante Fe	R	yes	Backup unit	
36.13	163	Bar Complex	Pool	280	Sante Fe	R	yes	Selected	
35.58	164	Flatwater	Pool	2885	Sante Fe	S	yes		
35.52	165	Flatwater	Riffle	350	Sante Fe	S	yes		
35.17	166	Flatwater	Run	1810	Sante Fe	S			
35.16	167	Bar Complex	Riffle	80	Deardorff	n/a		complex channel, poor transects	snorkel Deardorff
35.12	169	Bar Complex	Pool	195	Deardorff	n/a		complex channel, poor transects	
35.03	170	Bar Complex	Riffle	495	Deardorff	T			
34.96	171	Bar Complex	Run	365	Deardorff	T		good Q	
34.93	172	Bar Complex	Riffle	180	Deardorff	T			
34.66	173	Bar Complex	Run	1400	poor	n/a			
34.57	174	Flatwater	Pool	475	poor	n/a			
34.52	175	Bar Complex	Riffle	290	poor	n/a			
34.48	176	Bar Complex	Pool	190	poor	n/a			
34.42	177	Bar Complex	Run	320	poor	n/a			
34.37	178	Bar Complex	Glide	235	poor	n/a			
34.30	179	Bar Complex	Run	410	poor	n/a			
34.19	180	Bar Complex	Glide	575	poor	n/a			
34.07	181	Bar Complex	Run	640	poor	n/a			
34.00	182	Bar Complex	Riffle	345	poor	n/a			
33.91	183	Flatwater	Run	480	poor	n/a			
33.82	185	Bar Complex	Riffle	500	poor	n/a			
33.75	186	Bar Complex	Run	340	poor	n/a			
33.65	187	Bar Complex	Riffle	550	poor	n/a			
33.47	188	Flatwater	Run	945	poor	n/a			
33.43	189	Flatwater	Glide	225	poor	n/a			
33.39	190	Bar Complex	Riffle	165	poor	n/a			
33.20	191	Bar Complex	Pool	1045	poor	n/a			
33.16	192	Bar Complex	Riffle	180	poor	n/a			
33.05	193	Bar Complex	Run	590	poor	n/a			
32.96	194	Bar Complex	Riffle	460	poor	n/a			
32.46	195	Flatwater	Pool	2635	poor	n/a			
32.09	196	Flatwater	Pool	1990	poor	n/a		**Randomly Selected**	Hickman spill
32.03	197	Flatwater	Riffle	295	poor	n/a		Backup unit	

RM	ID	CHFORM	HABITAT	Length	Access	Group	Suggested	Notes	Reference
31.93	198	Flatwater	Run	550	poor	n/a		Backup unit	
31.88	200	Bar Complex	Riffle	225	poor	n/a			
31.69	201	Bar Complex	Run	1045	poor	n/a			
31.67	202	Bar Complex	Glide	110	poor	n/a		**Randomly Selected Extra Unit**	
31.63	203	Bar Complex	Riffle	180	poor	n/a			
31.51	204	Bar Complex	Run	620	poor	n/a			
31.49	205	Bar Complex	Glide	155	poor	n/a		Backup unit	
31.40	206	Bar Complex	Riffle	440	poor	n/a			
31.27	208	Flatwater	Run	720	poor	n/a			
31.15	209	Bar Complex	Riffle	605	Waterford	U			
31.10	210	Bar Complex	Pool	290	Waterford	U			Hickman Bridge
31.06	211	Bar Complex	Riffle	205	Waterford	U			snorkel Hickman
30.68	212	Flatwater	Run	1985	Waterford	U		partial access to u/s portion	
30.64	213	Flatwater	Glide	200	poor	n/a			
30.60	214	Flatwater	Riffle	230	poor	n/a			
30.47	215	Flatwater	Run	675	poor	n/a			
30.41	216	Bar Complex	Riffle	320	poor	n/a			
30.36	217	Bar Complex	Run	265	poor	n/a			
30.18	219	Bar Complex	Riffle	935	poor	n/a		extreme turbulence	
30.10	220	Bar Complex	Run	435	poor	n/a			
30.05	221	Bar Complex	Riffle	270	poor	n/a			
29.92	223	Flatwater	Pool	665	poor	n/a			
29.83	224	Flatwater	Run	485	poor	n/a			
29.72	225	Flatwater	Pool	610	poor	n/a		Backup unit	
29.55	226	Flatwater	Pool	895	poor	n/a			
29.53	227	Flatwater	Riffle	105	poor	n/a		Extra Unit	
29.46	228	Flatwater	Run	345	poor	n/a			
29.45	229	Flatwater	Riffle	70	poor	n/a			
29.37	230	Flatwater	Run	395	poor	n/a			
29.35	231	Flatwater	Glide	150	poor	n/a			
29.29	233	Flatwater	Run	320	poor	n/a			
29.20	234	Bar Complex	Run	460	Short	V	yes		
29.15	235	Bar Complex	Riffle	240	Short	V	yes		
29.04	236	Bar Complex	Run	605	Short	V	yes		RST
28.95	237	Bar Complex	Riffle	480	Short	V	yes		
28.95	238	ds_Flatwater	ds_Run		poor	n/a			downstream SRP

Lower Tuolumne River Instream Flow Study
Transect Placement Field Summary
Thursday–Friday, November 18–19, 2010

Participants:

Scott Wilcox (Stillwater)	Allison Boucher (TRC)
Russ Liebig (Stillwater)	Zac Jackson (USFWS)
Ken Jarrett (Stillwater)	Bob Hughes (CDFG)

The group met in Waterford on Thursday, November 18, for a tailgate session prior to heading out to the river. Scott Wilcox reviewed the site selection process and results of the October 5, 2010 office-based site selection workshop in Turlock, which included: 14 selected mesohabitat units; 3 extra units (intended for splitting of transects into multiple units where only one replicate was required); and 11 backup units. Russ Liebig reviewed the results of a reconnaissance survey of each habitat unit including: (1) general representativeness of habitat within the Lower Tuolumne River, (2) complexities that may limit modeling accuracy, and (3) physical accessibility. The reconnaissance survey of each habitat unit found that 13 of the 14 selected habitats were suitable for the study (i.e., representative, accessible, and modelable). The one selected unit that did not meet these criteria was restricted by limited access; however one backup unit had already been identified during the October 5 meeting as an appropriate alternative for that unit. In addition, two of the extra units and six of the backup units were found to be suitable in the event they were needed.

The Districts were able to secure vehicle access to each of the habitat units for transect placement, though complete access (e.g., both sides of the river) required to conduct the field study has not yet been obtained. The group visited each selected habitat unit for transect placement as well as suitable extra and backup units. During the process, the group eliminated one additional selected unit (Riffle #81) and included seven extra or backup units (including one added in the field [Run #83] not previously identified during the October 5 workshop).

At each habitat unit, agency representatives designated transect locations (or concurred with proposed transect locations suggested by Stillwater staff) sufficient to represent the hydraulic and habitat variability in the unit. A total of 40 transects were placed in 19 habitat units between River Mile 29.7 and 49.3. Participating agency representatives confirmed the locations as described in a draft version of this summary (Attachment 1).

Transect locations are described in Table 1 and shown in Attachment 2.

Table 1. Tuolumne River Instream Flow Study Transect Location Documentation

Channel Form	Unit Type	Unit & Transect Letter[1]	Tile Number[2]	Transect Characteristics	Location/Notes
Flatwater	Glide	24A	6	Deeper, slower	Approx. 110 ft upstream of riffle break at Unit 25
Flatwater	Glide	24B	6	Faster, shallower	Approx. 45 ft upstream of riffle break at Unit 25
Bar Complex	Riffle	25A	6	Faster, steeper	Approx. 100 ft from the top of bar complex
Bar Complex	Riffle	25B	6	Slower, flatter	Top of point bar on RR[3]; Approx. 100 ft downstream of mid-channel island on RL
Bar Complex	Run	26A	6	Head of run, more turbulent	Point bar on RR, approx. 50-75 ft downstream of Riffle 25
Bar Complex	Run	26B	6	Mid-run, less turbulent	Point bar on RR, large oak on RL, approx. 150 ft upstream of Riffle 27
Flatwater	Run	28A	7	More turbulent, faster, deeper	Approx. 100 ft downstream of Riffle 27; opening in the brush on RR
Flatwater	Run	28B	7	Flatter, less turbulent	Approx. 100 ft downstream of transect 28A
Flatwater	Glide	29A	7	Mid-glide, uniform	Supplements transects in selected glide 24
Flatwater	Riffle	30A	7	More varied hydraulic conditions	Approx. 50 ft from the top of unit; point bar on RR, over large woody debris on RL
Flatwater	Riffle	30B	7	More uniform conditions, faster	Approx. 40 ft downstream of RR bar
Flatwater	Run	82A	16		Off RR point just downstream of turn out of Riffle; complex flow and cover on RL
Flatwater	Run	82B	16		Downstream side of island with backwater on RR, between trees on RL
Flatwater	Run	82C	16	Faster, more cobble, than transects A & B	Off top of point bar on RR
Bar Complex	Run	83A	16	Narrow, fast	Backup provisional unit in case downstream selected Runs are less suitable. Subsequently decided to sample all of them because of different conditions in Run 83
Bar	Run	83B	16	Flatter, more	Downstream of 83A approx.

[1] Unit numbers from Tuolumne River Mapbook – IFIM Mesohabitats, 2010. Transects lettered from upstream to downstream within a unit.
[2] Tuolumne River Mapbook – IFIM Mesohabitats, 2010
[3] RR (river right) and RL (river left), defined as looking downstream

Channel Form	Unit Type	Unit & Transect Letter[1]	Tile Number[2]	Transect Characteristics	Location/Notes
Complex				laminar	100 ft
Flatwater	Run	84A	16/17	Faster portion of the run	Near fence gate at "boat launch" location
Flatwater	Run	84B	16/17	Flatter, slower portion of run	At valley oak RR, bedrock edge face RL
Flatwater	Run	84C	16/17	Pool-like portion, low velocity	Approx. 200 ft downstream of 84B
Bar Complex	Run	85A	17	Fast, shallow	Sample as extra run cross section due to cobble substrate; off of bar on RR
Flatwater	Pool	86A	17	Some higher velocity	Head of very large pool near corral
Flatwater	Pool	86B	17	Slow velocity in middle of pool	At gate access approx. 500 ft downstream of 86A; all middle of pool is approx. the same
Flatwater	Pool	86C	17	Shallower tail at bottom of pool	Marshy bar on RL; 350-400 ft downstream of picnic bench area on RL
Bar Complex	Pool	155A	31	Swifter section	Extra pool; transect at head
Bar Complex	Pool	155B	31	Shallow, slow	Extra pool; at tail; will get the mid pool conditions at downstream pools
Bar Complex	Riffle	156A	32	Across island at the top of the riffle	Would be good to add if units 160 & 162 don't work as bar complex riffles. The group subsequently decided to add unit 156 & only put 1 transect in unit 162.
Bar Complex	Riffle	156B	32	Between islands in middle of the riffle	
Bar Complex	Riffle	160A	33	At head with faster thalweg	Approx. 40 ft downstream of gravel conveyor
Bar Complex	Riffle	160B	33	Near tail in more uniform cross section	Approx. 100 ft downstream of 160A
Bar Complex	Run	161A	33	Head of run is faster	Open on RR bank
Bar Complex	Run	161B	33	Flatter, more uniform; slower at tail of run	
Bar Complex	Riffle	162A	33	Wide, shallow cross section	Above a transverse flow split & the backwater, at the downstream end of the left bank bar. Use Riffle 156 for two additional transects
Bar Complex	Pool	163A	33	Faster outflow from riffle	Head of Pool

Channel Form	Unit Type	Unit & Transect Letter[1]	Tile Number[2]	Transect Characteristics	Location/Notes
Bar Complex	Pool	163B	33	Mid Pool same as for 163A	Left bank end pin crosses 163C due to angle of the river at the bend
Bar Complex	Pool	163C	33	Shallower tail	Approx. 100 ft downstream of 163B tail; Right bank is directly below oak , then is first oak upstream of ravine on right bank. All pool cross sections are very wide (>300 ft)
Bar Complex	Glide	205A	42	Upstream end of glide	30 ft upstream of greenbelt bench at base of valley oak; work from left bank. Next to Waterford gated subdivision on RR.
Bar Complex	Glide	205B	42	Downstream end of glide, similar habitat	Above large woody debris on right bank; 1 tree downstream of 205A, at black walnut
Flatwater	Pool	225A	46	Upstream end	Cross section is at divider between upstream run; Right bank is open cobble bar
Flatwater	Pool	225B	46	Slow, deep, wide cross section	Approx. 200 ft downstream of 225A, in middle of unit; left bank campfire is near cross section, and open grassy area is on right bank
Flatwater	Pool	225C	46	Narrower tail	Approx. 200 ft from downstream end of unit. Thick brush on both sides.

Appendix B-2

Attachment 1

IFIM Transect Placement Field Summary
November 18-19

Resource Agency and Stakeholder
Concurrence on Transect Selection Summary

Lower Tuolumne River Instream Flow Study
Resource Agency and Stakeholder Concurrence of Transect Selection Summary

From: Bob Hughes (CDFG)
Sent via e-mail: Wednesday, January 05, 2011

The Department of Fish and Game concurs with the number and location of transects, as specified in the field trip summary and associated maps. Please let me know if there are any questions.

Robert W. Hughes, P.E.
Senior Hydraulic Engineer
California Department of Fish and Game
Office Phone: (916) 445-3362
Mobile Phone: (916) 591-2016

From: Zachary Jackson (USFWS)
Sent via e-mail: Thursday, January 06, 2011

I concur with the number of transects and locations.

Zac Jackson
Fish Biologist
Anadromous Fish Restoration Program
United States Fish and Wildlife Service
4001 N. Wilson Way
Stockton, CA 95205
Tel (209) 334-2968 x 408
Cell (209) 403-1457
Fax (209) 334-2171
Zachary_Jackson@fws.gov

From: Allison Boucher (Tuolumne River Conservancy)
Sent via e-mail: Thursday, January 06, 2011

We concur with the number and location of transects.

Allison Boucher
Tuolumne River Conservancy, Inc.

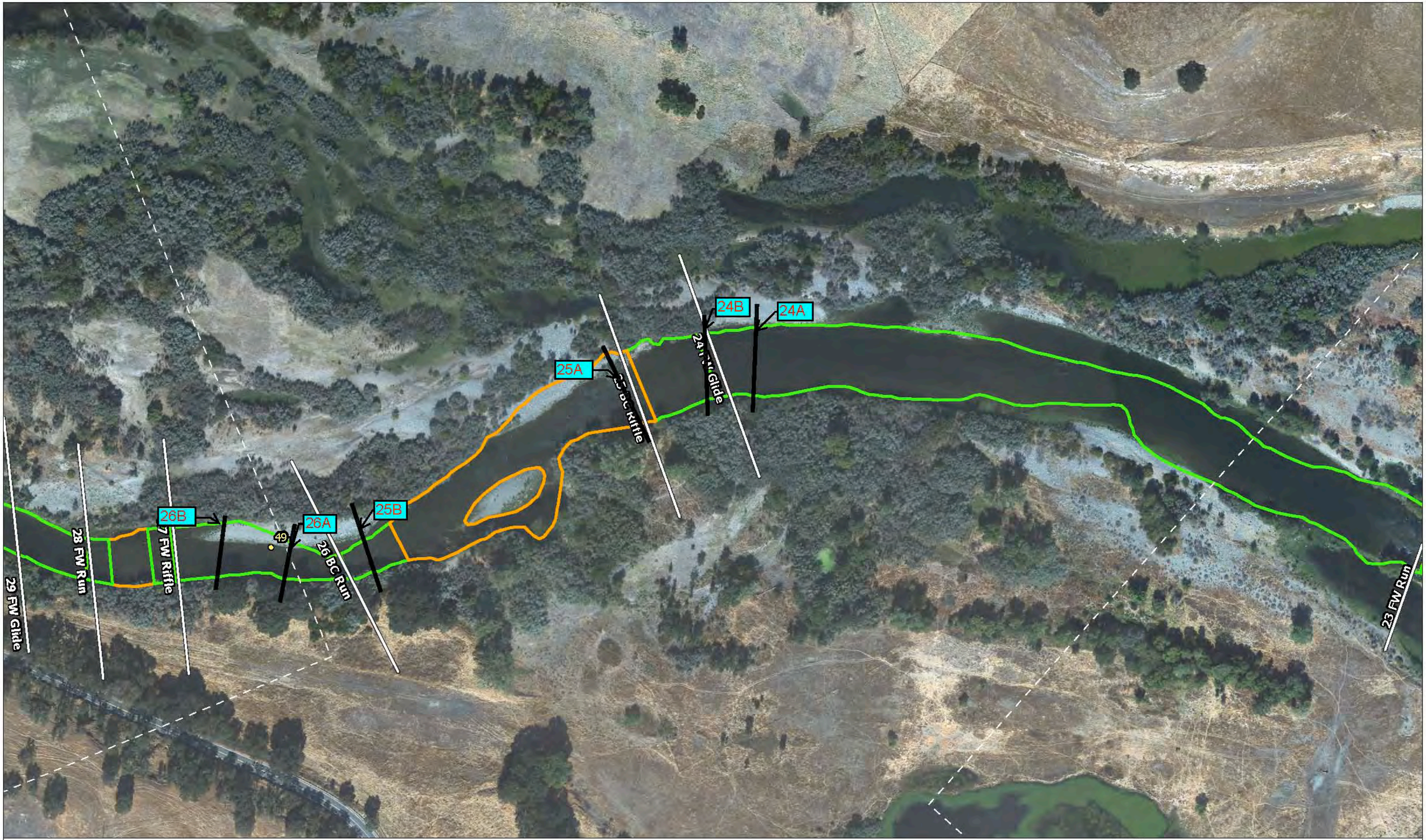
Appendix B-2

Attachment 2

IFIM Transect Placement Field Summary
November 18-19

Transect Placement Figures

Note: As documented in the November 28, 2012 workshop, transects 82a, 82b, and 83b were replaced with transects 159a, 159b, and 159c. Locations of transects 159a, 159b, and 159c are included in this attachment.



Tuolumne River - IFIM Mesohabitats, 2010

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

BCE Runs
BCE Riffles
BCE Pools

Meso Habitat reach
BC = Bar Complex
FW = Flatwater

Tile Boundary (shown white on the map)
River Miles
Side channel (ID labeled)

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)
Wetted perimeter were fisrt based on EA_mapping data (90's) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 06

Tuolumne River - IFIM Mesohabitats, 2010

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

BCE Runs
BCE Riffles
BCE Pools

Meso Habitat reach
BC = Bar Complex
FW = Flatwater

Tile Boundary (shown white on the map)
River Miles
Side channel (ID labeled)

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)
Wetted perimeter were fisrt based on EA_mapping data (90's) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 07

Tuolumne River - IFIM Mesohabitats, 2010

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

BCE Runs
BCE Riffles
BCE Pools

Meso Habitat reach
BC = Bar Complex
FW = Flatwater

Tile Boundary (shown white on the map)
River Miles
Side channel (ID labeled)

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)
Wetted perimeter were fisrt based on EA_mapping data (90's) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 16

Tuolumne River - IFIM Mesohabitats, 2010

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

BCE Runs
BCE Riffles
BCE Pools

Meso Habitat reach
BC = Bar Complex
FW = Flatwater

Tile Boundary (shown white on the map)
River Miles
Side channel (ID labeled)

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)
Wetted perimeter were fisrt based on EA_mapping data (90's) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 17

Tuolumne River - IFIM Mesohabitats, 2010

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

BCE Runs
BCE Riffles
BCE Pools

Meso Habitat reach
BC = Bar Complex
FW = Flatwater

Tile Boundary (shown white on the map)
River Miles
Side channel (ID labeled)

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)
Wetted perimeter were first based on EA_mapping data (90's) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 31

Tuolumne River - IFIM Mesohabitats, 2010

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

BCE Runs
BCE Riffles
BCE Pools

Meso Habitat reach
BC = Bar Complex
FW = Flatwater

Tile Boundary (shown white on the map)
River Miles
Side channel (ID labeled)

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)
Wetted perimeter were fisrt based on EA_mapping data (90's) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 32

Tuolumne River - IFIM Mesohabitats, 2010

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

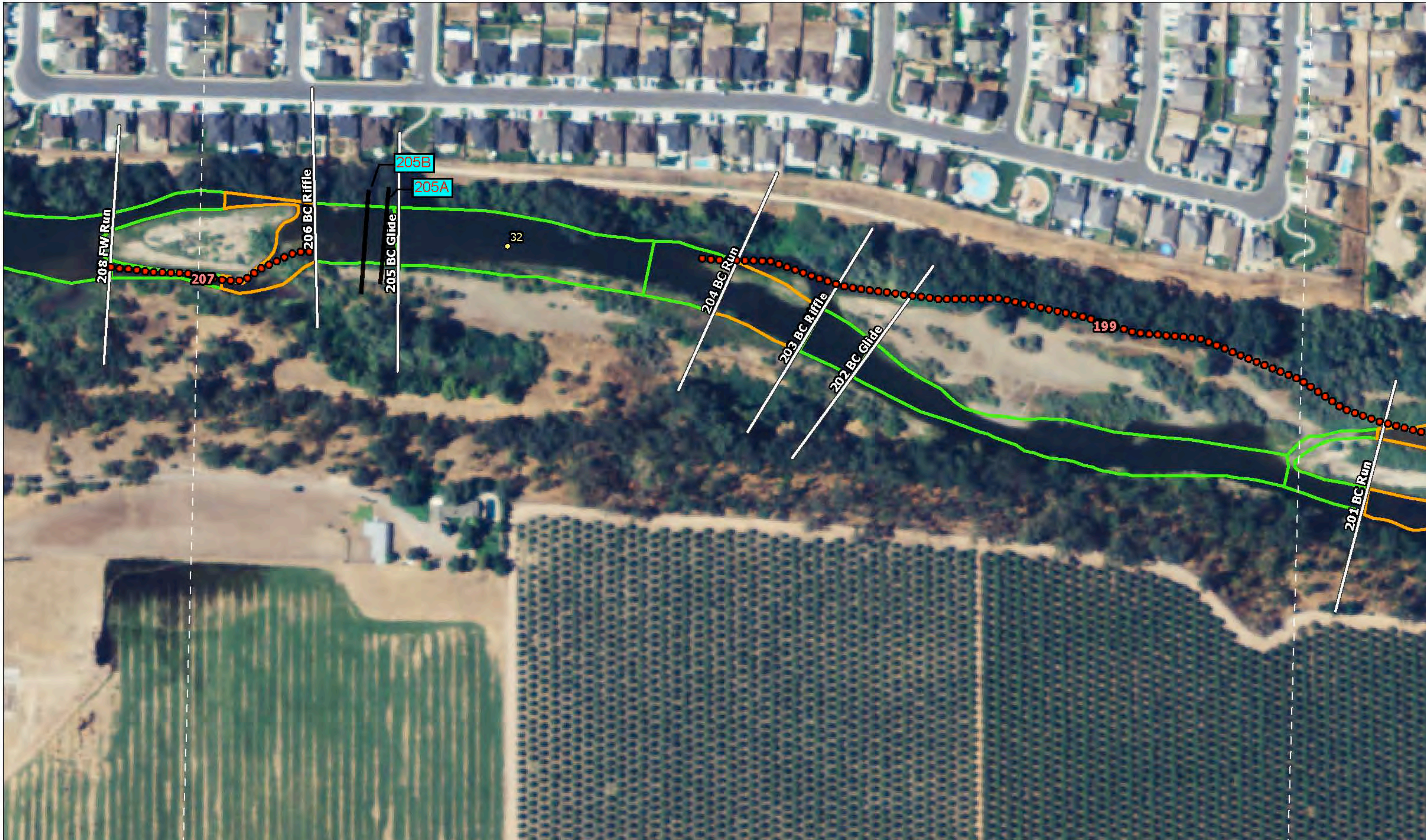
BCE Runs
BCE Riffles
BCE Pools

Meso Habitat reach
BC = Bar Complex
FW = Flatwater

Tile Boundary (shown white on the map)
River Miles
Side channel (ID labeled)

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)
Wetted perimeter were fisrt based on EA_mapping data (90's) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 33



Tuolumne River - IFIM Mesohabitats, 2010

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

BCE Runs
BCE Riffles
BCE Pools

Meso Habitat reach
BC = Bar Complex
FW = Flatwater

Tile Boundary (shown white on the map)
River Miles
Side channel (ID labeled)

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)
Wetted perimeter were fisrt based on EA_mapping data (90's) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 42

Tuolumne River - IFIM Mesohabitats, 2010

Stillwater Sciences
www.stillwatersci.com

0 125 250 500 Feet

BCE Runs
BCE Riffles
BCE Pools

Meso Habitat reach
BC = Bar Complex
FW = Flatwater

Tile Boundary (shown white on the map)
River Miles
Side channel (ID labeled)

METADATA
Tiles 29 to 47: NAIP, 6/29/2009 (130 cfs)
Tiles 1 to 29: Sanborn imagery, 09/25/2005 (335 cfs)
Wetted perimeter were fisrt based on EA_mapping data (90's) at 230 cfs, and later refined using 2005 & 2009 NAIP and field measurements from 2008 and 2009 surveys to adjust for channel migration.

Tile 46

Appendix C

PHABSIM Model Calibration Workshop Summary
November 28, 2012

Meeting Summary
Tuolumne River Instream Flow Study
PHABSIM Hydraulics Review Meeting
Wednesday, 28 November 2012, 9:00am
Stillwater Sciences, Davis, CA

Attendees: Robert Hughes (CDFG), Bill Cowan (CDFG), Jarvis Caldwell (HDR), Wayne Swaney (Stillwater), Scott Wilcox (Stillwater), Annie Manji (CDFG, briefly by phone)

Objectives

- Discuss feedback on review of hydraulic model from Lower Tuolumne River
- Determine if there are refinements to the existing model that can be made in a timely and cost-effective manner that will both 1) improve model performance, and 2) potentially affect habitat vs. flow results.
- Seek agreement on acceptability of the current/refined hydraulic model for its intended purpose.

Study Background

- Process
    - i. Originated with FERC order to look at instream flows following prior 10-year study.
    - ii. Convened series of workshops and field visits on reach and study site selection, transect selection, HSC selection
- Study Sites
    - i. Selected in the field in November 2010
    - ii. 40 transects grouped in 5 areas: Basso, Bobcat Flat, Santa Fe, Waterford and Delaware Rd.
    - iii. Replicates of riffle, run, pool, glide, by two channel types (flat, bar complex)
- Field Efforts
    - i. High flows in July 2011, mid flows in Sept 2011
    - ii. High runoff precluded low flows in 2011, variance request for September 2011 unsuccessful, low flows measured in June 2012.

iii. HSC site specific surveys conducted in February, March, May, and July 2012 at 100 cfs, 350 cfs, and 2,000 cfs (573 obs [4,620 fish] at 1,095 locations)

PHABSIM Model Information

- Reviewed Summary Statistic Printouts
    i. WSL mean error, WSL obs vs. predicted, VAF
    ii. WSL table
    iii. Calibration Flow table
- Reviewed On-line Model screens

Detailed Model Review

The group proceeded to systematically 1) review all calibration flows to determine a "best Q" for use at each site, 2) rerun the model with the new calibration flows, 3) review each resulting stage/Q regression relationship, 4) decide on which hydraulic model to use at each transect, 5) review each velocity distribution graphic for anomalies.

The following action items and model refinements resulted from the detailed model review.

Calibration Flows

- Basso Bridge Site: Use the average of the three glide transects (24A, 24B, 29A) for the mid-flow calibration (276 cfs)
- Bobcat Flat Site: Use the average flow measurement at transects 85A, 83A, 82C for the mid-flow calibration (282 cfs). Following the new model run, consider WSL refinements (within the measured range) at pool transects 86A, 86B, 86C to improve the VAF.
- Santa Fe Site: No change in the current calibration flow of 319 cfs.
- Waterford Site: No change in the current calibration flow of 308 cfs.
- Delaware Site: No change in the current calibration flow of 306 cfs.

Stage-Discharge Regression

- All regression relationships looked acceptable after the calibration flow adjustments.

- Check for a possible profile error near Station 25 on Transect 156B.

Velocity Distributions

- Transect 155B, consider suppressing negative River Left velocities with specified Manning's 'n' values.
- Transect 155A, consider suppressing peak velocity near Station 45 with specified Manning's 'n' values.
- Transects 86A, 86B, 86C: Readjust Manning's 'n' values (and WSL) for better VAF results.
- Transect 84C: Modify Manning's 'n' near Station 140 to limit magnitude of negative velocity prediction
- Transect 84A: Modify Manning's 'n' near Station 68 to limit magnitude of the simulated negative velocity
- Transect 26B: Modify Manning's 'n' near Stations 75 and ~95 to cap the simulated high velocity spikes
- Transect 26A: Double check the velocity data at Station 62.5 and look for any error in the negative velocity, although the photos indicate it is plausibly accurate as currently recorded.
- Transect 25A: Readjust Manning's 'n' values for better VAF results, where needed.

Model Selection

As part of the stage-discharge regression data review, hydraulic model selections were made. The model of choice for transects 9-162A-BR, 17-156B-BR, 25-84C-FN, 26-84B-FN, 27-84A-FN, and 38-25A-BR was MANSQ. All other transects will be simulated using a Log-Log model (IFG-4).

Transect Locations

It was noted during the meeting that three transects for Unit 159 in the hydraulic model replaced three Unit 82 and Unit 83 transects initially selected in the field. This need became apparent during transect installation, when high flows were circumventing the main channel and water was flowing parallel to the transect line at the initially selected sites, preventing modelable conditions. The replacement transects were selected in the same habitat types, with an effort to make them as similar to the original locations as possible. The Interested Parties group was notified of the proposed change prior to data collection, and comments requested. No written comments were received.

Next Steps

Participants in the meeting agreed that, with the above modifications, the hydraulic model would be suitably calibrated for use in the next phases of the analysis. The refined model will be made available to meeting participants as soon as it is complete, but no formal re-evaluation of its acceptability is necessary.

Appendix D

HSC Workshop Summary
September 20, 2010

Lower Tuolumne River Instream Flow Study
Study Coordination Meeting #2 — Summary
Monday, September 20, 2010, 10 AM – 5 PM Stillwater Sciences
279 Cousteau Place, Davis, CA

Attendees:

Scott Wilcox (Stillwater)
Russ Liebig (Stillwater)
Bob Hughes (CDFG)
Ron Yoshiyama (CCSF-SF)
Allison Boucher (TRC)
Zac Jackson (USFWS)
Shaara Ainsley (FishBio)

The purpose of this meeting was to compile, review, and discuss available salmon and steelhead Habitat Suitability Criteria (HSC) for the lower Tuolumne River, select HSC where possible, identify additional HSC literature data gathering needs, and discuss related topics. Scott Wilcox provided a brief overview of HSC and why they were needed for the IFIM study.

The technical group sequentially reviewed HSC and associated metadata from various sources for each species and lifestage, and either (1) selected HSC, (2) reduced the sources of HSC being considered, and/or (3) identified data needs and next steps. Decisions and/or actions on HSC for each species and lifestage are noted below.

Chinook Salmon Spawning

- A wide range of HSC from various sources were reviewed, and the CDFG site-specific Tuolumne curves matched the central tendencies of the other data sets well.
- **Action Item**: confirm that the number of observations and the methodology used in the CDFG spawning study were sufficiently robust. [Subsequent data searches by Stillwater revealed that 318 observations were used for the curves, and 10 study sites were spread over 9.2 miles that represented all of the dominant spawning reach. Thus, there does not seem to be an issue with data robustness.]
- **Decision**: Use site-specific Tuolumne River data for depth and velocity, from the CDFG study conducted in ~1982.

Tuolumne River Chinook Salmon Spawning Depth and Velocity Criteria*

Depth	Suitability Index	Velocity	Suitability Index
0.00	0.00	0.00	0.00
0.50	0.00	0.70	0.00
0.60	0.12	0.80	0.06
0.70	0.23	0.90	0.17
0.80	0.27	1.05	0.36
0.90	1.00	1.25	0.42
2.60	1.00	1.40	1.00
2.70	0.15	2.60	1.00
2.80	0.12	2.70	0.62
2.90	0.08	2.80	0.56
3.00	0.00	2.90	0.45
		3.05	0.22
		3.20	0.17
		3.80	0.07
		4.40	0.00

*From CDFG 1982

- **Decision:** Adopt, with small modifications based on data from other streams, the site-specific substrate HSC from CDFG. Other streams indicated frequent use of 1-2 inch gravel, which the site-specific Tuolumne data did not (perhaps due to availability limitations). Final substrate criteria agreed to by the technical group are specified below.

Tuolumne River Chinook Salmon Spawning Substrate Criteria*

Substrate	**Size (inches)**	**Suitability Index**
Organic, silt, sand, small gravel	Up to 1.0	0.0
Medium gravel	1-2	0.5
Large gravel	2-3	1.0
Very small cobble	3 – 4.5	1.0
Small cobble	4.5-6	0.7
Medium Cobble	6-9	0.0
Large cobble, boulder, bedrock	>9	0.0

*Adapted from CDFG 1982 with minor expansion to indicate suitability of 1-2 inch gravel.

- The technical group agreed that additional site-specific data collection for spawning would not lead to a decision narrow the HSC curves, and that sufficient additional data to justify expanding the curves was not possible given the current size of the population. Therefore, given that the current data set is robust at 318 observations, and is already site-specific, no additional site-specific data collection for spawning is planned.

Chinook Salmon Juveniles
The Stanislaus velocity HSC provided good representation of the central tendencies of the larger data set. Stanislaus depth HSC curve peaked slightly more to the right of most of the rest of the data sets.

- **Decisions:** (1) Use the Stanislaus HSC for velocity. (2) Use the Stanislaus HSC for depth, with a minor modification to include the peaks of other curves in the 1.31 – 2.10 foot depth range. (3) Do not apply substrate criteria to juveniles, since they do not typically select habitat based on substrate and may occur over the entire range of substrate possibilities.

Tuolumne River Chinook Salmon Juvenile Depth and Velocity Criteria*

Depth	Suitability Index	Velocity	Suitability Index
0.00	0.00	0.00	0.92
0.10	0.01	0.10	0.96
0.20	0.02	0.20	1.00
0.30	0.05	0.30	0.99
0.40	0.10	0.40	0.99
0.50	0.17	0.50	0.98
0.60	0.27	0.60	0.97
0.70	0.36	0.70	0.97
0.80	0.42	0.80	0.96
1.31	1.00	0.90	0.96
2.10	1.00	1.00	0.95
2.20	0.93	1.10	0.94
2.30	0.86	1.20	0.94
2.40	0.78	1.30	0.93
2.50	0.71	1.40	0.92
2.60	0.64	1.50	0.92
2.70	0.57	1.60	0.91
2.80	0.49	1.70	0.79
2.90	0.42	1.80	0.68
3.00	0.41	1.90	0.56
3.10	0.39	2.00	0.44
3.20	0.38	2.10	0.33
3.30	0.36	2.20	0.28
3.40	0.35	2.30	0.24
3.50	0.34	2.40	0.19
3.60	0.32	2.50	0.15
3.70	0.31	2.60	0.10

3.80	0.29	2.70	0.06
3.90	0.28	2.80	0.01
4.00	0.25	3.40	0.01
4.10	0.18	3.50	0.00
4.20	0.12		
4.30	0.08		
4.40	0.05		
4.50	0.03		
4.60	0.03		
4.70	0.02		
7.00	0.02		
7.10	0.00		

*From Stanislaus River. Depth curve modified.

Chinook Salmon Fry
Site-specific Tuolumne River HSC for fry are available. These HSC were compared to the fry HSC from the Stanislaus River (Stanislaus River data were used for juvenile HSC). The similarity between the two data sets, and their similarity to the central tendency of other data sets, was not as great as the technical group had hoped, and some type of hybrid curve was considered. Decisions on depth and velocity HSC for this life stage were deferred to the next meeting, pending review of the reports and metadata that may provide some insight on reasons for the differences.

Decision: As specified for the juvenile life stage, do not apply substrate criteria to fry.

Steelhead Adults
The technical group reviewed a few HSC from the literature, and initially focused on resident rainbow trout curves provided by the USFWS that are being used for steelhead on the Merced project, since they already had some level of agency concurrence. Several questions were raised about the origin of the curves, and the rationale for their use.

Since the Tuolumne River O. mykiss population is almost entirely resident, the technical group concurred that review of some Central Valley rainbow trout curves should be considered as well.

Action: Zac Jackson will research the background and source of the HSC being used for the Merced Project. Stillwater will compile some rainbow trout HSC for consideration. These will all be reviewed at the next HSC meeting.

<u>Upcoming meeting dates:</u>

Site Selection Meeting, October 5, 2010
HSC development 2nd meeting, October 20, 2010 at Stillwater in Davis, 9:00.

Appendix E

HSC Workshop Summary
October 20, 2010

Lower Tuolumne River Instream Flow Study
Study Coordination Meeting #4 — Summary
Wednesday, October 20, 2010, 9 AM – 5 PM Stillwater Sciences
279 Cousteau Place, Davis, CA

Attendees:

Scott Wilcox (Stillwater)
Russ Liebig (Stillwater)
Bob Hughes (CDFG)
Ron Yoshiyama (CCSF-SF)
Allison Boucher (TRC)
Mark Gard (USFWS)
Jim Inman (FishBio)

The purpose of this workshop was to compile, review, and discuss available steelhead Habitat Suitability Criteria (HSC) for the lower Tuolumne River, select remaining HSC where possible, identify additional HSC literature data gathering needs, and discuss related topics. Chinook salmon HSC were discussed at the September 20, 2010 workshop. Scott Wilcox provided a brief overview of remaining action items from the September 20 workshop and introduced the revised *O. mykiss* HSC data packet, which was expanded to include additional rainbow trout curves following the September 20 meeting.

The technical group sequentially reviewed *O. mykiss* HSC and associated metadata from various sources for each lifestage, and either (1) selected HSC, (2) reduced the sources of HSC being considered, and/or (3) identified data needs and next steps. Decisions and/or actions on HSC for each species and lifestage are noted below.

O. mykiss Adults

- The technical group had reviewed HSC during the September 20, 2010 workshop and initially focused on resident rainbow trout curves provided by the USFWS that are being used for the Merced project (SF American logistic regression curve). However, since the Tuolumne River *O. mykiss* population is almost entirely resident, the technical group concurred that review of additional Central Valley rainbow trout curves should be considered as well. Stillwater subsequently compiled additional rainbow trout HSC for comparison and consideration, and Bob Hughes reviewed the origin of the Merced curves. All of these data were reviewed and discussed by the group on October 20.
- The process for HSC selection generally used the following steps: 1) review tabular metadata for all HSC; 2) “filter” HSC datasets to consider further based on selection criteria in the study plan such as number of observations, category of criteria, geography, stream similarity, elevation, etc.; 3) review

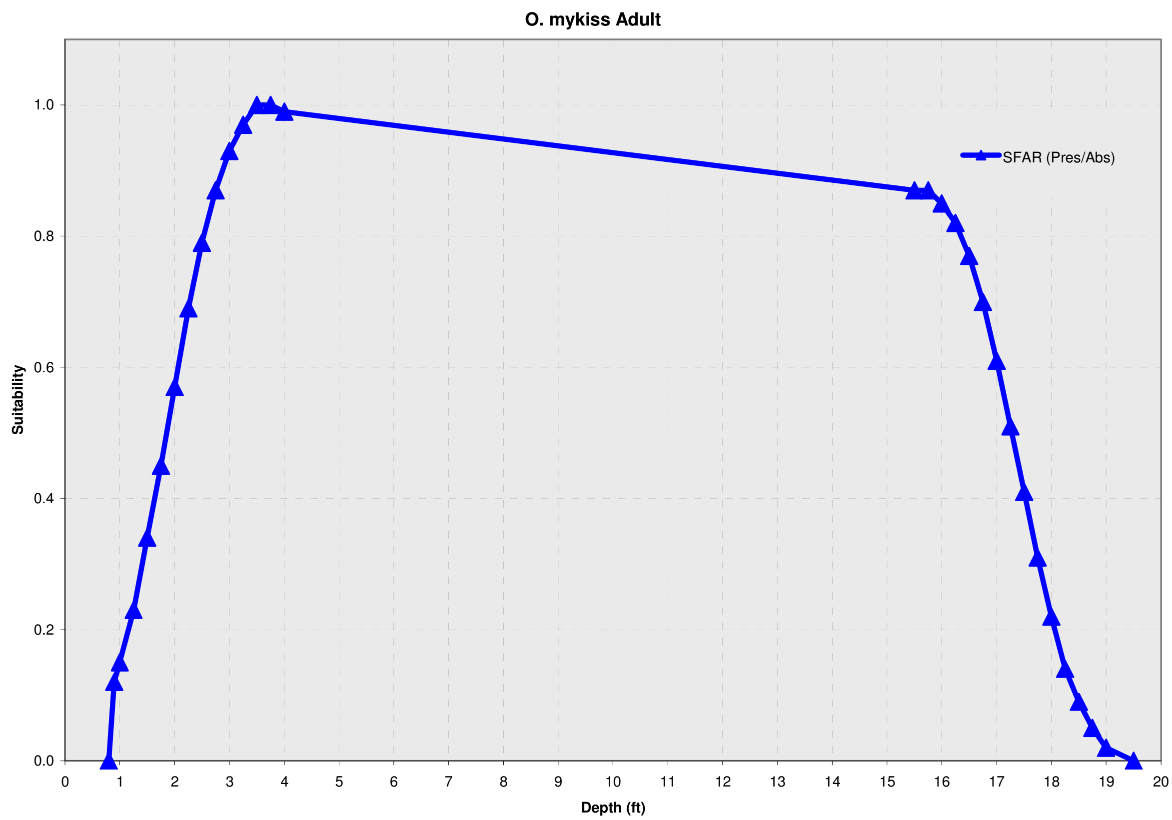
graphs of filtered HSC and discuss outliers, representative datasets, or development of a consensus curve.

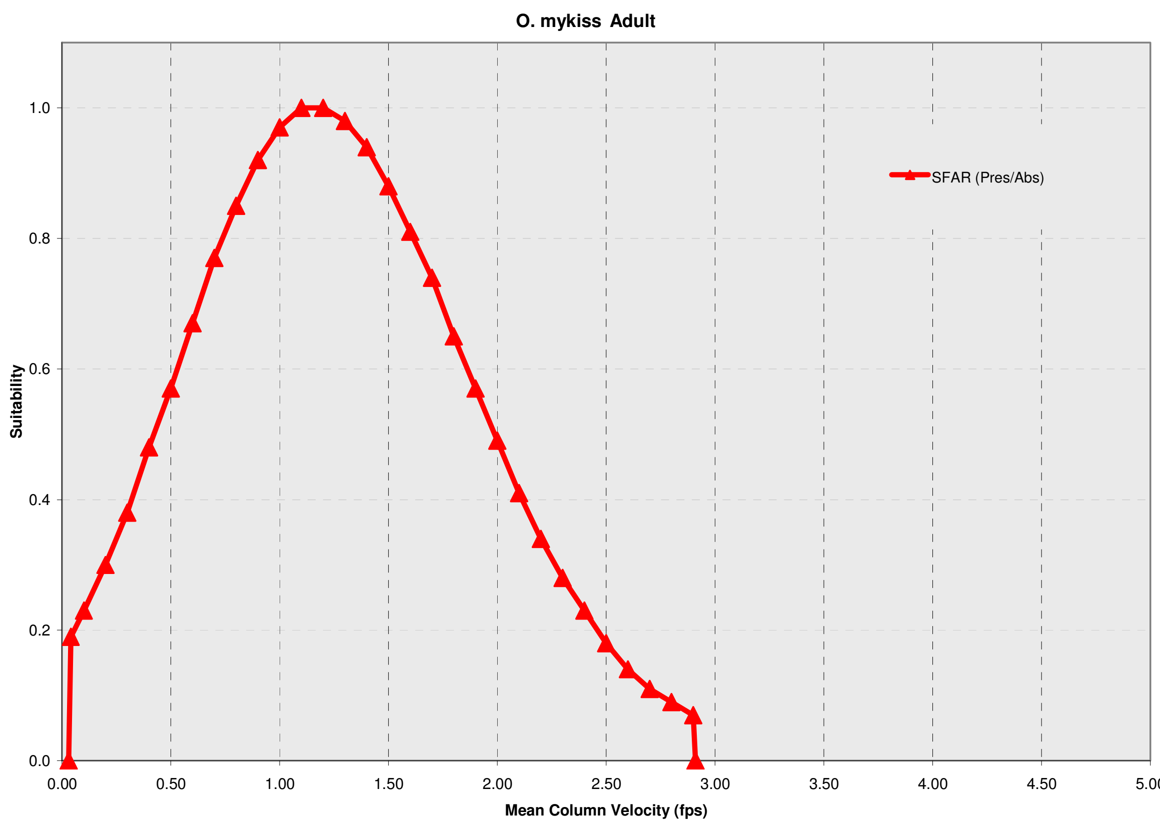
- **Decision**: The workshop group concurred on use the South Fork American River Logistic Regression (Pres/Abs) curves ("SFAR Pres/Abs") proposed by the USFWS for both velocity and depth.

Tuolumne River *O. mykiss* Adults Depth and Velocity Criteria*

Velocity (fps)	Suitability Index	Depth (ft)	Suitability Index
0.03	0.00	0.80	0.00
0.04	0.19	0.90	0.12
0.10	0.23	1.00	0.15
0.20	0.30	1.25	0.23
0.30	0.38	1.50	0.34
0.40	0.48	1.75	0.45
0.50	0.57	2.00	0.57
0.60	0.67	2.25	0.69
0.70	0.77	2.50	0.79
0.80	0.85	2.75	0.87
0.90	0.92	3.00	0.93
1.00	0.97	3.25	0.97
1.10	1.00	3.50	1.00
1.20	1.00	3.75	1.00
1.30	0.98	4.00	0.99
1.40	0.94	15.50	0.87
1.50	0.88	15.75	0.87
1.60	0.81	16.00	0.85
1.70	0.74	16.25	0.82
1.80	0.65	16.50	0.77
1.90	0.57	16.75	0.70
2.00	0.49	17.00	0.61
2.10	0.41	17.25	0.51
2.20	0.34	17.50	0.41
2.30	0.28	17.75	0.31
2.40	0.23	18.00	0.22
2.50	0.18	18.25	0.14
2.60	0.14	18.50	0.09
2.70	0.11	18.75	0.05
2.80	0.09	19.00	0.02
2.90	0.07	19.50	0.00
2.91	0.00		

* From USFWS 2004: Flow-habitat relationships for adult and juvenile rainbow trout in the Big Creek Project. USFWS Energy Planning and Instream Flow Branch. 31pp.


O. mykiss Adult
Suitability
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Depth (ft)
SFAR (Pres/Abs)


O. mykiss Adult
Suitability
1.0
0.8
0.6
0.4
0.2
0.0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
Mean Column Velocity (fps)
SFAR (Pres/Abs)

***O. mykiss* Spawning**

A wide range of HSC from various sources were reviewed; however, one single curve could not be identified to best fit the *O. mykiss* populations in the Tuolumne River. Therefore envelope curves were developed for depth and velocity, and a curve reflecting the central tendency of the data was developed for substrate, based on the Upper Trinity and Yuba curves.

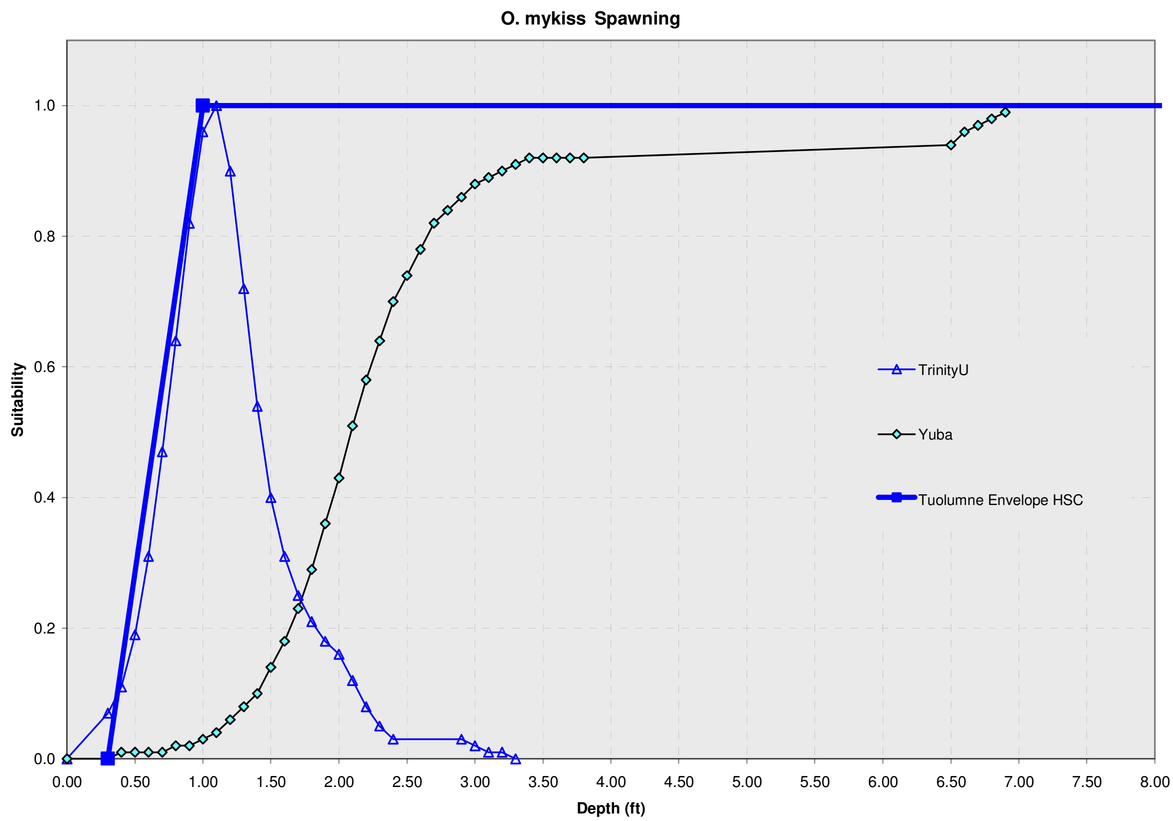
- **Decision:**
  - Velocity: Use an envelope curve including the ascending limb of the Upper Trinity curve to (x, y = 1.1, 1.0) over to (2.6, 1.0) of the Yuba curve, then straight-line down to (4.4, 0.0).
  - Depth: Use an envelope curve from (0.3, 0.0) to (1.0, 1.0) to (100.0, 1.0).
  - Substrate: Final substrate criteria agreed to by the technical group are specified below.

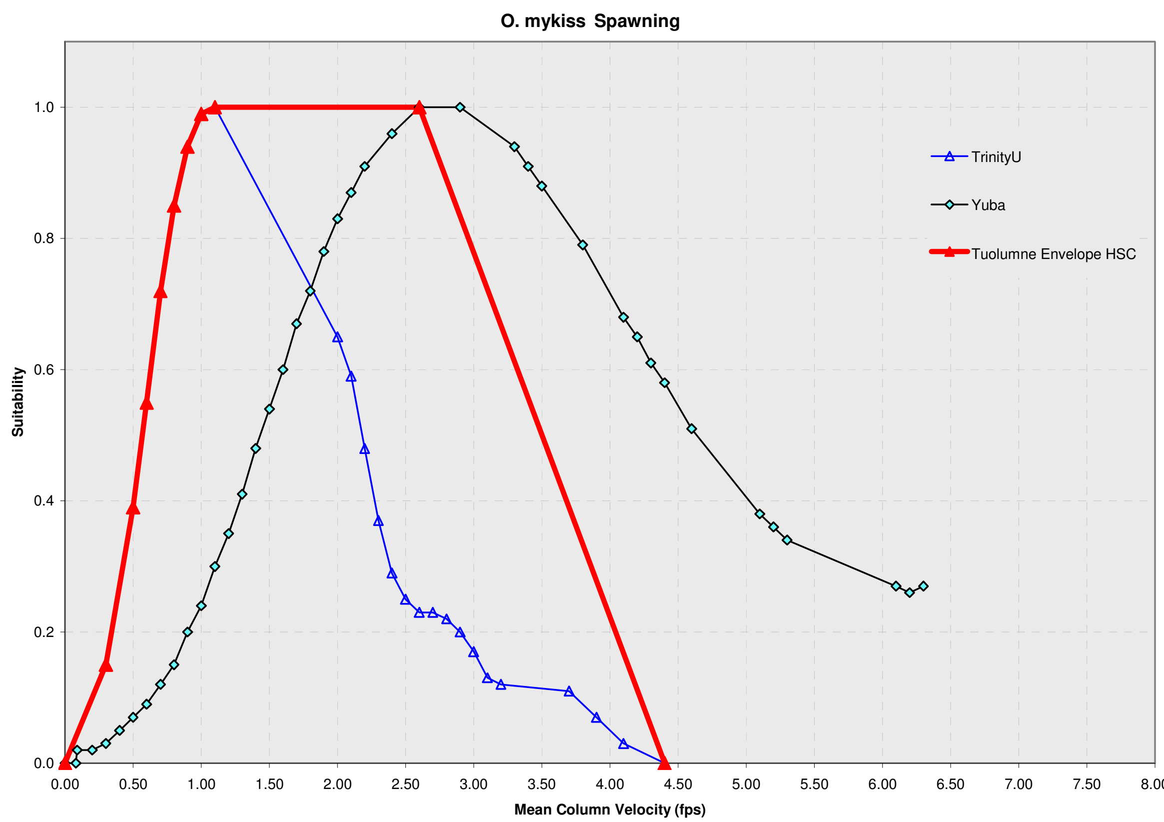
Tuolumne River *O. mykiss* Spawning Depth and Velocity Criteria

Velocity (fps)	Suitability Index	Depth (ft)	Suitability Index
0.00	0.00	0.30	0.00
0.30	0.15	1.00	1.00
0.50	0.39	100.00	1.00
0.60	0.55		
0.70	0.72		
0.80	0.85		
0.90	0.94		
1.00	0.99		
1.10	1.00		
2.60	1.00		
4.40	0.00		

Tuolumne River *O. mykiss* Spawning Substrate Criteria

Substrate	Size (inches)	Suitability Index
Organic, silt, sand, small gravel	Up to 1.0	0.38
Medium gravel	1-2	1.0
Large gravel	2-3	0.85
Very small cobble	3 – 4.5	0.28
Small cobble	4.5-6	0.05
Medium Cobble	6-9	0.00
Large cobble, boulder, bedrock	>9	0.00


O. mykiss Spawning
Suitability
Depth (ft)
TrinityU
Yuba
Tuolumne Envelope HSC
0.0
0.2
0.4
0.6
0.8
1.0
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00


O. mykiss Spawning
Suitability
Mean Column Velocity (fps)
TrinityU
Yuba
Tuolumne Envelope HSC
0.0
0.2
0.4
0.6
0.8
1.0
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00 5.50 6.00 6.50 7.00 7.50 8.00

***O. mykiss* Fry**

A wide range of HSC from various sources were reviewed that displayed similar results for fry. USFWS Yuba River curves were presented in the "filtered" data sets, but they varied from the central tendency of the other curves due to the statistical approach used to generate them.

- **Action Item:** Mark Gard to provide the underlying histograms and report for the Yuba River *O. mykiss* HSC prior to the November 22 meeting for comparison to other data.

***O. mykiss* Juveniles**

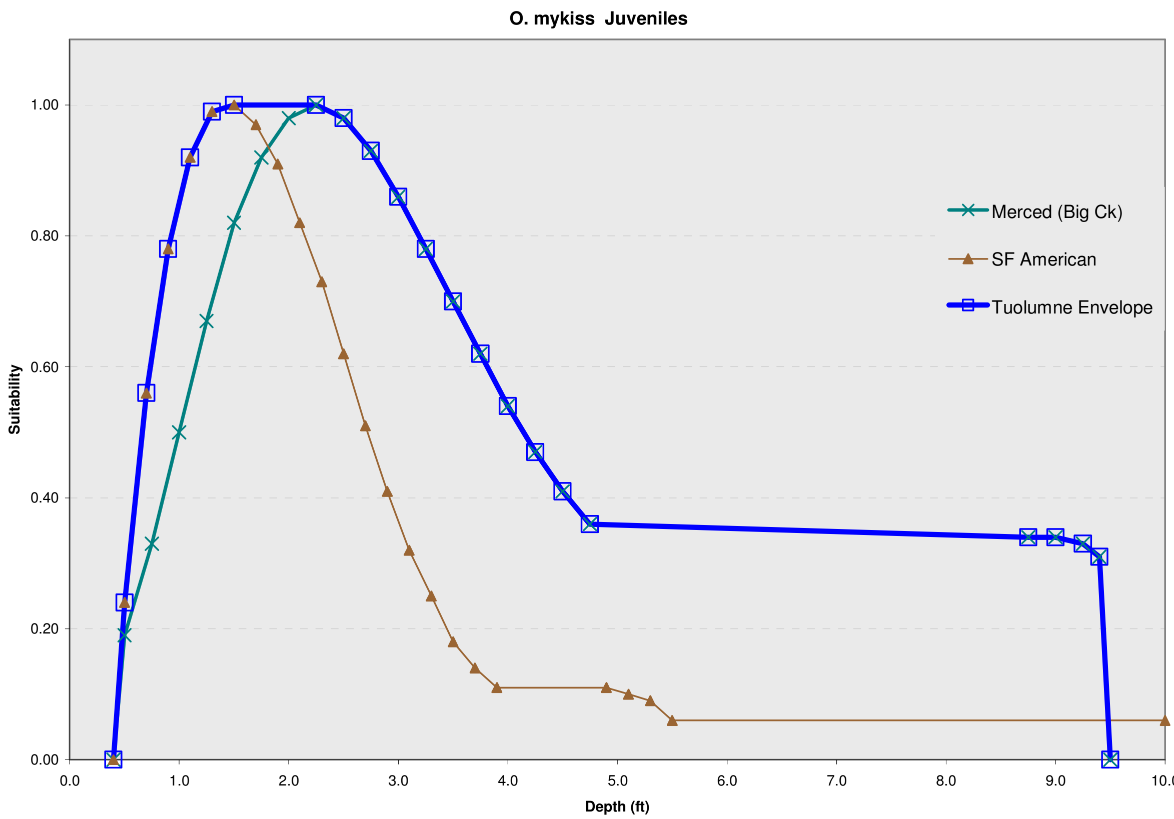
Decision: Recommended an envelope curve including the ascending limb of the SF American polynomial regression curve up to y=1, and across on y=1, following the descending limb of the SF American logistic regression curve. No substrate criteria to be applied to juveniles.

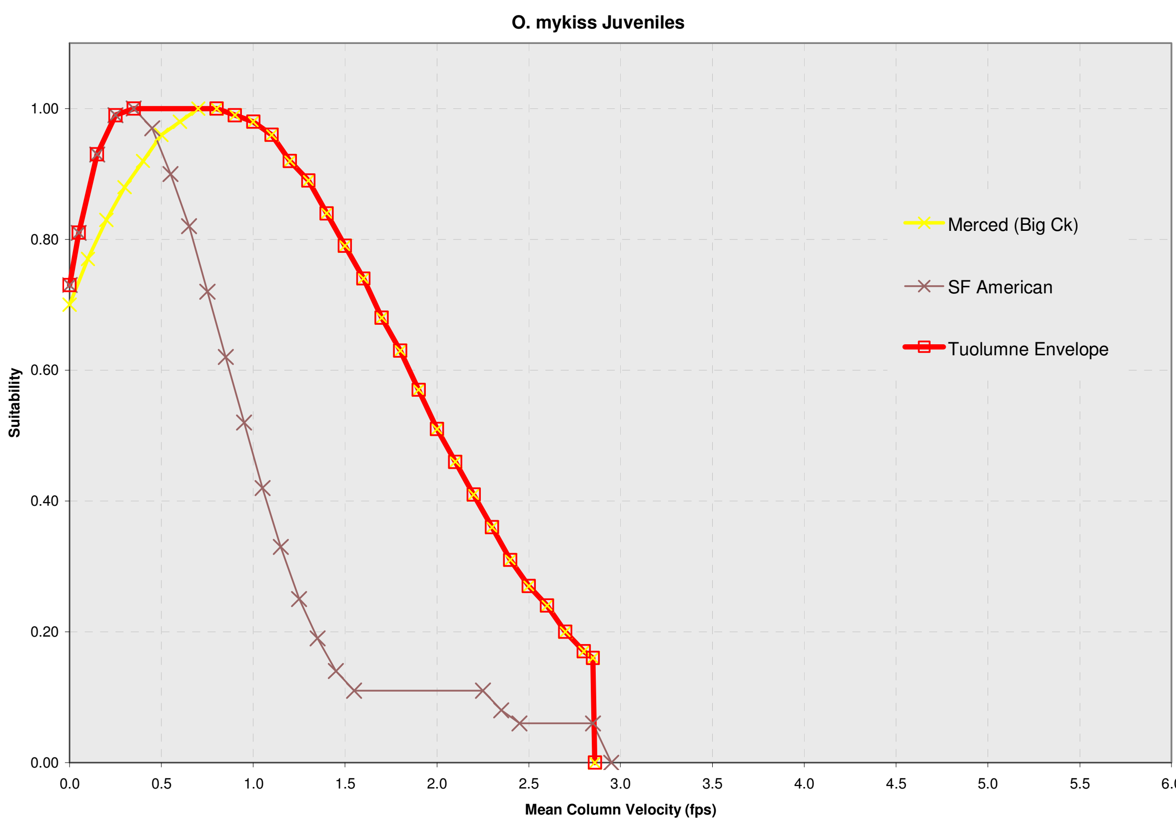
Upcoming meeting dates:

A third HSC development workshop was tentatively scheduled for November 22, 2010 at Stillwater in Davis, 9:00 AM, but was postponed due to subsequent scheduling and data availability conflicts. The next workshop is anticipated in early January.

Tuolumne River *O. mykiss* Juvenile Depth and Velocity Criteria

Velocity (fps)	Suitability Index	Depth (ft)	Suitability Index
0.00	0.73	0.40	0.00
0.05	0.81	0.50	0.24
0.15	0.93	0.70	0.56
0.25	0.99	0.90	0.78
0.35	1.00	1.10	0.92
0.80	1.00	1.30	0.99
0.90	0.99	1.50	1.00
1.00	0.98	2.25	1.00
1.10	0.96	2.50	0.98
1.20	0.92	2.75	0.93
1.30	0.89	3.00	0.86
1.40	0.84	3.25	0.78
1.50	0.79	3.50	0.70
1.60	0.74	3.75	0.62
1.70	0.68	4.00	0.54
1.80	0.63	4.25	0.47
1.90	0.57	4.50	0.41
2.00	0.51	4.75	0.36
2.10	0.46	8.75	0.34
2.20	0.41	9.00	0.34
2.30	0.36	9.25	0.33
2.40	0.31	9.40	0.31
2.50	0.27	9.50	0.00
2.60	0.24		
2.70	0.20		
2.80	0.17		
2.85	0.16		
2.86	0.00		


O. mykiss Juveniles
Suitability
1.00
0.80
0.60
0.40
0.20
0.00
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Depth (ft)
Merced (Big Ck)
SF American
Tuolumne Envelope


O. mykiss Juveniles
Suitability
1.00
0.80
0.60
0.40
0.20
0.00
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
Mean Column Velocity (fps)
Merced (Big Ck)
SF American
Tuolumne Envelope

Appendix F

HSC Workshop Summary
February 3, 2011

Lower Tuolumne River Instream Flow Study
Study Coordination Workshop #5 — Summary
Thursday, February 3, 2011, 9:00
Stillwater Office, Davis, CA

Attendees:

Scott Wilcox (Stillwater)	Ron Yoshiyama (CCSF-SF)
Russ Liebig (Stillwater)	Allison Boucher (TRC)
Bob Hughes (CDFG)	Dave Boucher (TRC)
Jenny O'Brien (CDFG)	Mark Gard (USFWS)
Steve Tsao (CDFG)	Zac Jackson (USFWS)
Bill Cowan (CDFG)	Shaara Ainsley (FishBio)

The purpose of this workshop was to compile, review, and discuss available *O. mykiss* and Chinook salmon Habitat Suitability Criteria (HSC) for the lower Tuolumne River, select remaining HSC where possible, identify additional HSC literature data gathering needs, and discuss related topics. HSC for Chinook salmon and *O. mykiss* were previously selected at the September 20, 2010 and October 20, 2010 workshops where the group had come to consensus on suitability criteria for Chinook salmon spawning (depth, velocity, and substrate), and juvenile (depth and velocity) lifestages, and *O. mykiss* spawning (depth, velocity, and substrate), adult (depth and velocity), and juvenile (depth and velocity) life stages. The group had decided at the September 20, 2010 workshop to not apply substrate criteria to the juvenile and fry life stages.

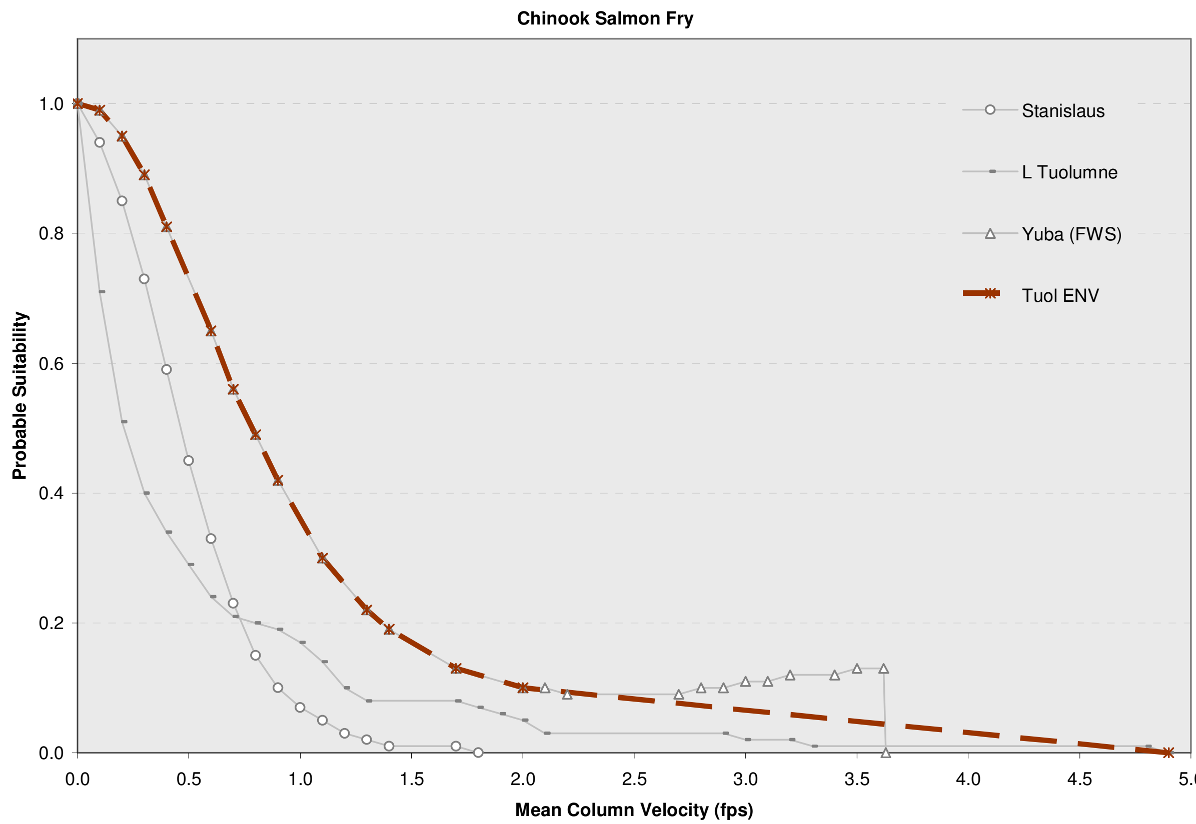
Scott Wilcox provided a brief overview of remaining action items from the previous workshops and introduced the revised Chinook salmon and *O. mykiss* HSC data packet compiled from USFWS data provided since the October workshop. The technical group reviewed Chinook salmon fry HSC and *O. mykiss* fry and adult HSC from various sources. The technical group also reviewed available cover HSC for Chinook salmon fry and *O. mykiss* fry provided by USFWS. Decisions and/or actions on HSC for each species and lifestage are noted below.

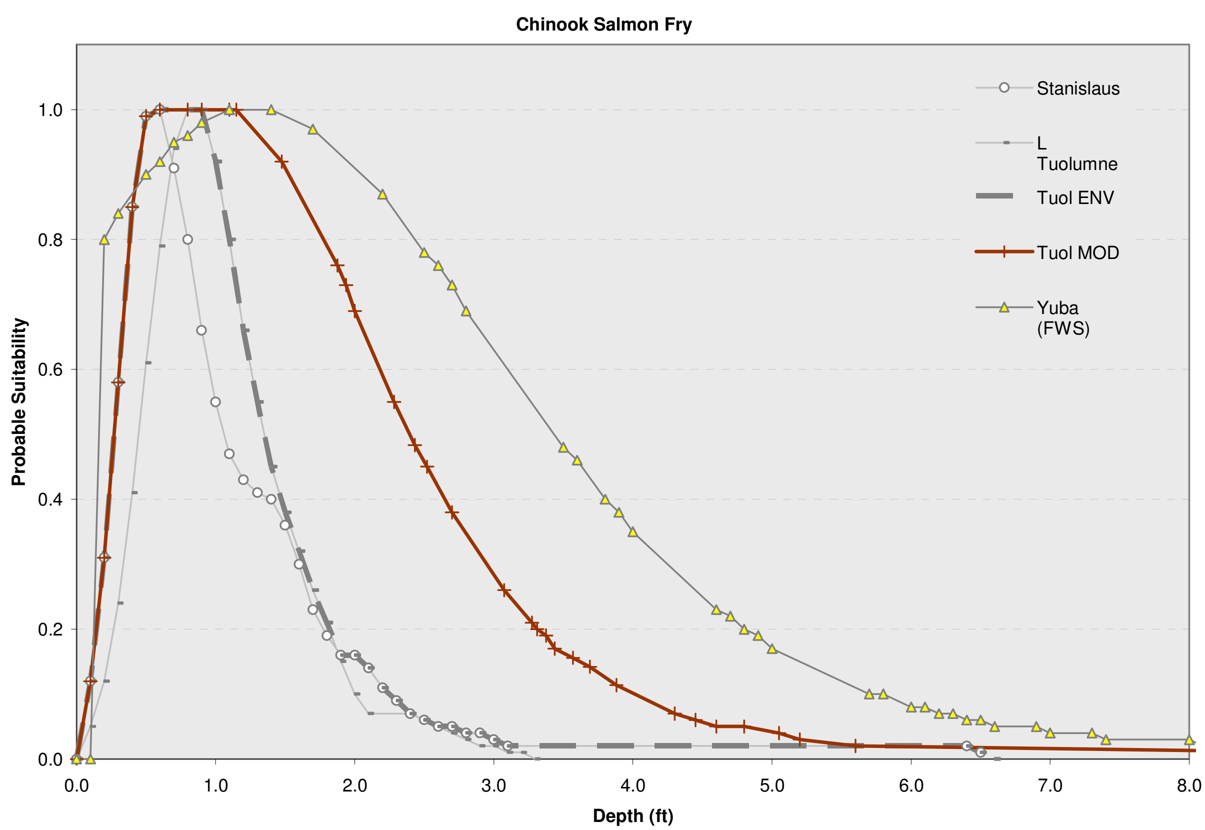
Chinook salmon fry

- The technical group had reviewed HSC during the September 20, 2010 workshop and initially narrowed the curve search to curves developed for the Tuolumne River and neighboring Stanislaus River. The similarity between the two data sets, and their similarity to the central tendency of other data sets, was not as great as the technical group had hoped, and some type of hybrid curve was considered. Decisions on depth and velocity HSC for this life stage had been deferred, pending review of the Tuolumne and Stanislaus reports that may provide some insight on reasons for the differences.

- Prior to the February 3, 2011 meeting, USFWS supplied additional background information for HSC they developed on the Yuba River, as well as additional unpublished HSC data they collected from Clear Creek.
- The group originally considered an "envelope" curve over the Stanislaus and Tuolumne curves, since the Stanislaus curve may have better correction for availability (being Category III curves), but the Tuolumne curve shows some greater utilization of higher velocities. When consensus was not reached, the group re-considered the Yuba River curves.
- **Velocity Decision**: The group concurred on the use of a modified Yuba River HSC curve for velocity (Tuol ENV). The modified curve was equal to the Yuba curve up to (2.0, 0.1), at which point the curve follows a straight line to (4.9, 0.0), the end point of the Tuolumne curve (see attached graphic and coordinate Table).
- **Depth**: The group did not come to consensus on the depth HSC curve. The most thoroughly discussed options included:
  1. An "envelope" over the Stanislaus and Tuolumne curves (Tuol ENV)
  2. Use an average between the envelope curve (Tuol ENV) and Yuba curves using the ascending limb of the Stanislaus curve, over to the Yuba curve at (1.1, 1.0) and down between the average of Tuol ENV and Yuba curves (Tuol MOD)
  3. Use the ascending limb of the Stanislaus curve, then the descending limb of the Yuba curve.

  Lacking consensus on this parameter, the Districts plan to apply option #2, since this option seemed to have the broadest support among the stakeholders present at the workshop.
- **Cover**: The group discussed the idea of using existing cover codes. Because of limited availability of published cover HSC and wide variation in codes, this item had been previously discussed as data to collect during field surveys in 2011, rather than trying to adapt other coding systems. Existing curves from the Yuba River and Clear Creek were presented by USFWS. The applicability, complexity, and sample size of the various cover code data were discussed. Possible use of Sacramento River cover codes was discussed, although the data were not presented or reviewed. Stillwater will consider combining cover data from various sources (including the USFWS Sacramento River Data) into a simplified cover code that could be circulated for comment.


Chinook Salmon Fry
Probable Suitability
Mean Column Velocity (fps)
Stanislaus
L Tuolumne
Yuba (FWS)
Tuol ENV
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0

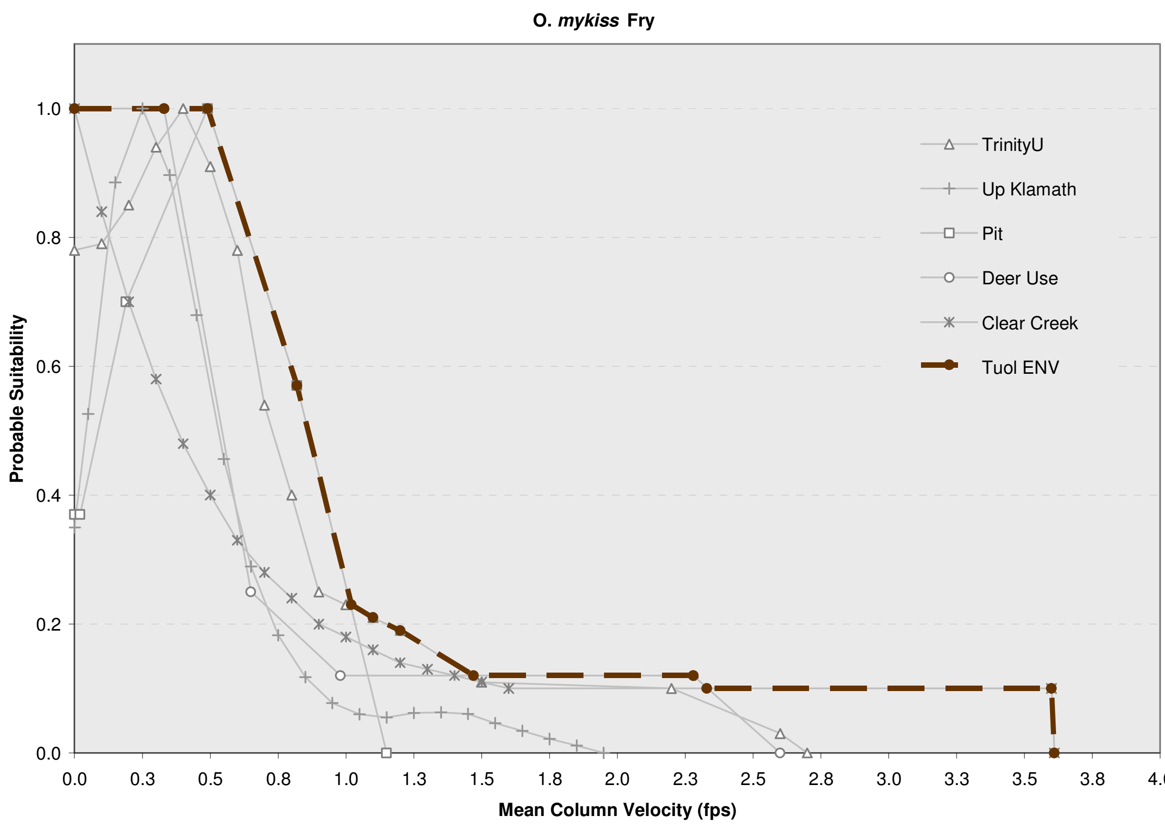

Chinook Salmon Fry
Probable Suitability
Depth (ft)
Stanislaus
L Tuolumne
Tuol ENV
Tuol MOD
Yuba (FWS)
0.0
0.2
0.4
0.6
0.8
1.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0

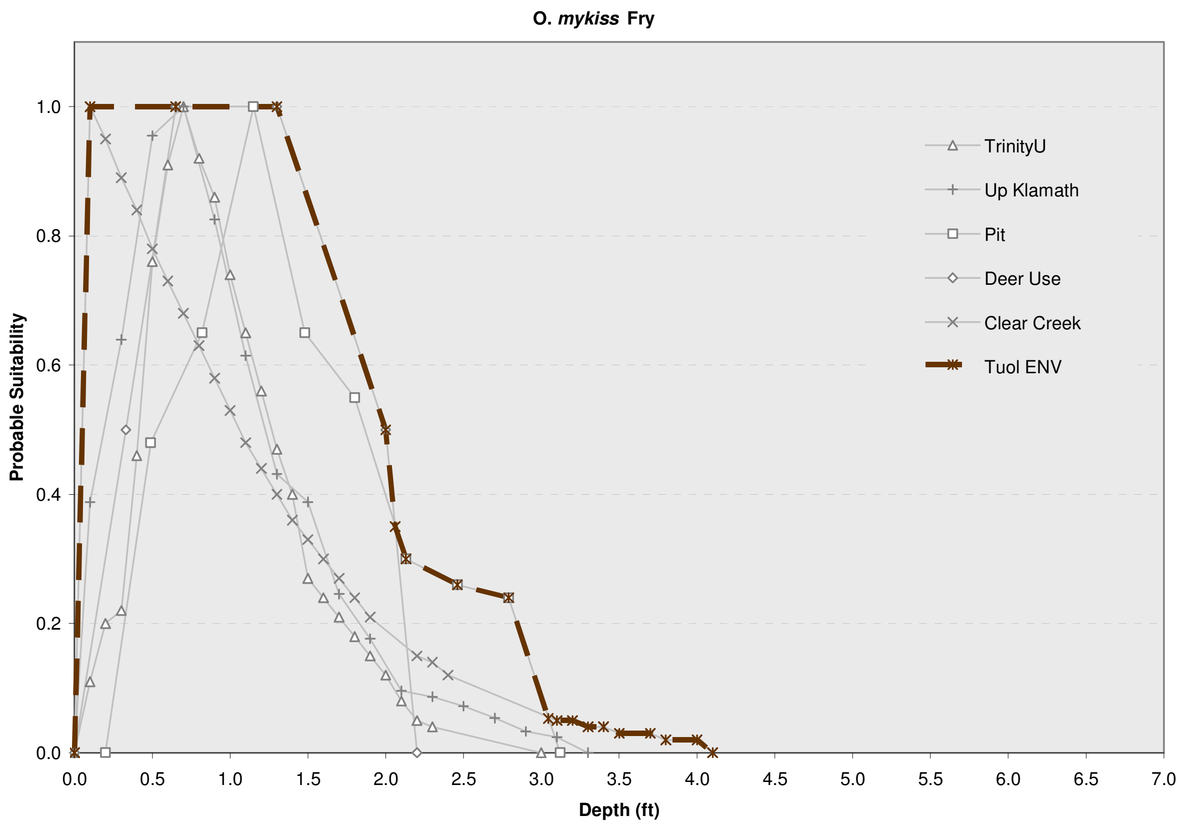
Chinook Salmon Fry: Velocity suitability criteria and three most discussed depth suitability criteria remaining following discussion on February 3, 2011

Tuol ENV		Tuol ENV		Tuol MOD		Yuba (FWS)	
Velocity	**Index**	**Depth**	**Index**	**Depth**	**Index**	**Depth**	**Index**
0	1	0.0	0.00	0.0	0.00	0.0	0.00
0.1	0.99	0.1	0.12	0.1	0.12	0.1	0.00
0.2	0.95	0.2	0.31	0.2	0.31	0.2	0.80
0.3	0.89	0.3	0.58	0.3	0.58	0.3	0.84
0.4	0.81	0.4	0.85	0.4	0.85	0.5	0.90
0.6	0.65	0.5	0.99	0.5	0.99	0.6	0.92
0.7	0.56	0.6	1.00	0.6	1.00	0.7	0.95
0.8	0.49	0.8	1.00	0.8	1.00	0.8	0.96
0.9	0.42	0.9	1.00	0.9	1.00	0.9	0.98
1.1	0.3	1.0	0.92	1.1	1.00	1.1	1.00
1.3	0.22	1.1	0.80	1.2	1.00	1.4	1.00
1.4	0.19	1.2	0.66	1.5	0.92	1.7	0.97
1.7	0.13	1.3	0.55	1.9	0.76	2.2	0.87
2	0.1	1.4	0.45	1.9	0.73	2.5	0.78
4.90	0.00	1.5	0.38	2.0	0.69	2.6	0.76
		1.6	0.32	2.3	0.55	2.7	0.73
		1.7	0.26	2.4	0.48	2.8	0.69
		1.8	0.21	2.5	0.45	3.5	0.48
		1.9	0.16	2.7	0.38	3.6	0.46
		2.0	0.16	3.1	0.26	3.8	0.40
		2.1	0.14	3.3	0.21	3.9	0.38
		2.2	0.11	3.3	0.2	4.0	0.35
		2.3	0.09	3.4	0.19	4.6	0.23
		2.4	0.07	3.4	0.17	4.7	0.22
		2.5	0.06	3.6	0.16	4.8	0.20
		2.6	0.05	3.7	0.14	4.9	0.19
		2.7	0.05	3.9	0.11	5.0	0.17
		2.8	0.04	4.3	0.07	5.7	0.10
		2.9	0.04	4.5	0.06	5.8	0.10
		3.0	0.03	4.6	0.05	6.0	0.08
		3.1	0.02	4.8	0.05	6.1	0.08
		6.4	0.02	5.1	0.04	6.2	0.07
		6.5	0.01	5.2	0.03	6.3	0.07
		6.6	0.00	5.6	0.02	6.4	0.06
				12.6	0.00	6.5	0.06
						6.6	0.05
						6.9	0.05
						7.0	0.04
						7.3	0.04
						7.4	0.03
						8.0	0.03
						8.1	0.02
						18.4	0.02
						18.5	0.00

O. mykiss Fry

- A wide range of HSC from various sources were reviewed during the October 20, 2010 HSC workshop that displayed similar results for fry. USFWS Yuba River curves were presented in the "filtered" data sets, but they varied from the central tendency of the other curves due to the statistical approach used to generate them. USFWS subsequently provided the report and curves with underlying fish utilization histograms for discussion.
- The USFWS suggested the workshop group drop the Yuba *O. mykiss* fry curves from consideration due to the limited number of observations, but to add USFWS unpublished Clear Creek fry curves instead.
- **Decision**: The workshop group concurred on the use of an envelope curve for both depth and velocity around the Trinity U., Up Klamath, Pit, Deer Use, and Clear Creek curves, generally following the most inclusive ("outside") parts of the curve.





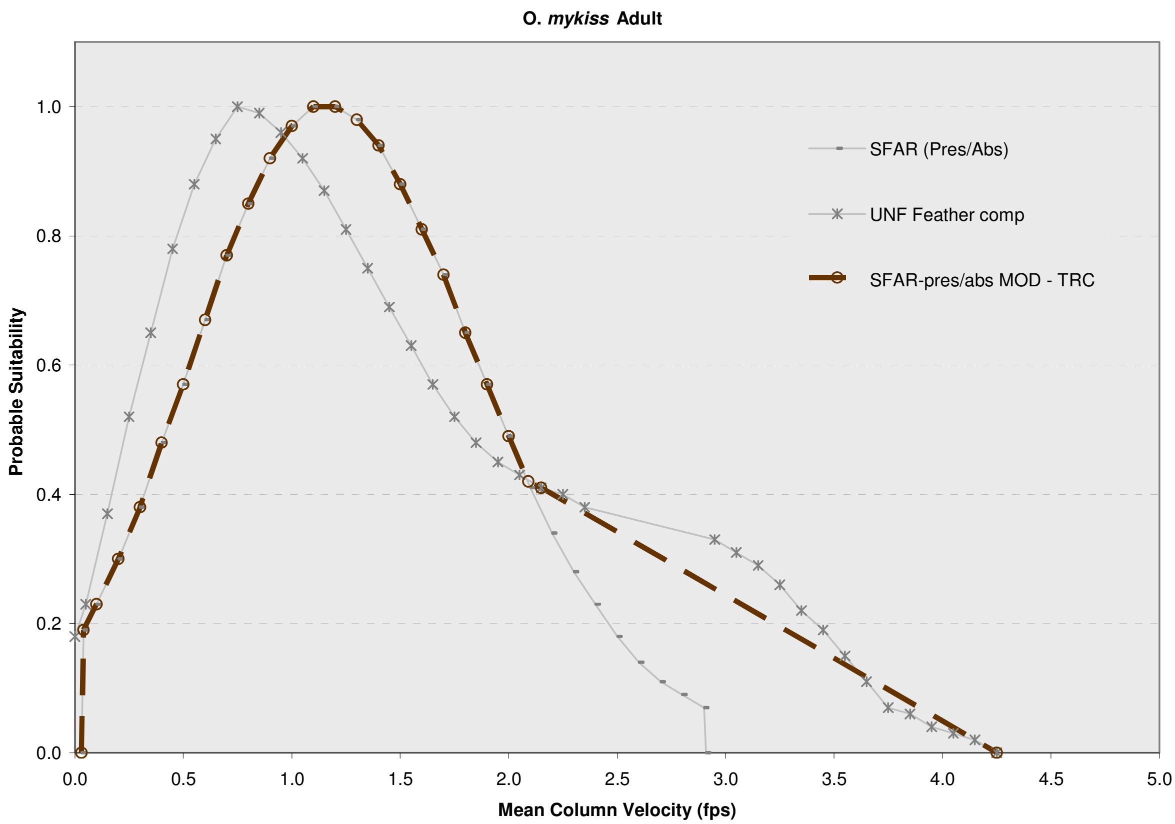
Tuolumne River suitability criteria for *O. mykiss* fry

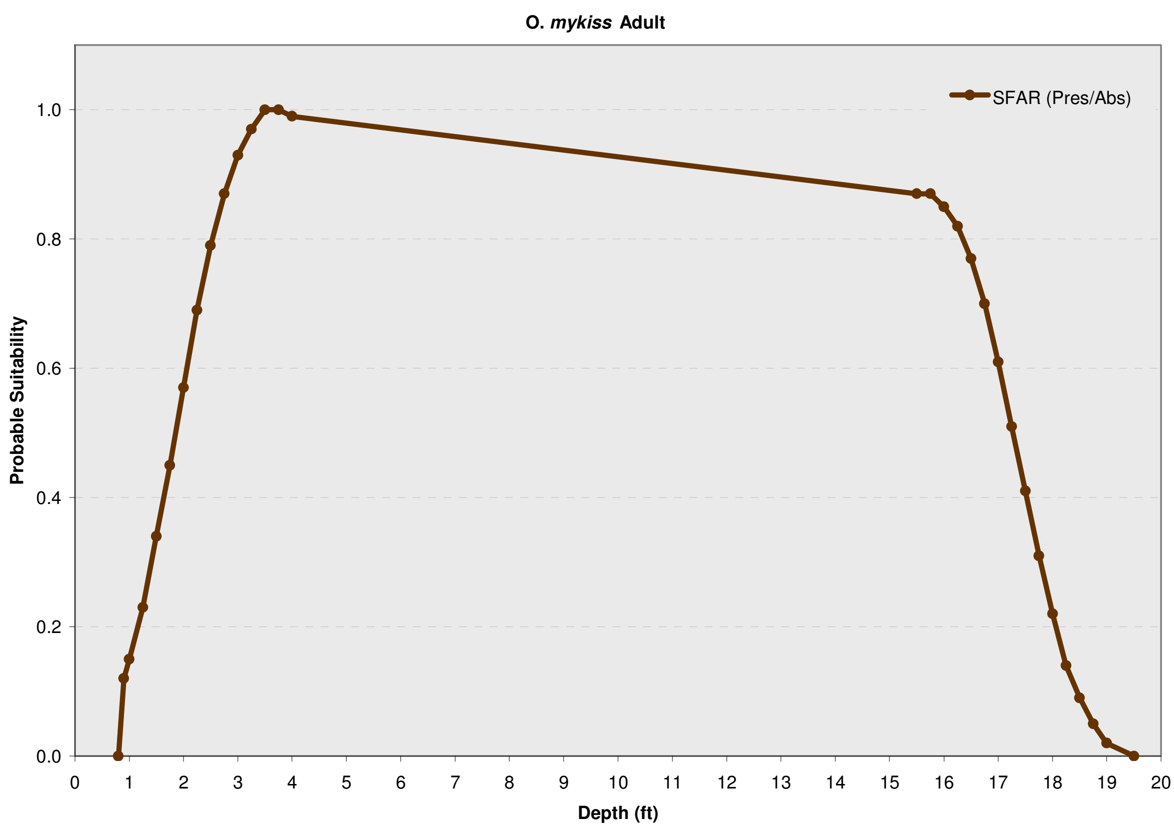
Velocity	Tuol ENV Index	Depth	Tuol ENV Index
0.00	1.00	0.00	0.00
0.33	1.00	0.10	1.00
0.49	1.00	0.65	1.00
0.82	0.57	1.30	1.00
1.02	0.23	2.00	0.50
1.10	0.21	2.06	0.35
1.20	0.19	2.13	0.30
1.47	0.12	2.46	0.26
2.28	0.12	2.79	0.24
2.33	0.10	3.05	0.05
3.60	0.10	3.10	0.05
3.61	0.00	3.20	0.05
		3.30	0.04
		3.40	0.04
		3.50	0.03
		3.70	0.03
		3.80	0.02
		4.00	0.02
		4.10	0.00

***O. mykiss* Adult**

- The workshop group had previously discussed use of the South Fork American River Logistic Regression (Pres/Abs) curves (SFAR Pres/Abs) proposed by the USFWS for both velocity and depth, and concurrence of the group was reported in the October 20, 2010 meeting summary. TRC suggested that the reported concurrence was in error in regard to their opinion, so the group re-opened the discussion.
- **Decision**: In response to TRC requests, the workgroup agreed to keep the South Fork American River Logistic Regression (Pres/Abs) curve (SFAR Pres/Abs) for depth, and use a modified curve for velocity. The modified velocity curve (SFAR Pres/Abs MOD-TRC) was equal to the SFAR Pres/Abs curve up to its intersection with the Upper North Fork Feather River composite curve (2.09, 0.42), at which point the modified curve follows a straight line to (4.25, 0.0), the end point of the UNF Feather comp curve.

<u>Post-Workshop Correspondence</u>
Subsequent to this February 3, 2011 workshop, TRC transmitted the attached email (Attachment #1) dated March 20, 2011, withdrawing their support for *O. mykiss* decisions regarding habitat suitability criteria.


O. *mykiss* Adult
Probable Suitability
Mean Column Velocity (fps)
SFAR (Pres/Abs)
UNF Feather comp
SFAR-pres/abs MOD - TRC
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0


O. *mykiss* Adult
Probable Suitability
Depth (ft)
SFAR (Pres/Abs)
0.0
0.2
0.4
0.6
0.8
1.0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Tuolumne River suitability criteria for *O. mykiss* adults

Velocity	SFAR pres/abs MOD-TRC Index	Depth	SFAR (Pres/Abs) Index
0.03	0.00	0.80	0.00
0.04	0.19	0.90	0.12
0.10	0.23	1.00	0.15
0.20	0.30	1.25	0.23
0.30	0.38	1.50	0.34
0.40	0.48	1.75	0.45
0.50	0.57	2.00	0.57
0.60	0.67	2.25	0.69
0.70	0.77	2.50	0.79
0.80	0.85	2.75	0.87
0.90	0.92	3.00	0.93
1.00	0.97	3.25	0.97
1.10	1.00	3.50	1.00
1.20	1.00	3.75	1.00
1.30	0.98	4.00	0.99
1.40	0.94	15.50	0.87
1.50	0.88	15.75	0.87
1.60	0.81	16.00	0.85
1.70	0.74	16.25	0.82
1.80	0.65	16.50	0.77
1.90	0.57	16.75	0.70
2.00	0.49	17.00	0.61
2.09	0.42	17.25	0.51
2.15	0.41	17.50	0.41
4.25	0.00	17.75	0.31
		18.00	0.22
		18.25	0.14
		18.50	0.09
		18.75	0.05
		19.00	0.02
		19.50	0.00

HSC development status

The following table summarizes sources of HSC curves to be used in the Tuolumne River Instream Flow Study.

Species	Life Stage	Depth	Velocity	Substrate[1]	Cover
Fall Chinook salmon	Spawning	L Tuolumne Sept 20, 2010	L Tuolumne Sept 20, 2010	Tuol/Wentworth Sept 20, 2010[2]	--
	Juvenile	Stanislaus (modified) Sept 20, 2010	Stanislaus Sept 20, 2010	--	TBD
	Fry	Tuol ENV[3] Feb 03, 2011	Tuol ENV Feb 03, 2011	--	TBD
O. mykiss	Adult	SFAR Pres/Abs Oct 20, 2010	SFAR Pres/Abs Oct 20, 2010 or SFAR Pres/Abs MOD-TRC Feb 2, 2011[4]	--	TBD
	Spawning	Tuolumne ENV Oct 20, 2010	Tuolumne ENV Oct 20, 2010	Tuolumne ENV Oct 20, 2010	--
	Juvenile	Tuolumne ENV Oct 20, 2010	Tuolumne ENV Oct 20, 2010	--	TBD
	Fry	Tuol ENV Feb 03, 2011	Tuol ENV Feb 03, 2011	--	TBD

1 The workgroup decided not to apply substrate criteria to fry and juvenile life stages since they do not typically select habitat based on substrate and may occur over a full range of possibilities.

2 Adapted from CDFG 1982 with minor expansion to indicate suitability of 1-2 inch gravel.

3 Lacking consensus on this parameter, the Districts plan to apply the Tuolumne Envelope curve (Tuol ENV) since this option seemed to have the broadest support among the stakeholders present at the workshop.

4 Although TRC subsequently withdrew their support for *O. mykiss* HSC curves, the Districts tentatively plan to use, or at least include, the *O. mykiss* adult curve (SFAR Pres/Abs MOD-TRC) modified at TRC's request.

Upcoming meeting dates:

There are no additional HSC meetings scheduled at this time. Additional meetings may be required following the collection of field data in 2011.

Appendix F

Attachment 1

HSC Workshop Summary
February 3, 2011

Resource Agency and Stakeholder Concurrence on Selection Summary

From: Allison Boucher [mailto:aboucher@bendbroadband.com]
Sent: Sunday, March 20, 2011 4:39 PM
To: Zachary_Jackson@fws.gov; wsears@sfwater.org; Whittaker, John; Wayne Swaney; walterw@mid.org; tramirez@sfwater.org; Tim O'Laughlin; theyne@dfg.ca.gov; stsao@dfg.ca.gov; steve@mlode.com; Shaara Ainsley; Scott@mcbaintrush.com; Scott Wilcox; Russell Liebig; Russ Kanz; Robert W. Hughes; rmyoshiyama@ucdavis.edu; rmnees@tid.org; rmasuda@calwaterlaw.com; Ramon_Martin@fws.gov; pbrantley@dfg.ca.gov; Patrick@tuolumne.org; Nsandkulla@bawsca.org; Noah Hume; Monica.Gutierrez@noaa.gov; Michelle_Workman@fws.gov; Mark_Gard@fws.gov; Maria Rea; kim_webb@fws.gov; Kelleigh Crowe; Karlha@tuolumne.org; jvick@sfwater.org; joyw@mid.org; john.devine@hdrinc.com; JMEANS@dfg.ca.gov; jkobrien@dfg.ca.gov; Jessie Raeder; Jesse.roseman@tuolumne.org; jen@riversandwater.com; Jarvis Caldwell; Greg Dias; Gantenbein@n-h-i.org; Erich Gaedeke; Eric@tuolumne.org; Donn Furman; dmarston@dfg.ca.gov; deltakeep@aol.com; deborah_giglio@fws.gov; Darren@mcbaintrush.com; Cindy@ccharles.net; chrissysonke@fishbio.com; Chris Shutes; andreafuller@fishbio.com; anadromous@bendbroadband.com; Alison_Willy@fws.gov; AJensen@bawsca.org; agengr6@aol.com
Cc: dave Boucher
Subject: IFIM O. mykiss

To all interested parties,

After much consideration, we are withdrawing our support for the IFIM O. mykiss decisions. We are not comfortable with the available studies and the resulting decisions.

We look forward to future meetings to discuss Tuolumne River O. mykiss, particularly steelhead.

Allison and Dave Boucher
Tuolumne River Conservancy, Inc.

Appendix G

Supplemental Habitat Suitability Index Information

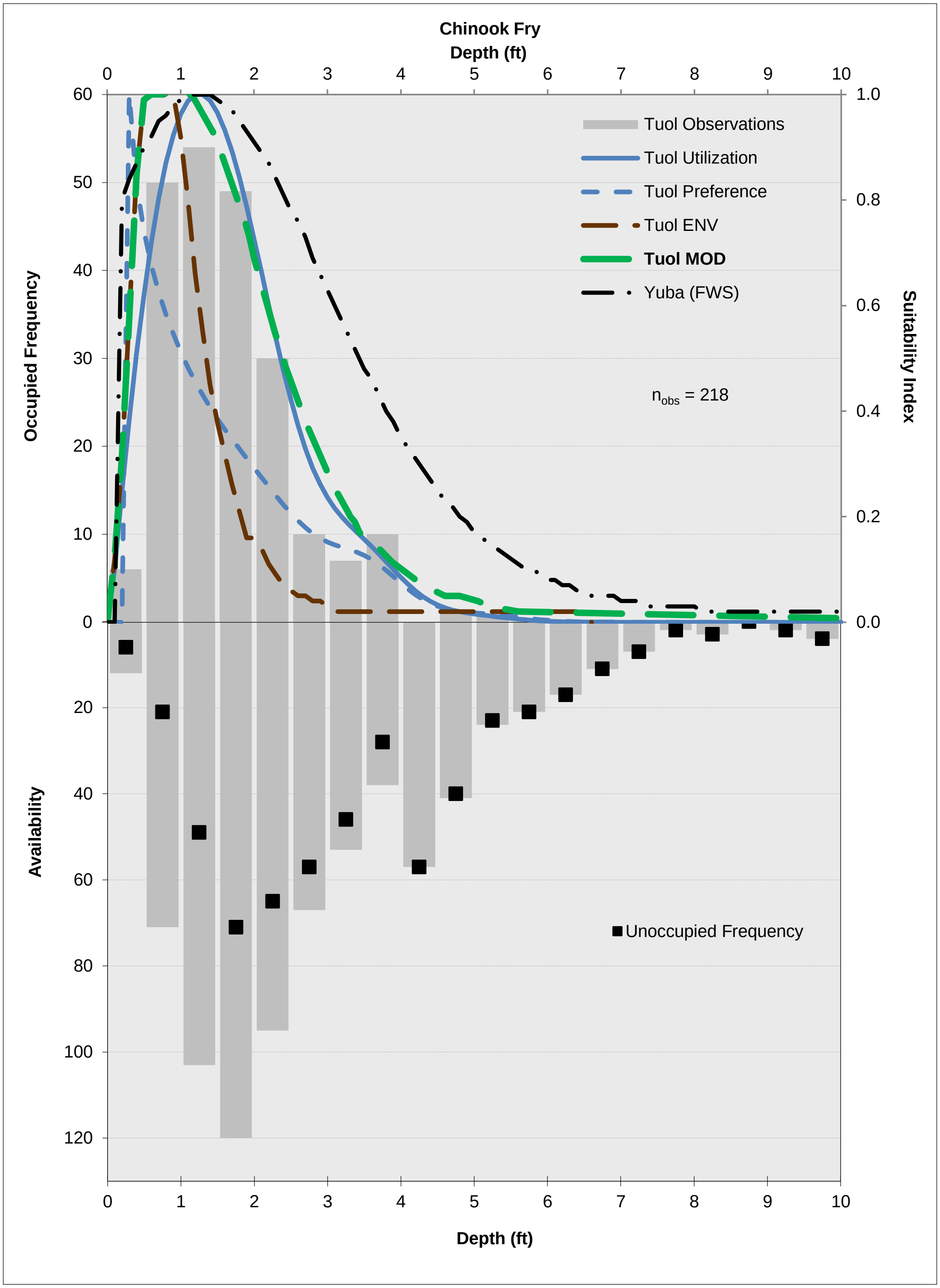


Figure G-1. Chinook salmon fry depth suitability criteria for the lower Tuolumne River; curve applied in the PHABSIM model was Tuol MOD.

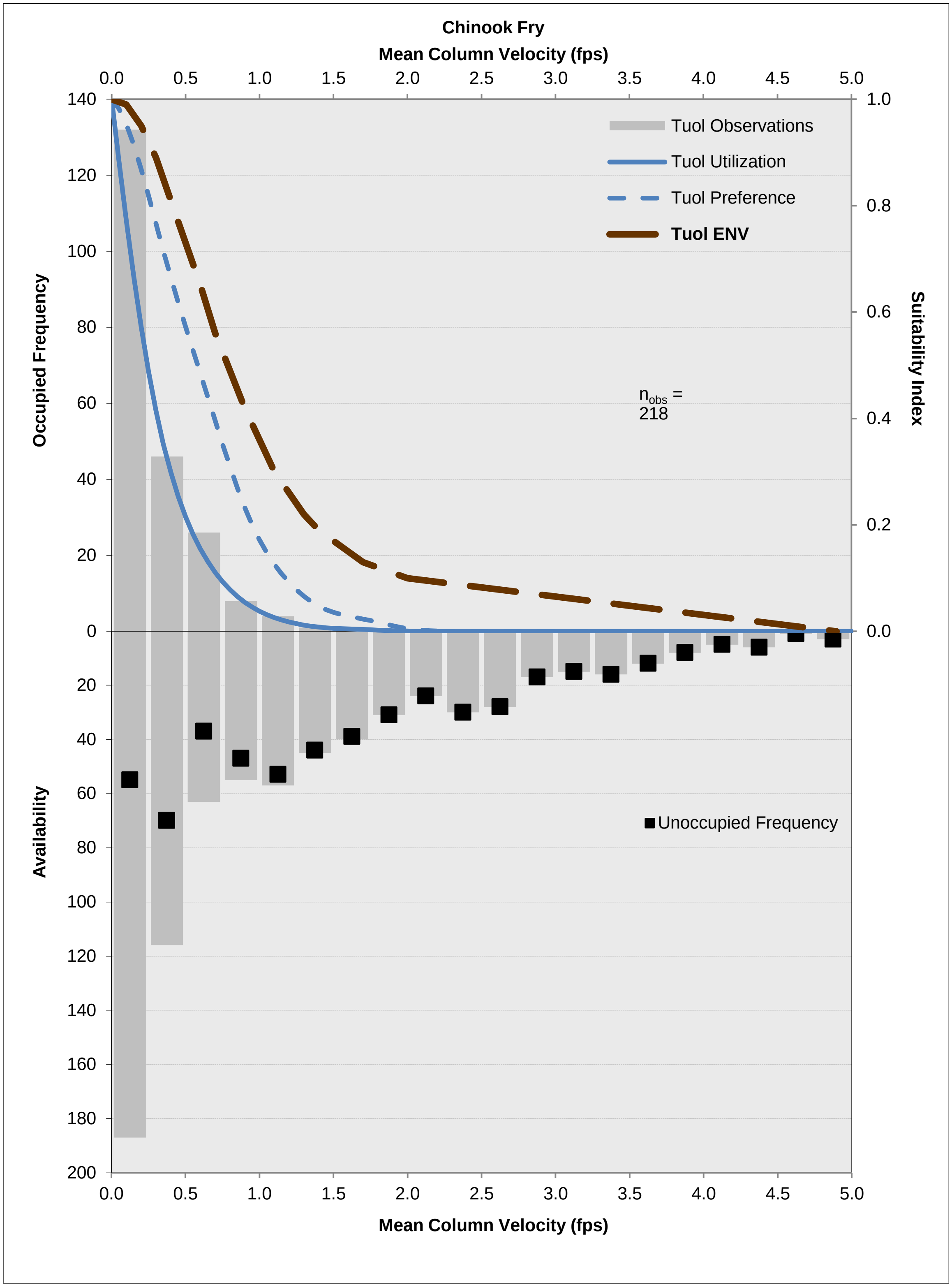


Figure G-2. Chinook salmon fry velocity suitability criteria for the lower Tuolumne River; curve applied in the PHABSIM model was Tuol ENV.

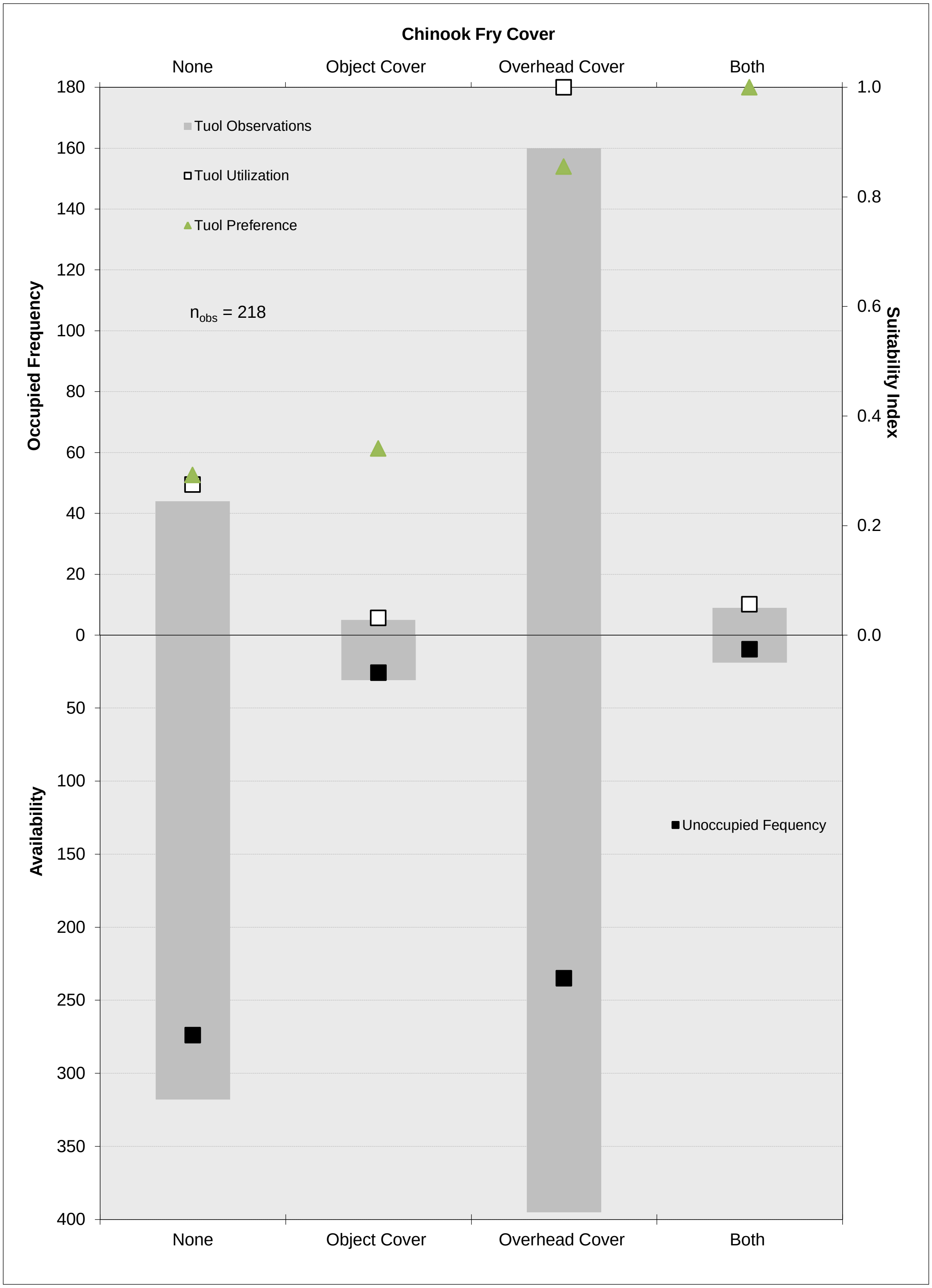


Figure G-3. Chinook salmon fry cover suitability criteria for the lower Tuolumne River.

Table G-1. Chinook fry habitat suitability criteria coordinates.

Tuolumne Site-specific			Tuolumne Env		Tuolumne Site-specific			Tuolumne Env		Tuolumne MOD		Yuba (FWS)	
Not Used			Used		Not Used			Not Used		Used		Not Used	
Velocity (fps)	Utilization Index	Preference Index	Velocity (fps)	Index	Depth (ft)	Utilization Index	Preference Index	Depth (ft)	Index	Depth (ft)	Index	Depth (ft)	Index
0.00	1.00	1.00	0.0	1.00	0.0	0.00	0.00	0.0	0.00	0.0	0.00	0.0	0.00
0.05	0.88	0.98	0.1	0.99	0.1	0.10	0.00	0.1	0.12	0.1	0.12	0.1	0.00
0.10	0.77	0.95	0.2	0.95	0.2	0.25	0.00	0.2	0.31	0.2	0.31	0.2	0.80
0.15	0.67	0.91	0.3	0.89	0.3	0.38	1.00	0.3	0.58	0.3	0.58	0.3	0.84
0.20	0.57	0.87	0.4	0.81	0.4	0.51	0.83	0.4	0.85	0.4	0.85	0.5	0.90
0.25	0.49	0.82	0.6	0.65	0.5	0.62	0.74	0.5	0.99	0.5	0.99	0.6	0.92
0.30	0.42	0.77	0.7	0.56	0.6	0.72	0.68	0.6	1.00	0.6	1.00	0.7	0.95
0.35	0.35	0.72	0.8	0.49	0.7	0.80	0.63	0.8	1.00	0.8	1.00	0.8	0.96
0.40	0.30	0.67	0.9	0.42	0.8	0.87	0.58	0.9	1.00	0.9	1.00	0.9	0.98
0.45	0.25	0.62	1.1	0.3	0.9	0.92	0.55	1.0	0.92	1.1	1.00	1.1	1.00
0.50	0.22	0.57	1.3	0.22	1.0	0.96	0.51	1.1	0.80	1.2	1.00	1.4	1.00
0.55	0.18	0.53	1.4	0.19	1.1	0.99	0.48	1.2	0.66	1.5	0.92	1.7	0.97
0.60	0.16	0.48	1.7	0.13	1.2	1.00	0.46	1.3	0.55	1.9	0.76	2.2	0.87
0.65	0.13	0.44	2.0	0.10	1.3	1.00	0.43	1.4	0.45	1.9	0.73	2.5	0.78
0.70	0.11	0.40	4.90	0.00	1.4	0.99	0.41	1.5	0.38	2.0	0.69	2.6	0.76
0.75	0.09	0.35			1.5	0.97	0.39	1.6	0.32	2.3	0.55	2.7	0.73
0.80	0.08	0.31			1.6	0.93	0.37	1.7	0.26	2.4	0.48	2.8	0.69
0.85	0.07	0.27			1.7	0.89	0.35	1.8	0.21	2.5	0.45	3.5	0.48
0.90	0.05	0.23			1.8	0.84	0.33	1.9	0.16	2.7	0.38	3.6	0.46
0.95	0.05	0.20			1.9	0.79	0.31	2.0	0.16	3.1	0.26	3.8	0.40
1.00	0.04	0.17			2.0	0.73	0.29	2.1	0.14	3.3	0.21	3.9	0.38
1.05	0.03	0.15			2.1	0.66	0.27	2.2	0.11	3.3	0.2	4.0	0.35
1.10	0.03	0.13			2.2	0.60	0.26	2.3	0.09	3.4	0.19	4.6	0.23
1.15	0.02	0.11			2.3	0.54	0.24	2.4	0.07	3.4	0.17	4.7	0.22
1.20	0.02	0.09			2.4	0.48	0.22	2.5	0.06	3.6	0.16	4.8	0.20
1.25	0.01	0.08			2.5	0.42	0.21	2.6	0.05	3.7	0.14	4.9	0.19
1.30	0.01	0.07			2.6	0.37	0.19	2.7	0.05	3.9	0.11	5.0	0.17
1.35	0.01	0.06			2.7	0.33	0.18	2.8	0.04	4.3	0.07	5.7	0.10
1.40	0.01	0.05			2.8	0.29	0.17	2.9	0.04	4.5	0.06	5.8	0.10
1.45	0.01	0.04			2.9	0.26	0.16	3.0	0.03	4.6	0.05	6.0	0.08

Table G-1. Chinook fry habitat suitability criteria coordinates.

Tuolumne Site-specific			**Tuolumne Env**		**Tuolumne Site-specific**			**Tuolumne Env**		**Tuolumne MOD**		**Yuba (FWS)**	
Not Used			Used		Not Used			Not Used		Used		Not Used	
Velocity (fps)	**Utilization Index**	**Preference Index**	**Velocity (fps)**	**Index**	**Depth (ft)**	**Utilization Index**	**Preference Index**	**Depth (ft)**	**Index**	**Depth (ft)**	**Index**	**Depth (ft)**	**Index**
1.50	0.01	0.04			3.0	0.24	0.15	3.1	0.02	4.8	0.05	6.1	0.08
1.55	0.01	0.03			3.1	0.22	0.15	6.4	0.02	5.1	0.04	6.2	0.07
1.60	0.00	0.03			3.2	0.20	0.14	6.5	0.01	5.2	0.03	6.3	0.07
1.65	0.00	0.03			3.3	0.18	0.14	6.6	0.00	5.6	0.02	6.4	0.06
1.70	0.00	0.02			3.4	0.17	0.13			12.6	0.00	6.5	0.06
1.75	0.00	0.02			3.5	0.16	0.13					6.6	0.05
1.80	0.00	0.02			3.6	0.14	0.12					6.9	0.05
1.85	0.00	0.01			3.7	0.13	0.11					7.0	0.04
1.90	0.00	0.01			3.8	0.11	0.10					7.3	0.04
1.95	0.00	0.01			3.9	0.10	0.09					7.4	0.03
2.00	0.00	0.01			4.0	0.09	0.07					8.0	0.03
2.05	0.00	0.00			4.1	0.07	0.06					8.1	0.02
					4.2	0.06	0.05					18.4	0.02
					4.3	0.05	0.04					18.5	0.00
					4.4	0.04	0.04						
					4.5	0.03	0.03						
					4.6	0.03	0.03						
					4.7	0.02	0.02						
					4.8	0.02	0.02						
					4.9	0.02	0.02						
					5.0	0.02	0.02						
					5.1	0.01	0.02						
					5.2	0.01	0.02						
					5.3	0.01	0.01						
					5.4	0.01	0.01						
					5.5	0.01	0.01						
					5.6	0.01	0.01						
					5.7	0.00	0.01						
					5.8	0.00	0.01						
					5.9	0.00	0.00						

Table G-2. Chinook fry cover habitat suitability criteria developed during site-specific surveys on the lower Tuolumne River.

Cover Type	Utilization Index	Preference Index
None	0.28	0.29
Object Cover	0.03	0.34
Overhead Cover	1.00	0.86
Both	0.06	1.00

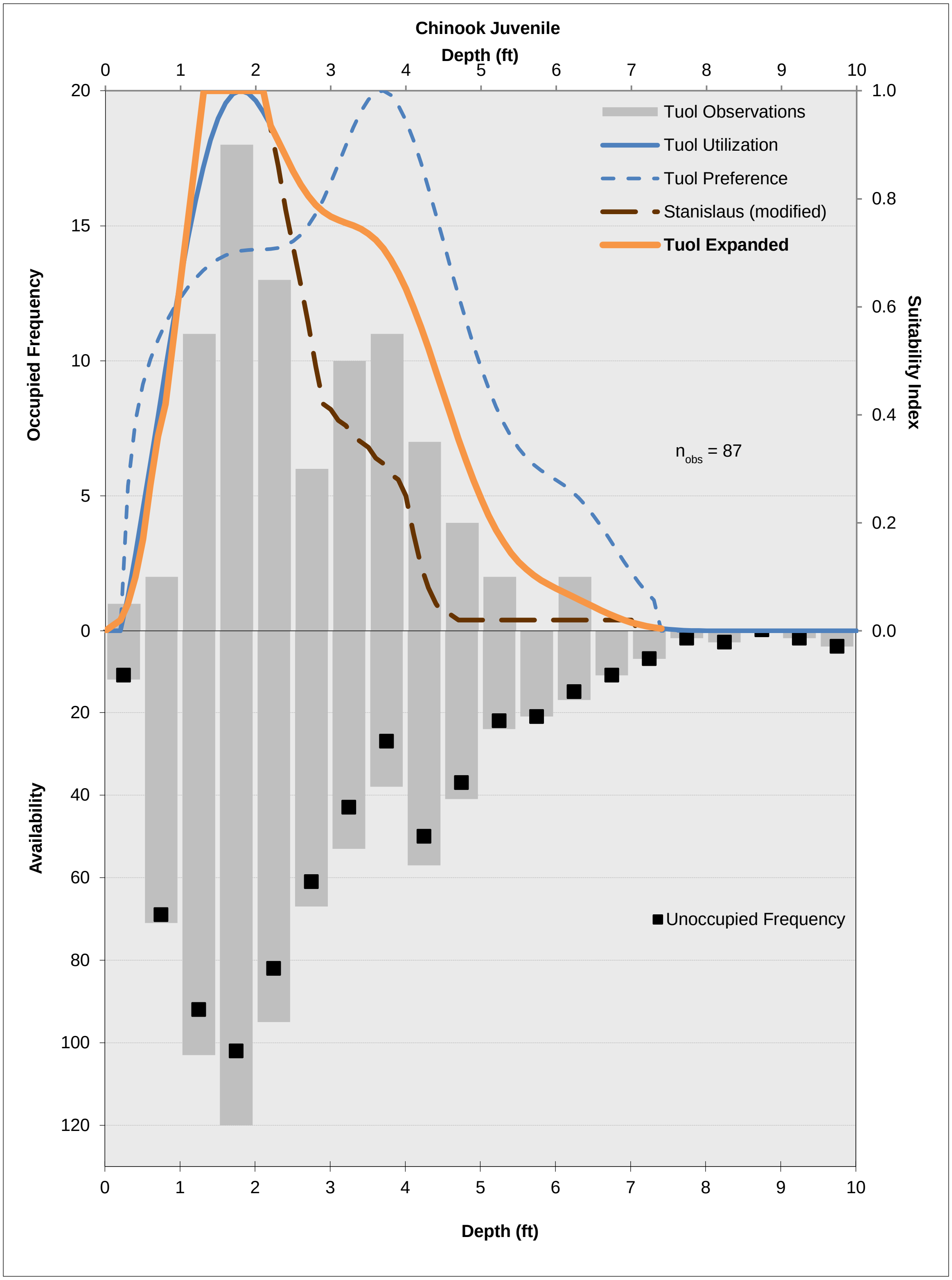


Figure G-4. Chinook salmon juvenile depth suitability criteria for the lower Tuolumne River; curve applied in the PHABSIM model was Tuol Expanded.

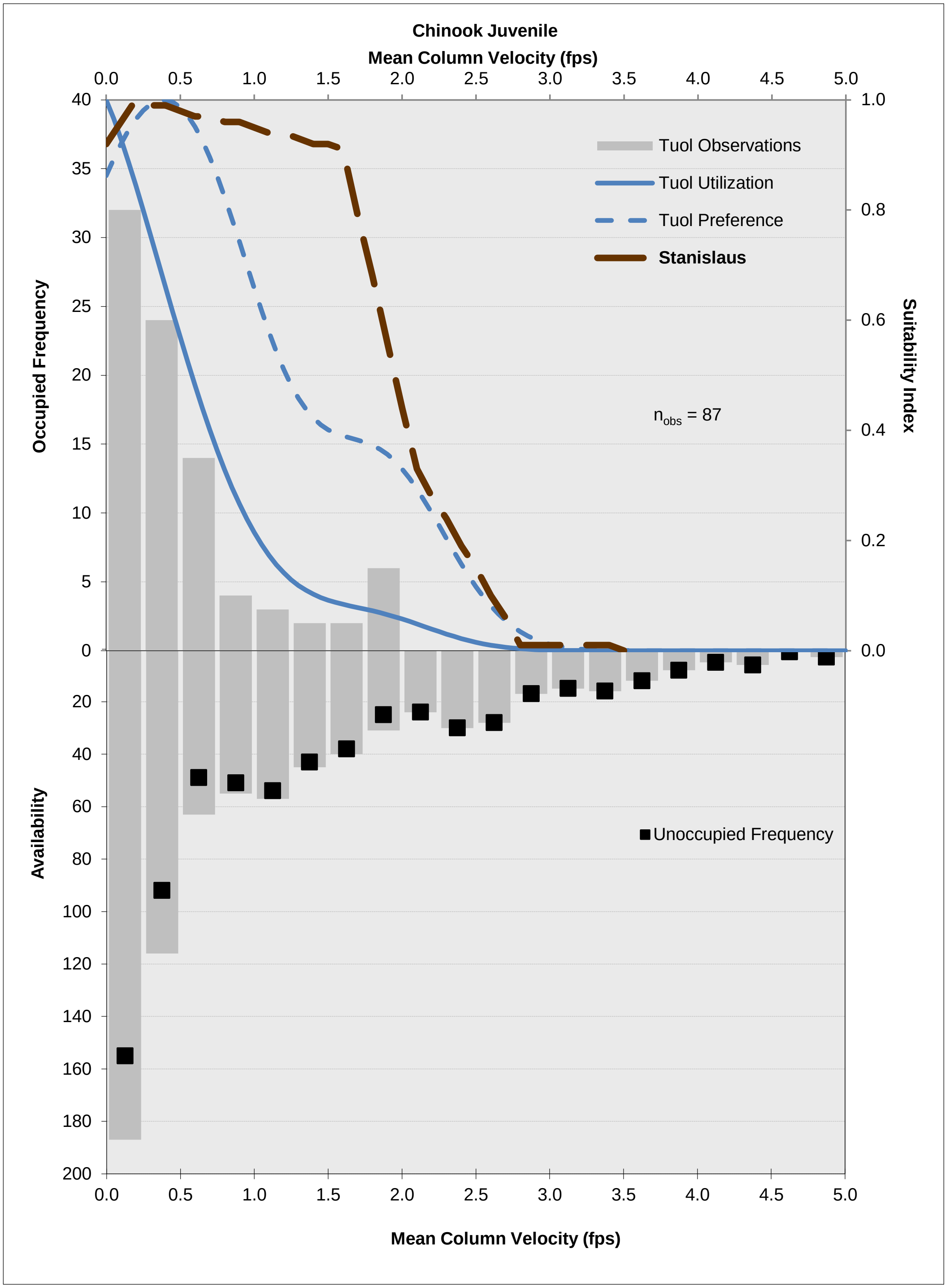


Figure G-5. Chinook salmon juvenile velocity suitability criteria for the lower Tuolumne River; curve applied in the PHABSIM model was Stanislaus.

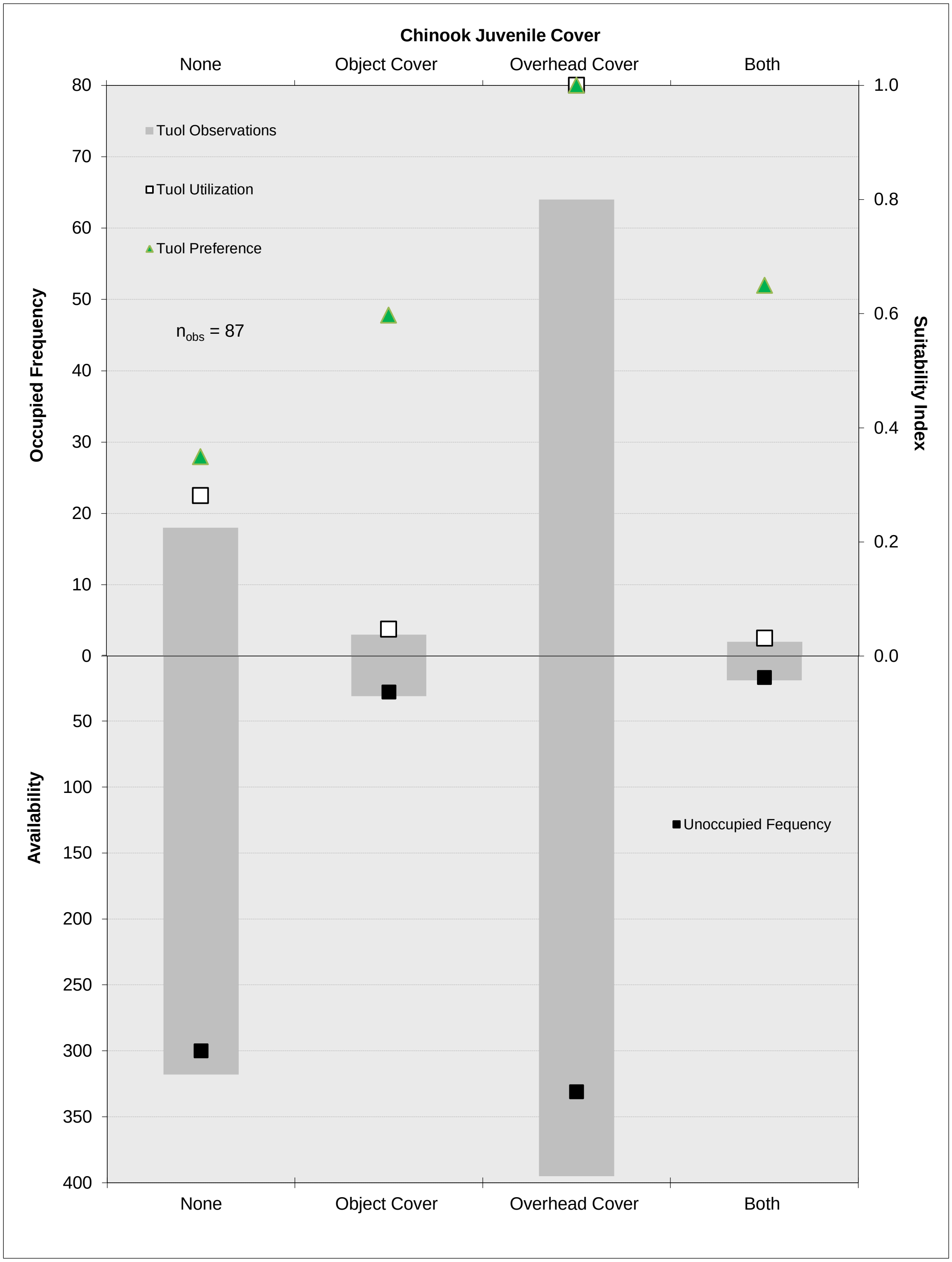


Figure G-6. Chinook salmon juvenile cover suitability criteria for the lower Tuolumne River.

Table G-3. Chinook salmon juvenile habitat suitability criteria coordinates.

Tuolumne Site-specific			Stanislaus		Tuolumne Site-specific			Stanislaus (modified)		Tuolumne Site-specific Expanded	
Not Used			Used		Not Used			Not Used		Used	
Velocity (fps)	Utilization Index	Preference Index	Velocity (fps)	Index	Depth (ft)	Utilization Index	Preference Index	Depth (ft)	Index	Depth (ft)	Index
0.00	1.00	0.86	0.0	0.92	0.0	0.00	0.00	0.00	0.00	0.0	0.00
0.05	0.97	0.89	0.1	0.96	0.1	0.00	0.00	0.10	0.01	0.1	0.01
0.10	0.93	0.92	0.2	1.00	0.2	0.00	0.00	0.20	0.02	0.2	0.02
0.15	0.89	0.94	0.3	0.99	0.3	0.06	0.27	0.30	0.05	0.3	0.05
0.20	0.84	0.96	0.4	0.99	0.4	0.14	0.39	0.40	0.10	0.4	0.10
0.25	0.80	0.98	0.5	0.98	0.5	0.23	0.46	0.50	0.17	0.5	0.17
0.30	0.75	0.99	0.6	0.97	0.6	0.31	0.50	0.60	0.27	0.6	0.27
0.35	0.71	1.00	0.7	0.97	0.7	0.40	0.54	0.70	0.36	0.7	0.36
0.40	0.66	1.00	0.8	0.96	0.8	0.48	0.57	0.80	0.42	0.8	0.42
0.45	0.61	1.00	0.9	0.96	0.9	0.57	0.59	1.31	1.00	1.3	1.00
0.50	0.57	0.99	1.0	0.95	1.0	0.65	0.62	2.10	1.00	2.1	1.00
0.55	0.52	0.97	1.1	0.94	1.1	0.73	0.64	2.20	0.93	2.2	0.94
0.60	0.48	0.95	1.2	0.94	1.2	0.80	0.65	2.30	0.86	2.3	0.91
0.65	0.44	0.93	1.3	0.93	1.3	0.86	0.67	2.40	0.78	2.4	0.88
0.70	0.40	0.90	1.4	0.92	1.4	0.91	0.68	2.50	0.71	2.5	0.85
0.75	0.36	0.86	1.5	0.92	1.5	0.95	0.69	2.60	0.64	2.6	0.83
0.80	0.33	0.82	1.6	0.91	1.6	0.98	0.70	2.70	0.57	2.7	0.81
0.85	0.30	0.78	1.7	0.79	1.7	0.99	0.70	2.80	0.49	2.8	0.79
0.90	0.27	0.74	1.8	0.68	1.8	1.00	0.70	2.90	0.42	2.9	0.78
0.95	0.24	0.70	1.9	0.56	1.9	1.00	0.71	3.00	0.41	3.0	0.77
1.00	0.21	0.66	2.0	0.44	2.0	0.98	0.71	3.10	0.39	3.1	0.76
1.05	0.19	0.62	2.1	0.33	2.1	0.96	0.71	3.20	0.38	3.2	0.76
1.10	0.17	0.58	2.2	0.28	2.2	0.94	0.71	3.30	0.36	3.3	0.75
1.15	0.16	0.54	2.3	0.24	2.3	0.91	0.71	3.40	0.35	3.4	0.74
1.20	0.14	0.51	2.4	0.19	2.4	0.88	0.71	3.50	0.34	3.5	0.74
1.25	0.13	0.48	2.5	0.15	2.5	0.85	0.72	3.60	0.32	3.6	0.72
1.30	0.12	0.46	2.6	0.10	2.6	0.83	0.73	3.70	0.31	3.7	0.71
1.35	0.11	0.44	2.7	0.06	2.7	0.81	0.75	3.80	0.29	3.8	0.69

Table G-3. Chinook salmon juvenile habitat suitability criteria coordinates.

Tuolumne Site-specific			**Stanislaus**		**Tuolumne Site-specific**			**Stanislaus (modified)**		**Tuolumne Site-specific Expanded**	
Not Used			Used		Not Used			Not Used		Used	
Velocity (fps)	**Utilization Index**	**Preference Index**	**Velocity (fps)**	**Index**	**Depth (ft)**	**Utilization Index**	**Preference Index**	**Depth (ft)**	**Index**	**Depth (ft)**	**Index**
1.40	0.10	0.42	2.8	0.01	2.8	0.79	0.77	3.90	0.28	3.9	0.66
1.45	0.10	0.41	3.4	0.01	2.9	0.78	0.80	4.00	0.25	4.0	0.63
1.50	0.09	0.40	3.5	0.00	3.0	0.77	0.83	4.10	0.18	4.1	0.60
1.55	0.09	0.39			3.1	0.76	0.86	4.20	0.12	4.2	0.56
1.60	0.08	0.39			3.2	0.76	0.90	4.30	0.08	4.3	0.52
1.65	0.08	0.39			3.3	0.75	0.93	4.40	0.05	4.4	0.48
1.70	0.08	0.38			3.4	0.74	0.96	4.50	0.03	4.5	0.44
1.75	0.08	0.38			3.5	0.74	0.98	4.60	0.03	4.6	0.40
1.80	0.07	0.37			3.6	0.72	1.00	4.70	0.02	4.7	0.36
1.85	0.07	0.37			3.7	0.71	1.00	7.00	0.02	4.8	0.32
1.90	0.07	0.36			3.8	0.69	0.99	7.10	0.00	4.9	0.28
1.95	0.06	0.34			3.9	0.66	0.97			5.0	0.24
2.00	0.06	0.33			4.0	0.63	0.94			5.1	0.21
2.05	0.05	0.31			4.1	0.60	0.91			5.2	0.19
2.10	0.05	0.29			4.2	0.56	0.87			5.3	0.16
2.15	0.04	0.27			4.3	0.52	0.82			5.4	0.14
2.20	0.04	0.25			4.4	0.48	0.77			5.5	0.13
2.25	0.03	0.23			4.5	0.44	0.72			5.6	0.11
2.30	0.03	0.20			4.6	0.40	0.67			5.7	0.10
2.35	0.03	0.18			4.7	0.36	0.62			5.8	0.09
2.40	0.02	0.16			4.8	0.32	0.57			5.9	0.09
2.45	0.02	0.14			4.9	0.28	0.53			6.0	0.08
2.50	0.02	0.12			5.0	0.24	0.49			6.1	0.07
2.55	0.01	0.10			5.1	0.21	0.45			6.2	0.06
2.60	0.01	0.08			5.2	0.19	0.41			6.3	0.06
2.65	0.01	0.07			5.3	0.16	0.38			6.4	0.05
2.70	0.01	0.05			5.4	0.14	0.36			6.5	0.04
2.75	0.00	0.04			5.5	0.13	0.34			6.6	0.04
2.80	0.00	0.03			5.6	0.11	0.32			6.7	0.03

Table G-3. Chinook salmon juvenile habitat suitability criteria coordinates.

Tuolumne Site-specific			Stanislaus		Tuolumne Site-specific			Stanislaus (modified)		Tuolumne Site-specific Expanded	
Not Used			Used		Not Used			Not Used		Used	
Velocity (fps)	Utilization Index	Preference Index	Velocity (fps)	Index	Depth (ft)	Utilization Index	Preference Index	Depth (ft)	Index	Depth (ft)	Index
2.85	0.00	0.03			5.7	0.10	0.31			6.8	0.03
2.90	0.00	0.02			5.8	0.09	0.30			6.9	0.02
2.95	0.00	0.02			5.9	0.09	0.29			7.0	0.02
3.00	0.00	0.01			6.0	0.08	0.28			7.1	0.01
3.05	0.00	0.01			6.1	0.07	0.27			7.2	0.01
3.10	0.00	0.01			6.2	0.06	0.26			7.3	0.01
3.15	0.00	0.00			6.3	0.06	0.25			7.4	0.00
					6.4	0.05	0.23				
					6.5	0.04	0.21				
					6.6	0.04	0.19				
					6.7	0.03	0.17				
					6.8	0.03	0.15				
					6.9	0.02	0.13				
					7.0	0.02	0.11				
					7.1	0.01	0.09				
					7.2	0.01	0.07				
					7.3	0.01	0.06				
					7.4	0.00	0.00				

Table G-4. Chinook salmon juvenile cover habitat suitability criteria developed during site-specific surveys on the lower Tuolumne River.

Cover Type	Utilization Index	Preference Index
None	0.28	0.35
Object Cover	0.05	0.60
Overhead Cover	1.00	1.00
Both	0.03	0.65

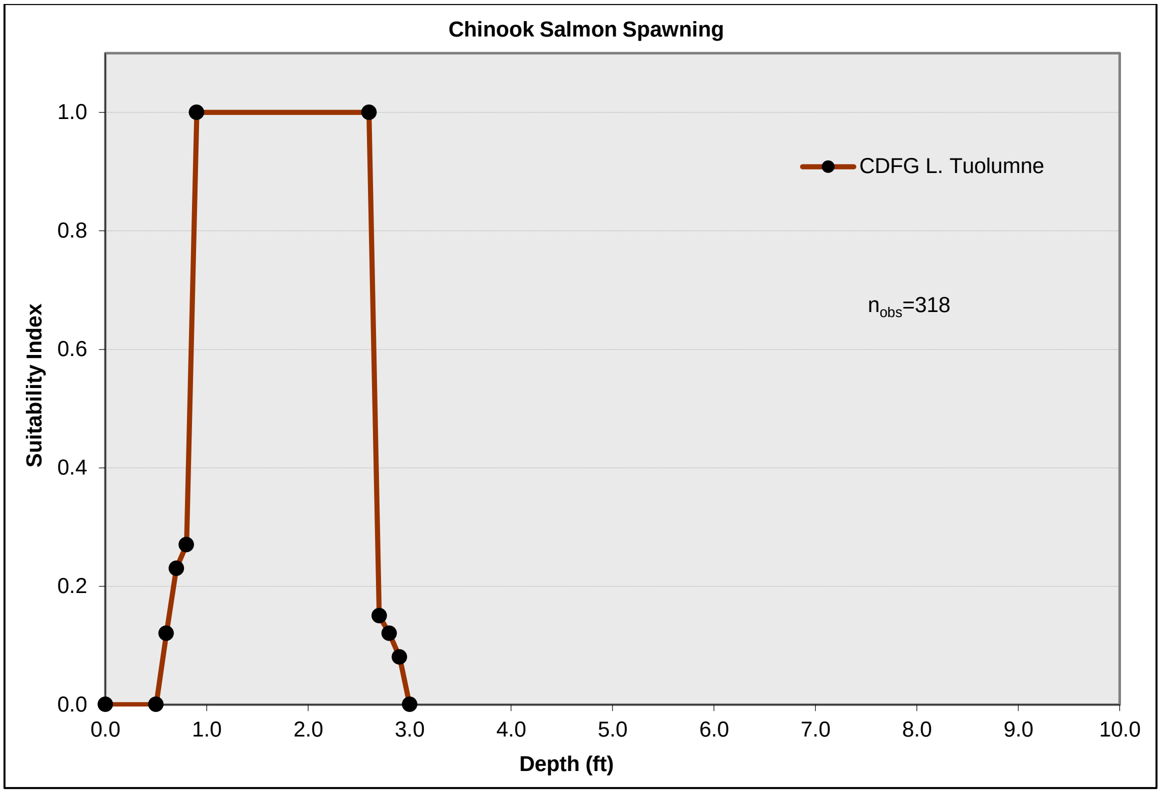


Figure G-7. Chinook salmon spawning depth suitability criteria for the lower Tuolumne River.

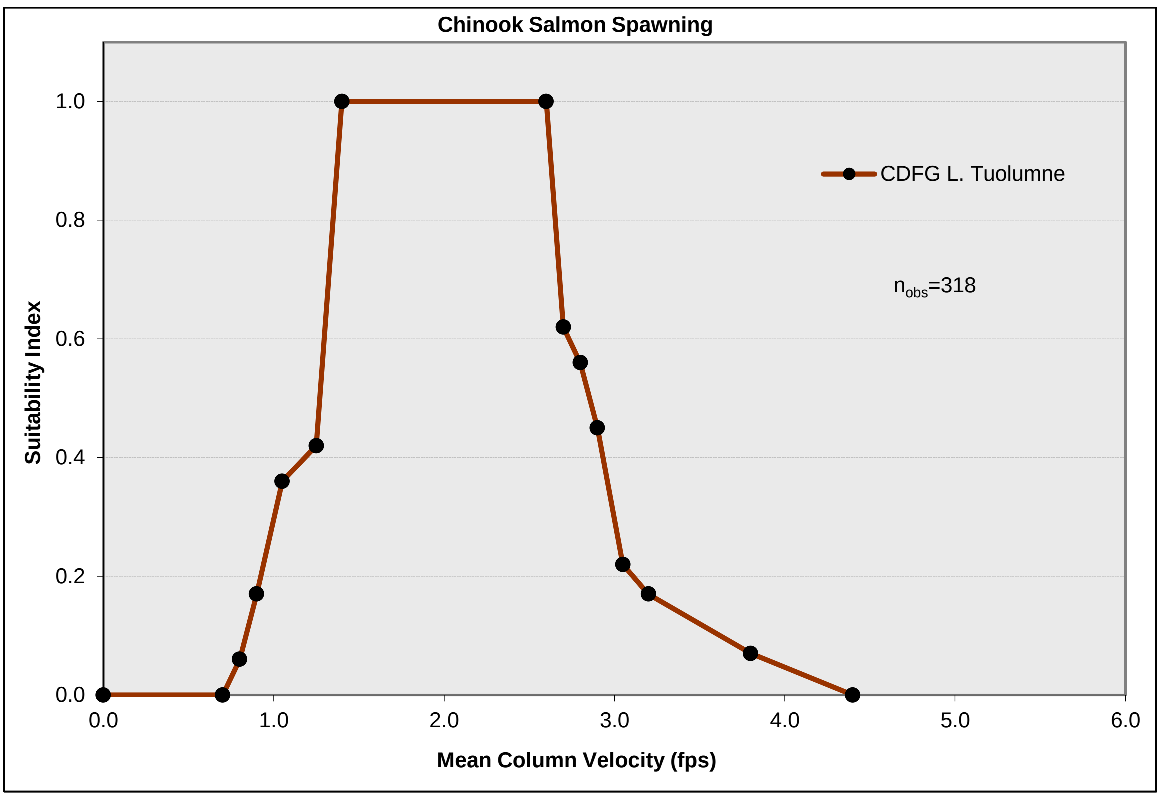


Figure G-8. Chinook salmon spawning velocity suitability criteria for the lower Tuolumne River.

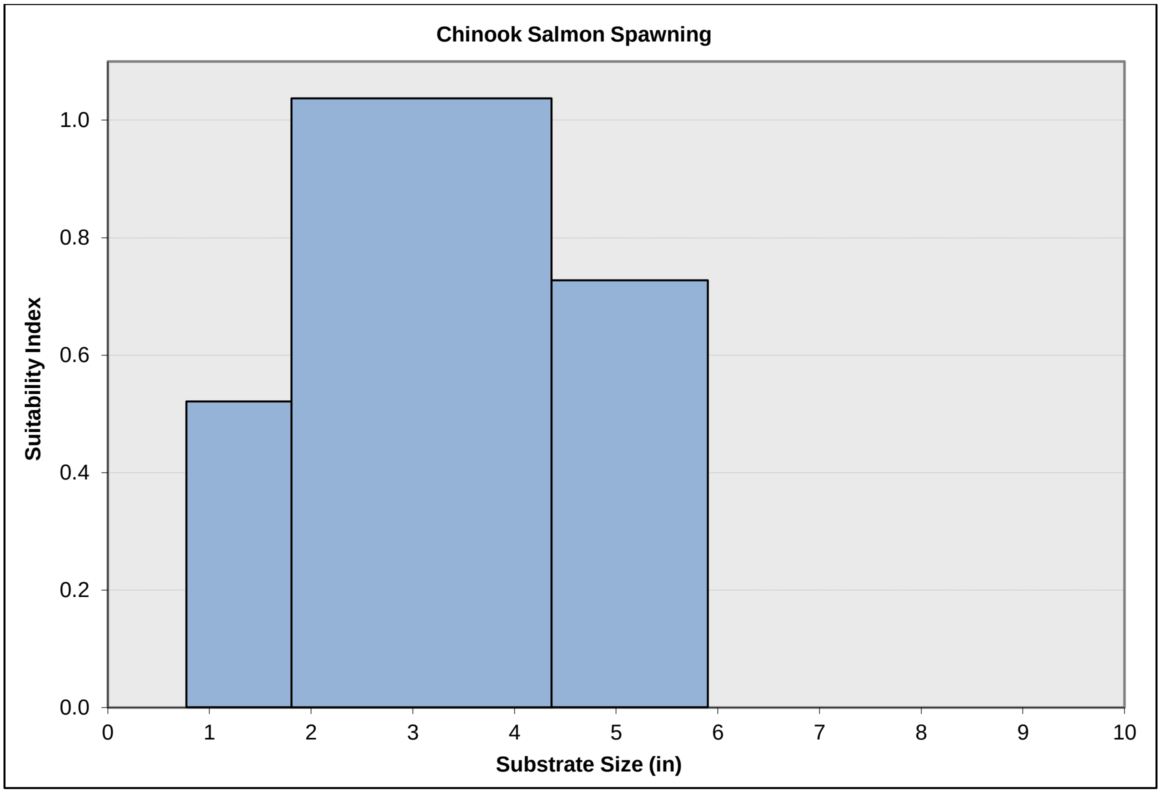


Figure G-9. Chinook salmon spawning substrate suitability criteria for the lower Tuolumne River.

Table G-5. Chinook spawning habitat suitability criteria.

L. Tuolumne CDFG		L. Tuolumne CDFG		Tuol/Wentworth*	
Used		Used		Used	
Velocity (fps)	**Index**	**Depth (ft)**	**Index**	**Substrate Size (in)**	**Index**
0.00	0.00	0.00	0.00	Up to 1.0	0.00
0.70	0.00	0.50	0.00	1-1.99	0.50
0.80	0.06	0.60	0.12	2-2.99	1.00
0.90	0.17	0.70	0.23	3 – 4.49	1.00
1.05	0.36	0.80	0.27	4.5-5.99	0.70
1.25	0.42	0.90	1.00	6-8.99	0.00
1.40	1.00	2.60	1.00	>9	0.00
2.60	1.00	2.70	0.15		
2.70	0.62	2.80	0.12		
2.80	0.56	2.90	0.08		
2.90	0.45	3.00	0.00		
3.05	0.22				
3.20	0.17				
3.80	0.07				
4.40	0.00				

* Adapted from CDFG 1982 with minor expansion to indicate suitability of 1-2 inch gravel.

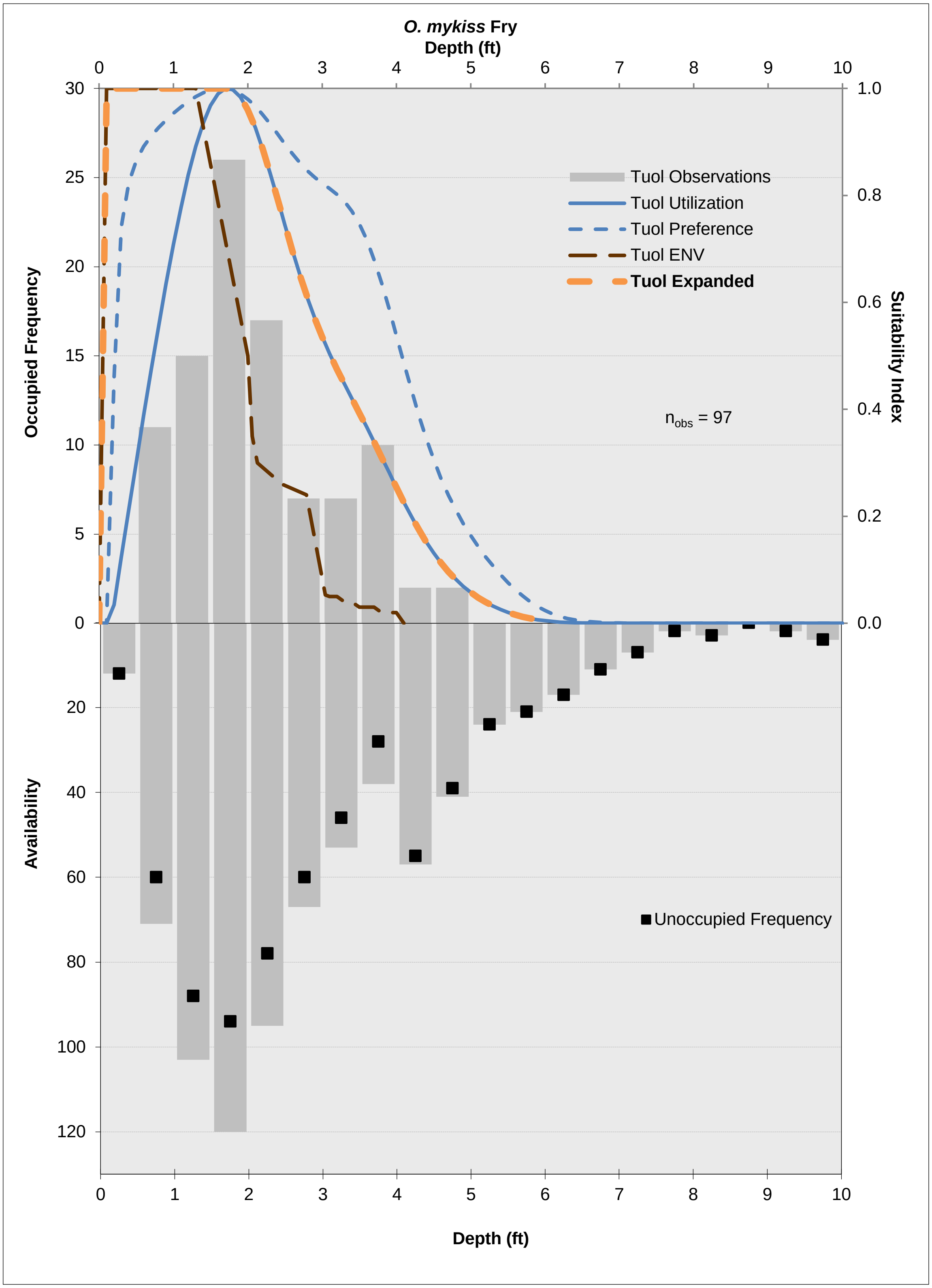


Figure G-10. *O. mykiss* fry depth suitability criteria for the lower Tuolumne River; curve applied in the PHABSIM model was Tuol Expanded.

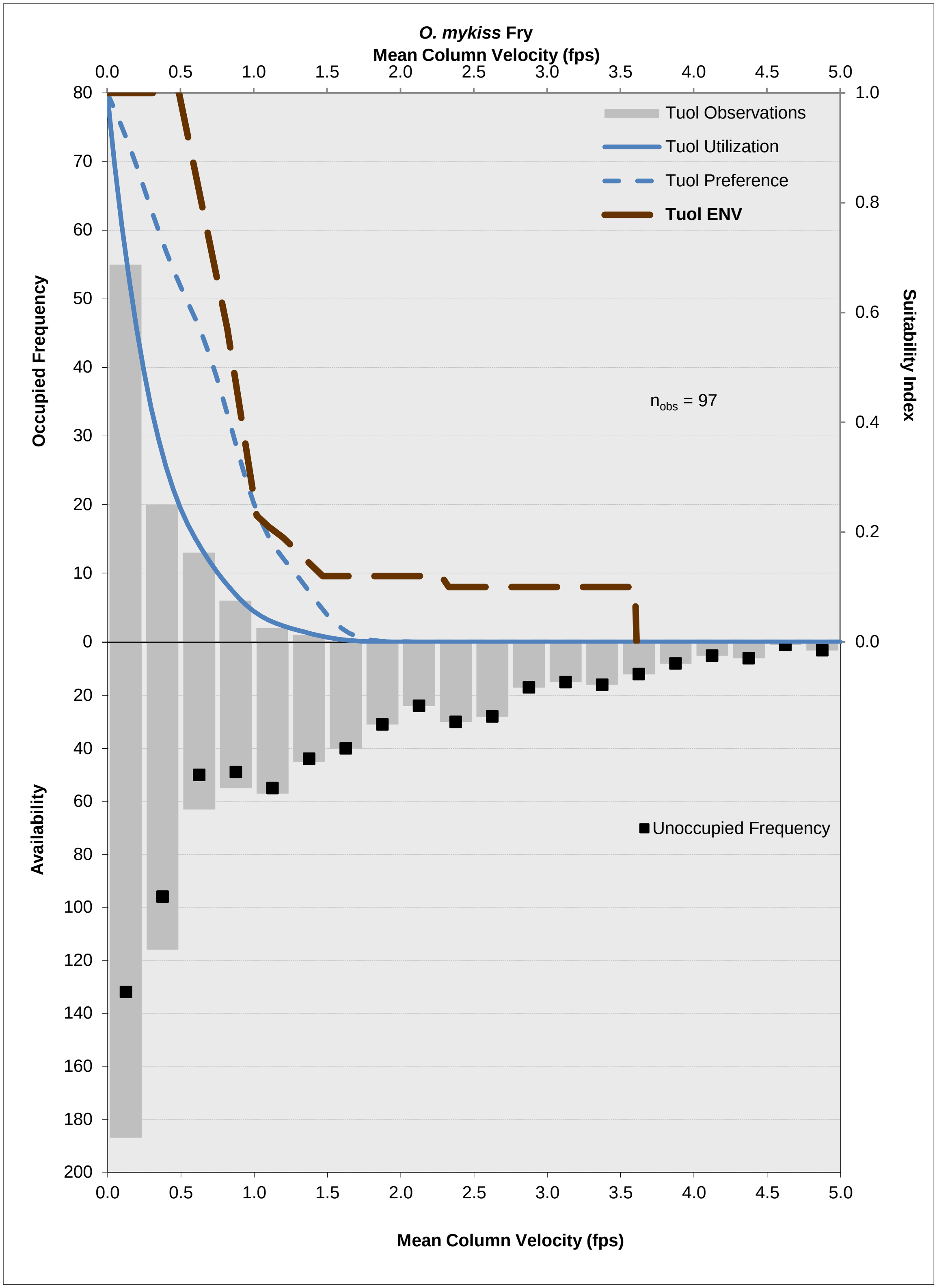


Figure G-11. *O. mykiss* fry velocity suitability criteria for the lower Tuolumne River; curve applied in the PHABSIM model was Tuol ENV.

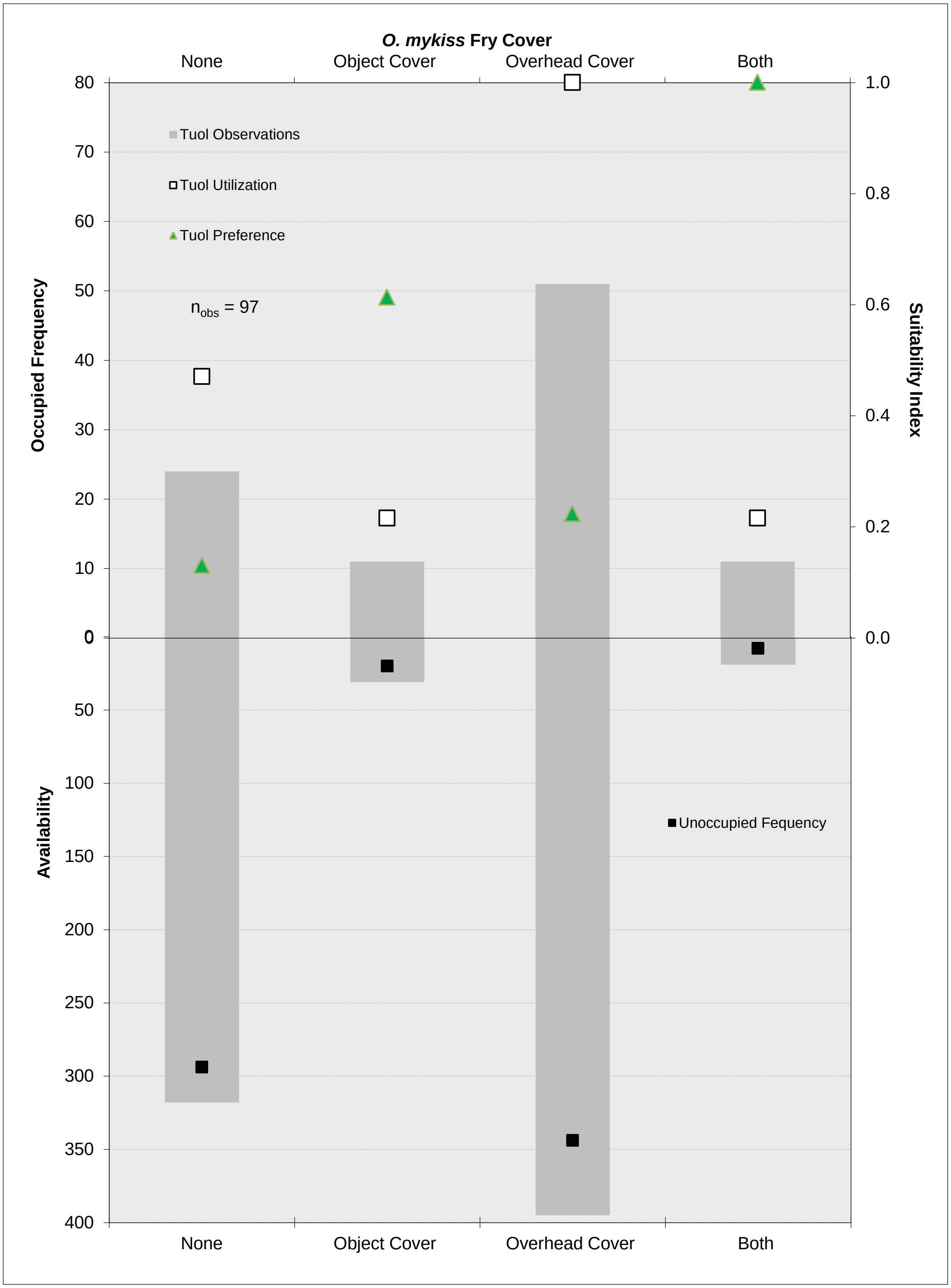


Figure G-12. *O. mykiss* fry cover suitability criteria for the lower Tuolumne River.

Table G-6. *O. mykiss* fry habitat suitability criteria coordinates.

Tuolumne Site-specific			Tuolumne Env		Tuolumne Site-specific			Tuolumne Env		Tuolumne Site-specific Expanded	
Not Used			Used		Not Used			Not Used		Used	
Velocity (fps)	**Utilization Index**	**Preference Index**	**Velocity (fps)**	**Index**	**Depth (ft)**	**Utilization Index**	**Preference Index**	**Depth (ft)**	**Index**	**Depth (ft)**	**Index**
0.00	1.00	1.00	0.00	1.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00
0.05	0.87	0.97	0.33	1.00	0.1	0.00	0.00	0.10	1.00	0.10	1.00
0.10	0.76	0.94	0.49	1.00	0.2	0.03	0.46	0.65	1.00	1.7	1.00
0.15	0.66	0.90	0.82	0.57	0.3	0.12	0.74	1.30	1.00	1.8	1.00
0.20	0.57	0.87	1.02	0.23	0.4	0.21	0.82	2.00	0.50	1.9	0.98
0.25	0.49	0.83	1.10	0.21	0.5	0.30	0.87	2.06	0.35	2.0	0.96
0.30	0.43	0.79	1.20	0.19	0.6	0.39	0.89	2.13	0.30	2.1	0.93
0.35	0.37	0.75	1.47	0.12	0.7	0.47	0.91	2.46	0.26	2.2	0.89
0.40	0.32	0.71	2.28	0.12	0.8	0.56	0.93	2.79	0.24	2.3	0.84
0.45	0.28	0.68	2.33	0.10	0.9	0.63	0.94	3.05	0.05	2.4	0.79
0.50	0.24	0.65	3.60	0.10	1.0	0.71	0.95	3.10	0.05	2.5	0.74
0.55	0.21	0.62	3.61	0.00	1.1	0.78	0.97	3.20	0.05	2.6	0.70
0.60	0.19	0.59	0.00	1.00	1.2	0.84	0.98	3.30	0.04	2.7	0.65
0.65	0.17	0.56	0.33	1.00	1.3	0.89	0.98	3.40	0.04	2.8	0.61
0.70	0.15	0.52	0.49	1.00	1.4	0.94	0.99	3.50	0.03	2.9	0.57
0.75	0.13	0.48	0.82	0.57	1.5	0.97	1.00	3.70	0.03	3.0	0.54
0.80	0.11	0.43	1.02	0.23	1.6	0.99	1.00	3.80	0.02	3.1	0.50
0.85	0.09	0.39	1.10	0.21	1.7	1.00	1.00	4.00	0.02	3.2	0.48
0.90	0.08	0.34	1.20	0.19	1.8	1.00	1.00	4.10	0.00	3.3	0.45
0.95	0.07	0.29	1.47	0.12	1.9	0.98	0.99			3.4	0.42
1.00	0.06	0.25	2.28	0.12	2.0	0.96	0.98			3.5	0.39
1.05	0.05	0.22	2.33	0.10	2.1	0.93	0.97			3.6	0.37
1.10	0.04	0.19	3.60	0.10	2.2	0.89	0.95			3.7	0.34
1.15	0.03	0.17	3.61	0.00	2.3	0.84	0.93			3.8	0.31
1.20	0.03	0.15			2.4	0.79	0.92			3.9	0.28
1.25	0.02	0.14			2.5	0.74	0.90			4.0	0.25
1.30	0.02	0.12			2.6	0.70	0.88			4.1	0.23
1.35	0.02	0.10			2.7	0.65	0.86			4.2	0.20
1.40	0.01	0.08			2.8	0.61	0.85			4.3	0.18

Table G-6. *O. mykiss* fry habitat suitability criteria coordinates.

Tuolumne Site-specific			Tuolumne Env		Tuolumne Site-specific			Tuolumne Env		Tuolumne Site-specific Expanded	
Not Used			Used		Not Used			Not Used		Used	
Velocity (fps)	**Utilization Index**	**Preference Index**	**Velocity (fps)**	**Index**	**Depth (ft)**	**Utilization Index**	**Preference Index**	**Depth (ft)**	**Index**	**Depth (ft)**	**Index**
1.45	0.01	0.07			2.9	0.57	0.83			4.4	0.15
1.50	0.01	0.05			3.0	0.54	0.82			4.5	0.13
1.55	0.01	0.04			3.1	0.50	0.81			4.6	0.11
1.60	0.00	0.02			3.2	0.48	0.80			4.7	0.10
1.65	0.00	0.02			3.3	0.45	0.79			4.8	0.08
1.70	0.00	0.01			3.4	0.42	0.77			4.9	0.07
1.75	0.00	0.01			3.5	0.39	0.75			5.0	0.06
1.80	0.00	0.00			3.6	0.37	0.72			5.1	0.05
					3.7	0.34	0.68			5.2	0.04
					3.8	0.31	0.64			5.3	0.03
					3.9	0.28	0.59			5.4	0.03
					4.0	0.25	0.54			5.5	0.02
					4.1	0.23	0.49			5.6	0.02
					4.2	0.20	0.44			5.7	0.01
					4.3	0.18	0.39			5.8	0.01
					4.4	0.15	0.35			5.9	0.01
					4.5	0.13	0.31			6.0	0.00
					4.6	0.11	0.27				
					4.7	0.10	0.24				
					4.8	0.08	0.21				
					4.9	0.07	0.19				
					5.0	0.06	0.16				
					5.1	0.05	0.14				
					5.2	0.04	0.12				
					5.3	0.03	0.11				
					5.4	0.03	0.09				
					5.5	0.02	0.08				
					5.6	0.02	0.06				
					5.7	0.01	0.05				

Table G-6. *O. mykiss* fry habitat suitability criteria coordinates.

Tuolumne Site-specific			Tuolumne Env		Tuolumne Site-specific			Tuolumne Env		Tuolumne Site-specific Expanded	
Not Used			Used		Not Used			Not Used		Used	
Velocity (fps)	**Utilization Index**	**Preference Index**	**Velocity (fps)**	**Index**	**Depth (ft)**	**Utilization Index**	**Preference Index**	**Depth (ft)**	**Index**	**Depth (ft)**	**Index**
					5.8	0.01	0.04				
					5.9	0.01	0.03				
					6.0	0.00	0.02				
					6.1	0.00	0.02				
					6.2	0.00	0.01				
					6.3	0.00	0.01				
					6.4	0.00	0.01				
					6.5	0.00	0.00				

Table G-7. *O. mykiss* fry cover habitat suitability criteria developed during site-specific surveys on the lower Tuolumne River.

Cover Type	Utilization Index	Preference Index
None	0.47	0.13
Object Cover	0.22	0.61
Overhead Cover	1.00	0.22
Both	0.22	1.00

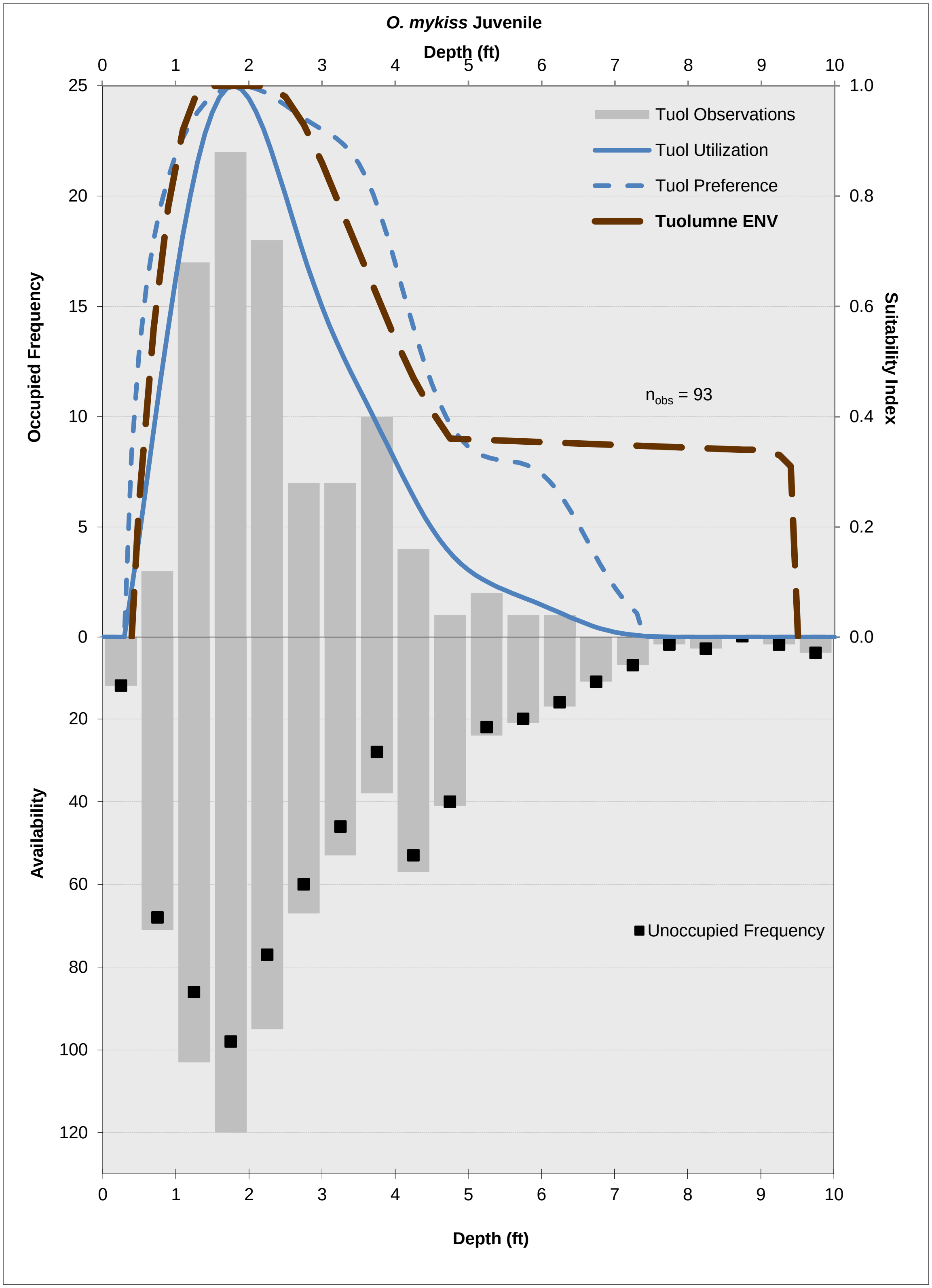


Figure G-13. *O. mykiss* juvenile depth suitability criteria for the lower Tuolumne River; curve applied in the PHABSIM model was Tuol ENV.

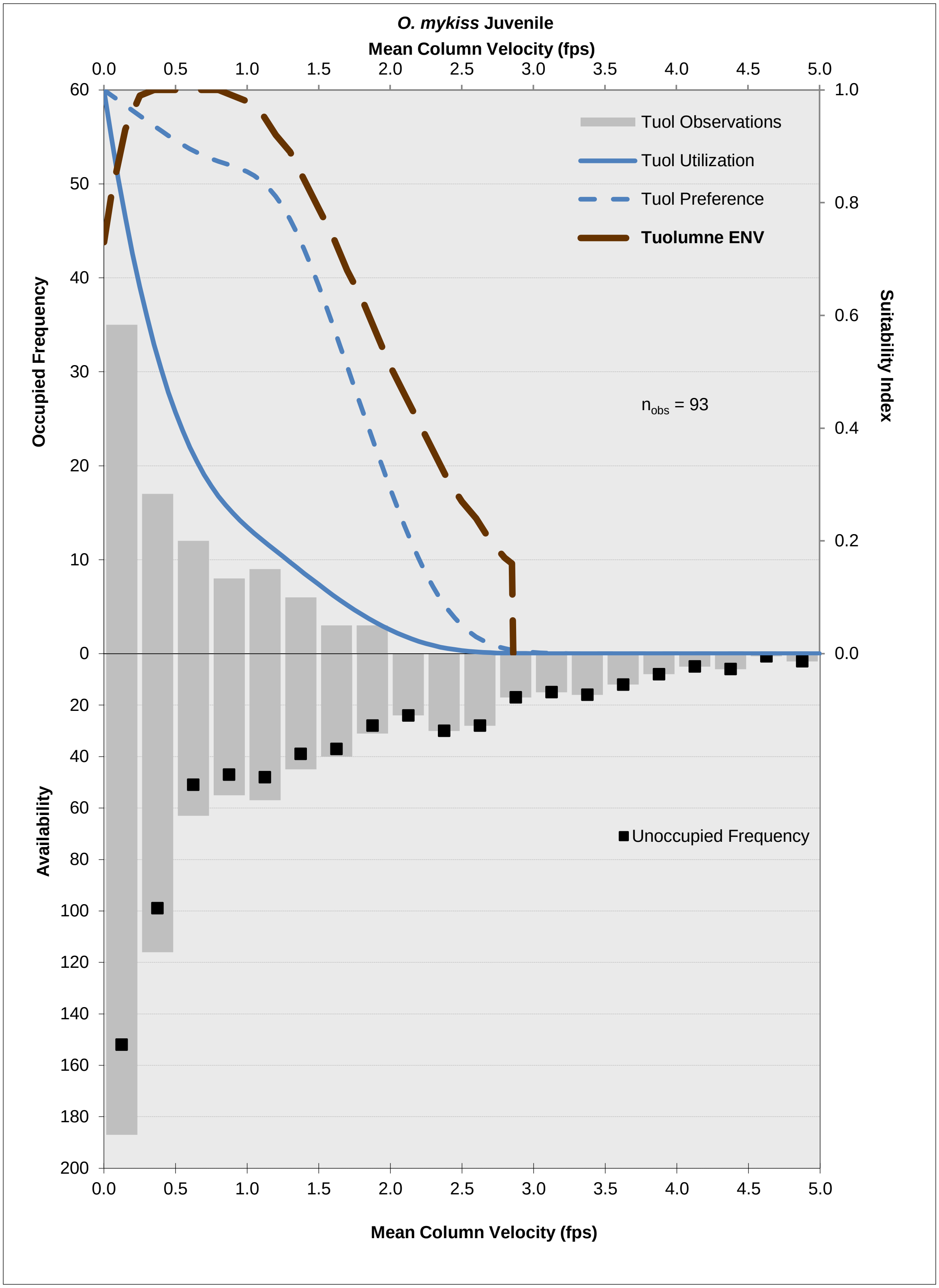


Figure G-14. *O. mykiss* juvenile velocity suitability criteria for the lower Tuolumne River; curve applied in the PHABSIM model was Tuol ENV.

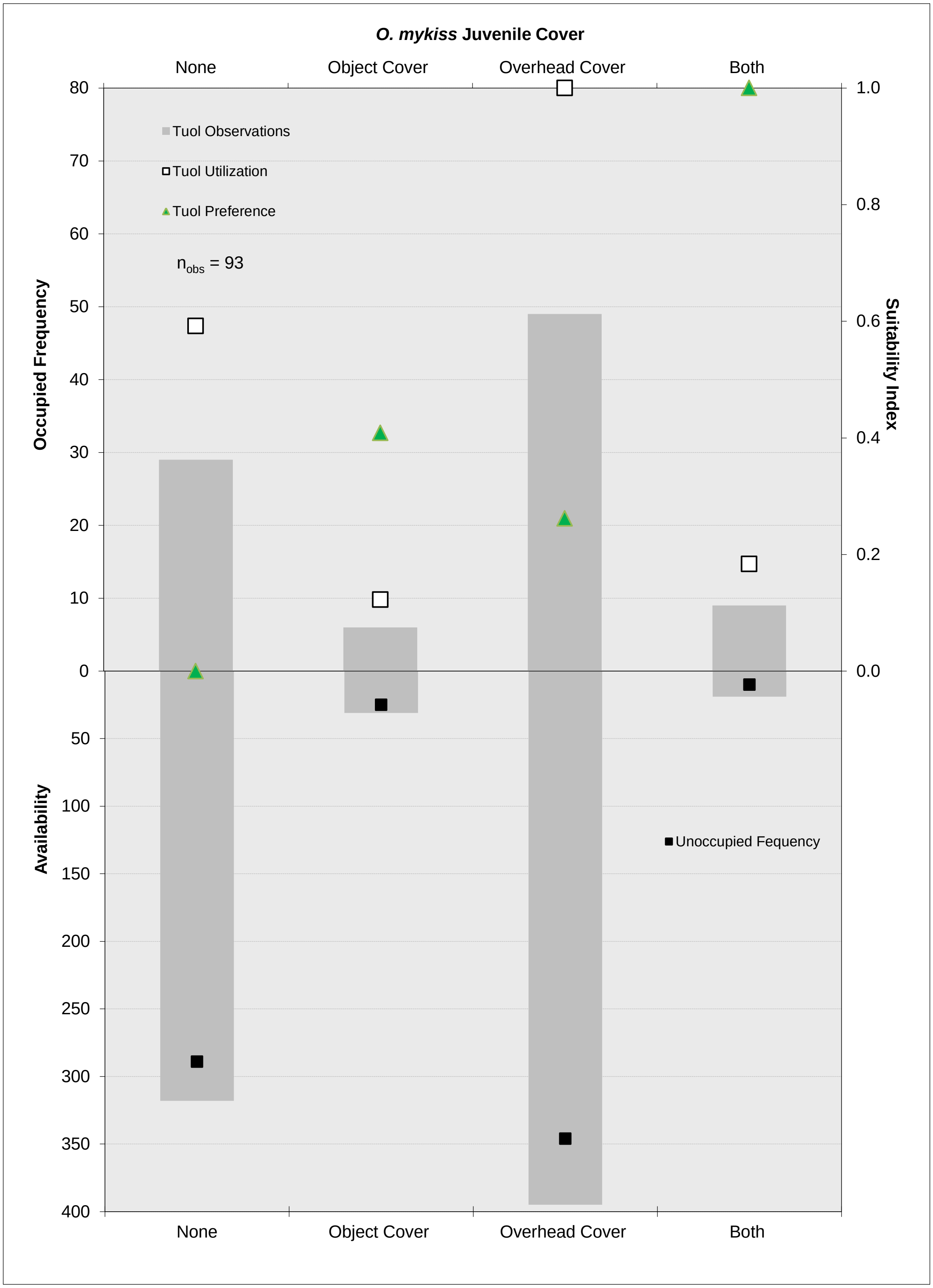


Figure G-15. *O. mykiss* juvenile cover suitability criteria for the lower Tuolumne River.

Table G-8. *O. mykiss* juvenile habitat suitability criteria coordinates.

Tuolumne Site-specific			Tuolumne Env		Tuolumne Site-specific			Tuolumne Env	
Not Used			Used		Not Used			Used	
Velocity (fps)	**Utilization Index**	**Preference Index**	**Velocity (fps)**	**Index**	**Depth (ft)**	**Utilization Index**	**Preference Index**	**Depth (ft)**	**Index**
0.00	1.00	0.86	0.00	0.73	0.0	0.00	0.00	0.40	0.00
0.05	0.97	0.89	0.05	0.81	0.1	0.00	0.00	0.50	0.24
0.10	0.93	0.92	0.15	0.93	0.2	0.00	0.00	0.70	0.56
0.15	0.89	0.94	0.25	0.99	0.3	0.00	0.00	0.90	0.78
0.20	0.84	0.96	0.35	1.00	0.4	0.09	0.33	1.10	0.92
0.25	0.80	0.98	0.80	1.00	0.5	0.18	0.52	1.30	0.99
0.30	0.75	0.99	0.90	0.99	0.6	0.28	0.63	1.50	1.00
0.35	0.71	1.00	1.00	0.98	0.7	0.37	0.72	2.25	1.00
0.40	0.66	1.00	1.10	0.96	0.8	0.47	0.78	2.50	0.98
0.45	0.61	1.00	1.20	0.92	0.9	0.56	0.83	2.75	0.93
0.50	0.57	0.99	1.30	0.89	1.0	0.65	0.87	3.00	0.86
0.55	0.52	0.97	1.40	0.84	1.1	0.73	0.91	3.25	0.78
0.60	0.48	0.95	1.50	0.79	1.2	0.80	0.93	3.50	0.70
0.65	0.44	0.93	1.60	0.74	1.3	0.86	0.95	3.75	0.62
0.70	0.40	0.90	1.70	0.68	1.4	0.91	0.97	4.00	0.54
0.75	0.36	0.86	1.80	0.63	1.5	0.95	0.98	4.25	0.47
0.80	0.33	0.82	1.90	0.57	1.6	0.98	0.99	4.50	0.41
0.85	0.30	0.78	2.00	0.51	1.7	1.00	1.00	4.75	0.36
0.90	0.27	0.74	2.10	0.46	1.8	1.00	1.00	8.75	0.34
0.95	0.24	0.70	2.20	0.41	1.9	0.99	1.00	9.00	0.34
1.00	0.21	0.66	2.30	0.36	2.0	0.98	1.00	9.25	0.33
1.05	0.19	0.62	2.40	0.31	2.1	0.95	0.99	9.40	0.31
1.10	0.17	0.58	2.50	0.27	2.2	0.92	0.99	9.50	0.00
1.15	0.16	0.54	2.60	0.24	2.3	0.88	0.98		
1.20	0.14	0.51	2.70	0.20	2.4	0.84	0.97		
1.25	0.13	0.48	2.80	0.17	2.5	0.80	0.96		
1.30	0.12	0.46	2.85	0.16	2.6	0.76	0.96		
1.35	0.11	0.44	2.86	0.00	2.7	0.72	0.95		
1.40	0.10	0.42			2.8	0.67	0.94		
1.45	0.10	0.41			2.9	0.64	0.93		

Table G-8. *O. mykiss* juvenile habitat suitability criteria coordinates.

Tuolumne Site-specific			**Tuolumne Env**		**Tuolumne Site-specific**			**Tuolumne Env**	
Not Used			Used		Not Used			Used	
Velocity (fps)	**Utilization Index**	**Preference Index**	**Velocity (fps)**	**Index**	**Depth (ft)**	**Utilization Index**	**Preference Index**	**Depth (ft)**	**Index**
1.50	0.09	0.40			3.0	0.60	0.92		
1.55	0.09	0.39			3.1	0.57	0.91		
1.60	0.08	0.39			3.2	0.54	0.90		
1.65	0.08	0.39			3.3	0.51	0.89		
1.70	0.08	0.38			3.4	0.48	0.88		
1.75	0.08	0.38			3.5	0.45	0.86		
1.80	0.07	0.37			3.6	0.43	0.83		
1.85	0.07	0.37			3.7	0.40	0.80		
1.90	0.07	0.36			3.8	0.37	0.77		
1.95	0.06	0.34			3.9	0.35	0.72		
2.00	0.06	0.33			4.0	0.32	0.68		
2.05	0.05	0.31			4.1	0.29	0.63		
2.10	0.05	0.29			4.2	0.27	0.58		
2.15	0.04	0.27			4.3	0.24	0.54		
2.20	0.04	0.25			4.4	0.22	0.50		
2.25	0.03	0.23			4.5	0.20	0.46		
2.30	0.03	0.20			4.6	0.18	0.43		
2.35	0.03	0.18			4.7	0.16	0.40		
2.40	0.02	0.16			4.8	0.15	0.38		
2.45	0.02	0.14			4.9	0.13	0.36		
2.50	0.02	0.12			5.0	0.12	0.34		
2.55	0.01	0.10			5.1	0.11	0.34		
2.60	0.01	0.08			5.2	0.10	0.33		
2.65	0.01	0.07			5.3	0.10	0.32		
2.70	0.01	0.05			5.4	0.09	0.32		
2.75	0.00	0.04			5.5	0.09	0.32		
2.80	0.00	0.03			5.6	0.08	0.32		
2.85	0.00	0.03			5.7	0.07	0.32		
2.90	0.00	0.02			5.8	0.07	0.31		
2.95	0.00	0.02			5.9	0.06	0.31		

Table G-8. *O. mykiss* juvenile habitat suitability criteria coordinates.

Tuolumne Site-specific			Tuolumne Env		Tuolumne Site-specific			Tuolumne Env	
Not Used			Used		Not Used			Used	
Velocity (fps)	Utilization Index	Preference Index	Velocity (fps)	Index	Depth (ft)	Utilization Index	Preference Index	Depth (ft)	Index
3.00	0.00	0.01			6.0	0.06	0.30		
3.05	0.00	0.01			6.1	0.05	0.28		
3.10	0.00	0.01			6.2	0.05	0.27		
3.15	0.00	0.00			6.3	0.04	0.25		
					6.4	0.04	0.23		
					6.5	0.03	0.20		
					6.6	0.02	0.18		
					6.7	0.02	0.16		
					6.8	0.02	0.13		
					6.9	0.01	0.11		
					7.0	0.01	0.09		
					7.1	0.01	0.07		
					7.2	0.00	0.06		
					7.3	0.00	0.04		
					7.4	0.00	0.00		

Table G-9. *O. mykiss* juvenile cover habitat suitability criteria developed during site-specific surveys on the lower Tuolumne River.

Cover Type	Utilization HSC	Preference HSC
None	0.59	0.00
Object Cover	0.12	0.41
Overhead Cover	1.00	0.26
Both	0.18	1.00

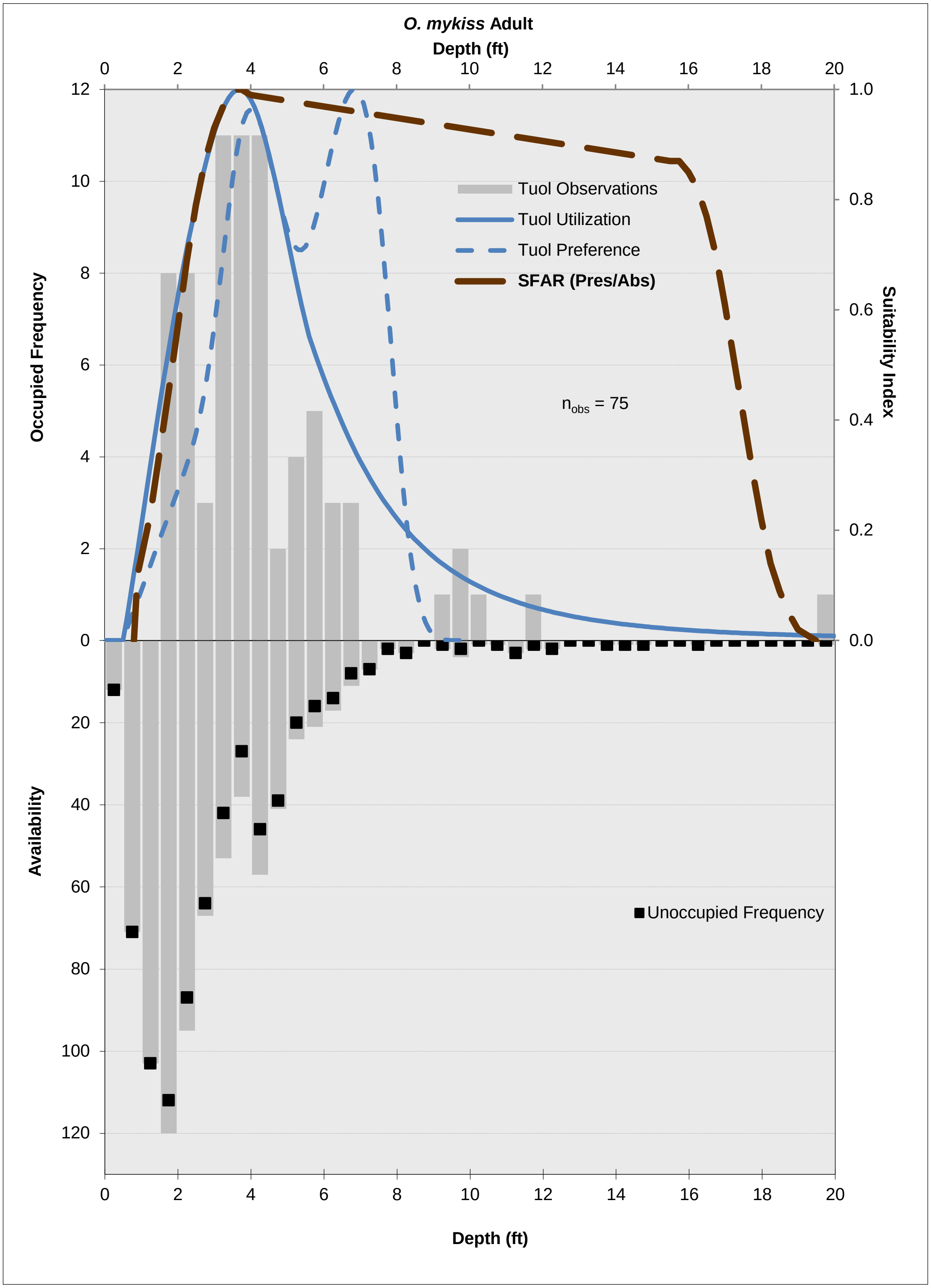


Figure G-16. *O. mykiss* adult depth suitability criteria for the lower Tuolumne River; curve applied in the PHABSIM model was SFAR (Pres/Abs).

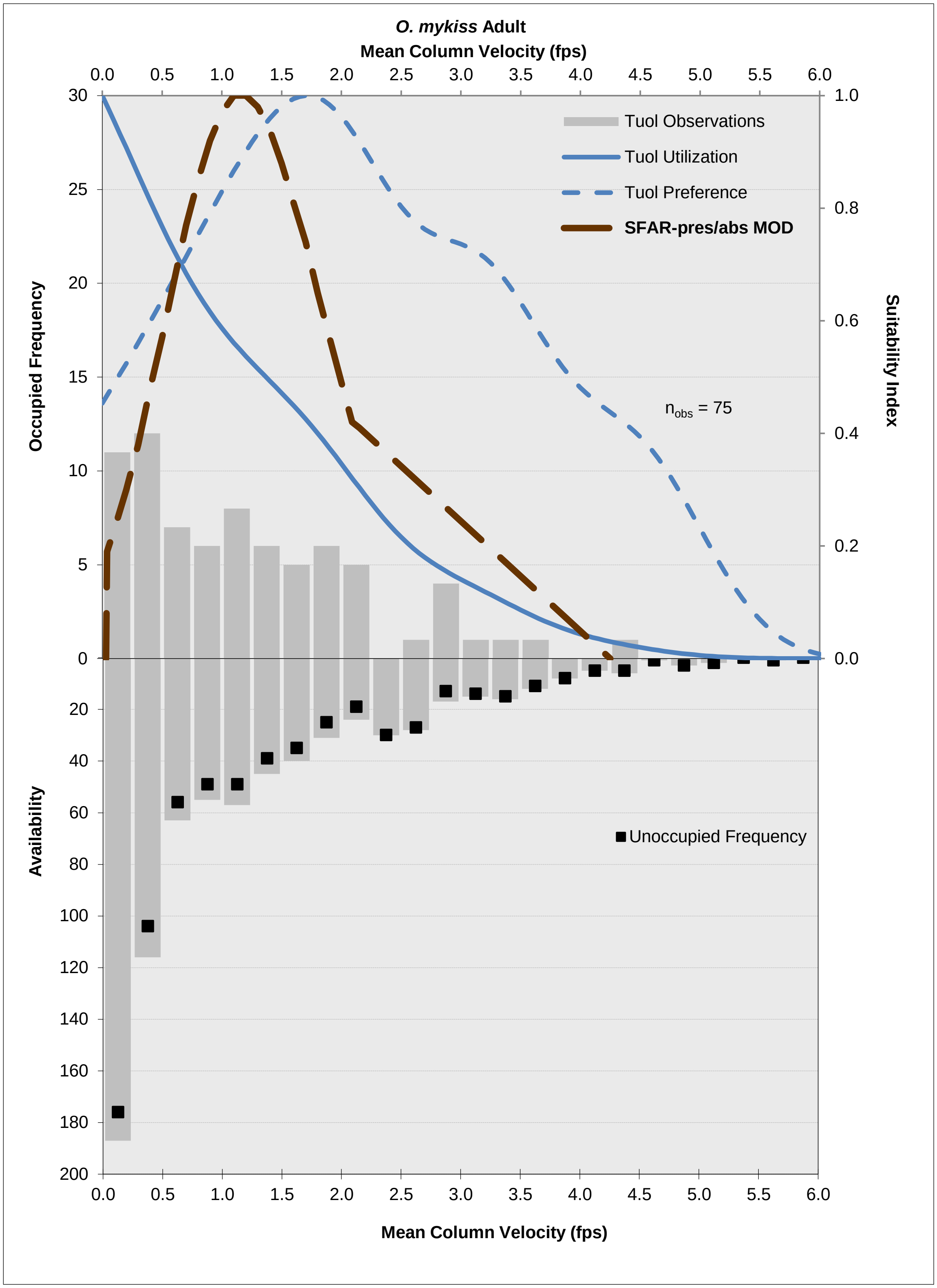


Figure G-17. *O. mykiss* adult velocity suitability criteria for the lower Tuolumne River; curve applied in PHABSIM model was SFAR pres/abs MOD).

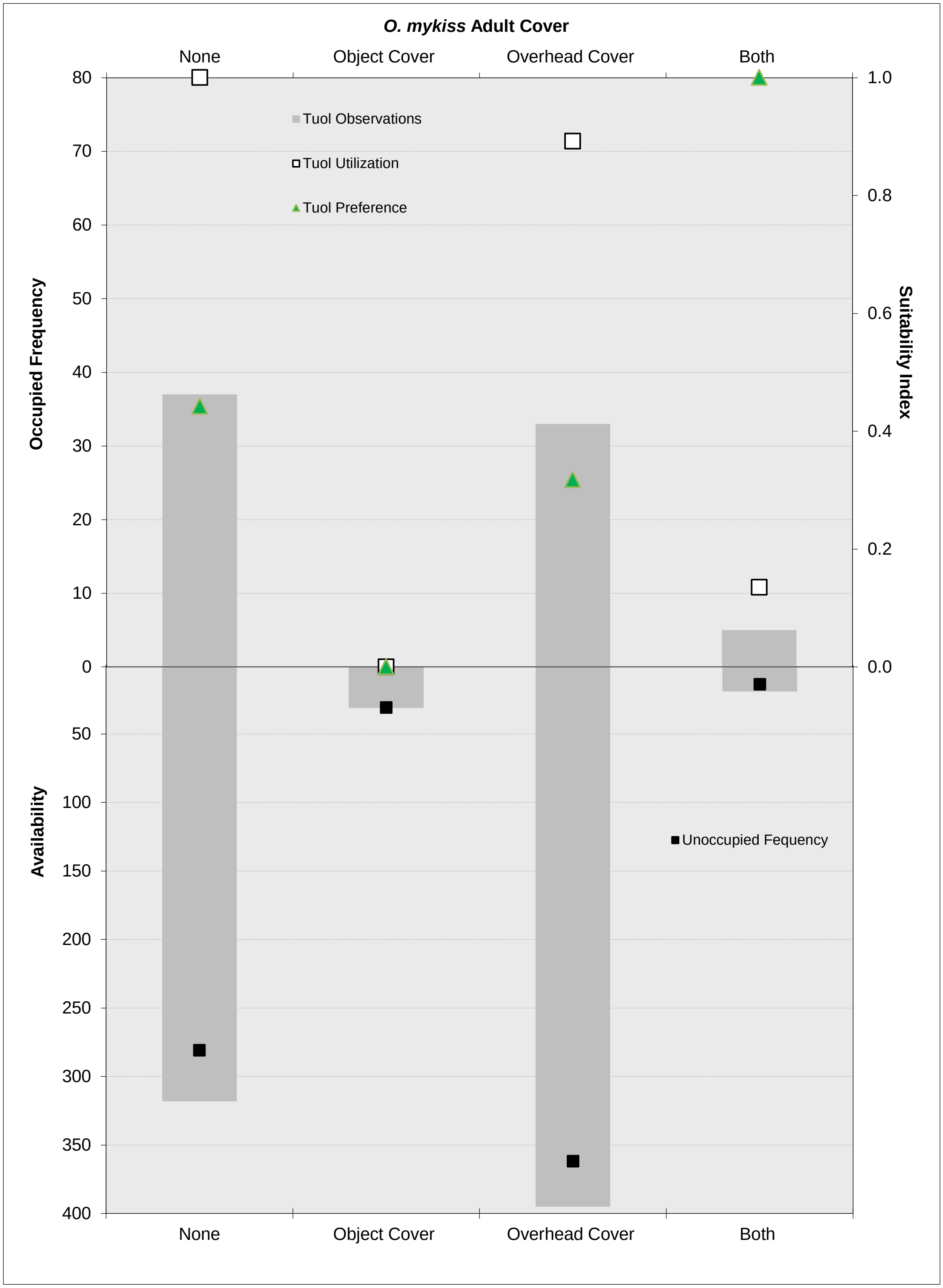


Figure G-18. *O. mykiss* adult cover suitability criteria for the lower Tuolumne River.

Table G-10. *O. mykiss* adult habitat suitability criteria coordinates.

Tuolumne Site-specific			SFAR Pres/Abs MOD		Tuolumne Site-specific			SFAR Pres/Abs	
Not Used			Used		Not Used			Used	
Velocity (fps)	**Utilization Index**	**Preference Index**	**Velocity (fps)**	**Index**	**Depth (ft)**	**Utilization Index**	**Preference Index**	**Depth (ft)**	**Index**
0.00	1.00	0.45	0.03	0.00	0.0	0.00	0.00	0.80	0.00
0.05	0.98	0.47	0.04	0.19	0.1	0.00	0.00	0.90	0.12
0.10	0.95	0.49	0.10	0.23	0.2	0.00	0.00	1.00	0.15
0.15	0.93	0.51	0.20	0.30	0.3	0.00	0.00	1.25	0.23
0.20	0.91	0.52	0.30	0.38	0.4	0.00	0.00	1.50	0.34
0.25	0.88	0.54	0.40	0.48	0.5	0.00	0.00	1.75	0.45
0.30	0.86	0.56	0.50	0.57	0.6	0.02	0.02	2.00	0.57
0.35	0.84	0.58	0.60	0.67	0.7	0.04	0.04	2.25	0.69
0.40	0.81	0.60	0.70	0.77	0.8	0.07	0.06	2.50	0.79
0.45	0.79	0.62	0.80	0.85	0.9	0.11	0.07	2.75	0.87
0.50	0.77	0.64	0.90	0.92	1.0	0.15	0.09	3.00	0.93
0.55	0.75	0.66	1.00	0.97	1.1	0.19	0.11	3.25	0.97
0.60	0.72	0.67	1.10	1.00	1.2	0.24	0.13	3.50	1.00
0.65	0.70	0.69	1.20	1.00	1.3	0.29	0.15	3.75	1.00
0.70	0.68	0.71	1.30	0.98	1.4	0.34	0.16	4.00	0.99
0.75	0.67	0.73	1.40	0.94	1.5	0.38	0.18	15.50	0.87
0.80	0.65	0.75	1.50	0.88	1.6	0.43	0.20	15.75	0.87
0.85	0.63	0.77	1.60	0.81	1.7	0.47	0.22	16.00	0.85
0.90	0.62	0.79	1.70	0.74	1.8	0.51	0.24	16.25	0.82
0.95	0.60	0.81	1.80	0.65	1.9	0.55	0.25	16.50	0.77
1.00	0.59	0.83	1.90	0.57	2.0	0.58	0.27	16.75	0.70
1.05	0.57	0.85	2.00	0.49	2.1	0.60	0.29	17.00	0.61
1.10	0.56	0.87	2.09	0.42	2.2	0.63	0.31	17.25	0.51
1.15	0.55	0.88	2.15	0.41	2.3	0.64	0.33	17.50	0.41
1.20	0.54	0.90	4.25	0.00	2.4	0.66	0.35	17.75	0.31
1.25	0.53	0.92			2.5	0.68	0.38	18.00	0.22
1.30	0.51	0.93			2.6	0.70	0.41	18.25	0.14
1.35	0.50	0.95			2.7	0.72	0.44	18.50	0.09
1.40	0.49	0.96			2.8	0.75	0.48	18.75	0.05
1.45	0.48	0.97			2.9	0.77	0.52	19.00	0.02

Table G-10. *O. mykiss* adult habitat suitability criteria coordinates.

Tuolumne Site-specific			SFAR Pres/Abs MOD		Tuolumne Site-specific			SFAR Pres/Abs	
Not Used			Used		Not Used			Used	
Velocity (fps)	**Utilization Index**	**Preference Index**	**Velocity (fps)**	**Index**	**Depth (ft)**	**Utilization Index**	**Preference Index**	**Depth (ft)**	**Index**
1.50	0.47	0.98			3.0	0.80	0.57	19.50	0.00
1.55	0.46	0.99			3.1	0.84	0.62		
1.60	0.45	0.99			3.2	0.87	0.67		
1.65	0.44	1.00			3.3	0.90	0.73		
1.70	0.43	1.00			3.4	0.93	0.78		
1.75	0.41	1.00			3.5	0.96	0.84		
1.80	0.40	1.00			3.6	0.98	0.88		
1.85	0.39	0.99			3.7	0.99	0.92		
1.90	0.37	0.98			3.8	1.00	0.94		
1.95	0.36	0.97			3.9	1.00	0.96		
2.00	0.35	0.96			4.0	0.99	0.96		
2.05	0.33	0.95			4.1	0.97	0.96		
2.10	0.32	0.93			4.2	0.95	0.95		
2.15	0.30	0.92			4.3	0.91	0.93		
2.20	0.29	0.90			4.4	0.87	0.91		
2.25	0.28	0.88			4.5	0.82	0.88		
2.30	0.26	0.87			4.6	0.77	0.85		
2.35	0.25	0.85			4.7	0.72	0.82		
2.40	0.24	0.83			4.8	0.67	0.80		
2.45	0.23	0.82			4.9	0.62	0.77		
2.50	0.22	0.80			5.0	0.57	0.75		
2.55	0.21	0.79			5.1	0.53	0.73		
2.60	0.20	0.78			5.2	0.49	0.72		
2.65	0.19	0.77			5.3	0.46	0.71		
2.70	0.18	0.76			5.4	0.44	0.71		
2.75	0.17	0.76			5.5	0.41	0.71		
2.80	0.16	0.75			5.6	0.40	0.73		
2.85	0.16	0.75			5.7	0.38	0.75		
2.90	0.15	0.74			5.8	0.37	0.77		
2.95	0.15	0.74			5.9	0.36	0.80		

Table G-10. *O. mykiss* adult habitat suitability criteria coordinates.

Tuolumne Site-specific			SFAR Pres/Abs MOD		Tuolumne Site-specific			SFAR Pres/Abs	
Not Used			Used		Not Used			Used	
Velocity (fps)	**Utilization Index**	**Preference Index**	**Velocity (fps)**	**Index**	**Depth (ft)**	**Utilization Index**	**Preference Index**	**Depth (ft)**	**Index**
3.00	0.14	0.74			6.0	0.35	0.83		
3.05	0.14	0.73			6.1	0.35	0.86		
3.10	0.13	0.73			6.2	0.34	0.89		
3.15	0.12	0.72			6.3	0.33	0.91		
3.20	0.12	0.71			6.4	0.32	0.94		
3.25	0.11	0.70			6.5	0.31	0.96		
3.30	0.11	0.69			6.6	0.29	0.98		
3.35	0.10	0.68			6.7	0.28	0.99		
3.40	0.10	0.66			6.8	0.26	1.00		
3.45	0.09	0.65			6.9	0.24	1.00		
3.50	0.09	0.63			7.0	0.22	0.99		
3.55	0.08	0.62			7.1	0.20	0.97		
3.60	0.08	0.60			7.2	0.18	0.95		
3.65	0.07	0.58			7.3	0.15	0.91		
3.70	0.07	0.56			7.4	0.13	0.86		
3.75	0.06	0.55			7.5	0.11	0.80		
3.80	0.06	0.53			7.6	0.09	0.73		
3.85	0.05	0.52			7.7	0.07	0.66		
3.90	0.05	0.50			7.8	0.06	0.58		
3.95	0.05	0.49			7.9	0.04	0.49		
4.00	0.04	0.48			8.0	0.03	0.41		
4.05	0.04	0.47			8.1	0.02	0.33		
4.10	0.04	0.46			8.2	0.02	0.26		
4.15	0.04	0.45			8.3	0.01	0.20		
4.20	0.03	0.45			8.4	0.01	0.15		
4.25	0.03	0.44			8.5	0.01	0.11		
4.30	0.03	0.43			8.6	0.00	0.07		
4.35	0.03	0.42			8.7	0.00	0.05		
4.40	0.02	0.41			8.8	0.00	0.03		
4.45	0.02	0.40			8.9	0.00	0.02		

Table G-10. *O. mykiss* adult habitat suitability criteria coordinates.

Tuolumne Site-specific Not Used			SFAR Pres/Abs MOD Used		Tuolumne Site-specific Not Used			SFAR Pres/Abs Used	
Velocity (fps)	**Utilization Index**	**Preference Index**	**Velocity (fps)**	**Index**	**Depth (ft)**	**Utilization Index**	**Preference Index**	**Depth (ft)**	**Index**
4.50	0.02	0.39			9.0	0.00	0.01		
4.55	0.02	0.38			9.1	0.00	0.01		
4.60	0.02	0.37			9.2	0.00	0.00		
4.65	0.01	0.36							
4.70	0.01	0.34							
4.75	0.01	0.32							
4.80	0.01	0.31							
4.85	0.01	0.29							
4.90	0.01	0.27							
4.95	0.01	0.25							
5.00	0.01	0.23							
5.05	0.01	0.21							
5.10	0.00	0.19							
5.15	0.00	0.17							
5.20	0.00	0.16							
5.25	0.00	0.14							
5.30	0.00	0.12							
5.35	0.00	0.11							
5.40	0.00	0.09							
5.45	0.00	0.08							
5.50	0.00	0.07							
5.55	0.00	0.06							
5.60	0.00	0.05							
5.65	0.00	0.04							
5.70	0.00	0.03							
5.75	0.00	0.03							
5.80	0.00	0.02							
5.85	0.00	0.02							
5.90	0.00	0.01							
5.95	0.00	0.01							

Table G-10. *O. mykiss* adult habitat suitability criteria coordinates.

Tuolumne Site-specific			SFAR Pres/Abs MOD		Tuolumne Site-specific			SFAR Pres/Abs	
Not Used			Used		Not Used			Used	
Velocity (fps)	**Utilization Index**	**Preference Index**	**Velocity (fps)**	**Index**	**Depth (ft)**	**Utilization Index**	**Preference Index**	**Depth (ft)**	**Index**
6.00	0.00	0.01							

Table G-11. *O. mykiss* adult cover habitat suitability criteria developed during site-specific surveys on the lower Tuolumne River.

Cover Type	Utilization Index	Preference Index
None	1.00	0.44
Object Cover	0.00	0.00
Overhead Cover	0.89	0.32
Both	0.14	1.00

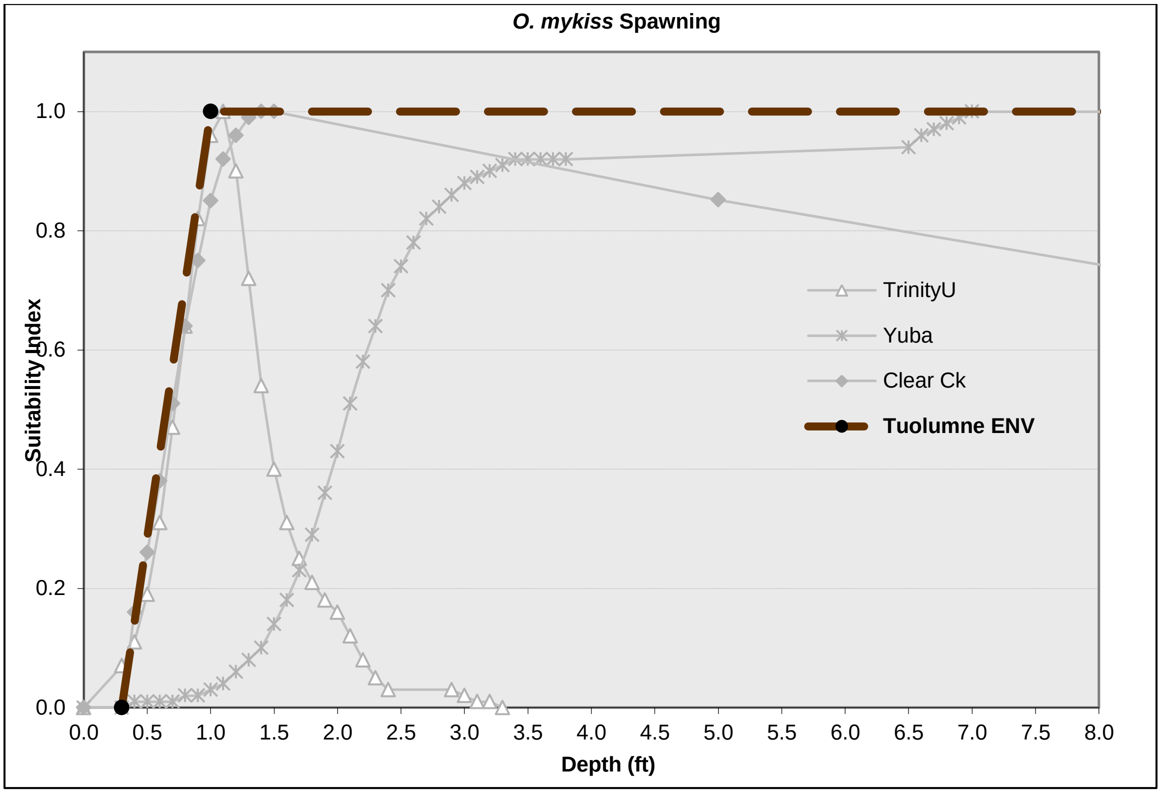


Figure G-19. *O. mykiss* spawning depth suitability criteria for the lower Tuolumne River; curve applied in the PHABSIM model was Tuolumne ENV.

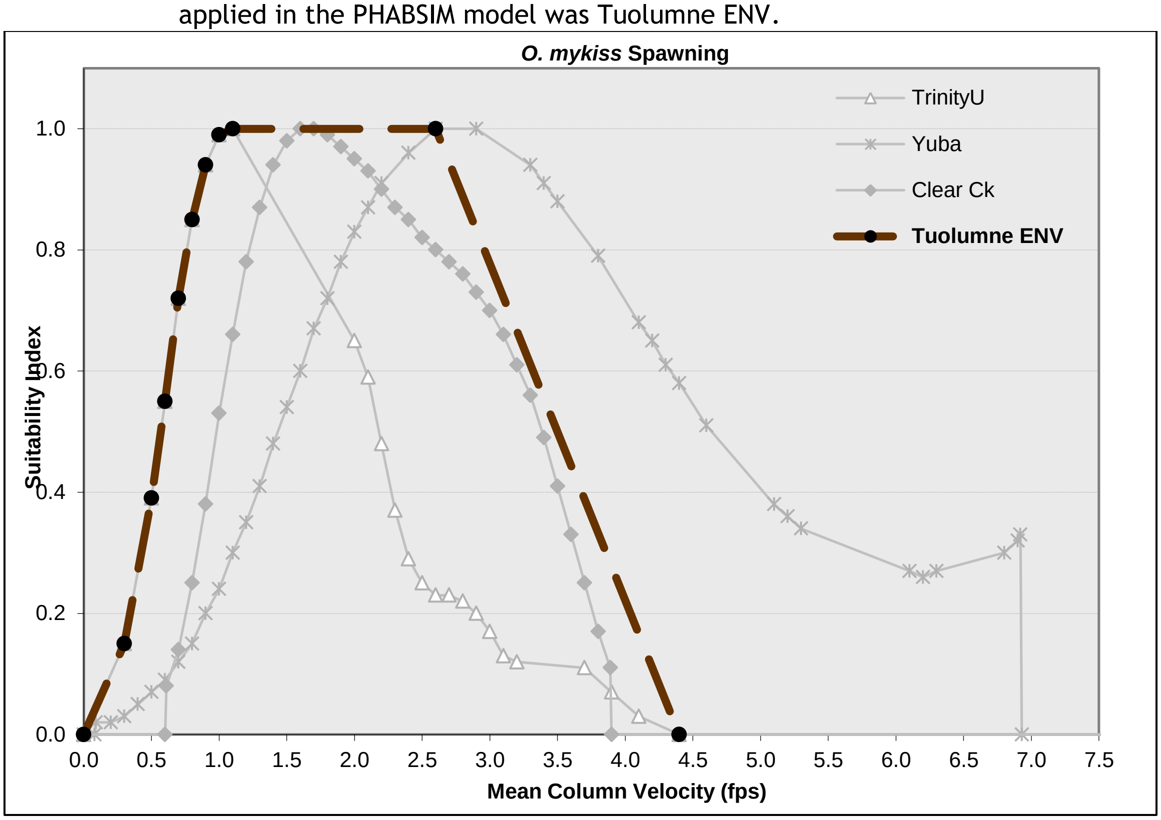


Figure G-20. *O. mykiss* spawning velocity suitability criteria for the lower Tuolumne River; curve applied in the PHABSIM model was Tuolumne ENV.

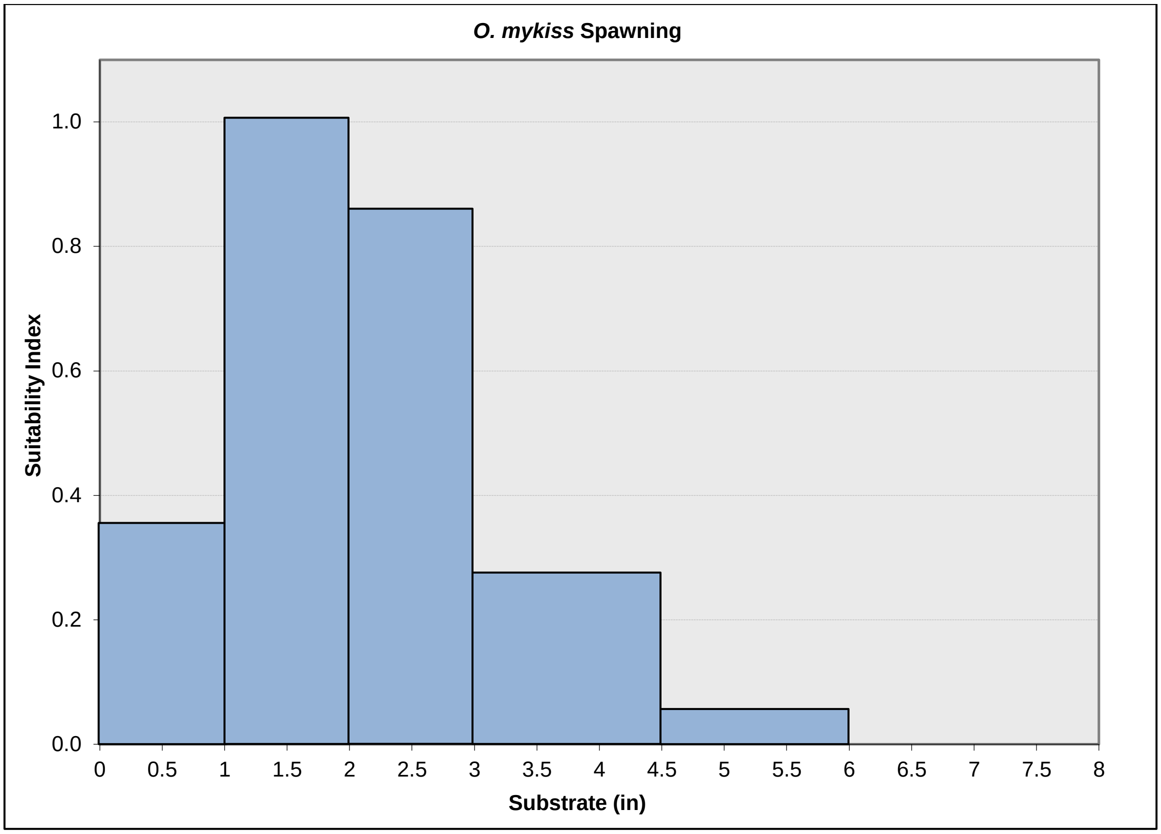


Figure G-21. *O. mykiss* spawning substrate suitability criteria for the lower Tuolumne River.

Table G-12. *O. mykiss* spawning habitat suitability criteria coordinates.

Tuolumne ENV		Tuolumne ENV		Tuolumne ENV	
Used		Used		Used	
Velocity (fps)	**Index**	**Depth (ft)**	**Index**	**Substrate Size (in)**	**Index**
0.00	0.00	0.30	0.00	Up to 1.0	0.38
0.30	0.15	1.00	1.00	1-1.99	1
0.50	0.39	100.00	1.00	2-2.99	0.85
0.60	0.55			3 – 4.49	0.28
0.70	0.72			4.5-5.99	0.05
0.80	0.85			6-8.99	0
0.90	0.94			>9	0
1.00	0.99				
1.10	1.00				
2.60	1.00				
4.40	0.00				
0.00	0.00				
0.30	0.15				
0.50	0.39				
0.60	0.55				
0.70	0.72				
0.80	0.85				
0.90	0.94				
1.00	0.99				
1.10	1.00				
2.60	1.00				
4.40	0.00				

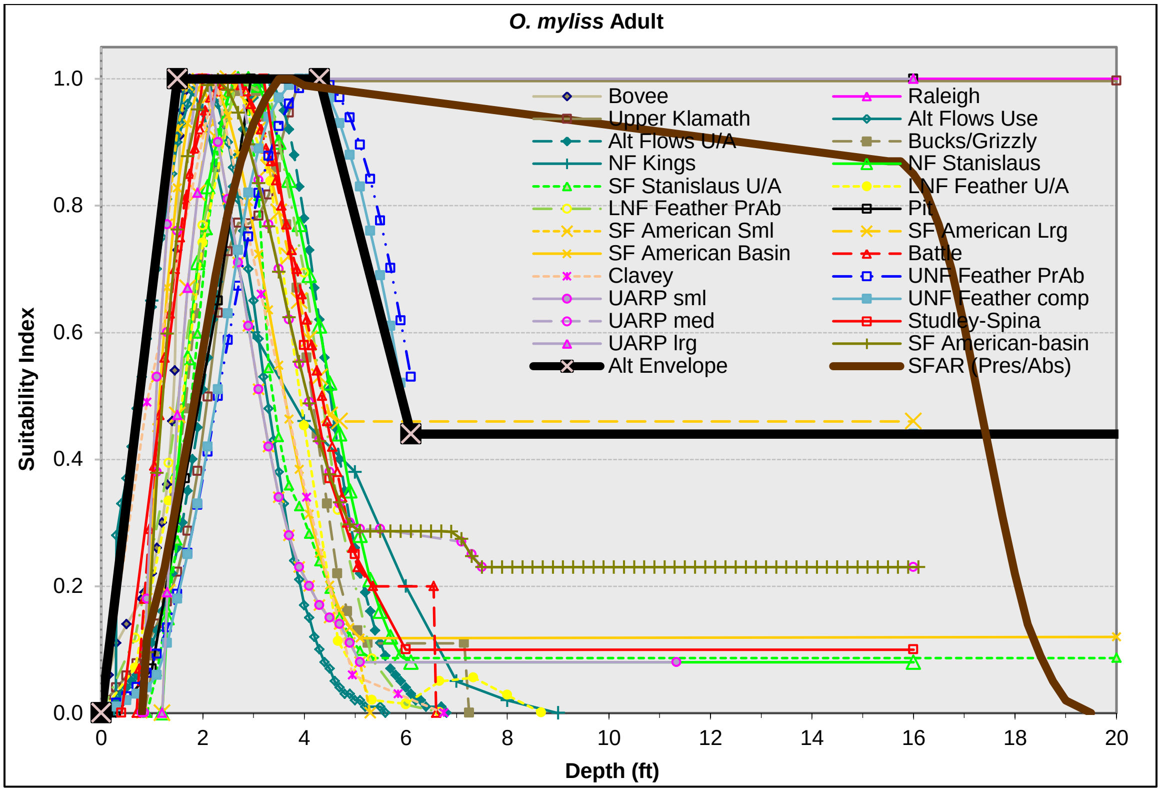


Figure G-22. Alternate depth-limited HSC envelope curve (Alt Envelope) for *O. mykiss* adults.

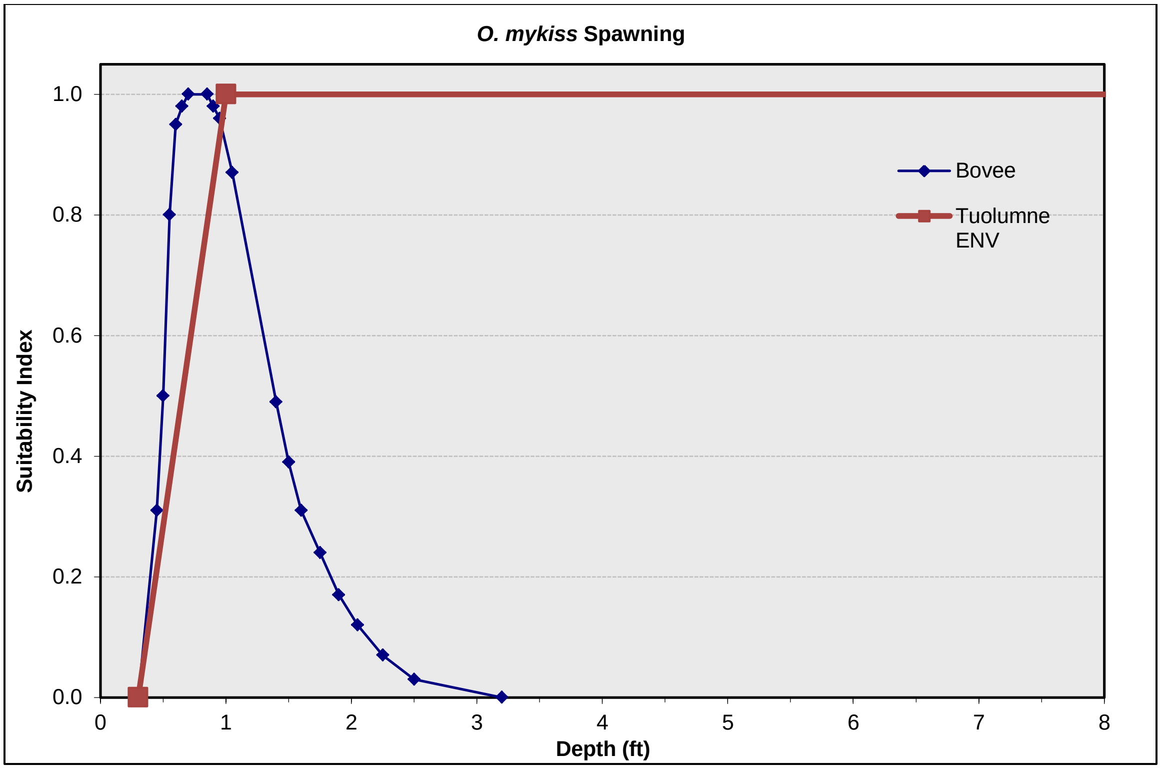


Figure G-23. Alternate depth-limited HSC curve (Bovee 1978) for *O. mykiss* spawning.

Appendix H

Supplemental Weighted Usable Area (WUA) Results

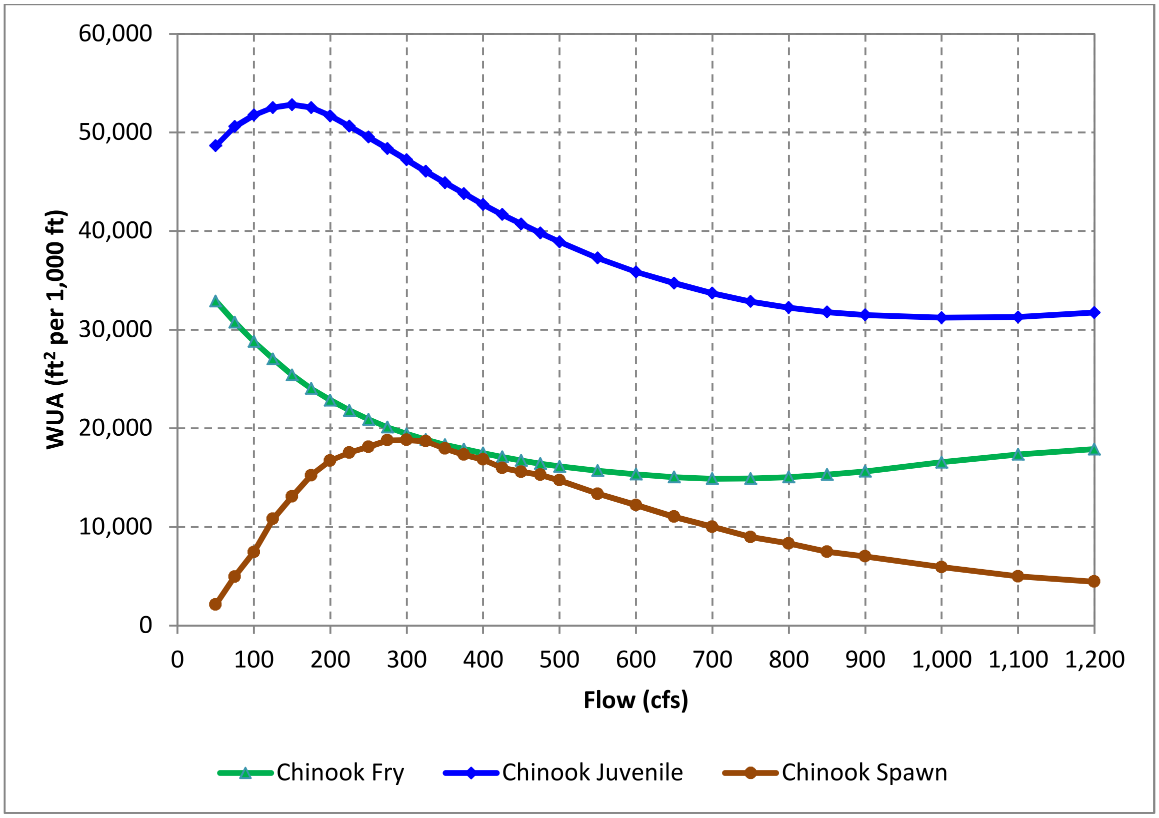


Figure H-1. Chinook salmon WUA for the lower Tuolumne River.

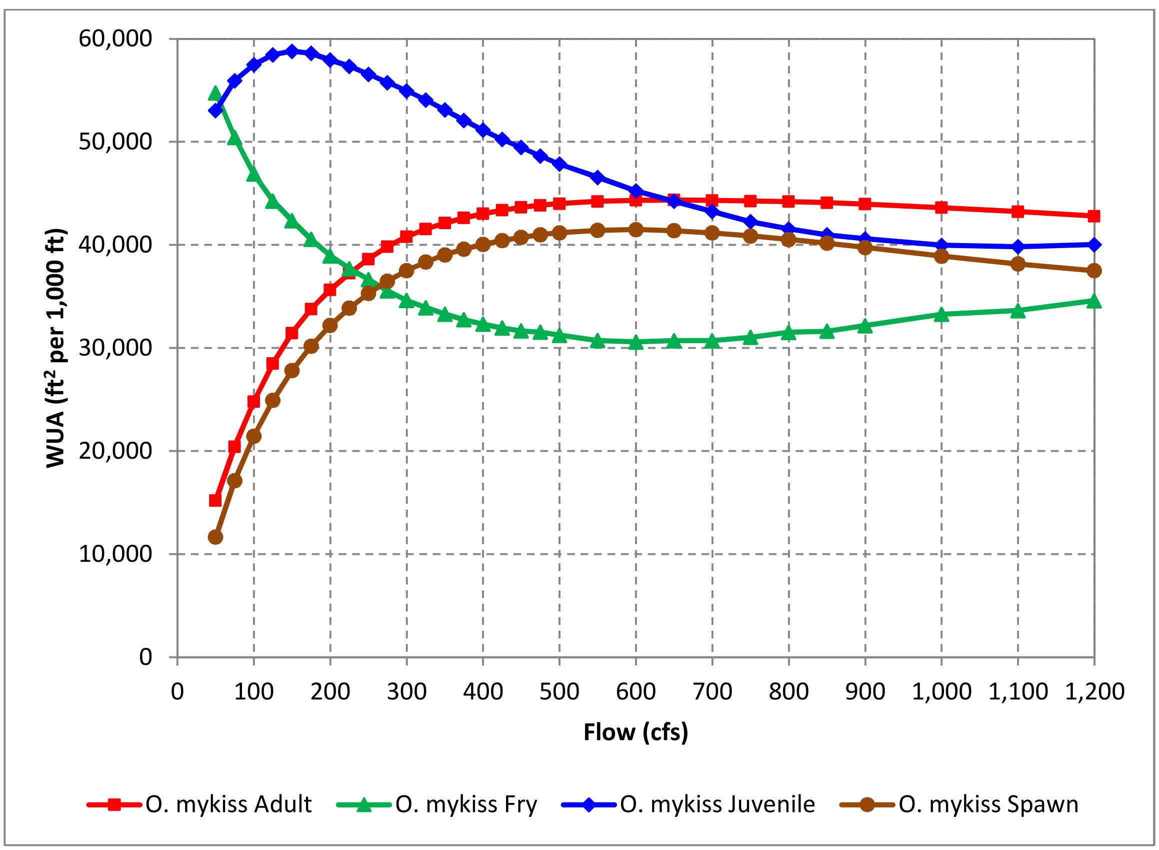


Figure H-2. *O. mykiss* WUA for the lower Tuolumne River.

Table H-1. Weighted Usable Area (WUA) Results for Chinook salmon

Simulated Discharge (cfs)	Chinook Juvenile	Chinook Fry	Chinook Spawning
50	48648.28	32897.03	2116.32
75	50596.55	30762.01	4950.27
100	51759.16	28799.02	7447.46
125	52516.33	27025.69	10807.84
150	52814.11	25415.04	13071.88
175	52526.09	24032.45	15233.00
200	51672.91	22847.85	16715.36
225	50618.49	21821.38	17532.14
250	49513.25	20907.80	18116.91
275	48370.69	20116.93	18788.06
300	47223.19	19427.09	18816.55
325	46052.38	18840.34	18687.83
350	44902.80	18335.55	17938.96
375	43795.04	17896.66	17321.83
400	42697.20	17480.39	16838.83
425	41665.85	17094.99	15973.93
450	40714.04	16744.73	15593.00
475	39786.06	16417.48	15275.23
500	38897.96	16137.46	14734.60
550	37261.25	15695.59	13349.39
600	35857.26	15349.23	12212.15
650	34713.81	15059.83	11024.56
700	33694.37	14891.10	10010.47
750	32852.21	14910.34	8975.34
800	32230.26	15056.86	8327.79
850	31779.36	15312.26	7479.93
900	31486.06	15642.33	7015.36
1000	31222.62	16553.40	5918.44
1100	31285.92	17354.90	4988.08
1200	31733.53	17894.26	4455.03

Table H-2. Weighted Usable Area (WUA) Results for *O. mykiss*

Simulated Discharge (cfs)	*O. mykiss* Adult	*O. mykiss* Juvenile	*O. mykiss* Fry	*O. mykiss* Spawning
50	15204.23	53029.98	54751.06	11648.21
75	20427.83	55934.07	50438.41	17137.87
100	24811.70	57493.70	46884.87	21449.10
125	28513.29	58459.15	44259.05	24938.94
150	31455.03	58803.13	42362.45	27813.79
175	33793.80	58594.14	40543.54	30187.09
200	35650.73	57943.69	38948.50	32190.74
225	37258.87	57339.70	37709.09	33876.89
250	38640.99	56555.18	36641.38	35297.01
275	39846.86	55752.38	35538.80	36497.83
300	40802.07	54951.57	34610.77	37512.27
325	41540.48	54073.44	33906.77	38341.84
350	42124.86	53088.40	33297.90	39040.29
375	42633.89	52086.89	32741.19	39594.69
400	43037.06	51131.27	32311.32	40055.69
425	43373.23	50231.29	31937.37	40433.29
450	43646.17	49456.44	31654.45	40738.98
475	43853.57	48619.69	31541.98	40987.72
500	44011.77	47845.36	31241.46	41182.09
550	44231.72	46549.31	30722.10	41418.38
600	44337.16	45230.46	30584.38	41490.77
650	44369.13	44239.98	30707.28	41385.58
700	44319.93	43244.78	30704.63	41171.44
750	44251.88	42255.11	31042.70	40869.42
800	44203.56	41549.14	31517.53	40529.14
850	44096.76	40986.94	31621.97	40166.12
900	43969.54	40592.09	32174.18	39751.73
1000	43625.76	39968.53	33270.24	38919.78
1100	43227.02	39831.84	33632.42	38155.59
1200	42801.13	40035.80	34594.15	37502.13

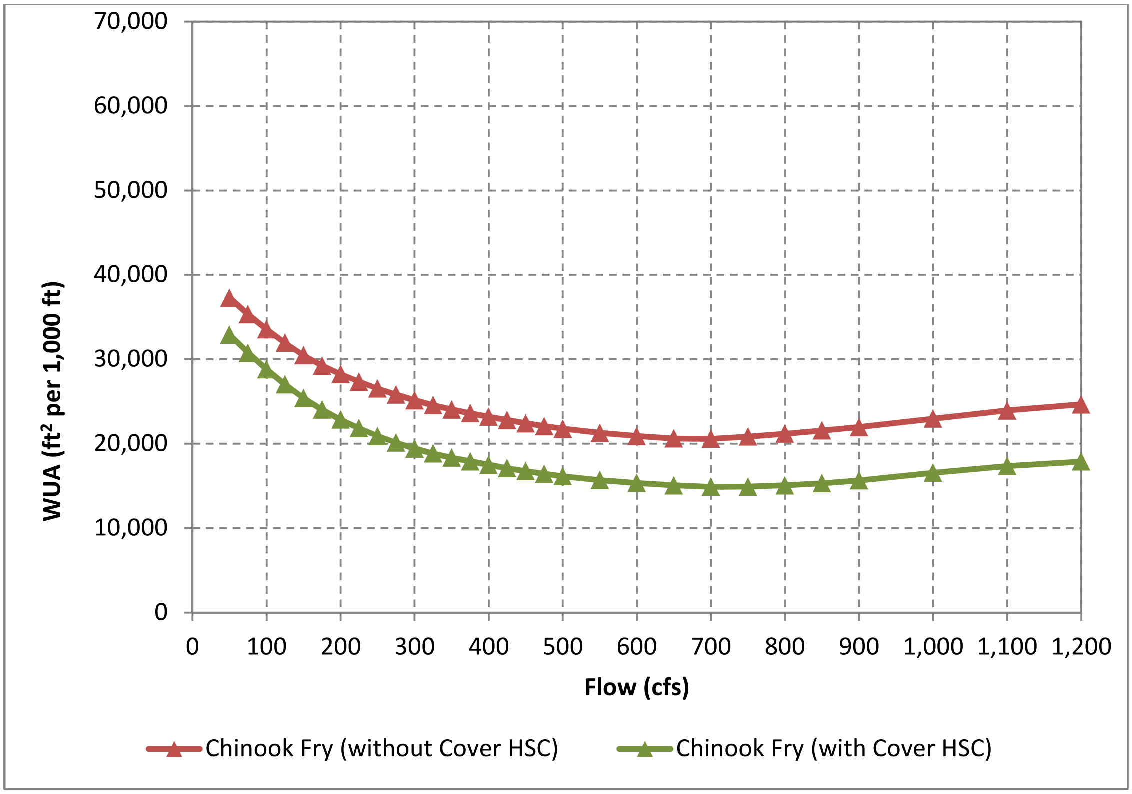


Figure H-3. Chinook salmon fry WUA comparison with and without cover criteria for the lower Tuolumne River.

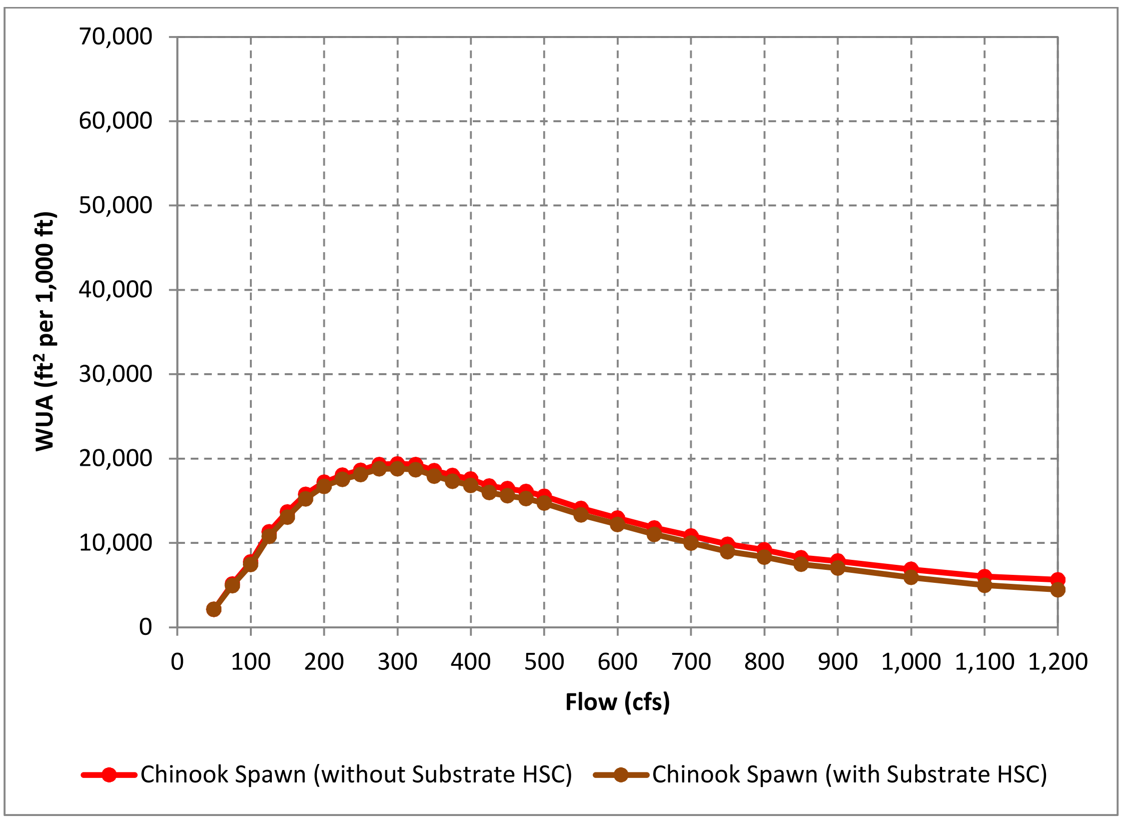


Figure H-4. Chinook salmon spawning WUA comparison with and without substrate criteria for the lower Tuolumne River.

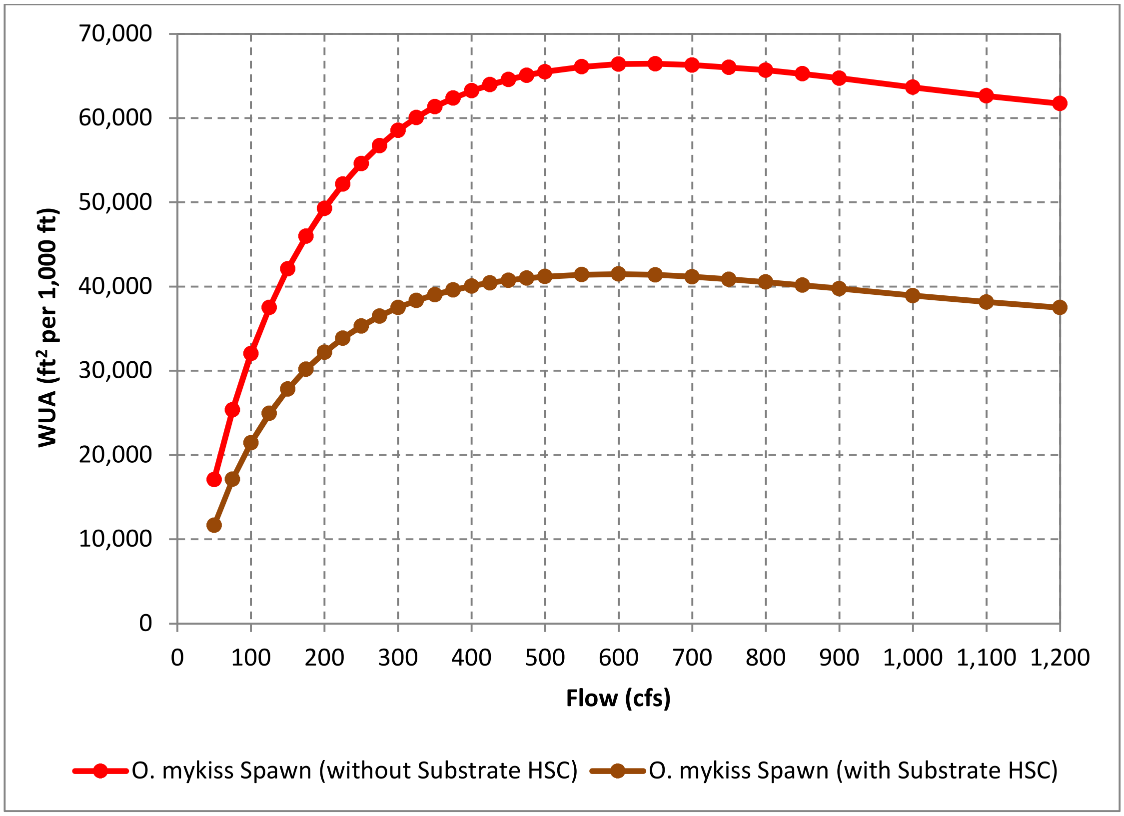


Figure H-5. *O. mykiss* spawning WUA comparison with and without substrate criteria for the lower Tuolumne River.

Appendix I

PHABSIM Site and Transect Photographs

Instream Flow Study

Lower Tuolumne River
Basso Bridge Reach

July 24, 2011, September 24, 2011, & June 26, 2012

R. Liebig, K. Jarrett, I. Pryor, W. Swaney, S. Araya, K. Orr, N. Jurjavcic, R. McLintock, H. Bowen, M. Reymann, and K. Rodriguez

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

IMGP0001

Medium Flow- 250 CFS- Benchmark 1 Setup September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

IMGP0003

Medium Flow- 250 CFS- Ken Jarrett at Benchmark 1

September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

IMGP0004

Medium Flow- 250 CFS- Benchmark 4 on River Left from Upstream

September 24, 2011

Lower Tuolumne River Instream Flow Study

Basso Bridge Reach

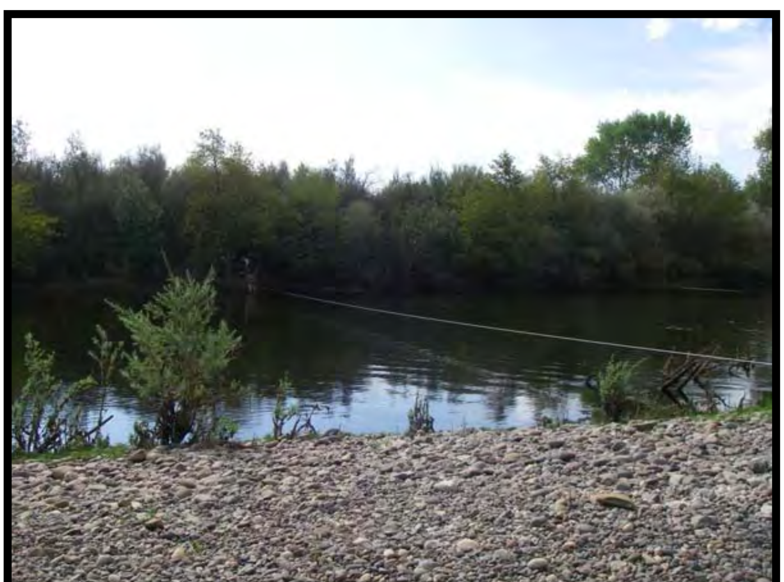
Low Flow- 100 CFS- Transect 24A-
Looking Downstream from River Right

IMGP0767

June 26, 2012

Lower Tuolumne River Instream Flow Study

Basso Bridge Reach



Medium Flow- 250 CFS- Transect 24A
Looking Downstream from River Right

IMGP0005

September 24, 2011

Lower Tuolumne River Instream Flow Study

Basso Bridge Reach

IMGP6265

High Flow- 600 CFS- Transect 24A- Looking Downstream from River Right

July 24, 2011

Lower Tuolumne River Instream Flow Study

Basso Bridge Reach

IMGP0768

Low Flow- 100 CFS- Transect 24A- Looking Upstream from River Right

June 26, 2012

Lower Tuolumne River Instream Flow Study

Basso Bridge Reach

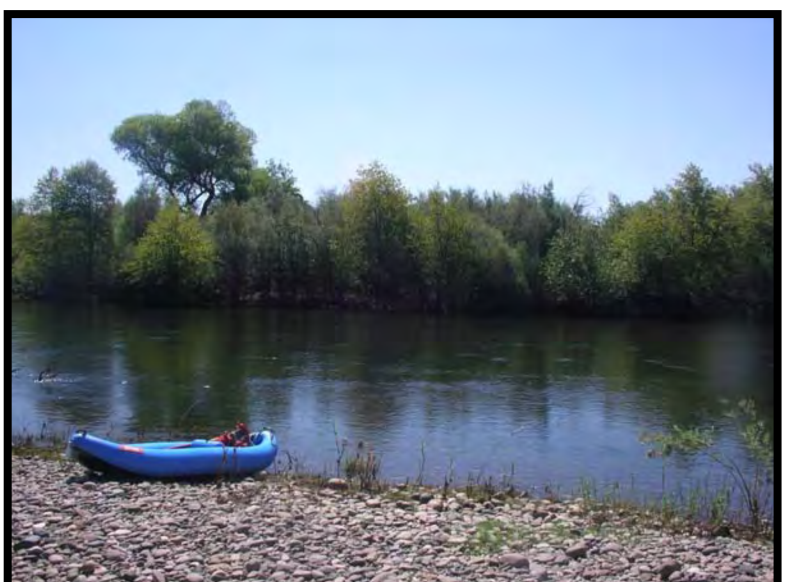
IMGP0006

Medium Flow- 250 CFS- Transect 24A
Looking Upstream from River Right

September 24, 2011

Lower Tuolumne River Instream Flow Study

Basso Bridge Reach



IMGP6266

High Flow- 600 CFS- Transect 24A-
Looking Upstream from River Right

July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 24A- Looking Across from River Right IMGP0766 June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 24A- Looking Across from River Right IMGP0010 September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

High Flow- 600 CFS- Transect 24A- Looking Across from River Right IMGP6264 July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 24B- Looking Across from River Right IMGP0764 June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 24B- Looking Across from River Right IMGP0007 September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

High Flow- 600 CFS- Transect 24B- Looking Across from River Right IMGP6267 July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 24B- Looking Downstream from River Right IMGP0765 June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 24B- Looking Downstream from River Right IMGP0008 September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

High Flow- 600 CFS- Transect 24B- Looking Downstream from River Right IMGP6268 July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 24B- Looking Upstream from River Right IMGP0763 June 26, 2012

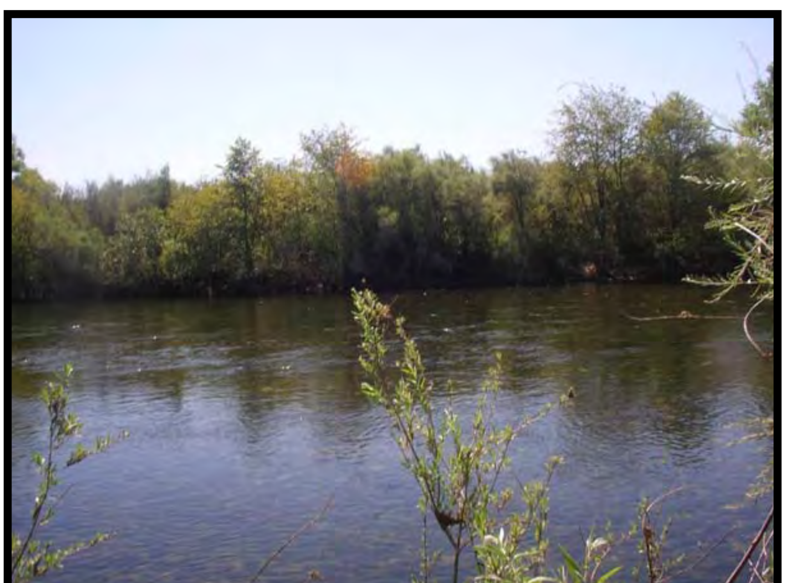
Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 24B- Looking Upstream from River Right

IMGP0009

September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach



High Flow- 600 CFS- Transect 24B- Looking Upstream from River Right

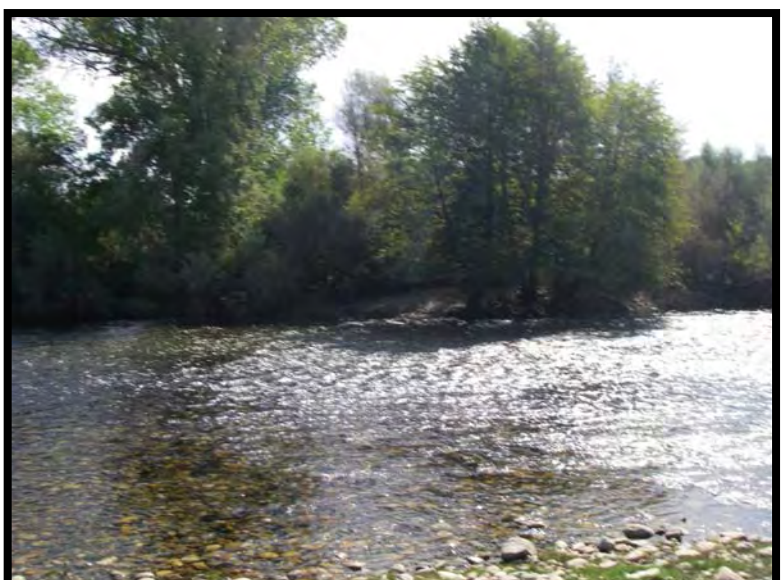
IMGP6269

July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 25A-
Looking Across from River Right
IMGP0761
June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach



Medium Flow- 250 CFS- Transect 25A-
Looking Across from River Right
IMGP0011
September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

High Flow- 600 CFS- Transect 25A- Looking Across from River Right

IMGP6270

July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 25A- Looking Downstream from River Right

IMGP0762

June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 25A- Looking Downstream from River Right

IMGP0012

September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

High Flow- 600 CFS- Transect 25A- Looking Downstream from River Right

IMGP6271

July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 25A- Looking Upstream from River Right

IMGP0760

June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 25A- Looking Upstream from River Right

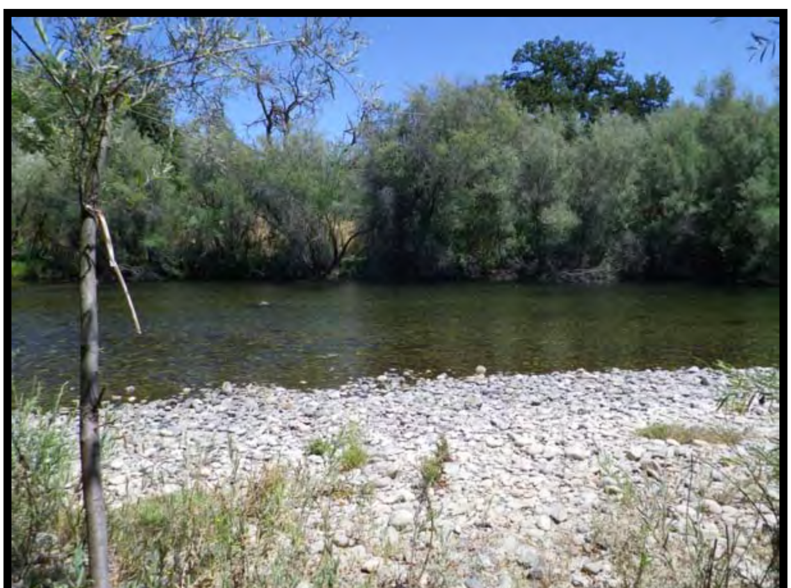
IMGP0013

September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

High Flow- 600 CFS- Transect 25A- Looking Upstream from River Right IMGP6273 July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

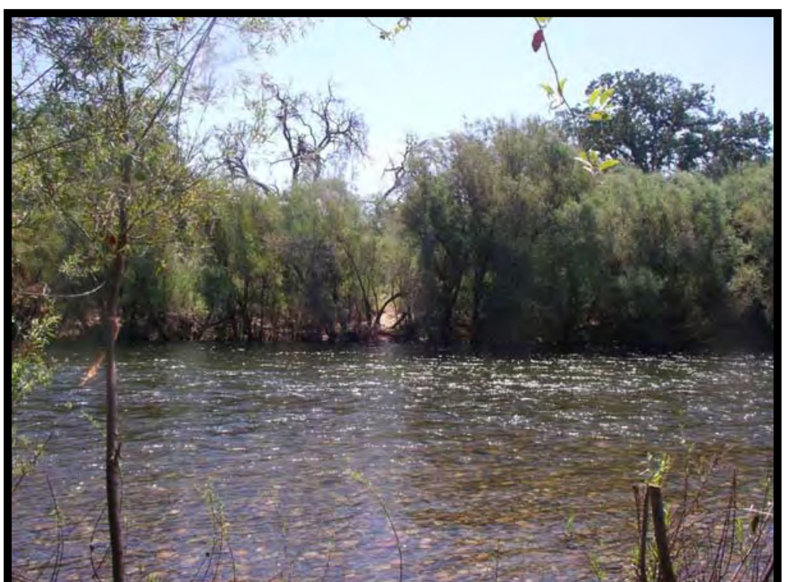


Low Flow- 100 CFS- Transect 25B- Looking Across from River Right IMGP0758 June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 25B- Looking Across from River Right IMGP0014 September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach



High Flow- 600 CFS- Transect 25B- Looking Across from River Right IMGP6274 July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 25B-
Looking Downstream from River Right
IMGP0759
June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 25B-
Looking Downstream from River Right
IMGP0015
September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

High Flow- 600 CFS- Transect 25B- Looking Downstream from River Right IMGP6275 July 24, 2011

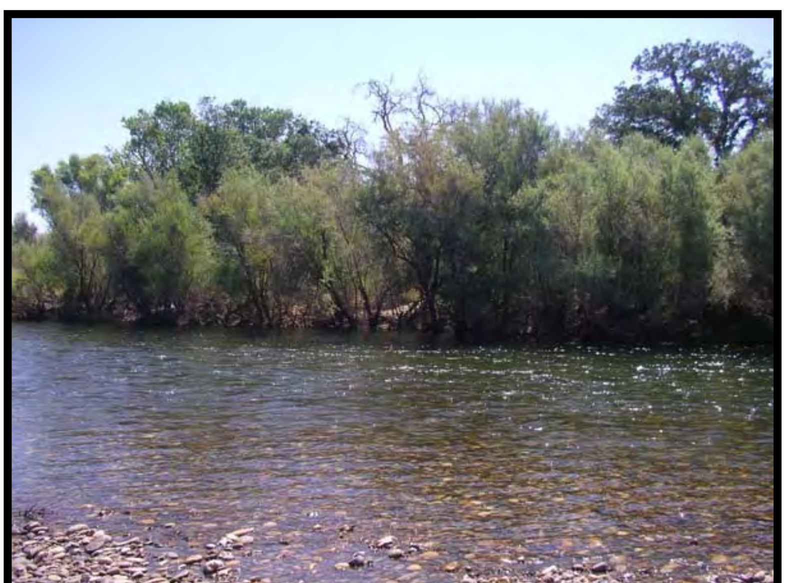
Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 25B- Looking Upstream from River Right IMGP0757 June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 25B- Looking Upstream from River Right IMGP0016 September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

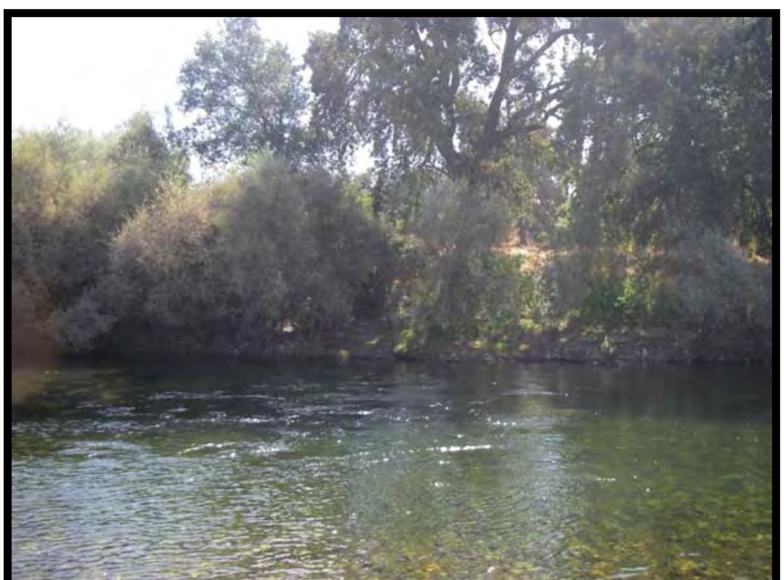


High Flow- 600 CFS- Transect 25B- Looking Upstream from River Right IMGP6276 July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 26A- Looking Across from River Right IMGP0755 June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach



Medium Flow- 250 CFS- Transect 26A- Looking Across from River Right IMGP0017 September 24, 2011

Lower Tuolumne River Instream Flow Study

Basso Bridge Reach

High Flow- 600 CFS- Transect 26A-
Looking Across from River Right

IMGP6277

July 24, 2011

Lower Tuolumne River Instream Flow Study

Basso Bridge Reach

Low Flow- 100 CFS- Transect 26A-
Looking Downstream from River Right

IMGP0756

June 26, 2012

Lower Tuolumne River Instream Flow Study

Basso Bridge Reach

Medium Flow- 250 CFS- Transect 26A-
Looking Downstream from River Right

IMGP0018

September 24, 2011

Lower Tuolumne River Instream Flow Study

Basso Bridge Reach

High Flow- 600 CFS- Transect 26A-
Looking Downstream from River Right

IMGP6278

July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 26A- Looking Upstream from River Right IMGP0754 June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 26A- Looking Upstream from River Right IMGP0019 September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

High Flow- 600 CFS- Transect 26A- Looking Upstream from River Right IMGP6279 July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 26B- Looking Across from River Right IMGP0747 June 26, 2012

Lower Tuolumne River Instream Flow Study

Basso Bridge Reach

Medium Flow- 250 CFS- Transect 26B-
Looking Across from River Right

IMGP0020

September 24, 2011

Lower Tuolumne River Instream Flow Study

Basso Bridge Reach

High Flow- 600 CFS- Transect 26B-
Looking Across from River Right

IMGP6280

July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 26B- Looking Downstream from River Right IMGP0748 June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 26B- Looking Downstream from River Right IMGP0021 September 24, 2011

Lower Tuolumne River Instream Flow Study — Basso Bridge Reach

High Flow- 600 CFS- Transect 26B- Looking Downstream from River Right — IMGP6281 — July 24, 2011

Lower Tuolumne River Instream Flow Study — Basso Bridge Reach

Low Flow- 100 CFS- Transect 26B- Looking Upstream from River Right — IMGP0746 — June 26, 2012

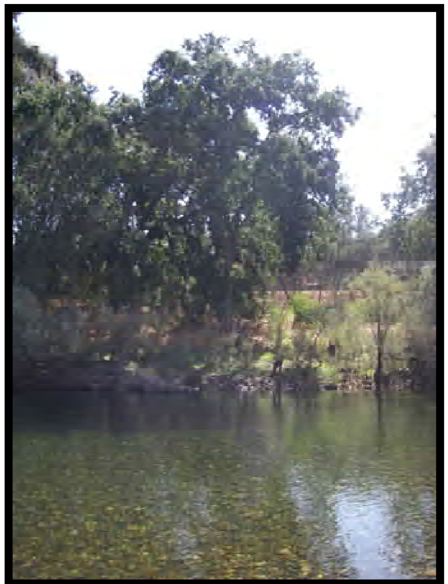
Lower Tuolumne River Instream Flow Study | Basso Bridge Reach

Medium Flow- 250 CFS- Transect 26B- Looking Upstream from River Right
IMGP0022
September 24, 2011

Lower Tuolumne River Instream Flow Study | Basso Bridge Reach

High Flow- 600 CFS- Transect 26B- Looking Upstream from River Right
IMGP6282
July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach



IMGP0023

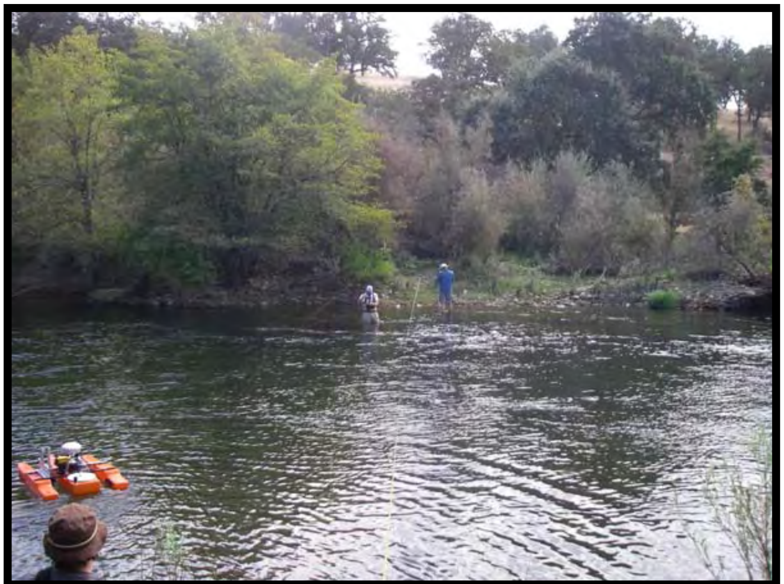
Medium Flow- 250 CFS- Benchmark 3 from Across, River Right September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

IMGP0744

Low Flow- 100 CFS- Transect 28A- Looking Across from River Right June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach



Medium Flow- 250 CFS- Transect 28A- Looking Across from River Right IMGP0024 September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

High Flow- 600 CFS- Transect 28A- Looking Across from River Right IMGP6283 July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 28A- Looking Downstream from River Right IMGP0745 June 26, 2012

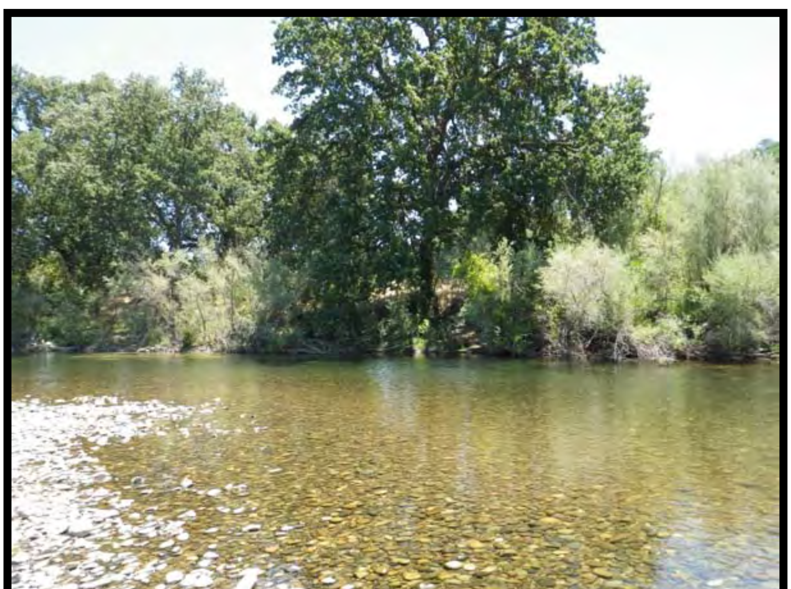
Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 28A- Looking Downstream from River Right IMGP0027 September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

High Flow- 600 CFS- Transect 28A- Looking Downstream from River Right IMGP6284 July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach



Low Flow- 100 CFS- Transect 26B- Looking Upstream from River Right IMGP0746 June 26, 2012

Lower Tuolumne River Instream Flow Study

Basso Bridge Reach

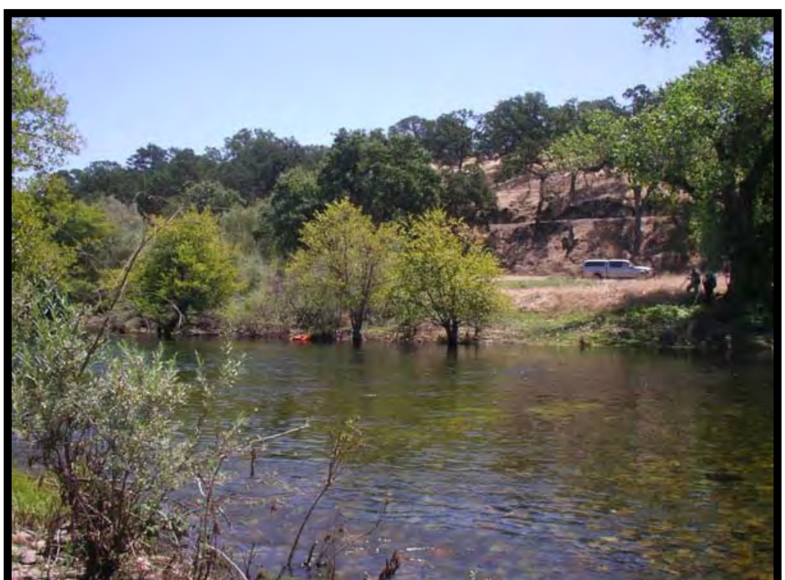
Medium Flow- 250 CFS- Transect 28A- Looking Upstream from River Right

IMGP0029

September 24, 2011

Lower Tuolumne River Instream Flow Study

Basso Bridge Reach



High Flow- 600 CFS- Transect 28A- Looking Upstream from River Right

IMGP6286

July 24, 2011

Lower Tuolumne River Instream Flow Study | Basso Bridge Reach

Low Flow- 100 CFS- Transect 28B- Looking Downstream from Head Pin for 28A River Right
IMGP0743
June 26, 2012

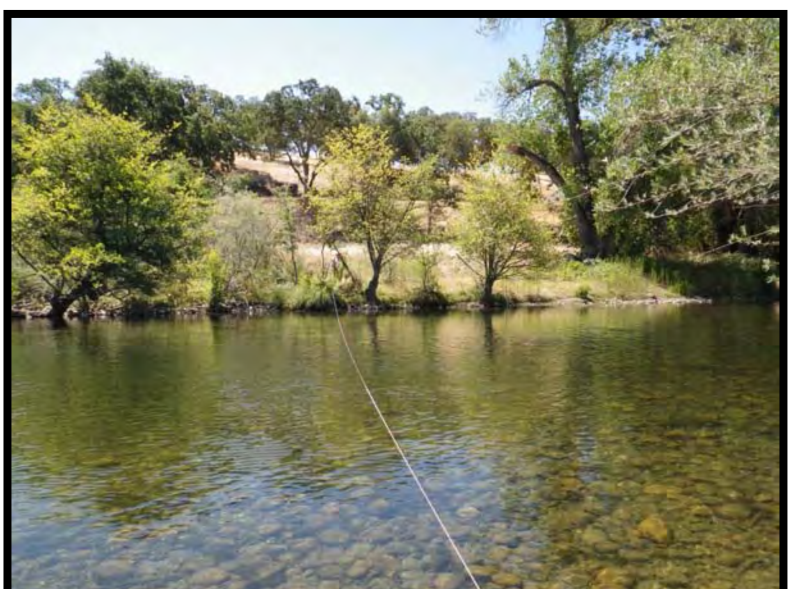
Lower Tuolumne River Instream Flow Study | Basso Bridge Reach

Medium Flow- 250 CFS- Transect 28B- Looking Downstream from River Right
IMGP0028
September 24, 2011

Lower Tuolumne River Instream Flow Study
Basso Bridge Reach

High Flow- 600 CFS- Transect 28B-
Looking Downstream from River Right
IMGP6285
July 24, 2011

Lower Tuolumne River Instream Flow Study
Basso Bridge Reach



Low Flow- 100 CFS- Transect 28B-
Looking Across from River Right
IMGP0740
June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 28B- Looking Across from River Right

IMGP0030

September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

High Flow- 600 CFS- Transect 28B- Looking Across from River Right

IMGP6287

July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 28B- Looking Upstream from River Right IMGP0741 June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 28B- Looking Upstream from River Right IMGP0031 September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

High Flow- 600 CFS- Transect 28B- Looking Upstream from River Right IMGP6288 July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 29A- Looking Across from River Right IMGP0738 June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 29A- Looking Across from River Right
IMGP0032
*29A was not photographed at 600 CFS
September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 29A- Looking Downstream from River Right
IMGP0739
June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 29A-
Looking Downstream from River Right

IMGP0033

* Transect 29A was not photographed at 600 CFS

September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 29A-
Looking Upstream from River Right

IMGP0737

June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 29A-
Looking Upstream from River Right
IMGP0034
*29A was not photographed at 600 CFS
September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 30A-
Looking Across from River Left
IMGP0735
June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 30A- Looking Across from River Left IMGP0035 September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

High Flow- 600 CFS- Transect 30A- Looking Across from River Left IMGP6289 July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 30A-
Looking Downstream from River Left

IMGP0736

June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 30A-
Looking Downstream from River Left

IMGP0036

September 24, 2011

Lower Tuolumne River Instream Flow Study

Basso Bridge Reach

High Flow- 600 CFS- Transect 30A-
Looking Downstream from River Left

IMGP6290

July 24, 2011

Lower Tuolumne River Instream Flow Study

Basso Bridge Reach

Low Flow- 100 CFS- Transect 30A-
Looking Upstream from River Left

IMGP0734

June 26, 2012

Lower Tuolumne River Instream Flow Study | Basso Bridge Reach

Medium Flow- 250 CFS- Transect 30A- Looking Upstream from River Left IMGP0037 September 24, 2011

Lower Tuolumne River Instream Flow Study | Basso Bridge Reach

High Flow- 600 CFS- Transect 30A- Looking Upstream from River Left IMGP6291 July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 30B- Looking Across from Tail Pin River Left
IMGP0732
June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 30B- Looking Across from River Left
IMGP0038
September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

High Flow- 600 CFS- Transect 30B-
Looking Across from River Left

IMGP6293

July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 30B-
Looking Upstream from River Left

IMGP0731

June 26, 2012

Lower Tuolumne River Instream Flow Study

Basso Bridge Reach

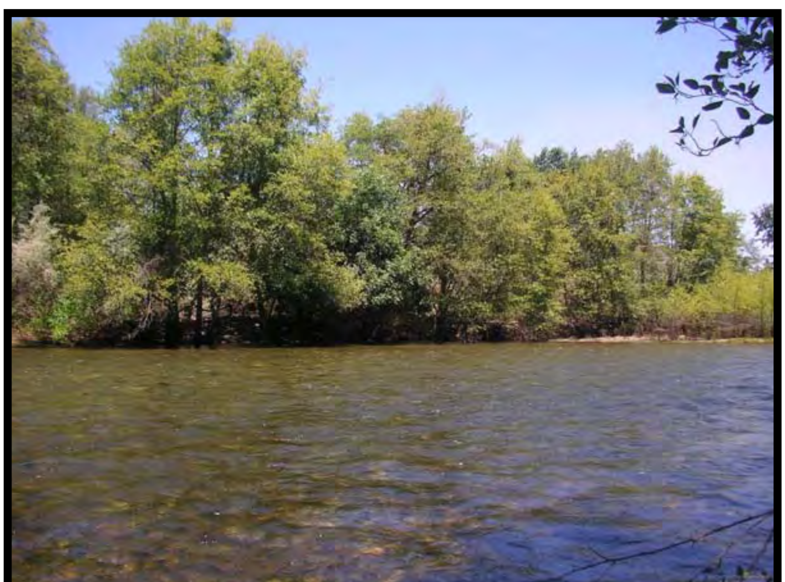
Medium Flow- 250 CFS- Transect 30B-
Looking Upstream from River Left

IMGP0039

September 24, 2011

Lower Tuolumne River Instream Flow Study

Basso Bridge Reach



High Flow- 600 CFS- Transect 30B-
Looking Upstream from River Left

IMGP6294

July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Low Flow- 100 CFS- Transect 30B-
Looking Downstream from River Left

IMGP0733

June 26, 2012

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

Medium Flow- 250 CFS- Transect 30B-
Looking Downstream from River Left

IMGP0041

September 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

High Flow- 600 CFS- Transect 30B- Looking Downstream from River Left

IMGP6292

July 24, 2011

Lower Tuolumne River Instream Flow Study Basso Bridge Reach

IMGP0040

Medium Flow- 250 CFS- Benchmark 1 at Base of Oak

September 24, 2011

Instream Flow Study

Lower Tuolumne River
Bobcat Flat Reach

July 25, 2011, September 25, 2011, & June 27, 2012

R. Liebig, K. Jarrett, I. Pryor, W. Swaney, S. Araya, K. Orr, N. Jurjavcic, R. McLintock, H. Bowen, M. Reymann, and K. Rodriguez

Lower Tuolumne River Instream Flow Study | Bobcat Flat Reach

IMGP0042

Mid Flow- 250 CFS- Transect 82A- Looking Across from River Right

September 25, 2011

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach

IMGP6295

High Flow- 600 CFS- Transect 82A-
Looking Across from River Right

July 25, 2011

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach

IMGP0043

Mid Flow- 250 CFS- Transect 82A-
Looking Downstream from River Right

September 25, 2011

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach

IMGP6296

High Flow- 600 CFS- Transect 82A-
Looking Downstream from River Right

July 25, 2011

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach

IMGP0044

Mid Flow- 250 CFS- Transect 82A-
Looking Upstream from River Right

September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP6297

High Flow- 600 CFS- Transect 82A-
Looking Upstream from River Right

July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP0045

Mid Flow- 250 CFS- Transect 82B-
Looking Across from River Right

September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP6298

High Flow- 600 CFS- Transect 82B-
Looking Across from River Right

July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP0046

Mid Flow- 250 CFS- Transect 82B-
Looking Downstream from River Right

September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP6299

High Flow- 600 CFS- Transect 82B-
Looking Downstream from River Right

July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP0047

Mid Flow- 250 CFS- Transect 82B-
Looking Upstream from River Right

September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP6300

High Flow- 600 CFS- Transect 82B-
Looking Upstream from River Right

July 25, 2011

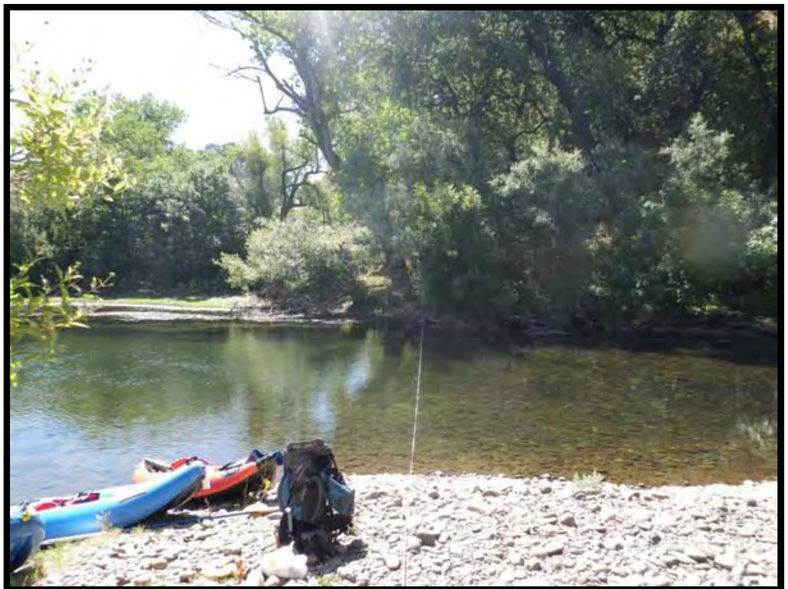
Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP0048

Mid Flow- 250 CFS- Benchmark 83

September 25, 2011

Lower Tuolumne River Instream Flow Study | Bobcat Flat Reach



IMGP0769

Low Flow- 100 CFS- Transect 82C-
Looking Across from River Right

June 27, 2012

Lower Tuolumne River Instream Flow Study | Bobcat Flat Reach

IMGP0049

Mid Flow- 250 CFS- Transect 82C
Looking Across from River Right

September 25, 2011

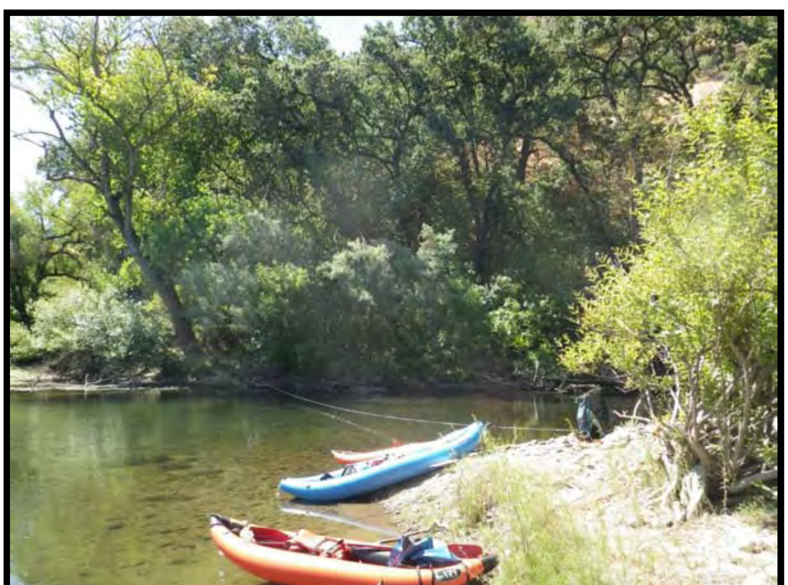
Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP6301

High Flow- 600 CFS- Transect 82C
Looking Across from River Right

July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach



IMGP0770

Low Flow- 100 CFS- Transect 82C-
Looking Downstream from River Left

June 27, 2012

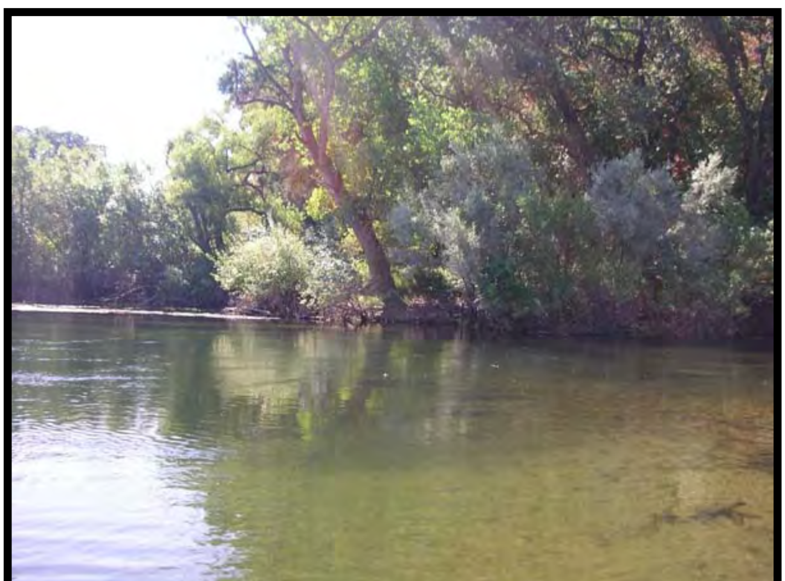
Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP0050

Mid Flow- 250 CFS- Transect 82C
Looking Downstream from River Right

September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach



IMGP6302

High Flow- 600 CFS- Transect 82C
Looking Downstream from River Right

July 25, 2011

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach

IMGP0771

Low Flow- 100 CFS- Transect 82C-
Looking Upstream from River Right

June 27, 2012

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach

IMGP0051

Mid Flow- 250 CFS- Transect 82C
Looking Upstream from River Right

September 25, 2011

Lower Tuolumne River Instream Flow Study — Bobcat Flat Reach

IMGP6303

High Flow- 600 CFS- Transect 82C
Looking Upstream from River Right

July 25, 2011

Lower Tuolumne River Instream Flow Study — Bobcat Flat Reach

IMGP0772

Low Flow- 100 CFS- Transect 82C- Looking Across
Main Channel from Far River Right Tail Pin

June 27, 2012

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP0052

Mid Flow- 250 CFS- Transect 82- Looking Across Main Channel from Far River Right Tail Pin

September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP6304

High Flow- 600 CFS- Transect 82C- Looking Across Main Channel from Far River Right Tail Pin

July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP0773

Low Flow- 100 CFS- Transect 82C- Looking Across Side Channel from Far River Right Tail Pin

June 27, 2012

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP0053

Mid Flow- 250 CFS- Transect 82C- Looking Across Side Channel from Far River Right Tail Pin

September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP6305

High Flow- 600 CFS- Transect 82C- Looking Across Side Channel from Far River Right Tail Pin

July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP0774

Low Flow- 100 CFS- Transect 83A- Looking Across from 1st Tail Pin River Right

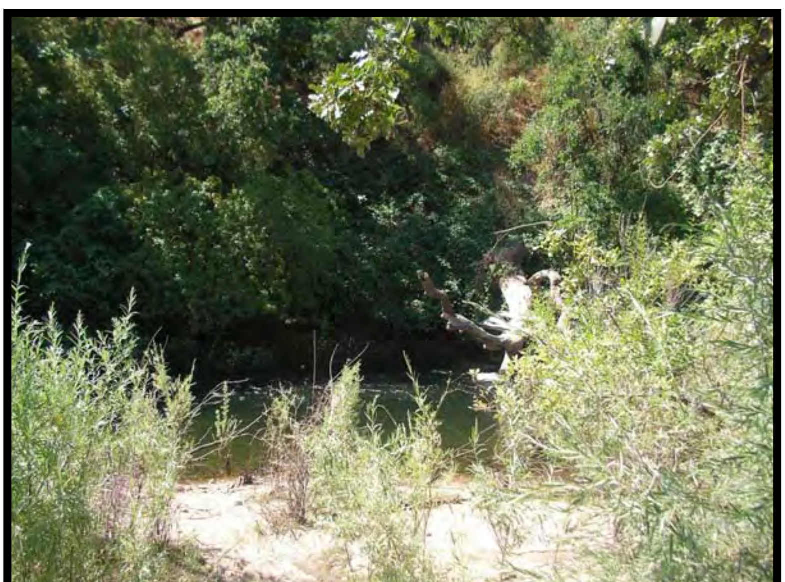
June 27, 2012

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Mid Flow- 250 CFS- Transect 83A- Looking Across from 1st Tail Pin River Right IMGP0054

September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach



High Flow- 600 CFS- Transect 83A- Looking Across from 1st Tail Pin River Right IMGP6309

July 25, 2011

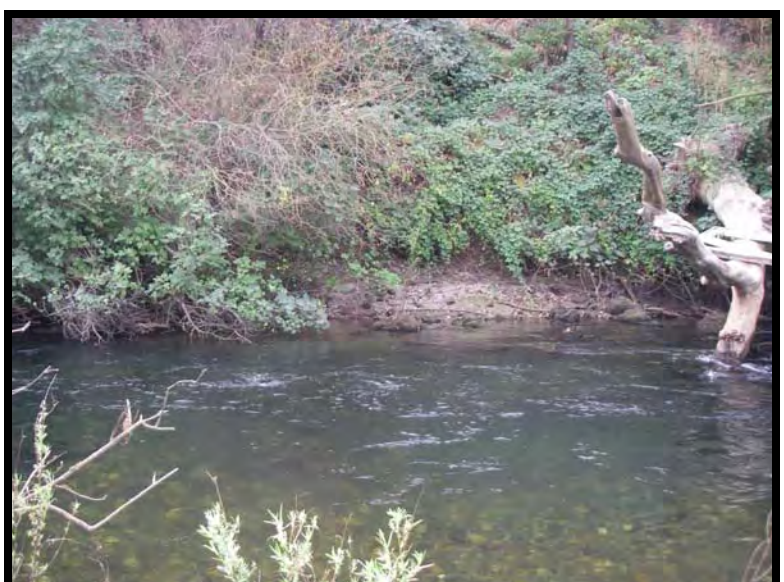
Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Low Flow- 100 CFS- Transect 83A- Looking Across from Wooden Stake River Right

IMGP0775

June 27, 2012

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach



Mid Flow- 250 CFS- Transect 83A- Looking Across from Wooden Stake River Right

IMGP0055

September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

High Flow- 600 CFS- Transect 83A- Looking Across from Wooden Stake River Right IMGP6306 July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Low Flow- 100 CFS- Transect 83A- Looking Downstream from River Right IMGP0776 June 27, 2012

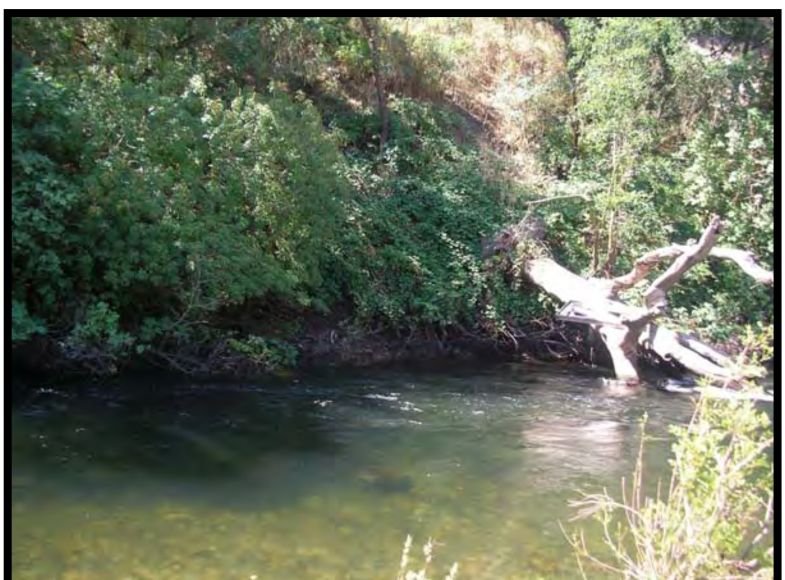
Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP0056

Mid Flow- 250 CFS- Transect 83A-
Looking Downstream from River Right

September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach



IMGP6307

High Flow- 600 CFS- Transect 83A-
Looking Downstream from River Right

July 25, 2011

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach

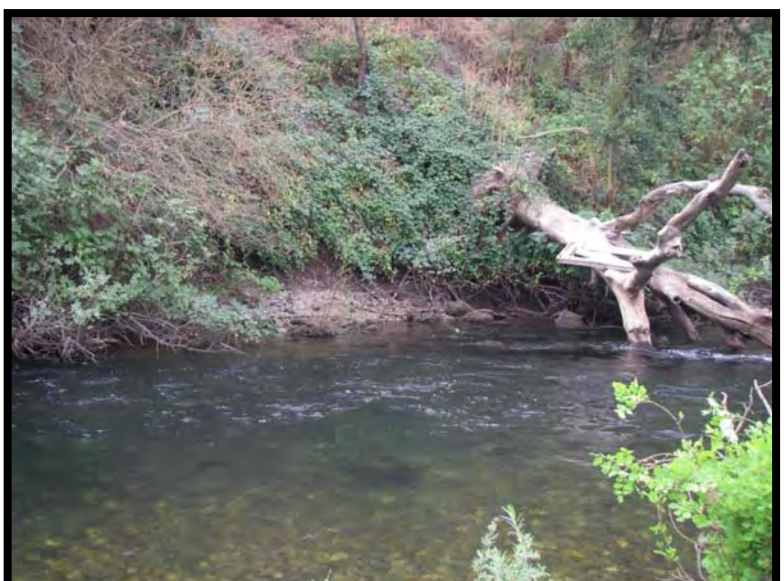
Low Flow- 100 CFS- Transect 83A-
Looking Upstream from River Right

IMGP0777

June 27, 2012

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach



Mid Flow- 250 CFS- Transect 83A-
Looking Upstream from River Right

IMGP0057

September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

High Flow- 600 CFS- Transect 83A- Looking Upstream from River Right IMGP6308 July 25, 2011

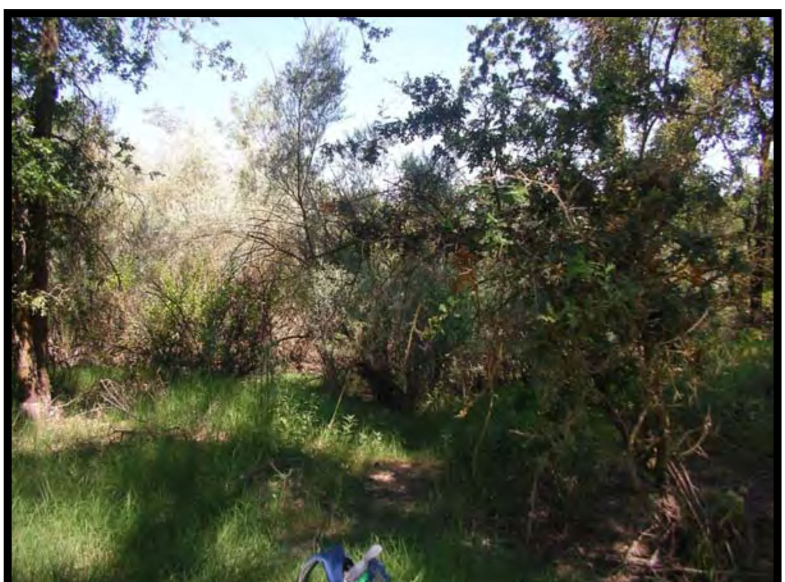
Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Low Flow- 100 CFS- Transect 83A- Looking Across Side Channel from 1st Tail Pin River Right IMGP0778 June 27, 2012

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Mid Flow- 250 CFS- Transect 83A- Looking Across Side Channel from 1st Tail Pin River Right IMGP0058 September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach



High Flow- 600 CFS- Transect 83A- Looking Across Side Channel from 1st Tail Pin River Right IMGP6311 July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP0779

Low Flow- 100 CFS- Transect 83A- Looking Downstream from 1st Tail Pin River Right

June 27, 2012

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP0059

Mid Flow- 250 CFS- Transect 83A- Looking Downstream from 1st Tail Pin River Right

September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP6310

High Flow- 600 CFS- Transect 83A- Looking Downstream from 1st Tail Pin River Right

July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP0062

Mid Flow- 250 CFS- Transect 83B- Looking Across from River Right

September 25, 2011

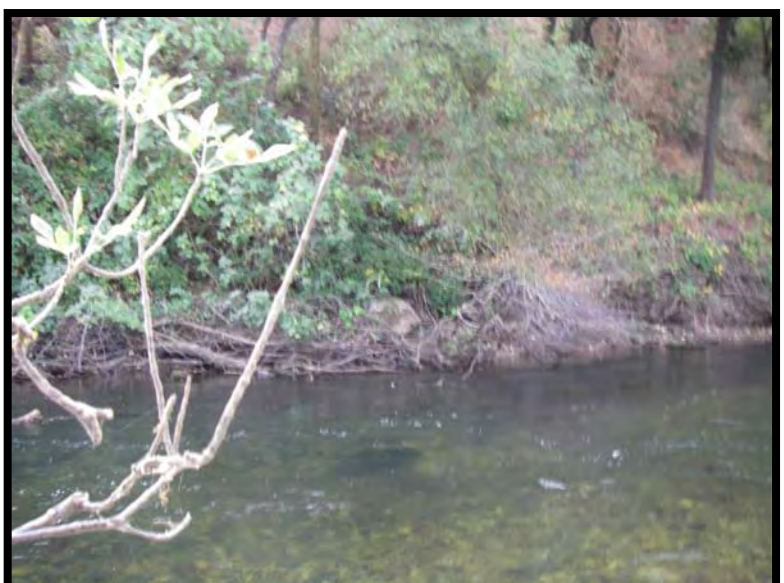
Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP6312

High Flow- 600 CFS- Transect 83B-
Looking Across from River Right

July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach



IMGP0063

Mid Flow- 250 CFS- Transect 83B0-
Looking Downstream from River Right

September 25, 2011

Lower Tuolumne River Instream Flow Study | Bobcat Flat Reach

IMGP6313

High Flow- 600 CFS- Transect 83B-
Looking Downstream from River Right

July 25, 2011

Lower Tuolumne River Instream Flow Study | Bobcat Flat Reach

IMGP0065

Mid Flow- 250 CFS- Transect 83B-
Looking Upstream from River Right

September 25, 2011

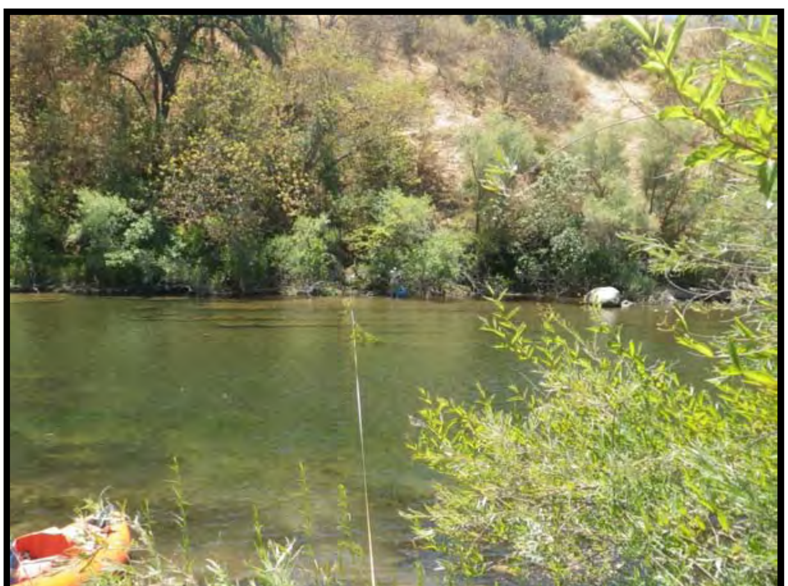
Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP6314

High Flow- 600 CFS- Transect 83B-
Looking Upstream from River Right

July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach



IMGP0787

Low Flow- 100 CFS- Transect 84A-
Looking Across from Tail Pin River Right

June 27, 2012

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach

Mid Flow- 250 CFS- Transect 84A- Looking Across from Tail Pin River Right

IMGP0066

September 25, 2011

Lower Tuolumne River Instream Flow Study

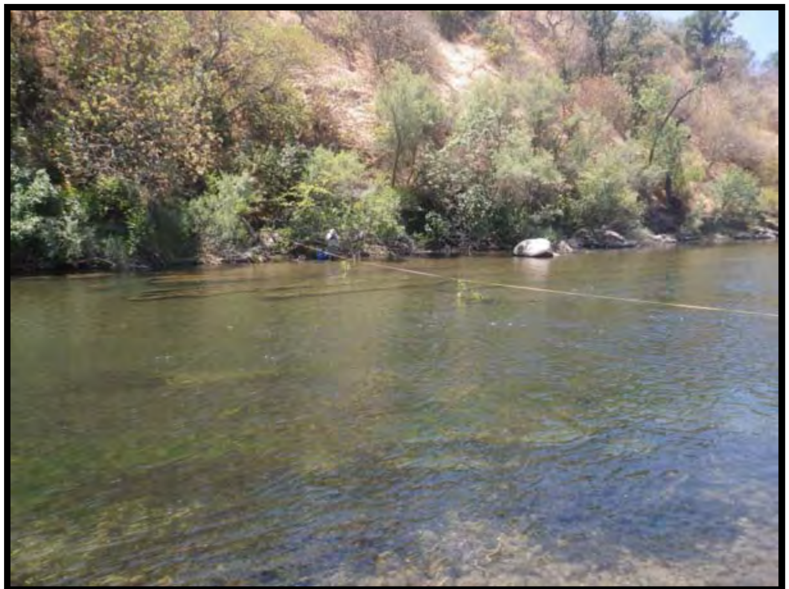
Bobcat Flat Reach

High Flow- 600 CFS- Transect 84A- Looking Across from Tail Pin River Right

IMGP6315

July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach



Low Flow- 100 CFS- Transect 84A-
Looking Downstream from River Right

IMGP0788

June 27, 2012

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Mid Flow- 250 CFS- Transect 84A-
Looking Downstream from River Right

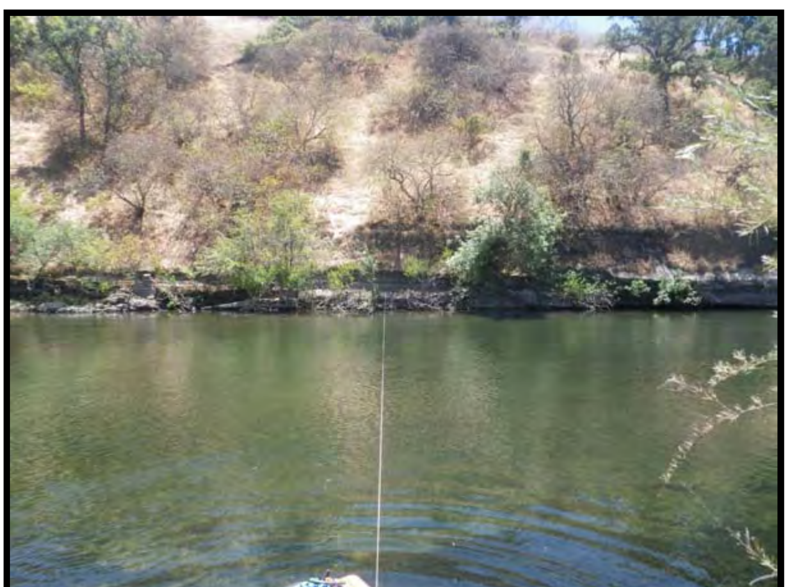
IMGP0067

September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

High Flow- 600 CFS- Transect 84A- Looking Downstream from River Right IMGP6316 July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach



Low Flow- 100 CFS- Transect 84B- Looking Across from Tail Pin River Right IMGP0789 June 27, 2012

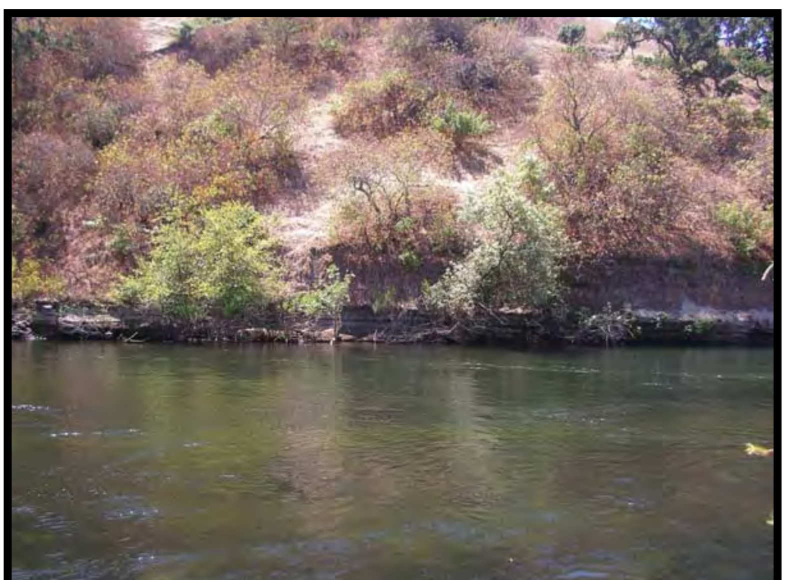
Lower Tuolumne River Instream Flow Study | Bobcat Flat Reach

IMGP0068

Mid Flow- 250 CFS- Transect 84B-
Looking Across from River Right

September 25, 2011

Lower Tuolumne River Instream Flow Study | Bobcat Flat Reach

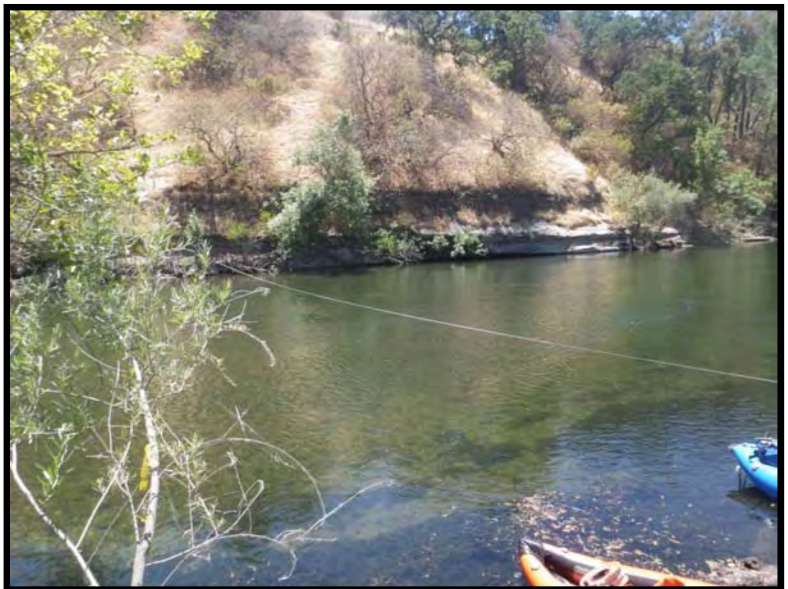


IMGP6317

High Flow- 600 CFS- Transect 84B-
Looking Across from River Right

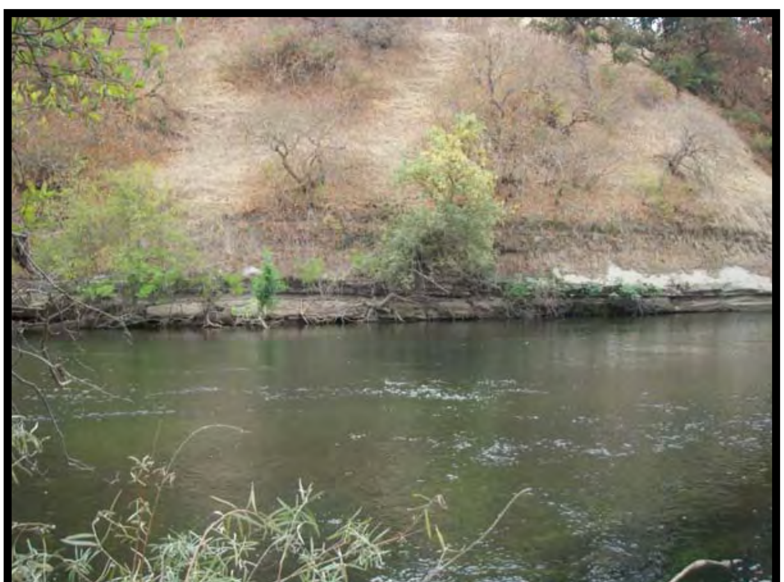
July 25, 2011

Lower Tuolumne River Instream Flow Study | Bobcat Flat Reach



Low Flow- 100 CFS- Transect 84B-
Looking Downstream from River Right
IMGP0790
June 27, 2012

Lower Tuolumne River Instream Flow Study | Bobcat Flat Reach



Mid Flow- 250 CFS- Transect 84B-
Looking Downstream from River Right
IMGP0069
September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

High Flow- 600 CFS- Transect 84B-
Looking Downstream from River Right
IMGP6318
July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Low Flow- 100 CFS- Transect 84B-
Looking Upstream from River Right
IMGP0791
June 27, 2012

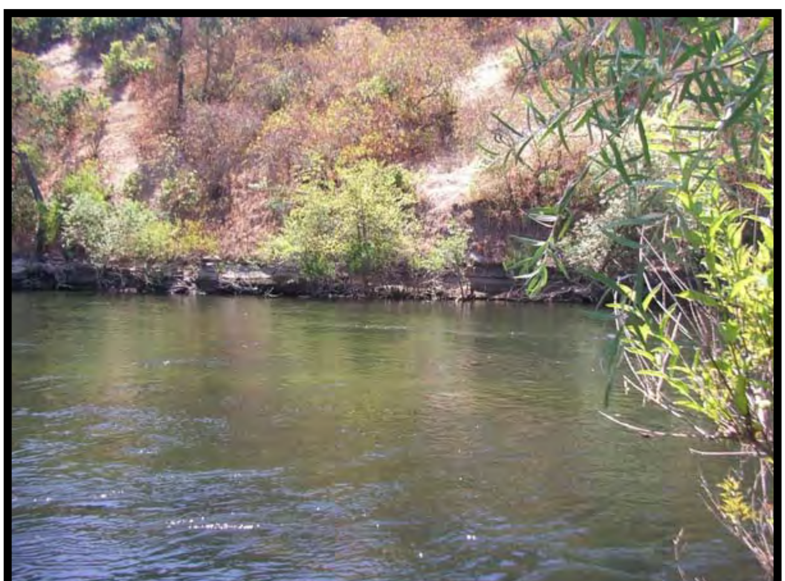
Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Mid Flow- 250 CFS- Transect 84B-
Looking Upstream from River Right

IMGP0070

September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

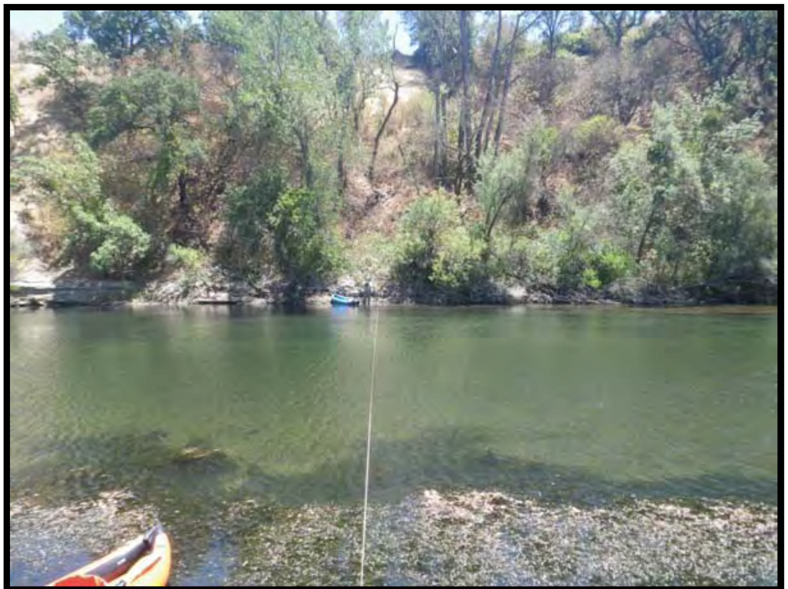


High Flow- 600 CFS- Transect 84B-
Looking Upstream from River Right

IMGP6319

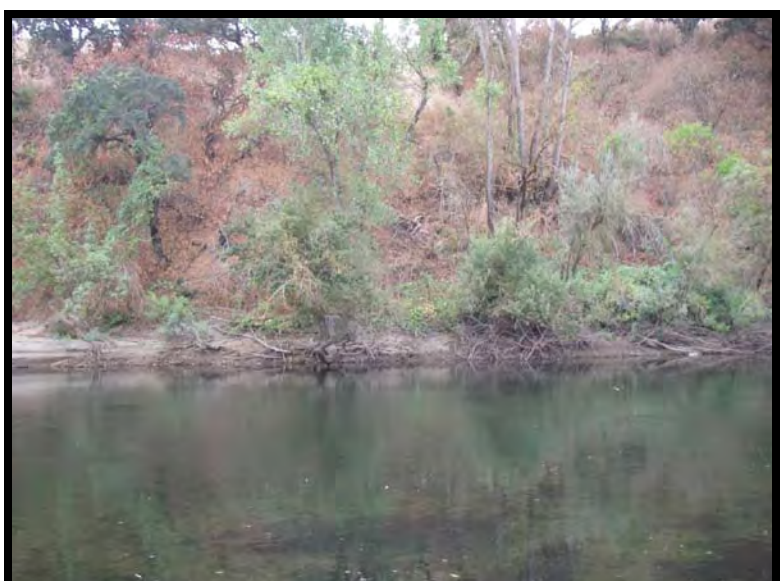
July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach



Low Flow- 100 CFS- Transect 84C-
Looking Across from River Right
IMGP0792
June 27, 2012

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach



Mid Flow- 250 CFS- Transect 84C-
Looking Across from River Right
IMGP0071
September 25, 2011

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach

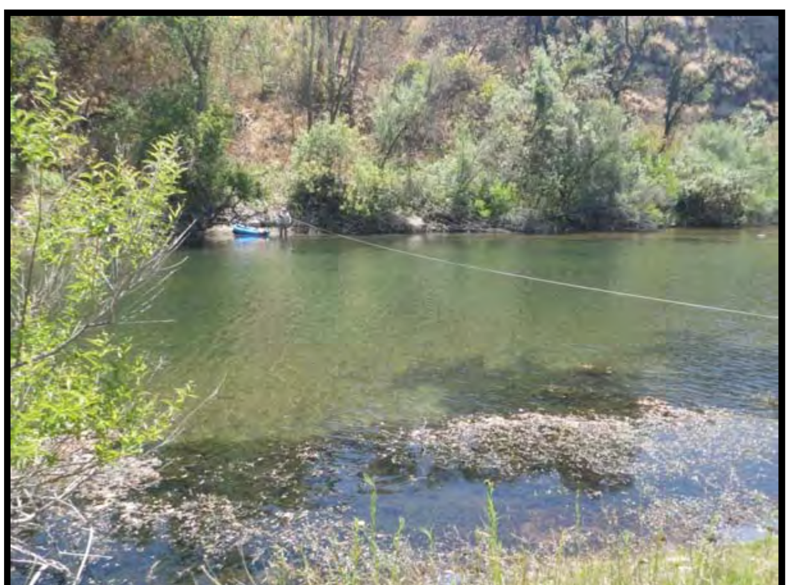
IMGP6320

High Flow- 600 CFS- Transect 84C-
Looking Across from River Right

July 25, 2011

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach



IMGP0793

Low Flow- 100 CFS- Transect 84C-
Looking Downstream from River Right

June 27, 2012

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach

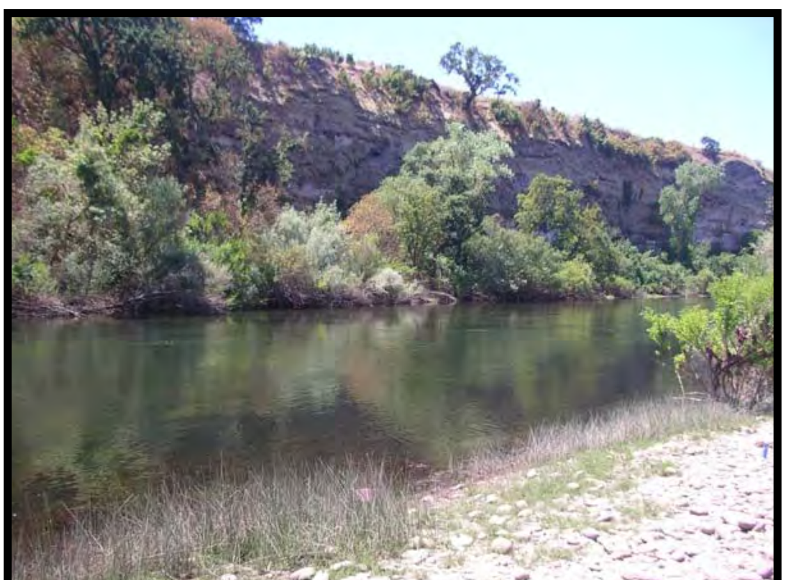
Mid Flow- 250 CFS- Transect 84C-
Looking Downstream from River Right

IMGP0072

September 25, 2011

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach



High Flow- 600 CFS- Transect 84C-
Looking Downstream from River Right

IMGP6321

July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Low Flow- 100 CFS- Transect 84C-
Looking Upstream from River Right
IMGP0794
June 27, 2012

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Mid Flow- 250 CFS- Transect 84C-
Looking Upstream from River Right
IMGP0074
September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

High Flow- 600 CFS- Transect 84C-
Looking Upstream from River Right

IMGP6322

July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Low Flow- 100 CFS- Transect 85A-
Looking Across from Tail Pin River Right

IMGP0796

June 27, 2012

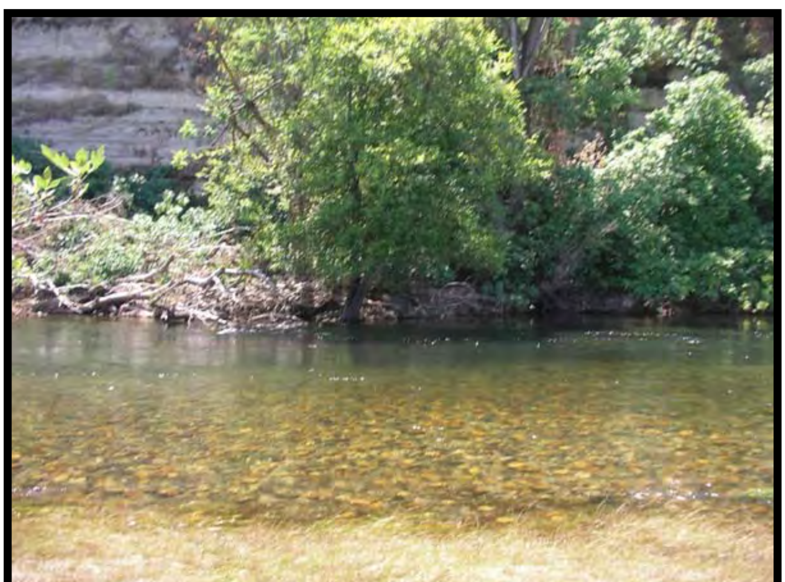
Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP0079

Mid Flow- 250 CFS- Transect 85A-
Looking Across from River Right

September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach



IMGP6323

High Flow- 600 CFS- Transect 85A-
Looking Across from River Right

July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Low Flow- 100 CFS- Transect 85A- Looking Downstream from River Right IMGP0797 June 27, 2012

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Mid Flow- 250 CFS- Transect 85A- Looking Downstream from River Right IMGP0080 September 25, 2011

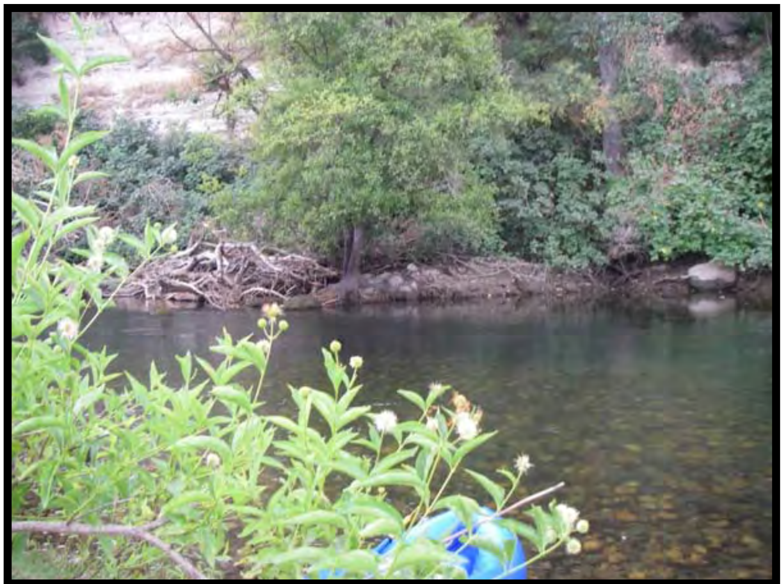
Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

High Flow- 600 CFS- Transect 85A-
Looking Downstream from River Right
IMGP6324
July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Low Flow- 100 CFS- Transect 85A-
Looking Upstream from River Right
IMGP0798
June 27, 2012

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

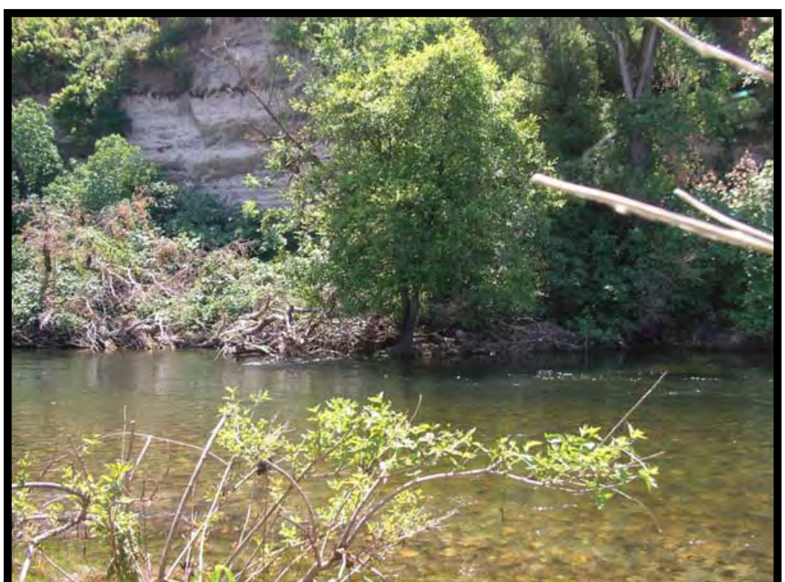


Mid Flow- 250 CFS- Transect 85A-
Looking Upstream from River Right

IMGP0081

September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach



High Flow- 600 CFS- Transect 85A-
Looking Upstream from River Right

IMGP6326

July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Low Flow- 100 CFS- Transect 86A- Looking Across from Tail Pin River Right IMGP0800 June 27, 2012

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Mid Flow- 250 CFS- Transect 86A- Looking Across from River Right IMGP0082 September 25, 2011

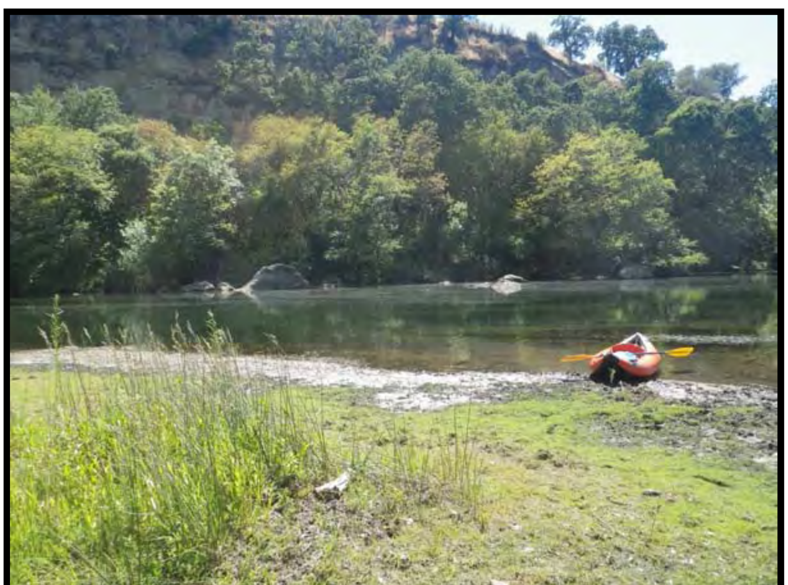
Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

High Flow- 600 CFS- Transect 86A- Looking Across from River Right

IMGP6327

July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach



Low Flow- 100 CFS- Transect 86A- Looking Downstream from River Right

IMGP0799

June 27, 2012

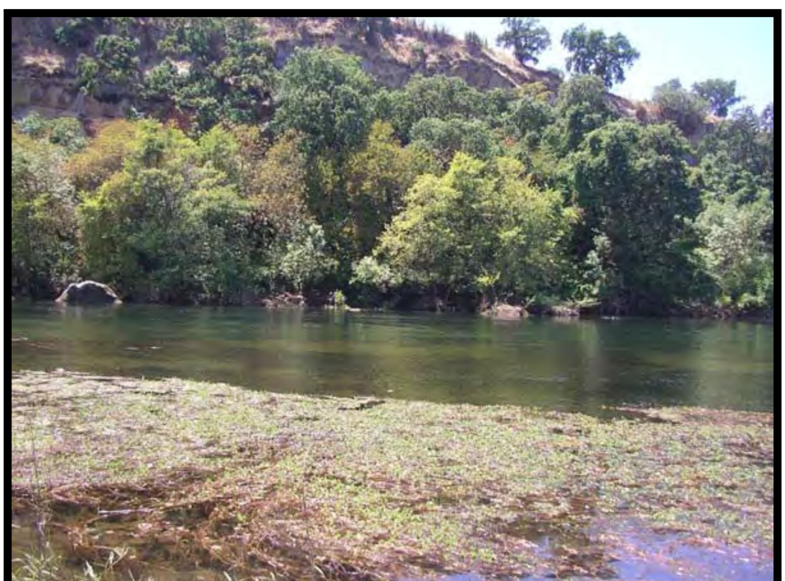
Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

IMGP0083

Mid Flow- 250 CFS- Transect 86A-
Looking Downstream from River Right

September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach



IMGP6328

High Flow- 600 CFS- Transect 86A-
Looking Downstream from River Right

July 25, 2011

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach

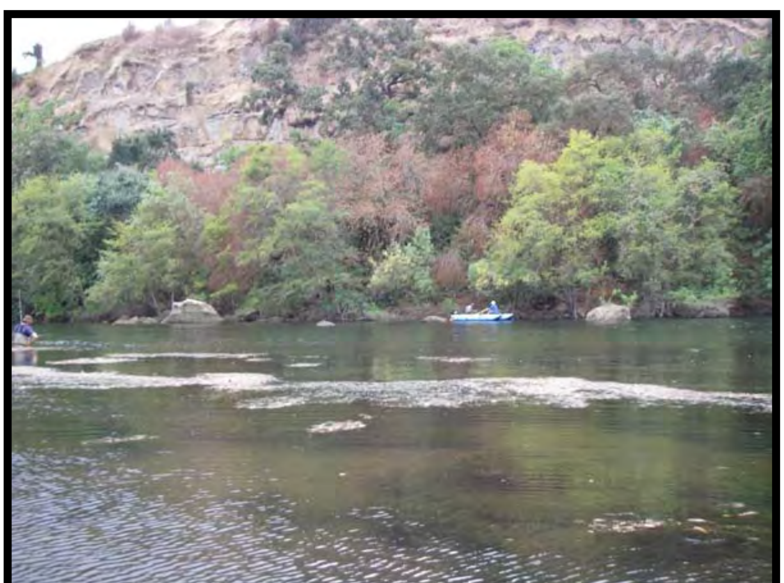
Low Flow- 100 CFS- Transect 86A-
Looking Upstream from River Right

IMGP0801

June 27, 2012

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach



Mid Flow- 250 CFS- Transect 86A-
Looking Upstream from River Right

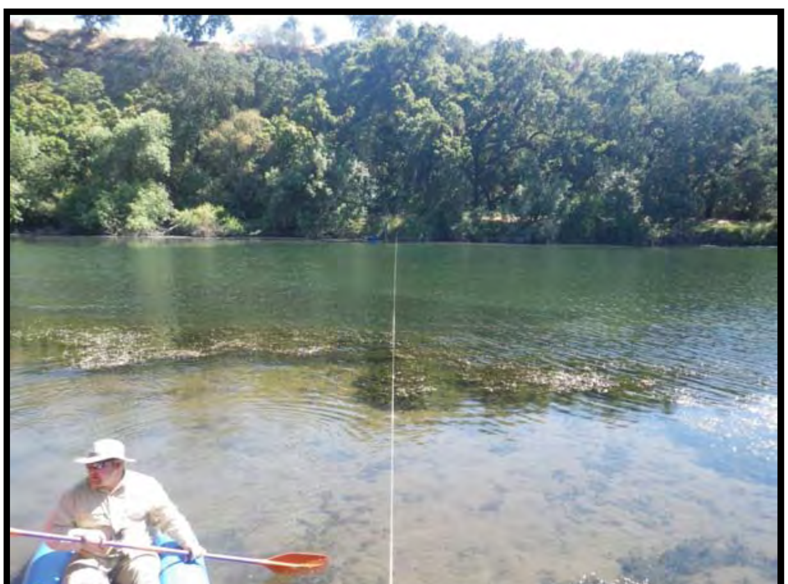
IMGP0084

September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

High Flow- 600 CFS- Transect 86A-
Looking Upstream from River Right
IMGP6329
July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach



Low Flow- 100 CFS- Transect 86B-
Looking Across from Tail Pin River Right
IMGP0806
June 27, 2012

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach

Mid Flow- 250 CFS- Transect 86B-
Looking Across from River Right

IMGP0085

September 25, 2011

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach

High Flow- 600 CFS- Transect 86B-
Looking Across from River Right

IMGP6330

July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Low Flow- 100 CFS- Transect 86B- Looking Downstream from River Right IMGP0807 June 27, 2012

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Mid Flow- 250 CFS- Transect 86B- Looking Downstream from River Right IMGP0087 September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

High Flow- 600 CFS- Transect 86B-
Looking Downstream from River Right
IMGP6331
July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Low Flow- 100 CFS- Transect 86B-
Looking Upstream from River Right
IMGP0808
June 27, 2012

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Mid Flow- 250 CFS- Transect 86B-
Looking Upstream from River Right

IMGP0088

September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

High Flow- 600 CFS- Transect 86B-
Looking Upstream from River Right

IMGP6332

July 25, 2011

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach

Low Flow- 100 CFS- Transect 86C-
Looking Across from Tail Pin River Right

IMGP0809

June 27, 2012

Lower Tuolumne River Instream Flow Study

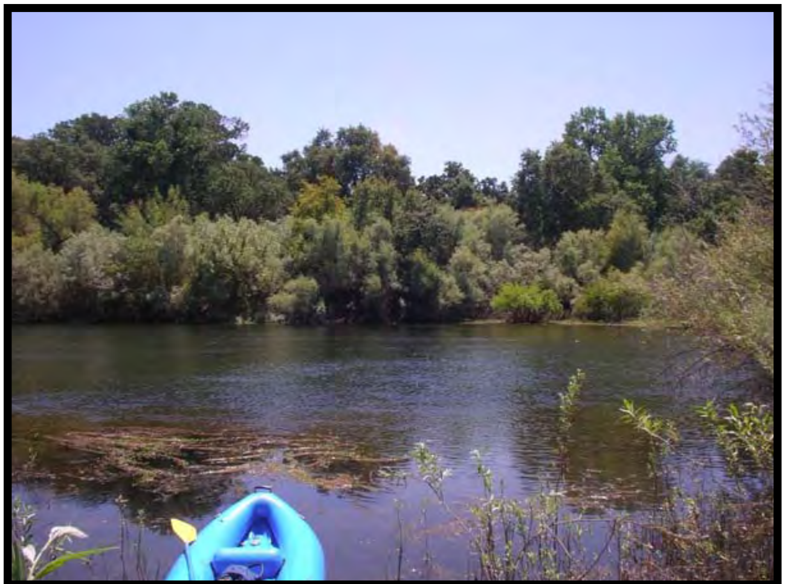
Bobcat Flat Reach

Mid Flow- 250 CFS- Transect 86C-
Looking Across from River Right

IMGP0089

September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach



High Flow- 600 CFS- Transect 86C-
Looking Across from River Right

IMGP6333

July 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Low Flow- 100 CFS- Transect 86C-
Looking Downstream from River Right

IMGP0810

June 27, 2012

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

Mid Flow- 250 CFS- Transect 86C-
Looking Downstream from River Right
IMGP0090
September 25, 2011

Lower Tuolumne River Instream Flow Study Bobcat Flat Reach

High Flow- 600 CFS- Transect 86C-
Looking Downstream from River Right
IMGP6334
July 25, 2011

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach

Low Flow- 100 CFS- Transect 86C-
Looking Upstream from River Right

IMGP0811

June 27, 2012

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach

Mid Flow- 250 CFS- Transect 86C-
Looking Upstream from River Right

IMGP0091

September 25, 2011

Lower Tuolumne River Instream Flow Study

Bobcat Flat Reach

IMGP6335

High Flow- 600 CFS- Transect 86C-
Looking Upstream from River Right

July 25, 2011

Instream Flow Study

Lower Tuolumne River
Santa Fe Reach

July 28, 2011, September 26, 2011, & June 28, 2012

R. Liebig, K. Jarrett, I. Pryor, W. Swaney, S. Araya, K. Orr, N. Jurjavcic, R. McLintock, H. Bowen, M. Reymann, and K. Rodriguez

Lower Tuolumne River Instream Flow Study — Santa Fe Reach

Low Flow- 100 CFS- Transect 155A- Looking Across from Tail Pin River Right

IMGP0822

June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 155A-
Looking Across from Tail Pin River Right
IMGP0092
September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 155A-
Looking Across From Tail Pin River Right
IMGP6339
July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 155A- Looking Downstream from River Right IMGP0824 June 28, 2012

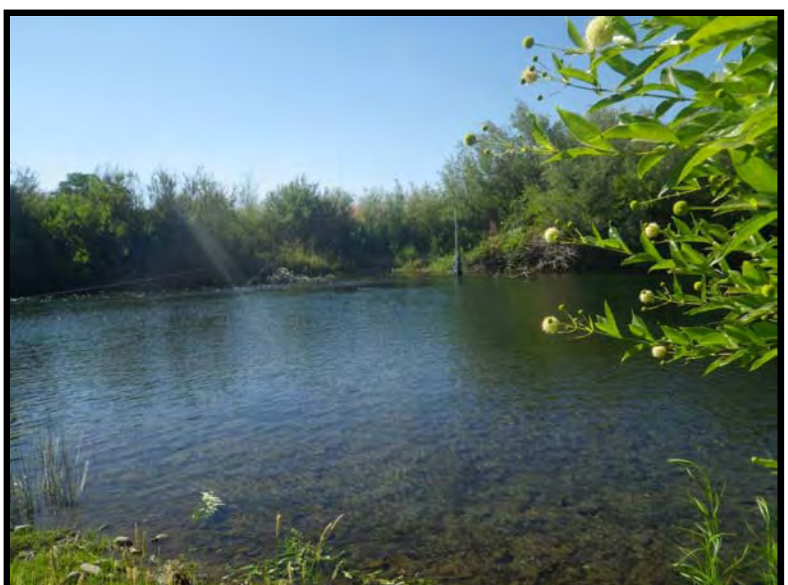
Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 155A- Looking Downstream from River Right IMGP0093 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 155A- IMGP6340 July 28, 2011
Looking Downstream from River Right

Lower Tuolumne River Instream Flow Study Santa Fe Reach



Low Flow- 100 CFS- Transect 155A- IMGP0823 June 28, 2012
Looking Upstream from River Right

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 155A-
Looking Upstream from River Right IMGP0094 September 26, 2011

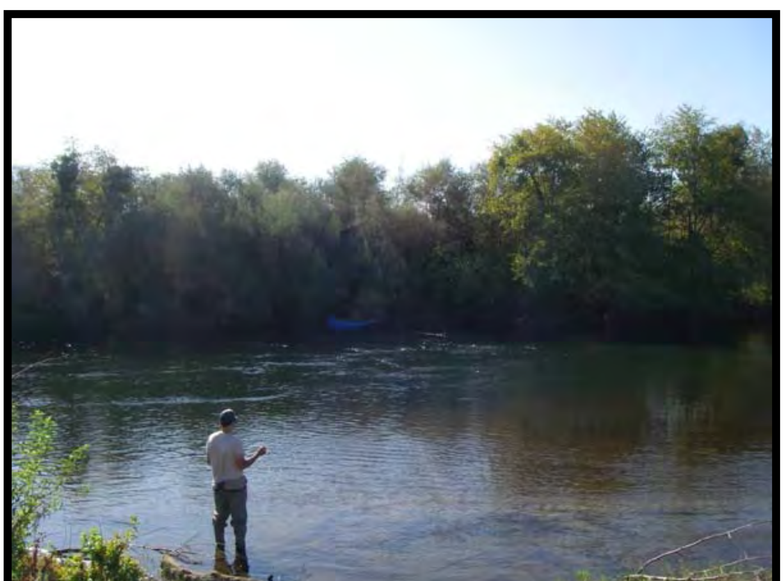
Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 155A-
Looking Upstream from River Right IMGP6341 July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 155B- Looking Across from Tail Pin River Right IMGP0826 June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach



Medium Flow- 250 CFS- Transect 155B- Looking Across from Tail Pin River Right IMGP0095 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 155B-
Looking Across from Tail Pin River Right IMGP6342 July 28, 2011

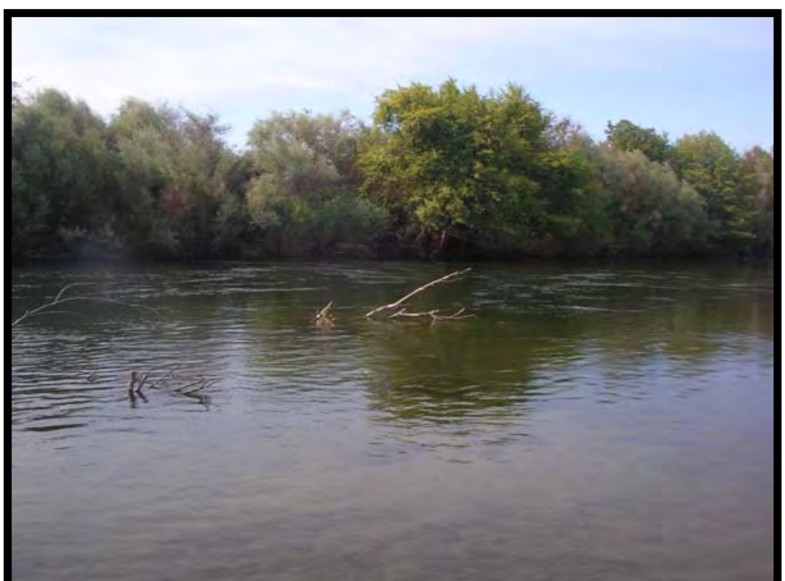
Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 155B-
Looking Downstream from River Right IMGP0825 June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 155B- Looking Downstream from River Right IMGP0096 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

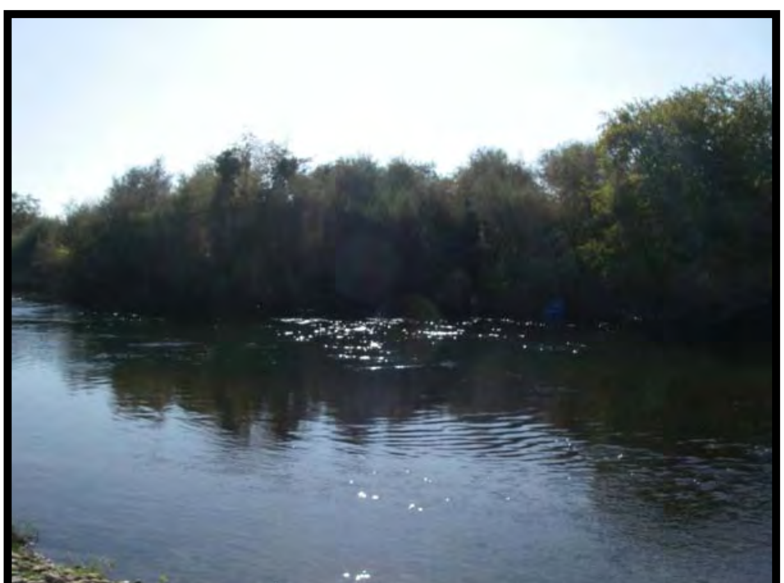


High Flow- 600 CFS- Transect 155B- Looking Downstream from River Right IMGP6343 July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 155B- Looking Upstream from River Right IMGP0827 June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

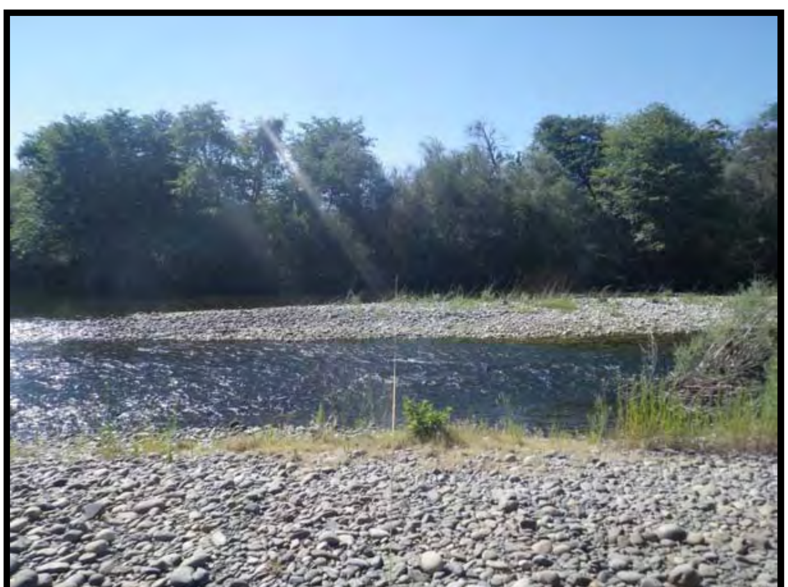


Medium Flow- 250 CFS- Transect 155B- Looking Upstream from River Right IMGP0097 September 26, 2011

Lower Tuolumne River Instream Flow Study | Santa Fe Reach

High Flow- 600 CFS- Transect 155B- Looking Upstream from River Right | IMGP6344 | July 28, 2011

Lower Tuolumne River Instream Flow Study | Santa Fe Reach



Low Flow- 100 CFS- Transect 156A- Looking Across from Tail Pin River Right | IMGP0830 | June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 156A- Looking Across from Tail Pin River Right IMGP0099 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 156A- Looking Across from Tail Pin River Right IMGP6346 July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 156A-
Looking Downstream from River Right
IMGP0829
June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 156A-
Looking Downstream from River Right
IMGP0098
September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 156A-
Looking Downstream from River Right
IMGP6345
July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 156A-
Looking Upstream from River Right
IMGP0831
June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

IMGP0102

Medium Flow- 250 CFS- Transect 156A-
Looking Upstream from River Right

September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

IMGP6347

High Flow- 600 CFS- Transect 156A-
Looking Upstream from River Right

July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 156B- Looking Across from Tail Pin River Right IMGP0832 June 28, 2012

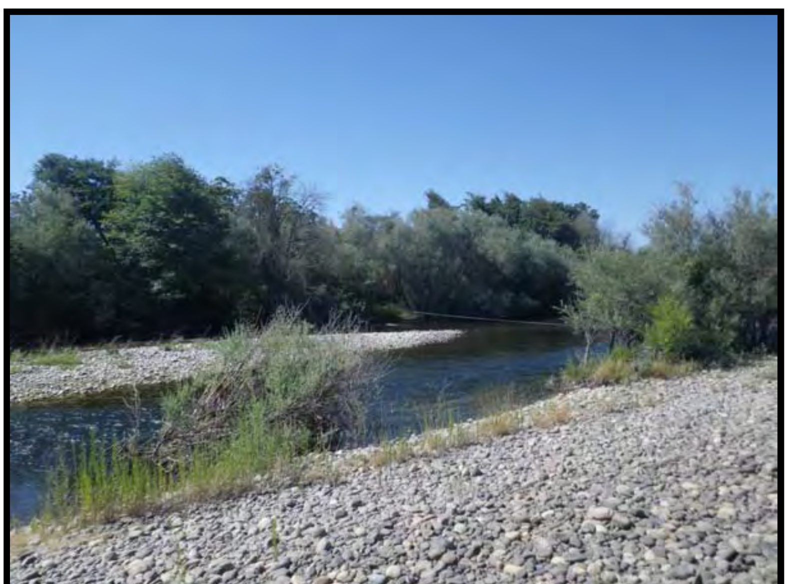
Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 156B- Looking Across from Tail Pin River Right IMGP0105 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 156B- Looking Across from Tail Pin River Right IMGP6349 July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach



Low Flow- 100 CFS- Transect 156B- Looking Downstream from River Right IMGP0834 June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 156B- Looking Downstream from River Right IMGP0103 September 26, 2011

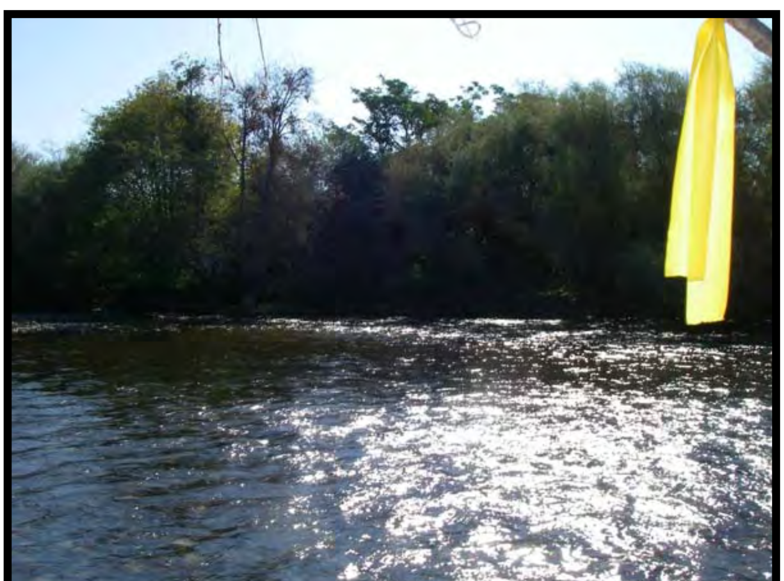
Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 156B- Looking Downstream from River Right IMGP6348 July 28, 2011

Lower Tuolumne River Instream Flow Study | Santa Fe Reach

Low Flow- 100 CFS- Transect 156B- Looking Upstream from River Right | IMGP0833 | June 28, 2012

Lower Tuolumne River Instream Flow Study | Santa Fe Reach



Medium Flow- 250 CFS- Transect 156B- Looking Upstream from River Right | IMGP0106 | September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 156B-
Looking Upstream from River Right IMGP6350 July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 159A-
Looking Across from Tail Pin River Right IMGP0837 June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 159A- Looking Across from Tail Pin River Right IMGP0107 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 159A- Looking Across from Tail Pin River Right IMGP6351 July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 159A- Looking Downstream from River Right IMGP0838 June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 159A- Looking Downstream from River Right IMGP0108 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 159A-
Looking Downstream from River Right
IMGP6352
July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 159A-
Looking Upstream from River Right
IMGP0839
June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 159A- Looking Upstream from River Right IMGP0109 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 159A- Looking Upstream from River Right IMGP6356 July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 159B- Looking Across from Tail Pin River Right IMGP0840 June 28, 2012

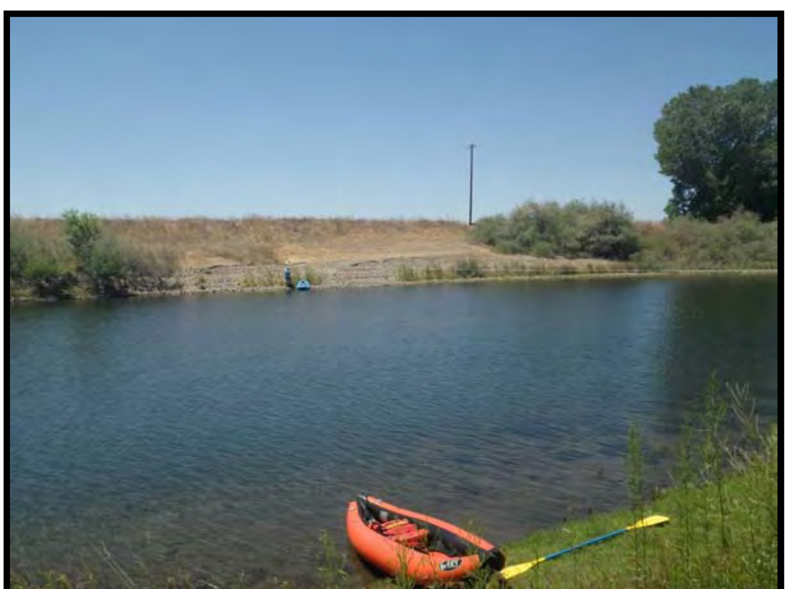
Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 159B- Looking Across from Tail Pin River Right IMGP0111 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 159B-
Looking Across from Tail Pin River Right
IMGP6357
July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach



Low Flow- 100 CFS- Transect 159B-
Looking Downstream from River Right
IMGP0841
June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 159B- Looking Downstream from River Right IMGP0112 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 159B- Looking Downstream from River Right IMGP6358 July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 159B-
Looking Upstream from River Right
IMGP0842
June 28, 2012

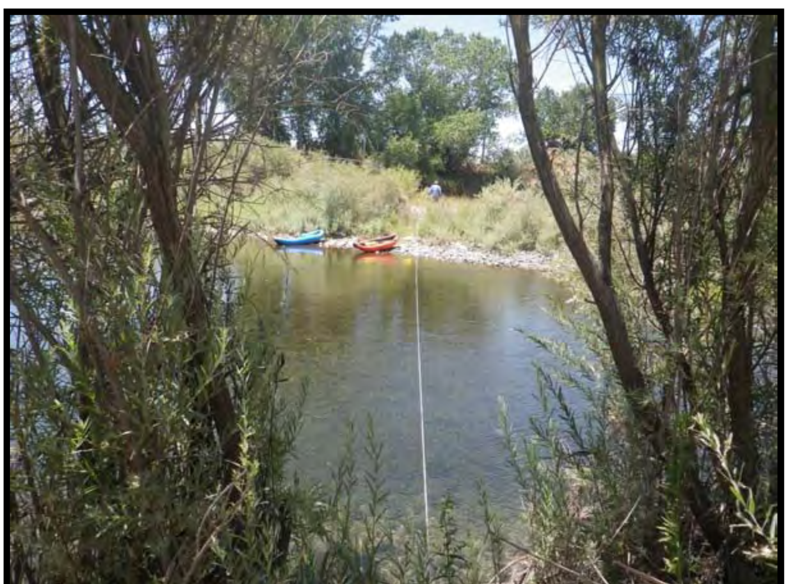
Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 159B-
Looking Upstream from River Right
IMGP0113
September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 159B- Looking Upstream from River Right IMGP6359 July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach



Low Flow- 100 CFS- Transect 159C- Looking Across from Tail Pin River Right IMGP0844 June 28, 2012

Lower Tuolumne River Instream Flow Study

Santa Fe Reach

Medium Flow- 250 CFS- Transect 159C-
Looking Across from Tail Pin River Right

IMGP0114

September 26, 2011

Lower Tuolumne River Instream Flow Study

Santa Fe Reach

High Flow- 600 CFS- Transect 159C-
Looking Across from Tail Pin River Right

IMGP6360

July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 159C- Looking Downstream from River Right IMGP0843 June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 159C- Looking Downstream from River Right IMGP0115 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 159C-
Looking Downstream from River Right
IMGP6361
July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 159C-
Looking Upstream from River Right
IMGP0845
June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 159C- Looking Upstream from River Right IMGP0116 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 159C- Looking Upstream from River Right IMGP6362 July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 160A-
Looking Across from Tail Pin River Right
IMGP0847
June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 160A-
Looking Across from Tail Pin River Right
IMGP0117
September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 160A- Looking Across from Tail Pin River Right

IMGP6363

July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 160A- Looking Downstream from River Right

IMGP0846

June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 160A- Looking Downstream from River Right IMGP0118 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 160A- Looking Downstream from River Right IMGP6364 July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 160A-
Looking Upstream from River Right IMGP0848 June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 160A-
Looking Upstream from River Right IMGP0119 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 160A-
Looking Upstream from River Right IMGP6365 July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 160B-
Looking Across from Tail Pin River Right IMGP0850 June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 160B- Looking Across from Tail Pin River Right IMGP0121 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 160B- Looking Across from Tail Pin River Right IMGP6367 July 28, 2011

Lower Tuolumne River Instream Flow Study

Santa Fe Reach

Low Flow- 100 CFS- Transect 160B-
Looking Downstream from River Right

IMGP0849

June 28, 2012

Lower Tuolumne River Instream Flow Study

Santa Fe Reach

Medium Flow- 250 CFS- Transect 160B-
Looking Downstream from River Right

IMGP0120

September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 160B-
Looking Downstream from River Right
IMGP6366
July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 160B-
Looking Upstream from River Right
IMGP0851
June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 160B- Looking Upstream from River Right IMGP0122 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 160B- Looking Upstream from River Right IMGP6368 July 28, 2011

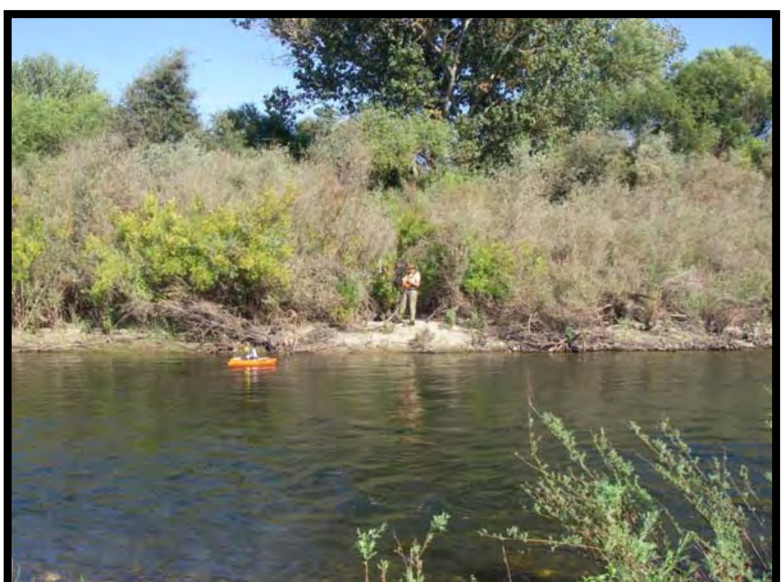
Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 161A-
Looking Across from Tail Pin River Right

IMGP0852

June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach



Medium Flow- 250 CFS- Transect 161A-
Looking Across from Tail Pin River Right

IMGP0123

September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 161A-
Looking Across from Head Pin River Right
IMGP6369
July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 161A-
Looking Downstream from River Left
IMGP0853
June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 161A- Looking Downstream from River Left

IMGP0124

September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 161A- Looking Downstream from River Left

IMGP6370

July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 161A- Looking Upstream from River Left IMGP0854 June 28, 2012

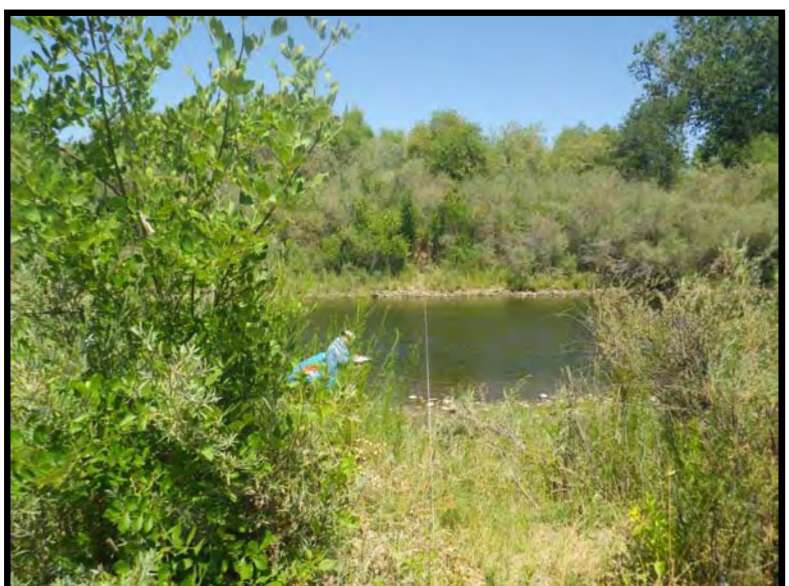
Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 161A- Looking Upstream from River Left IMGP0125 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 161A-
Looking Upstream from River Left
IMGP6371
July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach



Low Flow- 100 CFS- Transect 161B-
Looking Across from Head Pin River Left
IMGP0856
June 28, 2012

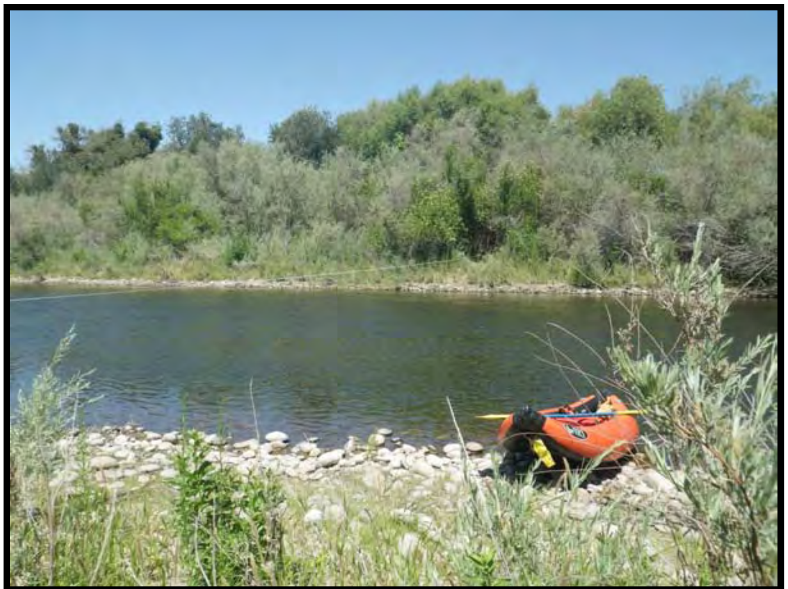
Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 161B-
Looking Across from Head Pin River Left
IMGP0126
September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 161B-
Looking Across from Head Pin River Left
IMGP6372
July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach



Low Flow- 100 CFS- Transect 161B- Looking Downstream from River Left IMGP0855 June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 161B- Looking Downstream from River Left IMGP0127 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 161B- Looking Downstream from River Left IMGP6373 July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 161B- Looking Upstream from River Left IMGP0857 June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 161B- Looking Upstream from River Left IMGP0128 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 161B- Looking Upstream from River Left IMGP6374 July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 163A-
Looking Across from Head Pin River Left
IMGP0859
June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 162A-
Looking Across from Head Pin River Left
IMGP0129
September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 162A- Looking Across from Head Pin River Left IMGP6375 July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 162A- Looking Downstream from River Left IMGP0861 June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 162A- Looking Downstream from River Left IMGP0130 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 162A- Looking Downstream from River Left IMGP6376 July 28, 2011

Lower Tuolumne River Instream Flow Study | Santa Fe Reach

Low Flow- 100 CFS- Transect 162A- Looking Upstream from 163A Head Pin River Left | IMGP0858 | June 28, 2012

Lower Tuolumne River Instream Flow Study | Santa Fe Reach

Medium Flow- 250 CFS- Transect 162A- Looking Upstream from River Left | IMGP0131 | September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 162A-
Looking Upstream from River Left
IMGP6377
July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 163A-
Looking Across from Head Pin River Left
IMGP0859
June 28, 2012

Lower Tuolumne River Instream Flow Study | Santa Fe Reach

Medium Flow- 250 CFS- Transect 163A- Looking Across from Head Pin River Left
IMGP0132
September 26, 2011

Lower Tuolumne River Instream Flow Study | Santa Fe Reach

High Flow- 600 CFS- Transect 163A- Looking Across from Head Pin River Left
IMGP6378
July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 163A- Looking Downstream from River Left IMGP0862 June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 163A- Looking Downstream from River Left IMGP0133 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 163A- Looking Downstream from River Left IMGP6379 July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 163A- Looking Upstream from River Left IMGP0864 June 28, 2012

Lower Tuolumne River Instream Flow Study | Santa Fe Reach

Medium Flow- 250 CFS- Transect 163A- Looking Upstream from River Left | IMGP0134 | September 26, 2011

Lower Tuolumne River Instream Flow Study | Santa Fe Reach

High Flow- 600 CFS- Transect 163A- Looking Upstream from River Left | IMGP6380 | July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 163B-
Looking Across from Head Pin River Left
IMGP0863
June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 163B-
Looking Across from Head Pin River Left
IMGP0135
September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 163B-
Looking Across from Head Pin River Left
IMGP6381
July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 163B-
Looking Downstream from River Left
IMGP0136
September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 163B- Looking Downstream from River Left IMGP6382 July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 163B- Looking Upstream from River Left IMGP0137 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 163B- Looking Upstream from River Left IMGP6383 July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 163C- Looking Across from Head Pin River Left IMGP0868 June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 163C- Looking Across from Head Pin River Left IMGP0140 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 163C- Looking Across from Head Pin River Left IMGP6384 July 28, 2011

Lower Tuolumne River Instream Flow Study | Santa Fe Reach

IMGP0866

Low Flow- 100 CFS- Transect 163C-
Looking Downstream from River Left

June 28, 2012

Lower Tuolumne River Instream Flow Study | Santa Fe Reach

IMGP0138

Medium Flow- 250 CFS- Transect 163C-
Looking Downstream from River Left

September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 163C- Looking Downstream from River Left IMGP6385 July 28, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Low Flow- 100 CFS- Transect 163C- Looking Upstream from River Left IMGP0869 June 28, 2012

Lower Tuolumne River Instream Flow Study Santa Fe Reach

Medium Flow- 250 CFS- Transect 163C- Looking Upstream from River Left IMGP0139 September 26, 2011

Lower Tuolumne River Instream Flow Study Santa Fe Reach

High Flow- 600 CFS- Transect 163C- Looking Upstream from River Left IMGP6386 July 28, 2011

Instream Flow Study

Lower Tuolumne River
Waterford Reach

July 29, 2011, September 27, 2011, & June 29, 2012

R. Liebig, K. Jarrett, I. Pryor, W. Swaney, S. Araya, K. Orr, N. Jurjavcic, R. McLintock, H. Bowen, M. Reymann, and K. Rodriguez

Lower Tuolumne River Instream Flow Study Waterford Reach

Low Flow- 100 CFS- Transect 205A- Looking Across from Head Pin IMGP0876 June 29, 2012

Lower Tuolumne River Instream Flow Study Waterford Reach

IMGP0162

Medium Flow- 250 CFS- Transect 205A- Looking Across from Head Pin September 27, 2011

Lower Tuolumne River Instream Flow Study Waterford Reach

IMGP6390

High Flow- 600 CFS- Transect 205A- Looking Across from Head Pin July 29, 2011

Lower Tuolumne River Instream Flow Study Waterford Reach

Low Flow- 100 CFS- Transect 205A- Looking Downstream from River Left IMGP0875 June 29, 2012

Lower Tuolumne River Instream Flow Study Waterford Reach

Medium Flow- 250 CFS- Transect 205A- Looking Downstream from River Left IMGP0165 September 27, 2011

Lower Tuolumne River Instream Flow Study Waterford Reach

High Flow- 600 CFS- Transect 205A-
Looking Downstream from River Left
IMGP6392
July 29, 2011

Lower Tuolumne River Instream Flow Study Waterford Reach

Low Flow- 100 CFS- Transect 205A-
Looking Upstream from River Left
IMGP0877
June 29, 2012

Lower Tuolumne River Instream Flow Study Waterford Reach

Medium Flow- 250 CFS- Transect 205A- Looking Upstream from River Left IMGP0166 September 27, 2011

Lower Tuolumne River Instream Flow Study Waterford Reach

High Flow- 600 CFS- Transect 205A- Looking Upstream from River Left IMGP6391 July 29, 2011

Lower Tuolumne River Instream Flow Study | Waterford Reach

Low Flow- 100 CFS- Transect 205B- Looking Across from Head Pin | IMGP0879 | June 29, 2012

Lower Tuolumne River Instream Flow Study | Waterford Reach

Medium Flow- 250 CFS- Transect 205B- Looking Across from Head Pin | IMGP0167 | September 27, 2011

Lower Tuolumne River Instream Flow Study Waterford Reach

High Flow- 600 CFS- Transect 205B- Looking Across from Head Pin IMGP6387 July 29, 2011

Lower Tuolumne River Instream Flow Study Waterford Reach

Low Flow- 100 CFS- Transect 205B- Looking Downstream from River Left IMGP0878 June 29, 2012

Lower Tuolumne River Instream Flow Study Waterford Reach

Medium Flow- 250 CFS- Transect 205B- Looking Downstream from River Left IMGP0168 September 27, 2011

Lower Tuolumne River Instream Flow Study Waterford Reach

High Flow- 600 CFS- Transect 205B- Looking Downstream from River Left IMGP6389 July 29, 2011

Lower Tuolumne River Instream Flow Study Waterford Reach

Low Flow- 100 CFS- Transect 205B-
Looking Upstream from River Left IMGP0880 June 29, 2012

Lower Tuolumne River Instream Flow Study Waterford Reach

Medium Flow- 250 CFS- Transect 205B-
Looking Upstream from River Left IMGP0169 September 27, 2011

Lower Tuolumne River Instream Flow Study Waterford Reach

IMGP6388

High Flow- 600 CFS- Transect 205B- Looking Upstream from River Left July 29, 2011

Instream Flow Study

Lower Tuolumne River
Delaware Reach

July 29, 2011, September 27, 2011, & June 29, 2012

R. Liebig, K. Jarrett, I. Pryor, W. Swaney, S. Araya, K. Orr, N. Jurjavcic, R. McLintock, H. Bowen, M. Reymann, and K. Rodriguez

Lower Tuolumne River Instream Flow Study — Delaware Reach

Medium Flow- 250 CFS- Benchmark

IMGP0150

September 27, 2011

Lower Tuolumne River Instream Flow Study | Delaware Reach

Low Flow- 100 CFS- Transect 255A-
Looking Across from Head Pin

IMGP0889

June 29, 2012

Lower Tuolumne River Instream Flow Study | Delaware Reach

Medium Flow- 250 CFS- Transect 255A
Looking Across from Head Pin

IMGP0157

September 27, 2011

Lower Tuolumne River Instream Flow Study | Delaware Reach

High Flow- 600 CFS- Transect 255A
Looking Across from Head Pin
IMGP6395
July 29, 2011

Lower Tuolumne River Instream Flow Study | Delaware Reach

Low Flow- 100 CFS- Transect 255A-
Looking Downstream from River Left
IMGP0890
June 29, 2012

Lower Tuolumne River Instream Flow Study Delaware Reach

Medium Flow- 250 CFS- Transect 255A IMGP0158 September 27, 2011
Looking Downstream from River Left

Lower Tuolumne River Instream Flow Study Delaware Reach

High Flow- 600 CFS- Transect 255A IMGP6396 July 29, 2011
Looking Downstream from River Left

Lower Tuolumne River Instream Flow Study Delaware Reach

Low Flow- 100 CFS- Transect 255A-
Looking Upstream from River Left
IMGP0891
June 29, 2012

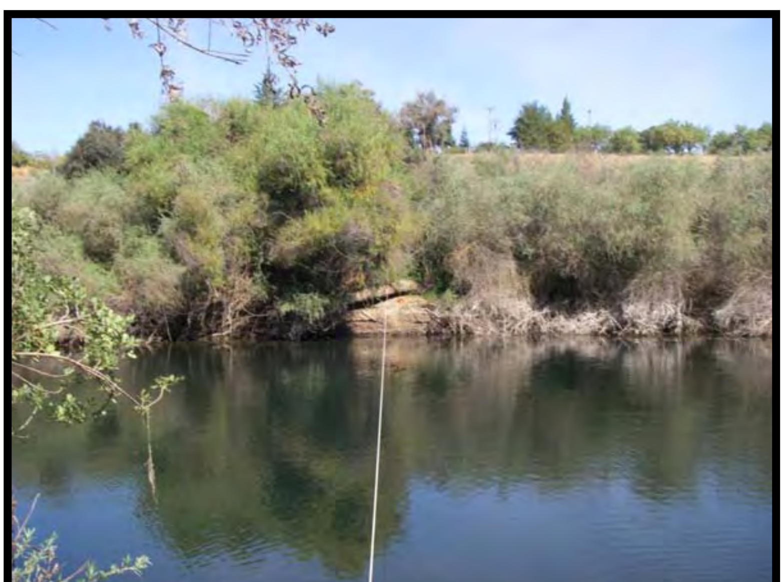
Lower Tuolumne River Instream Flow Study Delaware Reach

High Flow- 600 CFS- Transect 255A
Looking Upstream from River Left
IMGP6397
July 29, 2011

Lower Tuolumne River Instream Flow Study Delaware Reach

Low Flow- 100 CFS- Transect 255B-
Looking Across from Head Pin IMGP0886 June 29, 2012

Lower Tuolumne River Instream Flow Study Delaware Reach



Medium Flow- 250 CFS- Transect 255B
Looking Across from Head Pin IMGP0154 September 27, 2011

Lower Tuolumne River Instream Flow Study Delaware Reach

High Flow- 600 CFS- Transect 255B- Looking Across from Head Pin IMGP6398 July 29, 2011

Lower Tuolumne River Instream Flow Study Delaware Reach

Low Flow- 100 CFS- Transect 255B- Looking Downstream from River Left IMGP0888 June 29, 2012

Lower Tuolumne River Instream Flow Study

Delaware Reach

Medium Flow- 250 CFS- Transect 255B
Looking Downstream from River Left

IMGP0155

September 27, 2011

Lower Tuolumne River Instream Flow Study

Delaware Reach

High Flow- 600 CFS- Transect 255B-
Looking Downstream from River Left

IMGP6399

July 29, 2011

Lower Tuolumne River Instream Flow Study | Delaware Reach

Low Flow- 100 CFS- Transect 255B-
Looking Upstream from River Left
IMGP0887
June 29, 2012

Lower Tuolumne River Instream Flow Study | Delaware Reach

Medium Flow- 250 CFS- Transect 255B-
Looking Upstream from River Left
IMGP0156
September 27, 2011

Lower Tuolumne River Instream Flow Study Delaware Reach

High Flow- 600 CFS- Transect 255B- Looking Upstream from River Left IMGP6400 July 29, 2011

Lower Tuolumne River Instream Flow Study Delaware Reach

Low Flow- 100 CFS- Transect 255C- Looking Across from Head Pin IMGP0883 June 29, 2012

Lower Tuolumne River Instream Flow Study Delaware Reach

Medium Flow- 250 CFS- Transect 255C- Looking Across from Head Pin IMGP0151 September 27, 2011

Lower Tuolumne River Instream Flow Study Delaware Reach

High Flow- 600 CFS- Transect 255C- Looking Across from Head Pin IMGP6403 July 29, 2011

Lower Tuolumne River Instream Flow Study

Delaware Reach

Low Flow- 100 CFS- Transect 255C-
Looking Downstream from River Left

IMGP0884

June 29, 2012

Lower Tuolumne River Instream Flow Study

Delaware Reach

Medium Flow- 250 CFS- Transect 255C-
Looking Downstream from River Left

IMGP0152

September 27, 2011

Lower Tuolumne River Instream Flow Study

Delaware Reach

High Flow- 600 CFS- Transect 255C- Looking Downstream from River Left

IMGP6401

July 29, 2011

Lower Tuolumne River Instream Flow Study

Delaware Reach

Low Flow- 100 CFS- Transect 255C- Looking Upstream from River Left

IMGP0885

June 29, 2012

Lower Tuolumne River Instream Flow Study Delaware Reach

Medium Flow- 250 CFS- Transect 255C- Looking Upstream from River Left IMGP0153 September 27, 2011

Lower Tuolumne River Instream Flow Study Delaware Reach

High Flow- 600 CFS- Transect 255C- Looking Upstream from River Left IMGP6402 July 29, 2011

Appendix J

Prior PHABSIM Study Comparisons

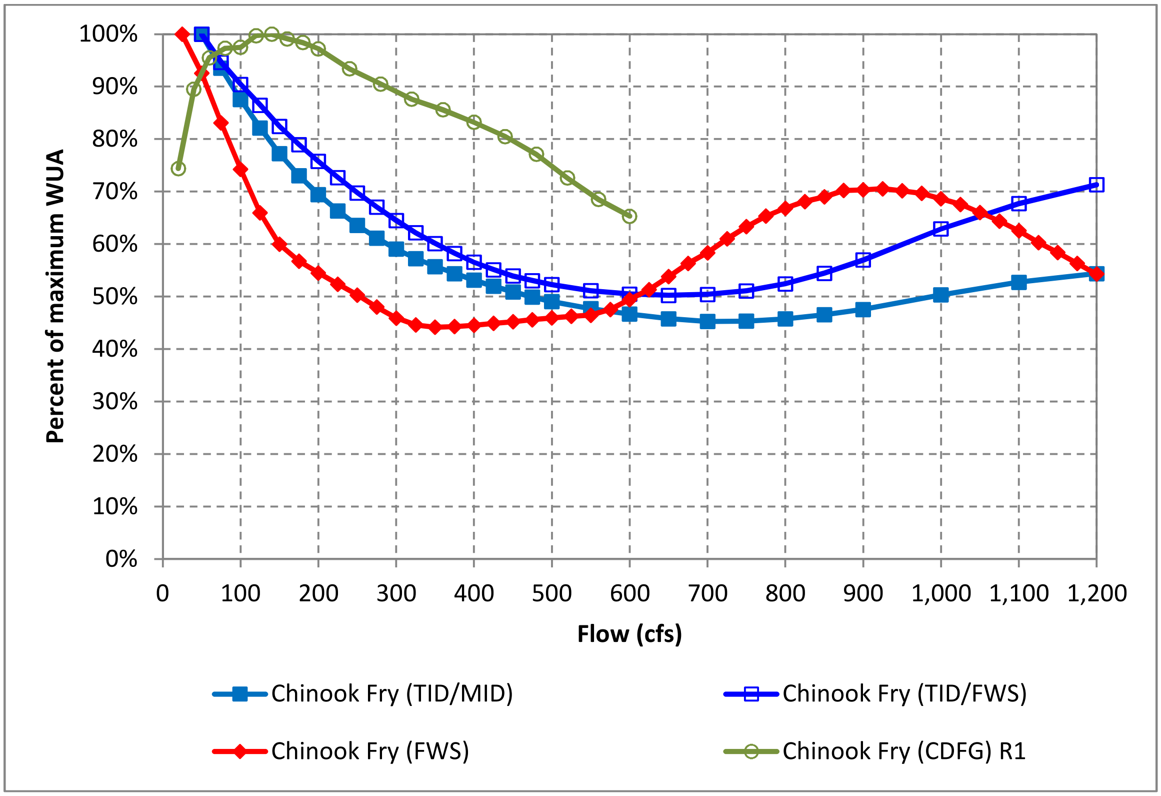


Figure J-1. Chinook salmon fry WUA comparisons to prior instream flow studies on the lower Tuolumne River.

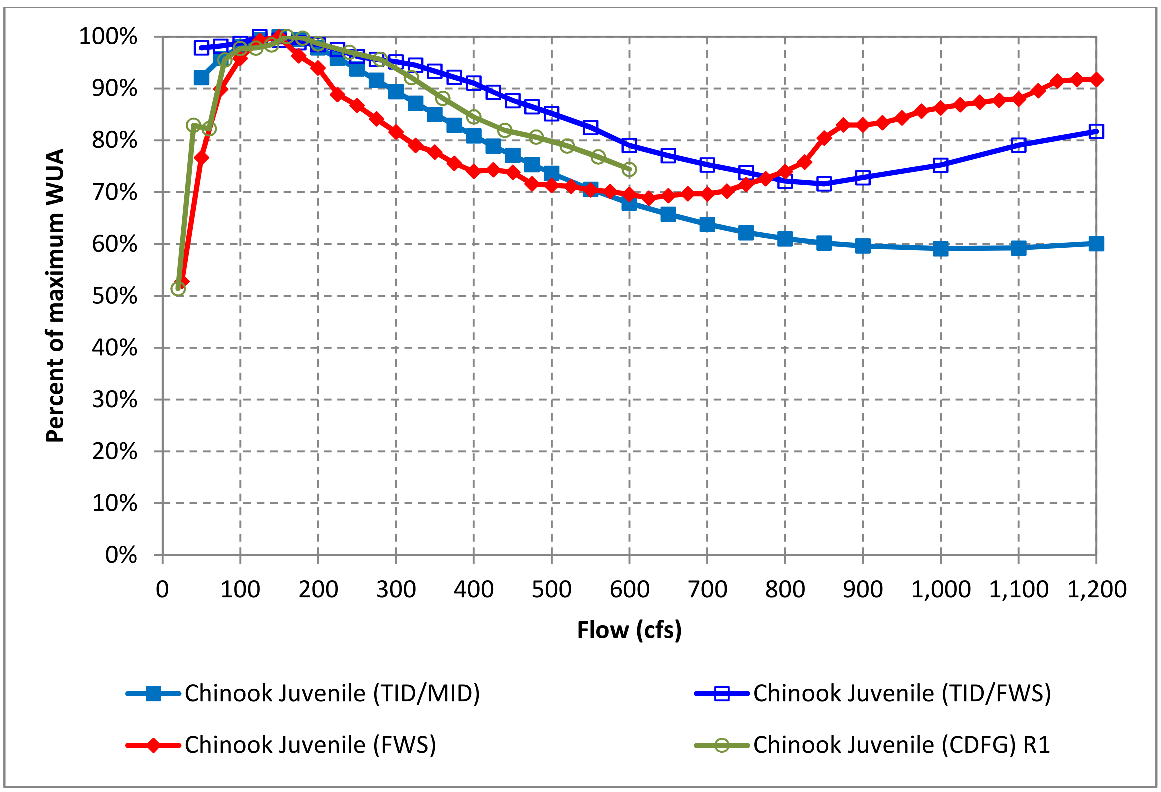


Figure J-2. Chinook salmon juvenile WUA comparisons to prior instream flow studies on the lower Tuolumne River.

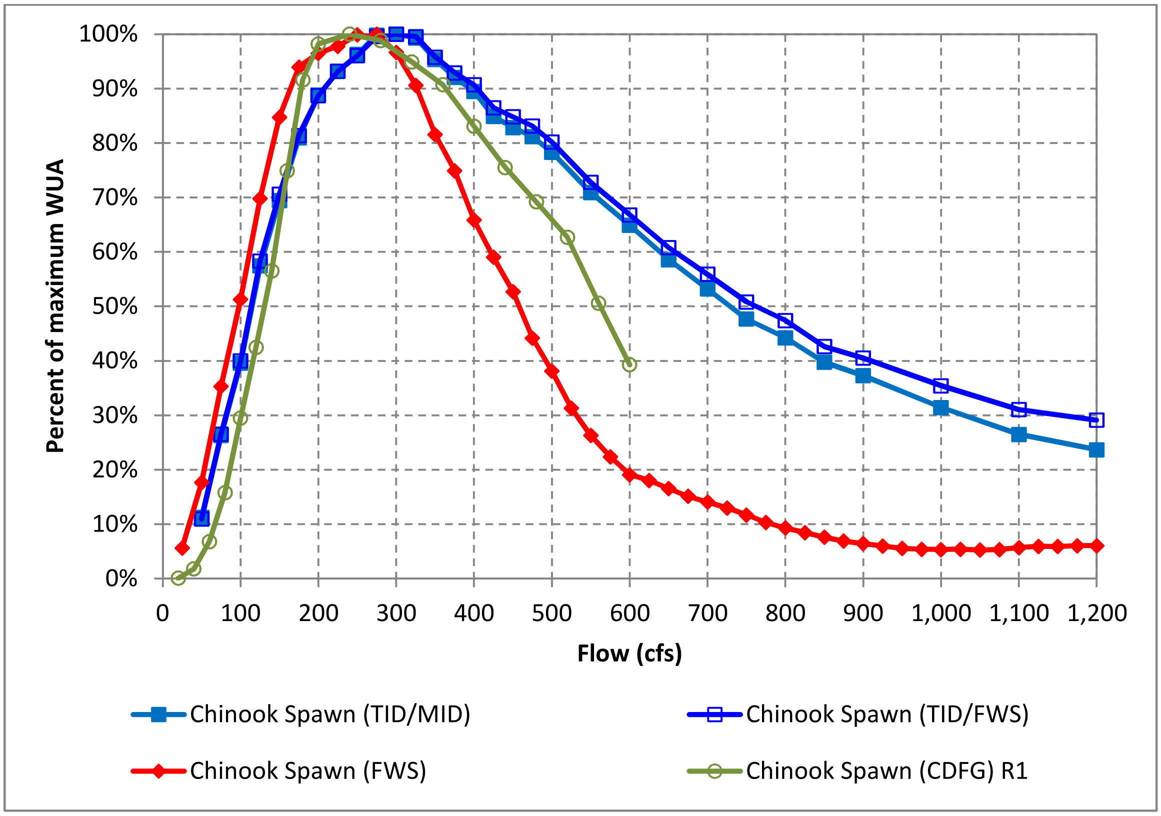


Figure J-3. Chinook salmon spawning WUA comparisons to prior instream flow studies on the lower Tuolumne River.

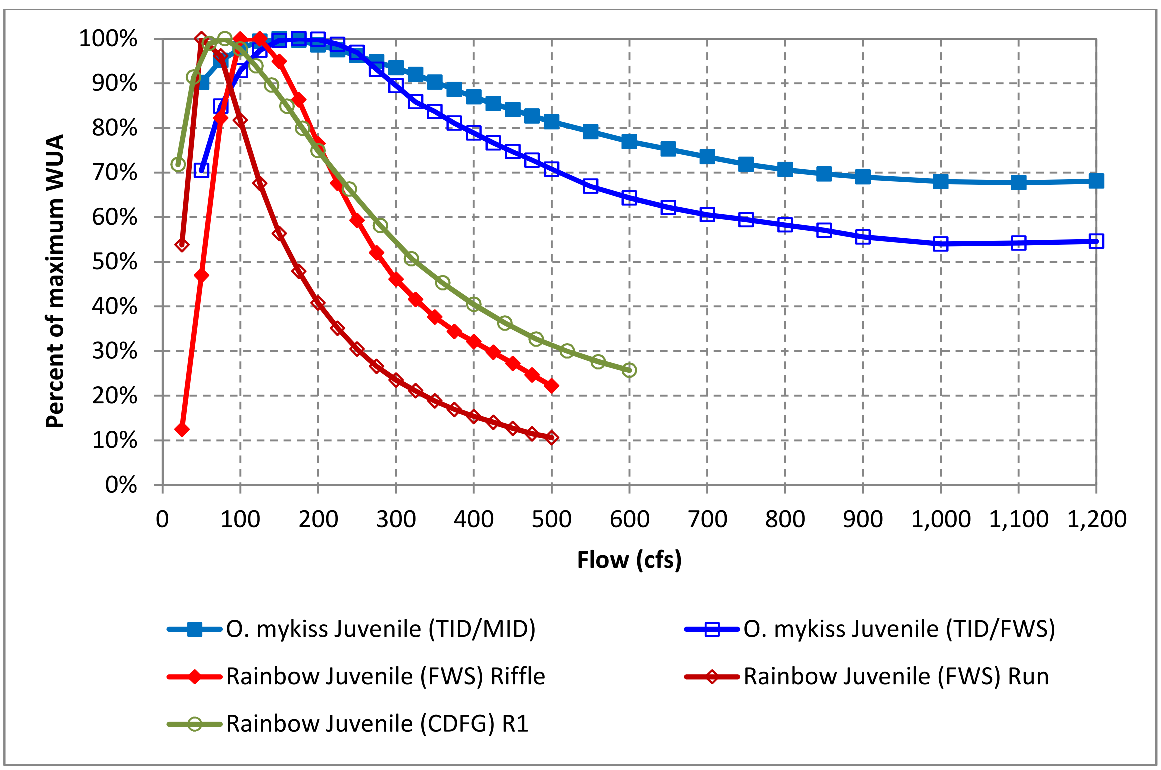


Figure J-4. *O. mykiss* juvenile WUA comparisons to prior instream flow studies on the lower Tuolumne River.

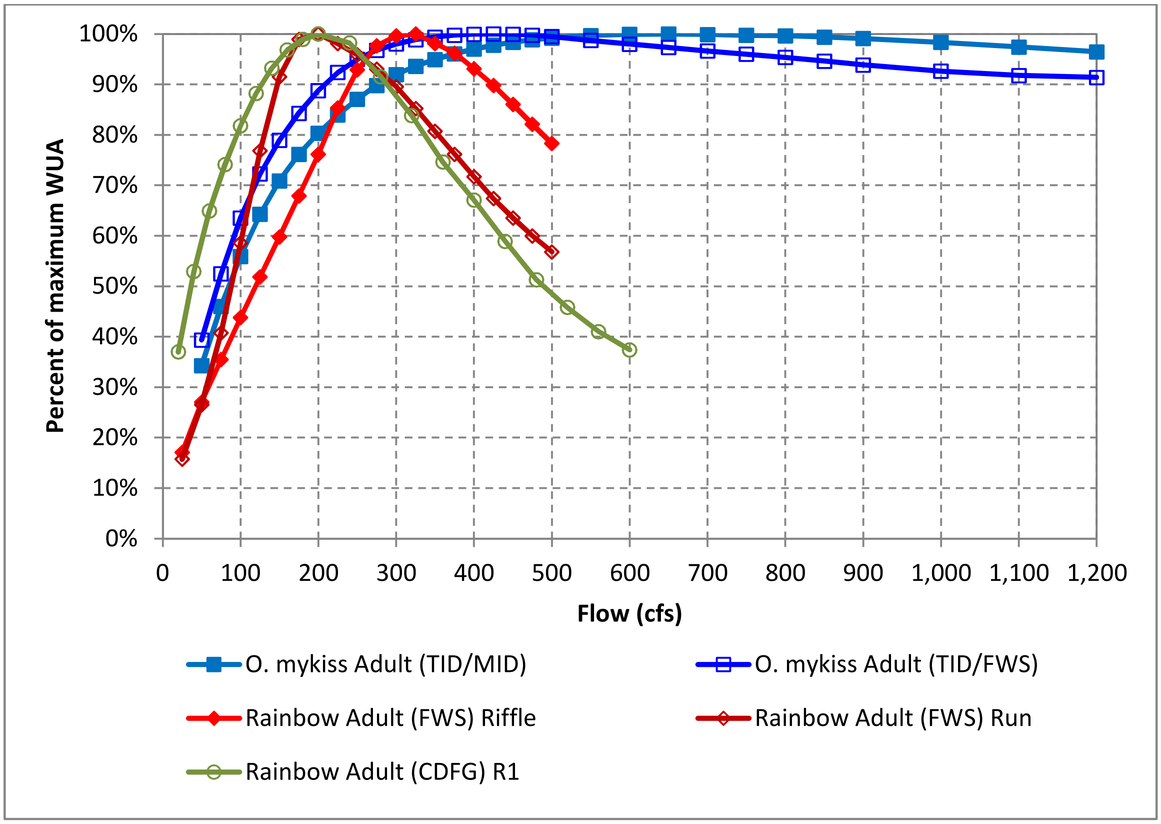


Figure J-5. *O. mykiss* adult WUA comparisons to prior instream flow studies on the lower Tuolumne River

Appendix K

Lower Tuolumne River Instream Flow Study Draft Report
Stakeholder Comments and Districts' Reply

From: Scott Wilcox

To: aboucher@bendbroadband.com; agengr6@aol.com; AJensen@bawsca.org; Alison_Willy@fws.gov; anadromous@bendbroadband.com; andreafuller@fishbio.com; Annie Manji <amanji@dfg.ca.gov>; Bill Sears <WSears@sfwater.org>; BParis@olaughlinparis.com; Chris Shutes <blancapaloma@msn.com>; chrissysonke@fishbio.com; Cindy@ccharles.net; Dale Stanton <dstanton@dfg.ca.gov>; deborah_giglio@fws.gov; deltakeep@aol.com; dmarston@dfg.ca.gov; Donn Furman <donn.w.furman@sfgov.org>; elevin@sfwater.org; Eric@tuolumne.org; Erich Gaedeke <Erich.Gaedeke@ferc.gov>; Gantenbein@n-h-i.org; Greg Dias <gregd@mid.org>; Jarvis Caldwell <jarvis.caldwell@hdrinc.com>; jen@riversandwater.com; Jenna Borovansky (jenna.borovansky@hdrinc.com); Jesse.roseman@tuolumne.org; Jessie Raeder <jessie@tuolumne.org>; Jim Hastreiter (james.hastreiter@ferc.gov); jkobrien@dfg.ca.gov; JMEANS@dfg.ca.gov; John J. Devine (john.devine@hdrinc.com); John Wooster <John.Wooster@noaa.gov>; Joy Warren (joyw@mid.org); Karlha@tuolumne.org; Kelleigh Crowe <kelleigh@stillwatersci.com>; kim_webb@fws.gov; Maria Rea <maria.rea@noaa.gov>; Mark_Gard@fws.gov; Michelle_Workman@fws.gov; Monica.Gutierrez@noaa.gov; Noah Hume <noah@stillwatersci.com>; Nsandkulla@bawsca.org; Pat Maloney (pemaloney@TID.ORG); Patrick@tuolumne.org; pbrantley@dfg.ca.gov; Peter Barnes <Peter.Barnes@waterboards.ca.gov>; Ramon_Martin@fws.gov; rmasuda@calwaterlaw.com; rmyoshiyama@ucdavis.edu; Robert W. Hughes <RWHUGHES@dfg.ca.gov>; Russell Liebig <russ@stillwatersci.com>; Scott Wilcox <Scott@stillwatersci.com>; Scott@mcbaintrush.com; Shaara Ainsley <shaaraainsley@fishbio.com>; Steve Boyd (seboyd@tid.org); steve@mlode.com; stsao@dfg.ca.gov; theyne@dfg.ca.gov; Tim O'Laughlin <towater@olaughlinparis.com>; tramirez@sfwater.org; walterw@mid.org; Wayne Swaney <wayne@stillwatersci.com>; Whittaker, John <JWhittaker@winston.com>; William Cowan (wcowan@dfg.ca.gov); wsears@sfwater.org; Zac Jackson (Zachary_Jackson@fws.gov)

Subject: Lower Tuolumne River Instream Flow Study Draft Report is available

Dear Interested Tuolumne River parties:

Per FERC Order dated 16 July 2009 (128 FERC ¶ 61,035), Turlock Irrigation District and Modesto Irrigation District ("Districts") conducted an instream flow study on the lower Tuolumne River that many of you have participated in or been following in one form or another via various workshops, field visits, and correspondence. Initial chapters of the draft report for this study were included in the Initial Study Report (ISR) filed on 17 January 2013 for the relicensing of the Don Pedro Project, and a summary presentation on the study was provided at the ISR meeting on 30 January 2013.

On behalf of the Districts, we are providing the full draft report for your review and comment. It can be downloaded from the following FTP site using the link and access credentials below:

https://files.stillwatersci.com/
Username: Tuolumne13
Password: IFIM2013

Per the study plan, this draft report is being distributed for 30-day agency review. Please provide any comments by COB on Monday, 1 April 2013.

Thank you for your participation and interest in this study.

Scott Wilcox
Senior Fisheries Biologist / Principal
direct 530-756-7550 x230
scott@stillwatersci.com

Stillwater Sciences
279 Cousteau Place, Suite 400, Davis, CA 95618
tel 530-756-7550 fax 530-756-7558
www.stillwatersci.com

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, California 95825-1846

In Reply Refer To:

Scott Wilcox
Senior Fisheries Biologist
Stillwater Sciences
279 Cousteau Place, Suite 400
Davis, California 95618

APR 8 2013

Subject: U.S. Fish and Wildlife Service Comments on the February 2013 Draft Report for the Lower Tuolumne River Instream Flow Study, FERC Project P-2299 on the Tuolumne River; Tuolumne and Stanislaus Counties, California

Dear Mr. Wilcox:

The U.S. Fish and Wildlife Service (USFWS or Service) has reviewed the February 2013 Draft Report (Draft Report) for the Lower Tuolumne River Instream Flow Study (Study) and is providing comments herein. The Don Pedro Hydroelectric Project (Project) is licensed by the Federal Energy Regulatory Commission (FERC or Commission), which required the Turlock Irrigation District and Modesto Irrigation District (Districts or TID/MID) to develop and implement the Instream Flow Incremental Methodology Study (IFIM) "to determine instream flows necessary to maximize Chinook salmon [*Oncorhynchus tshawytscha*] and *O. mykiss* [steelhead/rainbow trout] production and survival throughout their various life stages." (Commission Order of July 16, 2009; 128 FERC 61,035). The Tuolumne River IFIM Study Plan submitted on behalf of the Districts was approved with modifications by the Commission on May 12, 2012 (Order Modifying and Approving Instream Flow and Water Temperature Model Study Plans 131 FERC 62,110).

General Comments

The Study fails to meet the stated purpose to determine the instream flows necessary to maximize fall-run Chinook salmon and *O. mykiss* production and survival throughout their various life stages. Smoltification and the survival of juvenile migrants are highly dependent on water temperatures in the lower Tuolumne River (Mesick 2012) and fall pulse flows are needed to minimize straying by migrating adults (Marston *et al.* 2012). Neither of these life history stages was considered in the Study. Flows needed to meet USEPA (2003) water temperature targets for smoltification and outmigrant survival in the river below Modesto as well as adult attraction (Marston *et al.* 2012) should be assessed.

In the December 22, 2011, Study Plan Determination, the Commission staff recommended that the Districts modify their ongoing IFIM study to include an evaluation of Sacramento splittail (*Pogonichthys macrolepidotus*) and Pacific lamprey (*Entosphenus tridentatus*) if existing habitat suitability relationships are available. Despite this recommendation, habitat suitability for these species was not addressed in the Draft Report, although existing habitat suitability relationships for these species are available from the Service. The Service can provide examples of potential habitat suitability relationships for both splittail and Pacific lamprey that were used in the IFIM study for the Merced River Hydroelectric Project (FERC Project 2179) and from the Pacific Northwest (Gard 2009) that should be used for this Study, per the Commission's recommendation.

The July 16, 2009, Commission Order states: "The instream flow study shall also evaluate spring pulse flows of 1,000 to 5,000 cfs and fall pulse flows of up to 1,500 cfs from La Grange Dam." The Draft Report fails to explain how floodplain inundation was analyzed at the higher flows. It appears that only in-channel sampling occurred. The inundated floodplain is important to juvenile Sacramento splittail and salmonid rearing (Feyrer et al 2006, Harrell and Sommer 2003, Jeffres *et al.* 2008, Snider 2001, Snider and Titus 2000, Sommer *et al.* 2001, Sommer *et al.* 2002, Sommer *et al.* 2004a, Sommer *et al.* 2004b, Sommer *et al.* 2008), because the floodplain provides essential food resources for optimal rearing success. The inundated floodplain maximizes production and survival of juvenile salmonids and breeding for Sacramento splittail. Floodplain inundation is so important to early life stages of native riverine fishes that not sampling in the floodplain is inconsistent with conducting a study "to determine instream flows necessary to maximize fall-run Chinook salmon on *O. mykiss* production and survival throughout their various life stages" as required in the Commission Order, or to determine Project effects on the Sacramento splittail as recommended by Commission staff in the Study Plan Determination. The enclosed analysis by the Service of inundation areas on the Tuolumne River (USFWS 2008) is an appropriate and useful reference that was not utilized.

The Draft Report and developed habitat suitability criteria (HSC) fail to take into consideration the importance of cover type. The importance of instream wood and large woody material to salmonid rearing is well understood (Beechie and Sibley 1997, Bilby and Ward 1989, Bryant 1983, Cederholm et al 1997, Crispin *et al.* 1993, Everett and Ruiz 1993, Lemly and Hildebrand 2000, Merz 2001, Senter and Pasternack 2010). Large pieces of wood create both micro- and macro-habitat heterogeneity by forming pools, back eddies and side channels and by creating channel sinuosity and hydraulic complexity, including retention of spawning gravels. Snorkeling observations in the lower Yuba River have found that juvenile Chinook salmon show a strong preference for near-shore habitats with instream woody material (JSA 1992). Access to prey is an essential energetic component of juvenile spring-run Chinook and Central Valley steelhead survival. Juvenile salmonids with access to large woody material and the floodplain are likely to have greater growth and higher survivorship than individual juvenile salmonids that do not have access to this important foraging habitat (Harrell and Sommer 2003).

The added habitat complexity of various cover types provides juvenile salmonids numerous refugia from predators and water velocity, and provides efficient locations from which to feed (Crispin *et al.* 1993, Lemly and Hilderbrand 2000, Merz 2001). In an October 5, 2009, letter to Tim Ford of Turlock Irrigation District, the Service provided an example of a cover coding system in Table #3 that addresses the different types of cover that are important to analyze (Service's October 5, 2009 letter filed with the Commission as an enclosure to the Service's November 05, 2009 letter). The Service recommended adoption in our October 5, 2009, letter of a cover coding system that includes the following cover types: No cover, cobble, boulder, fine woody vegetation (<1" diameter), fine woody vegetation + overhead, branches, branches + overhead, log (>1' diameter), log + overhead, overhead cover (> 2' above substrate), undercut bank, aquatic vegetation, aquatic vegetation + overhead, and rip-rap. The Districts did not use this cover coding system, instead adopting a system that may not pick up critical distinctions between the types of woody cover and their instream contribution to salmonid and Sacramento spilttail rearing. For example, "branches" are an important spawning component for splittail in the floodplain, so this is a particularly important for the cover category. The collapsing of the cover types into four cover categories further exacerbates the loss of this cover category.

Specific Comments

Section 2, Methods, page 4: The one-dimension (1-D) methodology is not robust and can lead to errors in interpretation. Additionally, the Service is concerned that the one-flow velocity calibration also leads to errors in interpretation. For example, the *O. mykiss* Adult Depth and Velocity Criteria listed in Appendix E are lower than our understanding of optimal depth and velocities in rivers of similar size (*e.g.*, Yuba River) (USFWS 2010a, USFWS 2010b, USFWS 2010c); the *O. mykiss* spawning velocity and depth curves described in Appendix E are lower than the Service's understanding of habitat use collected (USFWSa); and the HSC developed for the *O. mykiss* fry and juveniles are much lower than what is acceptable to the Service. A more accurate methodology would be provided by the HSC developed by the Service for the Yuba River (USFWS 2010a and 2010b) or an equivalent source.

Section 2.4, Calibration Flows, page 8: The Service is of the opinion that the range of flows used in this study is inadequate, because it does not consider a wide range of flows similar to the pattern of the natural hydrograph. The Service recommends a higher range be used (*i.e.*, 300 cfs, 400 cfs, 600 cfs, 1,000 cfs, 1,500 cfs, 2,000 cfs, and 5,000 cfs). This range would give a better idea of how fish respond to higher flows similar to the magnitude of the natural hydrograph.

Section 2.5, Hydraulic Data Collection, page 9: The methods used for collecting the hydraulic data are satisfactory. However, additional data should be collected over a higher range of flows to include inundation of the floodplain to allow for maximum production and survival of salmonids.

Section 2.6, Substrate and Cover Data, page 10 and 11: The use of the modified Wentworth Scale for substrate is acceptable, but the cover categories utilized are not acceptable. Cover and cover-type are critical to salmonids and thus collapsing the measured cover into 4 categories (None, Object Cover, Overhead cover, Both) obscures the importance of this variable. The cover types described in Table 8 of the Draft Report collapse the differentiation of woody material into two sizes. In the Service's October 5, 2009, letter we recommended that woody material be classified as fine woody vegetation (less than one inch in diameter), branches, log (greater than one foot in diameter). Woody material sizes and types are very important as habitat criteria, and further collapsing this variable into "Object Cover" is not appropriate, because salmonids utilize these cover types in different ways and each of these cover types has an important habitat value. Inclusion of "rootwad" is an acceptable addition to the woody material category, but classifying it as overhead cover is likely to obscure the contribution of this type of structure within the river.

Section 2.8, Habitat Time Series, page 14: It is not appropriate to limit the upper range to 1,200 cfs because it takes away the ability to measure and analyze the contribution of the floodplain to salmonid and splittail production and breeding. The range should be extended up to at least 2,000 cfs, to allow for an analysis of the amount of habitat that might be gained at these higher flows. Important fry and juvenile salmonid habitat is provided when flows are high enough to provide cover in the form of submerged riparian vegetation along the riverbanks. It is likely that as flows increase beyond 1,200 cfs, the amount of cover provided by submerged vegetation would substantially increase. Higher flows would likely increase the amount of habitat available and maximize production and survival of the juvenile and adult Chinook salmon and *O. mykiss* due to inundation of areas with better cover and more food throughout their various life stages.

Section 2.9, Effective Habitat, page 15: A standard approach to calculating WUA should be used in conjunction with the "effective" WUA analysis utilized in this study. This is because standard methodologies are well understood and would provide validation (or rejection) of the effective WUA analysis.

The Service supports the use of the temperature model as part of the process of determining the amount of habitat. Water temperature for rearing and migrating juvenile Chinook salmon should be an important part of the analysis; however, "effective" habitat, which includes water temperature suitability, will only be applied to *O. mykiss* and only during the summer. In order to determine instream flows necessary to maximize Chinook salmon and *O. mykiss* production and survival throughout their various life stages, the final study must include an assessment of the flows needed to provide temperatures that support these species. The final study should include an assessment of the flows needed to meet the EPA temperature criteria (2003) for each life stage of Chinook salmon and *O. mykiss*.

Section 2.10, Habitat Suitability Criteria, page 15: The Service does not support the use of the existing curves as originally ordered by the FERC. In its May 12, 2010, Order, the Commission adopted its staff recommendations that "[i]n order to obtain and utilize the most up-to-date information and validate existing data, the Districts should conduct the field work necessary to develop specific HSC curves for the project." (Ordering Paragraph B, adopting staff recommendations in Paragraph 37). The Districts have not followed the Service's recommendation. The Service repeats its recommendation that the Districts use the steelhead curves developed for the Lower American River or from the Lower Yuba River (USFWS 2003, USFWS 2010a).

The Wentworth Scale provided in Appendix A appears to be very similar to the substrate scale recommended by the Service and is likely appropriate for this study.

Section 2.10.1 Existing habitat suitability criteria, page 15: The Service does not support the way the HSC were developed as presented in Table 12. While the spawning criteria for Chinook salmon are acceptable, cover should be included for all the additional categories, along with adjacent velocities for the juvenile and adult Chinook and *O. mykiss*. The Commission's May 12, 2010, Order recognized the value of these attributes, as it ordered the Districts to include measures of cover and adjacent velocity with the other more standard habitat metrics if additional habitat information is collected. (Ordering Paragraph B, adopting staff recommendations in Paragraph 37.)

Section 2.10.1, Site-specific habitat suitability criteria page 16: The approach for collecting HSC for the Chinook salmon and *O. mykiss* adult and juvenile life stages lacks certain aspects that are important. For example, data should have been collected at a different set and range of flows. While we agree with using 2,000 cfs as the maximum flow, the low and mid- range flows should have been higher. The Service recommends a minimum flow of at least 250 cfs, one mid-flow of at least 800 cfs, an additional mid-flow, and a 2,000 cfs maximum flow.

Section 2.10.2.1, Habitat suitability criteria site selection page 17: The Service agrees on the study site selection process. However, areas that have the potential to be inundated must be included in this study in order to develop flows that will maximize fall-run Chinook salmon and *O. mykiss* production and survival throughout their various life stages. The study excluded any dry areas and areas of potential inundation. It is essential that higher flows are included in the study, because the floodplain and habitat subject to potential inundation are very likely to improve and expand the amount of habitat, cover and food that would result in a healthier and more robust Chinook salmon and *O. mykiss* population.

2.10.2.2, Direct Observation and field measurements, page 23: The data collection methods were satisfactory. However, as noted previously, collection of cover data should have been completed. Without cover data, any HSC developed will not be satisfactory. Each cover type has a different contribution to each life stage of the species. Please review reports published by the Service (USFWS 2005, USFWS 2010b) for methods used for collecting HSC data for rearing juvenile *O. mykiss* and adult Chinook salmon.

2.10.2.3, Data Analysis, page 23: The Service agrees with the size ranges assigned to the various life stages, but the categories used for cover are not appropriate (see discussion under Section 3.1.2).

2.10.2.4 Adjacent velocity page 26: The methods used for this aspect of the study are satisfactory for the development of HSC for rearing juvenile salmonids.

Section 3.1.2 Site-specific habitat suitability criteria development and validation, page 26: The Service is supportive of the approach used in this stage of the HSC criteria development. However, additional flows should have been included in the HSC data collection process. As mentioned previously, the Service is in agreement with the 2,000 cfs maximum flow. However, for the low and mid-range flows, we recommend that higher and additional flows be used, with the low flow being at least 250 cfs.

The Service has recommended that cover be used to validate HSC for Chinook salmon and *O. mykiss* fry and juveniles. This is because cover is crucial to the accurate development of juvenile HSC. A full range of meaningful cover variables should be included in the validation process.

The Service does not support the decision to use the depth, mean column velocity curves that were selected, because cover was not included in the analysis, floodplain use was not measured, use at higher flows was not measured, and they appear to be biased toward lower flows. The

"Tuol Mod" curve for the Chinook fry depth and the "Tuol Env" curve for the Chinook fry show that higher flows are most likely desirable for optimal habitat.

Figure 6, page 32: The Service does not support the use of the cover categories shown in Figure 6. We recommend use of the cover categories utilized by the Service (USFWS 2005). The Service's cover categories have been extensively used and have been peer reviewed. Please refer to the Service's peer-reviewed publications that use cover categories for the HSC (USFWS 2005, USFWS 2010b).

Figures 7-9 and 10, 12-17, 19; pages 33-35, 37-41: The HSC do not reflect the most recent understanding of habitat use by Chinook salmon and *O. mykiss*. Juvenile salmonids use the inundated margins and floodplains of rivers during high flows, and this habitat is optimal for production and survival at this life-history stage. Measuring depth and velocity in the margins of the river during low flows and not measuring the velocities and depths associated with the high flows that lead to inundation (adjacent velocities), is likely to misrepresent flows needed for production and survival of Chinook salmon and *O. mykiss*.

Peer-reviewed Service publications (USFWS 2010a, USFWS 2010b, USFWS 2010c) should be used.

Figures 11 and 18, pages 36 and 42: The Service substrate data presented in these figures are appropriate, but the results presented in Figure 18 are not consistent with our understanding of Chinook salmon spawning preference. The Service has found that the size classes of 1-3 inch and 2-4 inch size substrate are optimal for Chinook salmon spawning.

Section 3.1.3, Adjacent velocity, page 33: The Service appreciates the fact that an effort was made to include adjacent velocity as part of the data collection process. Adjacent velocity is important in the development of HSC (USFWS 2010a, USFWS 2010b, USFWS 2010c). We recommend that Service data be included in the process. If the Tuolumne data are insufficient or inadequate, additional data collection is warranted. Peer review of the reports published by the Service has supported the use of adjacent velocity in developing juvenile salmonid HSC.

Section 3.2 Weighted Usable Area, page 45: The Service does not support the WUA results from the PHABSIM analysis for any life stage for Chinook salmon and *O. mykiss*. It is the Service's opinion that there is a strong bias towards lower flows in each case. The collection of criteria data at very low flows and the lack of data collected at higher flows has resulted in the WUA values that were selected. The Districts should review and utilize the WUA values for the Chinook adults and juveniles and the *O. mykiss* juveniles as presented in the Service reports (USFWS 2005, USFWS 2010a, USFWS 2010b, USFWS 2010c) and reports published by the National Marine Fisheries Service (NMFS), California Department of Fish and Wildlife, and other agencies and parties that concern rivers similar in size to the Tuolumne River.

Section 5 References, pages 60-62: The August 19, 2008, *Flow-Overbank Inundation Relationship for Potential Fall-Run Chinook Salmon and Steelhead/Rainbow Trout Juvenile Outmigration Habitat in the Tuolumne River* (USFWS 2008) was not included as a reference, but it is an important and relevant reference that should be utilized.

The majority of the instream flow references are out-of-date and do not represent the state of the science. The Service recommends utilizing recent literature on instream flow methodology.

Table 16, page 47: The representation of seasonal periodicity in this table is adequate for the purpose of modeling efforts.

Appendix B-1, Target Habitat Types: The habitat types to be sampled are appropriate; however, more units per habitat type should be sampled and doubling the number of units is appropriate.

The proposed habitat units appear acceptable; however, the backup units should also be included and additional transects as recommended by the Service should be added.

Appendix C, Study Background—Field Efforts: It was inappropriate to conduct the HSC surveys at such low flow (*i.e.*, 100 cfs, 350 cfs) and then analyze the HSC data at the high flow of 2,000 cfs. It would have been more appropriate to collect the HSC data at 300 cfs, 400 cfs, 600 cfs, 1,000 cfs, 1,500 cfs, 2,000 cfs, and 5,000 cfs, which would be consistent with the July 16, 2009, Commission Order while allowing for interpretation of floodplain effects.

Appendix C, Methods, Substrate and Cover Data: The substrate data that was used in the PHABSIM model are appropriate; however, the Service does not agree with the cover type categories used in the PHABSIM part of this study. The cover categories used should be based on real data, and an understanding of the cover needs of the species, such as those used in the Service's Instream Flow studies. The cover data are important, in that they are used along with the substrate data to calculate roughness values that are usually used for making adjustments in the roughness values used in calibration (USFWS 2003, USFWS 2005, USFWS 2010a, USFWS 2010b, USFWS 2010c).

Appendix C, Habitat Time Series: The range of flows used in the study was inappropriate, considering the potential the river has for higher flows. The Service's flow recommendations for instream flow monitoring are 300 cfs, 400 cfs, 600 cfs, 1,000 cfs, 1,500 cfs, 2,000 cfs, and 5,000 cfs.

Appendix C, Habitat suitability criteria: Serious consideration should be given to reviewing and utilizing the HSC for *O. mykiss* and fall-run Chinook salmon developed by the Service (USFWS 2005, USFWS 2010a, USFWS 2010b, USFWS 2010c). The HSC developed by the Service have undergone extensive peer-review and represent the most thorough understanding of the habitat needs of Chinook salmon and *O. mykiss*. Use of HSC that have not undergone such extensive utilization and review may under-represent the flow needs of these species.

Appendix C, Existing habitat suitability criteria data: The criteria used for the habitat suitability criteria data represent a good start. However, adjacent velocity data are also needed as part of development of the HSC data for the fry and juvenile life stages. The cover data collected as part of this study should be used without collapsing the categories. The use of presence/absence data is appropriate.

With regard to the depth and velocity criteria for fall-run Chinook salmon, these criteria are too low. In order to develop adequate HSC, a full range of flows, substrate characteristics, and cover must be used. The small range of low flows, lack of inclusion of multiple cover variables, and lack of measurement of adjacent velocity are all likely to result in low flows that do not meet the needs of Chinook salmon and *O. mykiss* for production and survival. As noted previously, inclusion of the depth and velocity data developed by the Service (USFWS 2003, USFWS 2005, USFWS 2010a, USFWS 2010b, USFWS 2010c) would be appropriate.

Appendix D, Chinook Salmon Spawning: The output for depth criteria does not appear to be consistent with our current understanding of habitat use by Chinook salmon. The depth criteria for spawning indicate that very low flows were favored. Based upon our current understanding of habitat use (USFWS 2010a), adult Chinook salmon favor a higher range of depths and velocities.

The Chinook salmon spawning substrate criteria are acceptable. They are very similar to what the Service has used effectively in various studies that have been conducted on a variety of rivers.

Appendix D, Chinook Salmon Juvenile Depth and Velocity Criteria: The Service does not support the use of the criteria developed for the juvenile Chinook salmon. The depth and velocity criteria do not represent the full range of floodplain inundation flows that would support juvenile salmonid production and survival, and appear biased toward lower flows. Cover is the primary component in developing accurate HSC values for juvenile fall-run Chinook. Although cover type and amount are important considerations for juvenile salmonid survival, they were not given adequate consideration in the HSC. The combination of depth, velocity (including adjacent velocity values) and cover are crucial to developing accurate HSC for juvenile Chinook salmon. As stated previously, the reports for the studies conducted by the Service should be reviewed and the existing Service-developed criteria should be utilized.

Appendix D, Chinook Salmon Fry: As described above, cover is a very important component for developing criteria for fry and juvenile Chinook salmon. Depth, velocity (including adjacent velocity), and cover are crucial for developing accurate HSC. Cover is particularly important because the fry and juvenile fish utilize cover to optimize foraging, avoid predation, and reduce the amount of energy expended. Existing criteria developed by the Service should be reviewed and utilized.

Appendix E, O. mykiss Adults: As described in previous comments, the Districts should utilize the HSC for *O. mykiss* that were developed by the Service in studies conducted on the Lower Yuba River (USFWS 2010a).

Although the Service supports the use of a variety of curves from various studies, in this case, the HSC for *O. mykiss* (steelhead) developed by the Service should be utilized. The adult *O. mykiss* criteria that are presented in the Draft Report appear to be biased toward lower velocities and depths. Higher flows need to be considered and analyzed, because higher flows may allow for higher amounts of food that can be utilized by the adult *O. mykiss*. In addition, the HSC should include cover, which is crucial for the adult fish.

Appendix E, O. mykiss Spawning: The data appear to show a bias toward lower flows, depths, and velocities, which is not consistent with the results in other studies conducted by the Service (USFWS 2010a).

The use of the substrate size presented in the Draft Report is acceptable.

Appendix E, O. mykiss Fry: The Service's HSC should be utilized in this study, as the Service's criteria data for *O. mykiss* fry have been collected in a number of robust studies in rivers and creeks in the Central Valley (USFWS 2010b, USFWS 2010c).

Appendix E, O. mykiss Juveniles: A proper and accurate HSC for *O. mykiss* juveniles should utilize depth, velocity (including adjacent velocity) and cover.

Appendix F, Chinook salmon fry: The Service is supportive of the velocity and depth HSC developed in this case. However, it best to consider the primary use of the criteria developed by the Service. The data for depth and velocity appear very similar for the "Tuol Mod" and Yuba (USFWS 2010b), so these criteria are likely appropriate.

With regard to the velocity suitability, "Tuol ENV" suitability criteria presented in the Chinook salmon fry table, the Service is not supportive of its use. These criteria are strongly biased toward lower velocities and flows. The use of Service's suitability criteria for Chinook salmon fry from the various studies conducted should be used. As noted previously, there are several reports from the Service that provide the criteria needed.

As noted previously, the use of adjacent velocities and cover is crucial to developing accurate criteria for fry and juvenile Chinook salmon fry.

Appendix F, O. mykiss Fry: The Service is not supportive of the criteria. The depth and velocity data are severely biased toward lower flows and velocities. Given the potential for more habitat associated with higher flows that can inundate areas that have good quality cover and food, higher flows should be considered in the analysis. Again, as described previously, adjacent velocities and cover are crucial to developing accurate HSC for *O. mykiss* fry.

Appendix F, O. mykiss Adult: It is the Service's opinion that the velocity and depth criteria that are presented in this report are inadequate as they do not consider higher flows. As described previously, higher flows could result in habitat inundation, which could result in a higher level of food and cover for the fish. This food and cover is expected to result in better survival, larger fish, and high production values for the fish. Cover should be included in the development of the adult HSC. It is recommended that the Districts use the HSC developed by the Service for the Yuba River, Clear Creek and any other rivers/creeks where juvenile steelhead/rainbow trout HSC were developed, as these data should provide the HSC characteristics that are similar to those required by adults. Review of the reports published by the Service, NMFS, California Department of Fish and Wildlife and other agencies and stakeholders is recommended.

Conclusion

The Service requests that our peer-reviewed HSC be used in the Study. If you have any questions regarding this response, please contact Deborah Giglio of my staff at (916) 414-6600.

Sincerely,

Daniel Welsh
Assistant Field Supervisor

Enclosures

cc: Kimberly Bose, Secretary, FERC
FERC #2299 Service List, Don Pedro Hydroelectric Project
John Devine DTA
Peter Barnes, SWRCB
Walter Ward, Modesto Irrigation District
Greg Dias, Modesto Irrigation District
William Johnston, Modesto Irrigation District

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USFWS. 2010a. Flow-habitat relationships for spring- and fall-run Chinook salmon and steelhead/rainbow trout spawning in the Yuba River. Sacramento Fish and Wildlife Office, Planning and Instream Flow Branch. August 26, 2010.

USFWS. 2010b. Flow-habitat relationships for juvenile fall/spring-run Chinook salmon and steelhead/rainbow trout rearing in the Yuba River. Sacramento Fish and Wildlife Office, Planning and Instream Flow Branch. October 8, 2010.

USFWS. 2010c. Relationships between flow fluctuations and redd dewatering and juvenile stranding for Chinook salmon and steelhead/rainbow trout in the Yuba River. Sacramento Fish and Wildlife Office, Planning and Instream Flow Branch. September 15, 2010.

Pursuant to the requirements of the FERC Order, the Lower Tuolumne River Instream Flow Study Draft Report was circulated for a 30-day review period (February 28, 2013 – April 1, 2013) to the resource agencies and interested parties (Appendix K-1). Following the 30-day review period, the USFWS provided comments on April 8, 2013 (Appendix K-2), which have been addressed in this final report. No other comments were received as of the date of this filing. Additional analyses, resulting from information provided by the USFWS in their April 8, 2013 letter and subsequent to the FERC December 22, 2011 relicensing Study Plan Determination, will be reported separately as described in the body of this report.

No.	USFWS comment	Districts' reply
General comments		
1	The Study fails to meet the stated purpose to determine the instream flows necessary to maximize fall-run Chinook salmon and *0. mykiss* production and survival throughout their various life stages. Smoltification and the survival of juvenile migrants are highly dependent on water temperatures in the lower Tuolumne River (Mesick 2012) and fall pulse flows are needed to minimize straying by migrating adults (Marston *et al.* 2012). Neither of these life history stages was considered in the Study. Flows needed to meet USEPA (2003) water temperature targets for smoltification and outmigrant survival in the river below Modesto as well as adult attraction (Marston *et al.* 2012) should be assessed.	The proposed methods for fulfilling the purpose of the study were detailed in the study plan filed with the Commission on October 14, 2009, and approved, pursuant to Ordering paragraphs (A) through (E) of the Commission's May 12, 2010 order. The study plan was followed during implementation of the study. Water temperature conditions are being addressed as part of relicensing study W&AR-14 (*Temperature Criteria Assessment*); the flow/water temperature assessment component of the study will be completed following the completion and review of study W&AR-16 (*Lower Tuolumne River Temperature Model*) and will subsequently be filed in conjunction with the Draft License Application. A 2D hydraulic model of over-bank flows up to 5,000 cfs was developed as part of the Pulse Flow Study report submitted on June 18, 2012 (Stillwater Sciences 2012).[1] Although an assessment of water temperature variations during spring and fall pulse flows is provided, assessment of either adult attraction flows or outmigrant survival was not included in the approved study plan (Stillwater Sciences 2009). A fall pulse flow is already provided under the current flow regime.
2	In the December 22, 2011, Study Plan Determination, the Commission staff recommended that the Districts modify their ongoing IFIM study to include an evaluation of Sacramento splittail *(Pogonichthys macrolepidotus)* and Pacific lamprey *(Entosphenus tridentatus)* if existing habitat suitability relationships are available. Despite this recommendation, habitat suitability for these species was not addressed in the Draft Report, although existing habitat suitability relationships for these species are available from the Service. The Service can provide examples of potential habitat suitability relationships for both	The Lower Tuolumne River Instream Flow Studies Study Plan (Stillwater Sciences 2009), including the development of an IFIM study, was filed with the Commission on October 14, 2009. The Study Plan was approved, pursuant to Ordering paragraphs (A) through (E) of the Commission's May 12, 2010 order. The December 22, 2011 FERC Relicensing Study Plan Determination expanded the study to include splittail and Pacific lamprey using available HSC, if available. The USFWS provided available HSC in their April 8, 2013 comment letter. The Districts will review the HSC for conformance with the same screening criteria applied to other HSC used for this study (including an assessment of applicability

[1] Stillwater Sciences. 2012. Lower Tuolumne River Instream Flow Studies: Pulse Flow Study Report. Prepared by Stillwater Sciences, Berkeley, California for Turlock Irrigation District and Modesto Irrigation District, California. June

No.	USFWS comment	Districts' reply
	splittail and Pacific lamprey that were used in the IFIM study for the Merced River Hydroelectric Project (FERC Project 2179) and from the Pacific Northwest (Gard 2009) that should be used for this Study, per the Commission's recommendation.	to the Tuolumne River, and if applicable, will include an additional assessment. Contrary to the USFWS' inference, the Commission did not specify particular HSC that "should be used for this Study." Due to the timing of the HSC availability, and that this additional analysis was recommended as part of FERC's Study Plan Determination during relicensing, the assessment will be conducted and reported separately.
3	The July 16, 2009, Commission Order states: "The instream flow study shall also evaluate spring pulse flows of 1,000 to 5,000 cfs and fall pulse flows of up to 1,500 cfs from La Grange Dam." The Draft Report fails to explain how floodplain inundation was analyzed at the higher flows. It appears that only in-channel sampling occurred. The inundated floodplain is important to juvenile Sacramento splittail and salmonid rearing (Feyrer et al 2006, Harrell and Sommer 2003, Jeffres *et al.* 2008, Snider 2001, Snider and Titus 2000, Sommer *et al.* 2001, Sommer *et al.* 2002, Sommer *et al.* 2004a, Sommer *et al.* 2004b, Sommer *et al.* 2008), because the floodplain provides essential food resources for optimal rearing success. The inundated floodplain maximizes production and survival of juvenile salmonids and breeding for Sacramento splittail. Floodplain inundation is so important to early life stages of native riverine fishes that not sampling in the floodplain is inconsistent with conducting a study "to determine instream flows necessary to maximize fall-run Chinook salmon on *O. mykiss* production and survival throughout their various life stages" as required in the Commission Order, or to determine Project effects on the Sacramento splittail as recommended by Commission staff in the Study Plan Determination. The enclosed analysis by the Service of inundation areas on the Tuolumne River (USFWS 2008) is an appropriate and useful reference that was not utilized.	In order to examine the broad flow ranges identified in the FERC July 16, 2009 Order, the Study Plan separated the study into two separate investigations. This conventional one-dimensional (1D) PHABSIM study, which examines in-channel habitat conditions at flows from approximately 100 cfs up to 1,000 cfs, and a 2D hydraulic model of over-bank flows up to 5,000 cfs developed as part of the Pulse Flow Study report (Stillwater Sciences 2012). As referenced in the IFIM Report, *"Separate from the IFIM study component of the Study Plan, a Pulse Flow Study Report was submitted on June 18, 2012".* The Pulse Flow Study report included development of a 2D hydraulic model to assess the habitat suitability at in-channel locations as well as adjacent overbank areas for flows of 1,000–5,000 cfs. It should be noted, however, that most of the studies cited by the USFWS refer to floodplains that bear little or no resemblance to channel conditions in the Tuolumne River, and the results of the studies should be interpreted accordingly. Additionally, USFWS has not cited any site-specific empirical data or studies to support the hypothesis it offers concerning Tuolumne River floodplain rearing.

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4	The Draft Report and developed habitat suitability criteria (HSC) fail to take into consideration the importance of cover type. The importance of instream wood and large woody material to salmonid rearing is well understood (Beechie and Sibley 1997, Bilby and Ward 1989, Bryant 1983, Cederholm et al1997, Crispin *et al.* 1993, Everett and Ruiz 1993, Lemly and Hildebrand 2000, Merz 2001, Senter and Pasternack 2010). Large pieces of wood create both micro- and macro-habitat heterogeneity by forming pools, back eddies and side channels and by creating channel sinuosity and hydraulic complexity, including retention of spawning gravels. Snorkeling observations in the lower Yuba River have found that juvenile Chinook salmon show a strong preference for near-shore habitats with instream woody material (JSA 1992). Access to prey is an essential energetic component of juvenile spring-run Chinook and Central Valley steelhead survival. Juvenile salmonids with access to large woody material and the floodplain are likely to have greater growth and higher survivorship than individual juvenile salmonids that do not have access to this important foraging habitat (Harrell and Sommer 2003).	No consistent and complementary cover criteria data from other sources were identified by the technical workgroup participants. During the February 3, 2011 HSC Workshop (Appendix F of the Draft Report), the group discussed the idea of using existing cover codes. Because of limited availability of published cover HSC and wide variation in codes and sample sizes, it was decided to collect additional site-specific data during field surveys in 2011, and investigate adapting information from other coding systems. Existing curves from the Yuba River and Clear Creek were presented by USFWS. The applicability, complexity, and sample size of the various cover code data were discussed. Possible use of Sacramento River cover codes was discussed, although the data were not presented or reviewed. The decision resulting from the consultation meetings was that the Districts would consider combining cover coding systems from various sources into a simplified cover code that could potentially have sufficient observations in each cover category to be reasonably applicable. The draft report presented such a coding system, and applied the cover criteria for species and life stages with sufficient observations, as described below. Fish cover availability was collected in the field during the IFIM and HSC site-specific field surveys and were applied for life stages with a sufficient sample size (i.e., n>150). Cover included 10 categories (recorded in the field as percent cover); however, initial analyses identified no discernible relationships for HSC preference using all 10 categories. In order to increase sample size and provide more meaningful results, cover types were grouped into four categories: • No Cover: (1) no available cover • Object Cover: (2) cobble, (3) boulder, (4) fine woody debris, (5) large woody debris • Overhead Cover: (6) overhanging vegetation, (7) aquatic vegetation, (8) undercut bank, (9) rootwad, and (10) water surface turbulence • Both: a combination of both overhead cover and object cover Site-specific cover HSC was applied where the number of observations were sufficient (i.e., >150). Additionally, a sensitivity analysis was completed and reported in Section 4.1.3: "In order to evaluate the effect of the cover parameter on the WUA results, the model was run both with and without cover for Chinook fry. The results presented in Appendix H (Figure H-3) suggest that cover has a relatively small influence in the magnitude of WUA, and no influence on the WUA versus flow relationship." Therefore, the flow model results were not greatly altered by the inclusion of cover, and is not anticipated to change with the

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		inclusion of alternate cover categories; the WUA curve shape and peaks remained the same, even though the magnitude of the curves varied.
5	The added habitat complexity of various cover types provides juvenile salmonids numerous refugia from predators and water velocity, and provides efficient locations from which to feed (Crispin *et al.* 1993, Lemly and Hilderbrand 2000, Merz 2001). In an October 5, 2009, letter to Tim Ford of Turlock Irrigation District, the Service provided an example of a cover coding system in Table #3 that addresses the different types of cover that are important to analyze (Service's October 5, 2009 letter filed with the Commission as an enclosure to the Service's November 05, 2009letter). The Service recommended adoption in our October 5, 2009, letter of a cover coding system that includes the following cover types: No cover, cobble, boulder, fine woody vegetation (<1" diameter), fine woody vegetation+ overhead, branches, branches+ overhead, log (>1' diameter), log+ overhead, overhead cover(> 2' above substrate), undercut bank, aquatic vegetation, aquatic vegetation + overhead, and rip-rap. The Districts did not use this cover coding system, instead adopting a system that may not pick up critical distinctions between the types of woody cover and their instream contribution to salmonid and Sacramento spilttail rearing. For example, "branches" are an important spawning component for splittail in the floodplain, so this is a particularly important for the cover category. The collapsing of the cover types into four cover categories further exacerbates the loss of this cover category.	See reply to USFWS Comment No. 4.

No.	USFWS comment	Districts' reply
Specific comments		
6	*Section* 2, *Methods, page* 4: The one-dimension (1D) methodology is not robust and can lead to errors in interpretation. Additionally, the Service is concerned that the one-flow velocity calibration also leads to errors in interpretation. For example, the *O. mykiss* Adult Depth and Velocity Criteria listed in Appendix E are lower than our understanding of optimal depth and velocities in rivers of similar size *(e.g.,* Yuba River) (USFWS 2010a, USFWS 2010b, USFWS 2010c); the *O. mykiss* spawning velocity and depth curves described in Appendix E are lower than the Service's understanding of habitat use collected (USFWSa); and the HSC developed for the *O. mykiss* fry and juveniles are much lower than what is acceptable to the Service. A more accurate methodology would be provided by the HSC developed by the Service for the Yuba River (USFWS 2010a and 20 l0b) or an equivalent source.	This study was conducted in compliance with the Study Plan approved by FERC, pursuant to Ordering paragraphs (A) through (E) of the Commission's May 12, 2010 order, and consistent with additional elements of the December 22, 2011 Study Plan Determination for related relicensing studies. The study was designed and implemented by an interagency workgroup as an objective, scientific, and empirical analysis of flow-habitat relationships. Critical components of the study were developed in consultation with the USFWS and other stakeholders; the Districts held a series of workshops and meetings covering initial study planning, habitat typing, site selection and transect placement, habitat suitability criteria (HSC) development, and model calibration (the workshop summaries were provided in Appendices A–F). The Service's data from various other rivers, in addition to many other data sources, were considered by the group during development of the HSC. Additionally, the workgroup included site-specific HSC validation surveys for certain species and lifestages. The validation efforts allowed for evaluation of each of the targeted species and life stages selected for validation (Chinook salmon fry and juvenile; *O. mykiss* fry, juvenile, and adult). In total, five of the species life stages were considered validated by the site-specific results and two curves were expanded. There were no HSC curves constricted by the results of the site-specific surveys.
7	*Section* 2.4, *Calibration Flows, page* 8: The Service is of the opinion that the range of flows used in this study is inadequate, because it does not consider a wide range of flows similar to the pattern of the natural hydro graph. The Service recommends a higher range be used (i*.e.,* 300 cfs, 400 cfs, 600 cfs, 1,000 cfs, 1,500 cfs, 2,000 cfs, and 5,000 cfs). This range would give a better idea of how fish respond to higher flows similar to the magnitude of the natural hydrograph.	See reply to USFWS Comment No. 3.
8	*Section* 2.5, *Hydraulic Data Collection, page* 9: The methods used for collecting the hydraulic data are satisfactory. However, additional data should be collected over a higher range of flows to include inundation of the floodplain to allow for maximum production and survival of salmonids.	See reply to USFWS Comment No. 3.

No.	USFWS comment	Districts' reply
9	*Section 2.6, Substrate and Cover Data, page 10 and 11:* The use of the modified Wentworth Scale for substrate is acceptable, but the cover categories utilized are not acceptable. Cover and cover-type are critical to salmonids and thus collapsing the measured cover into 4 categories (None, Object Cover, Overhead cover, Both) obscures the importance of this variable. The cover types described in Table 8 of the Draft Report collapse the differentiation of woody material into two sizes. In the Service's October 5, 2009, letter we recommended that woody material be classified as fine woody vegetation (less than one inch in diameter), branches, log (greater than one foot in diameter). Woody material sizes and types are very important as habitat criteria, and further collapsing this variable into "Object Cover" is not appropriate, because salmonids utilize these cover types in different ways and each of these cover types has an important habitat value. Inclusion of "rootwad" is an acceptable addition to the woody material category, but classifying it as overhead cover is likely to obscure the contribution of this type of structure within the river.	See reply to USFWS Comment No. 4.
10	*Section 2.8, Habitat Time Series, page 14:* It is not appropriate to limit the upper range to 1,200 cfs because it takes away the ability to measure and analyze the contribution of the floodplain to salmonid and splittail production and breeding. The range should be extended up to at least 2,000 cfs, to allow for an analysis of the amount of habitat that might be gained at these higher flows. Important fry and juvenile salmonid habitat is provided when flows are high enough to provide cover in the form of submerged riparian vegetation along the riverbanks. It is likely that as flows increase beyond 1,200 cfs, the amount of cover provided by submerged vegetation would substantially increase. Higher flows would likely increase the amount of habitat available and maximize production and survival of the juvenile and adult Chinook salmon and *O. mykiss* due to inundation of areas with better cover and more food throughout their various life stages.	See reply to USFWS Comment No. 3.

No.	USFWS comment	Districts' reply
11	*Section 2.9, Effective Habitat, page 15:* A standard approach to calculating WUA should be used in conjunction with the "effective" WUA analysis utilized in this study. This is because standard methodologies are well understood and would provide validation (or rejection) of the effective WUA analysis.	The WUA results presented in the Draft IFIM report were developed using "standard" methods, in accordance with the FERC order. The effective WUA analysis based upon temperature suitability of various river segments has not yet be completed, as described in Section 2.9 of the Draft Report, pending completion of the relicensing study W&AR-16 (*Lower Tuolumne River Temperature Model*).
12	The Service supports the use of the temperature model as part of the process of determining the amount of habitat. Water temperature for rearing and migrating juvenile Chinook salmon should be an important part of the analysis; however, "effective" habitat, which includes water temperature suitability, will only be applied to *O. mykiss* and only during the summer. In order to determine instream flows necessary to maximize Chinook salmon and *O. mykiss* production and survival throughout their various life stages, the final study must include an assessment of the flows needed to provide temperatures that support these species. The final study should include an assessment of the flows needed to meet the EPA temperature criteria (2003) for each life stage of Chinook salmon and *0. mykiss*.	See reply to USFWS Comment No. 11 regarding effective habitat. The effective habitat analysis will be conducted consistent with the FERC-approved Study Plan. The December 22, 2011 Study Plan Determination stated that EPA (2003) temperature criteria will be used by FERC staff in their evaluation of project effects "unless empirical evidence from the lower Tuolumne River is provided that suggests different criteria are appropriate for salmonids in the lower Tuolumne River." However, assessment of flows to meet EPA temperature criteria was not part of the FERC Order for this study. Once completed, the *Lower Tuolumne River Temperature Model* (W&AR-16) may be used to evaluate flows to meet various water temperature targets. In addition, studies W&AR-6 and W&AR-10 (salmon and steelhead modeling) include water temperature as part of the analysis.
13	*Section 2.10, Habitat Suitability Criteria, page 15:* The Service does not support the use of the existing curves as originally ordered by the FERC. In its May 12, 2010, Order, the Commission adopted its staff recommendations that "[i]n order to obtain and utilize the most up-to-date information and validate existing data, the Districts should conduct the field work necessary to develop specific HSC curves for the project." (Ordering Paragraph B, adopting staff recommendations in Paragraph 37). The Districts have not followed the Service's recommendation. The Service repeats its recommendation that the Districts use the steelhead curves developed for the Lower American River or from the Lower Yuba River (USFWS 2003, USFWS 2010a).	See reply to USFWS Comment No. 6.
14	The Wentworth Scale provided in Appendix A appears to be very similar to the substrate scale recommended by the Service and is likely appropriate for this study.	Comment noted.

No.	USFWS comment	Districts' reply
15	*Section 2.10.1 Existing habitat suitability criteria, page 15:* The Service does not support the way the HSC were developed as presented in Table 12. While the spawning criteria for Chinook salmon are acceptable, cover should be included for all the additional categories, along with adjacent velocities for the juvenile and adult Chinook and ***O.** mykiss.* The Commission's May 12, 2010, Order recognized the value of these attributes, as it ordered the Districts to include measures of cover and adjacent velocity with the other more standard habitat metrics if additional habitat information is collected. (Ordering Paragraph B, adopting staff recommendations in Paragraph 37.)	See reply to USFWS Comment No. 4 and No. 6 regarding cover and HSC development. Additionally, adjacent velocities were evaluated for all lifestages included in the site-specific surveys, which included juvenile Chinook salmon and juvenile and adult *O. mykiss*. The FERC-approved IFIM study did not include adult Chinook salmon HSC (except for spawning), since such evaluations would not be relevant. The results are included in Section 3.1.3 of the Draft Report. However, as noted in the report, the adjacent velocity assessment indicated that there is limited application of adjacent velocity methods to lower Tuolumne River conditions (in part due to the scale of the river); the differences in mean column velocity were small (0.06 to 0.25 fps) between occupied and adjacent areas, suggesting limited use (or lack) of well-developed shear zones or feeding lanes (which is consistent with more homogenous morphological and hydraulic conditions observed in the Tuolumne or other large alluvial valley rivers). In addition, the magnitude of the adjacent velocities was well within the preferred velocity ranges (e.g., suitability indices of >0.5) for continuous occupation of the point location (i.e., the adjacent velocity was within a velocity range typical of positions more continuously occupied by the species and life stage).
16	*Section 2.10.1, Site-specific habitat suitability criteria page 16:* The approach for collecting HSC for the Chinook salmon and ***O.** mykiss* adult and juvenile life stages lacks certain aspects that are important. For example, data should have been collected at a different set and range of flows. While we agree with using 2,000 cfs as the maximum flow, the low and mid- range flows should have been higher. The Service recommends a minimum flow of at least 250 cfs, one mid-flow of at least 800 cfs, an additional mid-flow, and a 2,000 cfs maximum flow.	HSC site-specific surveys were conducted during February, March, May, and July at 100 cfs, 350 cfs, and 2,000 cfs. The range of months and flows allowed for surveys under various conditions, across seasons, and included habitats added under high flows, such as over-bank and side-channel habitats. Additionally, 100 cfs is included in the range of flows surveyed during the IFIM study; it is unclear why USFWS would want to omit data at lower flows and only collect it at higher flows, as this would introduce bias into the results. The Districts see no benefit for repeating the surveys at alternate flows within the same range. Specific flows for collection of HSC data were not specified in the FERC-approved Study Plan, nor recommended by the Service during any of the numerous workshops on related subjects.

No.	USFWS comment	Districts' reply
17	*Section 2.10.2.1, Habitat suitability criteria site selection page* 17: The Service agrees on the study site selection process. However, areas that have the potential to be inundated must be included in this study in order to develop flows that will maximize fall-run Chinook salmon and *O. mykiss* production and survival throughout their various life stages. The study excluded any dry areas and areas of potential inundation. It is essential that higher flows are included in the study, because the floodplain and habitat subject to potential inundation are very likely to improve and expand the amount of habitat, cover and food that would result in a healthier and more robust Chinook salmon and *O. mykiss* population.	See reply to USFWS Comment No. 3 and No. 16. Additionally, areas that have the potential to be inundated were included in the HSC site-specific surveys during the 2,000 cfs effort; 36 over-bank terrace quadrats and 76 side-channel quadrats (a portion inundated under higher flow conditions) were included in the surveys (see Table 13 of the Draft Report).
18	*2.10.2.2, Direct Observation and field measurements, page 23:* The data collection methods were satisfactory. However, as noted previously, collection of cover data should have been completed. Without cover data, any HSC developed will not be satisfactory. Each cover type has a different contribution to each life stage of the species. Please review reports published by the Service (USFWS 2005, USFWS 2010b) for methods used for collecting HSC data for rearing juvenile *O. mykiss* and adult Chinook salmon.	See reply to USFWS Comment No. 4.
19	*2.10.2.3, Data Analysis, page 23:* The Service agrees with the size ranges assigned to the various life stages, but the categories used for cover are not appropriate (see discussion under Section 3.1.2).	See reply to USFWS Comment No. 4.
20	*2.10.2.4 Adjacent velocity page 26:* The methods used for this aspect of the study are satisfactory for the development of HSC for rearing juvenile salmonids.	Comment noted.
21	*Section 3.1.2 Site-specific habitat suitability criteria development and validation, page 26:* The Service is supportive of the approach used in this stage of the HSC criteria development. However, additional flows should have been included in the HSC data collection process. As mentioned previously, the Service is in agreement with the 2,000 cfs maximum flow. However, for the low and mid-range flows, we recommend that higher and additional flows be used, with the low flow being at least 250 cfs.	See reply to USFWS Comment No. 16.

No.	USFWS comment	Districts' reply
22	The Service has recommended that cover be used to validate HSC for Chinook salmon and *O. mykiss* fry and juveniles. This is because cover is crucial to the accurate development of juvenile HSC. A full range of meaningful cover variables should be included in the validation process.	See reply to USFWS Comment No. 4.
23	The Service does not support the decision to use the depth, mean column velocity curves that were selected, because cover was not included in the analysis, floodplain use was not measured, use at higher flows was not measured, and they appear to be biased toward lower flows. The "Tuol Mod" curve for the Chinook fry depth and the "Tuol Env" curve for the Chinook fry show that higher flows are most likely desirable for optimal habitat.	Cover data was collected during the field surveys (See reply to USFWS Comment No. 4). Over-bank habitat (floodplain) was surveyed during the Pulse-Flow Study (See reply to USFWS Comment No. 3), and the HSC site-specific surveys (See reply to USFWS Comment No. 16 and 17). The inclusion of cover (or not) is unrelated to the depth and velocity curves. Also, this comment is inconsistent with other USFWS comments. Please see USFWS's Comment No. 50, which states that, for "Chinook salmon fry: The Service is supportive of the velocity and depth HSC developed in this case." Additionally, the relationship of habitat to flow is indicated by the WUA versus flow results, and not solely or directly by evaluation of HSC curves.
24	*Figure 6, page 32:* The Service does not support the use of the cover categories shown in Figure 6. We recommend use of the cover categories utilized by the Service (USFWS 2005). The Service's cover categories have been extensively used and have been peer reviewed. Please refer to the Service's peer-reviewed publications that use cover categories for the HSC (USFWS 2005, USFWS 2010b).	See reply to USFWS Comment No. 4.
25	*Figures 7-9 and 10,12-17, 19; pages 33-35,37-41:* The HSC do not reflect the most recent understanding of habitat use by Chinook salmon and *O mykiss*. Juvenile salmonids use the inundated margins and floodplains of rivers during high flows, and this habitat is optimal for production and survival at this life-history stage. Measuring depth and velocity in the margins of the river during low flows and not measuring the velocities and depths associated with the high flows that lead to inundation (adjacent velocities), is likely to misrepresent flows needed for production and survival of Chinook salmon and *O mykiss*.	The selection and validation process of HSC was designed and implemented by an interagency workgroup as an objective, scientific, and empirical analysis of flow-habitat relationships. The HSC site-specific surveys were conducted at flows ranging between 100 cfs and 2,000 cfs, which inundated over-bank habitat (See also reply to USFWS Comment No. 16 and 17). The hydraulic model was developed using mid-flow calibration velocities (not low flows) when the active channel was inundated. Adjacent velocity was also measured and reported; however, the point of the Service's reference to "adjacent velocities" in relation to "high flows that lead to inundation" is unclear (See also reply to USFWS Comment No. 15).

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26	Peer-reviewed Service publications (USFWS 2010a, USFWS 2010b, USFWS 2010c) should be used.	Comment noted
27	*Figures 11 and 18, pages 36 and 42:* The Service substrate data presented in these figures are appropriate, but the results presented in Figure 18 are not consistent with our understanding of Chinook salmon spawning preference. The Service has found that the size classes of 1-3 inch and 2-4 inch size substrate are optimal for Chinook salmon spawning.	The HSC presented in Figure 18 represent *O. mykiss* spawning substrate suitability preference. Figure 11 includes spawning substrate suitability preference for Chinook salmon, which appears to be in line with the USFWS understanding.
28	*Section 3.1.3, Adjacent velocity, page 33:* The Service appreciates the fact that an effort was made to include adjacent velocity as part of the data collection process. Adjacent velocity is important in the development of HSC (USFWS 2010a, USFWS 2010b, USFWS 2010c). We recommend that Service data be included in the process. If the Tuolumne data are insufficient or inadequate, additional data collection is warranted. Peer review of the reports published by the Service has supported the use of adjacent velocity in developing juvenile salmonid HSC.	Adjacent velocity was surveyed and evaluated for each species and life stages included in the Lower Tuolumne River site-specific surveys (total obs =570), which was sufficient to produce statistically valid results; however, as noted in Sect. 3.1.3, the habitat conditions and use by various species and life stages within the Lower Tuolumne indicated that the magnitude of the adjacent velocities was well within the velocity range typical of positions occupied by the species and life stage (see also reply to USFWS Comment No. 15). The largest significant difference between mean column velocity and adjacent velocity was 0.25 fps (Chinook juveniles). As a result, there appears to be limited application of adjacent velocity analytical methods to lower Tuolumne River conditions.
29	*Section 3.2 Weighted Usable Area, page 45:* The Service does not support the WUA results from the PHABSIM analysis for any life stage for Chinook salmon and *O. mykiss*. It is the Service's opinion that there is a strong bias towards lower flows in each case. The collection of criteria data at very low flows and the lack of data collected at higher flows has resulted in the WUA values that were selected. The Districts should review and utilize the WUA values for the Chinook adults and juveniles and the *O. mykiss* juveniles as presented in the Service reports (USFWS 2005, USFWS 2010a, USFWS 2010b, USFWS 2010c) and reports published by the National Marine Fisheries Service (NMFS), California Department of Fish and Wildlife, and other agencies and parties that concern rivers similar in size to the Tuolumne River.	The instream flow study was designed and implemented by a collaborative workgroup including agency (USFWS, CDFG, etc.) and other stakeholders, as an objective, scientific, and empirical analysis of flow-habitat relationships using data collected over a range of flows. As such, the results are based on the collected data, and not opinion. The site-specific HSC data collection occurred at a range of flows, between 100 cfs and 2,000 cfs (see also reply to USFWS Comment No. 16 and 17). HSC data from the USFWS, NMFS, and CDFG was incorporated into the interagency workgroup discussions, and in some cases, was included in the selected HSC curves (see Appendices A-F of the Draft Report). Additionally, WUA is a model result based on considerable underlying data collected using standard methods, and is not "selected" by anyone. Using "WUA values for the Chinook adults and juveniles and the O. mykiss juveniles as presented in the Service reports" from other rivers would not be appropriate, as FERC ordered an instream flow study to determine WUA for the Tuolumne River. Lastly, the results of the two prior Lower Tuolumne River instream flow studies conducted by the USFWS and CDFG (USFWS 1995 and CDFG 1981) produced comparable results to this study (see section 4.2, *Comparison to Prior PHABSIM Study Results*, of the Draft Report).

No.	USFWS comment	Districts' reply
30	*Section 5 References, pages 60-62:* The August 19, 2008, *Flow-Overbank Inundation Relationship for Potential Fall-Run Chinook Salmon and Steelhead/Rainbow Trout Juvenile Outmigration Habitat in the Tuolumne River* (USFWS 2008) was not included as a reference, but it is an important and relevant reference that should be utilized.	A discussion comparing the results of the USFWS (2008) GIS analysis with 2D modeling conducted as part of the Pulse Flow Study (Stillwater Sciences 2012) was previously completed and included in Section 4.1.1 of that report
31	The majority of the instream flow references are out-of-date and do not represent the state of the science. The Service recommends utilizing recent literature on instream flow methodology.	This study was conducted in compliance with the Study Plan approved by FERC, pursuant to Ordering paragraphs (A) through (E) of the Commission's May 12, 2010 order. Additional information was considered, and in some cases, incorporated by the workgroup. Comparisons to prior studies on the Lower Tuolumne River, including the USFWS 1995 IFIM Report, were also incorporated into the report and are believed informative to the results. Prior Service comments regarding "state of the science" were previously addressed by FERC during the study planning phase.
32	*Table 16, page* 47: The representation of seasonal periodicity in this table is adequate for the purpose of modeling efforts.	Comment noted
33	*Appendix B-1, Target Habitat Types:* The habitat types to be sampled are appropriate; however, more units per habitat type should be sampled and doubling the number of units is appropriate.	As noted in the *Lower Tuolumne River Instream Flow Study Site Selection Meeting Summary* (Appendix B-1), two USFWS representatives participated in the study site selection workshop, and USFWS staff participated in transect selection. The study was conducted in accordance with the workshop direction, and USFWS staff concurred on the number and placement of transects (Appendix B-2, Attachment 1).
34	The proposed habitat units appear acceptable; however, the backup units should also be included and additional transects as recommended by the Service should be added.	As noted in the *Lower Tuolumne River Instream Flow Study Site Selection Meeting Summary* (Appendix B-1), "backup" units were selected near the randomly selected sites …in order to provide more options during field transect selection, in the event that an originally selected random unit was less acceptable for some reason (access, hydraulics, logistics, habitat characteristics, etc.). The field surveys were completed at transects placed during the Lower Tuolumne River Instream Flow Study. Transect Placement (see Appendix B-2), or according to the direction of the workgroup. See also response to USFWS Comment 33 above regarding USFWS staff previously concurring to the number and placement of transects.

No.	USFWS comment	Districts' reply
35	*Appendix* C, *Study Background-Field Efforts:* It was inappropriate to conduct the HSC surveys at such low flow *(i.e.,* 100 cfs, 350 cfs) and then analyze the HSC data at the high flow of 2,000 cfs. It would have been more appropriate to collect the HSC data at 300 cfs, 400 cfs, 600 cfs, 1,000 cfs, 1,500 cfs, 2,000 cfs, and 5,000 cfs, which would be consistent with the July 16, 2009, Commission Order while allowing for interpretation of floodplain effects.	Site-specific HSC surveys were conducted at a range of flows between 100 cfs and 2,000 cfs, which covers the full range of in-channel flows the 1D study was modeling. Excluding low flows from the analysis would result in a bias in the data, as described in the response to USFWS Comment No. 16.
36	*Appendix* C, *Methods, Substrate and Cover Data:* The substrate data that was used in the PHABSIM model are appropriate; however, the Service does not agree with the cover type categories used in the PHABSIM part of this study. The cover categories used should be based on real data, and an understanding of the cover needs of the species, such as those used in the Service's Instream Flow studies. The cover data are important, in that they are used along with the substrate data to calculate roughness values that are usually used for making adjustments in the roughness values used in calibration (USFWS 2003, USFWS 2005, USFWS 2010a, USFWS 2010b, USFWS 2010c).	See reply to USFWS Comment No. 4
37	*Appendix* C, *Habitat Time Series:* The range of flows used in the study was inappropriate, considering the potential the river has for higher flows. The Service's flow recommendations for instream flow monitoring are 300 cfs, 400 cfs, 600 cfs, 1,000 cfs, 1,500 cfs, 2,000 cfs, and 5,000 cfs.	See reply to USFWS Comment No. 3
38	*Appendix* C, *Habitat suitability criteria:* Serious consideration should be given to reviewing and utilizing the HSC for *O. mykiss* and fall-run Chinook salmon developed by the Service (USFWS 2005, USFWS 2010a, USFWS 2010b, USFWS 2010c). The HSC developed by the Service have undergone extensive peer-review and represent the most thorough understanding of the habitat needs of Chinook salmon and *O. mykiss*. Use of HSC that have not undergone such extensive utilization and review may under-represent the flow needs of these species.	See reply to USFWS Comment No. 6

No.	USFWS comment	Districts' reply
39	*Appendix* C, *Existing habitat suitability criteria data:* The criteria used for the habitat suitability criteria data represent a good start. However, adjacent velocity data are also needed as part of development of the HSC data for the fry and juvenile life stages. The cover data collected as part of this study should be used without collapsing the categories. The use of presence/absence data is appropriate.	See reply to USFWS Comment No. 15 and No. 28 regarding the application of adjacent velocity in the Lower Tuolumne River IFIM model. See also reply to USFWS Comment No. 4 regarding the use of cover HSC.
40	With regard to the depth and velocity criteria for fall-run Chinook salmon, these criteria are too low. In order to develop adequate HSC, a full range of flows, substrate characteristics, and cover must be used. The small range of low flows, lack of inclusion of multiple cover variables, and lack of measurement of adjacent velocity are all likely to result in low flows that do not meet the needs of Chinook salmon and *O. mykiss* for production and survival. As noted previously, inclusion of the depth and velocity data developed by the Service (USFWS 2003, USFWS 2005, USFWS 2010a, USFWS 2010b, USFWS 2010c) would be appropriate.	The site-specific HSC data collection occurred at a range of flows between 100 cfs and 2,000 cfs (see also reply to USFWS Comment No. 16 and No. 17). See reply to USFWS Comment No. 4 regarding the inclusion of cover HSC. See reply to USFWS Comment No. 15 and No. 28 regarding adjacent velocity measurements.
41	*Appendix D, Chinook Salmon Spawning:* The output for depth criteria does not appear to be consistent with our current understanding of habitat use by Chinook salmon. The depth criteria for spawning indicate that very low flows were favored. Based upon our current understanding of habitat use (USFWS 2010a), adult Chinook salmon favor a higher range of depths and velocities.	The Chinook spawning criteria were based on CDFG's 1982 site-specific data from the Lower Tuolumne River. It was found to be appropriate for use by the workgroup September 20, 2010 (Draft Report Appendix D).
42	The Chinook salmon spawning substrate criteria are acceptable. They are very similar to what the Service has used effectively in various studies that have been conducted on a variety of rivers.	Comment noted.

No.	USFWS comment	Districts' reply
43	*Appendix D, Chinook Salmon Juvenile Depth and Velocity Criteria:* The Service does not support the use of the criteria developed for the juvenile Chinook salmon. The depth and velocity criteria do not represent the full range of floodplain inundation flows that would support juvenile salmonid production and survival, and appear biased toward lower flows. Cover is the primary component in developing accurate HSC values for juvenile fall-run Chinook. Although cover type and amount are important considerations for juvenile salmonid survival, they were not given adequate consideration in the HSC. The combination of depth, velocity (including adjacent velocity values) and cover are crucial to developing accurate HSC for juvenile Chinook salmon. As stated previously, the reports for the studies conducted by the Service should be reviewed and the existing Service-developed criteria should be utilized.	The site-specific HSC data collection occurred at a range of flows between 100 cfs and 2,000 cfs and included flooded overbank and side-channel habitats (see also reply to USFWS Comment No. 16 and No. 17). Cover data was collected and applied where able (see also reply to USFWS Comment No. 4). Adjacent velocity was collected and included in the analysis (see also reply to USFWS Comment No. 15 and No. 28).
44	*Appendix D, Chinook Salmon Fry:* As described above, cover is a very important component for developing criteria for fry and juvenile Chinook salmon. Depth, velocity (including adjacent velocity), and cover are crucial for developing accurate HSC. Cover is particularly important because the fry and juvenile fish utilize cover to optimize foraging, avoid predation, and reduce the amount of energy expended. Existing criteria developed by the Service should be reviewed and utilized.	See reply to USFWS Comment No. 4 and No. 6.
45	*Appendix E, O. mvkiss Adults:* As described in previous comments, the Districts should utilize the HSC for *O. mykiss* that were developed by the Service in studies conducted on the Lower Yuba River (USFWS 2010a).	See reply to USFWS Comment No. 6.
46	Although the Service supports the use of a variety of curves from various studies, in this case, the HSC for *O. mykiss* (steelhead) developed by the Service should be utilized. The adult *O. mykiss* criteria that are presented in the Draft Report appear to be biased toward lower velocities and depths. Higher flows need to be considered and analyzed, because higher flows may allow for higher amounts of food that can be utilized by the adult *O. mykiss*. In addition, the HSC should include cover, which is crucial for the adult fish.	See reply to USFWS Comment No. 6 regarding HSC curve selection. See reply to USFWS Comment No. 3 regarding study flows. See reply to USFWS Comment No. 4 regarding cover HSC.

No.	USFWS comment	Districts' reply
47	*Appendix E, O. mykiss Spawning:* The data appear to show a bias toward lower flows, depths, and velocities, which is not consistent with the results in other studies conducted by the Service (USFWS 2010a). The use of the substrate size presented in the Draft Report is acceptable.	The instream flow study was designed and implemented by an interagency workgroup as an objective, scientific, and empirical analysis of flow-habitat relationships; the Service provides no data or analysis indicating the results are biased. Comparing flow results to another river is inappropriate, since this study was ordered and conducted for the Tuolumne River. In fact, the results are consistent with a prior instream flow study conducted by the Service for the Tuolumne River (and another study of the Tuolumne River by CDFG) (USFWS 1995 and CDFG 1981).
48	*Appendix E, O. mykiss Fry:* The Service's HSC should be utilized in this study, as the Service's criteria data for *O. mykiss* fry have been collected in a number of robust studies in rivers and creeks in the Central Valley (USFWS 2010b, USFWS 2010c).	See reply to USFWS Comment No. 47 and No. 6.
49	*Appendix E, O. mykiss Juveniles:* A proper and accurate HSC for *O. mykiss* juveniles should utilize depth, velocity (including adjacent velocity) and cover.	As noted in reply to USFWS Comment No. 15, adjacent velocities were evaluated for all lifestages included in the site-specific surveys, which included *O. mykiss* juveniles. See reply to USFWS Comment No. 4 regarding cover HSC.
50	*Appendix F, Chinook salmon* fry: The Service is supportive of the velocity and depth HSC developed in this case. However, it best to consider the primary use of the criteria developed by the Service. The data for depth and velocity appear very similar for the "Tuol Mod" and Yuba (USFWS 2010b), so these criteria are likely appropriate.	Comment noted.
51	With regard to the velocity suitability, "Tuol ENV" suitability criteria presented in the Chinook salmon fry table, the Service is not supportive of its use. These criteria are strongly biased toward lower velocities and flows. The use of Service's suitability criteria for Chinook salmon fry from the various studies conducted should be used. As noted previously, there are several reports from the Service that provide the criteria needed.	See reply to USFWS Comment No. 6.
52	As noted previously, the use of adjacent velocities and cover is crucial to developing accurate criteria for fry and juvenile Chinook salmon fry.	See reply to USFWS Comment No. 4, No. 6, No. 15, and No. 28.

No.	USFWS comment	Districts' reply
53	*Appendix F, O. mykiss Fry:* The Service is not supportive of the criteria. The depth and velocity data are severely biased toward lower flows and velocities. Given the potential for more habitat associated with higher flows that can inundate areas that have good quality cover and food, higher flows should be considered in the analysis. Again, as described previously, adjacent velocities and cover are crucial to developing accurate HSC for *O. mykiss* fry.	See reply to USFWS Comment No. 6 regarding criteria development. See reply to USFWS Comment No. 3 regarding study flows. See reply to USFWS Comment No. 4, No. 15, and No. 28 regarding cover and adjacent velocity.
54	*Appendix F, O. mykiss Adult*: It is the Service's opinion that the velocity and depth criteria that are presented in this report are inadequate as they do not consider higher flows. As described previously, higher flows could result in habitat inundation, which could result in a higher level of food and cover for the fish. This food and cover is expected to result in better survival, larger fish, and high production values for the fish. Cover should be included in the development of the adult HSC. It is recommended that the Districts use the HSC developed by the Service for the Yuba River, Clear Creek and any other rivers/creeks where juvenile steelhead/rainbow trout HSC were developed, as these data should provide the HSC characteristics that are similar to those required by adults. Review of the reports published by the Service, NMFS, California Department of Fish and Wildlife and other agencies and stakeholders is recommended.	See reply to USFWS Comment No. 6 regarding criteria development and Comment No. 4 regarding cover. Data were collected at low, mid, and very high flows (i.e., up to 2,000 cfs). Additionally, the Districts included the referenced HSC developed by the Service for the Yuba River and Clear Creek along with numerous other streams in the inter-agency HSC workshops (please refer to the workshop summaries in Appendices D–F). The selected curves were subsequently validated or expanded based on the site-specific Lower Tuolumne HSC survey results.
Conclusion		
55	The Service requests that our peer-reviewed HSC be used in the Study. If you have any questions regarding this response, please contact Deborah Giglio of my staff at (916) 414-6600.	As noted in the reply to USFWS Comment No. 6, the Service participated in study development and their HSC data were considered during selection of appropriate HSC for the Tuolumne River.