

**Placer County Water Agency  
Middle Fork American River Project  
(FERC No. 2079)**

**FINAL**

**AQ 1 – Instream Flow  
Technical Study Report**



**Placer County Water Agency  
P.O. Box 6570  
Auburn, CA 95604**

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## **1.0 INTRODUCTION**

This report describes the AQ 1 – Instream Flow Technical Study conducted by the Placer County Water Agency (PCWA) in accordance with the AQ 1 – Instream Flow Technical Study Plan (AQ 1 – TSP). The AQ 1 – TSP was included in the Supporting Document (SD) H of the Pre-Application Document (PAD) for the Middle Fork American River Project (MFP or Project) (PCWA 2007a). Two additional study items were requested by stakeholders after submittal of the PAD. The revised AQ 1 – TSP, with the additional study elements, was submitted to Federal Energy Regulatory Commission (FERC or Commission) in May 2008 (PCWA 2008a). FERC formally approved the study plan on July 18, 2008.

The purpose of the study is to characterize aquatic and riparian habitat as a function of flow using site specific channel topography, substrate data, hydrodynamics modeling, and ecologically based habitat modeling in the bypass and peaking reaches associated with the MFP. The information developed from this study, in combination with other FERC-approved resource studies (e.g., water temperature, geomorphology, fish passage, fish population, special-status amphibian and reptile, bioenergetics, and riparian resources studies), will provide a basis for streamflow-related resource management decisions.

A draft report was distributed to the Aquatic Technical Working Group (TWG) on January 15, 2009 for a 60-day comment period. The comment period ended on March 15, 2010. PCWA received one comment letter dated March 20, 2010 which is provided in Attachment A. PCWA's response is also provided in Attachment A. No changes to the report were made in response to the comment letter.

## **2.0 STUDY OBJECTIVES**

The specific AQ 1 – TSP study objectives include the following:

- Quantify the habitat versus flow relationships for fish, special-status amphibian, benthic macroinvertebrate, and riparian resources in the bypass and peaking reaches;
- Use the habitat versus flow relationships to develop a time series analysis of aquatic habitat under existing and unimpaired flow scenarios in the bypass and peaking reaches;
- Identify the time periods, flow conditions, and life stages when habitat may be a limiting factor for fish, benthic macroinvertebrate, special-status amphibian, and riparian populations for the existing and unimpaired hydrology scenarios; and
- Provide information necessary to quantify the potential effects of other alternative flow scenarios on aquatic and riparian habitat.

Figure AQ 1-1 shows the AQ 1 – TSP study objectives and the study elements associated with each objective. It also shows where information developed is documented.

### **3.0 STUDY IMPLEMENTATION**

Study elements described in the AQ 1 – TSP (PCWA 2007a) were initiated in 2007 and completed in 2009. A summary of the study elements that have been completed, deviations from the TSP, outstanding study elements, and any proposed modifications to the AQ 1 – TSP are discussed in the following subsections.

#### **3.1 STUDY ELEMENTS COMPLETED**

The following instream flow study elements were completed:

- Target species and/or guilds and life stages for modeling were selected in collaboration with the Aquatic TWG based on management importance and/or sensitivity to Project operations;
- Habitat suitability criteria (HSC) were developed in collaboration with the Aquatic TWG;
- Study reaches were stratified and study sites were selected in the field with concurrence from the Aquatic TWG;
- Study site selection was coordinated with the AQ 12 – Special-Status Amphibian and Aquatic Reptile TSP (AQ 12 – TSP), AQ 10 – Riparian Resources TSP (AQ 10 – TSP), and AQ 9 – Geomorphology TSP (AQ 9 – TSP) to provide modeling capabilities for those resource areas;
- Modeling cross-sections (one-dimensional (1D) modeling) and/or modeling reaches (two-dimensional (2D) modeling) were selected within each study site in collaboration with the Aquatic TWG for each study site;
- Hydrodynamics and habitat modeling was completed over the range of flows specified in the AQ 1 – TSP for each 1D and 2D study site;
- Time series analyses of habitat for impaired and unimpaired flows were completed at each 1D and 2D study site;
- Foothill Yellow-legged Frog (FYLF) validation data were summarized for habitat modeling;
- Study elements specific to the peaking reach were completed including hydrology summarization, flow monitoring with stage recorders, stranding evaluation, and effective habitat analysis;

- Sediment transport conditions in the bypass and peaking reaches were characterized; and
- Additional study elements requested by stakeholders were completed including evaluation of algae abundance/*Didymosphenia geminata* presence/absence at instream flow sites and evaluation of the flow required to inundate the historic natural river channel at Horseshoe Bar.

### **3.2 DEVIATIONS FROM TECHNICAL STUDY PLAN**

There was one deviation from the AQ 1 – TSP. An element of the AQ 1 – TSP was to evaluate the magnitude of flow required to inundate the historic natural river channel at Horseshoe Bar based on 1D hydraulic modeling. During implementation of the study element, it was obvious that very large flows would be required to inundate the channel and that 1D hydraulic modeling would be insufficient to describe flows necessary to inundate the historical channel at the study location. An alternative approach based on empirical monitoring of flows at the channel entrance was implemented. The method used a stage recorder near the entrance to the channel, an upstream real-time gage, and a survey of the channel entrance elevation to derive an estimate of the flow required to inundate the channel. The alternative empirical method and analysis is presented in this report. This alternative analysis provides information regarding the flow magnitude necessary to inundate the channel in sufficient detail to satisfy the objectives of this study element.

### **3.3 OUTSTANDING STUDY ELEMENTS**

There are no outstanding study elements from the AQ 1 – TSP.

### **3.4 PROPOSED MODIFICATIONS TO TECHNICAL STUDY PLAN**

No modifications are proposed to the AQ 1 – TSP.

### **4.0 EXTENT OF STUDY AREA**

The study area included the active channel and floodplain in the bypass reaches downstream of Project reservoirs/diversions, the peaking reach downstream of Oxbow Powerhouse, and selected comparison river reaches upstream or otherwise unaffected by the Project facilities. The study area is identified in Table AQ 1-1 and Map AQ 1-1. Some portions of the study area are very difficult to access due to the rugged terrain (Map AQ 1-1) and thus, field data were collected only in portions of the study area that were accessible and approved by the Aquatic TWG. The reaches upstream of and/or unaffected by the Project facilities were used to interpret riparian vegetation versus flow relationships; therefore, data collection in these reaches was limited to that purpose.

### **5.0 STUDY APPROACH**

The following describes the general instream flow modeling approach for all study streams, including: (1) selection of target species and/or guilds and identification of life

stage periodicity for target species; (2) development of HSC; (3) study area stratification, study site selection, and coordination with other studies; (4) study site modeling approach (hydrodynamics and habitat); (5) methods specific to the peaking reach; (6) evaluation of sediment transport conditions; and (7) additional study requests related to algae sampling and Horseshoe Bar channel inundation.

### **5.1 SELECTION OF TARGET SPECIES, LIFE STAGES, AND/OR GUILDS**

Species distributions of fish, special-status amphibians and reptiles, and riparian resources within the bypass and peaking reaches associated with the MFP were generated as part of the results of the AQ 2 – Fish Population Technical Study Report (AQ 2 – TSR) (PCWA 2009a), AQ 12 – Special-Status Amphibian and Aquatic Reptile Technical Study Report (AQ 12 – TSR) (PCWA 2008b), and SD F Section 9.0 (Riparian Resources) of the PAD (2007a). The species distributions (e.g., distribution maps) from the abovementioned technical studies were used to determine potential target species for instream flow habitat modeling for the MFP.

The aquatic species, life stages, and guilds to be used for instream flow habitat modeling were selected in collaboration with the Aquatic TWG based on management importance and/or potential sensitivity to Project operations. The primary species and life stages selected for instream flow modeling included rainbow trout (juvenile rearing, adult rearing, and spawning), hardhead (juvenile and adult rearing), and foothill yellow-legged frog (FYLF) (breeding and tadpoles). Also, a guild (or spatial niche) approach was selected to model habitat for all aquatic species (primary and secondary priority species/life stages). The guild/spatial niche approach included the primary species and life stages listed above, as well as secondary species/life stages including juvenile and adult Sacramento pikeminnow, Sacramento sucker, California roach, sculpin species, speckled dace, fry of all the fish species, and macroinvertebrates. Brown trout was not identified as an important management species by the resource agencies and, therefore, was not evaluated separately as a target species. In the spatial niche analysis, rainbow trout was used as a surrogate for brown trout, as the two species have similar habitat preferences for most life stages.

A life stage periodicity chart (i.e., season of occurrence) for the aquatic species in the study area (Figure AQ 1-2) was developed from existing information (Meehan and Bjornn 1991; Benke 1992, Moyle 2002), biologist observations, and study results (e.g., AQ 2 – TSR (PCWA 2009a), AQ 10 – TSR (PCWA 2009b), and AQ 12 – TSR (PCWA 2008b)).

### **5.2 DEVELOPMENT OF HABITAT SUITABILITY CRITERIA**

HSC for each selected aquatic species/life stage were developed collaboratively with the Aquatic TWG. Table AQ 1-2 shows the type of HSC developed for each species and life stage. The table also shows the priority status (primary or secondary) of each species/life stage for instream flow modeling and the source of the HSC. Univariate HSC (separate suitability developed for depth, velocity, and/or substrate) were developed for each of the primary target species and life stages, and for some of the

secondary priority species (note: for the secondary priority species, the univariate HSC were used to help develop the guilds for the spatial niche analysis).

The HSC developed for this study were applicable either to the late spring spawning/breeding period or the summer/fall rearing period. Suitability criteria were not developed for the winter or early spring period (cold water periods). Typically fish utilize comparatively low velocity water habitats during cold weather periods (Baltz et al. 1991; Vondracek et al. 1992). As a result, habitat modeling of winter habitat typically indicates that low flows provide suitable habitat (personal experience). However, maintenance of channel primary productivity and macroinvertebrate production capacity during the cold winter/early spring period may be an important consideration for maintaining the river ecological processes; therefore, wetted perimeter modeling was used to provide an index of potential winter/spring primary and benthic production capacity of the channel.

The information and approach used to develop the HSC and guilds for each species/life stage is described below.

### **5.2.1 Rainbow Trout Adult and Juvenile HSC**

Adult and juvenile rainbow trout (RBT) habitat suitability criteria (HSC) were developed using existing fish habitat use data sets collected from northern, west slope Sierra Nevada rivers. The existing fish habitat use data sets were reviewed by the Aquatic TWG for applicability to the river reaches associated with the MFP. The data sets that were determined to be most applicable were used to develop HSC for the MFP.

Four primary data sets were selected to develop the MFP HSC including: (1) Middle Fork Stanislaus River 2001 (TRPA 2002a); (2) North Fork Stanislaus River “high flow” 1991 (TRPA 1992); (3) large channel South Fork American River (TRPA 2000); and (4) the upper North Fork Feather River (TRPA 2002b) (Appendix A, Attachment A). These individual data sets have previously been used to generate habitat suitability criteria for various northern, west slope Sierra Nevada hydropower relicensing projects, including Middle Fork and South Fork Stanislaus rivers (Stanislaus), Upper American River Project (UARP), El Dorado Irrigation District, DeSabra, Big Creek, and others.

These data sets were used because they appeared not to have habitat availability limitations (habitat availability biases) present in the river at the time the data were collected. To minimize habitat availability biases, data sets with an equal effort sampling design and/or collected in medium sized rivers at medium flows were selected to increase the likelihood that a wide variety of habitat was present (available) at the time the fish were observed (i.e., fish present could select from a wide range of habitat). Data sets collected during low flow when only low velocities were present or data sets from small streams where only shallow depths were present were excluded. Where possible, data sets with measured habitat availability data were used to allow potential assessment of habitat availability biases in the data sets by using preference ratio calculations (fish use/habitat availability).

Univariate HSC for adult and juvenile RBT rearing were developed for water depth and water velocity. Substrate/cover HSC were not developed because abundant cover in the form of large substrates is present in all the streams/rivers associated with the MFP. It is believed that because cover is generally present, it is not an important factor in differentiating the habitat use of adult and juvenile rainbow trout in these rivers. This is not meant, however, to be a general statement that substrate/cover is not an important factor for other rivers or species/life stages. Habitat use data from each river data set were plotted (overlaid with each other) to create HSC for two different size classes of adult and two different size classes of juvenile rainbow trout (four different size classes in total). The size classes represented the size of rainbow trout present in smaller bypass streams (juvenile and adult classes of 5–<12 cm and 12–22.5 cm, respectively) and larger bypass or peaking river reaches (juvenile and adult classes of 5–<15 cm and 15–40 cm, respectively). The small bypass streams include Duncan, North and South Fork Long Canyon, and Long Canyon creeks. The large bypass and peaking reaches include the segments of the Middle Fork American and Rubicon rivers affected by operations of the MFP. It should be noted that the size class split between juveniles and adults was not based on empirically observed reproduction capability of fish in the study area, but based primarily on literature (Moyle 2002) and convention.

HSC were generated by enveloping the habitat use frequency data for each of the four primary data sets. Professional judgment was used where necessary to envelop the frequency data in a manner that did not give undue weight to outlier points and that created criteria that were consistent between fish size classes.

In addition to the four primary data sets used to create the HSC, three supplemental analyses were used as aides in the development of the HSC. Where applicable, the supplemental analyses were used to help make professional judgment adjustments to the HSC.

- *Enveloped Habitat Use HSC* – Two “validation” RBT habitat use data sets from medium sized rivers, Klamath River (TRPA 2004) and Pit River (Baltz and Vondracek 1985), were used to test the generality of the HSC (Appendix A, Figures A-1 to A-2).
- *HSC Comparison with Adjusted Preference Data* – For three of the four primary data sets, habitat use (U), availability (A), and adjusted preference ratio<sup>1</sup> (U/A) were plotted and compared to the enveloped HSC (Appendix A, Attachment B). Availability data were not collected for the North Fork Stanislaus 1991 data. The adjusted preference ratio was used to identify if there were potential habitat availability biases in the data. It should also be noted that the large channel South Fork American River juvenile velocity data set contained few fish and the U/A data were noisy and not used to assess the HSC.

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<sup>1</sup> Note that the preference ratio U/A was calculated only where the availability (A) was 10% or greater to avoid aberrant spikes in the U/A data.

- *Comparison with Other Project HSC* – The MFP HSC were compared to HSC from other projects:
  - The MFP small stream HSC were compared to the South Fork American River small stream data set (TRPA 2000) used to develop small stream HSC for the UARP (Appendix A, Figure A-3). The habitat use (U), availability (A), and adjusted preference ratio (U/A) information from the small stream data set were plotted with the MFP HSC.
  - The MFP small and large stream adult and juvenile HSC were compared to two sets of HSC used in recent relicensing projects: Stanislaus (TRPA 2002a) and UARP (TRPA 2000b).

Sensitivity analysis HSC were developed for small and large stream rainbow trout adult for both velocity and depth. These HSC were developed to test if increased suitability for faster velocity or increased suitability for deeper water would affect the final habitat versus flow relationships (i.e., how sensitive the final habitat results were to alternative HSC).

### **5.2.2 Rainbow Trout Spawning and Fry, Hardhead, Sacramento Pikeminnow and Sacramento Sucker HSC**

A database of existing HSC for rainbow trout spawning and fry, hardhead, Sacramento pikeminnow, and Sacramento sucker that had been used in recent instream flow projects in Sierra Nevada streams was compiled for potential use in the MFP instream flow study. The database was reviewed by the Aquatic TWG for applicability to MFP species and river reaches. The data that were determined to be most applicable were used to develop HSC for these species and life stages for the MFP.

Univariate HSC for rainbow trout spawning and rainbow trout fry (20–<50 mm), hardhead (juvenile and adult), Sacramento pikeminnow (juvenile and adult), and Sacramento sucker (juvenile and adult) were generated by plotting the most applicable HSC from other streams (Appendix B). From the plotted curves, a single envelope univariate HSC curve for velocity, depth, and substrate (rainbow trout spawning only) was developed.

### **5.2.3 Foothill Yellow-Legged Frog Breeding and Tadpole HSC**

HSC (water depth, water velocity, and substrate) for FYLF breeding and larval development (tadpoles) were developed as part of the AQ 12 – TSR (PCWA 2008b). The HSC were based on: (1) site-specific use data collected in spring - fall 2007 in the larger MFP rivers and streams (e.g., Rubicon and Middle Fork American rivers); and (2) recently collected use data collected from other northern Sierra Nevada rivers (Lind and Yarnell 2007) (Appendix C). Data from small streams where habitat availability (e.g., limited depth availability) may have affected habitat selection for oviposition (egg masses) or tadpoles were not included in the data set. Three habitat suitability levels (high, marginal, and not suitable) were developed for each life stage and habitat variable. These levels were based on the range of water depth, water velocity, and

substrate values observed for 90%, 10%, and 0% of egg masses or tadpole groups, respectively (Lind and Yarnell 2007).

Based on initial validation results for the FYLF modeling, the FYLF breeding HSC in the AQ 12 – TSR (PCWA 2008b) were modified. HSC were modified to make them applicable to 2D modeling when substrate in the study site was delineated into polygons with dominant and subdominant percentages (e.g., 40% cobble, 30% gravel, 30% boulder). Specifically, a code was developed to denote the presence of suitable breeding attachment substrate, regardless of the overall dominant substrate in the polygon. A percentage, 20% or greater, of breeding substrate in a substrate polygon was used to determine the suitability for breeding (Section 6.1.3 in the Results section for details).

#### **5.2.4 Guild/Spatial Niche Approach**

For all aquatic species and life stages (fish, amphibians, benthic macroinvertebrates) in the study area, including the primary species/life stages listed above, a guild approach was developed in collaboration with the Aquatic TWG to provide binary depth and velocity habitat criteria. Where univariate HSC were available for species/life stages, a relatively high value of habitat suitability (80%) was plotted on a depth and velocity plot to aid development of depth and velocity guilds. A high value of suitability was used to clearly show the potential habitat separation between species/life stages. For the other species/life stages, depth and velocity habitat suitability was obtained from the literature (see below). The depth and velocity plot was then divided into different categories (e.g., slow-shallow, fast-shallow, deep-slow) that approximately correspond to the depths and velocities utilized by different species/life stage guilds (e.g., fry, macroinvertebrates, etc.). Because some of the species/life stages overlapped in habitat use, it was not possible to select categories of depth and velocity that exclusively separated species/life stage guilds. The categories were selected at evenly spaced depth and velocity increments that provided as much separation as possible. Each species/life stage was then assigned to one or more of the depth and velocity guilds.

Information on depth and velocity use was obtained from the literature for speckled dace, riffle sculpin, California roach, and macroinvertebrates. Speckled dace, riffle sculpin, and California roach data were obtained from Moyle and Baltz (1985). The depth and velocity range where the largest percentages of fish were observed in the study was used for the depth and velocity plot and guild assignments. Macroinvertebrates were assigned to all of the guild categories except the shallowest (<0.25 feet) and the deepest categories (>4 feet) and where velocities were greater than 4 ft/s based on a combination of habitat use information for macroinvertebrates from Waters (1976), Gore et al. (2001), and USFWS (2006).

### **5.3 STUDY AREA STRATIFICATION, STUDY SITE SELECTION, AND COORDINATION WITH OTHER STUDIES**

Geomorphology, hydrology, and habitat data collected as part of previous studies (PCWA 2006a; PCWA 2006b; PCWA 2006c; PCWA 2007a) were used to stratify the

bypass and peaking reaches. The broadest strata were based on the results of the geomorphic classification of the river channels (PCWA 2006a; PCWA 2007a) (Map AQ 1-1) and hydrological management reaches (i.e., reaches that have similar flow regimes as a result of Project operations). These geomorphic/hydrologic management reaches are shown in Map AQ 1-1 and Table AQ 1-3.

Within the geomorphic/hydrologic reaches, the river was further stratified based on mesohabitat types. All accessible bypass and peaking reaches were mesohabitat mapped (typed), either by aerial video, helicopter, or foot travel, using the most detailed level of mesohabitat typing outlined in McCain et al. (1990) (i.e., a potential of 22 mesohabitat types) (PCWA 2007b). In consultation with the Aquatic TWG, these habitat types were collapsed into five mesohabitat types for instream flow modeling (pool, run, low gradient riffle, high gradient riffle, and cascade).

Due to access limitations within the study area, accessible study sites were selected within each of the different geomorphic/hydrologic reaches to represent the longer reaches. The representative study sites were at least 20–40<sup>+</sup> channel widths in length and contained a full complement and similar proportion of mesohabitat types to those present within the larger geomorphic/hydrologic reach. Where possible, the sites overlapped the 2006 geomorphology and riparian habitat quantitative study sites (QSS) (PCWA 2006a).

The locations of the study sites within each geomorphic/hydrologic reach are shown in Map AQ 1-1 and Table AQ 1-3. The specific location of the instream flow study sites was selected in the field during late summer 2007, with concurrence of Aquatic TWG representatives. Twelve all-discipline inclusive instream flow study sites were selected, where aquatic habitat, riparian habitat, and geomorphology would be modeled. An additional five riparian comparison study sites and two limited purpose study sites were also selected for modeling (see below).

The instream flow modeling sites in the peaking reach were selected to include representative habitat of fish, benthic macroinvertebrate, amphibian, and riparian resources that was sensitive to flow fluctuations. For example, sites were selected and modeled that contained fry rearing habitat, potential fish stranding locations, amphibian breeding habitat, and benthic macroinvertebrate habitat.

Study site selection in the bypass and peaking reaches was coordinated with other TSPs, including AQ 12 – TSP, AQ 9 – TSP, and AQ 10 – TSP. The study site selection was coordinated with the AQ 12 – TSP to include FYLF breeding and tadpole rearing habitat, where appropriate. FYLF breeding and tadpole rearing sites were identified for two bypass reach study sites above Ralston Afterbay (Middle Fork American River MF26.2 and Rubicon River R3.5) and potential breeding/rearing habitat was identified at the modeling sites in the peaking reach (MF14.1 and MF4.8). In addition, two limited purpose study sites were identified for stage-discharge modeling at FYLF breeding locations on comparison rivers (North Fork of the Middle Fork American River NFMF2.3 and North Fork American River NF35.7).

Selection of study sites was also coordinated with the AQ 9 – TSP and the AQ 10 – TSP to provide modeling data for these TSPs at each of the 12 general purpose instream flow study sites (Table AQ 1-3), at five riparian comparison stream sites, and at one special purpose geomorphology study site. The riparian comparison stream reaches were upstream of Project diversions on Duncan and South Fork Long Canyon creeks (D9.0 and SFLC4.2) and in the unimpaired North Fork of the Middle Fork American and North Fork American rivers (NFMF2.3, NF31.3, and NF53.7) (Tables AQ 1-1, AQ 1-3, and Map AQ 1-1). The one limited purpose geomorphology study site was located downstream of the Duncan Creek Diversion (D8.3).

#### **5.4 MODELING APPROACH**

Instream flow modeling was accomplished by sampling/modeling representative mesohabitat units within each of the study sites using 1D and/or 2D hydrodynamics and habitat models (Table AQ 1-3). The results for each mesohabitat type were weighted and combined to develop a representation of hydrodynamics and habitat for the larger geomorphic/hydrologic reach. The weighting was based on the percentage of each mesohabitat type within the geomorphic/hydrologic reach (Table AQ 1-4).

The sampling effort within each study site was determined in collaboration with the Aquatic TWG. Approximately 10 mesohabitat units (range of 8–14 units) within each geomorphic/hydrologic study site were sampled and modeled. In general, mesohabitat types were sampled approximately in proportion to their abundance within the larger geomorphic/hydrologic study reach (Table AQ 1-4). Small adjustments to the proportional sampling were made based on the importance or variability of particular mesohabitat types in consultation with the Aquatic TWG.

The representative study sites contained more mesohabitat units than were modeled/sampled. The specific mesohabitat units selected for modeling were those that were most representative of the mesohabitats in the geomorphic/hydrologic reach. Results from the 2006 Aquatic Habitat Characterization Study (PCWA 2006c) were used to compare mesohabitat types (e.g., average length, width, depth, and substrate) in the geomorphic/hydrologic reach with the mesohabitats in the study site. These data, along with a visual assessment of the representativeness of the mesohabitat units within the study site, were used to select the units to model. Final selection of the habitat units was completed in the field in collaboration with the Aquatic TWG.

For the 1D study sites, cross-sections were visually placed within the mesohabitat units to best represent the habitat over a range of flows. Concurrence regarding cross-section placement within mesohabitat units was obtained from the Aquatic TWG during a field visit to each instream flow study site. Table AQ 1-3 shows the study sites where 1D modeling was completed and the approximate number of mesohabitat units and cross-sections sampled.

Two-dimensional modeling was used to model the two study sites in the peaking reach (MF14.1 and MF4.8) and two FYLF breeding mesohabitat units in two study sites immediately upstream of Ralston Afterbay (MF26.2 and R3.5) (Table AQ 1-3). Two-

dimensional modeling was selected in the peaking reach and at the FYLF breeding locations to provide better spatial representation of habitat. The 2D modeling study sites in the peaking reach were selected to include representative habitat for aquatic species (fish, benthic macroinvertebrate, amphibian, and riparian resources) that were most sensitive to flow fluctuations. For example, study sites were selected that included potential fish stranding locations and amphibian breeding habitat.

The 2D modeling study sites in the peaking reach were selected to include the same proportion of mesohabitats that were present in the entire peaking reach. Each 2D modeling study site was approximately 0.75 miles long and included 10–11 mesohabitat types.

#### **5.4.1 Hydrodynamics Modeling**

PHABSIM 1D hydraulics modeling procedures (Milhous et al. 1989; Waddle 2001; TRPA 2009) were used for modeling depths and velocities at the cross-sections in the 1D study sites over a range of flows. River2D, a two-dimensional hydrodynamics model (Steffler and Blackburn 2001), was used to model depth and velocity at the 2D study sites. Channel topography and calibration data (water surface elevations and velocity measurements) were collected so that the 1D and 2D models could simulate a wide range of discharges appropriate to the hydrology of each reach (Table AQ 1-5). The calibration flows were selected in collaboration with the Aquatic TWG. All instream flow data and hydrodynamics modeling results were reviewed with Aquatic TWG representatives familiar with hydrodynamics modeling for their concurrence.

#### **Field Data Collected**

The field data that were collected for the instream flow modeling (1D or 2D modeling) included channel topography, water surface elevations, velocities, and substrate/vegetation.

##### Channel Topography

Channel topography, either in the form of cross-sections for 1D modeling or three-dimensional topography for the 2D modeling was collected at each study site. Cross-sections were marked with semi-permanent headpins and Global Positioning System (GPS) locations were recorded for the study sites (Table AQ 1-3). Cross-sections were surveyed with a standard survey level or laser level. Three-dimensional topography was collected with a combination of low elevation photogrammetry (out-of-bank topography), single beam or multi-beam sonar coupled with a survey grade GPS (in-water topography), and/or wading/walking measurements using a survey grade GPS.

##### Water Surface Elevations

For both 1D and 2D water surface modeling calibration, empirical water surface elevations were measured (surveyed) during at least three calibration discharges (low, medium, and high flow). The water surface elevations were measured at each cross-section (1D) or along the length of each 2D study site. These measurements provided

calibration data for the hydrodynamics models over the range of flows of interest (Table AQ 1-6). The target calibration flows were determined in collaboration with the Aquatic TWG and with input from the Recreation TWG (Table AQ 1-5).

Table AQ 1-5 shows the actual discharges measured. The actual and target discharges were generally very similar. In a few cases, large deviations that occurred between the measured and target discharges were anticipated in the AQ 1 – TSP. These included lower actual high flow calibration discharges than targeted in the Rubicon River because of flow release limitations from existing infrastructure at Hell Hole Dam and lower high flow calibration discharges in the Middle Fork American River below Middle Fork Interbay than targeted due to safety considerations.

### Velocity

Consistent with direction from the Aquatic TWG, empirical velocity data for velocity modeling were collected across each 1D cross-section (e.g., 15–20 locations) at the middle calibration discharge. The middle calibration discharge was generally 2–5<sup>+</sup> times greater than the current minimum instream flow requirements in each of the reaches. At several 2D study sites, validation velocities were collected at the high or middle calibration discharge. Table AQ 1-5 shows the target and measured calibration discharges for the velocity measurements. All velocities were collected with calibrated velocity meters. Discharges were measured using standard gaging techniques (Rantz 1982) and/or an acoustic doppler current profiler (ADCP).

### Substrate

Substrate data were collected across each cross-section at the 1D study sites or in polygons for the 2D study sites. The substrate data were collected using the substrate categories developed in consultation with the Aquatic TWG for the HSC criteria:

#### **MFP Field Collection Substrate Categories**

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##### **Organic debris, permanent vegetation**

Clay, silt	<0.1 in	Small cobble	3–6 in
Sand	0.1–0.2 in	Medium cobble	6–9 in
Small gravel	0.2–1.0 in	Large Cobble	9–12 in
Medium gravel	1–2 in	Boulder	>12.0 in
Large gravel	2–3 in	Bedrock	

Substrate height and vegetation polygons for hydrodynamics roughness were also mapped as part of the data collection at 2D modeling study sites. Vegetation roughness was based on the vegetation form (tree, shrub, herbaceous, grasses, or combination), size of trees and shrubs, and density (including dense blackberry bushes or California wild grape vines).

## 1D Study Site Hydraulics

For the 1D study sites, stage-discharge regressions, Manning's equation, and step-backwater models (WSP) were used to model water surface elevations and the IFG4 model was used for velocity modeling. In addition, the Average Parameter model was used to model wetted perimeter (Waddle 2001).

### Water Surface Elevation Modeling

Manning's equation, calibrated to measured stage-discharge data sets, was the preferred approach to model water surface elevations at all mesohabitat types except pools. In some instances where Manning's equation did not perform particularly well, a stage-discharge regression was used instead. Typically, pool water surface elevations were modeled with stage-discharge regressions. For the Rubicon River, however, WSP was used to model water surface elevations in pool mesohabitats, because high flow data were not available for creating robust stage-discharge regressions.

### Velocity Modeling

The IFG4 program was used to model velocity at individual cells across cross-sections. When using the model, professional judgment is often needed to modify the IFG4 Manning's N values at some cells to prevent unrealistic velocities on the edges of the channel (or at point locations in the channel) at high discharges. Specifically, professional judgment was used to cap the Manning's N values along each cross-section at an N minimum and N maximum value that corresponded to the 95% and 5% exceedance values of Manning's N values calculated at the site. Also, the Manning's N values for edge velocity cells that had very large, very small, or negative velocities were modified by using either an appropriate adjacent Manning's N value or using the Manning's N minimum or maximum values.

Negative velocities were measured at several of the cross-sections at each study site as a result of complicated velocity patterns present in pools, near channel margins, or behind large boulders. 1D velocity modeling (IFG4) is not well suited to modeling these types of velocity patterns. To determine how sensitive the final habitat results were to the negative velocity patterns/velocity modeling results, a sensitivity analysis was performed. Six study sites that contained multiple cross-sections with negative patterns were selected for the sensitivity analysis. For the sensitivity analysis, all negative calibration velocities were changed to positive velocities within the hydraulic models and the habitat results with and without negative velocities were compared. Negative velocities were removed in the IFG4 model by setting the negative Manning's N values at the negative velocity locations to positive N values. The hydraulics models were then run over the entire range of simulation flows. Habitat versus flow relationships for each species and life stage were then compared.

### Wetted Perimeter Modeling

The Average Parameter model was used to estimate wetted perimeter (width of channel bed wetted) over the range of discharges modeled. Wetted perimeter was modeled for each 1D cross-section at the study sites.

### **2D Study Site Hydrodynamics**

To model hydrodynamics at the 2D study sites, a stage-discharge regression was developed at the downstream boundary of each site. The regressions were used for the downstream boundary condition for the River2D models. At each site, the water surface elevations for the model were calibrated by globally adjusting the substrate/vegetation polygon roughness values at the site until the modeled water surface elevations matched the measured water surface elevation-discharge data sets. Validation velocity data sets were used to confirm the veracity of the velocity modeling results for the 2D models. Depth, velocity, and substrate output for each modeled discharge at each study site was used for inputs to the habitat modeling. Wetted bed area versus discharge was also output for each study site (i.e., similar to 1D wetted perimeter).

### **Special Purpose Modeling**

Special purpose modeling was conducted for analyses required in the AQ 10 – TSP and AQ 12 – TSP, including:

- AQ 10 – TSP: Stage-discharge relationships were developed up to the two-year recurrence interval on transects where riparian data were collected (Table AQ 1-3). The stage-discharge relationships were used to evaluate riparian resources within the study sites in relation to inundation timing and frequency. The analyses for riparian resources are described in the AQ 10 – TSR (PCWA 2009b).
- AQ 12 – TSP: Stage-discharge relationships were developed at two comparison river sites where FYLF populations and breeding occurs (NF35.7 and NFMF2.3) to potentially assist in interpreting hydrologic factors related to FYLF abundance (Table AQ 1-3).

### **5.4.2 Habitat Modeling**

Habitat modeling for the 1D and 2D sites was consistent with the Instream Flow Incremental Methodology (IFIM) (Bovee et al. 1998). The general approach was to: (1) develop habitat area versus flow relationships; (2) conduct a habitat time series analysis (1D and 2D sites); (3) complete an effective habitat analysis (peaking reach 2D sites); and (4) develop and evaluate validation data for large pool habitat use by fish and habitat use by FYLF (tadpoles and egg masses) at the 2D habitat modeling sites.

## **Habitat Area Versus Flow Relationships**

Habitat area versus flow relationships were developed over a wide range of flows (approximately the 90% exceedance unimpaired flow or greater) (Table AQ 1-6). Habitat modeling methods appropriate for each species/life stage or guild were developed in consultation with the Aquatic TWG.

Standard weighted usable area (WUA) versus flow relationships were developed for all species and life stages with univariate HSC. WUA was derived by using a composite suitability index (CSI) multiplied by each cell area of potential habitat. The CSI was calculated by multiplying the individual HSC suitability for depth, velocity, and/or substrate together (Waddle 2001). Substrate suitability was used only for rainbow trout spawning, FYLF breeding, and FYLF tadpoles. The results for each mesohabitat type at each study site were weighted to represent the proportion of mesohabitat types in the reach. The weighting factors for 1D and 2D study sites are provided in Table AQ 1-4. These weighting factors were developed in conjunction with the instream flow study site selection/mesohabitat mapping process (PCWA 2007b). Mesohabitat unit data for the twelve instream flows sites are presented in Appendix D.

Spatial niche habitat versus flow relationships were developed for all species/life stages. This was done by quantifying the amount of habitat in each depth and velocity niche at each flow. Wetted perimeter versus discharge relationships for each study site were also plotted.

## **Habitat Time Series**

The habitat versus flow relationships were combined with hydrology (impaired and unimpaired daily mean flows) over the period of record (1975 to 2007) to create a habitat time series for rainbow trout (spawning, adult, juvenile, fry), hardhead/Sacramento pikeminnow (juvenile and adult), and FYLF (breeding and tadpoles) (Map AQ 1-2 and Table AQ 1-7). Habitat time series plots and habitat exceedance plots were used to compare the amount of habitat during different biologically significant time periods (reproduction, rearing) and identify potential habitat limiting factors and time periods. For this analysis, the spawning time period for rainbow trout was March to May and the breeding period for FYLF was May 10–June 15 (Figure AQ 1-2). In addition, three different, but overlapping rearing periods for rainbow trout (adult and juvenile), hardhead/Sacramento pikeminnow (adult and juvenile), and FYLF tadpoles were used: June to October (summer/fall growing period), July to September (low flow/high temperature period), and September to October (base flow season). For rainbow trout fry, June to August was used for the rearing period. Habitat exceedance plots were created for each species and life stage for all years combined and for each of five water year types separately (wet, above normal, below normal, dry, and critically dry). The five year types were developed to separate the modeling into years of comparable water availability and are based on inflow to Folsom Reservoir, with extreme critical and critically dry years combined into a single critically dry year category as follows:

Water Year Types	Folsom Reservoir Inflow (ac/ft)
Critically Dry	<600,000
Dry	600,000—<1,000,000
Below Normal	1,000,000—<1,500,000
Above Normal	1,500,000—<2,400,000
Wet	2,400,000—<3,400,000
	≥3,400,000

### Effective Habitat Analysis

At the 2D study sites in the peaking reach (Table AQ 1-1), effective trout spawning, FYLF breeding and tadpole rearing, and macroinvertebrate food production habitat was calculated to characterize habitat for non-mobile or low mobility species/lifestages in a fluctuating flow regime. Effective habitat is the channel bed habitat that remains continuously suitable over time given the range of fluctuating flows that occur in that time period. An effective habitat algorithm was used to track effective habitat with changing flows and at the end of the particular flow change time period or season that was analyzed, only the habitat continuously suitable was counted as habitat. At the FYLF 2D study sites in the bypass reaches (also the 2D sites in the peaking reach) a simplified matrix effective habitat analysis was also completed for a fix set of flow range changes. In the bypass flow reaches this matrix approach has application to quantifying the effect of potential future operational flow changes of various magnitudes (e.g., boating flows) on FYLF habitat. The two separate analyses completed, (1) matrix effective habitat and (2) time series effective habitat, are described below:

In the first analysis, a matrix of effective habitat versus a fixed set of flow changes was generated for each study site. The matrix and associated figures provide a method to select a flow fluctuation range (e.g., 1000 to 200 cfs) and determine the resulting effective habitat. The total range of flows in the matrices was approximately 60 to 2500 cfs for the study sites in the peaking reach (MF14.1 and MF4.8) and approximately 5 to 930 cfs for the 2D sites in the bypass reaches (MF26.2 and R3.5). Effective habitat was calculated using the HSC for each life-stage and the substrate and the hydrodynamic model results in the 2D study sites. For rainbow trout spawning, two different analyses were made. One using the spawning HSC and one based on incubation criteria. The incubation analysis began with the spawning HSC (initial habitat area based on HSC), but then used simple incubation criteria to estimate the effective incubation habitat with changes in flow. Incubation criteria were approximated as a minimum depth to keep redds watered (0.2 ft or 0.06 m) (Gard 2006) and a nominal minimum water velocity at the redds (0.1 ft/sec or 0.03 m/s).

In the second analysis, an impaired and unimpaired time series analysis of effective habitat in the peaking reach (MF14.1 and MF4.8) was developed. The time series were based on the 15-minute impaired and the daily average unimpaired flows at the Oxbow

gage (1988–1995, 1997–2007 water years) (note 15-minute data was not available for 1996). Effective habitat time series were modeled for trout spawning/incubation, FYLF breeding, and macroinvertebrate food production. Effective time series habitat for FYLF tadpole habitat was not modeled because FYLF breeding habitat appeared to be a limiting factor and because a rational effective tadpole habitat analysis requires a suitable daily/hourly movement distance for tadpoles and an associated habitat tracking algorithm that incorporates the mobility of tadpoles, which is currently under development (Lind and Yarnell, personal communication, November, 2009). The details of each of the effective time series analyses are described below.

### Rainbow Trout Spawning/ Incubation

The effective habitat analysis for rainbow trout spawning used the HSC and the 2D hydrodynamic and substrate data to track habitat suitability over eight one-week spawning periods and corresponding 630 degree-day<sup>2</sup> (Celsius) incubation time periods (Benke 1992):

<b>Start Spawn Period</b>	<b>End Spawn Period</b>	<b>End Incubation (630 degree days)</b>
3/1/07	3/8/07	5/10/07
3/9/07	3/16/07	5/15/07
3/17/07	3/24/07	5/20/07
3/25/07	4/1/07	5/25/07
4/2/07	4/9/07	5/30/07
4/10/07	4/17/07	6/4/07
4/18/07	4/25/07	6/10/07
4/26/07	5/3/07	6/15/07

Consecutive one-week spawning periods were used for the rainbow trout effective spawning habitat analysis in recognition that the total time required for redd construction by individual salmonid females and subsequent spawning of a female/male pair takes a few days to less than a week (e.g., Greeley 1932; Estieve 2005) and that effective spawning habitat needs to occur only during this short time period (less than a week). Following each effective spawning period, effective incubation was tracked until 630 degree-days (Celsius) occurred for emergence (Benke 1992). Degree-days were calculated using the average daily water temperatures in the middle of the peaking reach (Figure AQ 1-3). In addition, the spawning habitat was “monitored” through the time series for scour of the gravels (e.g., during high flows). Scour was assumed to begin if the dimensionless critical shear stress (Shields Parameter) was greater than 0.4

<sup>2</sup> Degree days are the sum of average daily temperatures above freezing (0°C). Degree-days represent the developmental time for egg incubation and alevin emergence. Approximately 630 degree-days are required for rainbow trout incubation/emergence (Behnke, 1992).

for a 2.5 in (64 mm) gravel particle (May et al. 2009) (Section 5.6 Evaluation of Sediment Transport Conditions).

Based on empirically collected emergence data and the calculated incubation/emergence duration, spawning was assumed to occur during the period from March through early May with emergence occurring by mid-June. In 2009, emergence sampling in the headwater streams that are significantly colder than the peaking reach (Duncan, North Fork Long Canyon, South Fork Long Canyon) (Figure AQ 1-3), showed that spawning likely occurred from about the last half of April through mid-May (PCWA AQ 7 – Entrainment Report, In Prep.). In the peaking reach, warmer water temperatures would result in earlier spawning<sup>3</sup> than was estimated for the headwater streams. In 2007, rainbow trout fry were observed in the Middle Fork American River and Rubicon River upstream of Ralston Afterbay in early June and in Gas Canyon Creek (tributary to the peaking reach) in early May. It is estimated that spawning occurred in mid-March in Gas Canyon Creek. These data, in combination with the 2009 data, suggest that a March through early May spawning period and subsequent incubation and emergence by mid-June is a reasonable assumption (PCWA 2009a).

#### FYLF Breeding

The effective habitat analysis for FYLF breeding tracked effective habitat over three approximately 10–11 day periods (roughly the time required for eggs to hatch – see PCWA 2008b) from May 10 to June 15. Data collected in the MFP streams in 2007 (PCWA 2008b) and during 2009 as part of the FYLF validation data collection showed that egg masses have been laid as early as May 10 and have been observed intact (unhatched) as late as June 15.

#### Benthic Invertebrate Food Production

Effective habitat for benthic invertebrate food production was assumed to be the daily time series portion of the riverbed that remained wetted (including during the annual maintenance outage) with a depth greater than 0.25 feet and less than or equal to 4 feet and velocity less than 4 ft/sec (Section 5.2.4). A conservative aquatic invertebrate recolonization rate was used during the time periods when flows were increasing or decreasing to account for recolonization of substrate when suitable depths and velocities were present. If a previously unsuitable cell for macroinvertebrates had been wetted over the previous 45 days or more it was assumed to have a fully developed periphyton community and assumed to be readily colonizable (Perry and Perry 1986). Colonization of this type of substrate is linear and requires about 10 days to become complete (e.g., Waters 1964). Therefore, partial suitability (e.g., 1/10th per day (0.1 per day) was accounted for these cells during recolonization if depth and velocity were in

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<sup>3</sup> Spawning in rainbow trout is primarily controlled by genetics and photoperiod (Purdon 1993), but is also affected by water temperature (Morrison and Smith 1986), with colder temperatures delaying spawning timing and warmer temperatures causing earlier spawning timing.

the suitable range. If a previously unsuitable cell had been dry for more than a complete day and was just newly wetted, complete re-colonization was assumed to take 45 days (or more) (Gore 1982, Townsend and Hildrew 1976; Gersich and Brusven 1983). The linear rate of increase was then 1/45th of the cell's increased suitability (i.e., approximately 45 days are required to reach full suitability). Again partial suitability was accounted for these cells during recolonization if depth and velocity were in the suitable range (1/45th or 0.022 per day). A time series of impaired and unimpaired effective food production habitat was plotted for the 1988–2007 time period.

## **Habitat Modeling Validation**

### Large Pool Habitat Use

As part of habitat modeling, a small pilot study was conducted on fish habitat use in large slow-water pools. This was done to assist in the development of a logical habitat modeling approach for large pools. Three large pools in the Rubicon River (located from Ralston Afterbay to approximately two miles upstream) and four large pools in the Middle Fork American River (located from Ralston Afterbay to approximately 0.5 miles upstream; Appendix E, Map E-1) were snorkeled in the morning and afternoon to observe the spatial location and behavior (e.g., feeding or resting) of fish. Water velocity and depth were also measured at the locations where fish were observed and compared to the appropriate HSC.

### Foothill Yellow-Legged Frog Validation Data

FYLF egg mass and tadpole locations at known flows were surveyed at the 2D modeling sites above Ralston Afterbay (MF26.2 and R3.5) to provide validation data for the FYLF habitat modeling. Depth, velocity, water temperature, and substrate for attachment were recorded at the observed egg mass locations. Depth, velocity, and perching substrate were recorded for tadpole locations.

## **5.5 ADDITIONAL METHODS SPECIFIC TO THE PEAKING REACH**

Additional study elements specific to the peaking reach were: (1) summarize the peaking reach hydrology; (2) install stage monitors and analyze peaking pulse flow travel times; and (3) conduct a one-time empirical stranding evaluation.

### **5.5.1 Peaking Reach Hydrology**

Hydrology in the peaking reach was characterized using the Middle Fork American River Gage Below Oxbow Powerhouse (Oxbow gage). The U.S. Geological Survey refers to this gage as Middle Fork American River Nr. Foresthill, CA (Gage No. 11433300) and the California Data Exchange Center (CDEC) refers this gage as Middle Fork American River Nr. Oxbow PH (OXB). Five example water years were analyzed: 2006-wet, 1999-above normal, 2003-below normal, 2001-dry, and 1988-critically dry. Unimpaired and impaired mean daily flow data for the peaking reach from water year 1975 through 2007 were developed during the relicensing process by the Operations Model Technical Team. Fifteen-minute impaired flow data were available at the Oxbow

gage from 1988 through 2007 (excluding 1996). The following comparisons and characterizations of hydrology were developed:

- The 15-minute impaired flow data were plotted and compared with the unimpaired flow data (daily average) for the example water years.
- The impaired 15-minute flows were plotted for short time periods (April, July, and August/September) to show the shape and magnitude of the daily peaking events and the progression of peaking pattern from high spring flows to fall base flows.
- Daily peaking events were plotted on top of each other during the late spring to early fall months (April to September) when peaking was most prominent in the hydrology. This was done so the ensemble pattern and timing of the peaking events could be visualized.
- An idealized characterization of peaking events (May to September) was developed to show the general daily pattern of peaking events.
- Mean daily impaired and unimpaired flow data at the top, middle, and bottom of the peaking reach were developed to illustrate the effects of accretion on the hydrology of the reach (e.g., accretion from the North Fork of the Middle Fork American River, the North Fork American River, and other tributaries).

### **5.5.2 Stage Monitoring and Flow Travel Times**

Information developed from stage monitoring in the peaking reach was used to calculate water travel time along the length of the reach over a range of flows. The methods used to develop water travel time estimates are provided below.

Five Solinst Levellogger Gold Model 3001 pressure transducers were installed at various locations throughout the reach during the summers of 2007 and 2008 (Figure AQ 1-4). The pressure transducers were installed downstream of Oxbow Powerhouse, at the following locations:

- Above the Middle Fork American River Gage below Oxbow Powerhouse RM 23.75 (0.6 miles downstream of Oxbow Powerhouse);
- Cache Rock RM 19.3 (5.05 miles downstream of Oxbow Powerhouse);
- Otter Creek RM 14.5 (9.85 miles downstream of Oxbow Powerhouse);
- Drivers Flat RM 9.5 (14.85 miles downstream of Oxbow Powerhouse); and
- Below Mammoth Bar RM 1.4 (22.95 miles downstream of Oxbow Powerhouse).

Two barometric pressure loggers (Solinst Barologger Gold Model 3001) were installed, one each at the top (near Oxbow gage) of the reach and at the lower end of the reach

(near North Fork American River confluence). The final stage readings from the pressure transducers were corrected for barometric pressure by linearly interpolating barometric pressure along the length of the reach.

A linear regression of the travel velocity of peaking events (miles per hour) versus base flow in the river prior to peaking events was developed. The travel velocity of each peaking event in the regression was determined based on the time required for the front of a peaking discharge pulse to reach the stage monitoring stations. The front of the pulse was well defined and of similar shape along the length of the reach.

### **5.5.3 Empirical Stranding Evaluation**

Two empirical stranding evaluations were conducted in the peaking reach. One was a one-time evaluation of the effects of hydropower peaking flow fluctuations on standing of fish and the other was a dewatering evaluation of a high flow cut-off channel at Gray Eagle Bar during the low flow outage/powerhouse maintenance period.

The one-time empirical stranding evaluation of peaking flow fluctuations in the peaking reach was conducted on June 5, 2008 to characterize potential stranding and/or trapping of aquatic species in sensitive habitats. Fish that were stranded on gravel bars or trapped in off-channel habitat were quantified. Trapping of fish was evaluated as either permanent (likely to result in mortality) or temporary (unlikely to cause mortality). Temporary trapping was identified when, during the low flow portion of the peaking cycle, live fish were observed in permanently watered habitats disconnected from the main channel, but in habitat that would become reconnected (in less than 24 hours) during the high flow portion of the peaking cycle. The potential for predation of temporarily trapped fish (e.g., birds) was not specifically assessed. The surveys were concentrated in backwater and side channels areas and along river margins. Two general locations were selected for surveys that represented areas with a high potential for stranding. The two general locations surveyed were: (1) at Gray Eagle (RM 22.3–22.8) and American bars (RM 23.1–23.8); and (2) within the instream flow site at Fords Bar (RM 13.6–14.5). At both sites, over 0.9 miles (1.4 km) of river was surveyed on foot at low flow (98–246 cfs) immediately following the completion of a daily peaking event (ca. 900 cfs) (Appendix F, Map F-1 and F-2). Daily peaking had been occurring in the peaking reach since late February (Appendix F, Figure F-1).

Surveys consisted of walking the river margin and visually searching for stranded or trapped fish, as well as identifying areas that had the potential to strand or trap aquatic life. Using aerial photographs, surveyors delineated potential stranding/trapping areas and recorded any dead aquatic life stranded on the dewatered channel bed or live aquatic life trapped (isolated) in pools separated from the main channel.

The second study, Gray Eagle Bar high flow cut-off channel evaluation, was conducted along a small high flow side channel (868 feet in length) at Gray Eagle Bar (RM 22.3–22.4) (Appendix F, Map F-3). Water flows into the side channel when discharge in the main channel is greater than about 150 cfs. To quantify the main channel discharge versus side channel flow relationship, discharge and wetted habitat in the side channel

were quantified over a range of flows. The discharge in the side channel was measured with a calibrated Marsh McBirney velocity meter using standard gaging methods (Rantz 1982). Habitat within the side channel was also mapped.

## **5.6 EVALUATION OF SEDIMENT TRANSPORT CONDITIONS**

Special purpose modeling was conducted for analyses required in the AQ 9 – TSP (PCWA 2007a). The flow required to remove fines from gravel interstices and loosen gravel structure without excessive downstream displacement/loss of gravel was determined by calculating the discharge required to initiate gravel transport at selected cross-sections in the instream flow study sites (Appendix G, Table G-1). Initiation of motion was determined by using the hydraulic model estimates of bed shear stress ( $\tau$ ) and by using Shield's criterion that defines the critical shear stress ( $\tau_{ci}^*$ ) at which incipient motion occurs. The bed shear stress obtained from the hydraulic models and the Shield's criterion were used to determine the amount of gravel mobilized over a range of flows (see the flow range in Table AQ 1-6). Wilcock's (1996) method was used to calculate bed shear stress and the Wilcock and Crowe (2003) method was used to calculate the critical shear stress needed to initiate sediment movement for mixed-size sediment. Wilcock and Crowe (2003) was chosen since it considers how relative particle size variation within the sediment mixture and sand content influence sediment mobility. Calculation of bed shear stress and initiation of motion are described in more detail in Appendix G.

### **5.6.1 Initiation of Motion at the Study Sites**

Bulk sediment samples were collected in the field on transects where the dominant particle size fraction was gravel and determined suitable for use as spawning gravel (Appendix G, Table G-1). Both the surface (defined as a depth equal to the maximum particle size) and sub-surface layers were sampled and analyzed separately. The bulk samples were dried, sieved, and weighed in a laboratory to determine the percentages and sizes of sand and gravel in the sample. The median ( $D_{50}$ ) particle size was calculated for the surface bulk sample and the  $\tau_c^*$  needed to initiate motion of the  $D_{50}$  particle was calculated using the Wilcock and Crowe (2003) method outline above.

At each study transect, hydraulic modeling was performed for 35 different discharges ranging from low to high flows to predict flow depths and velocities continuously across the entire length of the study transects at multiple cells (i.e., stations) typically less than a few feet wide. The local grain shear stress using the  $D_{84}$  of the bulk sample and the Wilcock (1996) equation presented above was calculated at each modeling cell using the local flow depth and velocity values (see Appendix G for a detailed description of local shear stress calculation). Therefore, rather than calculating an average boundary shear stress using the average hydraulics of the entire cross-section, a shear stress value was calculated at multiple stations across each transect to obtain more accurate results. Based on the  $\tau_c^*$  value determined from each transects representative bulk sediment sample, the critical grain diameter ( $D_c$ ), or largest particle that could be mobilized by a given flow magnitude, was calculated. Graphic plots were made that compare the discharge on the x-axis against  $D_c$  on the y-axis. From these plots the

amount of flow needed to mobilize the  $D_{50}$  of the spawning size gravel was determined by identifying where the predicted critical grain diameter curves intersect the median grain diameter.

The goal of the analysis was to determine at what discharge initiation of motion (entrainment) of spawning gravels occurred. Because entrainment of gravel can be a continuous process with increasing discharge, that is, as discharge increases more and more gravel locations in the channel or across a cross-section become inundated and mobile, some reasonable threshold of gravel entrainment was needed to identify when “initiation of gravel movement” occurred. For this analysis, the discharge at which initiation of motion occurred for 25% of the gravel within the portion of the channel wetted at the high flow calibration discharge was used as the “initiation of motion” threshold. Table AQ 1-5 shows the target high flow calibration discharge at each site.

Approximately 37% of the initiation of motion cross-sections (1D study sites) were located in the tailout areas of pool mesohabitat units. The remaining cross-sections were located in other types of habitats (e.g., runs, low gradient riffles, high gradient riffles, pools) or complicated boulder channels. Some of these other habitat types were not as “well behaved” for the hydraulic and sediment transport modeling (e.g., uncertain hydraulics or exhibited extremely high flows for initiation of motion). Problematic sites were not included in the analysis.

A summary of the flow required to initiate motion of gravel sized particles, 0.3–2.5 inches (8–64 mm), and comparison of these flows with the hydrology frequency of occurrence for 1.5, 2.0, and 5.0 recurrence intervals was developed for the study sites.

## **5.7 ADDITIONAL STUDY ELEMENTS**

Two additional study elements (algae and Horseshoe Bar channel inundation) requested by stakeholders were included in the instream flow study as described below.

### **5.7.1 Algae**

PCWA collected algae samples to identify if *Didymosphenia geminata*, a nuisance algae species, was present in the study area and to document the abundance of algae. Algae samples were collected at each instream flow study site, at two comparison stream study sites (North Fork American River, South Fork Long Canyon Creek above the diversion), and at a study site at the top of the peaking reach (Appendix H, Table H-1).

Algae was assessed during late summer by using photographs and the field-based rapid periphyton survey protocol detailed in the Environmental Protection Agencies’ Rapid Bioassessment Protocol For Use in Streams and Wadeable Rivers (Barbour et al. 1999). Algae samples were a composite of all algae species observed at the site and were preserved in a dilution of Lugol’s iodine (Iodine-Potassium Iodide). Taxonomic identification of *Didymosphenia geminata* was conducted by Rhithron Associates, Inc; Missoula, MT. In addition, several supplemental dry algae samples (from six sites) were sent to Sarah Spaulding (US Geological Survey Fort Collins Science Center; Fort Collins, CO) for identification of *Didymosphenia geminata*.

To assess algae abundance, three transects across representative riffles were established. On each transect, three stratified random locations were selected (i.e., river right, center, and left). At these sites a viewing bucket was used to quantitatively characterize the algae cover. The viewing bucket was a 5 gallon bucket with a transparent bottom. A 49-dot grid was delineated on the bottom of the bucket. When submerged, the number of dots that occurred over: (1) macroscopic filamentous algae (macroalgae); (2) diatoms and other microscopic algal accumulations (microalgae); or (3) bare substrate was recorded. Additionally, the percentage of the gridded area suitable for algae cover was recorded. Stable substrates (boulder, cobble, gravel) were recorded as suitable for algae growth, while unstable substrates (loose sand, organics) were recorded as unsuitable.

### **5.7.2 Horseshoe Bar Inundation**

Horseshoe Bar is an oxbow bend in the Middle Fork American River that is bypassed during low to moderately high flows by a tunnel (Tunnel Chute) constructed by miners in the late 1800s. The relationship between flow in the Middle Fork American River and the amount of flow entering the historic natural channel in the Horseshoe Bar area was characterized using a combination of Oxbow gage hourly readings, pressure transducer measurements near the entrance of the channel, visual observations, and a surveyed cross-section at the entrance to the channel (Map AQ 1-3). A regression of main channel flow versus water stage near the entrance to the channel was used to estimate the main channel flow required to inundate the channel in Horseshoe Bar.

## **6.0 RESULTS**

The following describes the results of the instream flow study including: (1) habitat suitability criteria (HSC); (2) hydrodynamics modeling; (3) habitat modeling; (4) additional peaking reach analyses; (5) evaluation of sediment transport conditions; and (6) additional study requests related to algae and Horseshoe Bar channel inundation.

### **6.1 HABITAT SUITABILITY CRITERIA (HSC)**

The following describes the HSC developed for the MFP in consultation with the Aquatic TWG.

#### **6.1.1 Rainbow Trout Adult and Juvenile HSC**

##### **Enveloped Habitat Use HSC**

The four primary rainbow trout data sets from Sierra Nevada streams were used to create enveloped habitat use HSC for small stream and large stream sized juvenile and adult rainbow trout. After comparing the HSC with the two “validation” data sets, however, the original HSC were slightly modified to envelop all of the habitat use data (including the validation data sets). Slight adjustments to the velocity and depth HSC were made. The final HSC for juvenile and adult fish in the small and large streams are shown in Appendix A, Figures A-4, A-5, A-6, and A-7 and they are compared with all six

habitat use data sets in Appendix A, Figures A-1 and A-2. The HSC are plotted with the original four data sets in Appendix A, Attachment A.

### **HSC Comparison with Adjusted Preference Data and Sensitivity Analysis**

The envelope HSC were generally consistent with the adjusted preference (U/A) calculations for the same data sets, which indicated limited habitat availability bias in the data sets (Appendix A, Attachment B). There were two exceptions, however, that were observed for adult fish: (1) two data sets indicated a preference by adult rainbow trout for deeper water than was utilized; and (2) one data set indicated a preference by adult rainbow trout for faster water than was utilized. As a result, two sensitivity analysis adult HSC were created to test the effect HSC with suitability for deeper water and for faster water would have on the habitat modeling results (see results in Section 6.3.1). The sensitivity analysis HSC are listed below:

- The sensitivity depth HSC for adult fish with increased suitability for deep water habitat are shown in Appendix A, Figures A-6 and A-7. The MFP enveloped habitat use HSC had a suitability value of 0.3 for adults on the deep water side of curve. The sensitivity depth HSC assumes unconstrained use of deep water and sets the deep water HSC values to 1.0. In the habitat data sets, limited habitat use occurred in deep water, but also deep water availability was low in the data sets. The sensitivity depth HSC can, therefore, be used to test the potential effect of deep water habitat use on habitat modeling results.
- The sensitivity velocity HSC for adult fish (increased suitability for fast water habitat) are shown in Appendix A, Figure A-6 and A-7. Two of the three adjusted preference data sets were consistent with the MFP enveloped velocity use HSC. The Stanislaus 2001 adjusted preference data set, however, suggested a slightly higher velocity HSC based on limited data. Therefore, a sensitivity adult velocity HSC was created for modeling that increased the maximum suitability (1.0) from a velocity of 1.2 ft/s to a velocity of 1.5 ft/s.

### **Comparison With Other Project HSC**

The MFP HSC developed for small stream size fish were compared to the small stream use data set from the South Fork American River (TRPA 2000) and the UARP small channel HSC (created from these data) in Appendix A, Figure A-3. The MFP HSC for small stream size fish match the adjusted preference data from the South Fork American River (TRPA 2000) and appear to remove some of the depth and velocity habitat availability bias present in both the small stream data set and the UARP small channel HSC. This comparison helped confirm that the MFP HSC for small streams were an appropriate representation of habitat use in small streams.

For comparison purposes, the small and large stream MFP enveloped habitat use HSC were plotted with the HSC used on other projects: Stanislaus Project HSC and the UARP HSC (Appendix A, Attachment C). The largest difference was between the MFP small stream sized fish HSC and the UARP small channel HSC (see above). In most

other cases, the MFP enveloped use HSC were intermediate between the Stanislaus Project and the UARP HSC.

### **6.1.2 Rainbow Trout Spawning and Fry, Hardhead, Sacramento Pikeminnow and Sacramento Sucker HSC**

Envelope HSC developed for rainbow trout spawning and rainbow trout fry (20–<50 mm), hardhead (juvenile and adult), Sacramento pikeminnow (juvenile and adult), and Sacramento sucker (juvenile and adults) are shown in Appendix B. Only the rainbow trout spawning and hardhead curves were used for primary species/life stage analyses (Table AQ 1-2). Hardhead and Sacramento pikeminnow depth and velocity suitability curves were the same. The MFP enveloped depth curve for rainbow trout spawning showed reduced spawning suitability at depths greater than 1.5 ft and no spawning suitability at depths greater than 3 ft. A sensitivity analysis HSC with the depth modified to remain suitable in deep water was created to test the effect of spawning depth on habitat modeling results.

To further investigate the spawning depth issue, a brief review of the data used to create the rainbow trout spawning HSC and related data regarding deep water spawning are provided. The rainbow trout spawning habitat HSC used to develop the MFP spawning HSC show that limited data exists to support extensive utilization of deep water for spawning by resident rainbow trout. Most spawning observations in the data sets occurred in shallow water. Appendix B, Table B-1 and Figure B-1 show the historical rainbow trout spawning HSC and the metadata that were used to create the MFP HSC. All of the HSC indicate spawning occurs in shallow water less than 3 feet deep except three of the HSC (Raleigh et al. 1984; Smith and Aceituno 1987; TRPA unpublished Roaring River data). The data sources for these three HSC were investigated and the following was found:

- Raleigh et al. (1984) set deep water as suitable (up to 8.2 feet) based on a paper by Hartman and Galbraith (1970) documenting the spawning of Gerrard stock rainbow trout in the Lardeau River at depths from 1.6 to 8.2 feet. These fish, however, are the largest trout in the world (e.g., consistently reaching 22 lbs <http://www.fwcp.ca/version2/forms/gerrard-rainbow>) and it is doubtful the data are directly applicable to smaller resident trout such as those in the MFP. Raleigh et al. (1984) also cited steelhead data from Orcutt et al. (1968) who reported steelhead redds in depths from 0.7 to greater than 5.0 feet. These steelhead are much larger fish than resident trout in the MFP instream flow study (Section 5.2.1) and there is no information in the report to identify the frequency of spawning in different depths; thus, the applicability of the Raleigh et al. (1984) HSC to the MFP instream flow study is uncertain.
- Smith and Aceituno (1987) found spawning in habitat at depths up to just over 3 feet, but presented a suggested set of HSC indicating high suitability (1.0) in deep water. Presumably this was based on the fact that limited deeper water habitat was available at their sampling locations and the suggested “deep water

spawning” HSC was a conservative approach to dealing with uncertainty regarding whether fish would spawn in deep water.

- TRPA unpublished Roaring River data, found most fish spawning in shallow water. The spawning data were collected by a comprehensive snorkel survey of an extended 1+mile reach. Most redds were in shallow water (including some in negative velocity between large rocks). There was some spawning in a deep plunge-pool gravel deposit directly underneath a waterfall somewhere in the four to seven foot depth range. Of the 73 redds observed, 68 were in water shallower than 3.1 feet (all but one fish was in water less than 5.1 feet). The depth suitability for these HSC was set to 1.0 for deeper water to include the possibility of spawning below this one waterfall (Appendix B, Figure B-1) (Thomas R. Payne, Pers. Comm. 2009).

### **6.1.3 Foothill Yellow-Legged Frog Breeding and Tadpole HSC**

Appendix C, Tables C-1 and C-2 and Figure C-1 show the combined habitat suitability criteria for egg masses and tadpoles, respectively. Highly suitable habitat was assigned a suitability value of 1.0, marginal habitat suitability was assigned a suitability value of 0.1, and non-suitable habitat was assigned a suitability of value of 0.0. Appendix C, Tables C-1 and C-2 also include a brief description of the biological justification for the HSC categories. Appendix C, Figures C-2 and C-3 show the histograms for the MFP data and the Lind and Yarnell (2007) data for egg masses and tadpoles, respectively. Color overlays on the figures identify the HSC generated from the All River data (MFP and Lind and Yarnell 2007 data) (top) and from the MFP data only (bottom). Generally, the results are similar, and the All River HSC were selected for use in the MFP. Appendix C, Tables C-3 to C-5 show the HSC for the All River data compared with each of the individual river data sets (MFP and rivers in Lind and Yarnell 2007). Appendix C, Attachment A summarizes some experimental data results regarding velocity effects on tadpoles (Kupferberg et al. 2007).

Based on initial validation modeling results, it was determined that using only the dominant substrate type in the 2D model substrate polygons was an inadequate method of representing FYLF breeding habitat. Some substrate polygons that were dominated by small substrates (e.g., gravel) contained a subdominant percent of suitable breeding substrate for egg mass attachment (cobble, boulder). It was determined by the Aquatic TWG, based on field data, that for a substrate polygon to represent breeding habitat (1.0 suitable) the polygon must have only 20% (or more) suitable egg attachment substrate (cobble and boulder) present. The data used to make this determination were the empirical validation data (Section 6.3.4, Foothill Yellow-Legged Frog Validation Data), data collected by Amy Lind (USFS) during her PhD dissertation study, and recent data collected by Amy Lind and Sarah Yarnell (UC Davis) as part of an ongoing FYLF study. Because the 20% criterion was based on data and professional judgment, the Aquatic TWG determined that if additional new data became available during the MFP relicensing process that better clarifies the egg attachment substrate subdominant percentage and the change would significantly affect the FYLF breeding modeling

results, at the request of the resource agencies represented in the Aquatic TWG, the suitability criteria may be modified and the FYLF breeding habitat modeling re-analyzed.

### **6.1.4 Guild/Spatial Niche Approach**

Each species/life stage was assigned to one or more of the depth and velocity guilds. Eleven primary niches were identified to incorporate all species and life stages of interest in the MFP (Figure AQ 1-5). Each niche and the corresponding life stage of its species members are listed in Table AQ 1-8.

## **6.2 HYDRODYNAMICS MODELING**

### **6.2.1 1D Study Sites**

The 1D study site hydrodynamics modeling (supported by the data collection efforts) was successful at simulating depth and velocity at the cross-sections in the study sites over the range of discharges identified in Table AQ 1-6. The following describes the results of the data collections and modeling efforts.

#### **Channel Topography and Substrate**

Channel topography, measured velocities, and substrate measurements collected as part of the instream flow study are provided in Appendix I for each study site and for each cross-section.

#### **Water Surface Elevation Modeling**

Water surface elevation modeling was successfully completed at all study sites over the range of modeling flows (Table AQ 1-6 and Appendix J). Two modeling challenges were encountered, including stepped water surface elevations at some cross-sections and limited availability of high calibration flows in the Rubicon River. These are discussed below:

- Several study cross-sections had water surface elevations across the cross-sections that were higher in one portion of the channel and lower in another portion of the channel (Table AQ 1-9 and Figure AQ 1-6). In each case, the two different sides of the channel had similar shaped stage-discharge relationships except that one side was elevated above the other. Because the 1D hydraulics models do not readily model two separate stage relationships at a cross-section, a method was used where the topography in the portion of the channel with the high water surface elevation was shifted down (Figure AQ 1-6) until the water surface elevations on both sides matched. After this shift was completed, the hydraulics models were run. This method was successful in matching the observed water surface elevation behavior over the range of flows measured.
- In the Rubicon River, the highest flow release possible from Hell Hole Dam was not much greater than the medium calibration flow release (Tables AQ 1-5 and 1-6). To compensate for the relatively low maximum flow available for water

surface model calibration, all sites on the Rubicon River were modeled with either Manning's equation or a step-backwater model (WSP). These water surface models take into account the shape of the channel and typically provide the best extrapolation potential to flows greater than the maximum measured discharge.

### **Velocity Modeling**

Velocity modeling was based on measured velocity data collected at discharges approximately 2 to 5+ times greater than the existing minimum flows for each stream/river associated with the MFP (Tables AQ 1-5 and 1-6). This approach provided a good method for modeling velocity both below and above the existing minimum flows.

As discussed in Section 5.4.1 1D Study Site Hydraulics, negative velocity patterns occurred at some sites with complicated flow patterns and a sensitivity analysis was conducted with and without the negative velocity patterns at six study sites. At all of these study sites, the sensitivity analysis indicated that the final habitat modeling results were insensitive to the negative velocity patterns in the data sets (Appendix J).

For the final velocity modeling, the study sites were modeled with only minor adjustments to the measured calibration velocities. The Manning's N (roughness) values on the margins of the channels were modified where extremely low or negative velocities occurred. In addition, N maximum and N minimum values were used to facilitate velocity modeling at high discharges at each study site as discussed in the methods section (Section 5.4.1 1D Study Site Hydraulics). However, the negative velocity sensitivity analysis above indicates that these minor adjustments to velocity modeling were likely unnecessary and/or likely have little effect on the final habitat modeling results.

### **6.2.2 2D Study Sites**

The 2D hydrodynamics modeling successfully simulated depths and velocities at the study sites over the range of discharges identified in Table AQ 1-6. The following describes the results of the data collection and modeling efforts for the 2D modeling sites (MF4.8, MF14.1, MF26.2 upper and lower, and R3.5 upper and lower).

### **Channel Topography and Substrate**

Color contour maps of the channel topography at each of the 2D study sites are provided in Appendix K. Substrate and vegetation maps are also provided in Appendix K. The substrate maps include: (1) the original data collection substrate polygons coded by percentage of each substrate category; and (2) substrate maps recoded to match the HSC substrate modeling codes for rainbow trout spawning, FYLF egg masses, and for FYLF tadpoles. In addition, at the two study sites in the peaking reach (MF4.8 and MF14.1), maps of riparian vegetation for the AQ 10 – TSP (PCWA 2009b) are provided.

## **Water Surface Elevation Modeling**

The empirical stage-discharge regressions created near the downstream boundary of each of the 2D study sites to provide boundary conditions for the 2D modeling are shown in Appendix L.

At each of the study sites, the 2D models accurately calibrated to the measured water surface elevations. Calibration of substrate roughness height, which determines the accuracy of the modeled water surface elevations, was accomplished by globally scaling the roughness height in the substrate polygons so that modeled water surface elevations matched measured water surface elevations. The calibration results for the three calibration discharges (low, mid, and high discharge) at all of the study sites are shown in Table L-1 (Appendix L). The average error (modeled minus measured water surface elevations) ranged from -0.1 to 0.06 ft and the root mean square error averaged 0.10 ft and ranged from 0.04 to 0.15 ft.

Powerpoint files with images of water depth at each site for each of the modeled flows are provided in Appendix L, Attachment A. These can be run similar to a movie file to show the change in inundation/water depth at the study sites as a function of discharge.

## **Velocity Modeling**

Modeled velocity at each of the study sites for each of the modeled flows is provided in Appendix L, Attachment A (Powerpoint files).

Measured velocities showed that the 2D model velocities and velocity patterns were accurate (Figures L-5 to L-11, Appendix L). At the MF4.8, MF14.1, upper R3.5, and lower MF26.2 study sites, relatively high quality mean column velocity validation data (i.e., accurately located spatially in the study sites with accurate mean column velocity measurements) were collected across several cross-sections and/or in multiple partial cross-sections to test the mean column velocity accuracy of the 2D models. In addition, three discharge measurements taken at different locations in the MF14.1 study site that could be approximately located within the study site were used as approximate validation data. In the large rivers, where the validation data were collected as cross-sections the measured versus modeled data are presented as cross-section plots and in the small streams where some of the data was random, measured versus modeled data were plotted as scatter plots.

Some additional measured velocity data were available at the lower R3.5 and lower MF26.2 study sites for potential use as validation velocities; however, because these data were collected in coarse substrate and not collected correctly to measure mean column velocity, the data were not useful for validation of the 2D model mean column velocities. The measured velocity data were collected as point velocity measurements (0.6\*depth) in portions of the stream (coarse substrates) where velocity profiles are “S” shaped and require multiple velocity measurements in the vertical water column to determine the mean column velocity. The data are shown in Figures L-12 and L-13.

### **6.2.3 Special Purpose Modeling**

Special purpose stage-discharge relationships for analyses required for the AQ 10 – TSR (Riparian Resources) and AQ 12 – TSR (Special-status Amphibians and Aquatic Reptiles) are provided in Appendix J, Attachment A. Attachment A includes the 1D stage-discharge relationships in Excel format for each riparian cross-section in the 10 1D instream flow study sites and in the five riparian comparison study sites (Map AQ 1-1 and Table AQ 1-4). For the two 2D instream flow study sites in the peaking reach (MF4.8 and MF14.1), the stage-discharge results from the 2D modeling were used for the riparian analysis (Appendix L). Appendix J, Attachment A also includes the stage-discharge relationships that were developed at the two comparison river sites where FYLF populations and breeding occurs (NF35.7 and NFMF2.3) (AQ 12 – TSR).

## **6.3 HABITAT MODELING**

### **6.3.1 Habitat Versus Flow Relationships**

Plots and tables of weighted usable area (WUA), percent of maximum WUA, spatial niche habitat, and wetted perimeter versus discharge are presented for each study site in Appendix M.

#### **Weighted Usable Area Habitat versus Flow**

Habitat versus flow relationships indicated that relatively large flows (in comparison to the natural unimpaired summer flow) provide the maximum habitat for species and life stages that use fast and deep water such as adult rainbow trout. That is, the channels in the bypass and peaking reaches are relatively large, presumably because of frequent high magnitude winter and spring flow events, and are capable of providing habitat for these species/life stages at high flow. However, natural summer base flows in the rivers are relatively low (presumably due to limited groundwater storage in the upstream granite watersheds). Table AQ 1-10 and Appendix M provide information on impaired and unimpaired flows and habitat versus flow relationships for the streams/rivers associated with the MFP.

The rainbow trout adult habitat versus flow relationships typically reached a maximum at the highest discharge of all species/life stages. The species and life stages with the next highest habitat versus flow relationships, in descending order, were typically rainbow trout spawning, adult hardhead and Sacramento pikeminnow, juvenile rainbow trout, juvenile hardhead, pikeminnow, fry, and FYLF egg masses and tadpoles.

#### **Sensitivity HSC Comparisons**

Rainbow trout adult sensitivity HSC developed to test uncertainty regarding velocity or depth habitat use produced habitat versus flow relationships with shapes very similar to those from the primary adult rainbow trout HSC (Appendix M). In the small streams (Duncan, North and South Fork Long Canyon, and Long Canyon creeks), the adult rainbow trout HSC and sensitivity HSC WUA versus flow relationships were nearly identical. In the larger rivers, the shape of the WUA versus flow relationships were

nearly identical, however, the magnitude of the depth sensitivity (unrestricted use of deep water) WUA was higher than for the other HSC. Because the shapes of the curves were similar; however, when the relationships were used to create habitat time series analyses (Section 6.3.2) the results from the primary HSC and sensitivity HSC were practically identical.

Rainbow trout spawning sensitivity HSC (developed to test uncertainty of deep water spawning) produced habitat versus flow relationships different than those for the primary rainbow trout spawning HSC. The maximum habitat “inflection” point was typically similar for the two HSC (except in the large river, peaking reach sites), but at the highest flows, the depth sensitivity HSC habitat versus flow relationships typically showed greater habitat than the primary rainbow trout HSC habitat versus flow relationships (Appendix M). Most gravels at the instream flow sites were in the low flow channel in the tail of pools or in pockets on the margins of runs or behind boulders. At high flows (deeper water) these became less suitable with the primary HSC, but remained suitable for the sensitivity HSC. The primary and sensitivity test WUA versus flow relationships produced different results in the habitat time series analysis (Section 6.3.2).

### **Spatial Niche Habitat versus Flow**

Diversity of spatial niche habitat types was least at low flow and generally greater as flows increased (Appendix M). At low flow, shallow and/or slow velocity habitat was dominant at the study sites. As discharge increased, however, deeper and faster water niches increased as a relative percentage of the total amount of habitat. Generally in the intermediate flow ranges, the amount of spatial niche diversity was greatest. At the highest flows, fast water that did not provide habitat for any of the species typically became the dominant “habitat” type (although all of the other niche types were present as well).

The small stream spatial niche pattern was different than that of the large rivers. In the small streams (Duncan, North and South Fork Long Canyon, and Long Canyon creeks), shallow habitat was the dominant niche over a wide range of flows. In the larger rivers, a significant amount of moderately deep water niche habitat was present (even at low flows).

### **Wetted Perimeter versus Flow**

The wetted perimeter versus flow relationships for the study sites were relatively monotonic in their rate of increase in wetted perimeter with discharge. The rate of increase in wetted perimeter with increased flow was greatest at the lowest flows and least at the highest flows. However, the relationships typically did not have distinct inflection points (distinct breaks) where an increase in flow exhibited an obvious change in the wetted perimeter relationship (Appendix M).

### **6.3.2 Habitat Time Series**

Habitat time series exceedance plots for rainbow trout spawning (March–May), adult and juvenile rainbow trout and hardhead/Sacramento pikeminnow rearing (June–October), and rainbow trout fry (June–August) are provided in Appendix N. Habitat exceedance plots and time series plots by year are in Appendix N, Attachment A. In addition, exceedance plots for two alternative rearing periods, July to September (hot season) and September to October (fall base flow season) are also in Appendix N, Attachment A.

The habitat time series comparisons between impaired and unimpaired flow conditions provide an estimate of the difference between existing habitat (impaired) and the natural habitat potential (unimpaired) in the streams/ivers associated with the MFP.

#### **Small Streams**

In the small streams (Duncan, North and South Fork Long Canyon, and Long Canyon creeks), the amount of rainbow trout spawning habitat for impaired conditions was less than spawning habitat for unimpaired conditions (Figures N1A-1A, N2-1A, N3-1A, and N4A-1A). This was due to flow diversion during the spring. The amount of rainbow trout adult, juvenile, and fry habitat was generally the same for both impaired and unimpaired conditions (e.g., Figures N1A-2A, N2-2A, N3-2A, N4A-2A). This occurred because water was typically not diverted from the stream during the summer or fall, except during June (Table AQ 1-11).

#### **Middle Fork American River Bypass Reach**

In the Middle Fork American River bypass reach (French Meadows Dam to Middle Fork Interbay, Middle Fork Interbay to Ralston Afterbay), the impaired rainbow trout spawning and rearing habitat was, in general, equal to or greater than unimpaired habitat conditions. The same was true for hardhead and Sacramento pikeminnow habitat in the reach of river below Middle Fork Interbay. The few exceptions to the general results identified above, were as follows: (1) the spawning depth sensitivity run HSC indicated reduced spawning conditions at the top of the two reaches (immediately below French Meadows Dam and immediately below Middle Fork Interbay), where the lowest flows occur (e.g., Figure N5A-1B, N6A-1B); and (2) at these same locations, impaired adult rainbow trout habitat, was higher or equal to unimpaired habitat for the right side of the habitat exceedance plots (50 to 100% exceedance values), but lower for habitat on the left side of the exceedance plots (exceedance values from 0 to 50%) (e.g., Figures N5A-2A, N6A-2A) (Table AQ 1-11). That is, part of the time there was more habitat under impaired conditions and part of the time less habitat.

In general, the impaired habitat values in the Middle Fork American River exceeded those for the unimpaired habitat. This is in part due to augmented summer base flows required in the current FERC minimum flow releases compared to the historic unimpaired flows.

## **Rubicon River**

The results in the Rubicon River produced a pattern similar to that in the Middle Fork American River bypass reaches. In the upper half of the Rubicon River, impaired flow habitat for rainbow trout adult rearing was typically higher than unimpaired flow habitat for the 50 to 100% exceedance habitat values (right side of the exceedance plots) and lower for exceedance values less than 50% (Figure N8A-2A) (Table AQ 1-11). The amount of spawning habitat was greater for impaired flows versus unimpaired flows for the primary spawning HSC (Figure N8A-1A), but lower under impaired flows compared to unimpaired flows when using the depth sensitivity spawning HSC (Figure N8A-1B). However, for all other species and life stages and locations in the Rubicon River impaired habitat was equal to or greater than unimpaired habitat. Again, in part, this occurred due to the current FERC minimum flows being greater than unimpaired base flows.

## **Peaking Reach**

Generally the rainbow trout spawning (primary HSC or depth sensitivity HSC) and FYLF breeding habitat for impaired flow was similar to or greater than for unimpaired flow at the two peaking reach study sites (MF4.8 and MF14.1) (e.g., Figures N11-1A, N11-1C, N12-1A, N12-1C). Because of flow fluctuations in the peaking reach, however, an effective habitat analysis is more appropriate way to quantify breeding habitat (Section 6.3.3) (Table AQ 1-11).

Habitat for species/life stages that use relatively deep and fast water (rainbow trout adult and hardhead adult) was greater (or approximately equal) for impaired flows versus unimpaired flows (e.g., Figures N11-2A, N11-2E, N12-2A, N12-2E) (Table AQ 1-11). This occurred because flows in the peaking reach during the summer/fall are generally higher (faster velocity, deeper water) under existing impaired conditions (albeit fluctuating) than unimpaired conditions. Habitat for species and life stages that use slower velocity water (juvenile rainbow trout and hardhead, rainbow trout, FYLF tadpoles) had less habitat with impaired flows compared to unimpaired flows (e.g., Figures N11-2B, N11-2F, N12-2B, N12-2F) (Table AQ 1-11).

### **6.3.3 Effective Habitat Analysis**

The effective habitat analysis at the 2D modeling sites for (1) the matrix of modeled discharges and (2) for a time series of impaired and unimpaired flows is presented below.

#### **Effective Habitat Matrix**

The effective habitat flow matrix tables and associated plots are presented in Appendix O. To understand the effects of potential Project-related flow fluctuations that may be proposed during license negotiations, effective habitat was analyzed at the two bypass reach study sites (MF26.2 and R3.5) for FYLF egg masses and tadpoles. Each of the bypass reach study sites has an upper and lower habitat segment that was modeled and effective habitat matrices are presented for each segment separately. At the

peaking reach study sites (MF4.8 and MF14.1), effective habitat matrices are provided for rainbow trout spawning and incubation (primary HSC and depth sensitivity HSC), FYLF egg masses and tadpoles, and benthic macroinvertebrate food production.

The matrices/plots are designed to begin at a high starting flow and determine effective habitat for a lower ending flow (e.g., 1000 to 200 cfs). The habitat at the ending flow is the same if the flow changed once (1000 to 200 cfs) or continually cycled between the same flows. Also, the effective habitat would be the same if flows started at the low flow and cycled to the higher flow (200 to 1000 cfs), the plots and tables, however, are easier to read in the other direction.

Overall, the effective habitat matrix results show that for non-mobile or low mobility species/life stages (RBT spawning, FYLF breeding and tadpoles, and macroinvertebrates), changes in flow cause a large reduction in habitat. Species/life stages with narrow depth and velocity requirements (e.g., FYLF egg masses and tadpoles) showed a greater reduction in habitat with changing flow than species/life stages with broader depth and velocity habitat requirements (e.g., macroinvertebrate food production). Rainbow trout spawning was generally intermediate in sensitivity.

Based on the FYLF effective matrices a relatively narrow range of flow fluctuations would be required in the peaking reach to maintain breeding habitat. For example, at MF4.8 (Figure O-22) a flow change from 1018 cfs to 407 cfs leaves only 17% of the initial FYLF breeding habitat available (5202 to 895 ft<sup>2</sup>/1000 ft); 14% would remain at Fords Bar (MF14.1).

It also appears that fluctuations from peaking reduce the rainbow trout spawning potential in the peaking reach when flows in the reach are in the range of control of the Project. For example, at Fords Bar (MF14.1) the amount of spawning habitat available at 1018 cfs reduces to 22% if flow cycles down to 101 cfs (3563 to 792 ft<sup>2</sup>/1000 ft) (Figure O-22); only about 11% would remain at Buckeye Bar (MF4.8).

Effective rainbow trout incubation habitat at the two peaking reach study sites (Figures O-10 and O-19) was only slightly less sensitive to flow fluctuations compared to rainbow spawning habitat, even though incubation had less restrictive depth and velocity requirements than spawning.

### **Effective Habitat Time Series**

Effective habitat time series from 1988 to 2007 for the 15 min impaired flow data and the daily unimpaired flow data are shown for rainbow trout spawning and FYLF breeding in Figures O-16 and O-25 (Appendix O) for the peaking reach study sites (MF14.1 and MF4.8 study sites, respectively).

Average annual FYLF effective breeding habitat was generally always less with impaired flow than with unimpaired flow. Particularly at MF4.8 there was a relatively large difference between the amount of impaired and unimpaired habitat (Figure O-25).

Average annual rainbow trout effective spawning/incubation habitat was also generally less for impaired flows than for unimpaired flows (Figures O-16 and O-25). During a few years (1990,1992, 1994), however, impaired flow conditions provided better spawning habitat (Figure O-16). These were years when impaired flows were lower than unimpaired flows and held relatively steady.

The rainbow trout effective habitat time series for each year was made up of eight separate one week spawning periods and subsequent incubation computations. The average annual habitat was discussed above and presented in Figures O-16 and O-25, however, box and whisker plots that better show the spread of the data that were averaged to make those plots are shown in Figures (O-17 and O-26).

The results for the effective benthic macroinvertebrate habitat time series analysis are still being completed and will be provided to the Aquatic TWG in a short memo in late 2010.

### **6.3.4 Habitat Modeling Validation**

#### **Large Pool Habitat Use**

In the seven large pools studied (three Rubicon River pools and four Middle Fork American River pools), trout, hardhead, and Sacramento pikeminnow used habitat consistent with the MFP HSC developed for each species and consistent with the standard PHABSIM habitat modeling approach (Appendix E). Adult trout were primarily observed actively feeding on drift at the head of the pools in relatively fast velocity habitat during both the morning and afternoon surveys. In the afternoon, some trout moved to deep, slow velocity areas in the body of the pool. Adult trout in the body of the pools typically were holding (resting or potentially seeking cooler temperatures near the bottom of the pool). The adult rainbow MFP HSC developed for habitat modeling were most representative of the drift feeding fish in faster water habitat, not the holding fish. The juvenile trout observed were found near the margins of the stream in cover provided by cobble and boulders. The depths and velocities juvenile trout were observed using were consistent with the juvenile MFP HSC.

Adult and juvenile minnow species (hardhead, Sacramento pikeminnow, and California roach) were most often observed in the body and tail of the pools in slow moving water. Adult hardhead and Sacramento pikeminnow were frequently observed cruising the margins of the pools or holding position in the tail of pools. Some fish were observed drift feeding in the forward portion of the pools, often in velocity breaks (e.g., near boulders). Juvenile minnows and California roach were typically found along the stream margin (slow, shallower water) near submerged vegetation if it was present. Juvenile and adult hardhead/Sacramento pikeminnow observed habitat use was consistent with the MFP HSC used for modeling (Appendix E).

#### **Foothill Yellow-Legged Frog Validation Data**

A total of 25 egg masses and 39 tadpole measurements were collected for habitat modeling validation at the four 2D modeling sites (MF26.2 upper and lower and R3.5

upper and lower). Appendix P shows aerial photograph maps of each of the sites with the egg masses and tadpole locations identified. The study sites were modeled (hydraulics and habitat) at the discharge the egg masses and tadpoles were observed and the accuracy of the modeling versus the observations was determined.

In general, the FYLF modeling worked reasonably well. Seventy eight percent of the observed egg masses and tadpoles were modeled in completely suitable habitat (1.0 suitability). In total, 16 of the 25 egg masses (64%) and 34 of the 39 tadpoles (87%) were modeled to be in completely suitable habitat (1.0 combined suitability) (Table P-1, Appendix P). The remainder were located in 0.1 suitability habitat, except for two egg masses that were located in 0.0 suitability habitat.

In all cases, the modeled depth and substrate suitability for the egg masses and tadpoles was completely suitable (1.0). The egg masses and tadpoles (14 total) that were not in completely suitable habitat were modeled to be in lower quality (0.1 or 0.0 suitability) high velocity habitat (see Figure C-1). Twelve of the total were modeled in water velocity  $>0.11$  m/s for egg masses and  $>0.06$  m/s for tadpoles (0.1 suitability velocity) and two egg masses were modeled in 0.0 suitability water velocity ( $>0.25$  m/s). Appendix P, Attachment A has detailed Powerpoint files show the validation modeling results.

In five of the 14 instances that egg masses and/or tadpoles were modeled in suboptimal water velocity, they were also actually observed (measured in the field) in suboptimal velocity (water velocity  $>0.11$  or  $>0.06$  m/s for egg masses and tadpoles, respectively). In the other nine instances, the modeled velocities were over predicted by the 2D model. Likely this occurred because it is extremely difficult to model topography and/or velocity at a fine enough scale to pick up “micro” velocity patterns behind substrates such as cobbles and small boulders were FYLF lay egg masses or tadpoles often are found.

The FYLF validation modeling was particularly useful in correcting an initial deficiency in the substrate HSC. Initial validation modeling showed that several egg masses were in substrate polygons that were dominated by small, unsuitable substrates (gravels) but that actually had a suitable amount (20% or greater) of egg attachment substrate (cobbles and boulders). The initial validation modeling results were used along with other data to modify the HSC such that subdominant substrate was accounted for in a reasonable manner.

## **6.4 ADDITIONAL RESULTS SPECIFIC TO PEAKING REACH**

### **6.4.1 Peaking Reach Hydrology**

The peaking reach extends from Oxbow Powerhouse downstream to the high-water mark of Folsom Reservoir and includes two river segments: the Middle Fork American River from Oxbow Powerhouse to the confluence of the North Fork American River; and the North Fork American River from the confluence of the Middle Fork American River

to the high water mark of Folsom Reservoir. Mean daily and 15-minute hydrograph data for the peaking reach during the period of record are briefly summarized below.

### **Mean Daily Flow Hydrograph Pattern**

The mean daily flow hydrographs (Appendix Q) at the top, middle, and bottom of the peaking reach during different water years showed the following seasonal patterns: (1) winter impaired and unimpaired flows generally have similar high flow events (both the magnitude and duration of the flow events); (2) spring impaired flows are lower than the unimpaired flows; and (3) summer/fall impaired flows are typically higher and more variable than unimpaired flows. Accretion from the North Fork American River reduces the differences between the impaired and unimpaired flow patterns in winter and spring, but not during the summer/fall.

#### Winter

During the winter in wet and above normal water years, the daily impaired and unimpaired flow patterns were similar with variable, high winter flow events (storms, runoff) present in both sets of hydrology. In the below normal and drier water years, the winter impaired flows were often modified somewhat from the unimpaired flows; flows were either higher or lower depending on the year. The difference in some cases were relatively small, particularly below the North Fork/Middle Fork American River confluence where the unimpaired North Fork American River inflow resulted in a flow pattern more similar to an unimpaired flow pattern.

#### Spring

In all but the wet water years, the impaired spring runoff flows were reduced compared to the unimpaired hydrographs. This occurred due to snowmelt water being captured in the upstream reservoirs. Below the confluence of the Middle Fork American and North Fork American rivers, the impaired spring high flow hydrographs were augmented, but they were still less than unimpaired.

#### Summer/Fall

In all water year types, the summer/fall impaired flows were much higher and more variable than the unimpaired flows (see within day peaking pattern below). The exception occurred during the fall powerhouse maintenance period (2 to 4+ weeks) when peaking ceases and impaired flow had a magnitude similar to unimpaired flow. During the maintenance outage, impaired flow was held relatively steady, close to, but greater than the 75 cfs FERC minimum flow requirement.

### **Within-Day Peaking Pattern**

Fifteen-minute flow data from Middle Fork American River gage below Oxbow Powerhouse (USGS Gage No. 11433300) were used to illustrate flow fluctuations in the peaking reach on a daily basis during different seasons and water years (Appendix Q). The within-day magnitude and timing of flows in the peaking reach were affected by

releases from Oxbow Powerhouse. Oxbow Powerhouse was typically operated to follow daily power demand and to provide whitewater boating flows, and was not operated 24 hours per day (except in the wettest of water years and/or seasons of the year). This created daily and within-day flow fluctuations in the peaking reach (Appendix Q). Except during high flow periods of the year (e.g., winter or spring), releases from the Oxbow Powerhouse resulted in daily fluctuations in flow between about 200 cfs and 1,080 cfs. The maximum capacity of Oxbow Powerhouse is approximately 1,080 cfs (Figure AQ 1-7).

Figure AQ 1-8 shows idealized examples of peaking events in different months (May to September) by different water year types. The examples are based on an idealized unimodal peak, but frequently the daily events were more complicated and variable. Daily peaking duration can be short (a few hours) or longer (most of the day). In addition, depending on water year type, the amount of baseflow can vary and there can be multiple peaks and declines in flow over the day (Appendix R).

### Winter/Spring

During the winter/spring season, flows in the peaking reach can exceed 3,000 cfs due to natural runoff (typically in wetter water years). Considerable accretion can occur along the length of the peaking reach, particularly during the winter period from the North Fork of the Middle Fork American River, Volcano Creek, Otter Creek, Canyon Creek, and North Fork American River watersheds. When flows were high, no peaking occurred (e.g., powerhouse is run continuously). During low flow water years, peaking occurred through the winter/spring season.

### Summer/Fall

During the summer/fall season, daily peaking events typically started in the morning, ramping up from a low nighttime base flow (100–200 cfs) at a rate of approximately 250 to 450 cfs/hr to a high peak flow (approximately 1,000 cfs) followed by an evening down-ramp (approximately 250–450 cfs/hr) back to the base flow (Appendix R). Each up-ramping and down-ramping period lasted for approximately 3 hours. During the summer, Project operations at Oxbow Powerhouse were voluntarily modified to accommodate commercial whitewater boating by releasing water 2 or 3 hours earlier than would otherwise occur to meet peak energy demand.

## **6.4.2 Stage Monitoring and Flow Travel Times**

### **Travel Velocity**

Travel velocity and base flow for 17 peaking flow events were used to create a travel velocity relationship (Figure AQ 1-9):

$$\text{Travel Velocity mph} = 0.0026 * \text{Base Flow cfs} + 1.96; R^2=0.88$$

During typical summer operations (200 cfs base flow, 1000 cfs peak), the travel velocity of peaking pulse events was approximately 2.5 mph. Travel velocity was constant

along the length of the reach. At higher base flows (e.g., 300 cfs), the travel velocity increased (2.8 mph) and at lower base flows (e.g., 100 cfs) travel velocity decreased (2.3 mph). Lower peak flows (e.g., 800 cfs) also decreased the travel velocity, but because few peaking events were lower than the approximately 1,000 cfs an empirical relationship was not created.

### **Shape of Peaking Flow Pulse**

The shape of the up-ramp of the peaking events was similar along the length of the peaking reach, but the length of the peak flow period shortened and the down-ramp rate of the pulse attenuated (slowed) as the pulse moved downstream. Figure AQ 1-10 graphically shows the relative stage and timing at each of the pressure transducers along the peaking reach for an example peaking event. The figure also shows the pulses superimposed upon each other (timing shifted based on the 2.5 mph travel velocity) so that the shape of the pulse as it moves downstream can be compared. Figure AQ 1-11 shows several consecutive peaking events superimposed.

The length of the peak flow period shortens as the pulse moves downstream because some of the released water is “used up” filling the channel. For example, below Mammoth Bar, the duration of the peak is shortened by approximately 2 hours compared to the peak at Oxbow Powerhouse. The duration of the peak is generally shortened by approximately 1 hour per 10 miles of travel distance downstream.

The rate of the peaking event down-ramp changes as the peak travels downstream. At the top of the reach, the down-ramps are relatively rapid with decreases in flow at a rate similar to the up-ramp rate (250 to 450 cfs/hr, 3 hours to down-ramp). With increasing distance downstream, down-ramps are slower and have a longer duration (Figure AQ 1-11). This occurs because during the down-ramp the channel upstream of any particular location is full of water and must drain; the longer the length of channel upstream of a location, the slower the down-ramp rate and the longer the down-ramp duration. For example, just downstream of Mammoth Bar (22.35 miles downstream of Oxbow Powerhouse), the down-ramp is at least three times slower than at Oxbow Powerhouse. A 900 cfs down-ramp below Mammoth Bar takes 9<sup>+</sup> hours (about 100 cfs/hr) compared to about 3 hours at Oxbow Powerhouse.

### Travel Times

Distances between specific points in the peaking reach and water travel times between those points are summarized on Table AQ 1-12 (Map AQ 1-4). Table AQ 1-13 shows the times flows would be at specific locations in the peaking reach given a specific starting time, in two hour increments. The information presented in both of these tables is based on a flow travel rate of 2.5 mph.

### Magnitude of Stage Change

The amount of stage change from base flow to the peak flow varied depending on the local slope and channel shape at any particular location in the reach. The total stage

change for typical summer peaking events ranged from approximately 1 to 2.3 feet (average 1.8 feet), depending on location.

### **6.4.3 Empirical Stranding Evaluation**

During the one-time peaking flow stranding study conducted on June 5th, 2008, a total distance of 2.1 miles of the peaking reach was surveyed immediately after cessation of a daily peaking event of 900 cfs (900 cfs down to ca. 100 cfs). The areas surveyed represent areas with a high potential for stranding, characterized by large bar features with varying topography (e.g., low-lying or backwater areas) and relatively shallow slopes. One dead sculpin was observed stranded in the Fords Bar study area and approximately 289 live fish were observed temporally trapped (isolated) in disconnected pools in the Gray Eagle Bar - American Bar study area (Appendix F, Table F-1). No fish were observed that were permanently trapped. The majority of fish temporarily trapped (approximately 250 fish) were located in a dredge hole developed by recent mining activities. Temporarily trapped/isolated fish consisted of a mix of species (trout fry, California roach, hardhead, Sacramento pikeminnow, and sculpin) that were found swimming in pool areas isolated from the main channel. It was estimated that the trapped fish would survive until another peaking event inundated the habitat. The trapping pools were very near to the active channel, and in most cases had some flow-through or were at groundwater level (i.e., had subsurface hydraulic connectivity to the main channel) (see photographs in Appendix F, Attachment A).

As part of the Gray Eagle Bar cut-off channel dewatering study, flows in the side channel and the Middle Fork American River main channel were measured on four days over a range of discharges during the annual maintenance outage in November 2008. The flow within the main channel (measured at the Middle Fork American River Nr. Oxbow PH gage (OXB)) was related to the flows measured within the side channel (Appendix F, Figure F-2). Based on the field observations under the different flow conditions, connectivity between the main channel and side channel occurred when flows within the main channel were greater than approximately 150 cfs. At approximately 150 cfs in the main channel, surface water no longer flowed through the side channel, resulting in isolated pool habitat within the side channel (although some subsurface, intragravel flow was likely occurring). The riffle in the mid-section and the downstream end of the side channel were dewatered at this flow (Appendix F, Map F-4; Appendix F, Attachment B). As the flow decreased to 126 cfs, the isolated pool habitat remained, but no surface flow within the side channel was observed. Photographs of habitat conditions within the side channel under the different flow conditions are shown in Appendix F, Attachment B.

The total number of days and the average number of days per year when flows were less than 150 cfs in the main channel were compared under impaired and unimpaired flow conditions (Appendix F, Figures F-3a and F-3b). The average number of 'events' or times when flows dropped below 150 cfs was also calculated for impaired and unimpaired flow conditions (Appendix F, Figure F-4). Under unimpaired flow conditions, the side channel typically was not connected with the main channel during August, September, and October. In contrast, under impaired flow conditions flows were often

greater than 150 cfs in the main channel during these months (except during the annual maintenance outage in October), resulting in flow through the side channel most of the time (Appendix F, Figures F-3a and F-3b). Under current Project operations, however, partly because water is in the side channel more often, the number of times the side channel switches between watered and disconnected increases (Appendix F, Figure F-4).

The above analyses are based on a “static” channel. Because the hydraulic controls at the top of Gray Eagle Bar on both the main channel and the side channel are composed of cobbles and small boulders, the channel is actually “dynamic.” It is anticipated that the main channel versus side channel flow relationship is altered each time large flow events modify the alluvial channel.

## **6.5 EVALUATION OF SEDIMENT TRANSPORT CONDITIONS**

Estimates of the flow required to initiate motion of 25% of the gravel substrate were obtained at 10 1D study sites (25 transects total) and at the two 2D study sites in the peaking reach (Table G-1, Appendix G). To aid interpretation of the results and to provide robust initiation of motion estimates at sites where measured estimates were variable or uncertain, the modeled data were regressed against the 1.5, 2.0, and 5.0 year impaired and 1.5 year unimpaired flow recurrence intervals at the study sites (Figures G-5 and G-6). Relatively good correlations (i.e.,  $R^2 = 0.9$ ) were obtained for the regressions of the 25% initiation flow versus the 1.5 and 2.0 year impaired recurrence interval flows. The regression flows required to move gravels were  $1.94 * 1.5$  year impaired recurrence flow or  $0.91 * 2.0$  year impaired recurrence flow.

Two of the study sites, MF44.7 and R25.7, immediately below large dams (French Meadows and Hell Hole dams, respectively) appeared to correlate better with higher recurrence flows (e.g., 5.0 year recurrence) and poorly with the lower recurrence interval flows. This is likely because the 1.5 and 2.0 year impaired recurrence flows are very low at these sites and likely gravels are being moved during less frequent, but higher flow events (e.g., 5.0 year recurrence flows).

A relatively robust estimate of the flow required to initiate motion at each of the study sites was obtained by using the 2.0 year impaired recurrence flow (see Regression column Table G-1). For the two study sites, MF44.7 and R25.7, that didn't correlate well with the 2.0 year recurrence flows, the actual modeled 25% gravel initiation flow appear to be the best estimate (Table G-1).

## **6.6 ADDITIONAL STUDY ELEMENTS**

### **6.6.1 Algae**

In general, *Didymosphenia geminata* was present throughout the study area (Appendix H, Table H-1). *Didymosphenia geminata* was present at 9 of the 12 instream flows sites, at one of the two comparison river sites, and at the extra sampling site at the top of the peaking reach (Horseshoe Bar). Likely, however, it was present at all of the sites but not collected. For example, *Didymosphenia geminata* was not present in the

sample from the South Fork Long Canyon below the diversion (SFLC2.3), but was present at a comparison site just upstream SFLC4.2 (above the South Fork Long Canyon diversion). *Didymosphenia geminata* was not present at the lowest instream flow study site on the Rubicon River (R3.5), but was present in the two sites upriver. The only streams/rivers where *Didymosphenia geminata* was not documented in samples collected as part of this study were North Fork Long Canyon Creek and the North Fork American River. The North Fork of the Middle Fork American River was not sampled for *Didymosphenia geminata*.

Based on the summer algae abundance surveys, algae coverage was not dense at most of the instream flow sites (see photographs in Appendix H, Attachment A). Cumulative filamentous macroalgae and microalgae coverage ranged from a high of 85.5% at Middle Fork American River below Ralston Afterbay (MF23.5) to a low of 10.7% at the Rubicon River near Ellicott Bridge (R20.9) (Appendix H, Table H-2). The highest density of algae was observed downstream of Ralston Afterbay. Appendix H, Table H-3 provides the details of the algal abundance sampling at each transect.

### **6.6.2 Horseshoe Bar Inundation**

The stage-discharge regression developed for the entrance to the Horseshoe Bar historic natural channel indicated that a flow of approximately 23,000 cfs in the main stem Middle Fork American River is required to begin inundation of the historic channel (Figure AQ 1-12 and Table AQ 1-14). Visual observations by the caretaker at Horseshoe Bar, John Close, corroborate that a very high discharge is needed to inundate the channel (Figure AQ 1-13). During the spring of 2009 a discharge of 11,007 cfs occurred in the main channel (March 2, 2009). The caretaker observed that no water entered the historic channel. Stage measurements in the main channel near the entrance of the historic channel indicated that the water surface elevation was 2.6 feet below the entrance to the historic channel at that time. The caretaker also observed that flow did enter the Horseshoe Bar channel during the 36,000 cfs high flow event of December 31st, 2005, consistent with the analysis.

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**Personal Communication**

Lind, A. and S. Yarnell. (November, 2009)

**TABLES**

**Table AQ 1-1. Instream Flow Study Reaches and Modeling Methods.**

Study Reaches/Sites	Bypass Reaches	Peaking Reach	Reach Upstream of Project Facilities	Site Name	Number of Mesohabitat Units Sampled	Discharges for Model Calibration (cfs) <sup>1</sup> (V = Velocity data collection)				Modeling Methods
						Aquatic Habitat Modeling				
						Low	Med	High	Extra <sup>2</sup>	
<b>Duncan Creek</b>										
Duncan Creek upstream of Diversion			●	D9.0	3	4	17	109	Based on availability of spring high flows (HF)	Develop stage-discharge relationship for riparian vegetation comparisons
Duncan Creek below Diversion	●			D8.3	3	3	11	51	NA	1D
	●			D6.3	10	4	16 <sup>v</sup>	54	NA	1D
<b>North Fork Long Canyon Creek</b>										
North Fork Long Canyon Creek below Diversion	●			NFLC1.9	12	2	5 <sup>v</sup>	15	NA	1D
<b>South Fork Long Canyon Creek</b>										
South Fork Long Canyon Creek upstream of Diversion			●	SFLC4.2	3	4	10-23 <sup>v</sup>	34	NA	Develop stage-discharge relationship for riparian vegetation comparisons
South Fork Long Canyon Creek below Diversion	●			SFLC2.3	11	7	18 <sup>v</sup>	29	NA	1D
<b>Long Canyon Creek</b>										
Long Canyon Creek below North and South Fork Long Canyon Creek	●			LC9.0	9	17	27 <sup>v</sup>	53	NA	1D
<b>Middle Fork American River Upstream of Middle Fork Interbay</b>										
Middle Fork American River below French Meadows Reservoir	●			MF44.7	8	10	54 <sup>v</sup>	181	NA	1D
Middle Fork American River Immediately above Middle Fork Interbay <sup>3</sup>	●			MF36.2	11	12-16	64 <sup>v</sup>	225	NA	1D

**Table AQ 1-1. Instream Flow Study Reaches and Modeling Methods (continued).**

Study Reaches/Sites	Bypass Reaches	Peaking Reach	Reach Upstream of Project Facilities	Site Name	Number of Mesohabitat Units Sampled	Discharges for Model Calibration (cfs) <sup>1</sup> (V = Velocity data collection)				Modeling Methods
						Aquatic Habitat Modeling				
						Low	Med	High	Extra <sup>2</sup>	
Middle Fork American River from Middle Fork Interbay to Ralston Afterbay										
Middle Fork American River between Middle Fork Interbay and Ralston Afterbay	●			MF26.2	13	17-24	90 <sup>v</sup>	188	NA	1D plus 2D for Amphibian habitat
Middle Fork American River Downstream of Ralston Afterbay										
Middle Fork American River below Ralston Afterbay		●		MF14.1	10	101	393 <sup>v</sup>	1040	NA	2D
Middle Fork American River above North Fork American River confluence		●		MF4.8	10	111	453 <sup>v</sup>	910	NA	2D
Rubicon River										
Rubicon River below Hell Hole Reservoir <sup>4</sup>	●			R25.7	12	23	66 <sup>v</sup>	77	NA	1D
Rubicon River Near Ellicott Bridge <sup>4</sup>	●			R20.9	13	32	77-86 <sup>v</sup>	130	NA	1D
Rubicon River Near Ralston Afterbay <sup>4</sup>	●			R3.5	14	36.6-48.6	83 <sup>v</sup>	218	NA	1D plus 2D for Amphibian habitat
Other Tributaries										
North Fork Middle Fork American River			●	NFMF2.3	3	15	94	214	260	Develop stage-discharge relationship for riparian vegetation comparisons. One amphibian transect at this site.
North Fork American River			●	NF31.3	4	30	656	1171	1883	Develop stage-discharge relationship for riparian vegetation comparisons
North Fork American River			●	NF35.7	2	33	744	1099	NA	Develop stage-discharge relationship for amphibian breeding habitat.

**Table AQ 1-1. Instream Flow Study Reaches and Modeling Methods (continued).**

Study Reaches/Sites	Bypass Reaches	Peaking Reach	Reach Upstream of Project Facilities	Site Name	Number of Mesohabitat Units Sampled	Discharges for Model Calibration (cfs) <sup>1</sup> (V = Velocity data collection)				Modeling Methods
						Aquatic Habitat Modeling				
						Low	Med	High	Extra <sup>2</sup>	
Other Tributaries (continued)										
Shirttail Creek - Tributary to North Fork American River			●	ST0.1	1	0.8	29.5	59.6	NA	Develop stage-discharge relationship for amphibian breeding habitat.
North Fork American River			●	NF53.7	3	26	574	1939	NA	Develop stage-discharge relationship for riparian vegetation comparisons. Limited access at high flows.

<sup>1</sup>The target discharges were developed in consultation with the Aquatic and Recreation TWG. The discharges shown are the actual discharges measured.

<sup>2</sup>Based on availability of spring high flows.

<sup>3</sup>The accessible section of stream in this section of river is short in length and may not be representative of a larger reach of river.

<sup>4</sup>The facilities at Hell Hole Reservoir are limited in their release capabilities. The flow range measured was the widest range of flows available.

**Table AQ 1-2. Habitat Suitability Criteria Methods for Aquatic Species Associated with the Middle Fork Project.**

Species / Life Stage	Modeling Priority <sup>1</sup>	Type of Habitat Suitability Criteria		Source of Data
		Univariate Suitability Curve	Guild	
Rainbow Trout				
Adult	Primary	X	X <sup>2</sup>	Enveloped Use Data Histograms
Juvenile	Primary	X	X <sup>2</sup>	Enveloped Use Data Histograms
Fry	Secondary	X	X <sup>2</sup>	Enveloped Literature HSC
Hardhead				
Adult	Primary	X	X	Enveloped Literature HSC
Juvenile	Primary	X	X	Enveloped Literature HSC
Sacramento Pikeminnow				
Adult	Secondary	X	X	Enveloped Literature HSC
Juvenile	Secondary	X	X	Enveloped Literature HSC
Sacramento Sucker				
Adult	Secondary		X	Enveloped Literature HSC
Juvenile	Secondary		X	Enveloped Literature HSC
California Roach	Secondary		X	Enveloped Literature HSC
Sculpin/Speckled Dace	Secondary		X	Enveloped Literature HSC
Macroinvertebrates <sup>3</sup>	Secondary		X	Enveloped Literature HSC
Foothill Yellow-legged Frog <sup>4</sup>				
Breeding	Primary	X	X	Enveloped Use Data Histograms
Tadpoles	Primary	X	X	Enveloped Use Data Histograms
Riparian Vegetation <sup>5</sup>	Primary			Literature

<sup>1</sup>Primary priority species / life stage were modeled individually; secondary priority species / life stages were modeled as part of the guild / spatial niche modeling approach.

<sup>2</sup>Note that rainbow trout habitat suitability criteria were assumed to be approximately similar to brown trout habitat suitability and were used to represent trout in the guild approach.

<sup>3</sup>A wetted perimeter HSC was used for macroinvertebrates in addition to the guild / spatial niche modeling approach.

<sup>4</sup>FYLF HSC data is presented in the AQ - 12 Amphibian TSR (PCWA 2008b) and the AQ - 1 TSR (this report).

<sup>5</sup>Inundation frequency and timing were used as HSC for riparian vegetation and are presented in the AQ - 10 TSR (PCWA 2009b).

**Table AQ 1-3. Instream Flow Study Detailed Site Information.<sup>1</sup>**

Site Name	Geomorphic Reach <sup>2</sup>	River Mile Location of Site	UTM-Coords at Beginning of Site (Downstream River Mile) (Zone 10N, NAD83)	Number of						Comments
				Mesohabitats (Cross-sections)					Special Purpose Cross-sections	
				Total	HGR	LGR	RUN	POOL		
<b>Duncan Creek</b>										
D9.0	Abv Diversion	9.0 - 9.2	718174, 4335012	3 (3)	n/a	n/a	n/a	n/a	3	Riparian Site Only
D8.3	DUN-R2	8.0 - 8.5	717228, 4334321	3 (3)	n/a	n/a	n/a	n/a	3	Limited Purpose Site 3 Geomorphic Cross-sections Only
D6.3	DUN-R2	6.1 - 6.5	715520, 4332094	10 (22)	2 (4)	2 (2)	2 (4)	4 (12)	0	Instream Flow, Geomorphic, and Riparian Site
<b>North Fork Long Canyon Creek</b>										
NFLC1.9	NFLONG-R1	1.7 - 2.1	716314, 4324314	12 (18)	2 (3) <sup>3</sup>	3 (3)	3 (3)	4 (9)	3	Instream Flow, Geomorphic, and Riparian Site
<b>South Fork Long Canyon Creek</b>										
SFLC4.2	Abv Diversion	4.6 - 4.9	720388, 4326694	3 (3)	n/a	n/a	n/a	n/a	3	Riparian Site Only
SFLC2.3	SFLONG-R1	2.2 - 2.6	717821, 4324192	11 (19)	2 (2)	2 (3)	3 (5)	4 (9)	0	Instream Flow, Geomorphic, and Riparian Site
<b>Long Canyon Creek</b>										
LC9.0	LONG-R2	8.7 - 9.2	712229, 4319403	8 (18)	1 (2)	2 (4)	2 (3)	3 (9)	2	Instream Flow, Geomorphic, and Riparian Site
<b>Middle Fork American River Upstream of Middle Fork Interbay</b>										
MF44.7	MFAR-R5	44.7 - 45.1	716554, 4329824	8 (19)	2 (3)	1 (1)	2 (3)	3 (12)	0	Instream Flow, Geomorphic, and Riparian Site
MF36.2 <sup>4</sup>	MFAR-R5	36.0-36.2	708184, 4322341	11 (17)	3 (4)	1 (1)	3 (3)	4 (9)	0	Instream Flow, Geomorphic, and Riparian Site
<b>Middle Fork American River from Middle Fork Interbay to Ralston Afterbay</b>										
MF26.2 <sup>5</sup>	MFAR-R4	25.9 - 26.4	696388, 4320083	9 (17) <sup>5</sup> 3 (7) <sup>5</sup>	2 (4) <sup>5</sup>	2 (2) <sup>5</sup> 1 (1) <sup>5</sup>	2 (4) <sup>5</sup> 1 (3) <sup>5</sup>	3 (7) <sup>5</sup> 1 (3) <sup>5</sup>	0	Instream Flow, Geomorphic, and Riparian Site (1D) Amphibian Site (2D)

**Table AQ 1-3. Instream Flow Study Detailed Site Information (continued).<sup>1</sup>**

Site Name	Geomorphic Reach <sup>2</sup>	River Mile Location of Site	UTM-Coords at Beginning of Site (Downstream River Mile) (Zone 10N, NAD83)	Number of						Comments
				Mesohabitats (Cross-sections)					Special Purpose Cross-sections	
				Total	HGR	LGR	RUN	POOL		
<b>Middle Fork American River Downstream of Ralston Afterbay</b>										
MF14.1 <sup>6</sup>	MFAR-R3	13.8 – 14.5	685560, 4313771	10 (2D) <sup>6</sup>	1 (2D) <sup>6</sup>	3 (2D) <sup>6</sup>	2 (2D) <sup>6</sup>	4 (2D) <sup>6</sup>	0	2D Instream Flow, Geomorphic, and Riparian Site
MF4.8 <sup>6</sup>	MFAR-R1	4.1 – 4.8	675208, 4310856	11 (2D) <sup>6</sup>	0 <sup>6</sup>	3 (2D) <sup>6</sup>	4 (2D) <sup>6</sup>	4 (2D) <sup>6</sup>	0	2D Instream Flow, Geomorphic, and Riparian Site
<b>Rubicon River</b>										
R25.7	RUB-R3	25.1 - 26.2	720666, 4319717	12 (25)	2 (4)	3 (4)	3 (6)	3 (11)	1	Instream Flow, Geomorphic, and Riparian Site
R20.9	RUB-R2	20.2 - 21.0	717255, 4314092	13 (22)	3 (5) <sup>3</sup>	1 (1)	5 (5)	4 (11)	0	Instream Flow, Geomorphic, and Riparian Site
R3.5 <sup>5</sup>	RUB-R1	2.6 - 3.7	697150, 4319188	10 (18) <sup>5</sup> 4 (5) <sup>5</sup>	2 (3) <sup>5</sup>	2 (2) <sup>5</sup> 1 (1) <sup>5</sup>	3 (5) <sup>5</sup> 1 (1) <sup>5</sup>	3 (8) <sup>5</sup> 2 (3) <sup>5</sup>	0	Instream Flow, Geomorphic, and Riparian Site (1D) Amphibian Site (2D)
<b>Other Tributaries (North Fork American River and North Fork of the Middle Fork American River)</b>										
NFMF2.3	Other Trib.	3.1 - 2.4	697380, 4321935	3 (4)	n/a	n/a	n/a	n/a	4	Riparian and Amphibian Site
NF31.3	Other Trib.	30.5 – 31.8	677360, 4317941	4 (4)	n/a	n/a	n/a	n/a	4	Riparian Site Only
NF35.7	Other Trib.	35.6 - 36.0	681311, 4322809	2 (2)	n/a	n/a	n/a	n/a	2	Amphibian Site Only
NF53.7	Other Trib.	53.1 - 53.3	691215, 4338605	3 (3)	n/a	n/a	n/a	n/a	3	Riparian Site Only (Limited Access at High Flows)

<sup>1</sup>Study sites and modeling cross-sections were selected in the field in coordination with the Aquatic TWG in August and October 2007.

<sup>2</sup>See Map AQ 1-1 for reach descriptions.

<sup>3</sup>One cross-section comes from a run mesohabitat.

<sup>4</sup>The accessible section of stream in this section of river is short in length and may not be representative of a larger reach.

<sup>5</sup>Mixed 1D and 2D habitat modeling. Original 1D cross sections replaced by 2D modeling for amphibian habitat.

<sup>6</sup>Site selected for 2D modeling. No cross-sections are required for 2D modeling.

**Table AQ 1-4a. Reach Habitat Mapping and 1D Instream Flow Study Site Cross-sections and Mesohabitat Percentages by Mesohabitat Type.**

Reach/Site	Instream Flow Mesohabitat Units	Overall Reach			Instream Flow Site					
		Frequency	% Length	% Length w/o CAS	Number of Cross-sections		Cross-section %	Mesohabitat Units Used		Weighting Factor Per Transect for Reach
					1D	2D		1D	2D	
<b>Duncan Creek Below Diversion</b>										
D8.3	CAS	22	3.0%	--	0	--	0.0%	0	--	--
	HGR	75	24.4%	25.2%	0	--	0.0%	0	--	--
	LGR	25	7.5%	7.7%	0	--	0.0%	0	--	--
	RUN	44	13.9%	14.3%	0	--	0.0%	0	--	--
	POOL	143	51.2%	52.8%	3 <sup>1</sup>	--	100.0%	3	--	--
	Totals	309	100.0%	100.0%	3	--	100.0%	3	--	--
D6.3	CAS	22	3.0%	--	0	--	0.0%	0	--	--
	HGR	75	24.4%	25.2%	4	--	18.2%	2	--	6.30%
	LGR	25	7.5%	7.7%	2	--	9.1%	2	--	3.86%
	RUN	44	13.9%	14.3%	4	--	18.2%	2	--	3.58%
	POOL	143	51.2%	52.8%	12	--	54.5%	4	--	4.40%
	Totals	309	100.0%	100.0%	22	--	100.0%	10	--	--
NFLC1.9	CAS	11	1.8%	--	0	--	0.0%	0	--	--
	HGR	65	23.8%	24.2%	3	--	16.7%	2	--	8.07%
	LGR	45	17.4%	17.7%	3	--	16.7%	3	--	5.91%
	RUN	35	14.8%	15.1%	3	--	16.7%	3	--	5.02%
	POOL	126	42.2%	43.0%	9	--	50.0%	4	--	4.78%
	Totals	282	100.0%	100.0%	18	--	100.0%	12	--	--
<b>South Fork Long Canyon Creek Below Diversion</b>										
SFLC2.3	CAS	13	2.7%	--	0	--	0.0%	0	--	--
	HGR	45	14.8%	15.2%	2	--	10.5%	2	--	7.59%
	LGR	51	16.3%	16.8%	3	--	15.8%	2	--	5.60%
	RUN	68	27.0%	27.7%	5	--	26.3%	3	--	5.55%
	POOL	123	39.2%	40.3%	9	--	47.4%	4	--	4.48%
	Totals	300	100.0%	100.0%	19	--	100.0%	11	--	--
<b>Long Canyon Creek Above Ramsey Crossing</b>										
LC9.0	CAS	16	4.8%	--	0	--	0.0%	0	--	--
	HGR	26	13.0%	13.6%	2	--	11.1%	1	--	6.81%
	LGR	31	25.4%	26.7%	4	--	22.2%	2	--	6.67%
	RUN	25	15.4%	16.2%	3	--	16.7%	2	--	5.38%
	POOL	72	41.5%	43.6%	9	--	50.0%	3	--	4.84%
	Totals	170	100.0%	100.0%	18	--	100.0%	8	--	--
<b>Middle Fork American River Below French Meadows Dam</b>										
MF44.7	CAS	11	5.0%	--	0	--	0.0%	0	--	--
	HGR	17	17.1%	18.0%	3	--	15.8%	2	--	5.98%
	LGR	6	4.8%	5.1%	1	--	5.3%	1	--	5.09%
	RUN	16	15.8%	16.6%	3	--	15.8%	2	--	5.55%
	POOL	38	57.3%	60.3%	12	--	63.2%	3	--	5.03%
	Totals	88	100.0%	100.0%	19	--	100.0%	8	--	--

Table AQ 1-4a. Reach Habitat Mapping and 1D Instream Flow Study Site Cross-sections and Mesohabitat Percentages by Mesohabitat Type (continued).

Reach/Site	Instream Flow Mesohabitat Units	Overall Reach			Instream Flow Site					
		Frequency	% Length	% Length w/o CAS	Number of Cross-sections		Cross-section %	Mesohabitat Units Used		Weighting Factor Per Transect for Reach
					1D	2D		1D	2D	
Middle Fork American River Above Middel Fork Interbay										
MF36.2	CAS	11	5.0%	--	0	--	0.0%	0	--	--
	HGR	17	17.1%	18.0%	4	--	23.5%	2	--	4.49%
	LGR	6	4.8%	5.1%	1	--	5.9%	2	--	5.09%
	RUN	16	15.8%	16.6%	3	--	17.6%	2	--	5.55%
	POOL	38	57.3%	60.3%	9	--	52.9%	3	--	6.70%
Totals	88	100.0%	100.0%	17	--	100.0%	9	--	--	
Middle Fork American River Above Ralston Afterbay										
MF26.2	CAS	44	5.6%	--	0	0	0.0%	0	0	
	HGR	78	20.0%	21.2%	4	0	17.4%	2	0	5.29%
	LGR	25	6.6%	6.9%	2	0	8.7%	2	1	3.47%
	RUN	85	27.0%	28.6%	4	3	30.4%	2	1	4.09%
	POOL	135	40.9%	43.3%	7	3	43.5%	3	1	4.33%
Totals	367	100.0%	100.0%	17	6	100.0%	9	3		
Rubicon River Above Parsley Bar (Helicopter Site)										
R25.7	CAS	4	2.5%	--	0	--	0.0%	0	--	--
	HGR	20	12.9%	13.2%	4	--	16.0%	2	--	3.30%
	LGR	23	18.0%	18.5%	4	--	16.0%	4 <sup>2</sup>	--	4.62%
	RUN	25	24.3%	24.9%	6	--	24.0%	3	--	4.15%
	POOL	43	42.4%	43.4%	11	--	44.0%	3	--	3.95%
Totals	115	100.0%	100.0%	25	--	100.0%	12	--	--	
Rubicon River Below Ellicott Bridge										
R20.9	CAS	115	11.9%	--	0	--	0.0%	0	--	--
	HGR	154	22.2%	25.2%	5 <sup>3</sup>	--	22.7%	3	--	5.04%
	LGR	33	3.4%	3.9%	1	--	4.5%	1	--	3.88%
	RUN	166	21.8%	24.7%	5	--	22.7%	5	--	4.94%
	POOL	229	40.7%	46.2%	11	--	50.0%	4	--	4.20%
Totals	697	100.0%	100.0%	22	--	100.0%	13	--	--	
Rubicon River at Confluence with Long Canyon Creek										
R3.5/LC0.0	CAS	3	1.8%	--	0	0	0.0%	0	0	--
	HGR	13	11.4%	11.6%	3	0	13.0%	2	0	3.88%
	LGR	16	11.5%	11.7%	2	1	13.0%	2	1	3.90%
	RUN	22	27.2%	27.7%	5	1	26.1%	3	1	4.61%
	POOL	28	48.1%	49.0%	8	3	47.8%	3	2	4.45%
Totals	82	100.0%	100.0%	18	5	100.0%	10	4	--	

<sup>1</sup>Special purpose sediment transport cross-sections.<sup>2</sup>One transect is special purpose (water surface elevation only).<sup>3</sup>One transect is from a step run (STP) mesohabitat unit.

Cas = Cascade, HGR = High Gradient Riffle, LGR = Low Gradient Riffle, Run = Run, Pool = Pool.

Table AQ 1-4b. Reach Habitat Mapping and 2D Instream Flow Study Site Mesohabitat Percentages by Mesohabitat Type.

Reach/Site	Instream Flow Mesohabitat Units	Overall Reach			Instream Flow Site			
		Frequency	% Length	% Length w/o CAS	Frequency	% Length	Total Length (ft)	Weighting Factor Per Habitat Type for Reach
Middle Fork American River at Otter Creek								
MF14.1	CAS	9	2.4%	--	0	0.0%	--	--
	HGR	16	4.5%	4.6%	1	6.9%	276	0.1658
	LGR	31	10.7%	11.0%	3	12.2%	487	0.2262
	RUN	53	28.5%	29.2%	2	27.1%	1084	0.2690
	POOL	60	53.9%	55.2%	4	53.9%	2157	0.2561
	Totals	169	100.0%	100.0%	10	100.0%	4004	
Middle Fork American River near Mammoth Bar								
MF4.8	CAS	3	0.3%	--	0	0.0%	--	--
	HGR	11	2.7%	3%	0	0.0%	--	--
	LGR	20	7.8%	7.9%	3	9.4%	369	0.2128
	RUN	45	29.9%	30.0%	4	36.0%	1417	0.2114
	POOL	51	59.3%	59.5%	5	54.7%	2154	0.2763
	Totals	130	100.0%	100.0%	12	100.0%	3940	--

Cas = Cascade, HGR = High Gradient Riffle, LGR = Low Gradient Riffle, Run = Run, Pool = Pool.

**Table AQ 1-5. Target and Actual Instream Flow Modeling Calibration Flows by Facility.**

Facility/ Location	Current FERC License Instream Flow Requirement <sup>1</sup>	Target Calibration Flow/Release <sup>2</sup>	Actual Calibration Flow/Release
Duncan Creek Diversion Dam	Dry: 4 cfs or natural Wet: 8 cfs or natural	4-8, 16 <sup>3</sup> , 44	3-4, 11-17 <sup>3</sup> , 51-54
North Fork Long Canyon Diversion Dam	All Times: 2 cfs or natural	2, 5 <sup>3</sup> , 11	2, 5 <sup>3</sup> , 15
South Fork Long Canyon Diversion Dam	Dry: 2.5 cfs or natural Wet: 5 cfs or natural	2.5-5, 10 <sup>3</sup> , 21	7, 18 <sup>3</sup> , 29
Long Canyon Creek	None	4.5-7, 15 <sup>3</sup> , 47.5 (NF and SF releases above plus natural accretion)	17, 27 <sup>3</sup> , 53
French Meadows Dam	Dry: 4 cfs Wet: 8 cfs	4-8, 48 <sup>3</sup> , 187	10-16, 54-64 <sup>3</sup> , 181-225
Middle Fork Interbay	Dry: 12 cfs or natural Wet: 23 cfs or natural	12-23, 100 <sup>3</sup> , 374 <sup>4</sup>	17-24, 90 <sup>3</sup> , 188
Below Oxbow Powerhouse	All Times: 75 cfs bl. NF of MF Confluence	75, 368 <sup>3</sup> , 1000 <sup>3</sup> .	101-111, 393-453 <sup>3</sup> , 910-1040
Hell Hole Dam	Dry: 10 cfs June 1 – Oct 14 6 cfs Oct 15 – May 31 Wet: 20 cfs May 15 – Dec 14 10 cfs Dec 15 – May 14	10-20, 80 <sup>3,5</sup> , 315 <sup>5</sup>	23, 66 <sup>3,5</sup> , 77 <sup>5</sup>
Rubicon River Below South Fork Rubicon River	None	10-20 <sup>6</sup> , 104 <sup>6</sup> , 370 <sup>6</sup>	32-49, 77-86 <sup>3</sup> , 130-218

<sup>1</sup>CDWR current year forecast of unimpeded run-off of the American River to Folsom Reservoir: Dry <1,000,000 a/f, Wet > 1,000,000 a/f.

<sup>2</sup>These are target flows identified by the Aquatic TWG.

<sup>3</sup>Flows for velocity data collection.

<sup>4</sup>The canyon is narrow in this reach and 374 cfs may be too high to safely work in the channel. A flow release will be made as close to 374 cfs as can be safely worked.

<sup>5</sup>The facilities at Hell Hole Dam are limited in their release capabilities. The medium flow was reduced to approximately 65 cfs. The highest possible flow was released. The Aquatic TWG was informed regarding the flows to be released and consulted regarding hydraulic model development options.

<sup>6</sup>Hell Hole release plus natural accretion. This is an approximate target.

**Table AQ 1-6. Instream Flow Discharge Modeling Range for Each Study Site.**

Instream Flow Study Reaches / Sites	Model Calibration Discharge (cfs)			Instream Flow Modeling Range (cfs)	Riparian, Geomorphic, Amphibian Special Purpose Modeling Range (cfs)	
	Low	Medium	High			
<b>Duncan Creek</b>						
Duncan Creek upstream of Diversion	D9.0	3.5	17.2	108.7	NA	1.6 - 408
Duncan Creek below Diversion	D8.3	3.3	10.7	50.7	NA	1.6 - 408
	D6.3	3.9	15.6	53.8	1.6 - 110	1.6 - 408
<b>North Fork Long Canyon Creek</b>						
North Fork Long Canyon Creek below Diversion	NFLC1.9	2.1	4.9	14.5	0.8 - 27.5	0.8 - 65
<b>South Fork Long Canyon Creek</b>						
South Fork Long Canyon Creek above Diversion	SFLC4.2	3.5	10.3, 23	33.9	NA	0.1 - 175
South Fork Long Canyon Creek below Diversion	SFLC2.3	7.4	17.7	28.6	1.0 - 52.5	7.4 - 129
<b>Long Canyon Creek</b>						
Long Canyon Creek below North and South Fork Long Canyon Creek	LC9.0	16.8	26.7	52.5	1.8 - 118.8	1.8 - 340
<b>Middle Fork American River Upstream of Middle Fork Interbay</b>						
Middle Fork American River below French Meadows Reservoir	MF44.7	9.8	54.4	181	1.5 - 470	1.5 - 1313
Middle Fork American River Immediately above Middle Fork Interbay	MF36.2	11.8, 15.8	63.8	225	1.5 - 470	1.5 - 1769
<b>Middle Fork American River from Middle Fork Interbay to Ralston Afterbay</b>						
Middle Fork American River between Middle Fork Interbay and Ralston Afterbay	MF26.2	16.6, 24.2	89.6	188.4	5 - 935	5 - 2447
<b>Middle Fork American River Downstream of Ralston Afterbay</b>						
Middle Fork American River below Ralston Afterbay	MF14.1	101.3	392.9	1040.4	10 - 2500 (3000, 4000, 6000, 8000)*	30 - 11171
Middle Fork American River above North Fork American River confluence	MF4.8	111.4	452.5	910.1	10 - 2500 (3000, 4000, 6000, 8000)*	30 - 11369
<b>Rubicon River</b>						
Rubicon River below Hell Hole Reservoir	R25.7	22.6	66.2	76.9	4 - 925	4 - 3576
Rubicon River Near Ellicott Bridge	R20.9	32.4	76.5, 86.3	129.8	4 - 925	4 - 3799
Rubicon River Near Ralston Afterbay	R3.5	36.6, 48.6	82.7	218.1	4 - 925	4 - 6338
<b>Other Tributaries</b>						
North Fork Middle Fork American River	NFMF2.3	15.2	93.9	214.3, 259.5	NA	6 - 3017
North Fork American River	NF31.3	30.2	656.2	1170.8, 1882.7	NA	12 - 8620
North Fork American River	NF35.9	33.4	743.8	1099	NA	13 - 8620
Shirttail Creek - Tributary to North Fork American River	ST0.1	0.8	29.5	59.6	NA	0.3 - 300
North Fork American River	NF53.7	25.8	574.3	1939.4	NA	10 - 7693

\* For some analyses (initiation of gravel movement, time series analysis) flows were modeled to 8000 cfs

Table AQ 1-7. Instream Flow Study Sites and Hydrology Model Nodes.

River / Instream Flow Site	Hydrology Model Nodes		
	Primary Hydrology Node	Downstream Node	Upstream Node
<b>Bypass and Above Diversion Reaches</b>			
<b>Duncan Creek</b>			
Duncan Creek D9.0	800.804/804.805 (same flow)	--	--
Duncan Creek D8.3	800.804/804.805 (same flow)	--	--
Duncan Creek D6.3	800.804/804.805 (same flow)	805.806	--
<b>Upper Middle Fork American River</b>			
Middle Fork American River MF44.7	530.802 (dss file)	802.806 + 806 accretion	--
Middle Fork American River MF36.2	806.810	806.810 + 810 accretion	--
Middle Fork American River MF26.2	813.845	--	810.812
<b>Long Canyon Creek</b>			
South Fork Long Canyon SFLC4.2	820.822	--	--
South Fork Long Canyon SFLC2.3	820.822	--	--
North Fork Long Canyon NFLC1.9	817.819	--	--
Long Canyon LC9.0	825.828	830.842	--
<b>Rubicon River</b>			
Rubicon River R25.7	540.832	832.835	--
Rubicon River R20.9	834.836	840.842 + 842 accretion	--
Rubicon River R3.5	842.815	842.815 + 815 accretion	--
<b>Peaking Reach</b>			
Middle Fork American River MF14.1	860.863		855.857
Middle Fork American River MF4.8	866.868	868.870	--
<b>Comparison River Reaches</b>			
<b>North Fork American River</b>			
North Fork American River NF53.7	NF Gage Scaled	--	--
North Fork American River NF36.0	865.868	--	--
North Fork American River NF31.3	865.868	--	--
<b>North Fork Middle Fork American River</b>			
North Fork Middle Fork American River NFMF2.3	849.855	--	--

**Table AQ 1-8. Depth and Velocity Guilds for the Aquatic Species in the Middle Fork Project for use in the Spatial Niche Analysis.**

<b>Guild Name (by water depth / velocity type)</b>	<b>Life Stage</b>	<b>Species Members</b>	<b>Velocity Range (ft/s)</b>	<b>Depth Range (ft)</b>
Very Shallow	All:	Limited use by all species	All	<0.25
Shallow / Slow	Fry:	All Species	0 - 0.6	0.25 - 1.9
	Juvenile:	Hardhead, Sac Sucker, Sac Pikeminnow, Trout California Roach, Sculpin, Speckled Dace		
	Breeding/Tadpole:	Foothill Yellow-Legged Frog		
	Aquatic:	Macroinvertebrates		
Shallow / Medium	Spawning:	Trout Sculpin, Speckled Dace, California Roach	>0.6 - 1.6	0.25 - 1.9
	Juvenile:	Trout, Sac Sucker <sup>1</sup>		
	Aquatic:	Macroinvertebrates		
	Spawning:	Trout Sculpin, Speckled Dace		
Shallow / Fast	Adult:	Sac Sucker <sup>1</sup>	>1.6 - 2.5	0.25 - 1.9
	Aquatic:	Macroinvertebrates		
	Adult:	Hardhead, Sac Pikeminnow, Sac Sucker, Trout		
	Juvenile:	Hardhead, Sac Pikeminnow, Sac Sucker, Trout		
Medium / Slow	Aquatic:	Macroinvertebrates	0 - 0.6	>1.9 - 4.0
	Adult:	Trout, Hardhead, Sac Pikeminnow, Sac Sucker		
	Juvenile:	Trout, Sac Sucker <sup>1</sup>		
Medium / Medium	Aquatic:	Macroinvertebrates	>0.6 - 1.6	>1.9 - 4.0
	Adult:	Sac Sucker <sup>1</sup> , Trout <sup>1</sup>		
	Juvenile:	Hardhead, Sac Pikeminnow, Sac Sucker, Trout		
Medium / Fast	Aquatic:	Macroinvertebrates <sup>1</sup>	>1.6 - 2.5	>1.9 - 4.0
	Adult:	Hardhead, Sac Pikeminnow, Sac Sucker, Trout		
	Juvenile:	Hardhead, Sac Pikeminnow		
Deep / Slow	Aquatic:	Macroinvertebrates <sup>1</sup>	0 - 0.6	>4.0 <sup>+</sup>
	Adult:	Hardhead, Sac Pikeminnow, Sac Sucker, Trout <sup>1</sup>		
	Juvenile:	Hardhead, Sac Pikeminnow		
Deep / Medium	Aquatic:	Macroinvertebrates <sup>1</sup>	>0.6 - 1.6	>4.0 <sup>+</sup>
	Adult:	Sac Sucker <sup>1</sup> , Trout <sup>1</sup>		
Deep / Fast	Aquatic:	Macroinvertebrates <sup>1</sup>	>1.6 - 2.5	>4.0 <sup>+</sup>
	Adult:	Limited use by species except for macroinvertebrates in shallow to medium depth water (0.25 - 4 ft) and velocity less than 4 ft/s		
Very Fast	All:	Limited use by species except for macroinvertebrates in shallow to medium depth water (0.25 - 4 ft) and velocity less than 4 ft/s	>2.5 <sup>+</sup>	All

<sup>1</sup>Limited use in this niche.

**Table AQ 1-9. Instream Flow Cross-sections with Stepped Water Surface Elevations.**

<b>River/Site</b>	<b>No. Cross-sections</b>	<b>Cross-section ID</b>
Duncan Creek		
D6.3	4	9, 18, 20, 22
South Fork Long Canyon Creek		
SFLC2.3	1	10
Long Canyon Creek		
LC9.0	1	17
Middle Fork American River		
MF26.2	1	14
Rubicon River		
R20.9	1	5
R3.5	1	1

**Table AQ 1-10. Impaired and Unimpaired Hydrology Summary for each Instream Flow Study Site.**

Instream Flow Study Reaches / Sites	Hydrology Model Node	Impaired or Unimpaired	September and October Mean Flow (cfs)	Minimum Flow (cfs)	10% Mean Annual Flow	Mean Annual Flow (MAF)	Exceedance Flows (cfs)					Current FERC License Instream Flow Requirement <sup>1</sup>	
							10%	20%	50%	80%	90%		
<b>Duncan Creek</b>													
Duncan Creek below Diversion	D6.3	804.805	IMPAIRED	1.6	0.1	1.4	13.9	17.0	14.0	6.3	1.2	0.8	Dry: 4 cfs or natural Wet: 8 cfs or natural
		804.805	UNIMPAIRED	2.0	0.1	4.0	39.6	112.0	57.0	8.7	1.2	0.8	
<b>North Fork Long Canyon Creek</b>													
North Fork Long Canyon Creek below Diversion	NFLC1.9	817.819	IMPAIRED	0.4	0.02	0.5	5.3	8.8	4.1	2.0	0.4	0.2	All Times: 2 cfs or natural
		817.819	UNIMPAIRED	0.4	0.02	1.0	9.9	28.0	15.4	2.2	0.4	0.2	
<b>South Fork Long Canyon Creek</b>													
South Fork Long Canyon Creek below Diversion	SFLC2.3	820.822	IMPAIRED	0.7	0.04	0.9	9.0	11.3	6.4	3.0	0.6	0.4	Dry: 2.5 cfs or natural Wet: 5 cfs or natural
		820.822	UNIMPAIRED	0.7	0.04	1.8	18.4	51.5	29.4	4.2	0.6	0.4	
<b>Long Canyon Creek</b>													
Long Canyon Creek below North and South Fork Long Canyon Creek	LC9.0	825.828	IMPAIRED	1.8	0.1	3.1	30.5	65.7	31.1	8.1	1.7	1.1	Dry: 2.5 cfs or natural Wet: 5 cfs or natural
		825.828	UNIMPAIRED	1.8	0.1	4.4	44.5	121.3	65.9	9.6	1.7	1.1	
<b>Middle Fork American River Upstream of Middle Fork Interbay</b>													
Middle Fork American River below French Meadows Reservoir	MF44.7	530.802	IMPAIRED	9.5	2.6	2.0	20.2	15.0	12.0	9.7	8.1	5.7	Dry: 4 cfs Wet: 8 cfs
		530.802	UNIMPAIRED	8.2	0.3	17.0	170.1	487.1	262.0	41.8	5.3	3.5	
Middle Fork American River Immediately above Middle Fork Interbay	MF36.2	806.810	IMPAIRED	19.8	5.3	10.5	104.8	254.0	148.0	39.0	18.0	15.0	Dependent on upstream release (see above)
		806.810	UNIMPAIRED	17.4	2.5	26.7	267.2	743.9	437.8	72.7	13.8	9.7	
<b>Middle Fork American River from Middle Fork Interbay to Ralston Afterbay</b>													
Middle Fork American River between Middle Fork Interbay and Ralston Afterbay	MF26.2	813.845	IMPAIRED	35.9	6.2	12.3	122.7	230.4	114.4	45.5	29.5	22.3	Dry: 12 cfs or natural Wet: 23 cfs or natural
		813.845	UNIMPAIRED	39.3	5.1	40.5	404.8	1092.1	669.7	122.1	32.3	21.9	
<b>Middle Fork American River Downstream of Ralston Afterbay</b>													
Middle Fork American River below Ralston Afterbay	MF14.1	860.863	IMPAIRED	488.8	46.9	115.5	1154.5	2356.4	1545.5	754.8	313.6	138.0	All Times: 75 cfs bl. NF of MF Confluence
		860.863	UNIMPAIRED	157.7	23.6	140.2	1402.0	3610.8	2270.1	466.2	129.5	90.2	
Middle Fork American River above North Fork American River confluence	MF4.8	866.868	IMPAIRED	498.3	55.5	118.3	1183.4	2417.0	1595.6	769.4	330.0	149.0	Dependent on upstream release (see above)
		866.868	UNIMPAIRED	167.2	30.9	143.1	1430.9	3674.9	2312.4	480.2	138.4	98.6	

**Table AQ 1-10. Impaired and Unimpaired Hydrology Summary for each Instream Flow Study Site.**

Instream Flow Study Reaches / Sites	Hydrology Model Node	Impaired or Unimpaired	September and October Mean Flow (cfs)	Minimum Flow (cfs)	10% Mean Annual Flow	Mean Annual Flow (MAF)	Exceedance Flows (cfs)					Current FERC License Instream Flow Requirement <sup>1</sup>	
							10%	20%	50%	80%	90%		
Rubicon River													
Rubicon River below Hell Hole Reservoir	R25.7	540.832	IMPAIRED	22.5	0.3	4.2	42.0	27.0	23.0	20.0	12.0	11.0	Dry: 10 cfs June 1 – Oct 14 6 cfs Oct 15 – May 31 Wet: 20 cfs May 15 – Dec 14 10 cfs Dec 15 – May 14
		540.832	UNIMPAIRED	39.2	0.0	40.8	407.6	1144.2	613.1	131.4	18.4	11.1	
Rubicon River Near Ellicott Bridge	R20.9	834.836	IMPAIRED	41.1	8.3	12.1	121.1	201.2	109.6	48.0	33.1	27.1	Dependent on upstream release (see above)
		834.836	UNIMPAIRED	57.8	3.7	48.7	486.8	1297.9	727.9	163.7	36.6	25.4	
Rubicon River Near Ralston Afterbay	R3.5	842.815	IMPAIRED	59.7	8.9	32.2	322.0	753.9	381.4	95.4	54.0	40.4	Dependent on upstream release (see above)
		842.815	UNIMPAIRED	78.4	4.1	69.6	696.2	1781.0	1103.4	234.2	58.9	38.6	

<sup>1</sup>CDWR current year forecast of unimpeded run-off of the American River to Folsom Reservoir: Dry <1,000,000 a/f, Wet > 1,000,000 a/f.

**Table AQ 1-11. Habitat Time Series Summary Results. Impaired Habitat Versus Unimpaired Habitat (↑ means impaired is greater than unimpaired, ↓ means impaired is less than unimpaired, ≈ means impaired and unimpaired are approximately equal).**

Instream Flow Study Reaches / Sites	Hydrology Node	Reach Location	Rainbow Trout Spawning	Rainbow Trout Spawning Depth Sensitivity	Rainbow Trout Adult (June - October)	Rainbow Trout Juvenile (June - October)	Rainbow Trout Fry	Hardhead / Pikeminnow Juvenile (June - October)	Hardhead / Pikeminnow Adult (June - October)	FYLF Egg Mass and Tadpoles	Comments	
<b>Duncan Creek</b>												
Duncan Creek below Diversion	D6.3	804.805	Top	↓ Dry Years	↓ All Years	≈*	≈*	≈	NA	NA	--	*Decrease at 0-20% Exceedance Flows
		805:806	Bottom	↑ All Years	↓ All Years	≈*	≈	≈	NA	NA	--	*Decrease at 0-20% Exceedance Flows
<b>North Fork Long Canyon Creek</b>												
North Fork Long Canyon Creek below Diversion	NFLC1.9	817.819	Center	↓ All Years	↓ All Years	≈	≈	≈	NA	NA	--	
<b>South Fork Long Canyon Creek</b>												
South Fork Long Canyon Creek below Diversion	SFLC2.3	820.822	Center	↓ All Years	↓ All Years	≈*	≈	≈	NA	NA	--	*Decrease at 0-20% Exceedance Flows
<b>Long Canyon Creek</b>												
Long Canyon Creek below North and South Fork Long Canyon Creek	LC9.0	825.828	Top	↓ Dry Years	↓ Dry Years	≈*	≈	≈	NA	NA	--	*Decrease at 0-20% Exceedance Flows
		830:842	Bottom	↑ Most Years	↑ Most Years	≈	≈	≈	NA	NA	--	
<b>Middle Fork American River Upstream of Middle Fork Interbay</b>												
Middle Fork American River below French Meadows Reservoir	MF44.7	530.802	Top	↑ All Years	↓ All Years	↓ Mixed**	↑ All Years*	↑ All Years	NA	NA	--	**Decrease 0-50%, Increase 50 -100% Exceedance Flows
		802:806 + 806 Acc.	Bottom	↑ All Years	↑ Most Years*	≈	↑ All Years	↑ All Years	NA	NA	--	*Decrease in Critically Dry Years
Middle Fork American River Immediately above Middle Fork Interbay	MF36.2	806.810	Top	↑ All Years	↑ Most Years*	↑ All Years*	↑ All Years	↑ All Years	NA	NA	--	*Decrease Critically Dry Years or 0-20% Exceedance
		806:810 + 810 Acc.	Bottom	↑ All Years	↑ Most Years*	↑ Most Years	↑ All Years	↑ All Years	NA	NA	--	*Decrease in Critically Dry Years
<b>Middle Fork American River from Middle Fork Interbay to Ralston Afterbay</b>												
Middle Fork American River between Middle Fork Interbay and Ralston Afterbay	MF26.2	810:812	Top	↑ All Years	↓ BI Norm Years	↓ 0-50% Exceed	≈	↑ All Years	↑ Most Years	≈*	--	*Decrease at 0-40% Exceedance
		813.845	Bottom	↑ All Years	↑ All Years	≈	↑ Most Years	↑ Most Years	↑ Most Years	≈	↑ All Years	* Tadpoles About Equal All Years
<b>Middle Fork American River Downstream of Ralston Afterbay</b>												
Middle Fork American River below Ralston Afterbay	MF14.1	855:857	Top	↓ Most Years <sup>1</sup>	↓ Most Years <sup>1</sup>	↑ All Years	↓ All Years	↓ All Years	↓ All Years	≈	↓ Most Years <sup>1</sup>	<sup>1</sup> For RBT spawning and FYLF see the effective habitat analysis
Middle Fork American River above North Fork American River confluence	MF4.8	855:857	Top	↓ Most Years <sup>1</sup>	↓ Most Years <sup>1</sup>	↑ All Years	↓ All Years	↓ All Years	↓ All Years	≈	↓ Most Years <sup>1</sup>	<sup>1</sup> For RBT spawning and FYLF see the effective habitat analysis
<b>Rubicon River</b>												
Rubicon River below Hell Hole Reservoir	R25.7	540:832	Top	↑ All Years	↓ All Years	↓ Mixed**	≈	↑ All Years	NA	NA	--	**Decrease 0-50%, Increase 50 -100% Exceedance Flows
		832:835	Bottom	↑ All Years	↓ Dry Years	↓ Mixed**	≈	↑ All Years	NA	NA	--	**Decrease 0-50%, Increase 50 -100% Exceedance Flows
Rubicon River Near Ellicott Bridge	R20.9	834.836	Top	↑ All Years	↓ All Years	↓ Mixed**	↑ All Years	↑ All Years	↑ All Years	≈	--	**Decrease 0-50%, Increase 50 -100% Exceedance Flows
		840:842 + 842 Acc.	Bottom	↑ All Years	↑ Some Years*	≈	↑ All Years	↑ All Years	↑ All Years	≈	--	*Decrease Critically Dry Years
Rubicon River Near Ralston Afterbay	R3.5	842:815	Top	↑ All Years	↑ Most Years	≈	↑ All Years	↑ All Years	↑ All Years	≈	↑ All Years*	* Tadpoles About Equal All Years
		842:815 + 815 Acc.	Bottom	↑ All Years	↑ Most Years	≈	↑ All Years	↑ All Years	↑ All Years	≈	↑ All Years*	* Tadpoles About Equal All Years

**Table AQ 1-12. Distances Between Points in Peaking Reach and Associated Water Travel Times.**

Location	River Mile	Use	Distance from Oxbow PH to Location (Miles)	Elapsed Travel Time in Hours <sup>1</sup> (Distance/ 2.5 mph)
<b>Middle Fork American River</b>				
Indian Bar Rafting Access	24.35	Put-in	0	0
USGS Gage No. 11433300	23.10	Gage	1.25	.5
Cache Rock	19.3	Landmark	5.05	2.0
Fords Bar	14.10	Instream Flow Site/Trail crossing	10.25	4.1
Canyon Creek	10.9	Put-in	13.45	5.4
Ruck-a-Chucky	9.22	Take-out/put-in/trail crossing	15.13	6.1
Poverty Bar	6.30	Trail crossing	18.05	7.2
Buckeye Bar	4.8	Instream Flow Site	19.55	7.8
Mammoth Bar	2.15	Take-out/put-in/trail crossing	22.20	8.9
Confluence	0	Take-out/put-in	24.35	9.7
<b>North Fork American River</b>				
Confluence	20.95	Take-out/put-in	24.35	9.7
Birdsall Access (Coffer Dam Crossing)	17.30	Take-out/put-in/trail crossing	28.00	11.2
Oregon Bar	15.65	Take-out	29.65	11.9

<sup>1</sup>Travel time assumes a base flow of 200 cfs and a peak flow of approximately 1,000 cfs. Travel time changes depending upon the base flow and the peak flow. For example, water travel time is faster when the base flow is higher or when the peak flow is higher.

Table AQ 1-13. Flow Arrival Time by Location.

Release Time	Indian Bar Rafter Access	USGS Gage No. 11433300	Cache Rock	Fords Bar (IF Site)	Canyon Creek	Ruck-a-Chucky	Poverty Bar	Buckeye Bar (IF Site)	Mammoth Bar	Confluence	Birdsall Access	Oregon Bar Access
12:00 AM	12:00 AM	12:30 AM	2:00 AM	4:00 AM	5:30 AM	6:00 AM	7:15 AM	7:45 AM	9:00 AM	9:45 AM	11:15 AM	12:00 PM
2:00 AM	2:00 AM	2:30 AM	4:00 AM	6:00 AM	7:30 AM	8:00 AM	9:15 AM	9:45 AM	11:00 AM	11:45 AM	1:15 PM	2:00 PM
4:00 AM	4:00 AM	4:30 AM	6:00 AM	8:00 AM	9:30 AM	10:00 AM	11:15 AM	11:45 AM	1:00 PM	1:45 PM	3:15 PM	4:00 PM
6:00 AM	6:00 AM	6:30 AM	8:00 AM	10:00 AM	11:30 AM	12:00 PM	1:15 PM	1:45 PM	3:00 PM	3:45 PM	5:15 PM	6:00 PM
8:00 AM	8:00 AM	8:30 AM	10:00 AM	12:00 PM	1:30 PM	2:00 PM	3:15 PM	3:45 PM	5:00 PM	5:45 PM	7:15 PM	8:00 PM
10:00 AM	10:00 AM	10:30 AM	12:00 PM	2:00 PM	3:30 PM	4:00 PM	5:15 PM	5:45 PM	7:00 PM	7:45 PM	9:15 PM	10:00 PM
11:00 AM	11:00 AM	11:30 AM	1:00 PM	3:00 PM	4:30 PM	5:00 PM	6:15 PM	6:45 PM	8:00 PM	8:45 PM	10:15 PM	11:00 PM
12:00 PM	12:00 PM	12:30 PM	2:00 PM	4:00 PM	5:30 PM	6:00 PM	7:15 PM	7:45 PM	9:00 PM	9:45 PM	11:15 PM	12:00 AM
2:00 PM	2:00 PM	2:30 PM	4:00 PM	6:00 PM	7:30 PM	8:00 PM	9:15 PM	9:45 PM	11:00 PM	11:45 PM	1:15 AM	2:00 AM
4:00 PM	4:00 PM	4:30 PM	6:00 PM	8:00 PM	9:30 PM	10:00 PM	11:15 PM	11:45 PM	1:00 AM	1:45 AM	3:15 AM	4:00 AM
6:00 PM	6:00 PM	6:30 PM	8:00 PM	10:00 PM	11:30 PM	12:00 AM	1:15 AM	1:45 AM	3:00 AM	3:45 AM	5:15 AM	6:00 AM
8:00 PM	8:00 PM	8:30 PM	10:00 PM	12:00 AM	1:30 AM	2:00 AM	3:15 AM	3:45 AM	5:00 AM	5:45 AM	7:15 AM	8:00 AM
10:00 PM	10:00 PM	10:30 PM	12:00 AM	2:00 AM	3:30 AM	4:00 AM	5:15 AM	5:45 AM	7:00 AM	7:45 AM	9:15 AM	10:00 AM
12:00 AM	12:00 AM	12:30 AM	2:00 AM	4:00 AM	5:30 AM	6:00 AM	7:15 AM	7:45 AM	9:00 AM	9:45 AM	11:15 AM	12:00 PM
Distance (miles)	0	1.25	5.05	10.25	13.45	15.13	18.05	19.55	22.20	24.35	28.00	29.65
Travel Time <sup>1</sup> (hrs)	0	0:30	2:00	4:00	5:30	6:00	7:15	7:45	9:00	9:45	11:15	12:00

<sup>1</sup>Travel time is 2.5 mph and assumes a base flow of 200 cfs and a peak flow of 1,000 cfs. Travel time is faster when either base flow or peak flow increases. Travel time is rounded to the nearest 15 minute increment.

**Table AQ 1-14. Summary of Flow in the Middle Fork American River Main Channel Versus Stage near the Entrance to the Horseshoe Bar Historic Natural Channel (Entrance Elevation = 103.96 ft).**

Discharge (cfs)	Stage (ft) <sup>1</sup>	Date	Time of Peak	Photograph <sup>2</sup>	Photograph Comment
Year 2009					
6678	100.20	2/24/2009	8:00	Yes	Photo taken at 9:30
11007	101.34	3/2/2009	19:00	No	--
5615	99.48	5/5/2009	14:00	Yes	Photo of 4850 cfs at 19:30
3045	98.11	3/5/2009	0:45	No	--
Year 2006					
36369	105.86 <sup>3</sup>	12/31/2005	11:00	No	--

<sup>1</sup>Relative stage based on a benchmark set at a relative elevation of 100 ft.

<sup>2</sup>Photographs located in Figure AQ 1-13.

<sup>3</sup>Estimated stage from stage-discharge regression (Stage = 0.78892 Q<sup>0.280517</sup> + 90.69).

**FIGURES**

**Figure AQ 1-1. Technical Study Plan Objectives and Study Elements.**

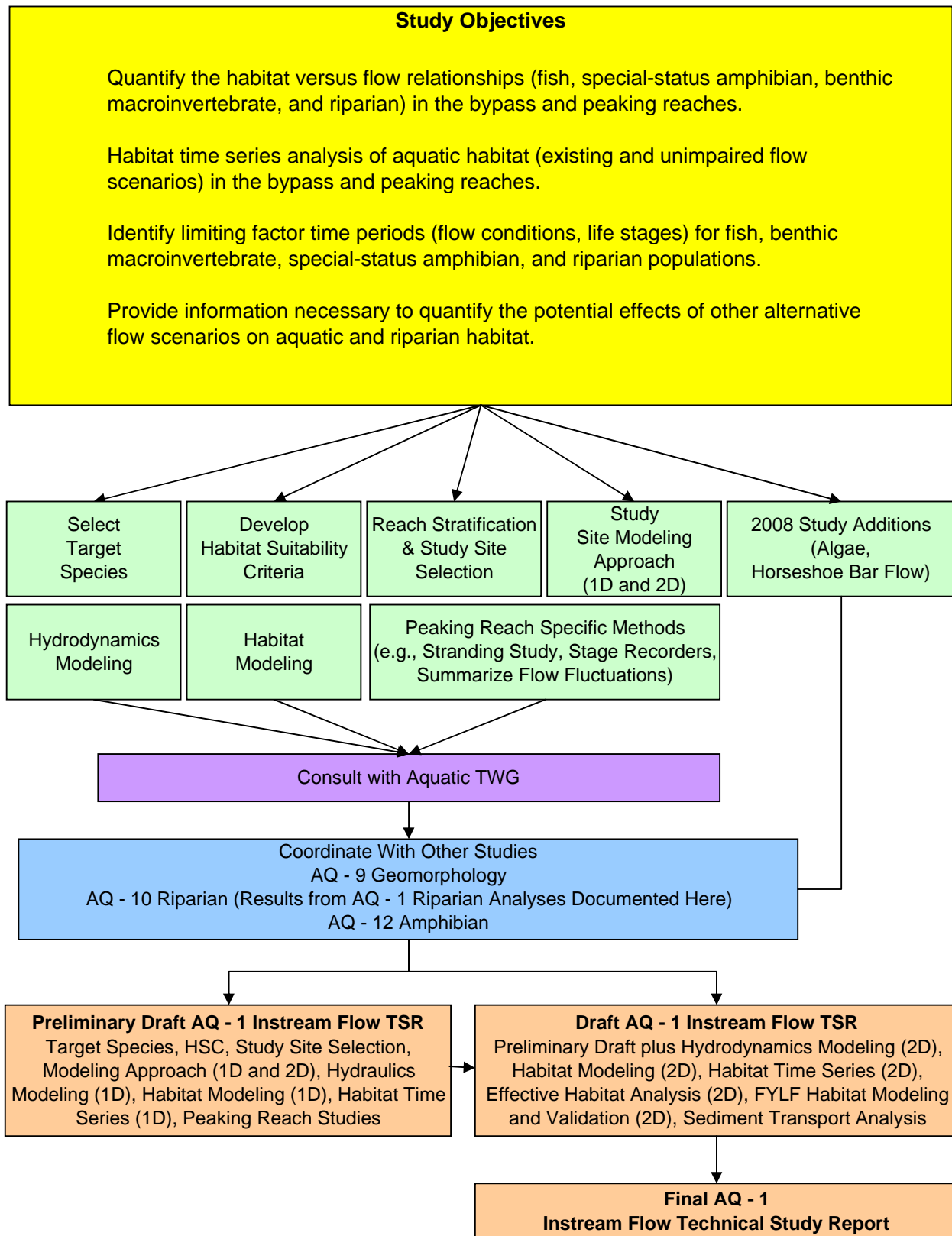
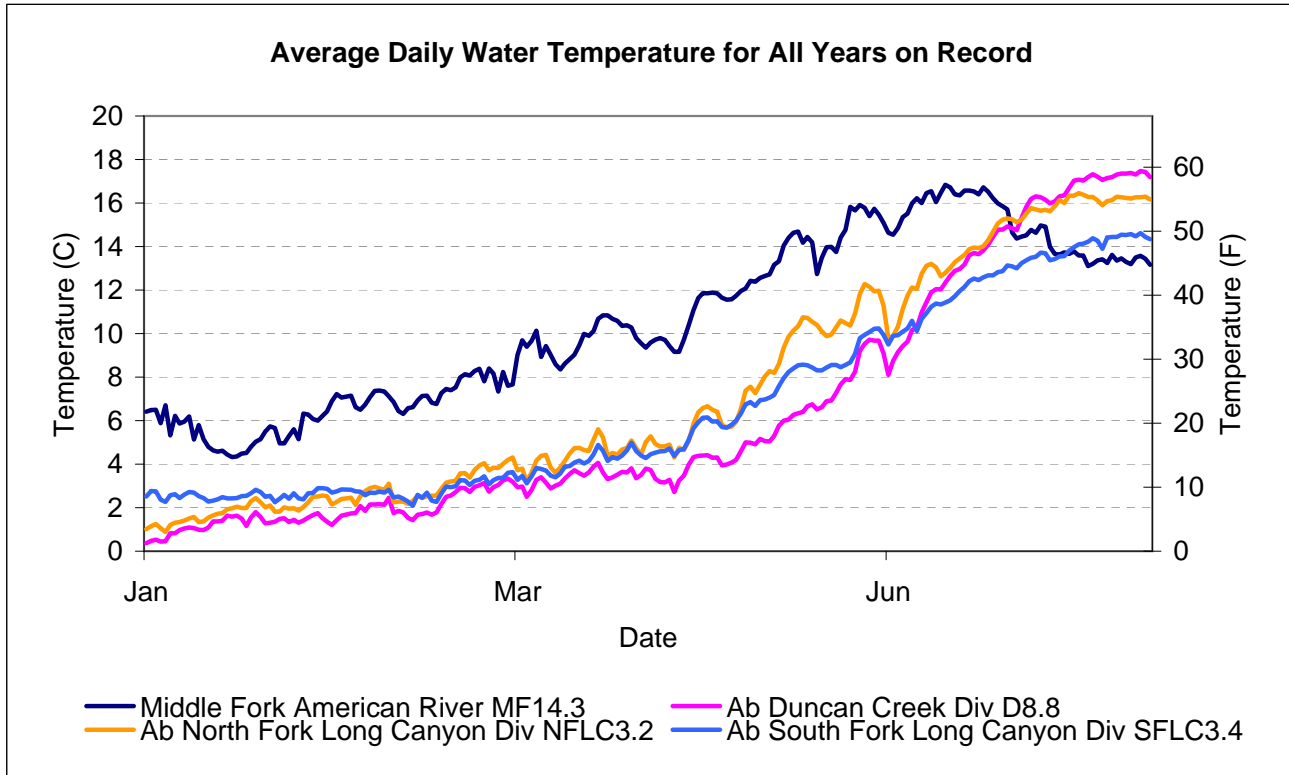


Figure AQ 1-2. Periodicity Chart for Aquatic Species and Life Stages in the Middle Fork Project.

Species	Month											
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
<b>Rainbow Trout</b>												
Spawning												
Incubation												
Fry												
Juvenile												
Adult												
<b>Brown Trout</b>												
Spawning												
Incubation												
Fry												
Juvenile												
Adult												
<b>Sacramento Pikeminnow</b>												
Spawning												
Incubation												
Fry												
Juvenile												
Adult												
<b>Hardhead</b>												
Spawning												
Fry												
Juvenile												
Adult												
<b>California Roach</b>												
Spawning												
Incubation												
Fry												
Juvenile												
Adult												
<b>Sacramento Sucker</b>												
Spawning												
Incubation												
Fry												
Juvenile												
Adult												
<b>Speckled Dace</b>												
Spawning												
Incubation												
Fry												
Juvenile												
Adult												
<b>Sculpin<sup>1</sup></b>												
Spawning												
Incubation												
Fry												
Juvenile												
Adult												
<b>Foothill Yellow-Legged Frog</b>												
Breeding												
Incubation												
Tadpoles												
Juvenile												
Adult												

<sup>1</sup>Sculpin refers to both ruffle sculpin and prickly sculpin.

**Figure AQ 1-3. Average Daily Water Temperature for All Years on Record<sup>1</sup> in the Peaking Reach (MF14.3) Compared to above Small Stream Diversion Temperatures<sup>2</sup> (Duncan Creek D8.8, North Fork Long Canyon NFLC3.2, South Fork Long Canyon SFLC3.4).**



<sup>1</sup>Years on record: MF14.3 (2005, 2006, 2007, 2008); D8.8 (2004, 2005, 2007, 2008, 2009); NFLC3.2 (2005, 2007, 2008, 2009); SFLC3.4 (2004 - 2009).

<sup>2</sup>Logger ID#: MF14.3 (875833, 875832, 1018173); D8.8 (1048905, 1018178, 829413, 680548); NFLC3.2 (829439, 1018159, 829438); SFLC3.4 (875813, 1018176). Primary logger was used if complete, redundant logger used to fill gaps.

**Figure AQ 1-4. Pressure Transducer Installation for Stage Monitoring.**

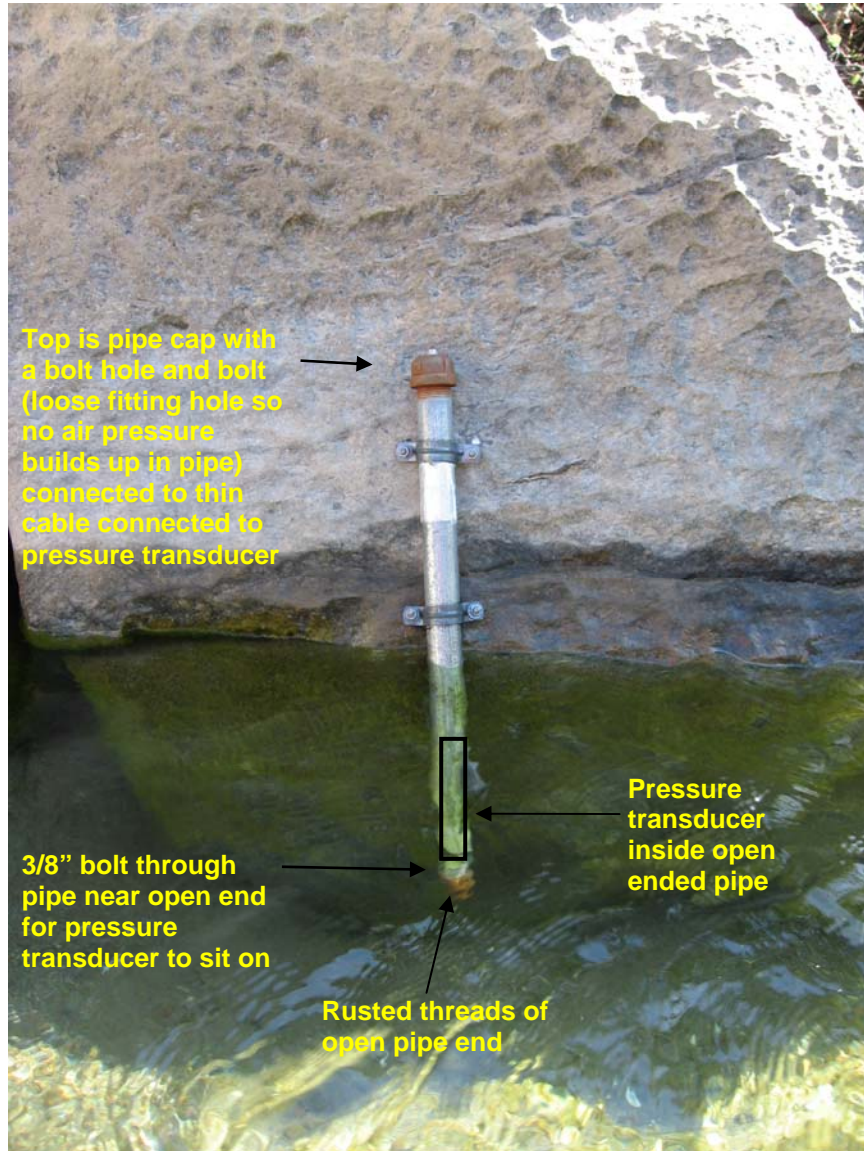
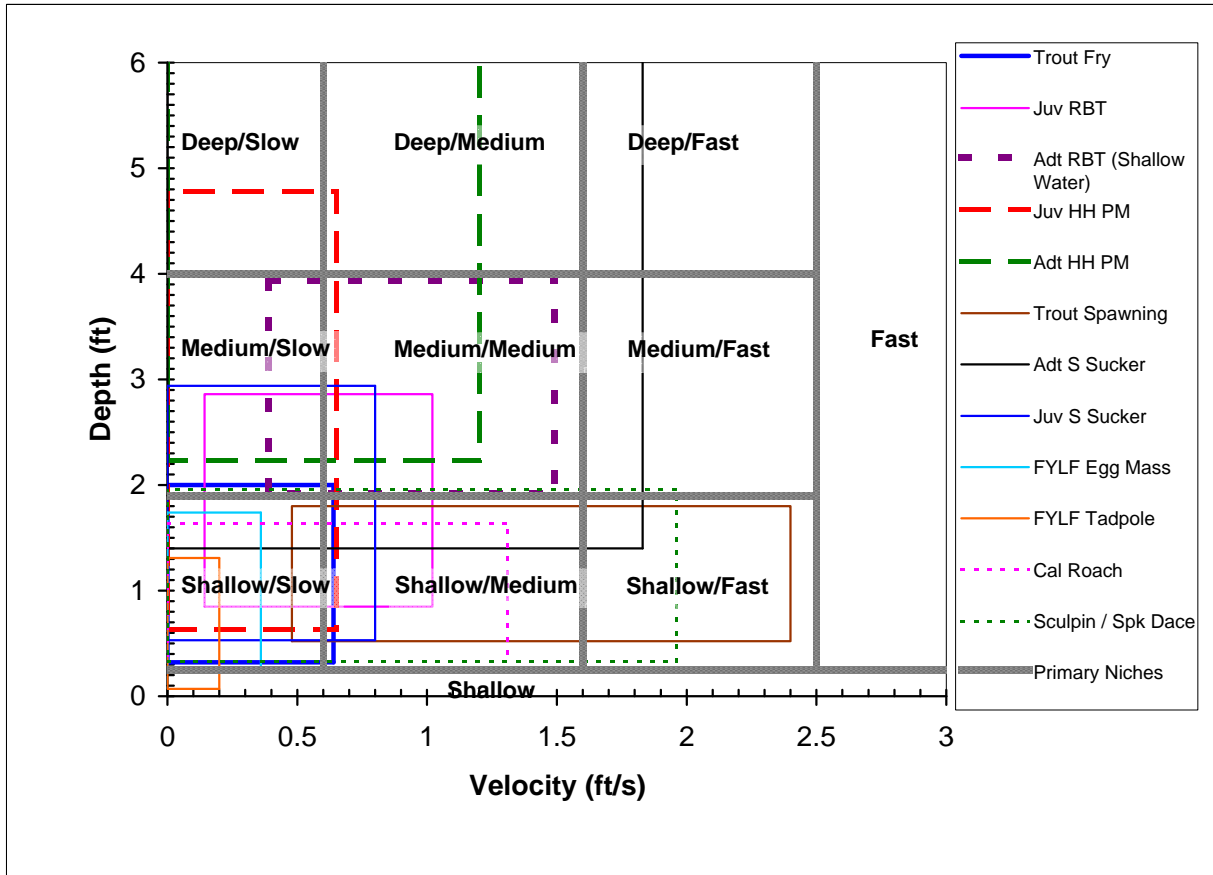
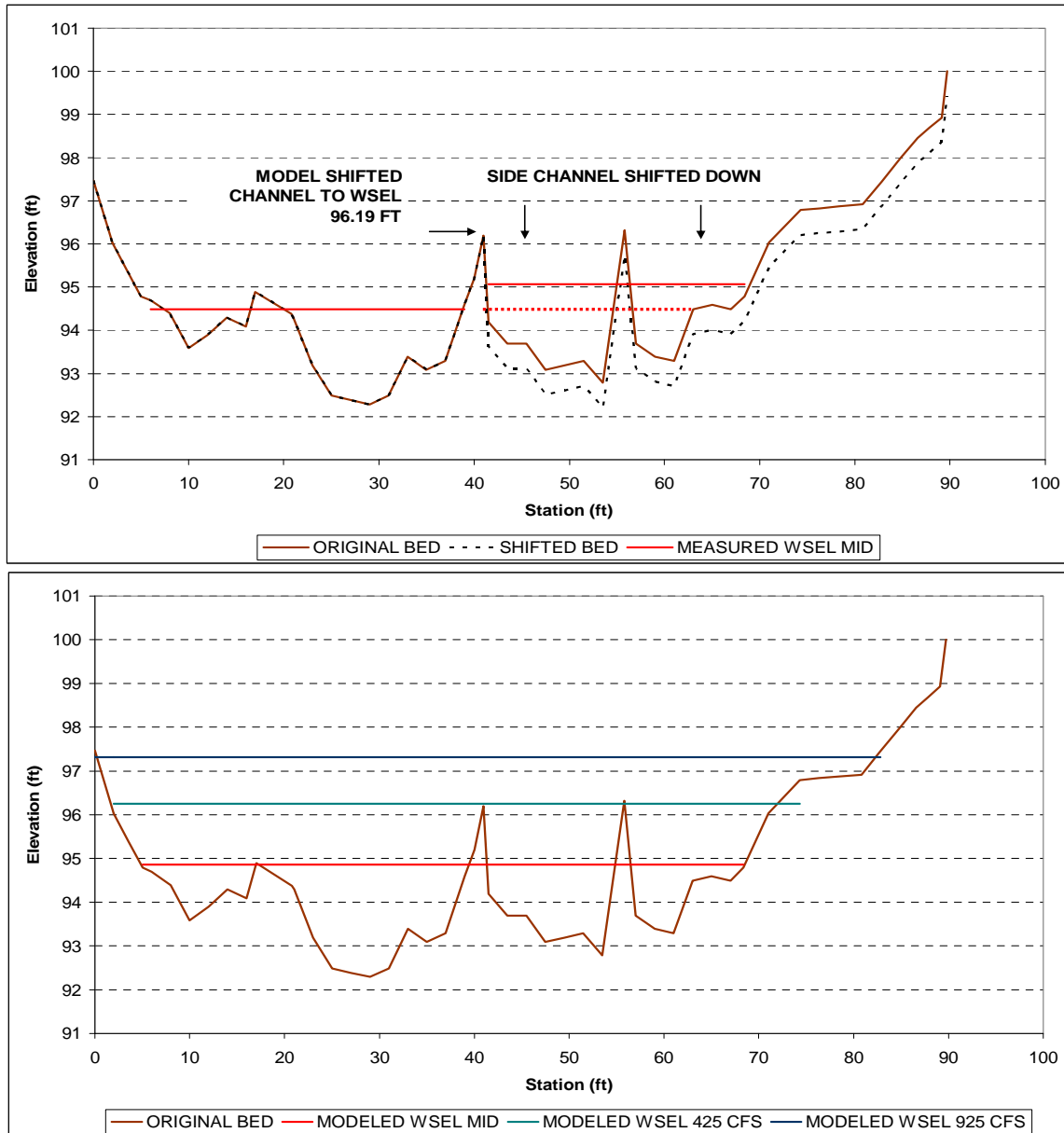


Figure AQ 1-5. Depth and Velocity Guilds for the Aquatic Species in the Middle Fork Project for Use in the Spatial Niche Analysis.

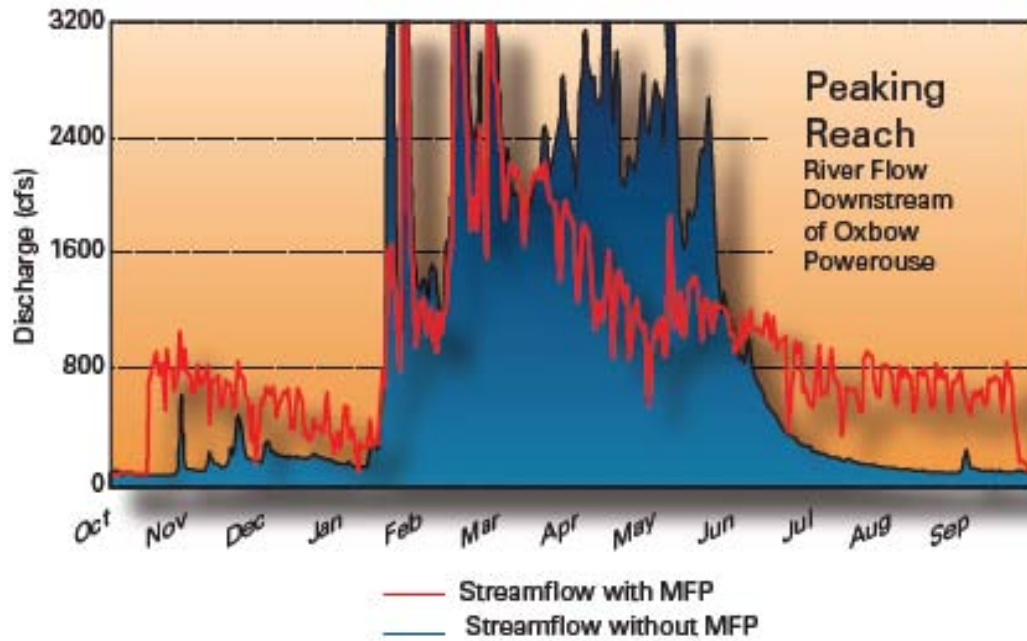


Fry = Rainbow Trout, RBT = Rainbow Trout, HH = Hardhead, PM = Sacramento Pikeminnow, Spawn = Trout Spawning, S = Sacramento, FYLF = Foothill Yellow-Legged Frog, Cal = California, Spk = Speckled, Juv = Juvenile, Adt = Adult

**Figure AQ 1-6. Modeling Methodology for Stepped Water Surface Elevations: Channel Used to Model Flows at Rubicon 3.5, Transect 1 from 4 to 425 cfs (top) and from 425 to 925 cfs (bottom).**



**Figure AQ 1-7. Example of Project Modification of Flows in the Peaking Reach (Mean Daily Flows).**



Note: Peaking operations at Oxbow Powerhouse may result in substantial fluctuations of flow in the peaking reach.

**Figure AQ 1-8. Idealized Examples of Releases from Oxbow Powerhouse During Wet, Above Normal, Below Normal, Dry, and Critically Dry Years.**

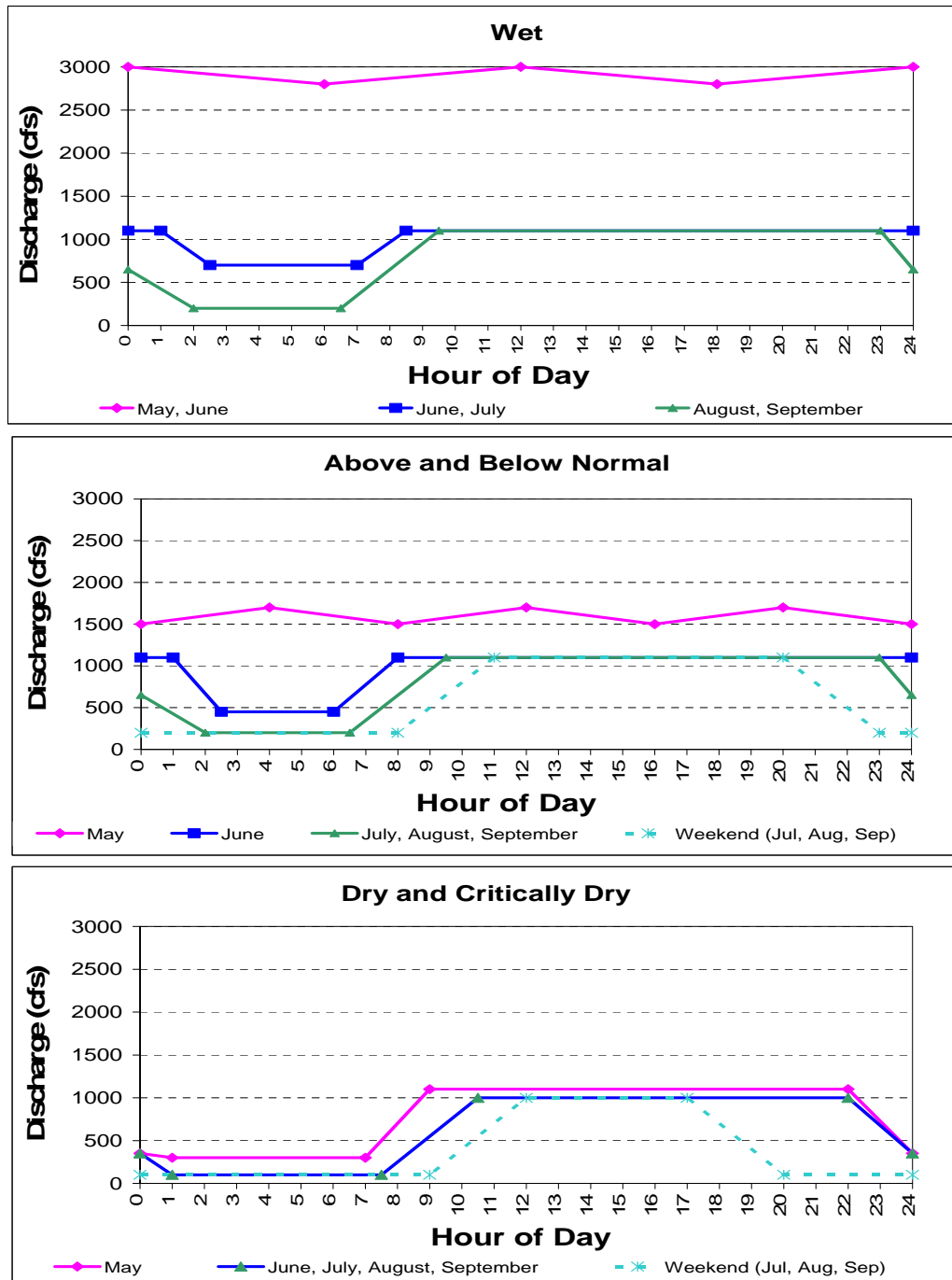
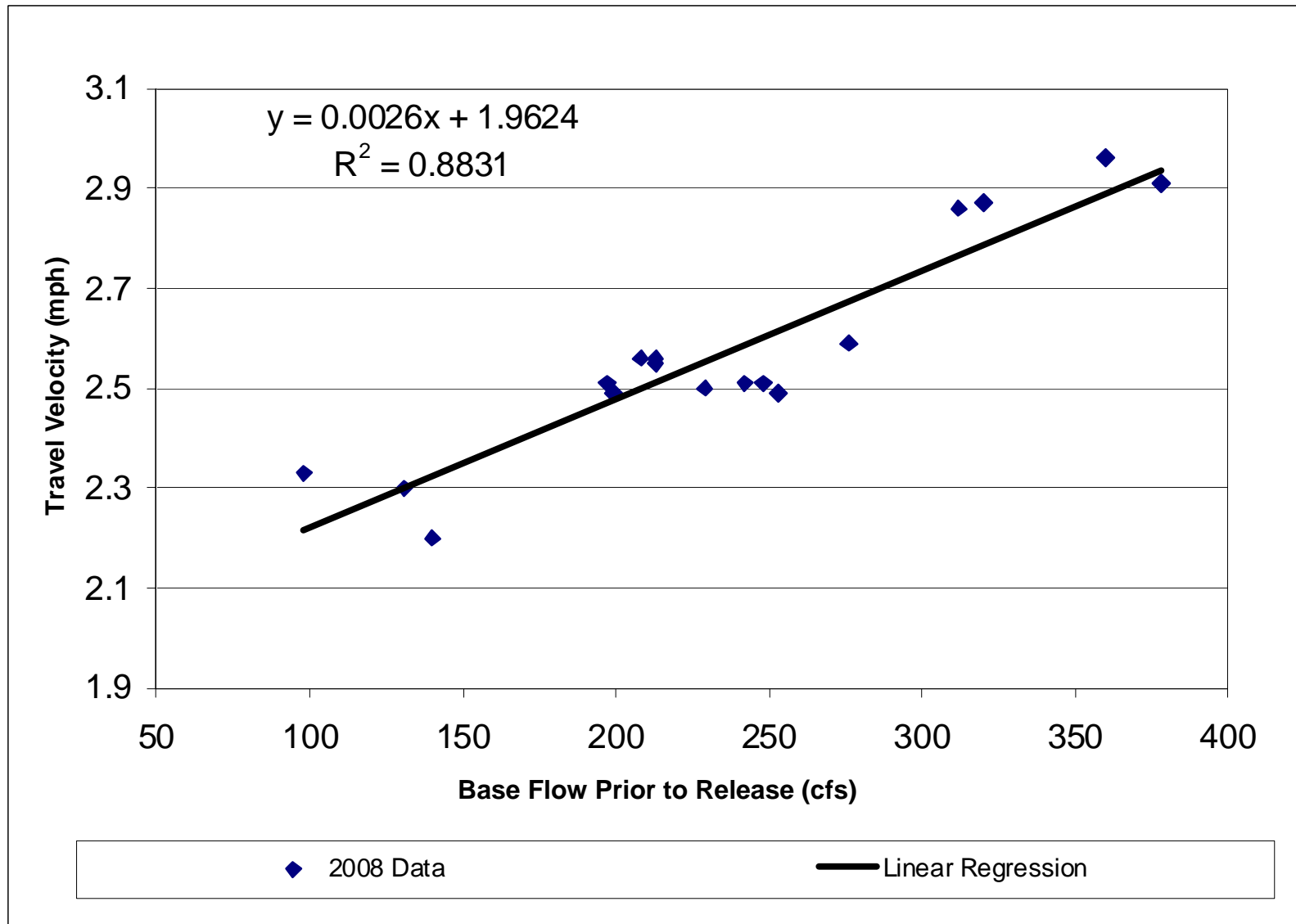
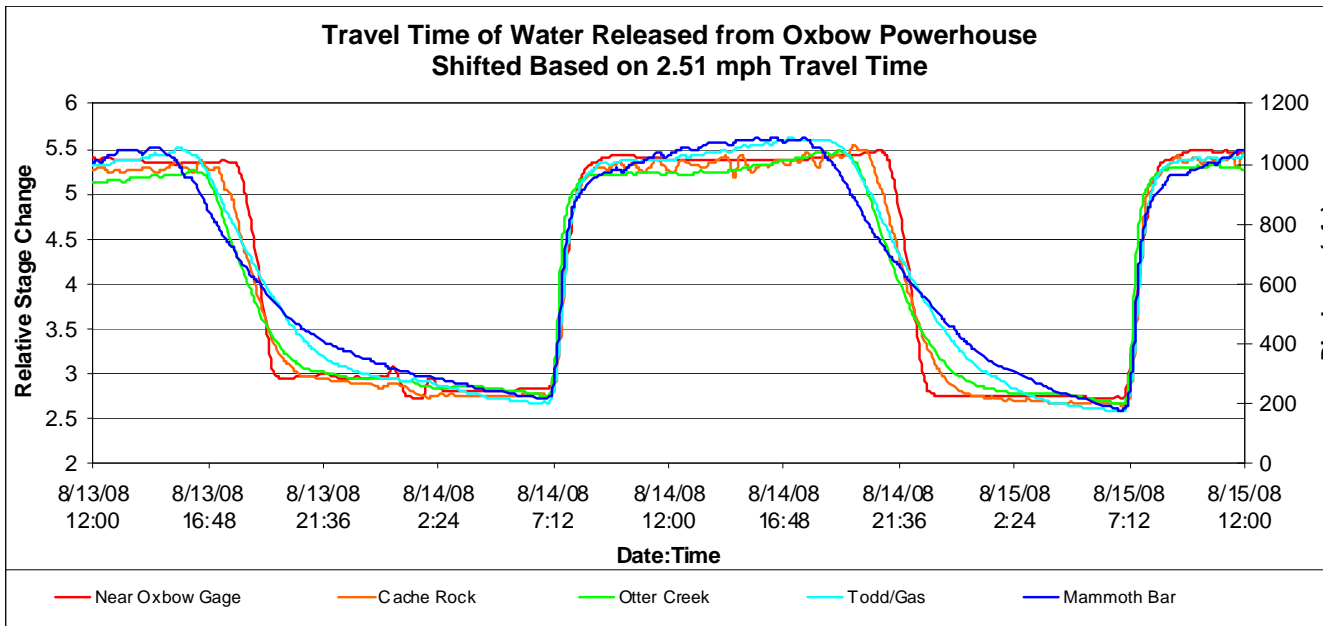
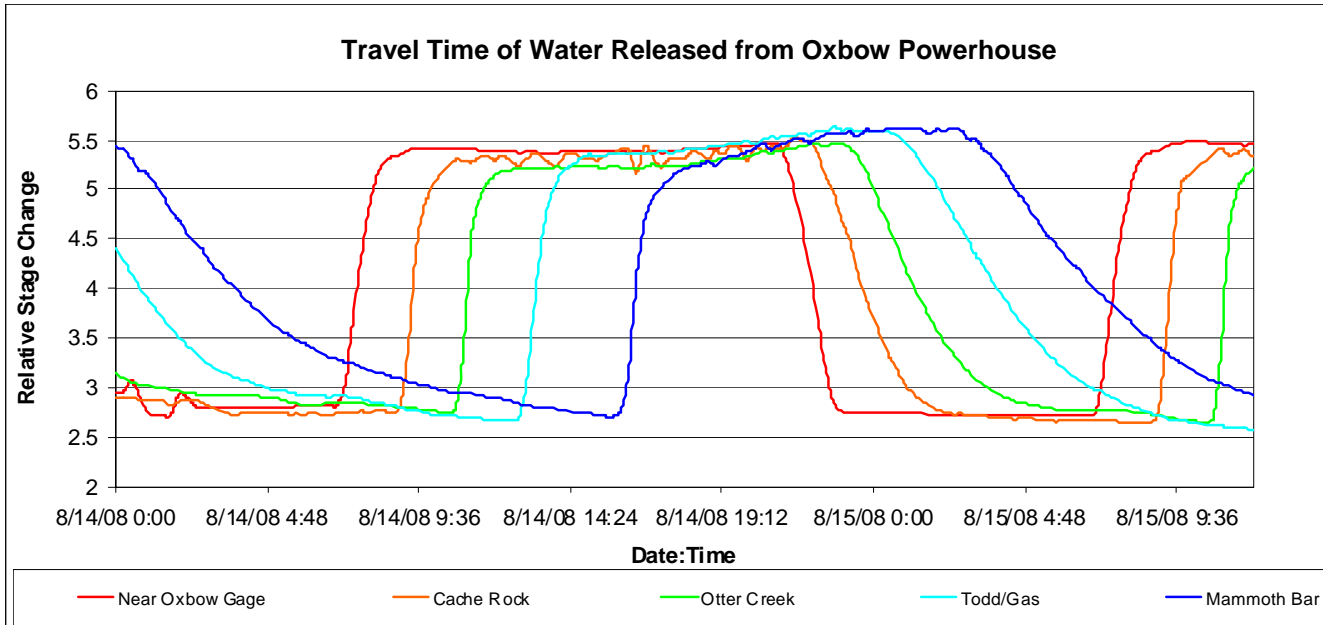
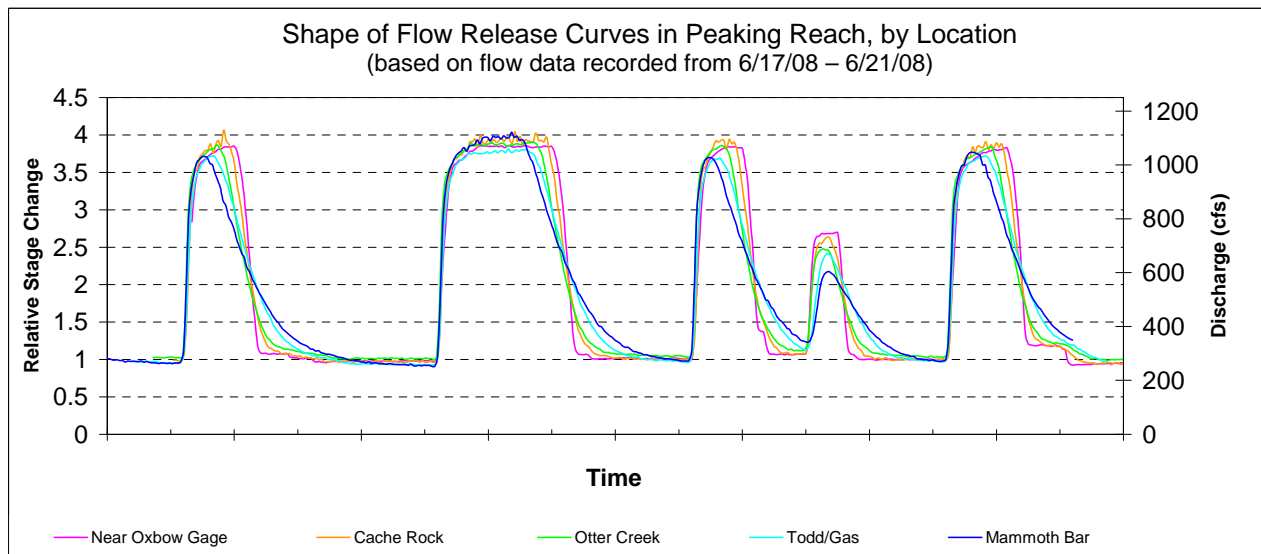


Figure AQ 1-9. Peaking Reach Base Flow/Travel Velocity Relationship.



**Figure AQ 1-10. Water Travel Time during Up-ramp and Down-ramp.**



**Figure AQ 1-11. Shape of Flow Release Curves in Peaking Reach by Location.**

This figure shows the shape of the flow release curves at different locations in the peaking reach. Each curve has been shifted to overlie the curve near the Oxbow gage to illustrate the following points:

- In general, the up-ramp from low base flow to high peaking flow, in terms of discharge (e.g., change in cfs per hour) remains the same throughout the reach.
- The shape of the flow release curve changes with location in the peaking reach. The farther downstream, the narrower the width of the top of the curve and the slower the down-ramp.
- The slope of the down-ramp changes as the peak travels downstream. At the top of the reach, the down-ramps are relatively rapid with decreases in flow at a rate similar to the up-ramp rate (250 to 450 cfs/hr, 3 hours to down-ramp). Down-ramps are slower and have a longer duration (slower down-ramp rate) depending on the distance downstream.

Figure AQ 1-12. Stage-Discharge Curve in the Middle Fork American River Main Channel Versus Stage at the Entrance to the Historical Natural Horseshoe Bar Channel.

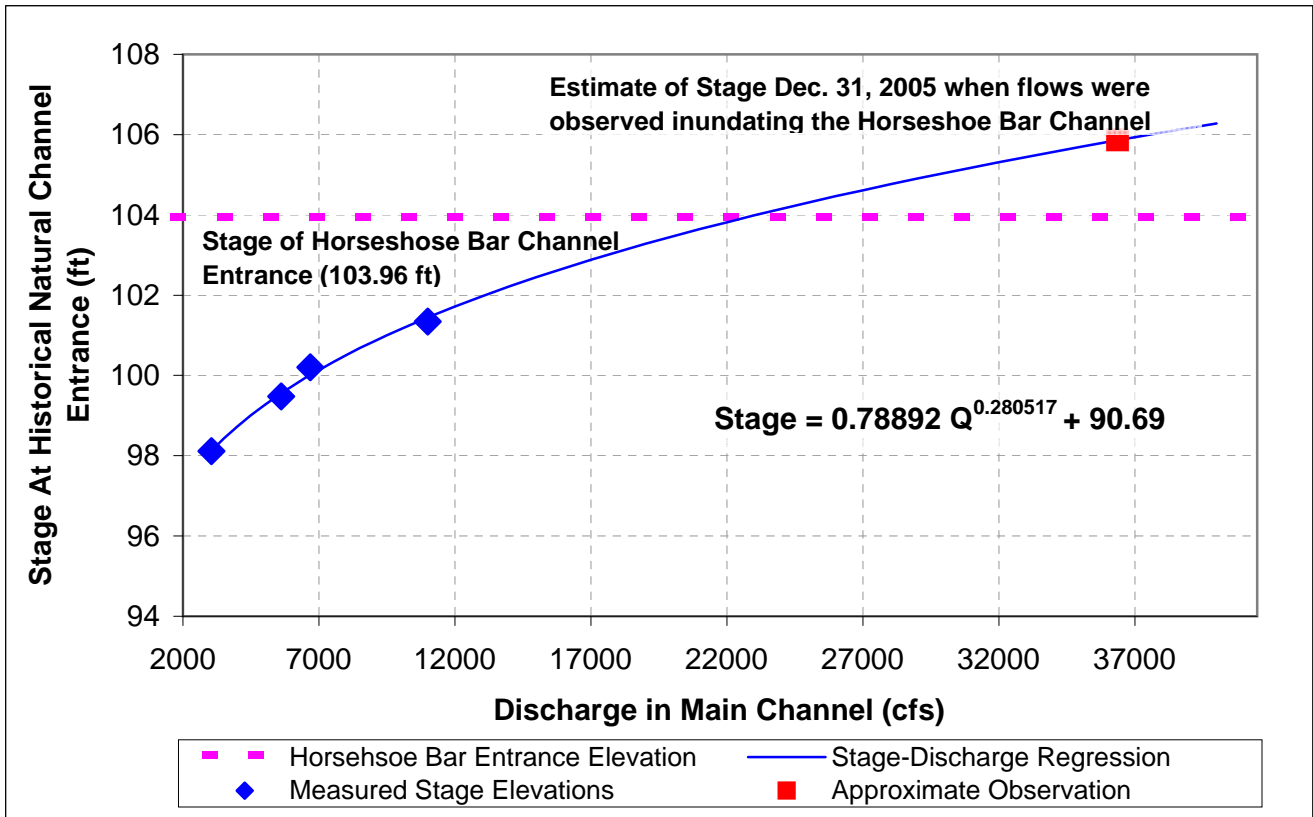
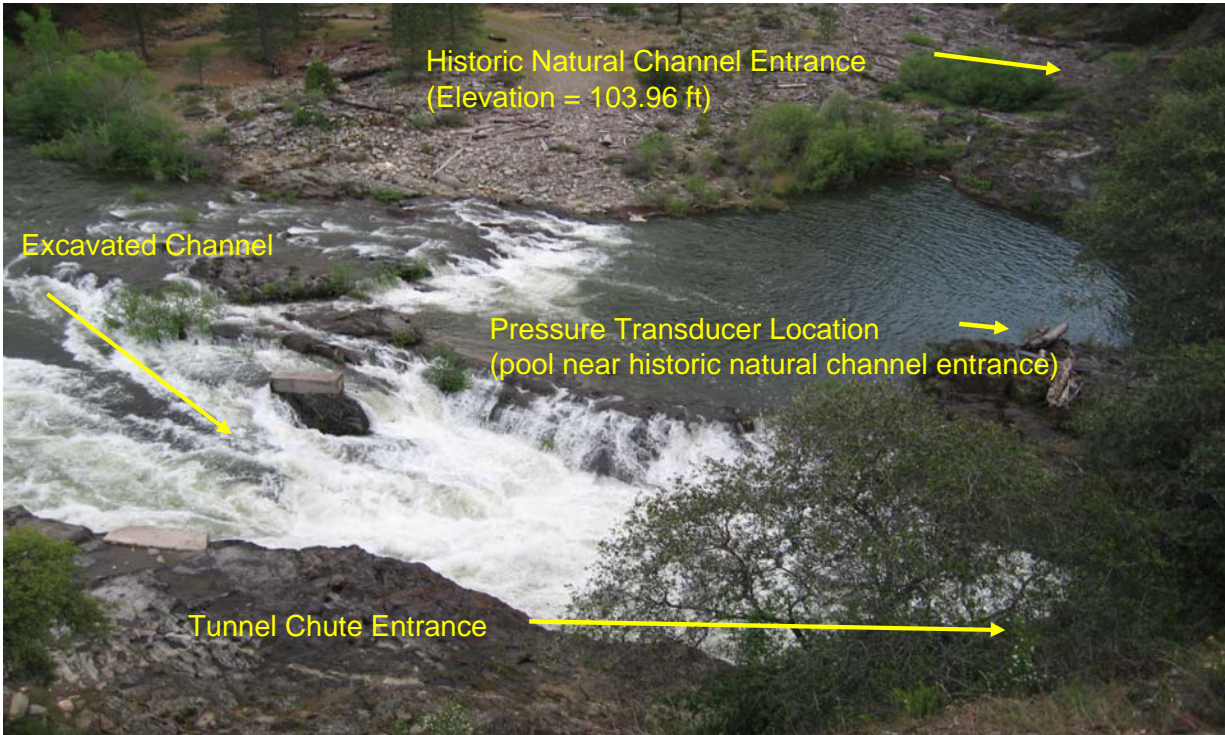


Figure AQ 1-13. Pictures of the Horseshoe Bar and Tunnel Chute Area at Moderately High Flows: 4900 cfs (top) and 6700 cfs (bottom).



**MAPS**

**APPENDIX A**

**Juvenile and Adult Rainbow Trout  
Habitat Suitability Criteria (Developed from Habitat Use Data)**

**List of Figures**

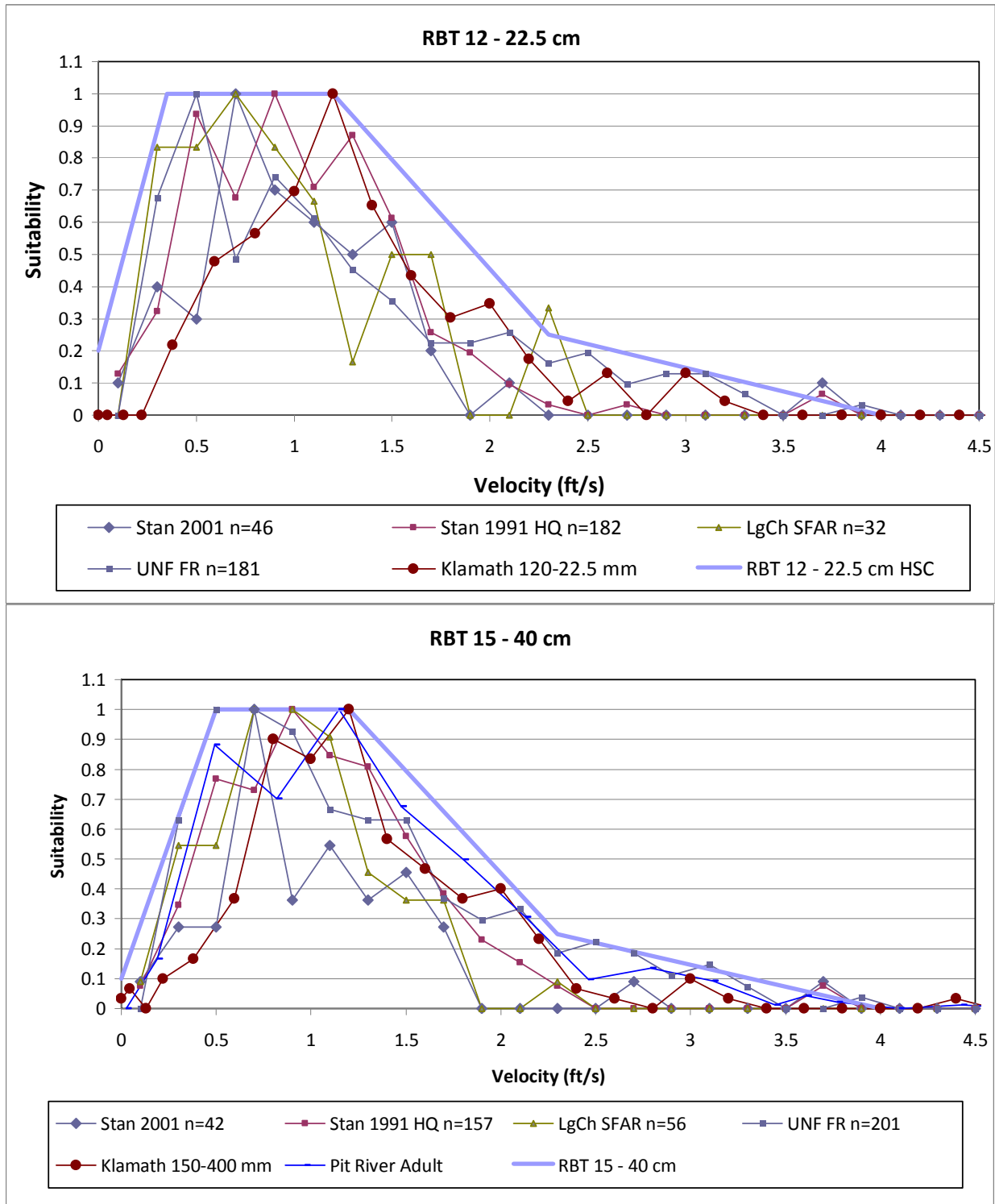
- Figure A-1a. Rainbow trout adult velocity suitability criteria for small stream size fish (top) and larger river size fish (bottom) enveloped on the Stanislaus 2001, Stanislaus 1991, South Fork American River, and Upper North Fork Feather River habitat use data.
- Figure A-1b. Rainbow trout adult depth suitability criteria for small stream size fish (top) and larger river size fish (bottom) enveloped on the Stanislaus 2001, Stanislaus 1991, South Fork American River and Upper North Fork Feather River habitat use data.
- Figure A-2a. Rainbow trout juvenile velocity suitability criteria for small stream size fish (top) and larger river size fish (bottom) enveloped on the Stanislaus 2001, Stanislaus 1991, South Fork American River, and Upper North Fork Feather River habitat use data.
- Figure A-2b. Rainbow trout juvenile depth suitability criteria for small stream size fish (top) and larger river size fish (bottom) enveloped on the Stanislaus 2001, Stanislaus 1991, South Fork American River, and Upper North Fork Feather River habitat use data.
- Figure A-3. MFP HSC for small stream size fish juveniles (5-12 cm) and adults (12-22.5 cm) compared to UARP small stream HSC and small stream data: use (U), availability (A), and adjusted preference (U/A).
- Figure A-4. Small stream rainbow trout juvenile velocity and depth suitability.
- Figure A-5. Large river rainbow trout juvenile velocity and depth suitability.
- Figure A-6. Small stream rainbow trout adult velocity and depth suitability and sensitivity analyses.
- Figure A-7. Large river rainbow trout adult velocity and depth suitability and sensitivity analyses.

**List of Attachments**

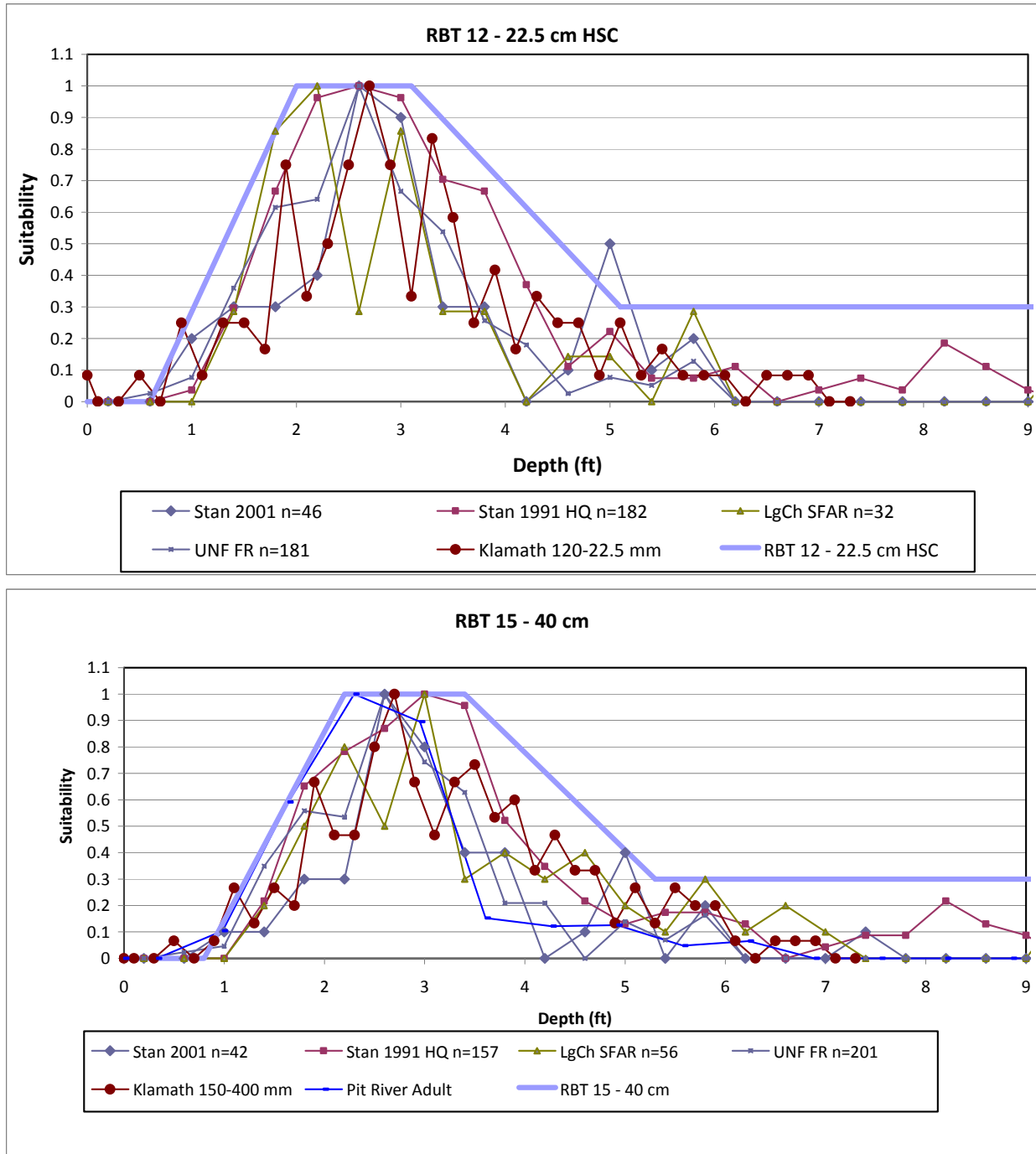
- Attachment A. MFP Adult and Juvenile Rainbow Trout Enveloped Habitat Suitability Criteria and Habitat Use Datasets.
- Attachment B. MFP Adult and Juvenile Rainbow Trout Enveloped Habitat Suitability Criteria and Habitat Use (U), Availability (A), and Adjusted Preference Datasets.
- Attachment C. MFP Adult and Juvenile Rainbow Trout Enveloped Habitat Suitability Criteria (HSC) and Stanislaus Project and Upper American River Project Habitat HSC.

**FIGURES**

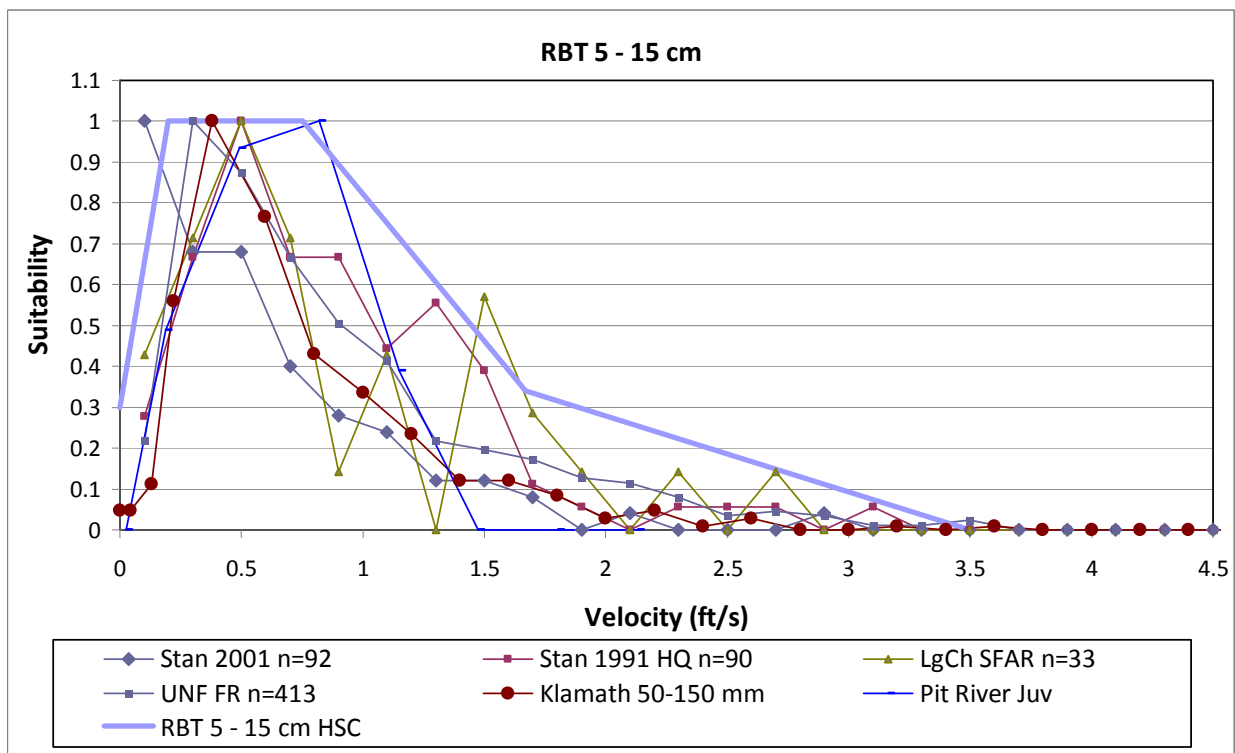
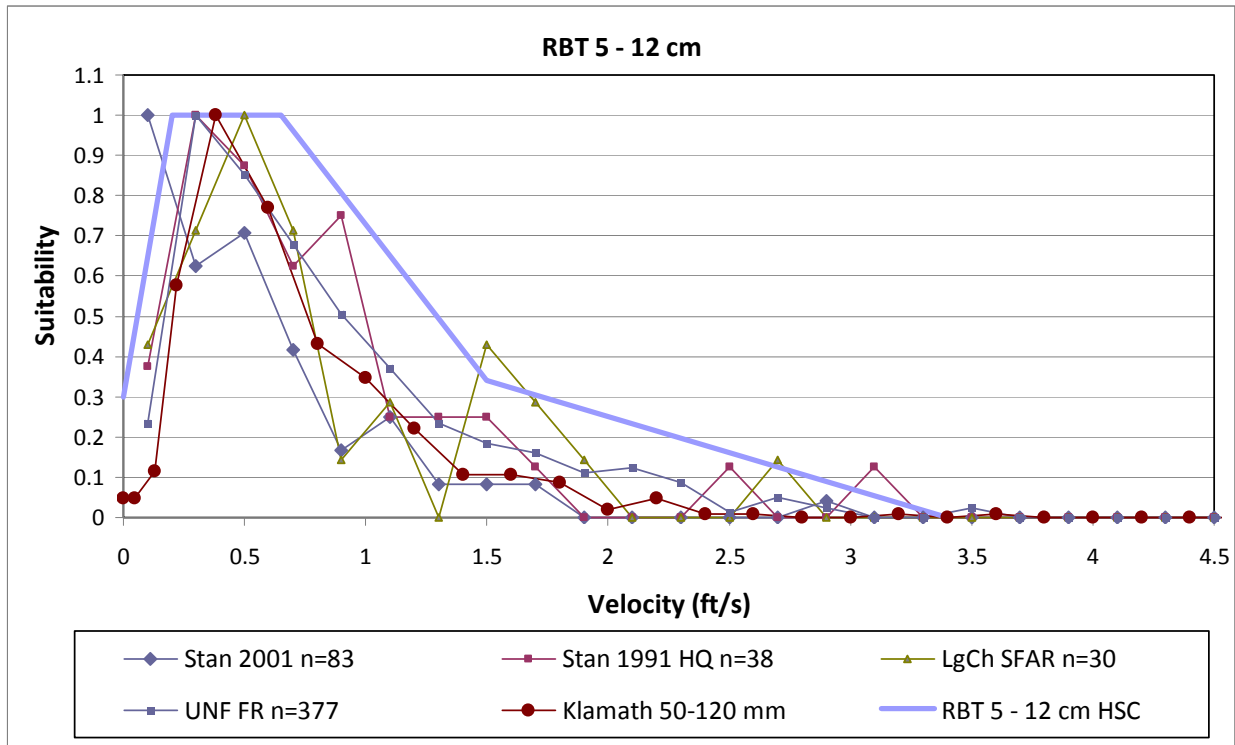
**Figure A-1a. Rainbow trout adult velocity suitability criteria for small stream size fish (top) and larger river size fish (bottom) enveloped on the Stanislaus 2001, Stanislaus 1991, South Fork American River, and Upper North Fork Feather River habitat use data. Two “validation” data sets are also included: the Klamath River data for both fish sizes and the Pit River data for the largest adult fish size.**



**Figure A-1b. Rainbow trout adult depth suitability criteria for small stream size fish (top) and larger river size fish (bottom) enveloped on the Stanislaus 2001, Stanislaus 1991, South Fork American River and Upper North Fork Feather River habitat use data. Two “validation” data sets are also included: the Klamath River data for both fish sizes and the Pit River data for the largest adult fish size.**



**Figure A-2a. Rainbow trout juvenile velocity suitability criteria for small stream size fish (top) and larger river size fish (bottom) enveloped on the Stanislaus 2001, Stanislaus 1991, South Fork American River, and Upper North Fork Feather River habitat use data. Two “validation” data sets are also included: the Klamath River data for both fish sizes and the Pit River data for the largest adult fish size.**



**Figure A-2b. Rainbow trout juvenile depth suitability criteria for small stream size fish (top) and larger river size fish (bottom) enveloped on the Stanislaus 2001, Stanislaus 1991, South Fork American River, and Upper North Fork Feather River habitat use data. Two “validation” data sets are also included: the Klamath River data for both fish sizes and the Pit River data for the largest adult fish size.**

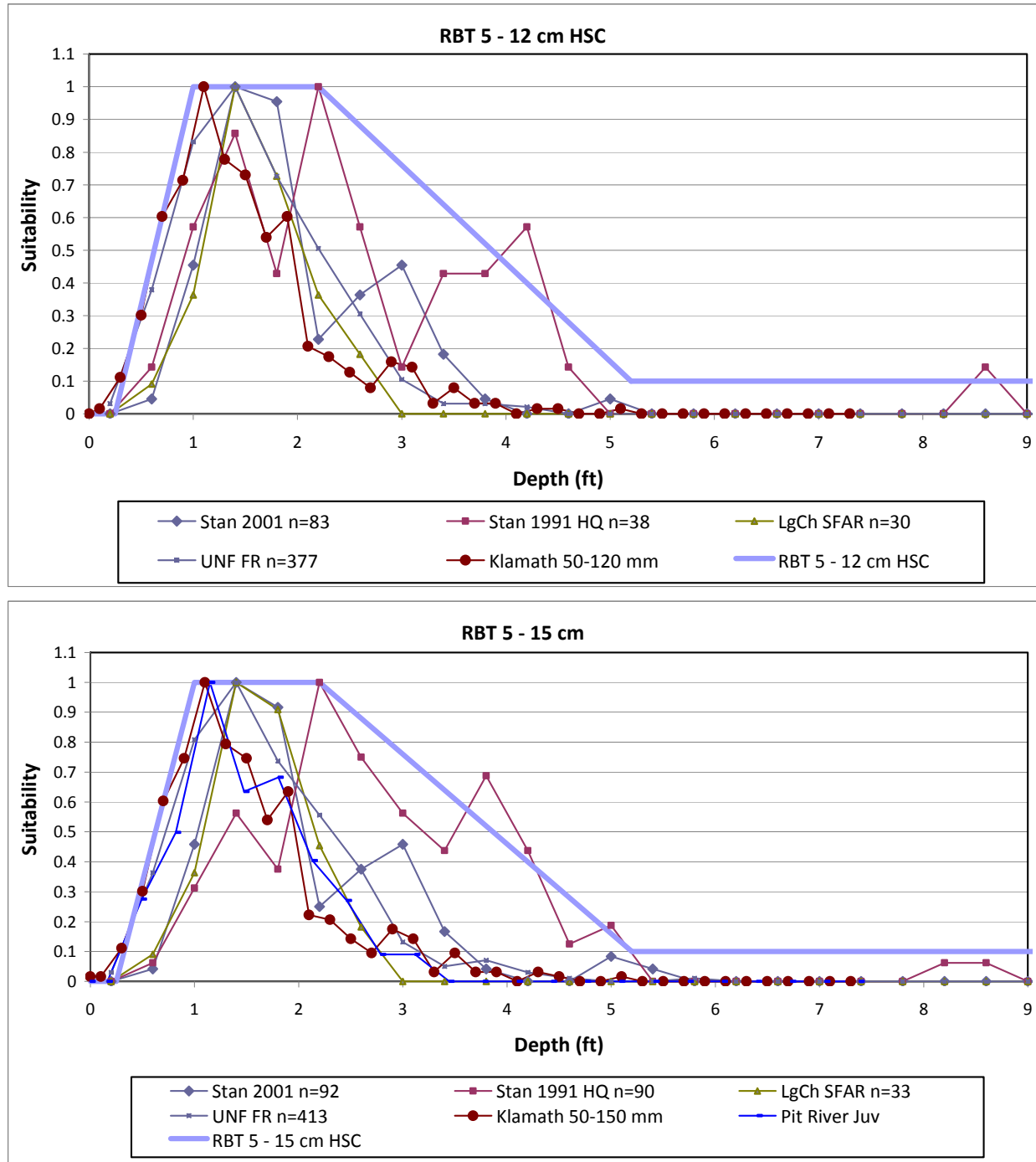


Figure A-3. MFP HSC for small stream size fish juveniles (5-12 cm) and adults (12-22.5 cm) compared to UARP small stream HSC and small stream data: use (U), availability (A), and adjusted preference (U/A).

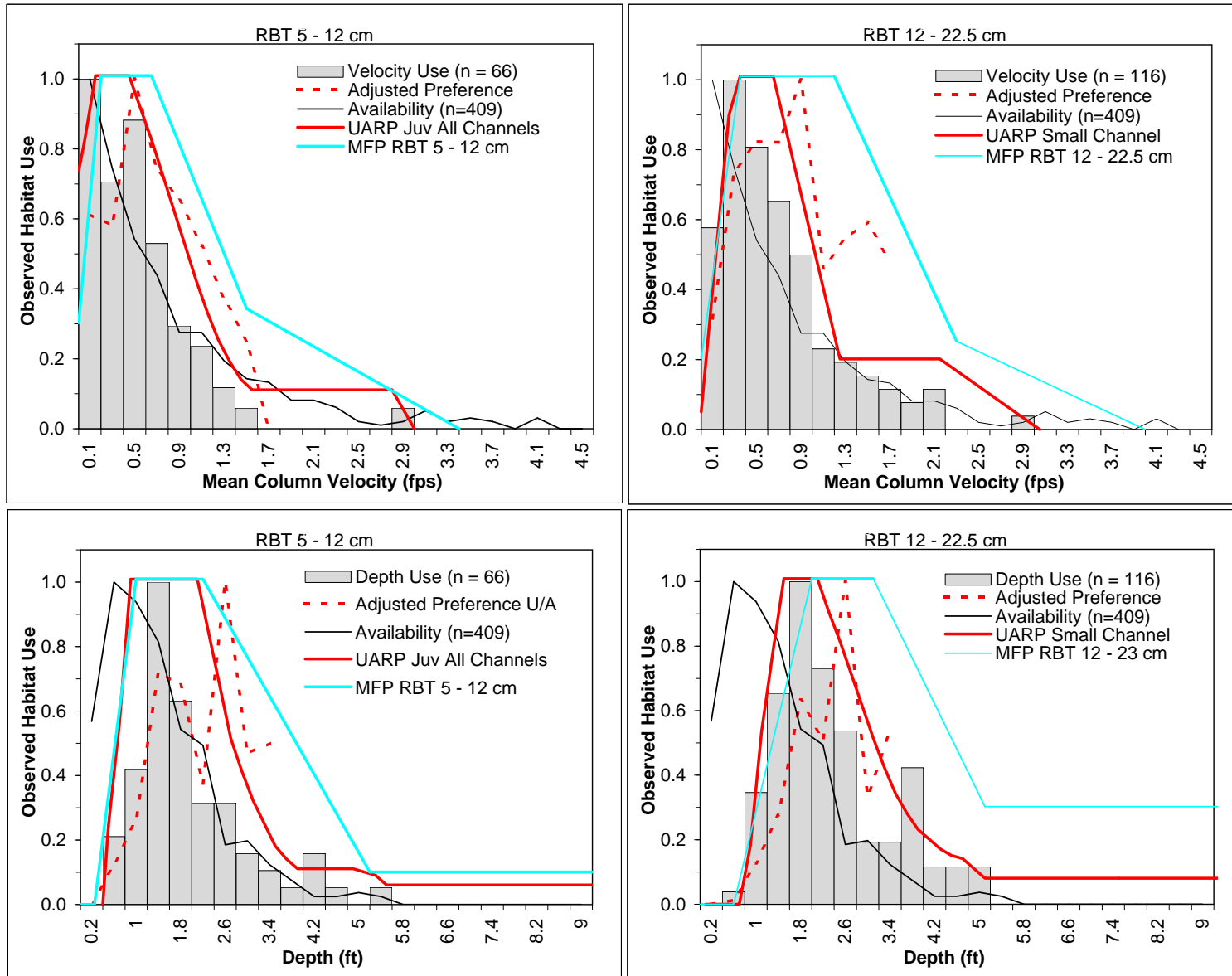
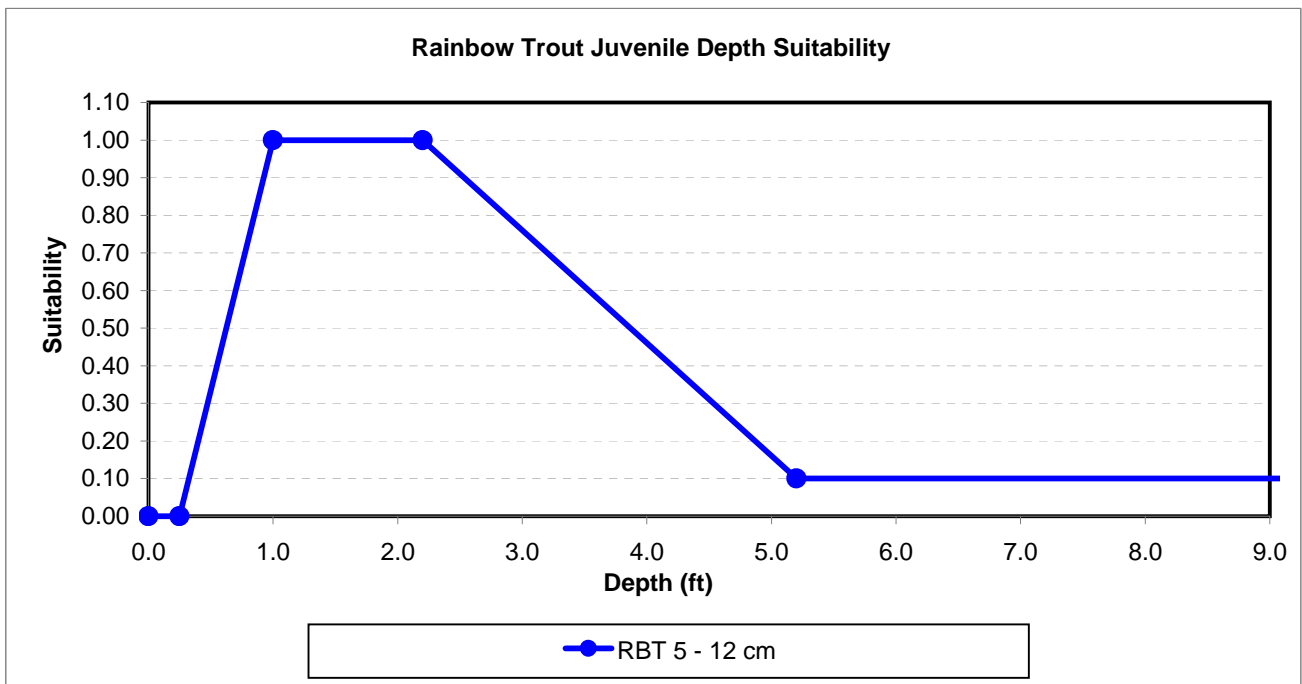
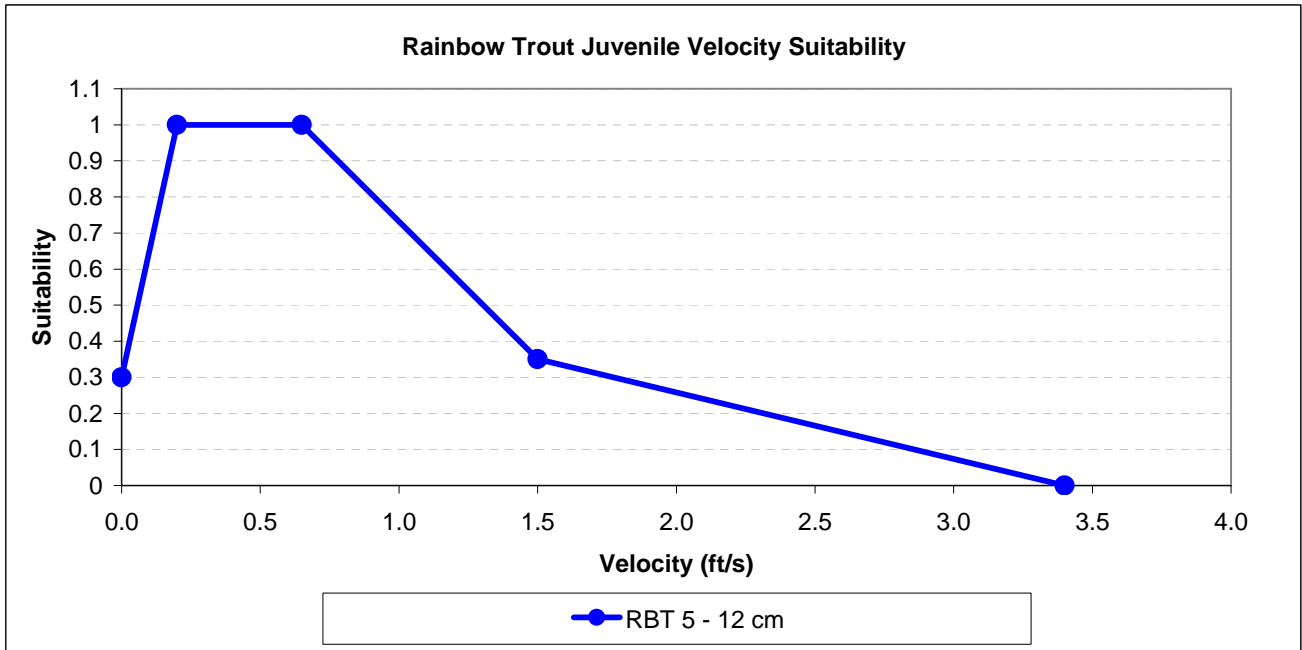


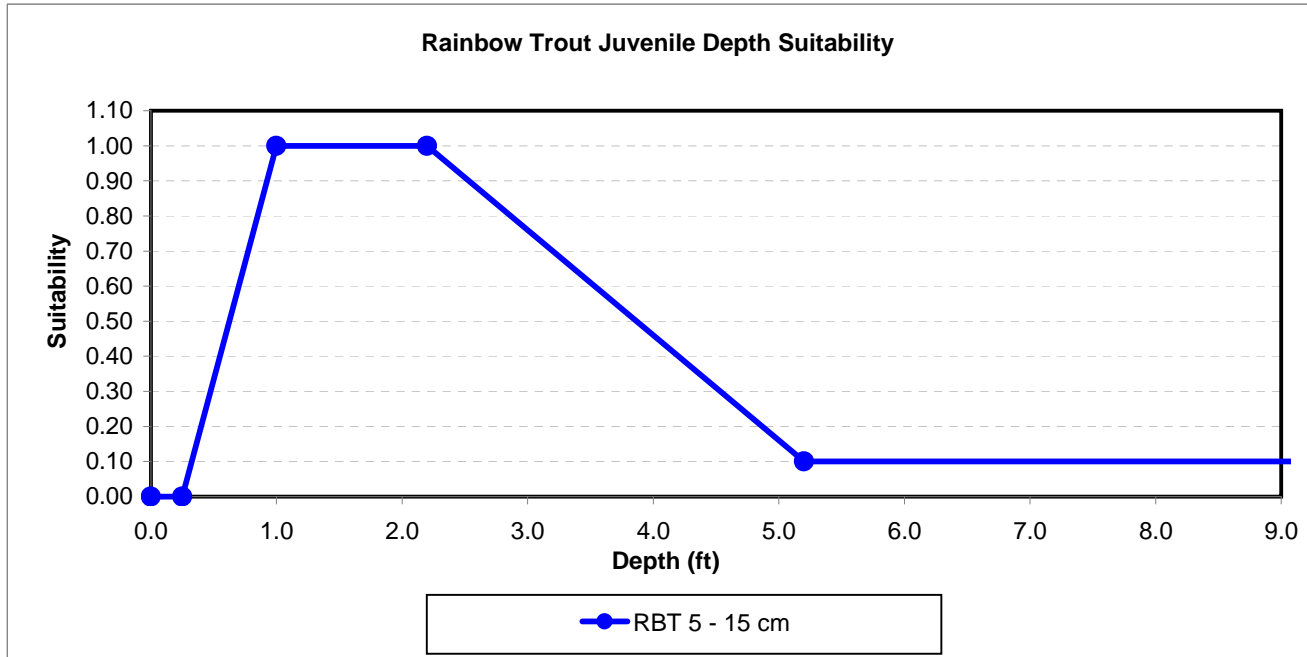
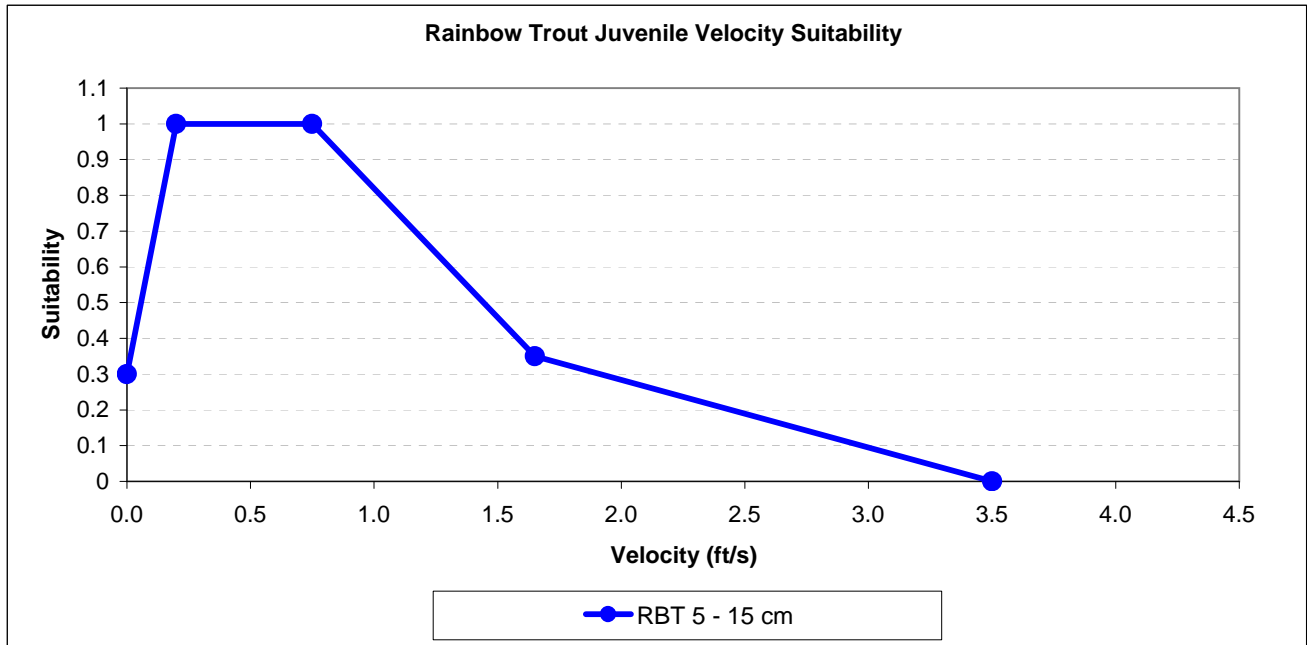
Figure A-4. Small stream rainbow trout juvenile velocity and depth suitability.



RBT 5 - 12 cm	
MCVel (ft/s)	SI
0.00	0.3
0.20	1.00
0.65	1.00
1.50	0.35
3.40	0.00

RBT 5 - 12 cm	
Depth (ft)	SI
0.00	0.00
0.25	0.00
1.00	1.00
2.20	1.00
5.20	0.10
10.00	0.10

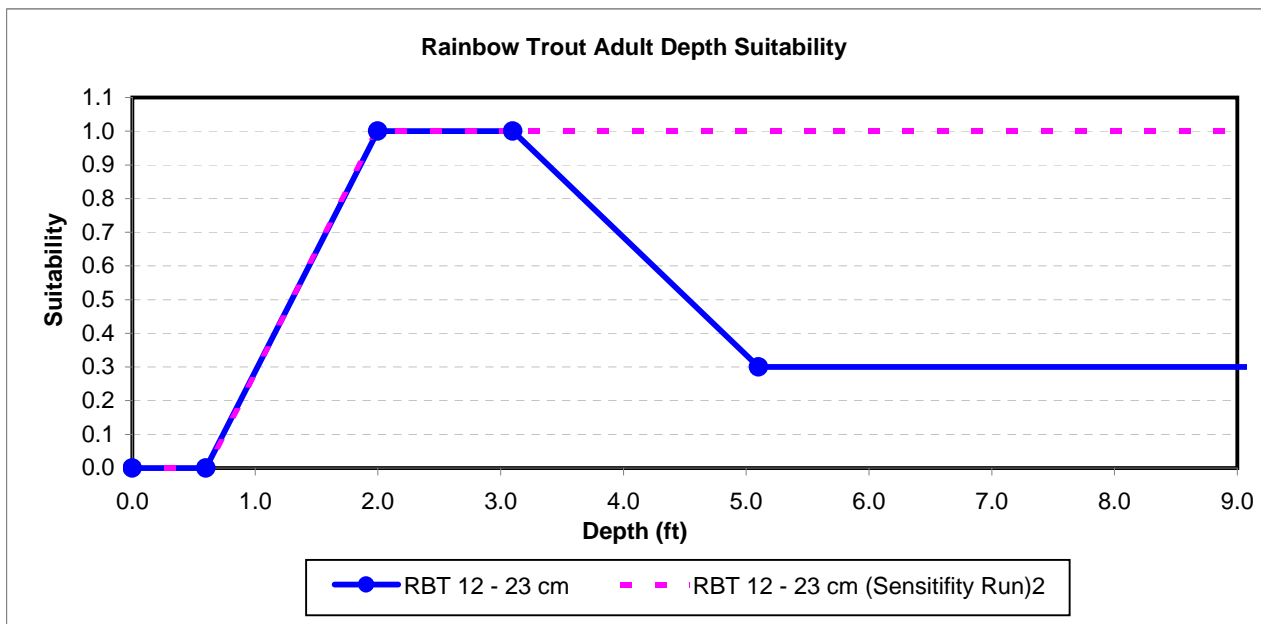
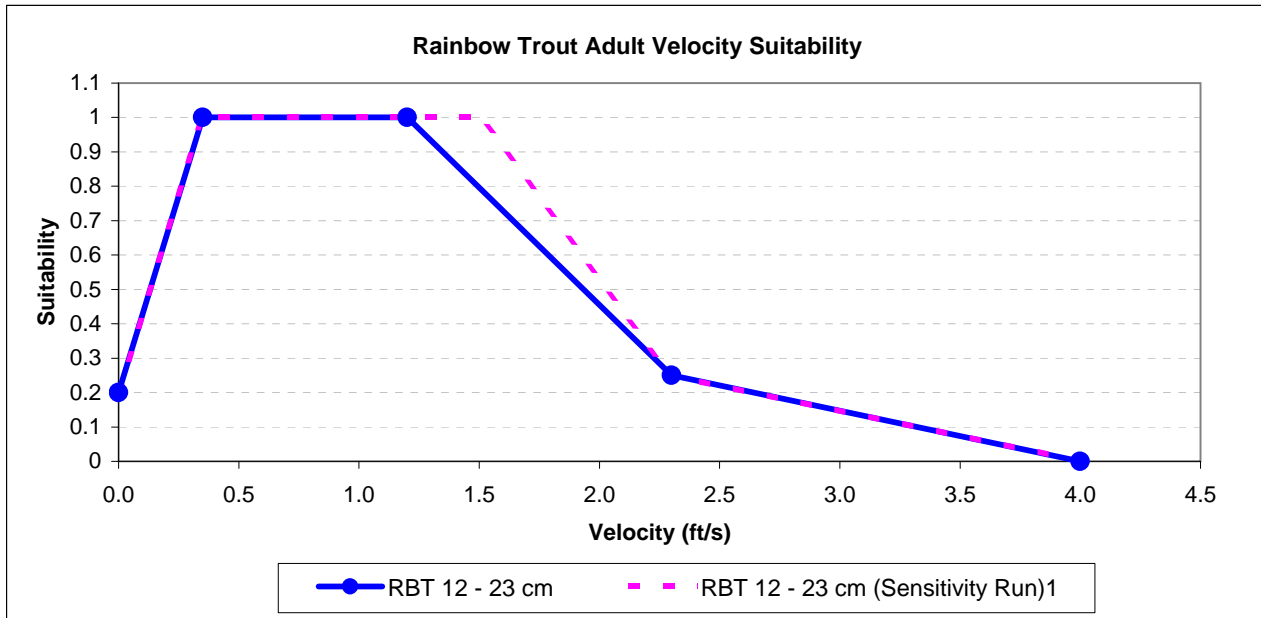
Figure A-5. Large river rainbow trout juvenile velocity and depth suitability.



RBT 5 - 15 cm	
MCVel (ft/s)	SI
0.00	0.3
0.20	1.00
0.75	1.00
1.65	0.35
3.50	0.00

RBT 5 - 15 cm	
Depth (ft)	SI
0.00	0.00
0.25	0.00
1.00	1.00
2.20	1.00
5.20	0.10
10.00	0.10

Figure A-6. Small stream rainbow trout adult velocity and depth suitability and sensitivity analyses.



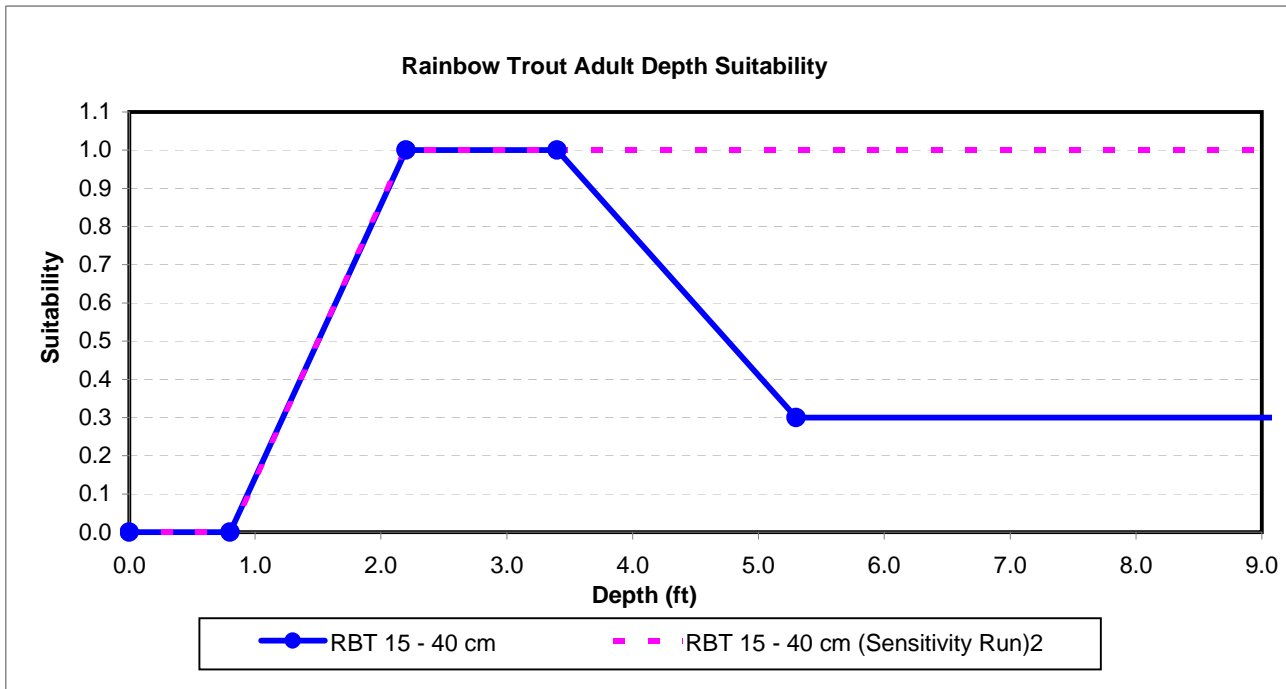
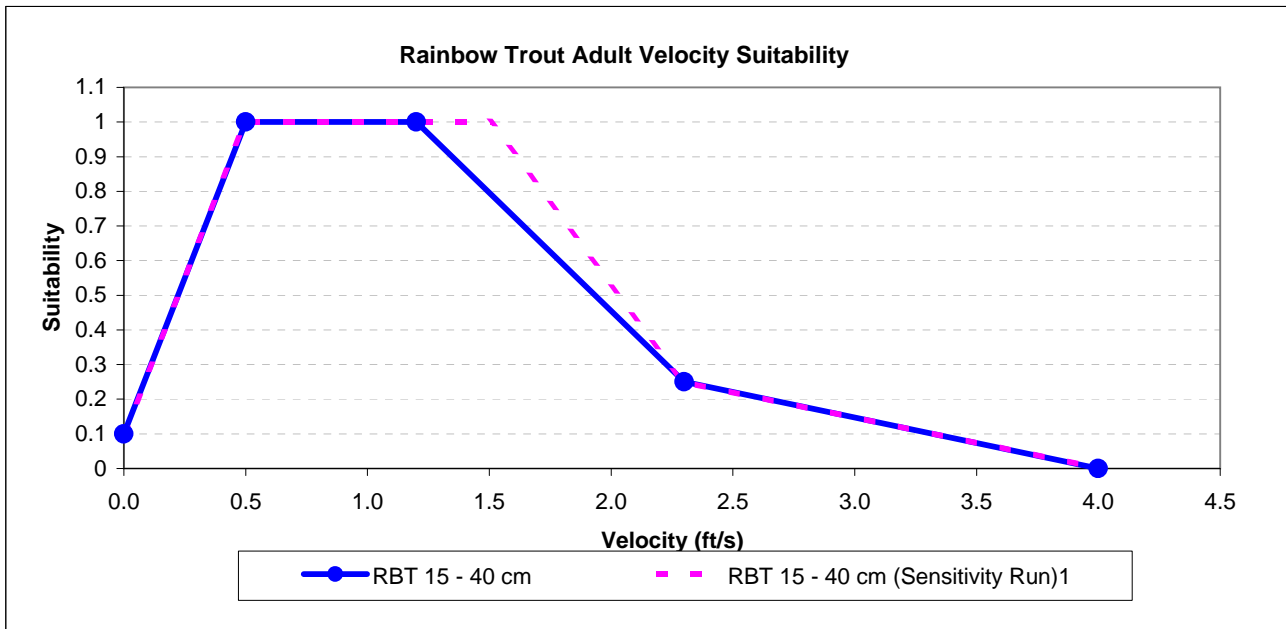
RBT 12 - 23 cm		RBT 12 - 23 cm (Sensitivity Run) <sup>1</sup>	
MCVel (ft/s)	SI	MCVel (ft/s)	SI
0.00	0.2	0.00	0.2
0.35	1.00	0.35	1.00
1.20	1.00	1.50	1.00
2.30	0.25	2.30	0.25
4.00	0.00	4.00	0.00

<sup>1</sup>Sensitivity Analysis Curve

RBT 12 - 23 cm		RBT 12 - 23 cm (Sensitivity Run) <sup>2</sup>	
Depth (ft)	SI	Depth (ft)	SI
0.00	0.00	0.00	0.00
0.60	0.00	0.60	0.00
2.00	1.00	2.00	1.00
3.10	1.00	3.10	1.00
5.10	0.30	5.70	1.00
10.00	0.30	10.00	1.00

<sup>2</sup>Sensitivity Analysis Curve

Figure A-7. Large river rainbow trout adult velocity and depth suitability and sensitivity analyses.



RBT 15 - 40 cm		RBT 15 - 40 cm (Sensitivity Run) <sup>1</sup>	
MCVel (ft/s)	SI	MCVel (ft/s)	SI
0.00	0.1	0.00	0.1
0.50	1.00	0.50	1.00
1.20	1.00	1.50	1.00
2.30	0.25	2.30	0.25
4.00	0.00	4.00	0.00

<sup>1</sup>Sensitivity Analysis Curve

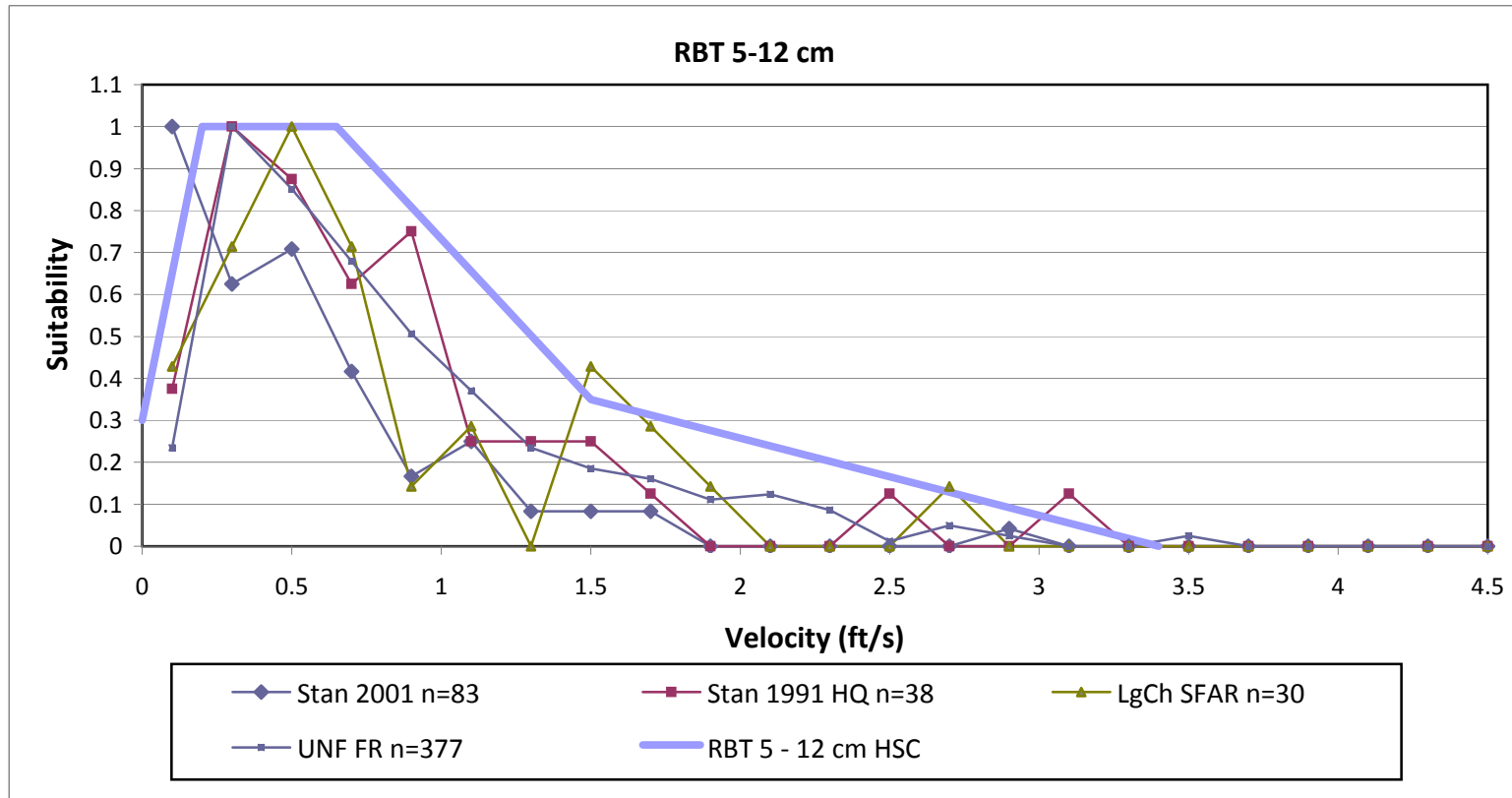
RBT 15 - 40 cm		RBT 15 - 40 cm (Sensitivity Run) <sup>2</sup>	
Depth (ft)	SI	Depth (ft)	SI
0.00	0.00	0.00	0.00
0.80	0.00	0.80	0.00
2.20	1.00	2.20	1.00
3.40	1.00	3.40	1.00
5.30	0.30	6.00	1.00
10.00	0.30	10.00	1.00

<sup>2</sup>Sensitivity Analysis Curve

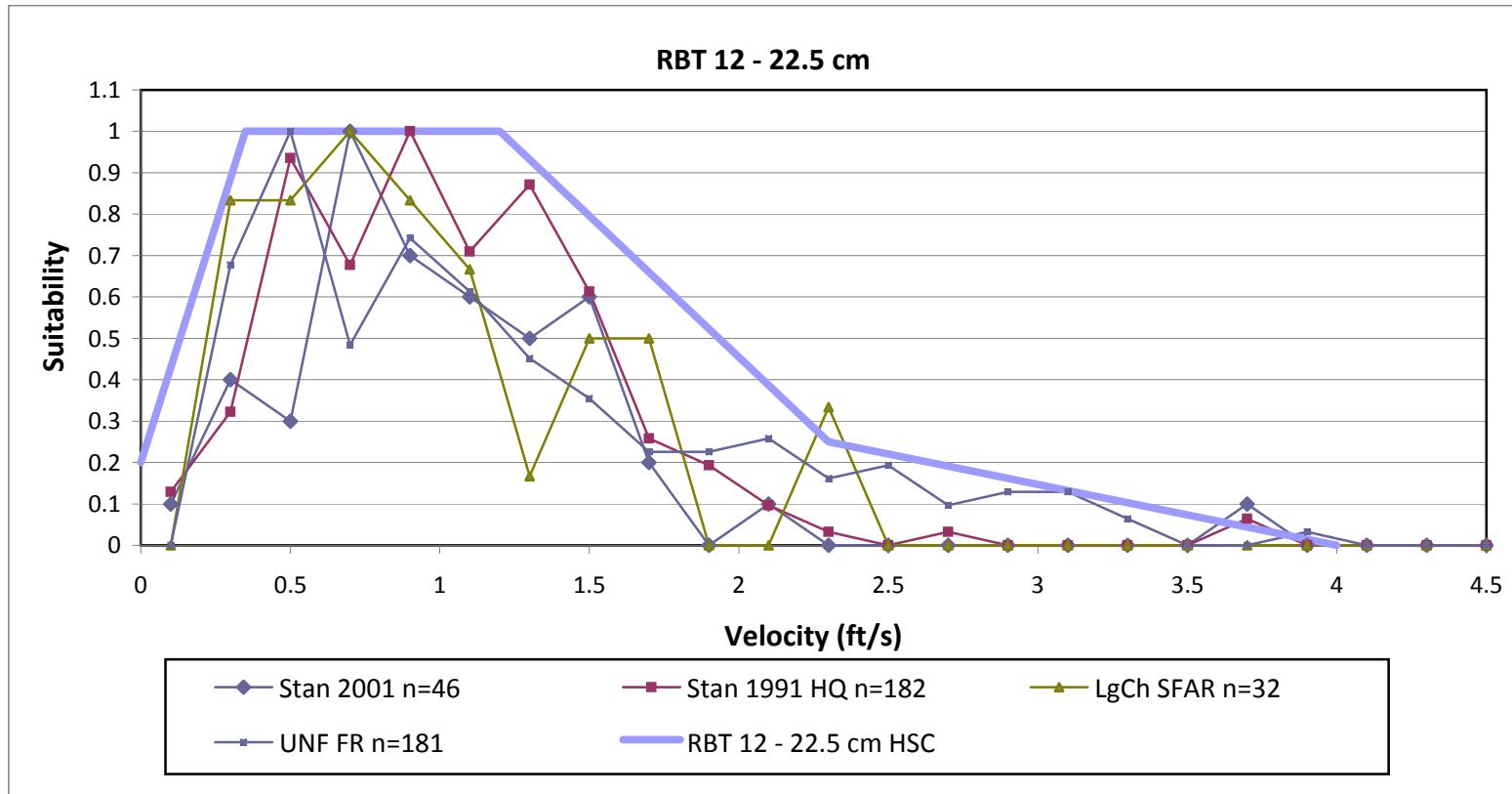
**ATTACHMENT A**

**MFP Adult and Juvenile Rainbow Trout Enveloped Habitat Suitability Criteria and  
Habitat Use Datasets**

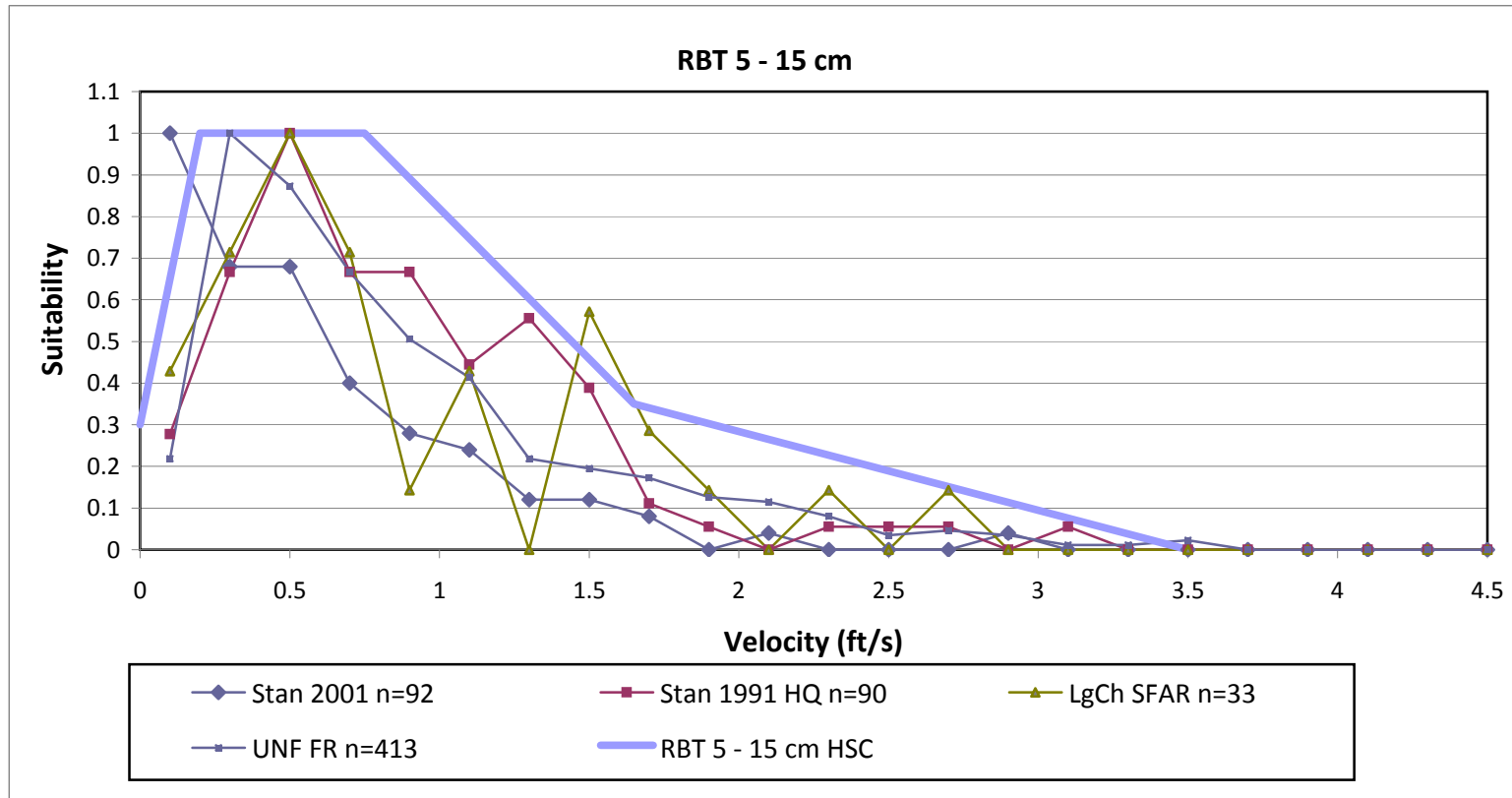
**Figure 1. MFP juvenile velocity habitat suitability criteria and habitat use data for small stream size rainbow trout (5-12 cm).**



**Figure 2. MFP adult velocity habitat suitability criteria and habitat use data for small stream size rainbow trout (12-22.5 cm).**



**Figure 3. MFP juvenile velocity habitat suitability criteria and habitat use data for large stream size rainbow trout (5-15 cm).**



**Figure 4. MFP adult velocity habitat suitability criteria and habitat use data for large stream size rainbow trout (15-40 cm).**

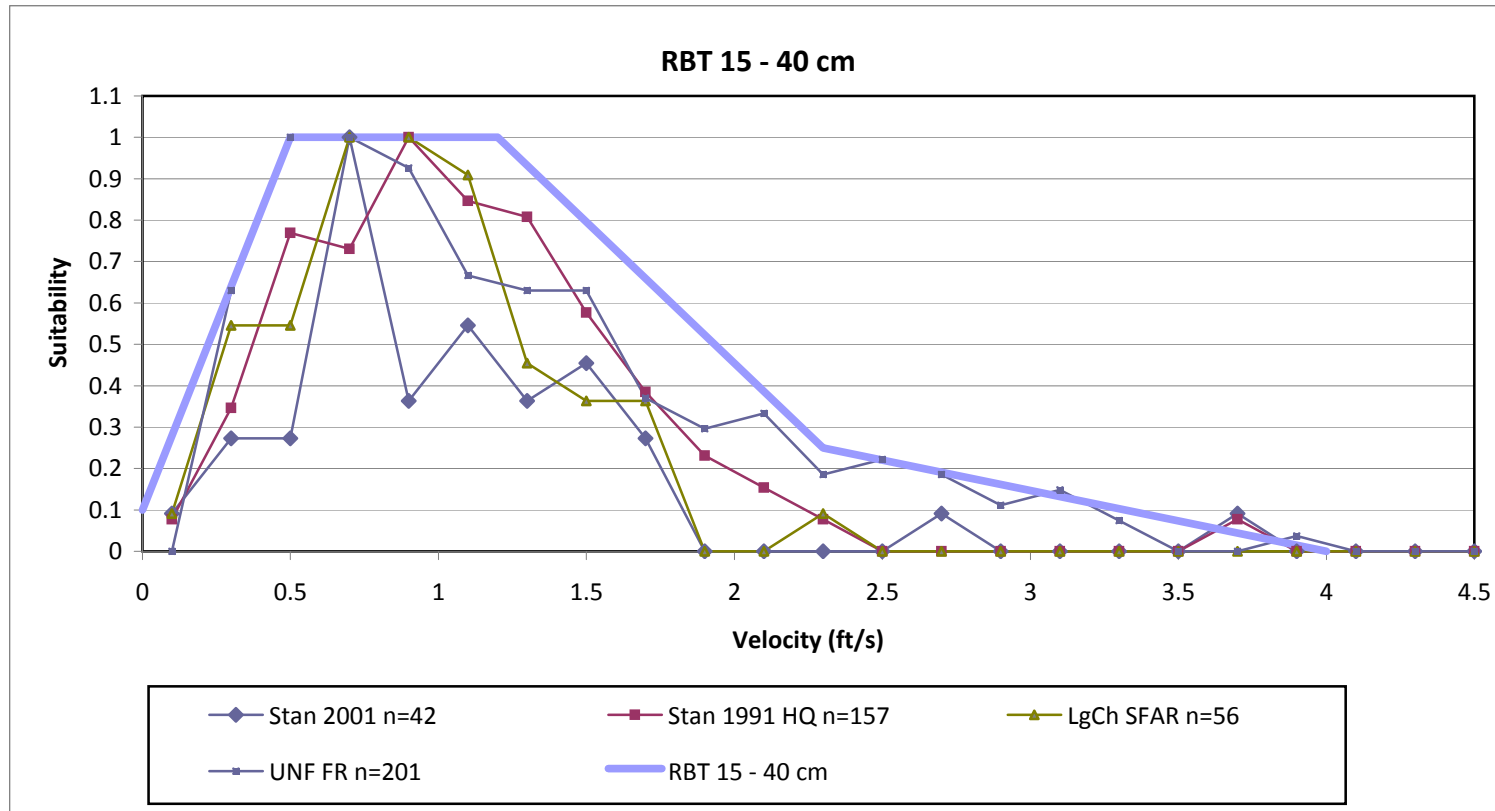
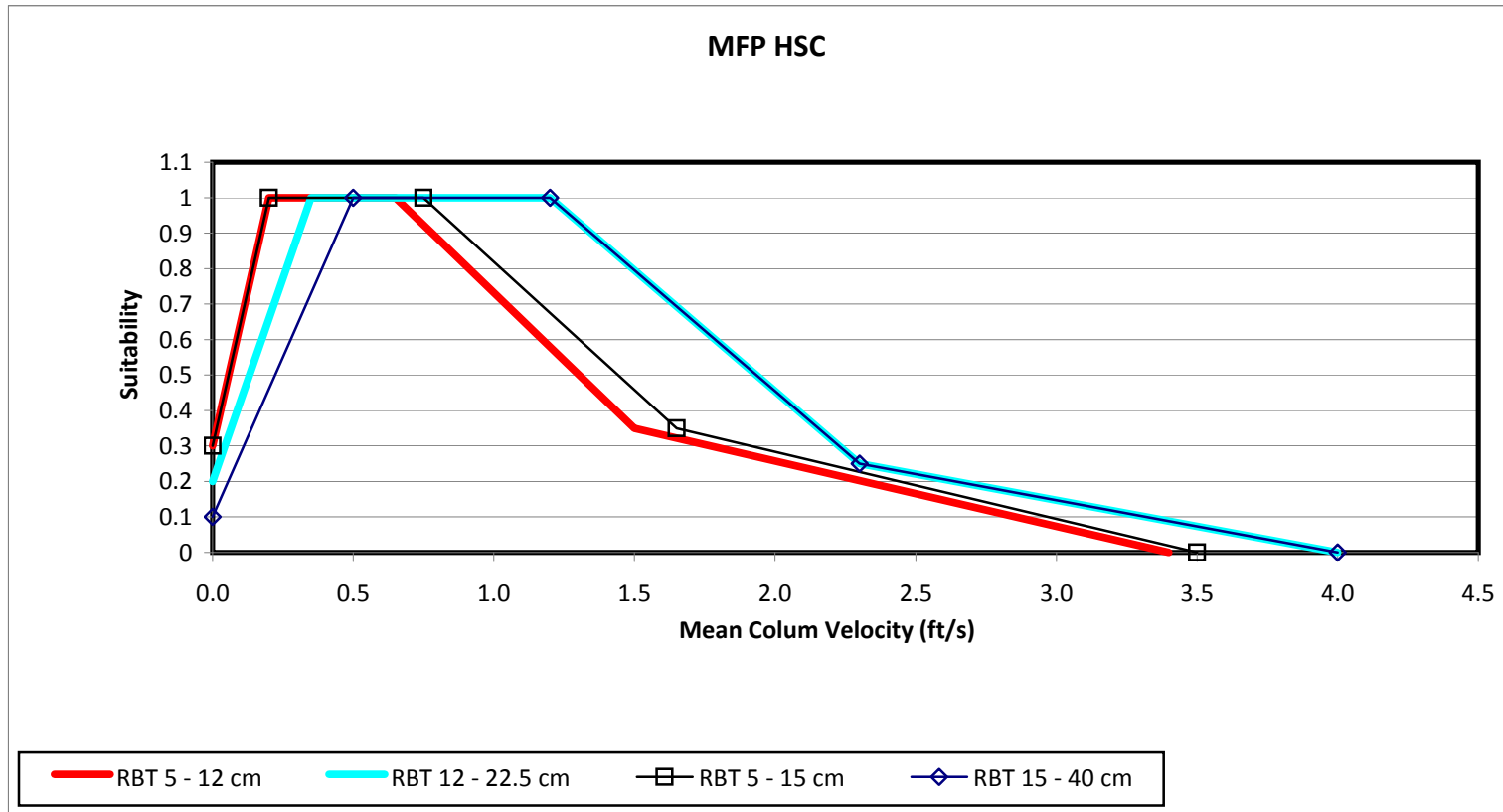
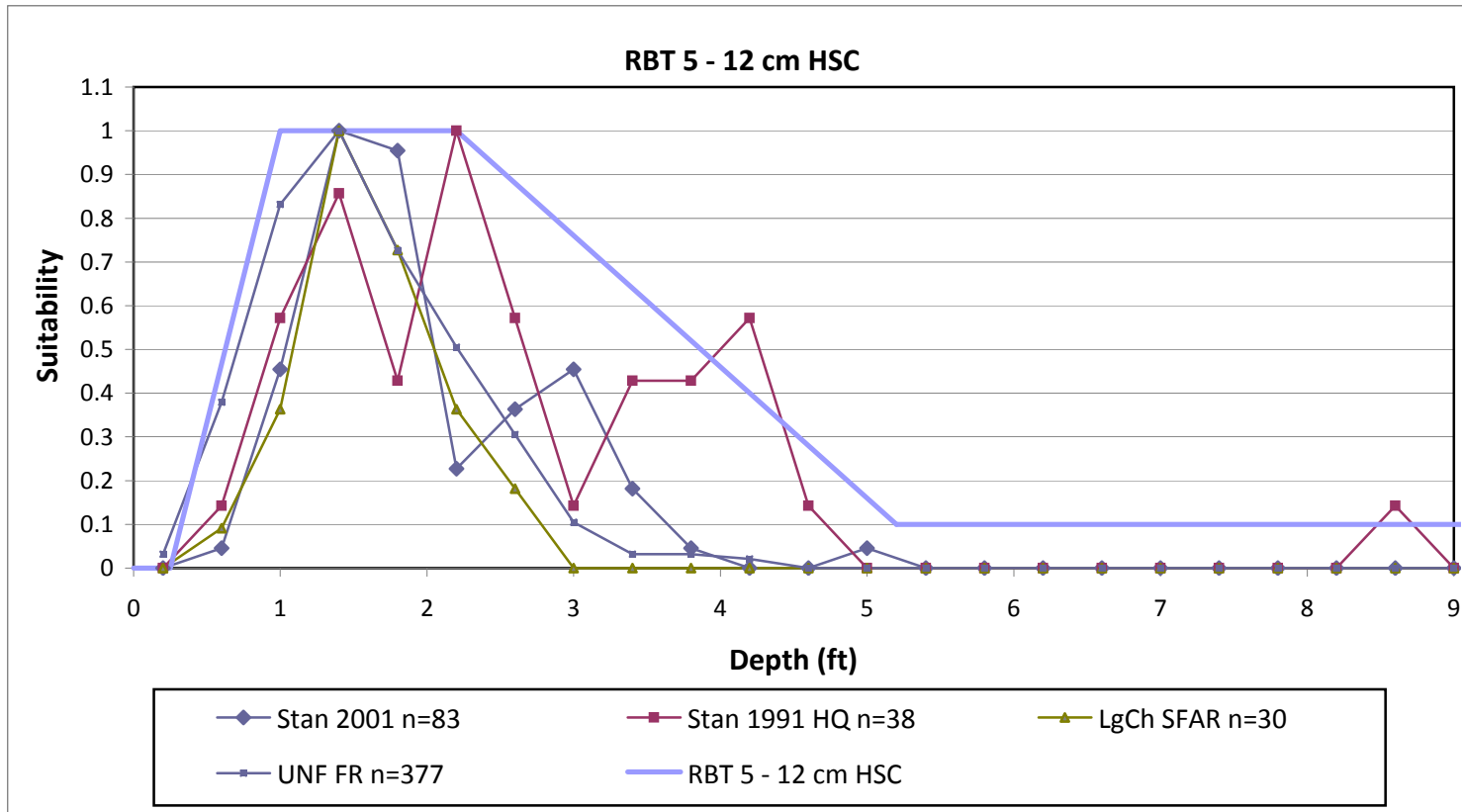


Figure 5. All MFP velocity habitat suitability criteria for rainbow trout.



**Figure 6. MFP juvenile depth habitat suitability criteria and habitat use data for small stream size rainbow trout (5-12 cm).**



**Figure 7. MFP adult depth habitat suitability criteria and habitat use data for small stream size rainbow trout (12-22.5 cm).**

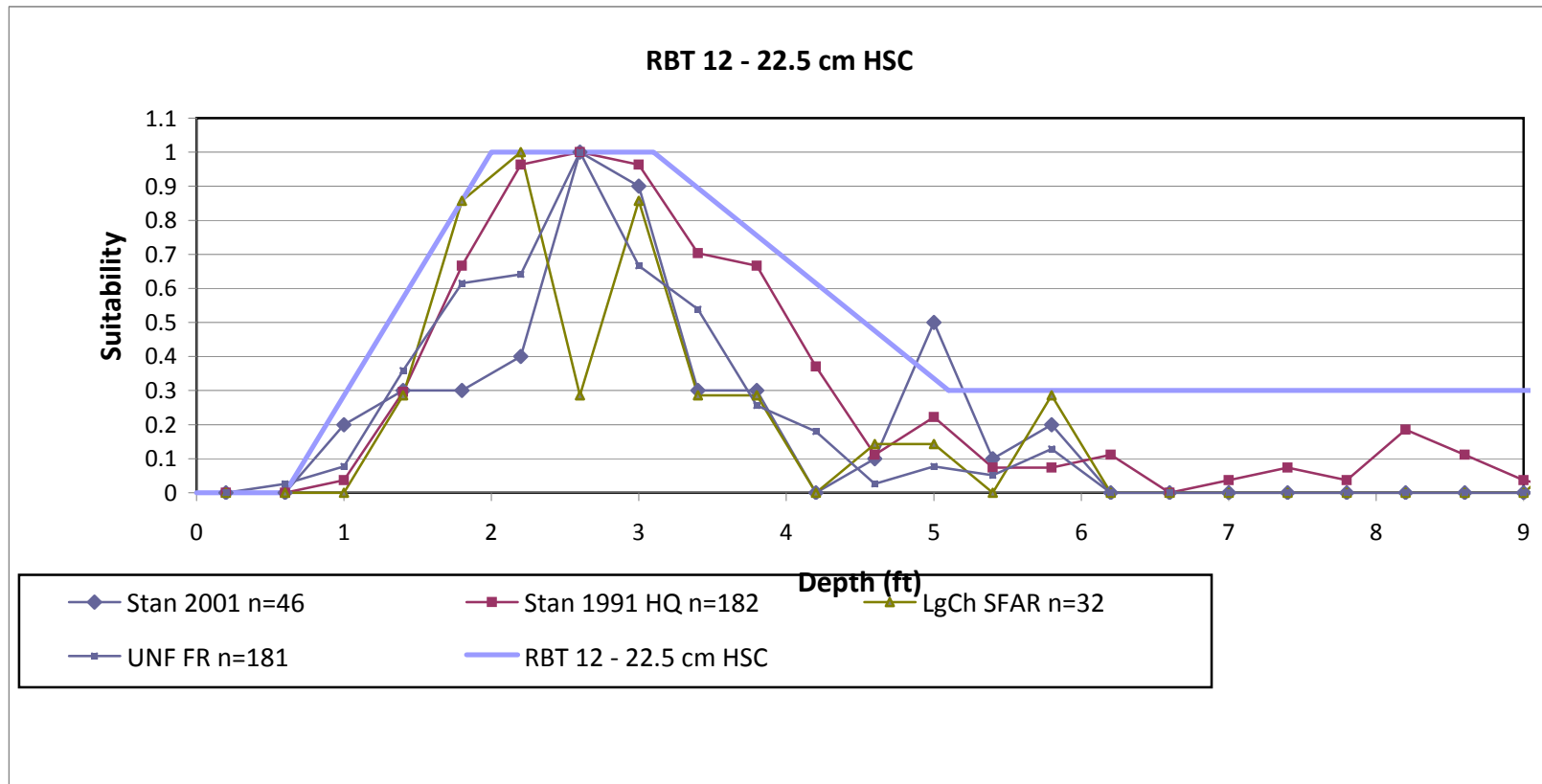
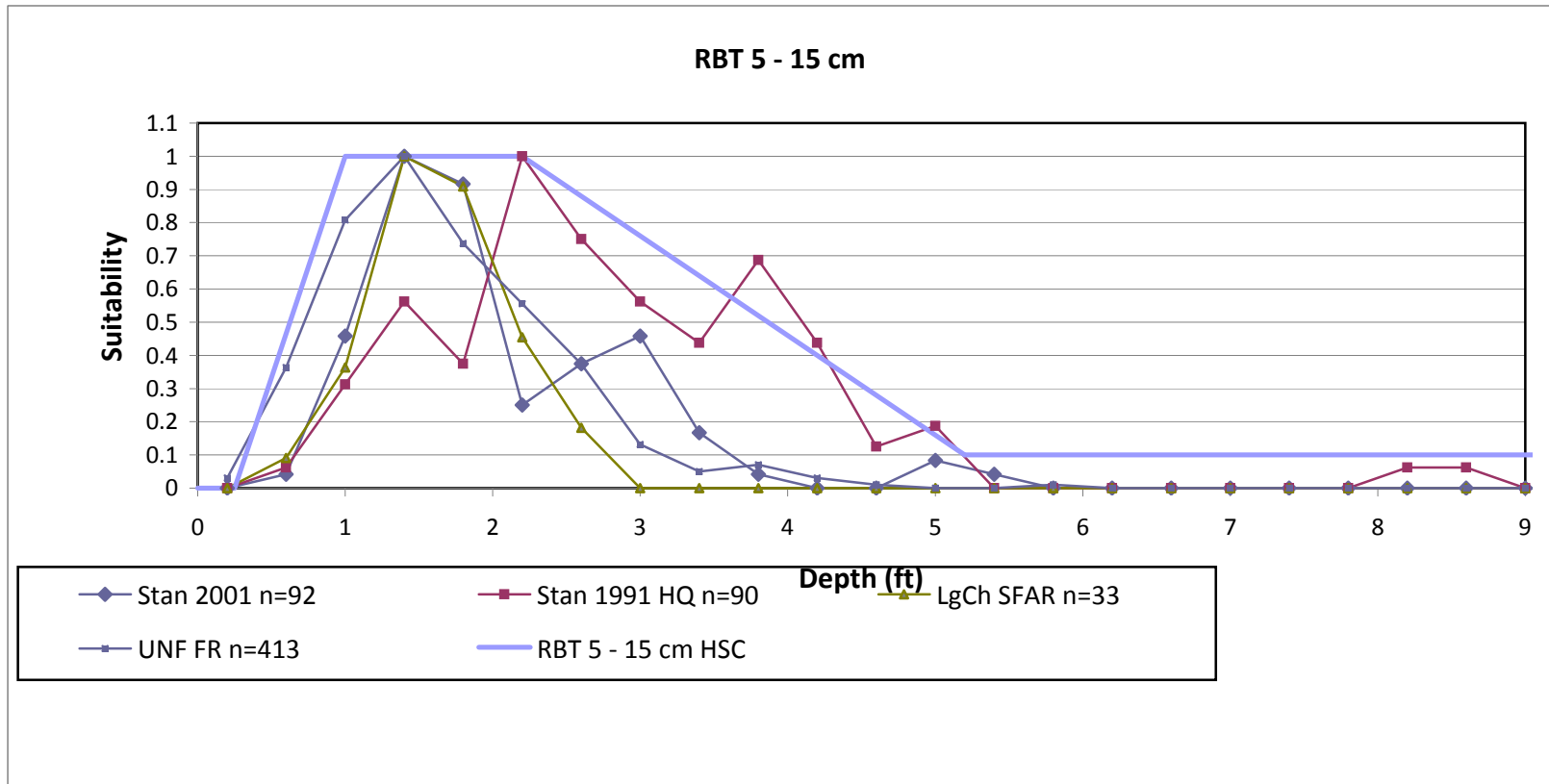


Figure 8. MFP juvenile depth habitat suitability criteria and habitat use data for large stream size rainbow trout (5-15 cm).



**Figure 9. MFP adult depth habitat suitability criteria and habitat use data for large stream size rainbow trout (15-40 cm).**

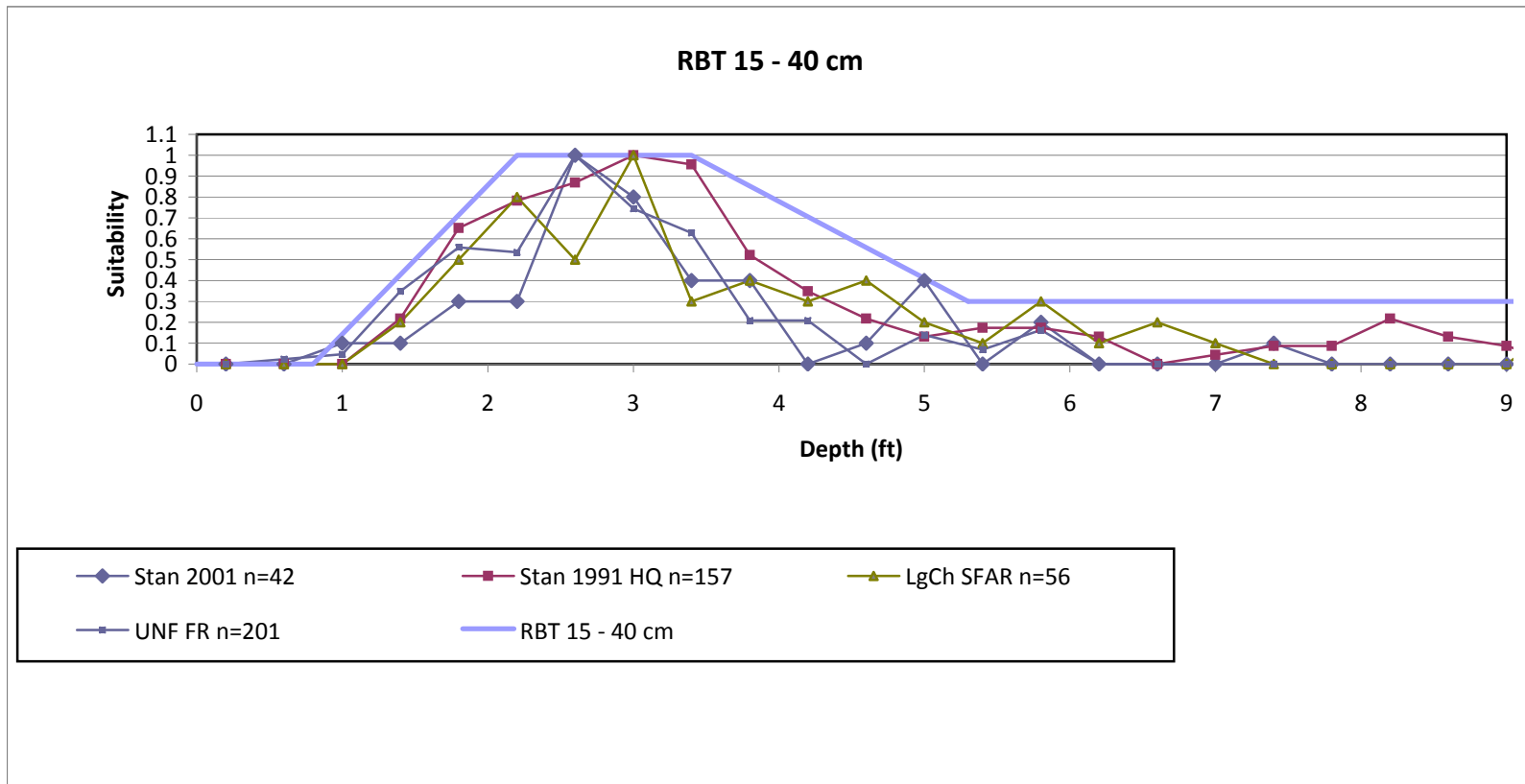
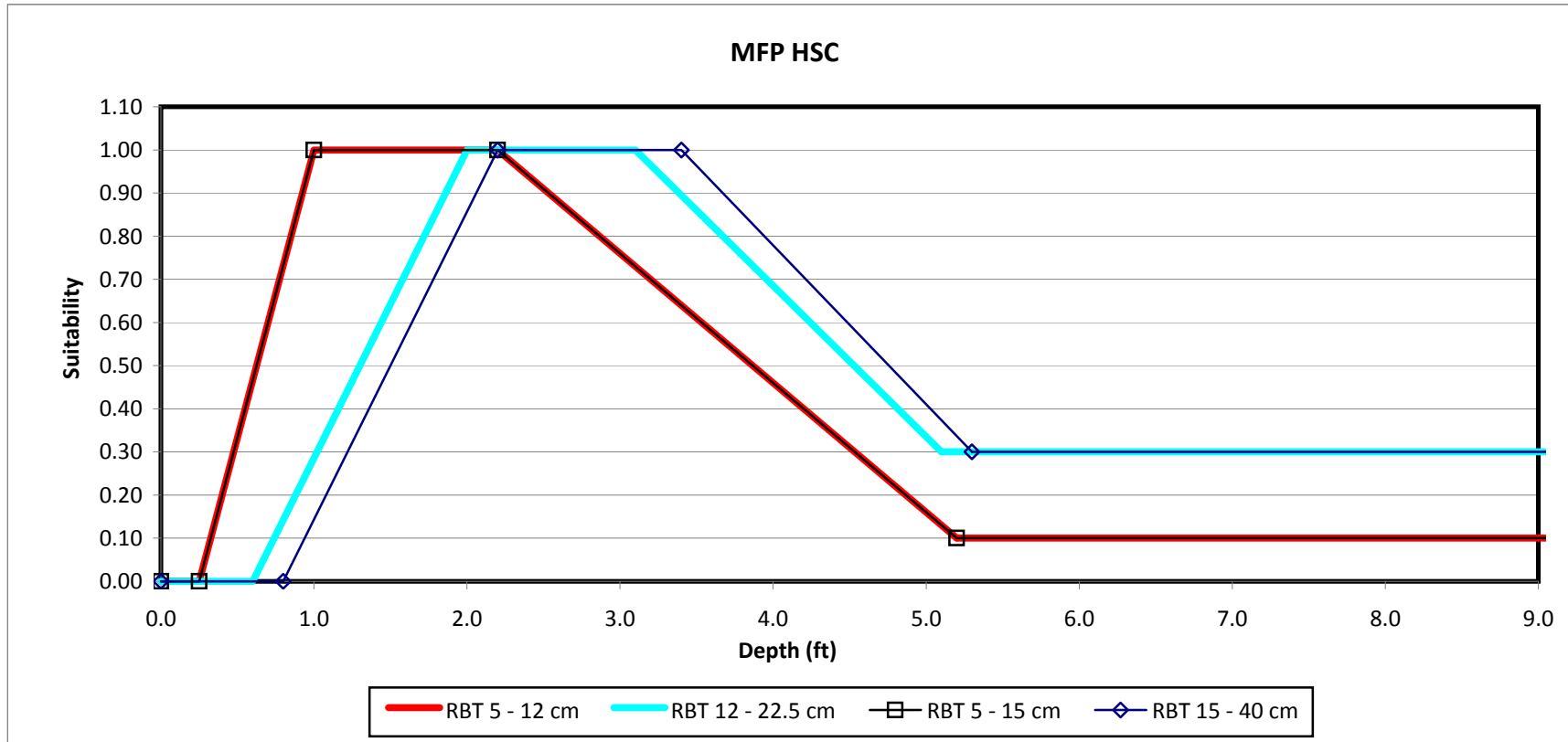


Figure 10. All MFP velocity habitat suitability criteria for rainbow trout.



**ATTACHMENT B**

**MFP Adult and Juvenile Rainbow Trout Enveloped Habitat Suitability Criteria and  
Habitat Use (U), Availability (A), and Adjusted Preference Datasets**

**Figure 1. MFP juvenile rainbow trout velocity habitat suitability criteria, habitat use, availability and adjusted preference (U/A) for small stream size fish (by river dataset).**

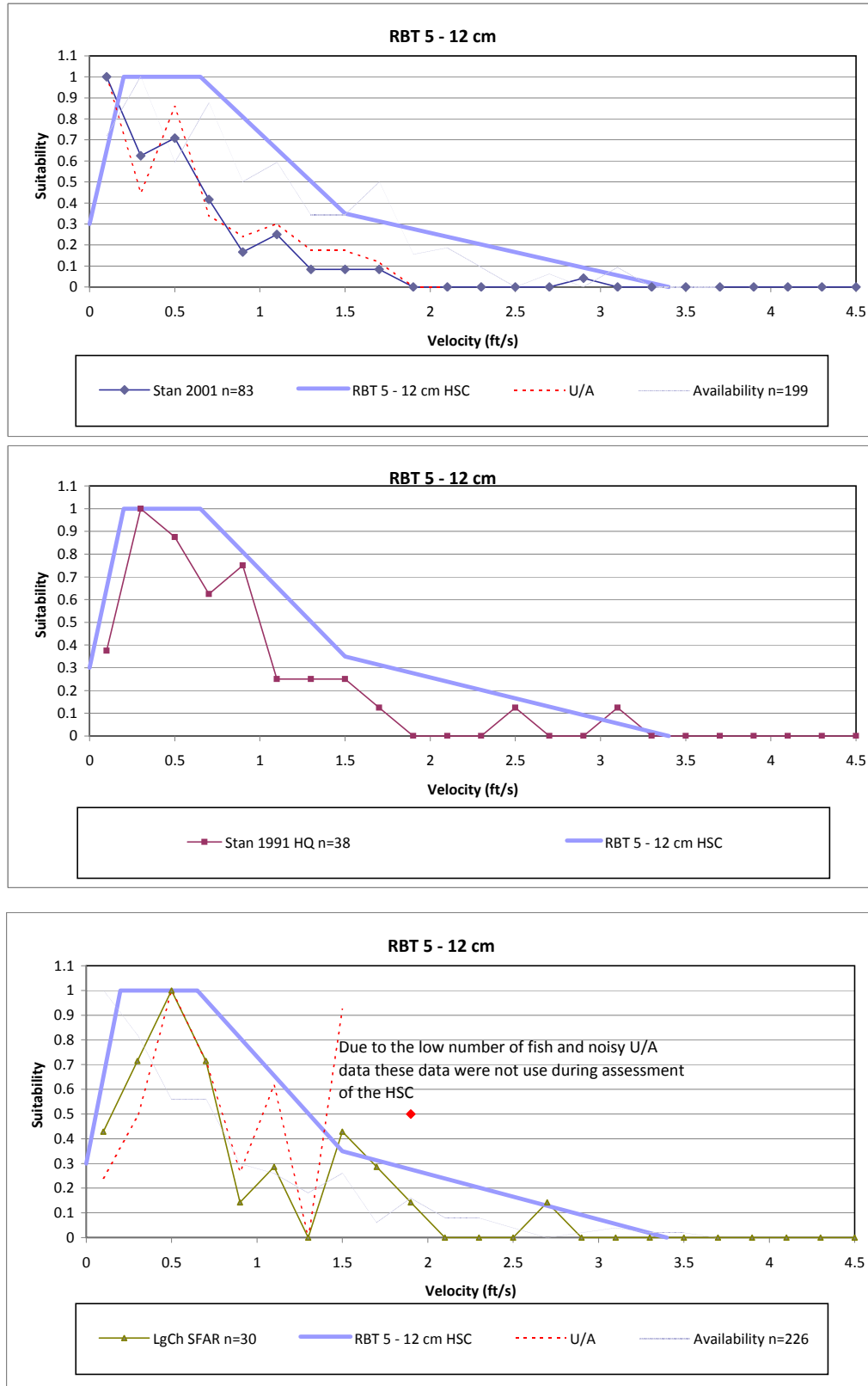
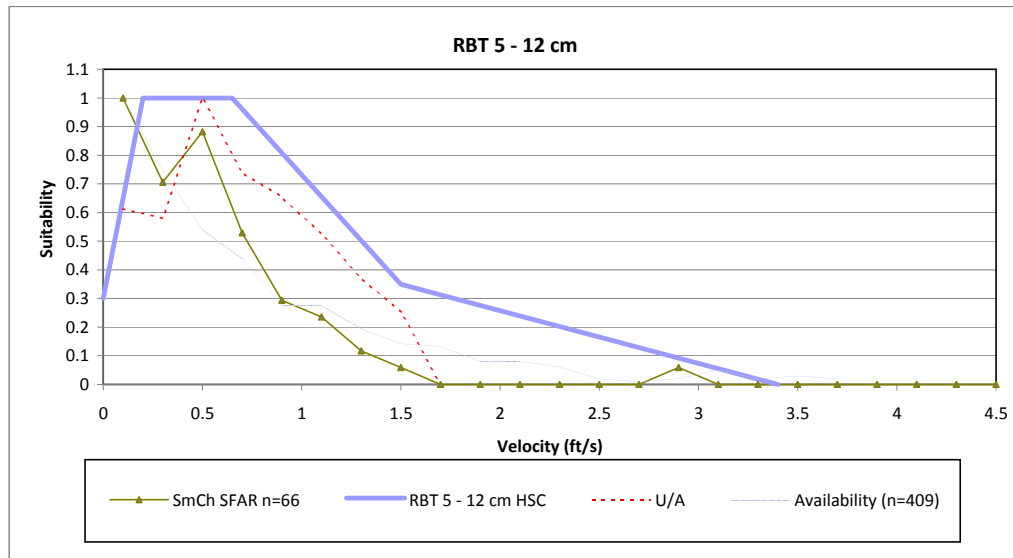
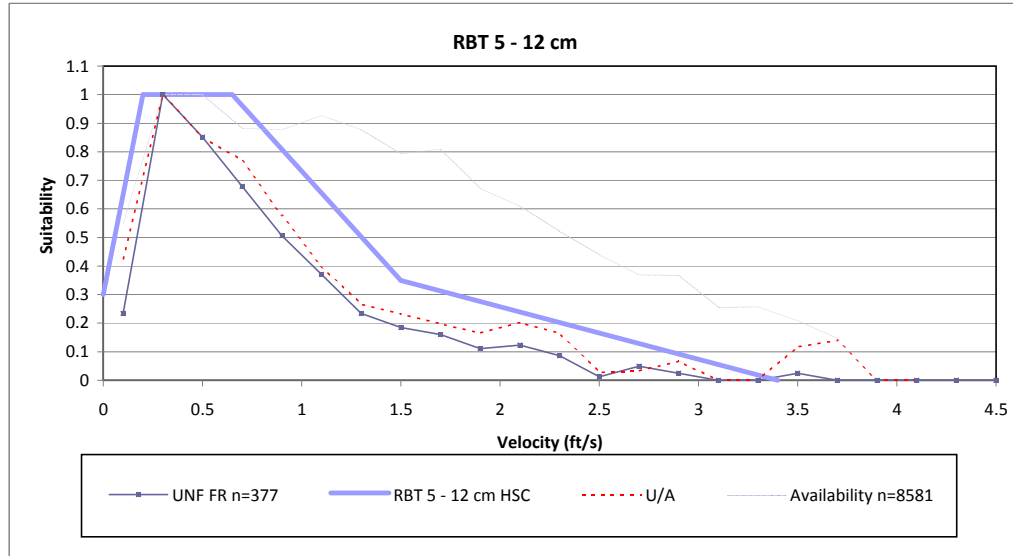
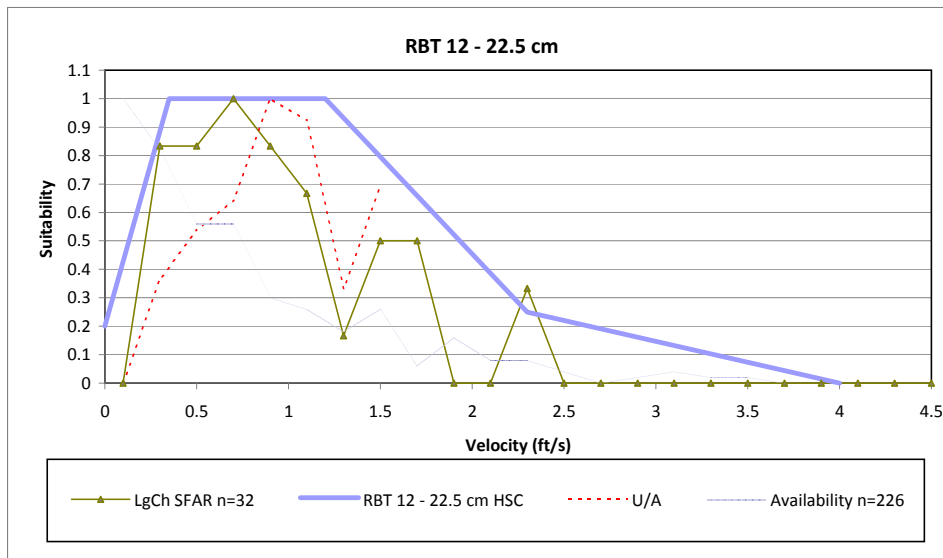
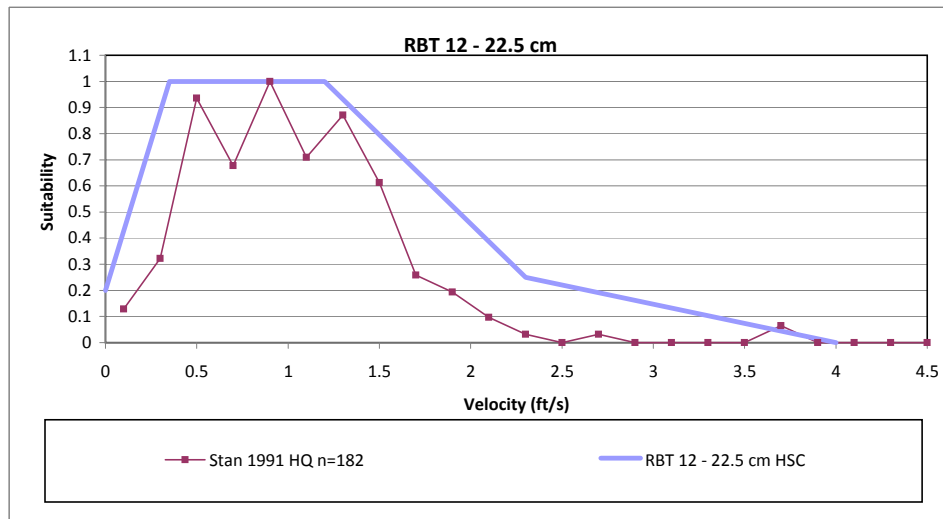
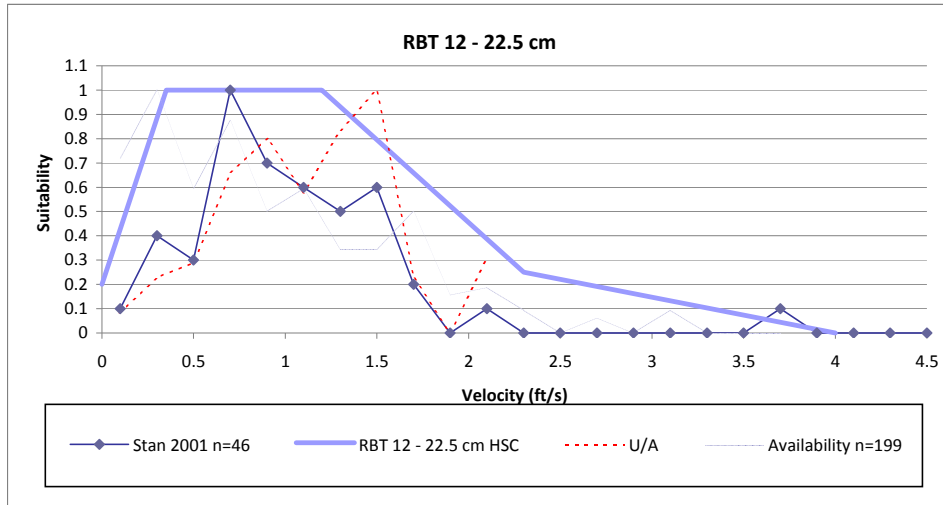


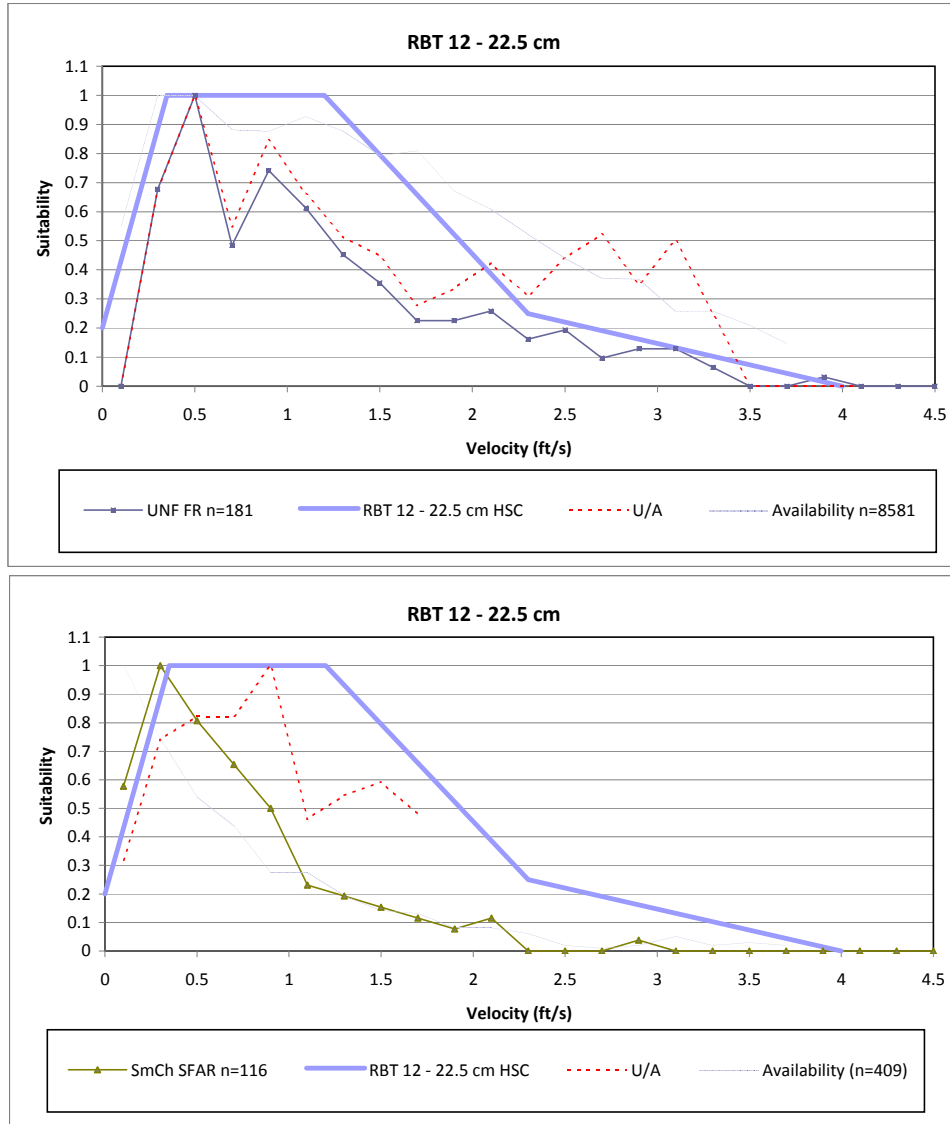
Figure 1. MFP juvenile rainbow trout velocity habitat suitability criteria, habitat use, availability and adjusted preference (U/A) for small stream size fish (by river dataset) (continued).



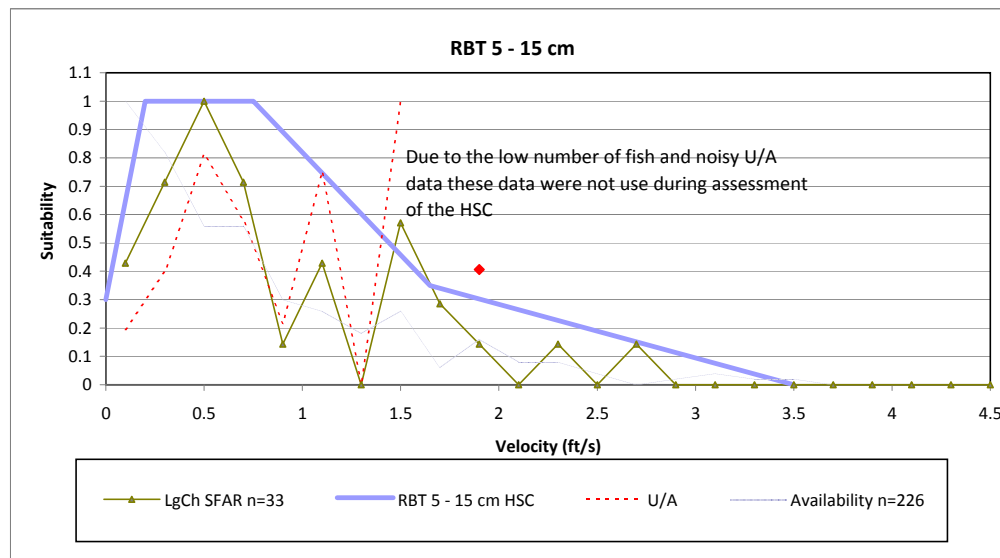
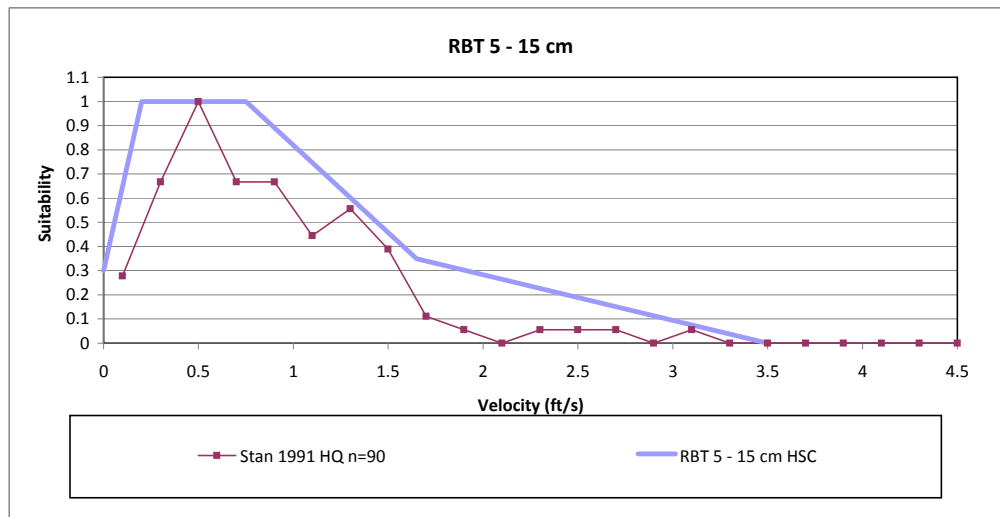
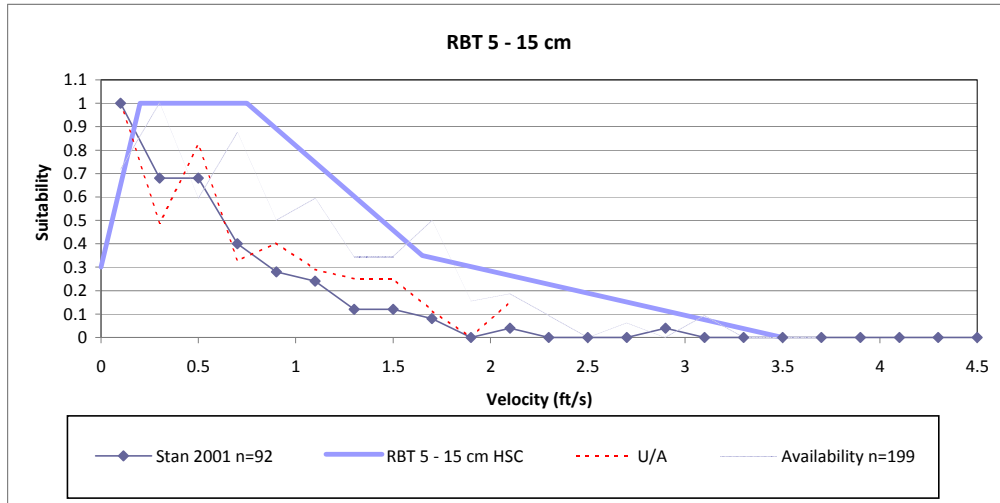
**Figure 2. MFP adult rainbow trout velocity habitat suitability criteria, habitat use, availability and adjusted preference (U/A) for small stream size fish (by river dataset).**



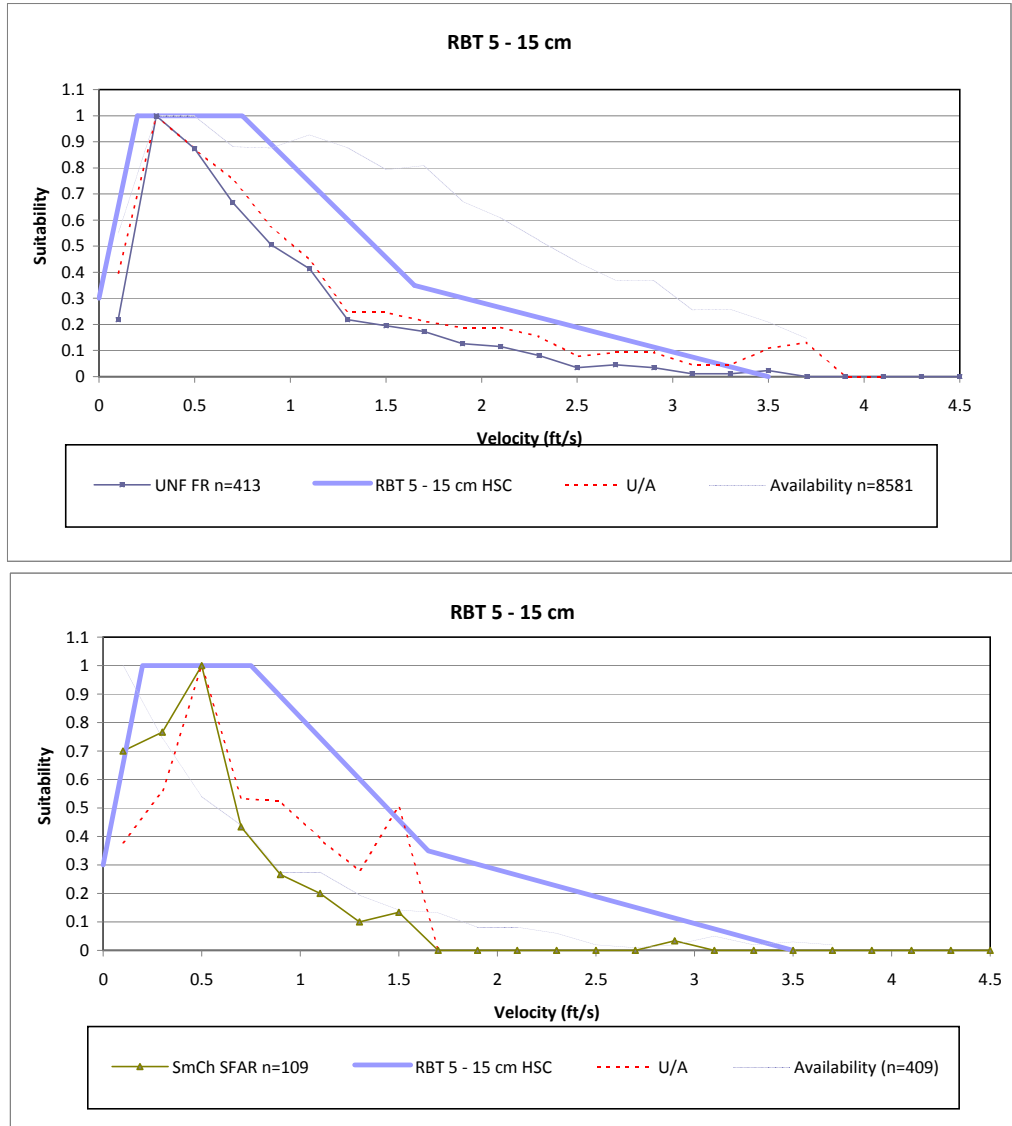
**Figure 2. MFP adult rainbow trout velocity habitat suitability criteria, habitat use, availability and adjusted preference (U/A) for small stream size fish (by river dataset) (continued).**



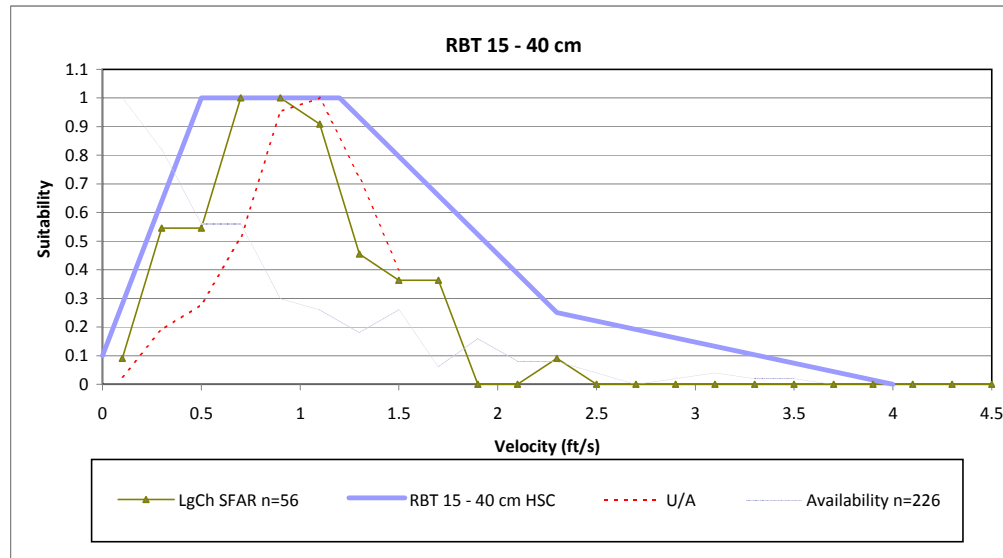
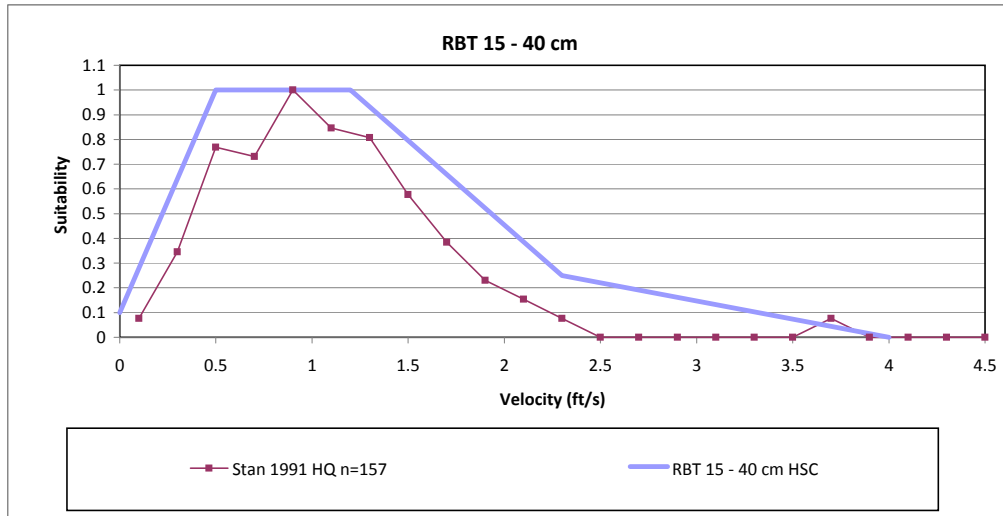
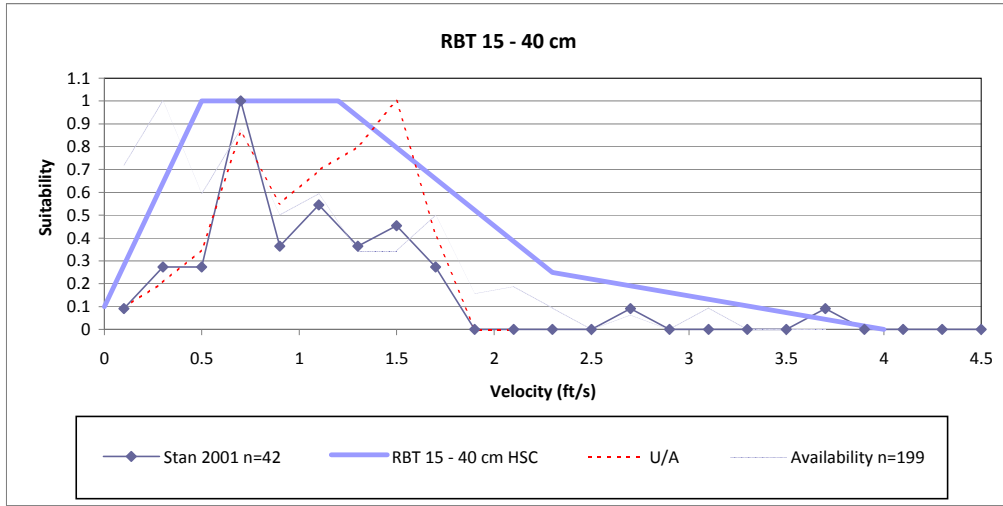
**Figure 3. MFP juvenile rainbow trout velocity habitat suitability criteria, habitat use, availability and adjusted preference (U/A) for large stream size fish (by river dataset).**



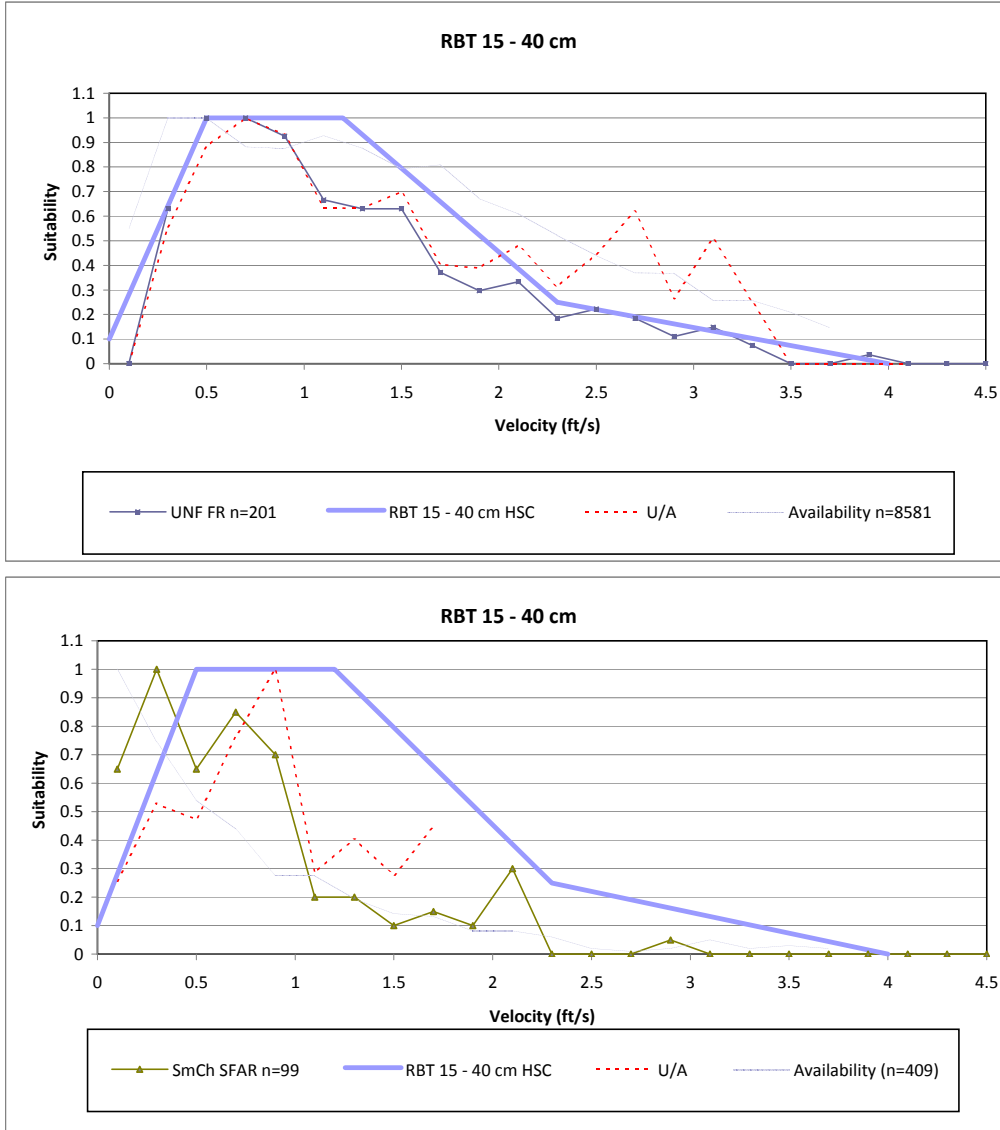
**Figure 3. MFP juvenile rainbow trout velocity habitat suitability criteria, habitat use, availability and adjusted preference (U/A) for large stream size fish (by river dataset) (continued).**



**Figure 4. MFP adult rainbow trout velocity habitat suitability criteria, habitat use, availability and adjusted preference (U/A) for large stream size fish (by river dataset).**



**Figure 4. MFP adult rainbow trout velocity habitat suitability criteria, habitat use, availability and adjusted preference (U/A) for large stream size fish (by river dataset) (continued).**



**Figure 5. MFP juvenile rainbow trout depth habitat suitability criteria, habitat use, availability and adjusted preference (U/A) for small stream size fish (by river dataset).**

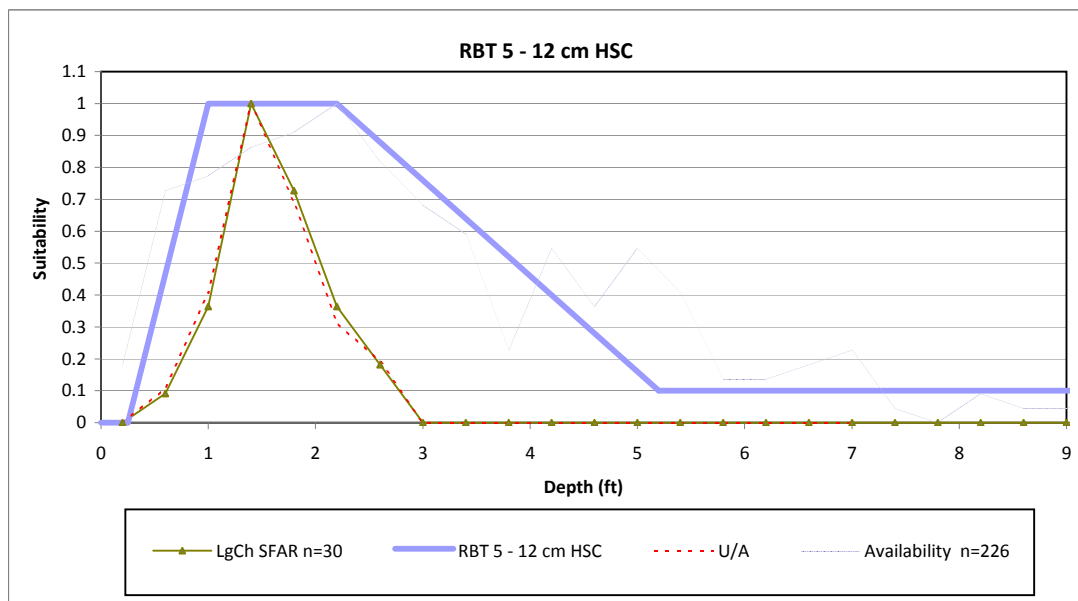
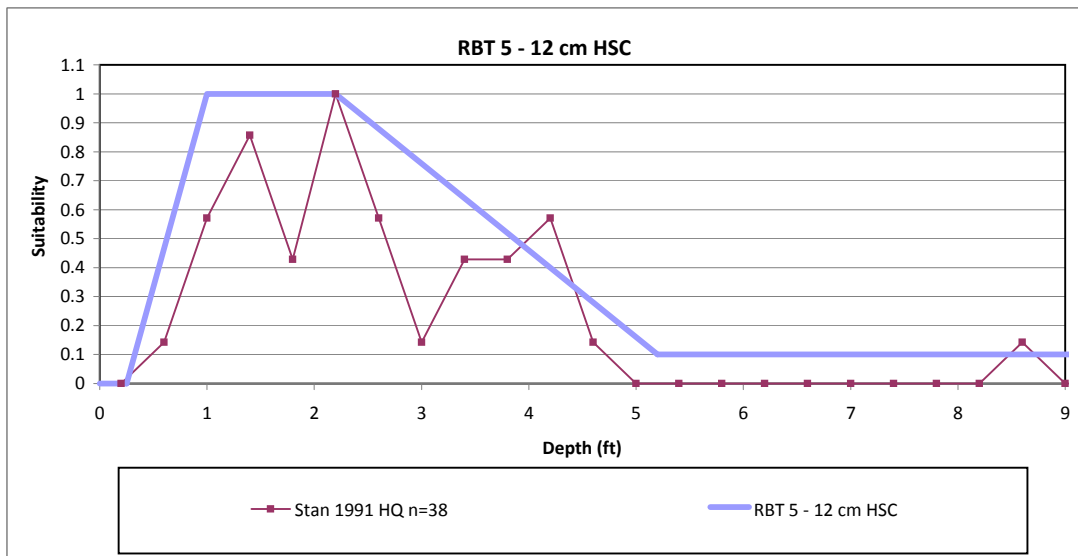
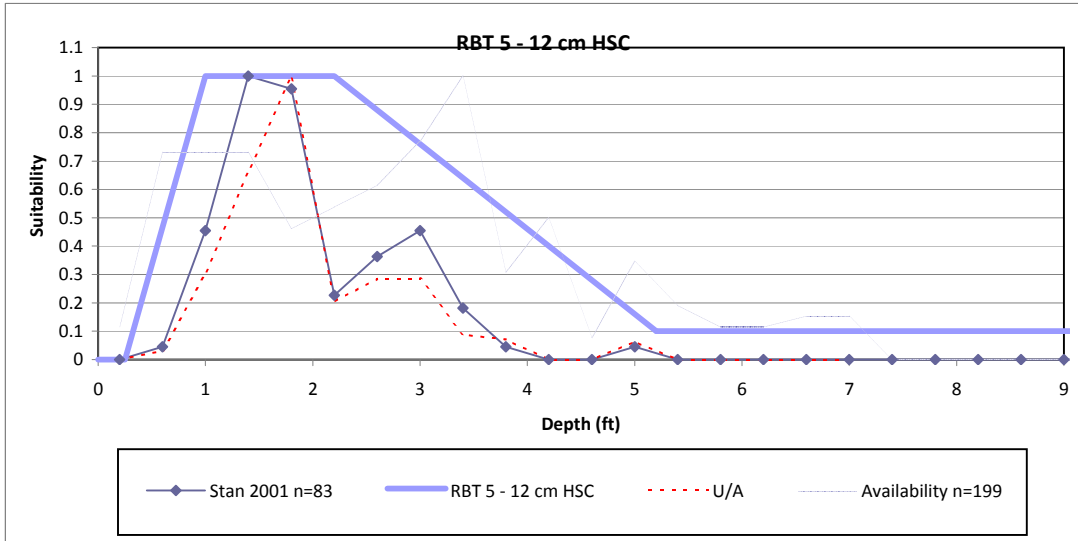


Figure 5. MFP juvenile rainbow trout depth habitat suitability criteria, habitat use, availability and adjusted preference (U/A) for small stream size fish (by river dataset) (continued).

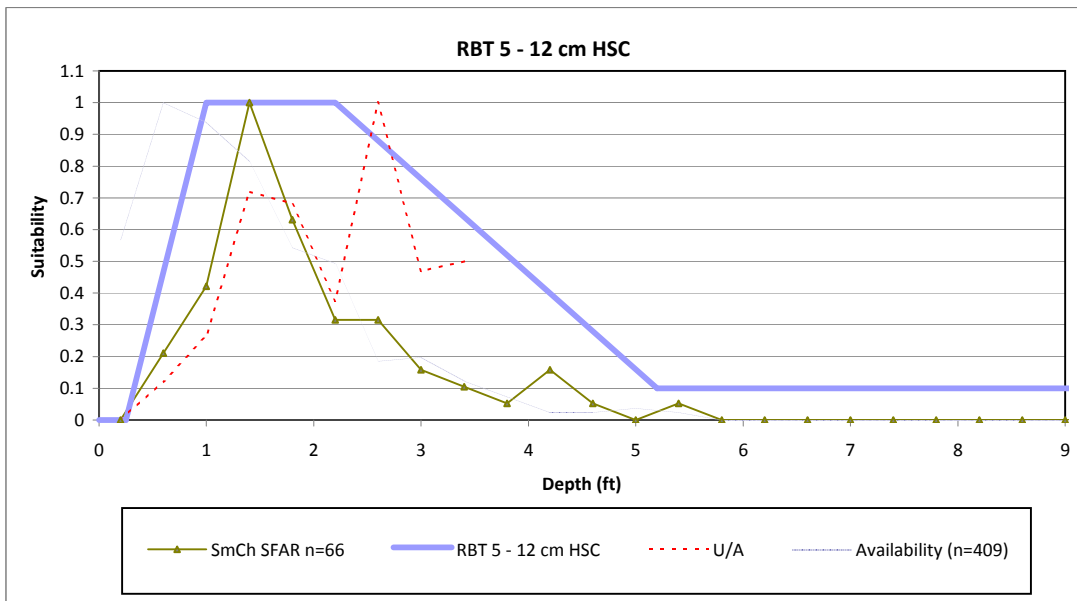
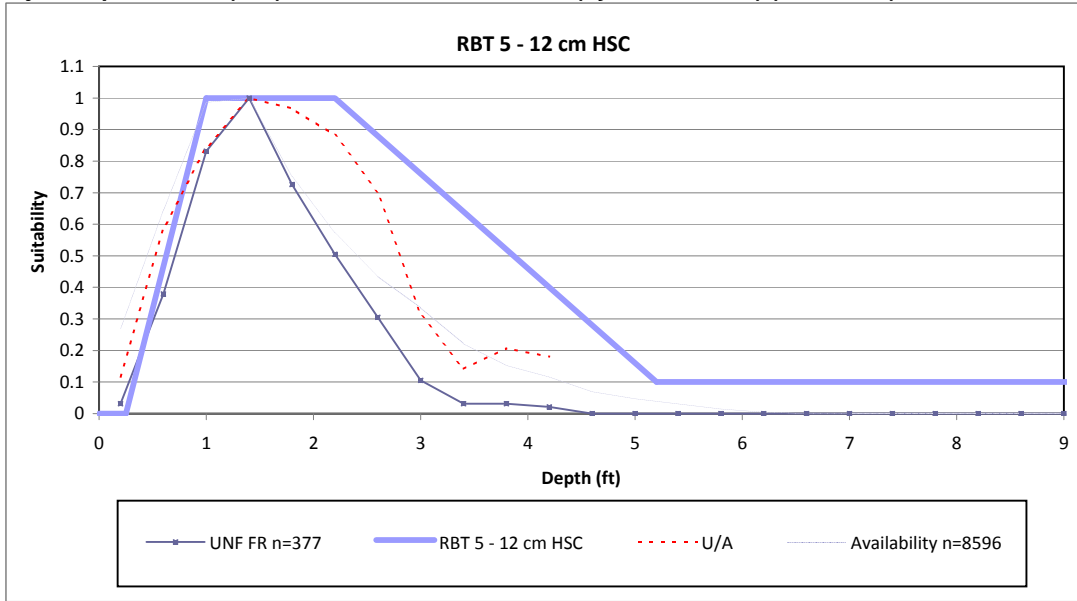


Figure 6. MFP adult rainbow trout depth habitat suitability criteria, habitat use, availability and adjusted preference (U/A) for small stream size fish (by river dataset).

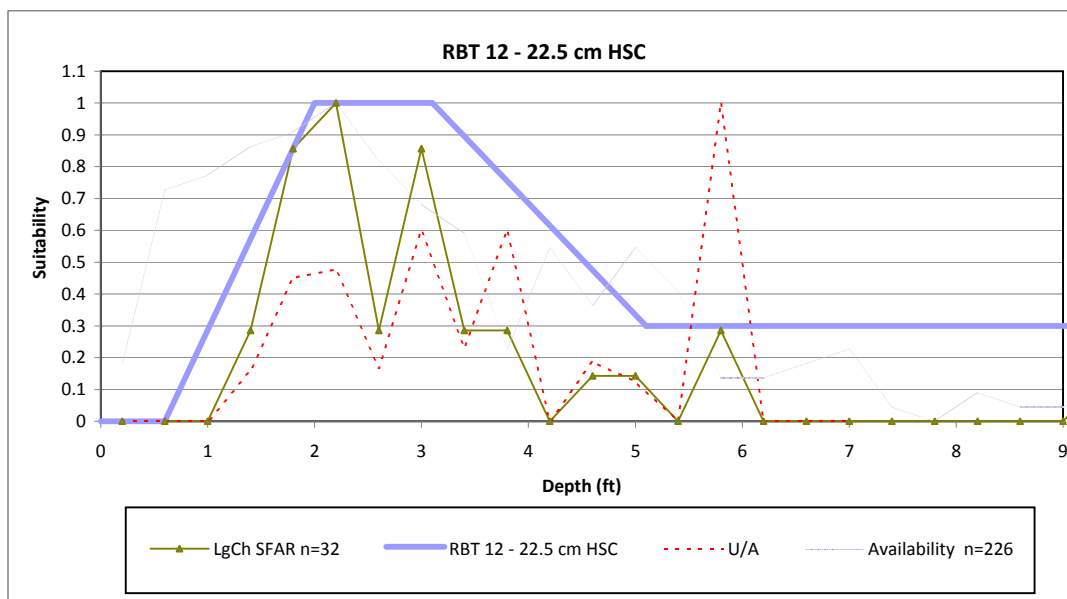
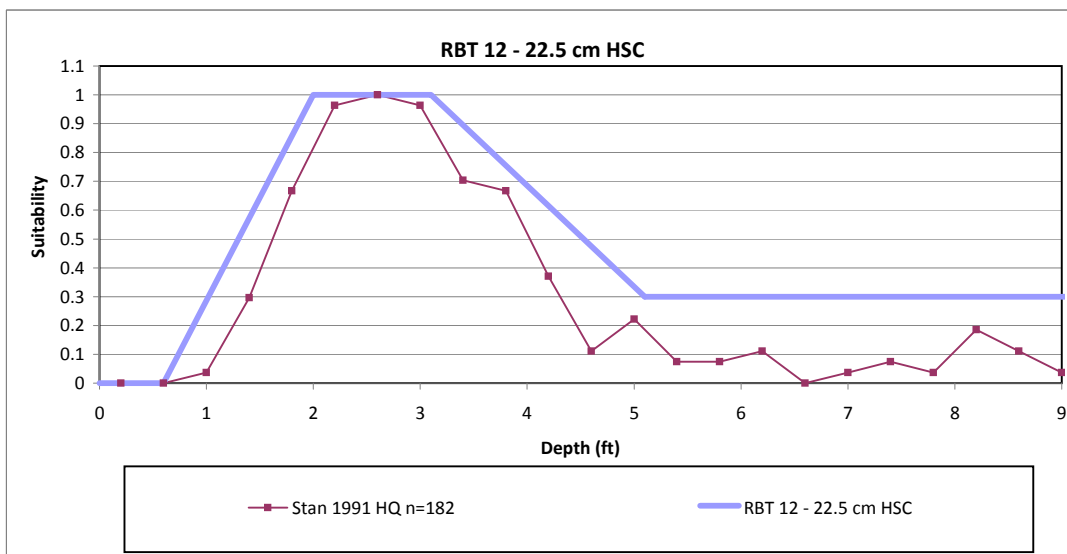
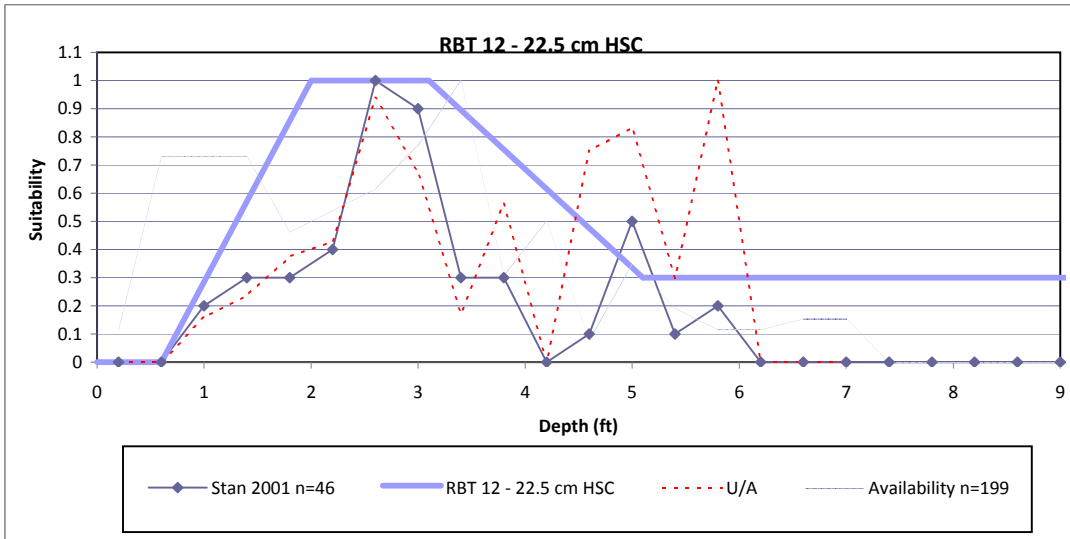
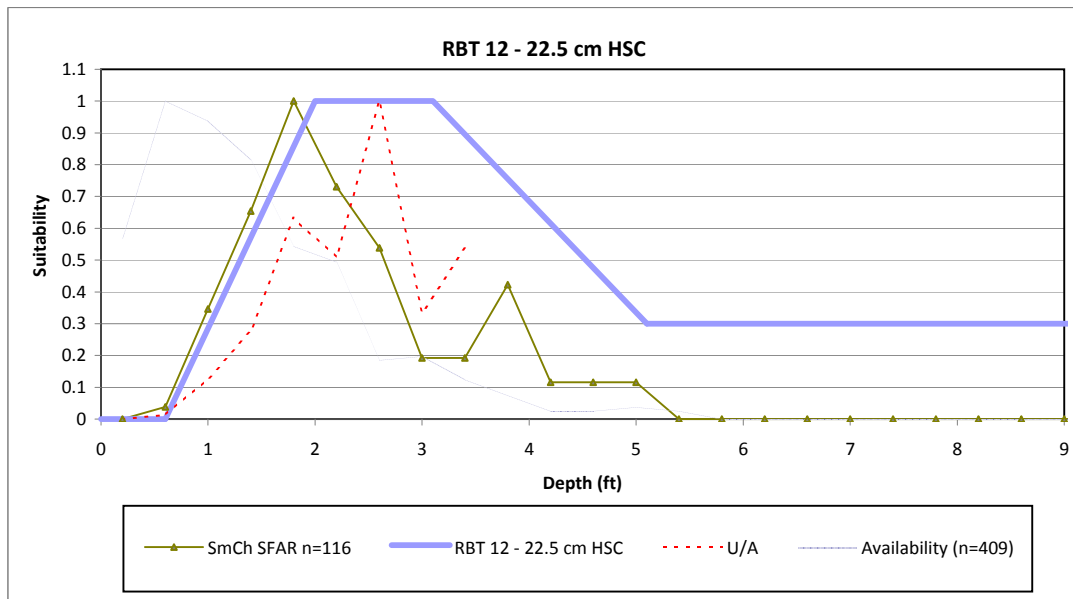
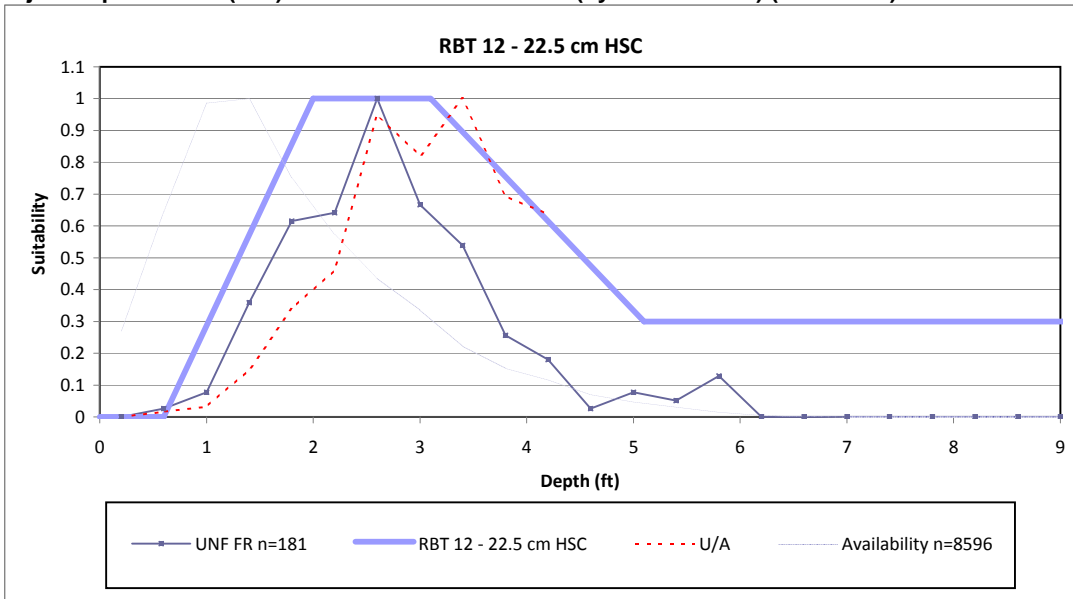


Figure 6. MFP adult rainbow trout depth habitat suitability criteria, habitat use, availability and adjusted preference (U/A) for small stream size fish (by river dataset) (continued).



**Figure 7. MFP juvenile rainbow trout depth habitat suitability criteria, habitat use, availability and adjusted preference (U/A) for large stream size fish (by river dataset).**

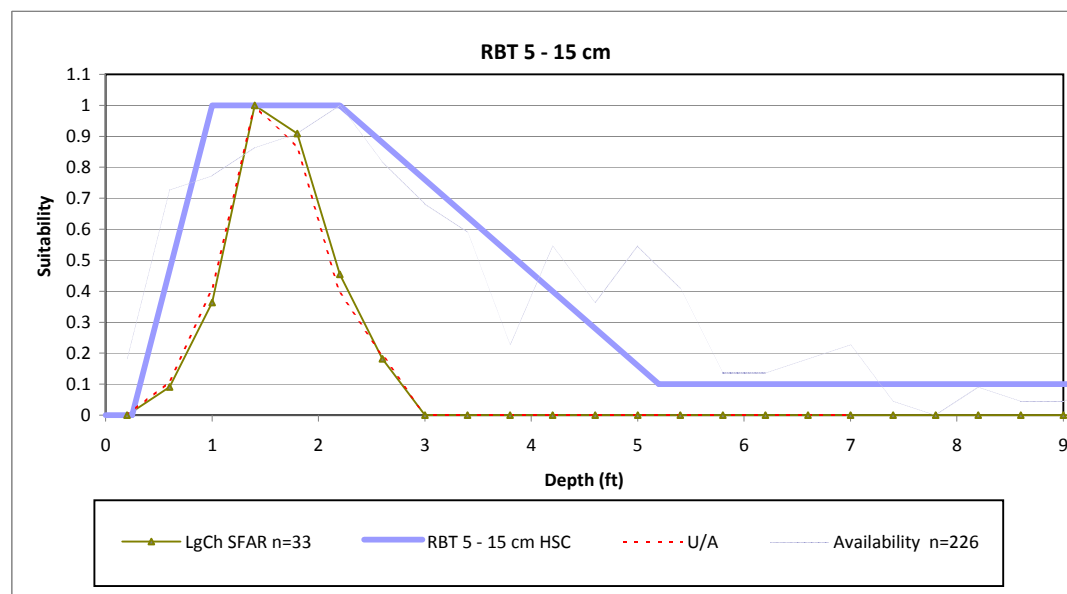
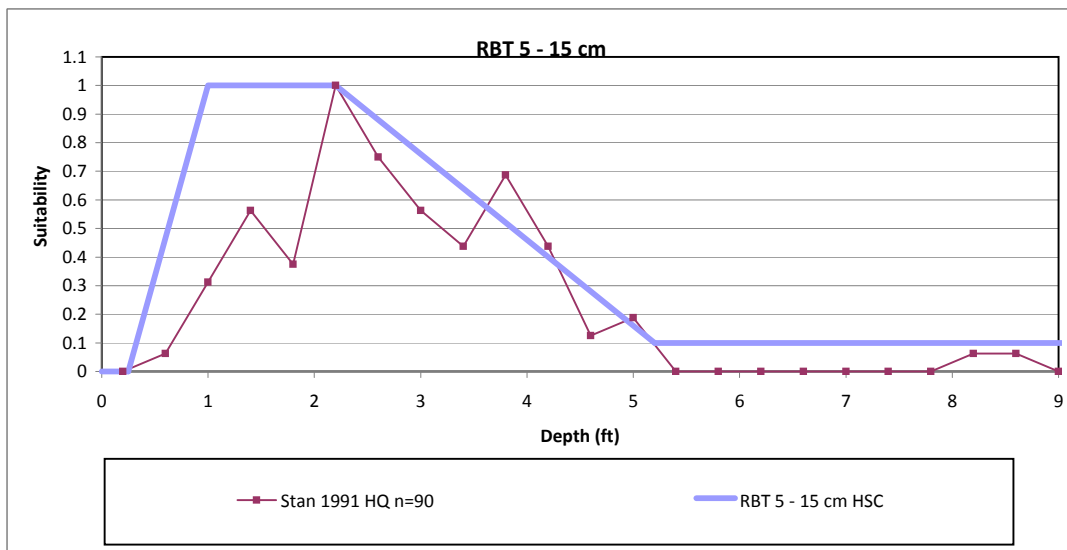
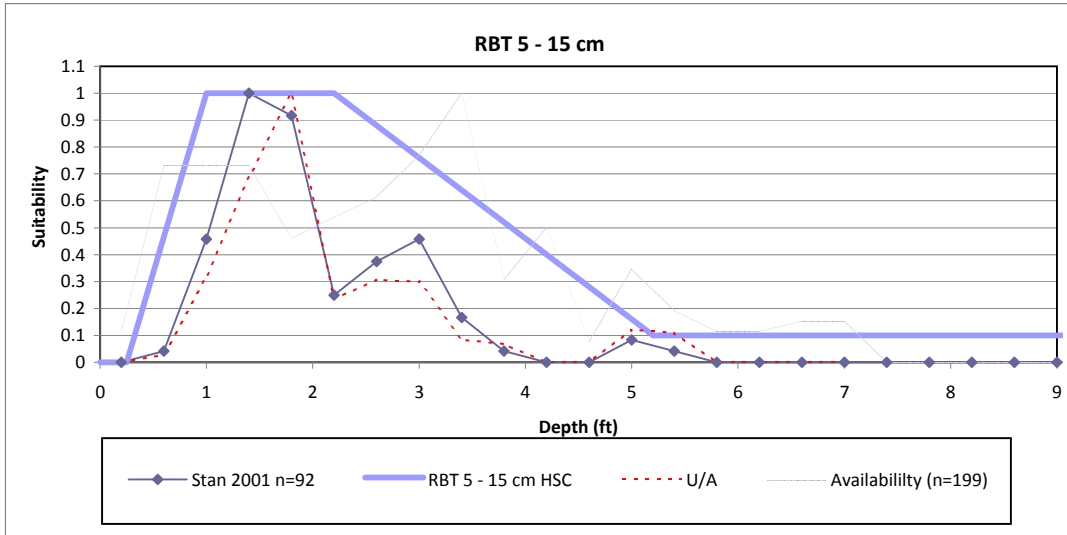
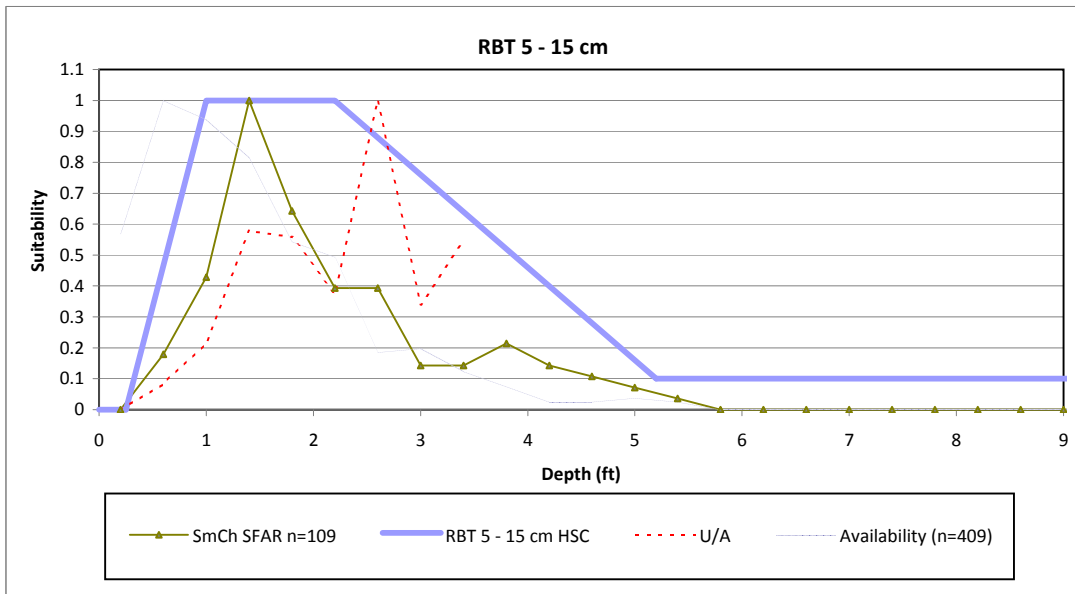
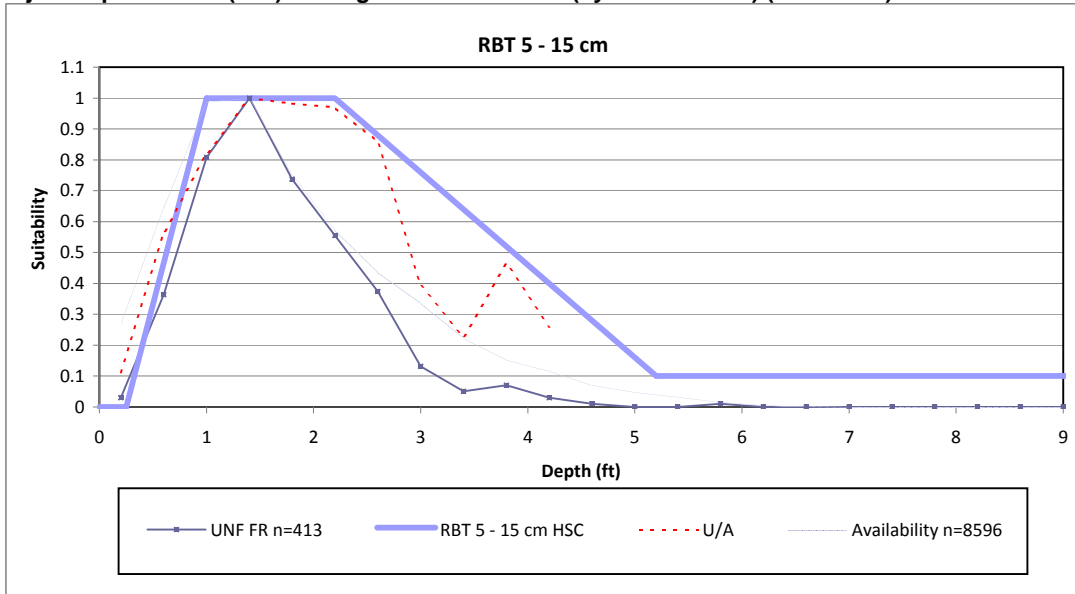
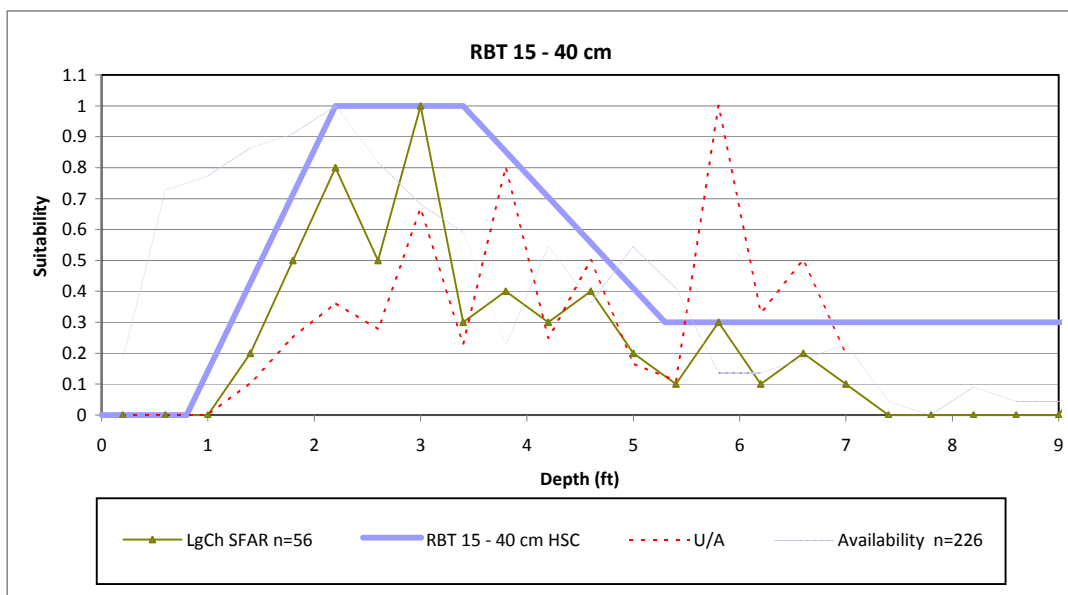
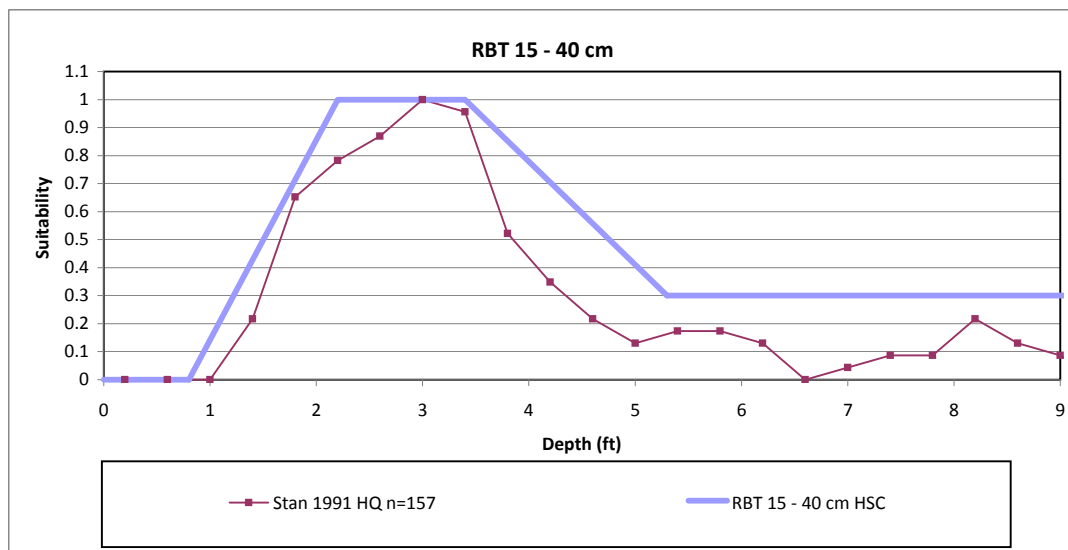
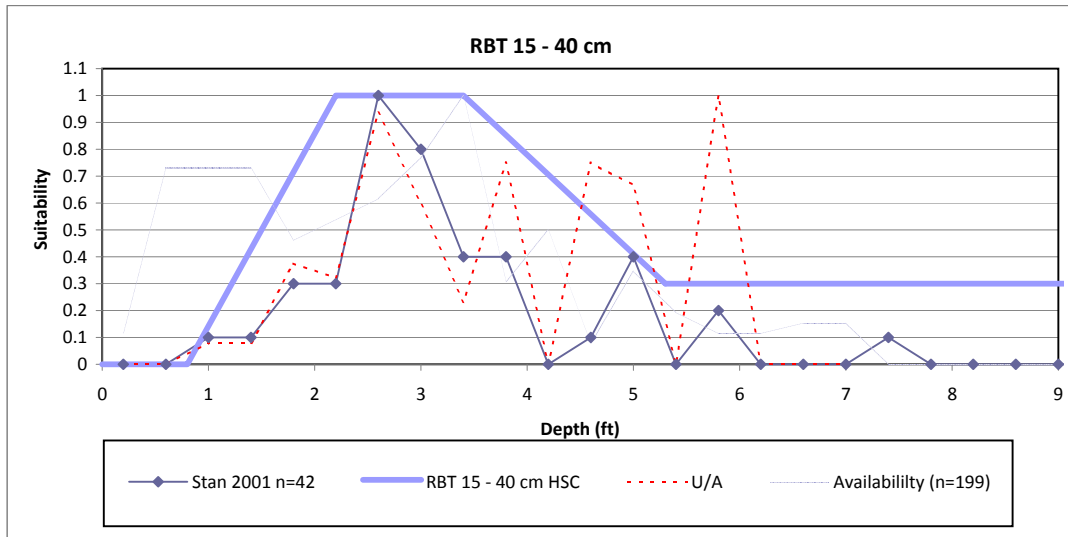


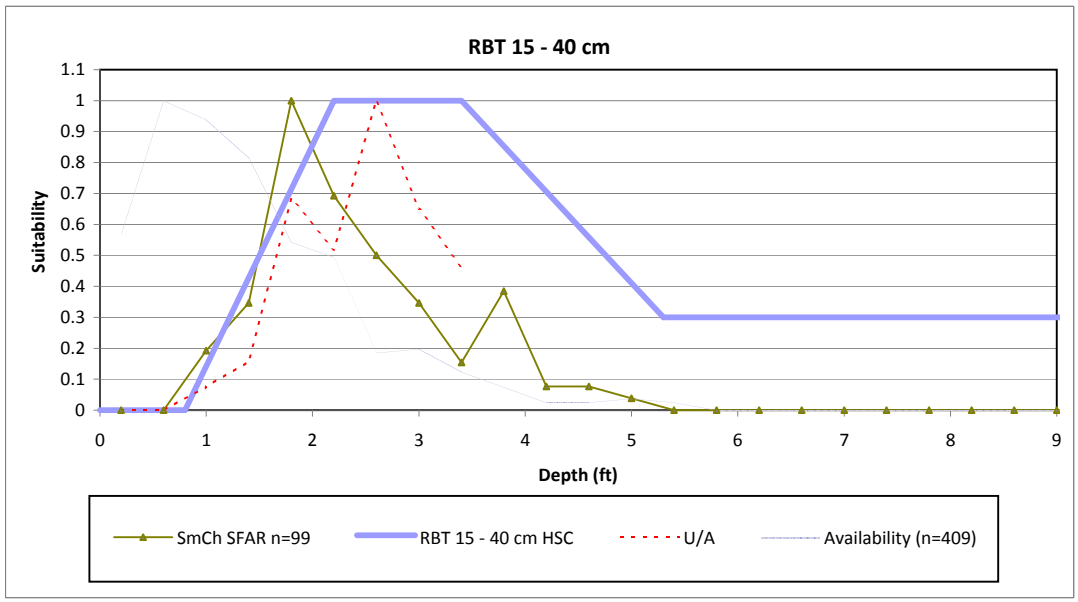
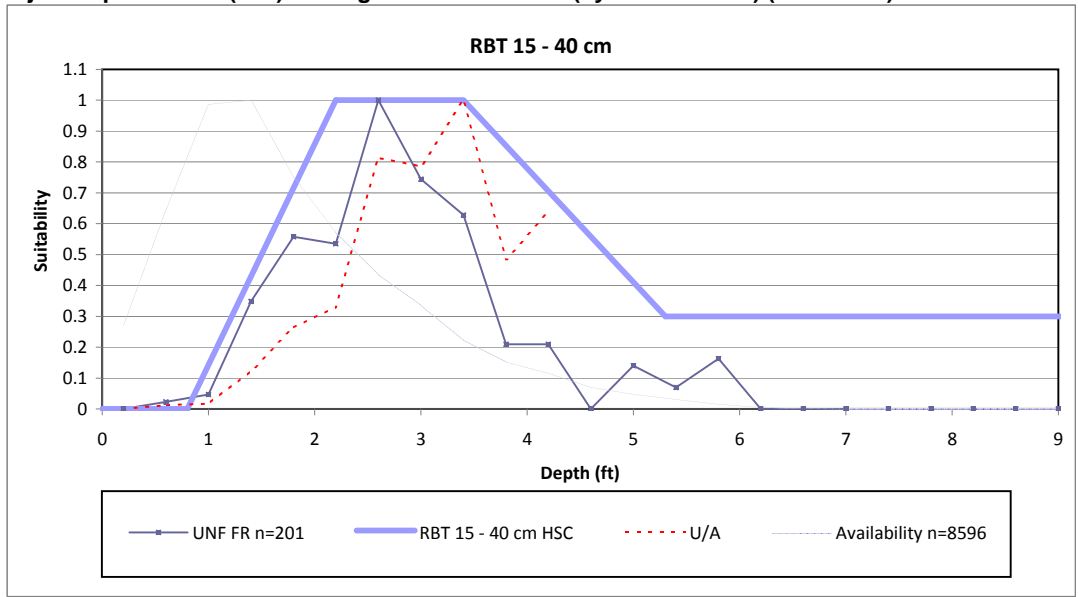
Figure 7. MFP juvenile rainbow trout depth habitat suitability criteria, habitat use, availability and adjusted preference (U/A) for large stream size fish (by river dataset) (continued).



**Figure 8. MFP adult rainbow trout depth habitat suitability criteria, habitat use, availability and adjusted preference (U/A) for large stream size fish (by river dataset).**



**Figure 8. MFP adult rainbow trout depth habitat suitability criteria, habitat use, availability and adjusted preference (U/A) for large stream size fish (by river dataset) (continued).**



**ATTACHMENT C**

**MFP Adult and Juvenile Rainbow Trout Enveloped Habitat Suitability Criteria (HSC) and Stanislaus Project and Upper American River Project Habitat HSC**

Figure 1. MFP juvenile velocity HSC for small stream size rainbow trout (5-12 cm) compared to juvenile UARP and juvenile Stanislaus datasets.

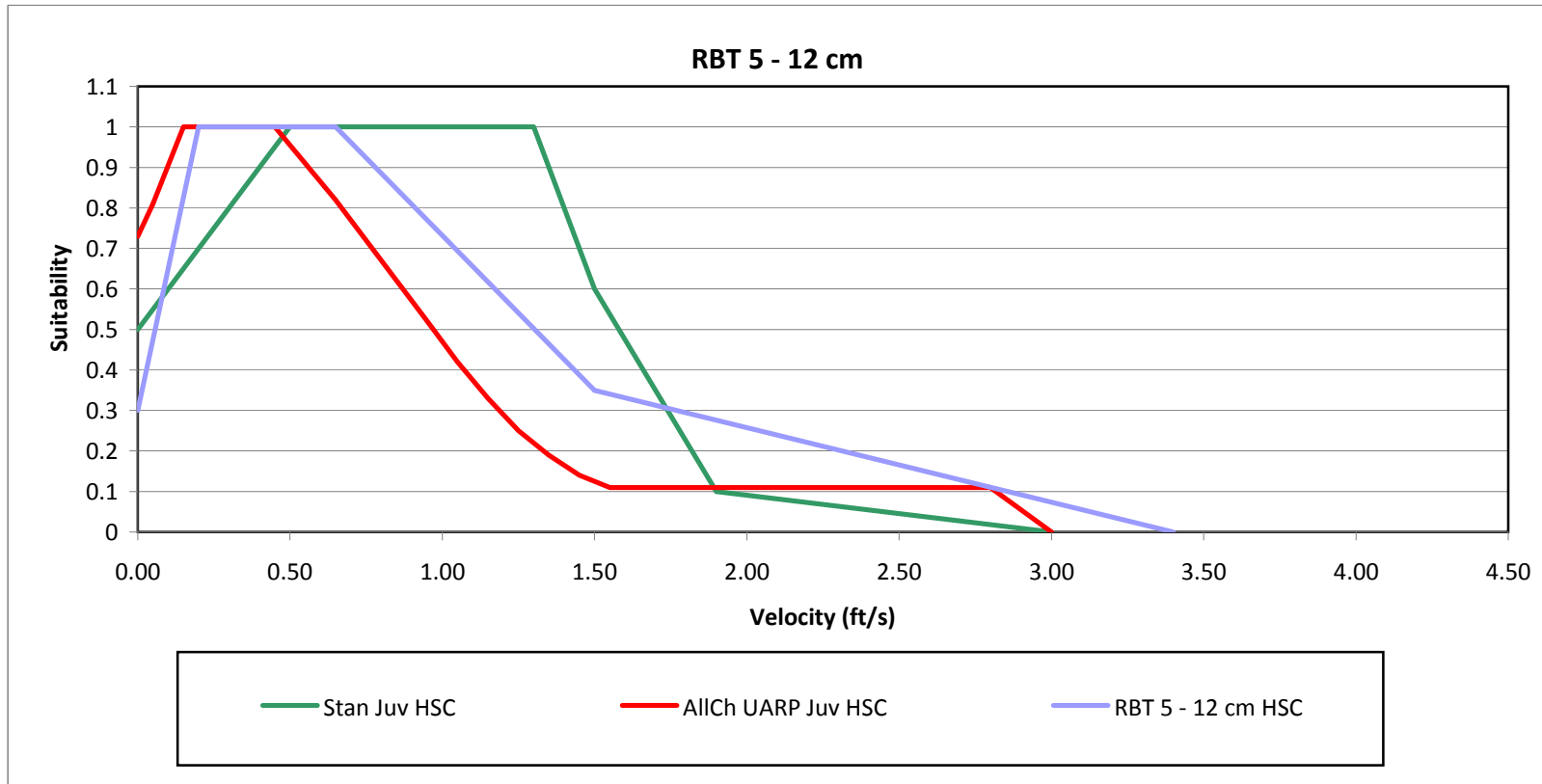


Figure 2. MFP adult velocity HSC for small stream size rainbow trout (12-22.5 cm) compared to juvenile UARP and juvenile Stanislaus datasets.

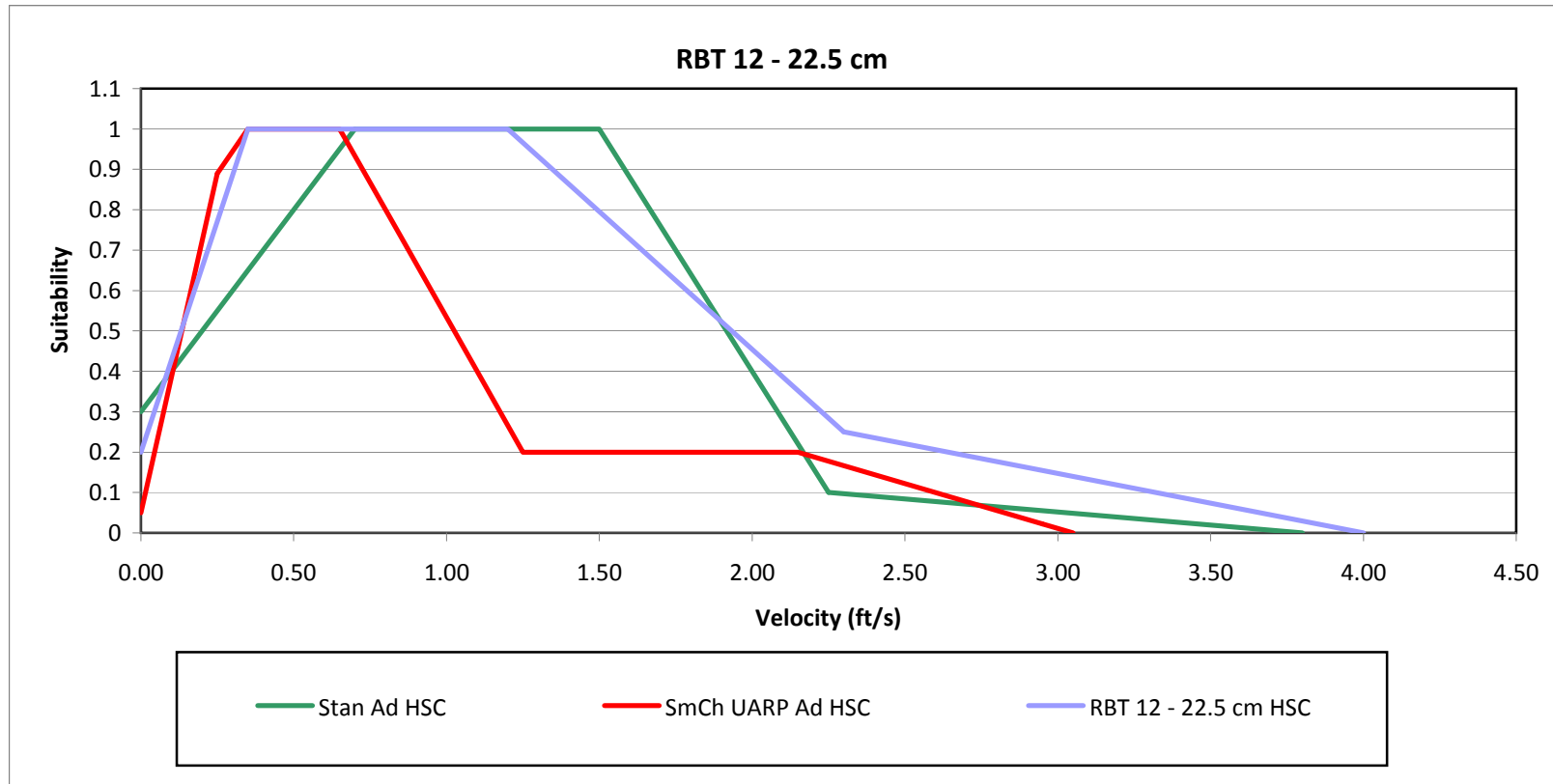


Figure 3. MFP juvenile velocity HSC for large stream size rainbow trout (5-15 cm) compared to juvenile UARP and juvenile Stanislaus datasets.

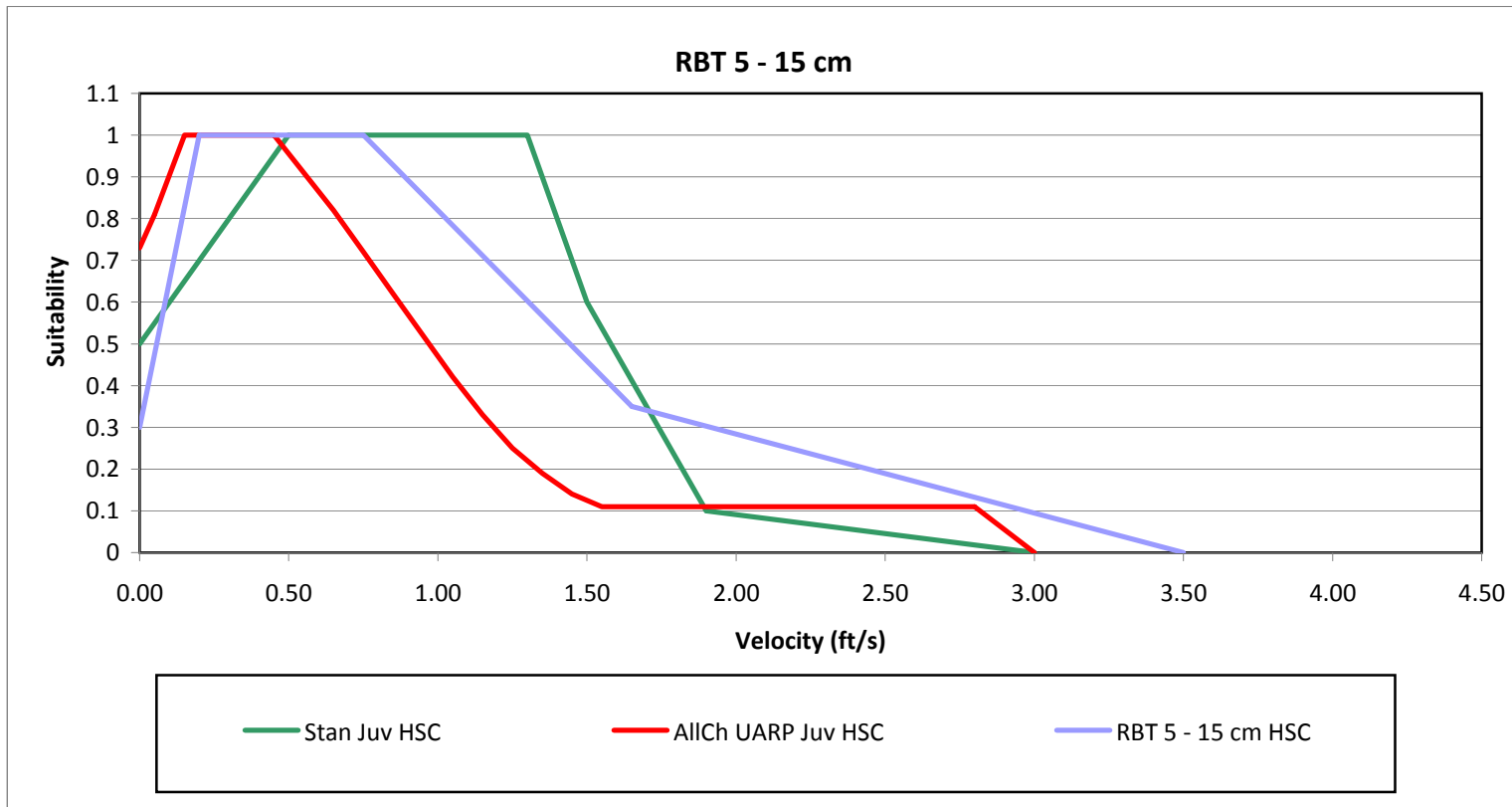


Figure 4. MFP adult velocity HSC for large stream size rainbow trout (15-40 cm) compared to juvenile UARP and juvenile Stanislaus datasets.

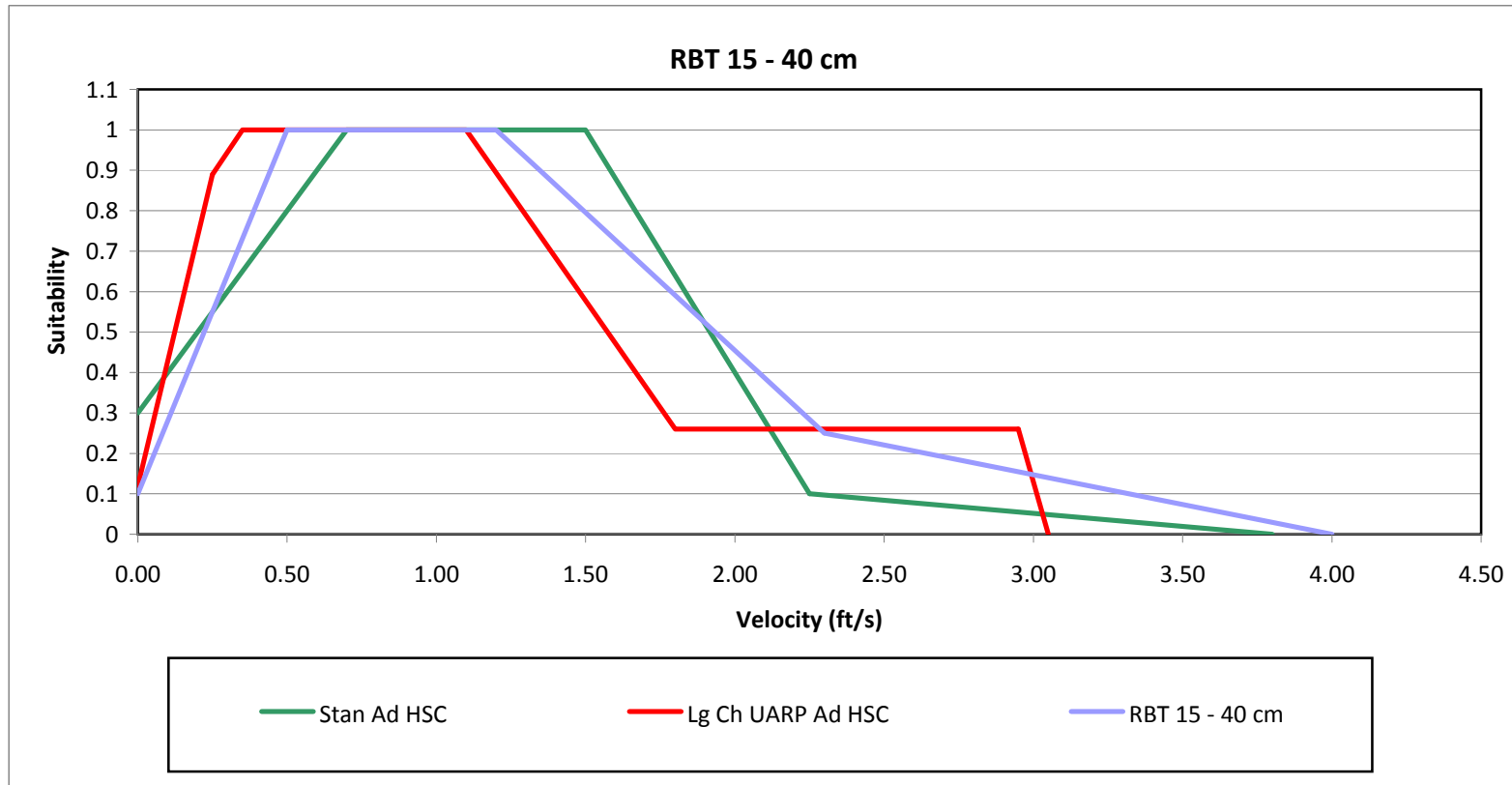


Figure 5. All MFP velocity HSC for rainbow trout.

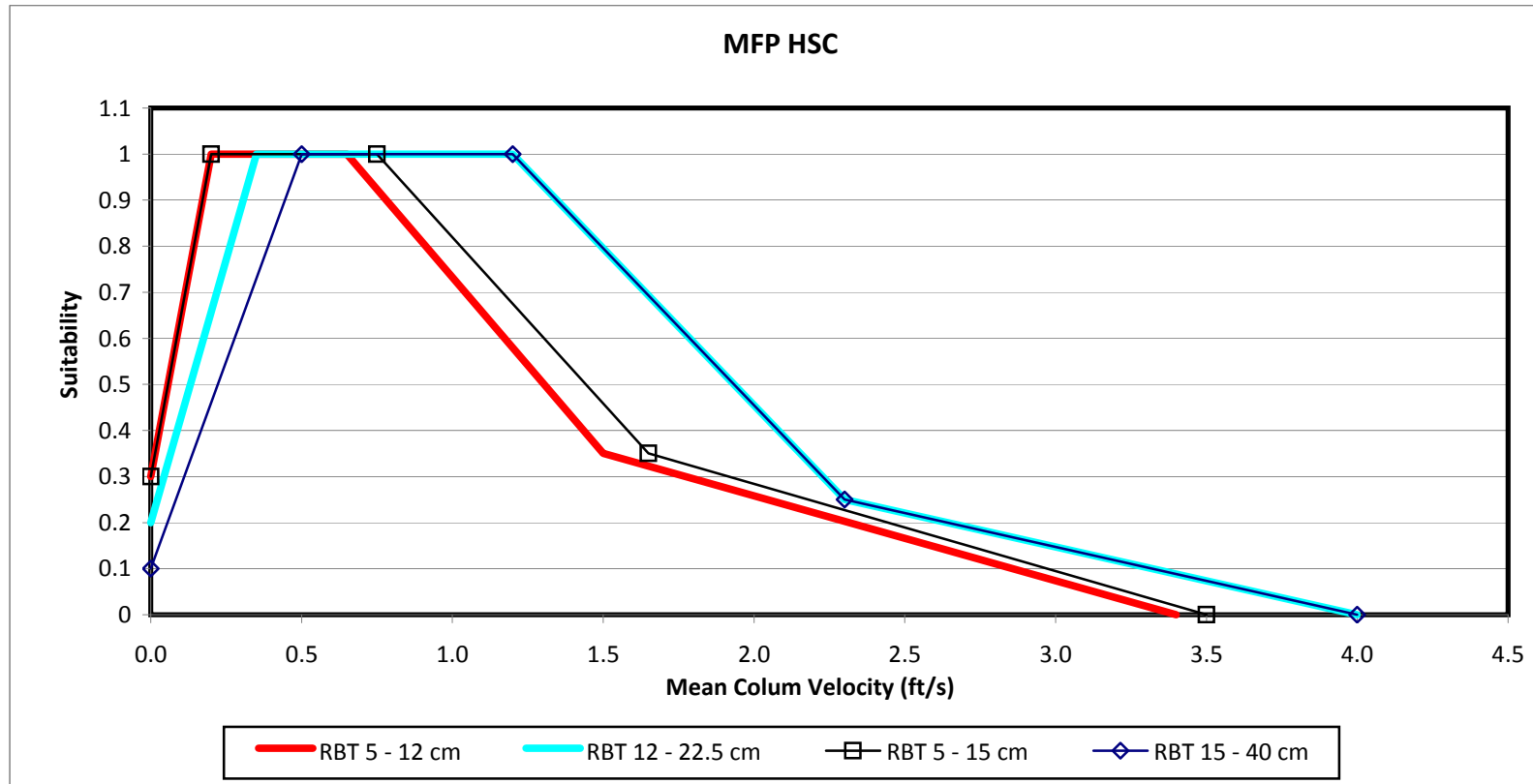
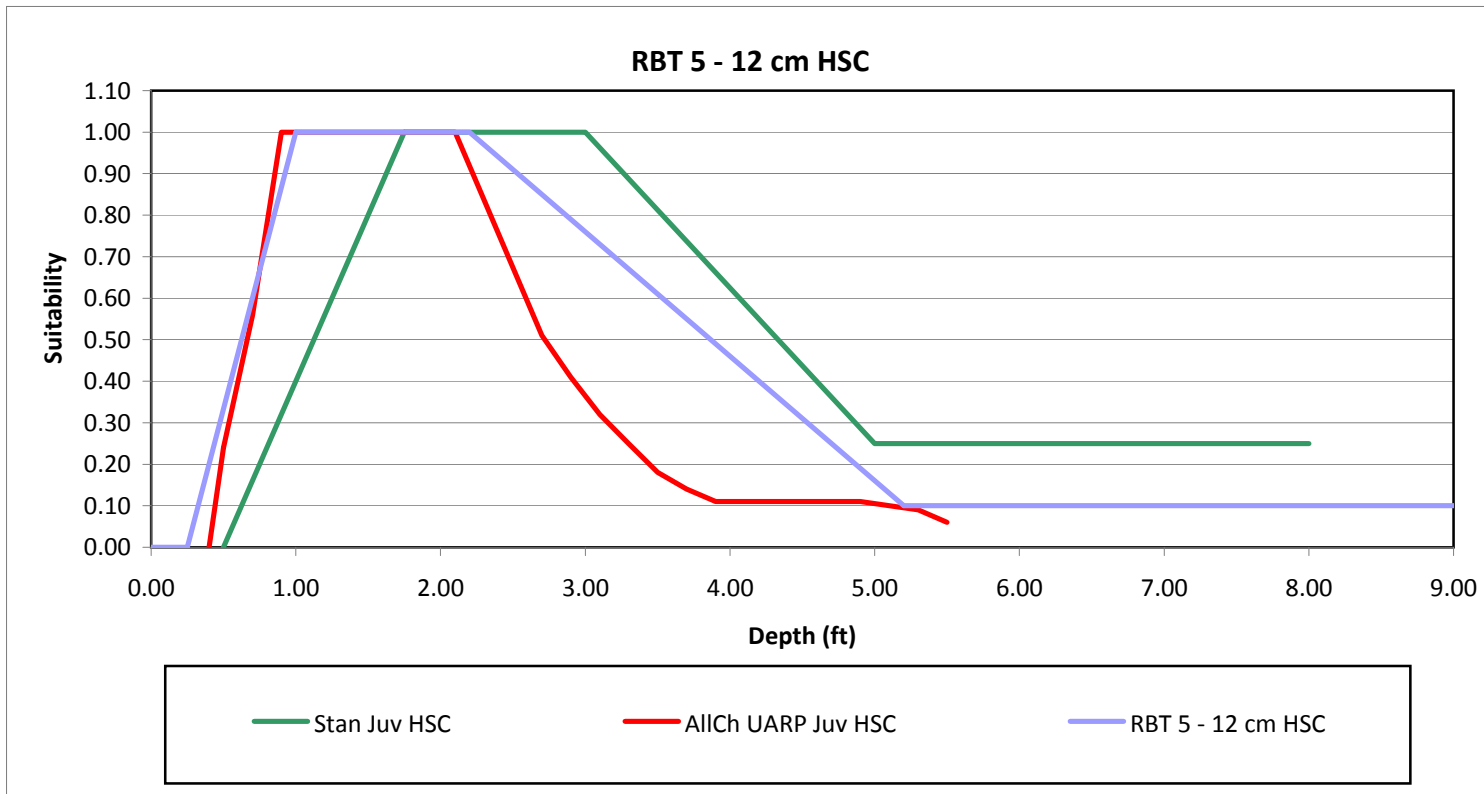
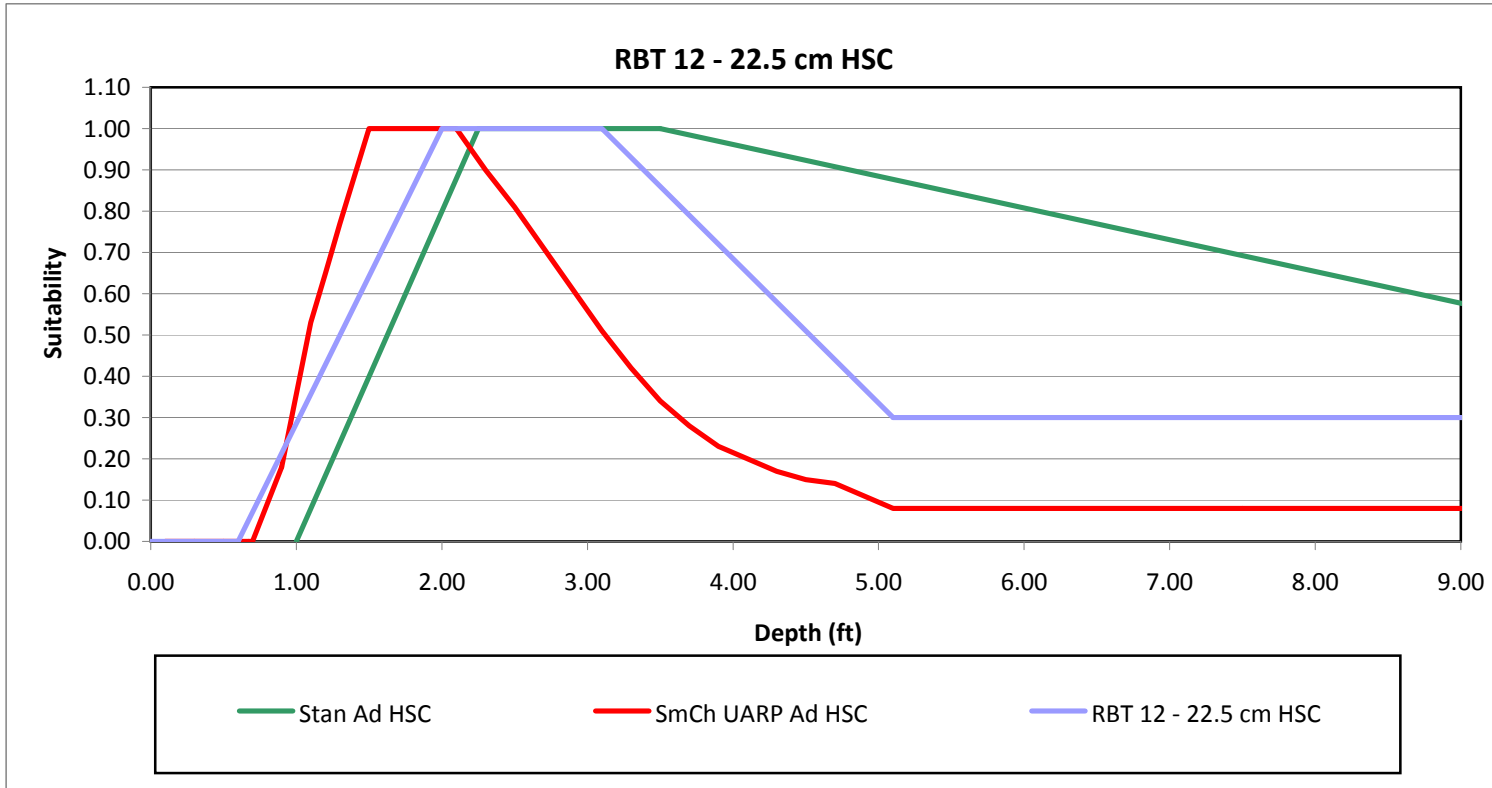


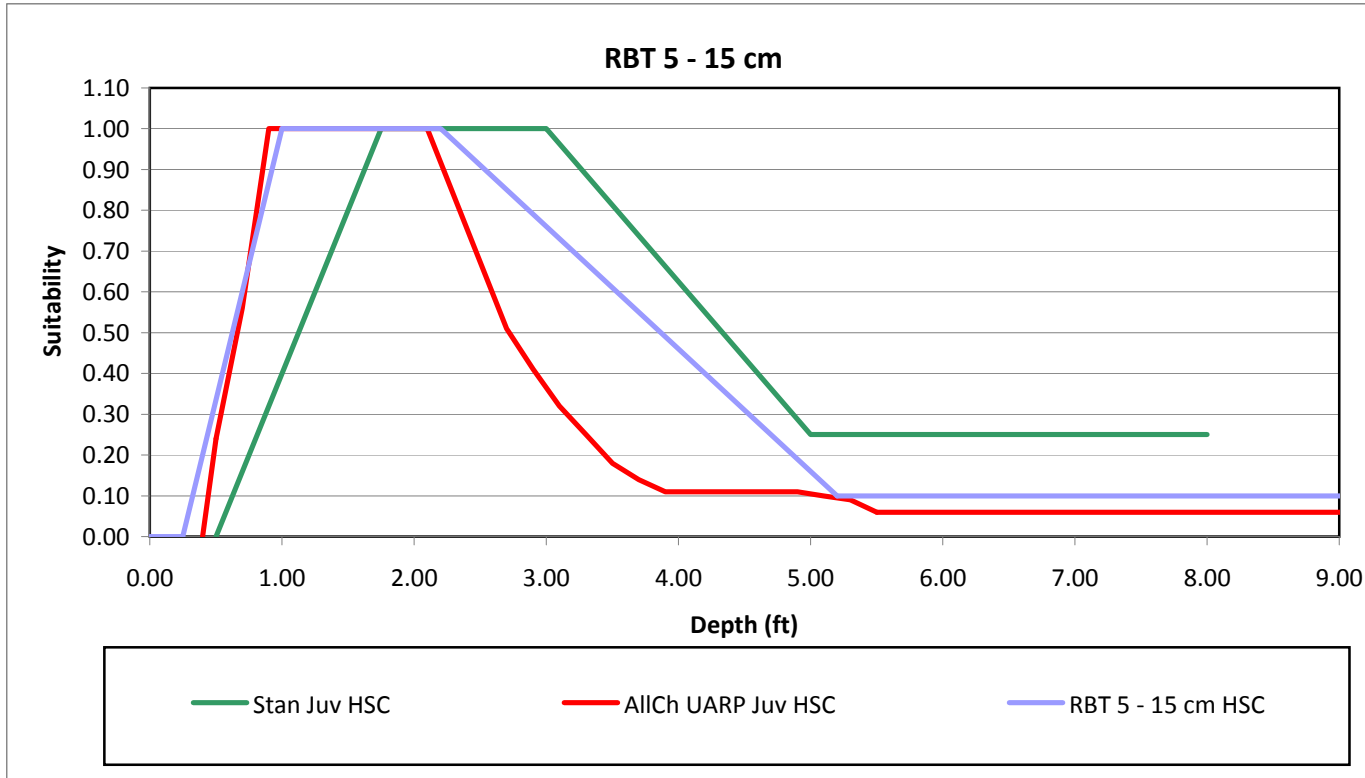
Figure 6. MFP juvenile depth HSC for small stream size rainbow trout (5-12 cm) compared to juvenile UARP and juvenile Stanislaus datasets. .



**Figure 7. MFP adult depth HSC for small stream size rainbow trout (12-22.5 cm) compared to juvenile UARP and juvenile Stanislaus datasets.**



**Figure 8. MFP juvenile depth HSC for large stream size rainbow trout (5-15 cm) compared to juvenile UARP and juvenile Stanislaus datasets.**



**Figure 9. MFP adult depth HSC for large stream size rainbow trout (15-40 cm) compared to juvenile UARP and juvenile Stanislaus datasets.**

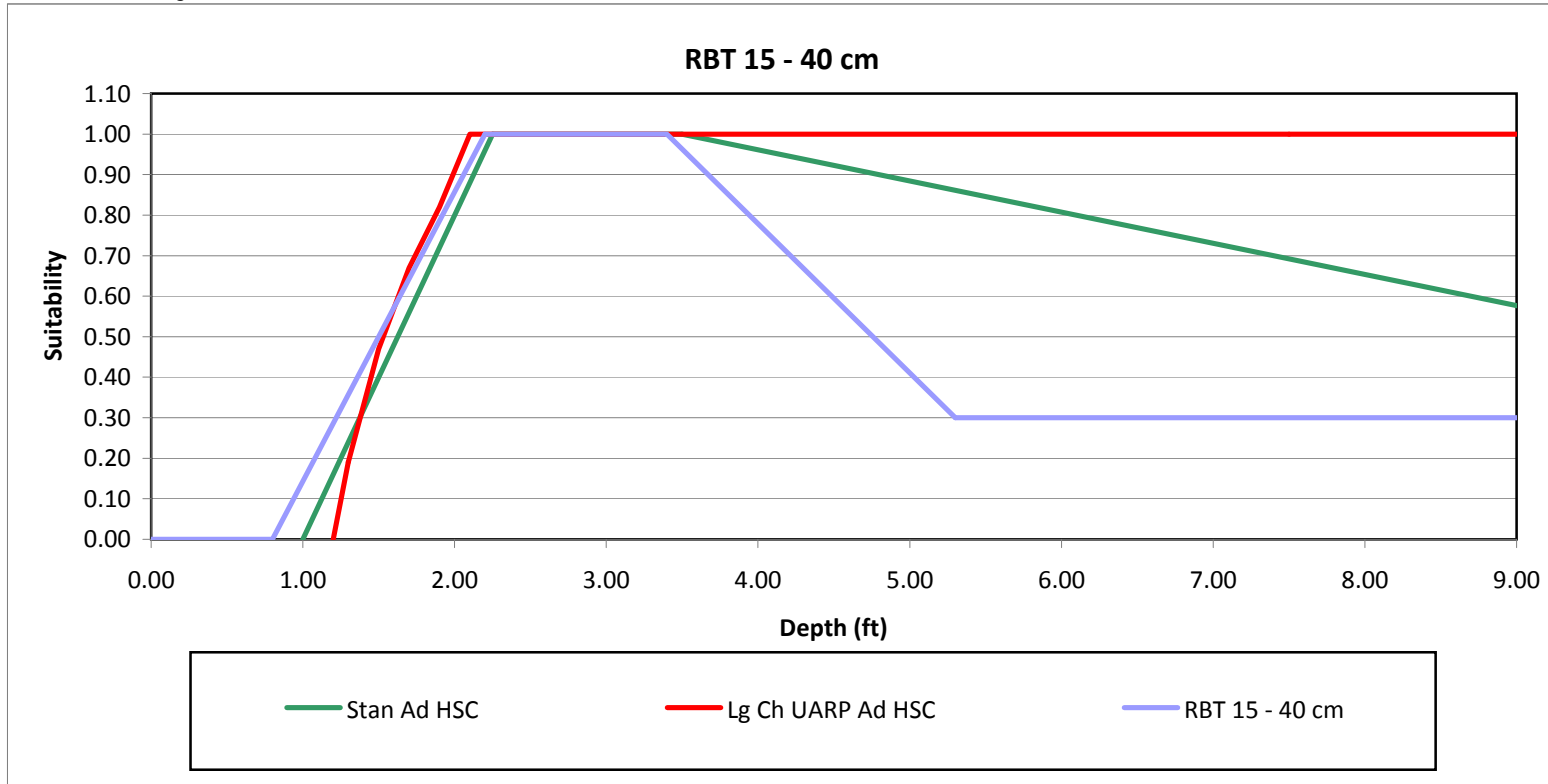
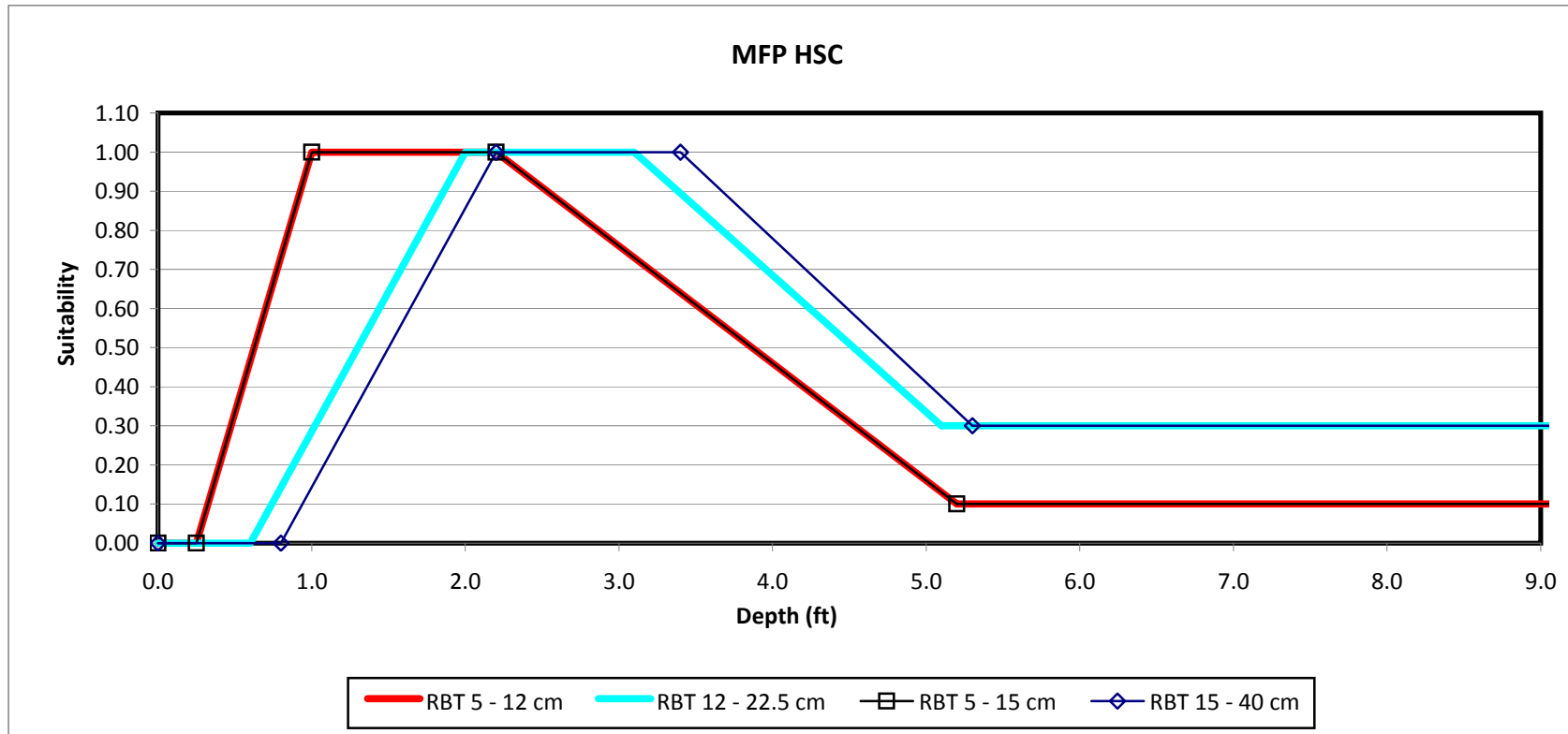


Figure 10. All MFP depth HSC for rainbow trout.



## **APPENDIX B**

### **Habitat Suitability Criteria for Rainbow Trout Fry and Spawning, and for Juvenile and Adult Hardhead, Sacramento Pikeminnow, and Sacramento Sucker (Developed from Literature Based Habitat Suitability Criteria)**

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**TABLES**

**Table B-1. Rainbow Trout Spawning Habitat Suitability Curve Metadata.**

Curve ID	Used for MFP	Fish Characteristics		Sample Size <sup>1</sup>		Stream Location			Stream Characteristics <sup>2</sup>						Sampling Info					Available HSC Curves				Notes	Reference						
		Species	Lifestage	Min Length (cm)	Max Length (cm)	No. HSC Obs	No. Fish	Country	State	River	Min Elevation (ft msl)	Max Elevation (ft msl)	Width (ft)	Mean Streamflow (cfs)	Low Streamflow (cfs)	High Streamflow (cfs)	Mean Slope (%)	Min Water Temperature (°F)	Max Water Temperature (°F)	Species Composition <sup>3</sup>	Site-Specific?	Sampling Season	Survey Design <sup>4</sup>			Observation Method <sup>5</sup>	Curve Type <sup>6</sup>	Curve Smoothing <sup>7</sup>	Total Depth	Mean Col	Focal
Bovee	Y	RBT	spawning			USA,CAN	OR,ID,BC	various												N				Cat I		Y	Y		Y		Bovee 1978
Raleigh	Y	RBT	spawning			USA,CAN	OR,ID,CA,BC	various												N				Cat I		Y	Y		Y	original substrate code modified to approximate Bovee code	Raleigh et al. 1984
Roaring	Y	RBT	spawning	13	30	73	USA	CA	Roaring	1,300	1,600	30-40	40		4-6	45	50	rbt,brn,scp	Y	Apr-May	total stream	DO uw	Cat II		Y	Y		Y		TRPA unpublished HSC data	
UNFFR	Y	RBT	spawning	15	40	172	USA	CA	upper NF Feather	2,300	3,500	40-50	35-150		0.5-2.6	46	57	rbt,skr,scp	Y	April	reaches	DO uw	Cat II	hist w Sturges rule	Y	Y		Y		TRPA 2002	
Butt	Y	RBT	spawning	15	40	57	USA	CA	Butt Creek	3,180	3,260	18	5-10		4.5	48	52	rbt	Y	April	reaches	DO uw	Cat II	hist w Sturges rule	Y	Y		Y		TRPA 2002	
NF Kings	Y	RBT	spawning			51	USA	CA	NF Kings & tribs					<5	30	low-high			Y		proportional		Cat II		Y	Y		Y	original substrate code modified to approximate Bovee code	EA Engineering, Science, and Technology, Inc. 1987	
E Sierra	Y	RBT	spawning			50	USA	CA	various	4,400	9,400	7-26			low-high				Y		reaches		Cat III		Y	Y		Y		Smith and Aceituno 1987	
Klamath River	Y	RBT	spawning			66	USA	CA	upper Klamath	3,335	3,750	87	325		1.7	55	62	rbt,skr,scp, chub,imp	Y	July-Sept	EA	DO uw	Cat II					Y	Only substrate HSC were used	TRPA 2004	

<sup>1</sup># HSC observations is number of independent measurements at fish positions, # fish is total number of fish seen at the measurement locations

<sup>2</sup>stream habitat characteristics during the period of sampling for HSC

<sup>3</sup>species abbreviations: chs=chinook salmon, coh=coho salmon, sth=steelhead, rbt=rainbow trout (resident), brn=brown trout, brk=brook trout, bul=bull trout, cut=cutthroat trout, wtf=whitefish, skr=suckers, scp=sculpin, pkm=pikeminnow, hdh=hardhead, dac=dac

<sup>4</sup>survey design: sampling design used to collect hsc data, i.e. reaches - samples collected in representative reach(es), proportional - samples collected within mesohabitat types with effort in proportional to availability, equal-area - samples collected with effort equalized among habitat types

<sup>5</sup>observation method: DOuw-direct observation underwater (snorkeling/scuba), DOow-direct observation out-of-water (wading, boat, or bank observation), EF-electrofishing, VID-underwater video, NET-seining or other net capture, Other (see comments)

<sup>6</sup>curve type: Cat I - hand-drawn or a composite of various curves based on professional judgment, Cat II - based on habitat use data, Cat III - based on habitat use data adjusted by habitat availability data, Bio - bioenergetics hsc

<sup>7</sup>curve smoothing: method used (if any) to smooth raw observation or frequency histogram data

<sup>8</sup>see hsc data sets for cover and substrate coding details

Table B-2. Rainbow Trout Fry Habitat Suitability Curve Metadata.

Curve ID	Used for MFP	Fish Characteristics				Sample Size <sup>1</sup>		Stream Location			Stream Characteristics <sup>2</sup>						Sampling Info					Available HSC Curves					Notes	Reference				
		Species	Life-stage	Length Min (cm) Max (cm)		No. HSC Obs	No. Fish	Country	State	River	Elevation Min (ft msl) Max (ft msl)	Width Mean (ft) Min (ft) Max (ft)	Streamflow Low (cfs) High (cfs)	Mean Slope (%)	Water Temperature Mean (°F) Min (°F) Max (°F)	Species Composition <sup>3</sup>	Site-Specific?	Sampling Season	Survey Design <sup>4</sup>	Observ Method <sup>5</sup>	Curve Type <sup>6</sup>	Curve Smoothing <sup>7</sup>	Total Depth	Velocity Mean Col	Focal	Cover <sup>8</sup>			Substrate <sup>3</sup>			
Bovee	N	RBT	fry				USA,CAN	OR,ID,BC	various																					Bovee 1978		
Raleigh	Y	RBT	fry				USA,CAN	OR,ID,CA,BC	various																					Original substrate code modified to approximate Bovee code.	Raleigh et al. 1984	
E Sierra	N	RBT	fry			50	USA	CA	various	4,400	9,400	7	26		low-high															Smith and Aceituno 1987		
Pit	Y	RBT	fry			61	USA	CA	Pit	1,445	2,650	40	200	50	150	0.7-1.1	65		rbt,skr,scp,hdh,pkm			PROP	DO uw	Cat III						Curve points taken from IFG HSC summary printout, preference estimated using electivity ratios, see data for definitions.	Baltz and Vondracek 1985	
Battle	Y	RBT	fry	2	4	212	USA	CA	Battle	1,400	3,000	14	29	4	108	1-5	36	73	rbt,scp		May-Dec	EA	DO uw	Cat II	polynomial regr						TRPA 2002	
MF Stanislaus Use	Y	RBT	fry			45	USA	CA	MF Stanislaus																				Used Stanislaus HSC.	TRPA 2002		
Alt Q's pref and util	Y	RBT	fry				USA	CA	Tule																				Not included intentionally.	Wise et al. 1987		
Up Klamath	Y	RBT	fry	2	4	175	186	USA	OR	upper Klamath	3,335	3,750	87		325 mean	1.7	55	62	rbt,skr,scp, chub,Imp		July-Sept	EA	DO uw	Cat III	3pt running means						TRPA 2004	
NFKings	Y	RBT	fry			51	-	USA	CA	NF Kings & tribs					<5	30	low-high				proportional			Cat II					Original substrate code modified to approximate Bovee code.	EA Engineering, Science, and Technology, Inc.		
Deer Use and Electivity	Y	RBT	fry					USA	CA	Deer	30	3,475			100	200		55	rbt,brn,skr,scp, hdh,pkm,rch, dac,smb		June-Oct	RCH	DO uw	Cat II and III	histogram					Curve points taken from IFG HSC summary printout.	Moyle & Baltz 1985	
Yosemite	Y	RBT	fry			406		USA	CA	Eleanor, Cherry					15	36		46	73	rbt,skr,scp		July-Aug	RCH	DO uw	Cat II	histogram					Curve points approximated from graphs.	Baltz & Moyle 1984
Studley-Spina*	Y	BRN	fry					USA	CA																				Thomas Studley, Pers. Comm.			

\*brown trout data  
<sup>1</sup># HSC observations is number of independent measurements at fish positions, # fish is total number of fish seen at the measurement locations  
<sup>2</sup>stream habitat characteristics during the period of sampling for HSC  
<sup>3</sup>species abbreviations: chs=chinook salmon, coh=coho salmon, sth=steelhead, rbt=rainbow trout (resident), brn=brown trout, brk=brook trout, bul=bull trout, cut=cutthroat trout, wtf=whitefish, skr=suckers, scp=sculpin, pkm=pikeminnow, hdh=hardhead, dac=dac  
<sup>4</sup>survey design: sampling design used to collect hsc data, i.e. reaches - samples collected in representative reach(es), proportional - samples collected within mesohabitat types with effort in proportional to availability, equal-area - samples collected with effort equalized among habitat types  
<sup>5</sup>observation method: DOuw-direct observation underwater (snorkeling/scuba), DOow-direct observation out-of-water (wading, boat, or bank observation), EF-electrofishing, VID-underwater video, NET-seining or other net capture, Other (see comments)  
<sup>6</sup>curve type: Cat I - hand-drawn or a composite of various curves based on professional judgment, Cat II - based on habitat use data, Cat III - based on habitat use data adjusted by habitat availability data, Bio - bioenergetics hsc  
<sup>7</sup>curve smoothing: method used (if any) to smooth raw observation or frequency histogram data  
<sup>8</sup>see hsc data sets for cover and substrate coding details

Table B-3. Hardhead Juvenile Habitat Suitability Curve Metadata.

Curve ID		Fish Characteristics				Sample Size <sup>1</sup>		Stream Location			Stream Characteristics <sup>2</sup>							Sampling Info					Available HSC Curves				Notes	Reference							
Name	Used for MFP	Species	Life-stage	Length		No. HSC Obs	No. Fish	Country	State	River	Elevation		Width			Streamflow			Mean Slope (%)	Water Temperature			Species Composition <sup>3</sup>	Site-Specific?	Sampling Season	Survey Design <sup>4</sup>	Observ Method <sup>5</sup>	Curve Type <sup>6</sup>	Curve Smoothing <sup>7</sup>	Velocity		Cover <sup>8</sup>	Substrate <sup>8</sup>		
				Min (cm)	Max (cm)						Min (ft msl)	Max (ft msl)	Mean (ft)	Min (ft)	Max (ft)	Mean (cfs)	Low (cfs)	High (cfs)		Mean (°F)	Min (°F)	Max (°F)								Total Depth	Mean Col				
NFFR - Density, Util, Pref, PrAb,	Y	Hardhead	juv	<15		140		USA	CA	NF Feather	925	2,010	avg 70-106				96	131	0.4-1.1		64	72	skr,rbt,pkm,hdh,smb	Y	July-Aug	EA	DO uw	II and III		Y	Y	Y		4 methods used (utilization, preference, pres-abs, density)	TRPA 2001
Pit Pref and Util	Y	Hardhead	juv			90		USA	CA	Pit	1,445	2,650	40	200		50	150	0.7-1.1				skr,rbt,pkm,hdh	Y	summer	RCH	DO uw	II and III		Y	Y	Y	Y	2 methods used (utilization and preference; preference curve reweighted to equalize effort)	Baltz and Vondracek 1985	
Deer	Y	Hardhead	juv	<16cm SL		81		USA	CA	Deer	30	3,500	20	50		100	200	1		55	90			June-Oct		II and electivity		Y	Y	Y		Y	electivity and reaches	Moyle and Baltz 1985	
W Sierra	Y	Hardhead	juv	<12cm TL		537		USA	CA	Sierra streams	203	1,460	6	59				0.1-2.9		49	77			July - Oct	RCH	I/II		Y	Y			reaches surveyed; curve points approximated from graphs; includes data from Moyle & Baltz 1985	Knight 1985		

<sup>1</sup># HSC observations is number of independent measurements at fish positions, # fish is total number of fish seen at the measurement locations

<sup>2</sup>stream habitat characteristics during the period of sampling for HSC

<sup>3</sup>species abbreviations: chs=chinook salmon, coh=coho salmon, sth=steelhead, rbt=rainbow trout (resident), brn=brown trout, brk=brook trout, bul=bull trout, cut=cutthroat trout, wtf=whitefish, skr=suckers, scp=sculpin, pkm=pikeminnow, hdh=hardhead, dac=dac

<sup>4</sup>survey design: sampling design used to collect hsc data, i.e. reaches - samples collected in representative reach(es), proportional - samples collected within mesohabitat types with effort in proportional to availability, equal-area - samples collected with effort equalized among habitat types

<sup>5</sup>observation method: DOuw-direct observation underwater (snorkeling/scuba), DOow-direct observation out-of-water (wading, boat, or bank observation), EF-electrofishing, VID-underwater video, NET-seining or other net capture, Other (see comments)

<sup>6</sup>curve type: Cat I - hand-drawn or a composite of various curves based on professional judgment, Cat II - based on habitat use data, Cat III - based on habitat use data adjusted by habitat availability data, Bio - bioenergetics hsc

<sup>7</sup>curve smoothing: method used (if any) to smooth raw observation or frequency histogram data

<sup>8</sup>see hsc data sets for cover and substrate coding details

Table B-4. Hardhead Adult Habitat Suitability Curve Metadata.

Curve ID	Used for MFP	Fish Characteristics			Sample Size <sup>1</sup>		Stream Location			Stream Characteristics <sup>2</sup>							Sampling Info					Available HSC Curves				Notes	Reference						
		Species	Life-stage	Length Min (cm) Max (cm)	No. HSC Obs	No. Fish	Country	State	River	Elevation Min (ft msl) Max (ft msl)	Width Mean (ft) Min (ft) Max (ft)			Streamflow Mean (cfs) Low (cfs) High (cfs)			Mean Slope (%)	Water Temperature Mean (°F) Min (°F) Max (°F)			Species Composition <sup>3</sup>	Site-Specific?	Sampling Season	Survey Design <sup>4</sup>	Observ Method <sup>5</sup>			Curve Type <sup>6</sup>	Curve Smoothing <sup>7</sup>	Total Depth	Mean Col	Cover <sup>8</sup> Focal	Substrate <sup>8</sup>
SFAR-PrAb, Pref and Util	Y	Hardhead	adult	>15	93		USA	CA	SF American	1,900	2,000	71		154		1.3	62	71			Aug				II and III							equal area; 3 methods used (utilization, preference, presence-absence)	TRPA 2000
NFFR - Pref, Util, Density, PrAb	Y	Hardhead	adult	>15	140		USA	CA	NF Feather	925	2,010	avg 70 - 106		96	131	0.4-1.1	64	72	skr,rbt,pkm, hdh,smb	Y	July-Aug	EA	DO uw	II and III	Y	Y		Y			4 methods used (utilization, preference, pres-abs, density)	TRPA 2001	
Pit Pref and Util	Y	Hardhead	adult		72		USA	CA	Pit	1,445	2,650	40	200	50	150	0.7-1.1			skr,rbt,pkm, hdh,smb	Y	summer	RCH	DO uw	II and III	Y	Y		Y	Y		2 methods used (utilization and preference; preference curve reweighted to equalize effort)	Baltz and Vondracek 1985	
Deer Util and Electivity	Y	Hardhead	adult	>16 SL	57		USA	CA	Deer	30	3,500	20	50	100	200	1	50	90			June-Oct				II and III	Y	Y	Y		Y	2 methods used (utilization and electivity)	Moyle and Baltz 1985	
Deer 3 juv + adult	Y	Hardhead	juv + adult	>10 TL	282		USA	CA	Deer	500	1,500	50	60	120	140	-	59	70			Aug-Sept				II	Y	Y				only pools surveyed	Alley 1977	
W Sierra	Y	Hardhead	adult	>12 TL	437		USA	CA	Sierra streams	203	1,460	6	59			0.1-2.9	49	77			July - Oct				I/II	Y	Y				reaches surveyed	Knight 1985	

<sup>1</sup># HSC observations is number of independent measurements at fish positions, # fish is total number of fish seen at the measurement locations

<sup>2</sup>stream habitat characteristics during the period of sampling for HSC

<sup>3</sup>species abbreviations: chs=chinook salmon, coh=coho salmon, sth=steelhead, rbt=rainbow trout (resident), brn=brown trout, brk=brook trout, bul=bull trout, cut=cutthroat trout, wtf=whitefish, skr=suckers, scp=sculpin, pkm=pikeminnow, hdh=hardhead, dac=dac

<sup>4</sup>survey design: sampling design used to collect hsc data, i.e. reaches - samples collected in representative reach(es), proportional - samples collected within mesohabitat types with effort in proportional to availability, equal-area - samples collected with effort equalized among habitat types

<sup>5</sup>observation method: DOuw-direct observation underwater (snorkeling/scuba), DOow-direct observation out-of-water (wading, boat, or bank observation), EF-electrofishing, VID-underwater video, NET-seining or other net capture, Other (see comments)

<sup>6</sup>curve type: Cat I - hand-drawn or a composite of various curves based on professional judgment, Cat II - based on habitat use data, Cat III - based on habitat use data adjusted by habitat availability data, Bio - bioenergetics hsc

<sup>7</sup>curve smoothing: method used (if any) to smooth raw observation or frequency histogram data

<sup>8</sup>see hsc data sets for cover and substrate coding details

**Table B-5. Sacramento Pikeminnow Juvenile Habitat Suitability Curve Metadata.**

Curve ID		Fish Characteristics				Sample Size <sup>1</sup>		Stream Location					Stream Characteristics <sup>2</sup>							Sampling Info						Available HSC Curves				Notes	Reference					
Name	Used for MFP	Species	Life-stage	Length		No. HSC Obs	No. Fish	Country	State	River	Elevation		Width			Streamflow			Mean Slope (%)	Water Temperature			Species Composition <sup>3</sup>	Site-Specific?	Sampling Season	Survey Design <sup>4</sup>	Observ Method <sup>5</sup>	Curve Type <sup>6</sup>	Curve Smoothing <sup>7</sup>	Velocity			Cover <sup>8</sup>	Substrate <sup>9</sup>		
				Min (cm)	Max (cm)						Min (ft msl)	Max (ft msl)	Mean (ft)	Min (ft)	Max (ft)	Mean (cfs)	Low (cfs)	High (cfs)		Mean (°F)	Min (°F)	Max (°F)								Total Depth	Mean Col	Focal				
NFFR-Density, Util, Pref, PrAb	Y	PM/HH	juv	5	15	140		USA	CA	NF Feather	925	2010	avg 70-106				96	131	0.4-1.1		64	72	skr,rbt,pkm,hdh,smb	Y	July-Aug	EA	DO uw	II and III			Y	Y	Y		4 methods used (utilization, preference, pres-abs, density)	TRPA 2001
Pit Pref and Util	Y	PM	juv			88		USA	CA	Pit	1445	2650	40	200		50	150	0.7-1.1				skr,rbt,pkm,hdh,smb	Y	summer	RCH	DO uw	II and III			Y	Y	Y	Y	2 methods used (utilization and preference; preference curve reweighted to equalize effort)	Baltz and Vondracek 1985	
Deer	Y	PM	juv	<16cm SL		141		USA	CA	Deer	30	3,500	20	50		100	200	1		55	90			June-Oct		II and electivity			Y	Y	Y	Y	electivity and reaches	Moyle and Baltz 1985		
W Sierra	Y	PM	juv	< 12 cm SL		717		USA	CA	Sierra streams	203	1,460	6	59				0.1-2.9		49	77		Y	July-Oct	RCH		I/II			Y	Y			reaches surveyed; curve points approximated from graphs; includes data from Moyle & Baltz 1985	Knight 1985	

<sup>1</sup># HSC observations is number of independent measurements at fish positions, # fish is total number of fish seen at the measurement locations

<sup>2</sup>stream habitat characteristics during the period of sampling for HSC

<sup>3</sup>species abbreviations: chs=chinook salmon, coh=coho salmon, sth=steelhead, rbt=rainbow trout (resident), brn=brown trout, brk=brook trout, bul=bull trout, cut=cutthroat trout, wtf=whitefish, skr=suckers, scp=sculpin, pkm=pikeminnow, hdh=hardhead, dac=dac

<sup>4</sup>survey design: sampling design used to collect hsc data, i.e. reaches - samples collected in representative reach(es), proportional - samples collected within mesohabitat types with effort in proportional to availability, equal-area - samples collected with effort equalized among habitat types

<sup>5</sup>observation method: DOuw-direct observation underwater (snorkeling/scuba), DOow-direct observation out-of-water (wading, boat, or bank observation), EF-electrofishing, VID-underwater video, NET-seining or other net capture, Other (see comments)

<sup>6</sup>curve type: Cat I - hand-drawn or a composite of various curves based on professional judgment, Cat II - based on habitat use data, Cat III - based on habitat use data adjusted by habitat availability data, Bio - bioenergetics hsc

<sup>7</sup>curve smoothing: method used (if any) to smooth raw observation or frequency histogram data

<sup>8</sup>see hsc data sets for cover and substrate coding details

Table B-6. Sacramento Pikeminnow Adult Habitat Suitability Curve Metadata.

Curve ID	Used for MFP	Fish Characteristics			Sample Size <sup>1</sup>		Stream Location			Stream Characteristics <sup>2</sup>						Sampling Info					Available HSC Curves				Notes	Reference	
		Name	Species	Life-stage	Length Min (cm) Max (cm)	No. HSC Obs	No. Fish	Country	State	River	Elevation Min (ft msl) Max (ft msl)	Width Mean (ft) Min (ft) Max (ft)	Streamflow Mean (cfs) Low (cfs) High (cfs)	Mean Slope (%)	Water Temperature Mean (°F) Min (°F) Max (°F)	Species Composition <sup>3</sup>	Site-Specific?	Sampling Season	Survey Design <sup>4</sup>	Observation Method <sup>5</sup>	Curve Type <sup>6</sup>	Curve Smoothing <sup>7</sup>	Total Depth	Velocity Mean Col			Focal
NFFR - Pref, Util, Density, PrAb	Y	Sac Pikeminnow	adult	>15	70		USA	CA	NF Feather	925 2010	avg 70-106	96 131	0.4-1.1	64 72	skr,rbt,pkm,hdh,smb	Y	July-Aug	EA	DO uw	II and III		Y	Y		Y	4 methods used (utilization, preference, pres-abs, density)	TRPA 2001
Pit Pref and Util	Y	Sac Pikeminnow	adult		97		USA	CA	Pit	1445 2650	40 200	50 150	0.7-1.1		skr,rbt,pkm,hdh,smb	Y	summer	RCH	DO uw	II and III		Y	Y		Y	2 methods used (utilization and preference; preference curve reweighted to equalize effort)	Baltz and Vondracek 1985
Deer Util and Electivity	Y	Sac Pikeminnow	adult	>16 SL	49		USA	CA	Deer	30 3,500	20 50	100 200	1	50 90			June-Oct			II and III		Y	Y	Y	Y	2 methods used (utilization and electivity)	Moyle and Baltz 1985
Deer 3 Juv +Adult	Y	Sac Pikeminnow	adult	>10 TL	92		USA	CA	Deer	50 1500	50 60	120 140		59 70			Aug-Sept			II		Y	Y			only pools surveyed	Alley 1977
W Sierra	Y	Sac Pikeminnow	adult	>12 TL	195		USA	CA	Sierra streams	203 1,460	6 59		0.1-2.9	49 77			July - Oct			I/II		Y	Y			reaches surveyed	Knight 1985

<sup>1</sup># HSC observations is number of independent measurements at fish positions, # fish is total number of fish seen at the measurement locations

<sup>2</sup>stream habitat characteristics DURING THE PERIOD OF SAMPLING FOR HSC

<sup>3</sup>species abbreviations: chs=chinook salmon, coh=coho salmon, sth=steelhead, rbt=rainbow trout (resident), bm=brown trout, brk=brook trout, bul=bull trout, cut=cutthroat trout, wtf=whitefish, skr=suckers, scp=sculpin, pkm=pikeminnow, hdh=hardhead, dac=dac

<sup>4</sup>survey design: sampling design used to collect hsc data, i.e. reaches - samples collected in representative reach(es), proportional - samples collected within mesohabitat types with effort in proportional to availability, equal-area - samples collected with effort equalized among habitat types

<sup>5</sup>observation method: DOuw-direct observation underwater (snorkeling/scuba), DOow-direct observation out-of-water (wading, boat, or bank observation), EF-electrofishing, VID-underwater video, NET-seining or other net capture, Other (see comments)

<sup>6</sup>curve type: Cat I - hand-drawn or a composite of various curves based on professional judgment, Cat II - based on habitat use data, Cat III - based on habitat use data adjusted by habitat availability data, Bio - bioenergetics hsc

<sup>7</sup>curve smoothing: method used (if any) to smooth raw observation or frequency histogram data

<sup>8</sup>see hsc data sets for cover and substrate coding details

Table B-7. Sacramento Sucker Juvenile Habitat Suitability Curve Metadata.

Curve ID	Used for MFP	Fish Characteristics				Sample Size <sup>1</sup>		Stream Location					Stream Characteristics <sup>2</sup>							Sampling Info						Available HSC Data					Notes	Reference
		Life-Stage	Length	No. HSC Obs	No. Fish	Country	State	River	Elevation	Width	Streamflow	Mean	Water Temperature	Species Composition <sup>3</sup>	Site-Specific?	Sampling Season	Survey Design <sup>4</sup>	Observ Method <sup>5</sup>	Curve Type <sup>6</sup>	Curve Smoothing <sup>7</sup>	Velocity	Total Depth	Mean Col	Focal	Cover <sup>8</sup>	Substrate <sup>8</sup>						
Yosemite	Y	Sac	juv	5 (SL)	12 (SL)	116		USA	CA	Eleanor, Cherry				15	36		46	73		Y	July-Aug			II		Y	Y	Y		Y	curve points approximated from graphs	Baltz and Moyle 1984
NFFR-Pref, Util, Density, PrAb	Y	Sac	juv	5	15	88	88	USA	CA	lower NF Feather	925	2010	70-106		96	131	0.75	64	72	skr,rbt,pkm,hdh,smb	Y	July-Aug	EA	DO	II and III		Y	Y		Y	4 methods used (utilization, preference, pres-abs, density)	TRPA 2001
Pit Pref and Util	Y	Sac	juv		15	130		USA	CA	Pit	1445	2650		40	200	50	150	0.9		skr,rbt,pkm,hdh,smb	Y	summer		DO	II and III		Y	Y		Y	2 methods used (utilization and preference; preference curve reweighted to equalize effort)	Baltz and Vondracek 1985
Deer	Y	Sac	juv	5	12	31		USA	CA	Deer	30	1700			210		1.5	57	90	skr,rbt,pkm,hdh,smb	Y	Spr/Fall	reach	DO	II		Y	Y		Y	2 methods used (utilization and electivity)	Moyle and Baltz 1985

<sup>1</sup># HSC observations is number of independent measurements at fish positions, # fish is total number of fish seen at the measurement locations

<sup>2</sup>stream habitat characteristics during the period of sampling for HSC

<sup>3</sup>species abbreviations: chs=chinook salmon, coh=coho salmon, sth=steelhead, rbt=rainbow trout (resident), brn=brown trout, brk=brook trout, bul=bull trout, cut=cutthroat trout, wtf=whitefish, skr=suckers, scp=sculpin, pkm=pikeminnow, hdh=hardhead, dac=dac

<sup>4</sup>survey design: sampling design used to collect hsc data, i.e. reaches - samples collected in representative reach(es), proportional - samples collected within mesohabitat types with effort in proportional to availability, equal-area - samples collected with effort equalized among habitat types

<sup>5</sup>observation method: DOuw-direct observation underwater (snorkeling/scuba), DOow-direct observation out-of-water (wading, boat, or bank observation), EF-electrofishing, VID-underwater video, NET-seining or other net capture, Other (see comments)

<sup>6</sup>curve type: Cat I - hand-drawn or a composite of various curves based on professional judgment, Cat II - based on habitat use data, Cat III - based on habitat use data adjusted by habitat availability data, Bio - bioenergetics hsc

<sup>7</sup>curve smoothing: method used (if any) to smooth raw observation or frequency histogram data

<sup>8</sup>see hsc data sets for cover and substrate coding details

Table B-8. Sacramento Sucker Adult Habitat Suitability Curve Metadata.

Curve ID	Used for MFP	Fish Characteristics				Sample Size <sup>1</sup>		Stream Location			Stream Characteristics <sup>2</sup>							Sampling Info						Available HSC Data					Comments	Reference						
		Species	Life-stage	Length Min (cm)	Length Max (cm)	No. HSC Obs	No. Fish	Country	State	River	Elevation Min (ft msl)	Elevation Max (ft msl)	Mean Width (ft)	Min Width (ft)	Max Width (ft)	Mean Streamflow (cfs)	Low Streamflow (cfs)	High Streamflow (cfs)	Mean Slope (%)	Mean Water Temperature (°F)	Min Water Temperature (°F)	Max Water Temperature (°F)	Species Composition <sup>3</sup>	Site-Specific?	Sampling Season	Survey Design <sup>4</sup>	Observation Method <sup>5</sup>	Curve Type <sup>6</sup>			Curve Smoothing <sup>7</sup>	Total Depth	Mean Col	Focal	Cover <sup>8</sup>	Substrate <sup>9</sup>
Yosemite	Y	Sac	adult	13	30	399		USA	CA	Eleanor, Cherry				15	36		46	73					Y	July-Aug			DO	II		Y	Y	Y		Y	curve points approximated from graphs	Baltz & Moyle 1984
Pit Pref and Use	Y	Sac	adult			256		USA	CA	Pit	1445	2650	40	200		50	150	0.9				skr,rbt,pkm,hdh,smb	Y				DO	II and III		Y	Y		Y	Y	2 methods used (utilization and preference; preference curve reweighted to equalize effort)	Baltz and Vondracek 1985
Deer 3 Juv+Adult	Y	Sac	juv+adult	10		172		USA	CA	Deer	500	1500	50			120	140		59	70		skr,rbt,pkm,hdh	Y	Aug-Sept	pools	DO	II		Y	Y				only pools surveyed	Alley 1977	
NFFR-Pref, Util, Density, PrAb	Y	Sac	adult	16		76	76	USA	CA	lower NF Feather	925	2010	70-106			96	131	0.75	64	72		skr,rbt,pkm,hdh,smb	Y	July-Aug	EA	DO	II, III, IV		Y	Y		Y		4 methods used (utilization, preference, pres-abs, density)	TRPA 2001	
UNFFR	Y	Sac	adult	16	46	89	132	USA	CA	upper NF Feather	2300	3500	40	80		40	140	1.5	57	72		skr,rbt,pkm	Y	June-Aug	EA	DO	composite		Y	Y		Y		6 curve types developed, composite curve is based on average values, density HSC derived from quadrat counts according to depth and velocity ranges	TRPA 2002	

<sup>1</sup># HSC observations is number of independent measurements at fish positions, # fish is total number of fish seen at the measurement locations

<sup>2</sup>stream habitat characteristics DURING THE PERIOD OF SAMPLING FOR HSC

<sup>3</sup>species abbreviations: chs=chinook salmon, coh=coho salmon, sth=steelhead, rbt=rainbow trout (resident), brn=brown trout, brk=brook trout, bul=bull trout, cut=cutthroat trout, wtf=whitefish, skr=suckers, scp=sculpin, pkm=pikeminnow, hdh=hardhead, dac=dac

<sup>4</sup>survey design: sampling design used to collect hsc data, i.e. reaches - samples collected in representative reach(es), proportional - samples collected within mesohabitat types with effort in proportional to availability, equal-area - samples collected with effort equalized among habitat types

<sup>5</sup>observation method: DOuw-direct observation underwater (snorkeling/scuba), DOow-direct observation out-of-water (wading, boat, or bank observation), EF-electrofishing, VID-underwater video, NET-seining or other net capture, Other (see comments)

<sup>6</sup>curve type: Cat I - hand-drawn or a composite of various curves based on professional judgment, Cat II - based on habitat use data, Cat III - based on habitat use data adjusted by habitat availability data, IV - incl bioenergetics, density, and presence/

<sup>7</sup>curve smoothing: method used (if any) to smooth raw observation or frequency histogram data

<sup>8</sup>see hsc data sets for cover and substrate coding details

**Table B-9. References Cited in HSC Metadata.**

Curve Name	Citation
<b>Rainbow Trout</b>	
Yosemite <sup>2</sup>	Baltz, D. M. and P. B. Moyle. 1984. Segregation by species and size class of rainbow trout ( <i>Salmo gairdneri</i> ) and Sacramento sucker ( <i>Catostomus occidentalis</i> ) in California streams. Environmental Biology of Fishes 10:101-110.
Pit	Baltz, D. M. and B. Vondracek. 1985. Appendix 1-D Suitability and Microhabitat preference curves, in : Pit 3, 4, and 5 Project Bald Eagle and Fish Study. Prepared by BioSystems Analysis, Inc. and U.C. Davis. Report for Pacific Gas and Electric Company.
Bovee	Bovee, K.D. 1978. Probability-of-use criteria for the family Salmonidae. Instream Flow Information Paper No. 4. Cooperative Instream Flow Service Group, U.S. Fish & Wildlife Service, Fort Collins, CO. FWS/OBS-78/07. 79 pp.
NF Kings	EA Engineering, Science, and Technology, Inc. 1987. Development of habitat suitability criteria for trout in the Kings River Basin, California. Final Report, August 1987. Report 009.4-87.10 prepared for Pacific Gas and Electric Company Research and Development Program.
Raleigh	Raleigh, R. F., T. Hickman, R. C. Solomon, and P. C. Nelson. 1984. Habitat suitability information: rainbow trout. U.S. Fish and Wildlife Service, Division of Biological Services (FWS/OBS-82d/10.60). Washington, DC.
Deer Use and Electivity	Moyle, P. B. and D. M. Baltz. 1985. Microhabitat use by an assemblage of California stream fishes: developing criteria for instream flow determinations. Transactions of the American Fisheries Society 114: 695-704.
Studly-Spina <sup>3</sup>	PGE (personal communication with Thomas Studley)
E Sierra	Smith, G.E. and M.E. Aceituno 1987. Habitat preference criteria for brown, brook, and rainbow trout in eastern Sierra Nevada streams, final report. Stream Evaluation Report 87-2. California Department of Fish & Game, Sacramento, California.
CAWG	Southern California Edison. 2004. CAWG-3 Instream Flow Studies - PHABSIM. Prepared by ENTRIX Inc. for SCE, Big Creek, CA. April, 2004
MF Stanislaus Use	Thomas R. Payne & Associates (TRPA). 1992. Instream flow study for the Middle Fork Stanislaus River, Spring Gap-Stanislaus Hydroelectric Project (FERC 2130). Document prepared for Pacific Gas and Electric Company, San Ramon, California.
UNFFR, Butt	TRPA. 2002. Habitat Suitability criteria for rainbow trout and Sacramento suckers in the Upper North Fork Feather River Project (FERC No.2105). Report prepared for Pacific Gas and Electric Company, San Ramon, California. 86pp.
Stanislaus, Battle	TRPA. 2002. Instream flow study for the Middle Fork Stanislaus River, Spring Gap-Stanislaus Hydroelectric Project (FERC 2130). Document prepared for Pacific Gas and Electric Company, San Ramon, California.
UARP	TRPA. 2003. Determining appropriate HSC for use in the South Fork American River Basin. Presented May 8, 2003 to the UARP Technical Working Group.
Klamath	TRPA. 2004. Klamath Hydroelectric Project (FERC NO. 2082). Habitat suitability criteria. Report to PacifiCorp, Portland, Oregon. 64pp. + appendices.
Roaring <sup>3</sup>	TRPA. Unpublished HSC data.
Alt Qs Pref	Wise L.M., W.S. Lifton, and K.A. Voos. 1987. Trout habitat suitability criteria for the response of fish populations to altered stream flow. Prepared for Pacific Gas and Electric Co. and Southern California Edison.

**Table B-9. References Cited in HSC Metadata (continued).**

Curve Name	Citation
<b>Hardhead</b>	
Deer 3 juv+adult	Alley, D.W. 1977. The energetic significance of microhabitat selection by fishes in a foothill Sierra stream. M.S. Thesis, University of California, Davis. 267 pp.
Pit Pref and Util	Baltz, D. M. and B. Vondracek. 1985. Appendix 1-D Suitability and Microhabitat preference curves, in : Pit 3, 4, and 5 Project Bald Eagle and Fish Study. Prepared by BioSystems Analysis, Inc. and U.C. Davis. Report for Pacific Gas and Electric Company.
Deer / Deer Use and Electivity	Moyle, P.B. and D.M. Baltz. 1985. Microhabitat use by an assemblage of California Stream fishes: Developing criteria for instream flow determinations. Transactions of the American Fisheries Society. 114:695-704.
W. Sierra	Knight, N.J. 1985. Microhabitats and temperature requirements of hardhead ( <i>Mylopharadon conocephalus</i> ) and Sacramento squawfish ( <i>Ptychochellus grandis</i> ), with notes for some other native California stream fishes. Ph D. University of California, Davis.
SFAR-PrAb, Pref, and Util	TRPA. 2000. Determining appropriate HSC for use in the South Fork American River Basin. Testing the transferability of generic and California-specific HSC. Report submitted to El Dorado Irrigation District, Placerville, California. 100pp.
NFFR Density,Util, Pref,PrAb	TRPA. 2001. Development of habitat suitability criteria for the Poe project (FERC No. 2107), North Fork Feather River, California. Report prepared for Pacific Gas and Electric Company, San Ramon, California. 103pp.
<b>Sacramento Pikeminnow</b>	
Deer 3 juv+adult	Alley, D.W. 1977. The energetic significance of microhabitat selection by fishes in a foothill Sierra stream. M.S. Thesis, University of California, Davis. 267 pp.
Pit Pref and Util	Baltz, D. M. and B. Vondracek. 1985. Appendix 1-D Suitability and Microhabitat preference curves, in : Pit 3, 4, and 5 Project Bald Eagle and Fish Study. Prepared by BioSystems Analysis, Inc. and U.C. Davis. Report for Pacific Gas and Electric Company.
W Sierra	Knight, N.J. 1985. Microhabitats and temperature requirements of hardhead ( <i>Mylopharadon conocephalus</i> ) and Sacramento squawfish ( <i>Ptychochellus grandis</i> ), with notes for some other native California stream fishes. Ph D. University of California, Davis.
Deer / Deer Use and Electivity	Moyle, P.B. and D.M. Baltz. 1985. Microhabitat use by an assemblage of California Stream fishes: Developing criteria for instream flow determinations. Transactions of the American Fisheries Society. 114:695-704.
NFFR-Density, Util, Pref, PrAb	TRPA. 2001. Development of habitat suitability criteria for the Poe project (FERC No. 2107), North Fork Feather River, California. Report prepared for Pacific Gas and Electric Company, San Ramon, California. 103pp.
<b>Sacramento Sucker</b>	
Deer 3 juv+adult <sup>4</sup>	Alley, D.W. 1977. The energetic significance of microhabitat selection by fishes in a foothill Sierra stream. M.S. Thesis, University of California, Davis. 267 pp.
Yosemite <sup>4</sup>	Baltz, D. M. and P. B. Moyle. 1984. Segregation by species and size class of rainbow trout ( <i>Salmo gairdneri</i> ) and Sacramento sucker ( <i>Catostomus occidentalis</i> ) in California streams. Environmental Biology of Fishes 10:101-110.
Pit Pref and Util <sup>4</sup>	Baltz, D. M. and B. Vondracek. 1985. Appendix 1-D Suitability and Microhabitat preference curves, in : Pit 3, 4, and 5 Project Bald Eagle and Fish Study. Prepared by BioSystems Analysis, Inc. and U.C. Davis. Report for Pacific Gas and Electric Company.
NFFR-Pref, Util, Density, PrAb <sup>4</sup>	TRPA 2001. Development of habitat suitability criteria for the Poe project (FERC No. 2107), North Fork Feather River, California. Report prepared for Pacific Gas and Electric Company, San Ramon, California. 103pp.
UNFFR <sup>4</sup>	TRPA. 2002. Habitat Suitability criteria for rainbow trout and Sacramento suckers in the Upper North Fork Feather River Project (FERC No.2105). Report prepared for Pacific Gas and Electric Company, San Ramon, California. 86pp.

<sup>1</sup>Refer to tables B-1 through B-8.<sup>2</sup>Utilization data; collected at site.<sup>3</sup>No reference or metadata.<sup>4</sup>Limited metadata.

**FIGURES**

Figure B-1A. Rainbow Trout Spawning Habitat Suitability Curve Data Sets Used to Develop the MFP Habitat Suitability Criteria.

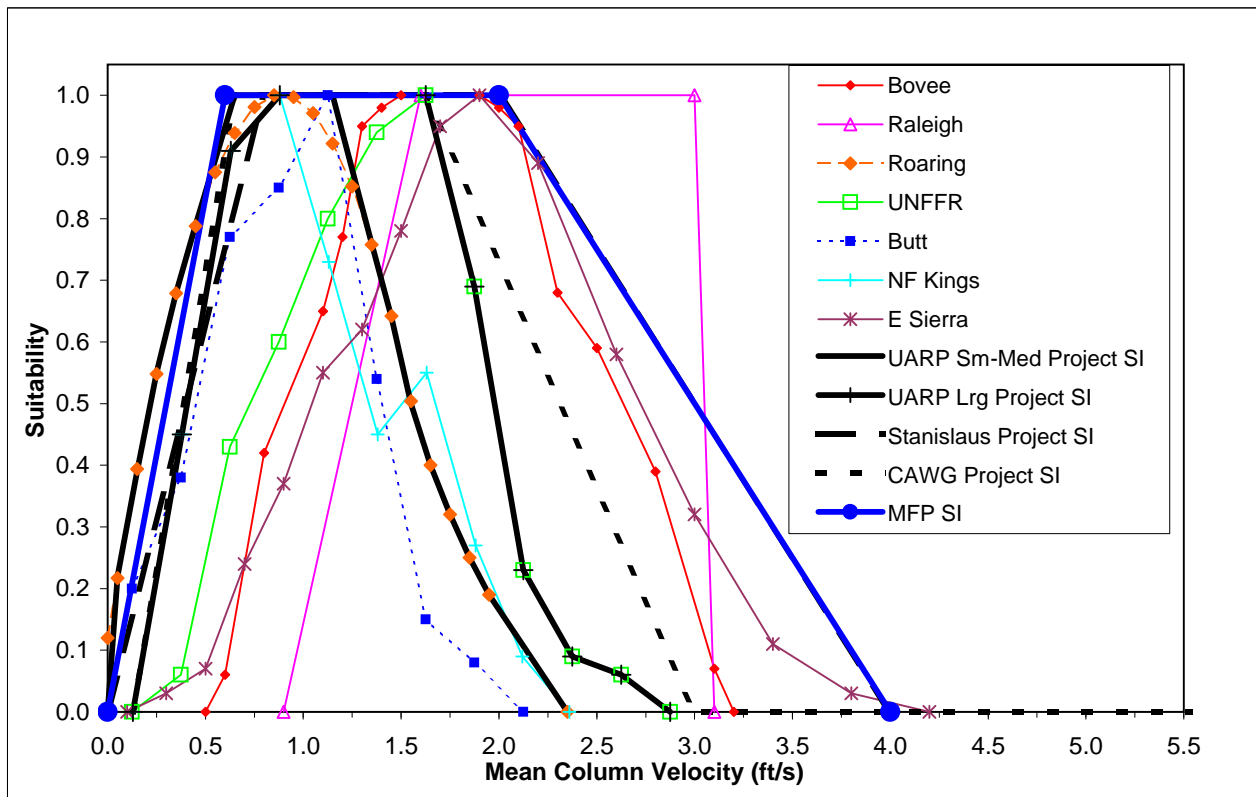
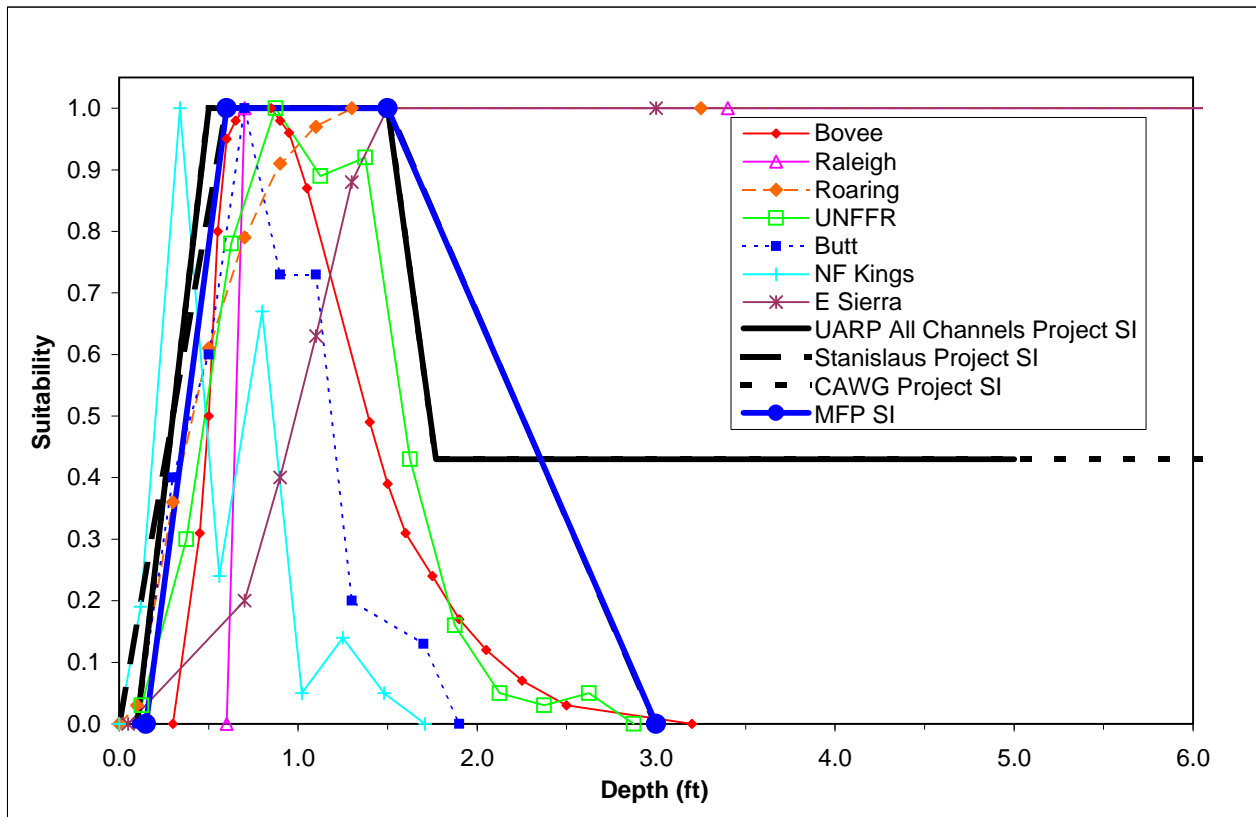
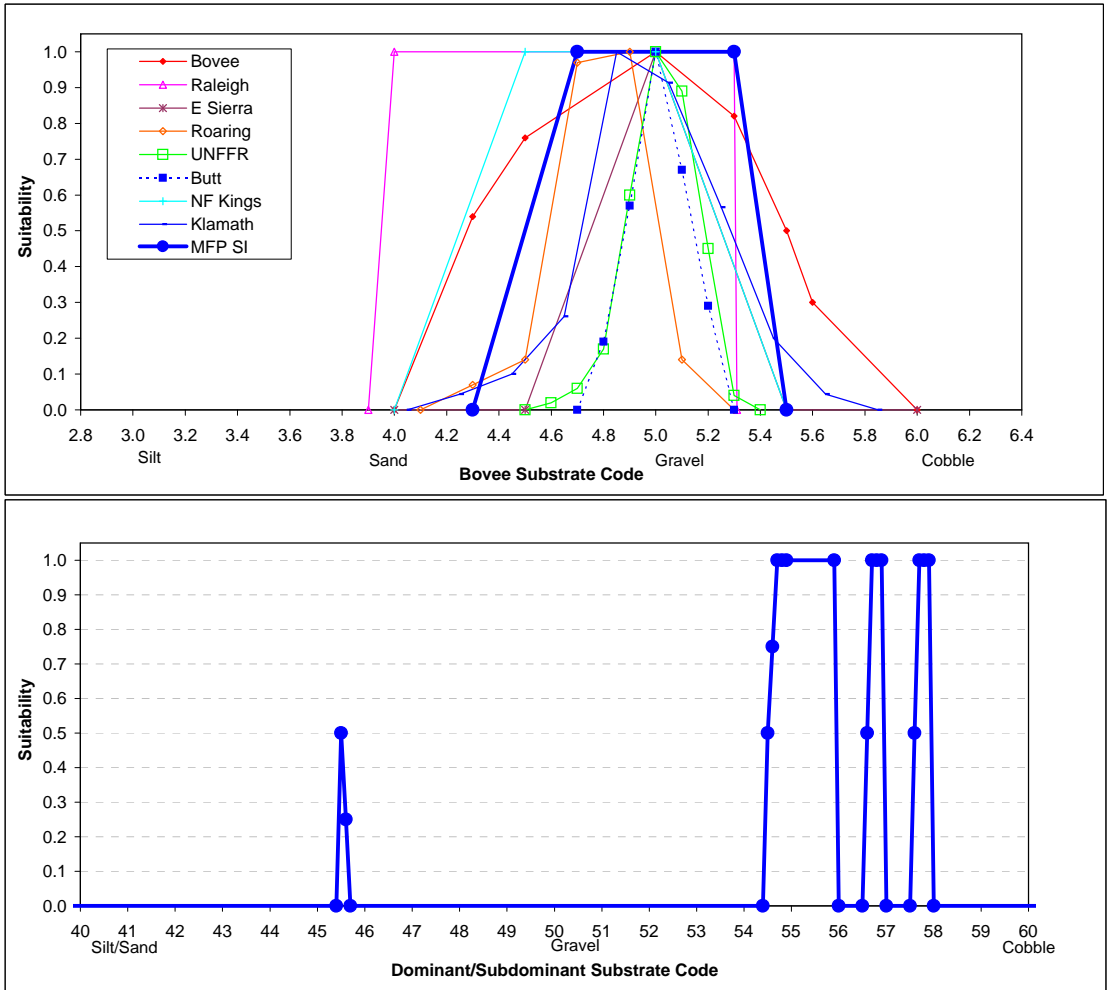


Figure B-1B. Rainbow Trout Spawning Habitat Suitability Curve Data Sets Used to Develop the MFP Bovee Format Substrate HSC (top) and the Dominant/Subdominant Format Substrate HSC (bottom).



Bovee Format Spawning		Dominant/Subdominant Format Spawning		Rainbow Trout Spawning Substrate Code		
Substrate	SI	Substrate	SI	Code	Substrate Type	Size Range (in)
0	0	0	0	4	silt and sand	<0.1 - 0.2
4.30	0.00	45.4	0	5	small, medium, large gravel	0.2-3"
4.70	1.00	45.5	0.5	6	small, medium, large cobble	3-12
5.30	1.00	45.6	0.25	7	Other - organic material - leaf/detritus	
5.50	0.00	45.7	0		(large) woody debris	
		54.4	0		small, large boulder	
		54.5	0.5		rough bedrock	
		54.6	0.75		smooth bedrock	
		54.7	1	*Most data used to generate spawning HSC used 2.5" as the upper gravel size, 3" was used here for consistency (CDFG)		
		54.8	1			
		54.9	1			
		55.9	1			
		56	0			
		56.5	0			
		56.6	0.5			
		56.7	1			
		56.8	1			
		56.9	1			
		57	0			
		57.5	0			
		57.6	0.5			
		57.7	1			
		57.8	1			
		57.9	1			
		58	0			
		99.9	0			

Figure B-2. Rainbow Trout Fry Habitat Suitability Curve Data Sets Used to Develop the MFP Habitat Suitability Criteria.

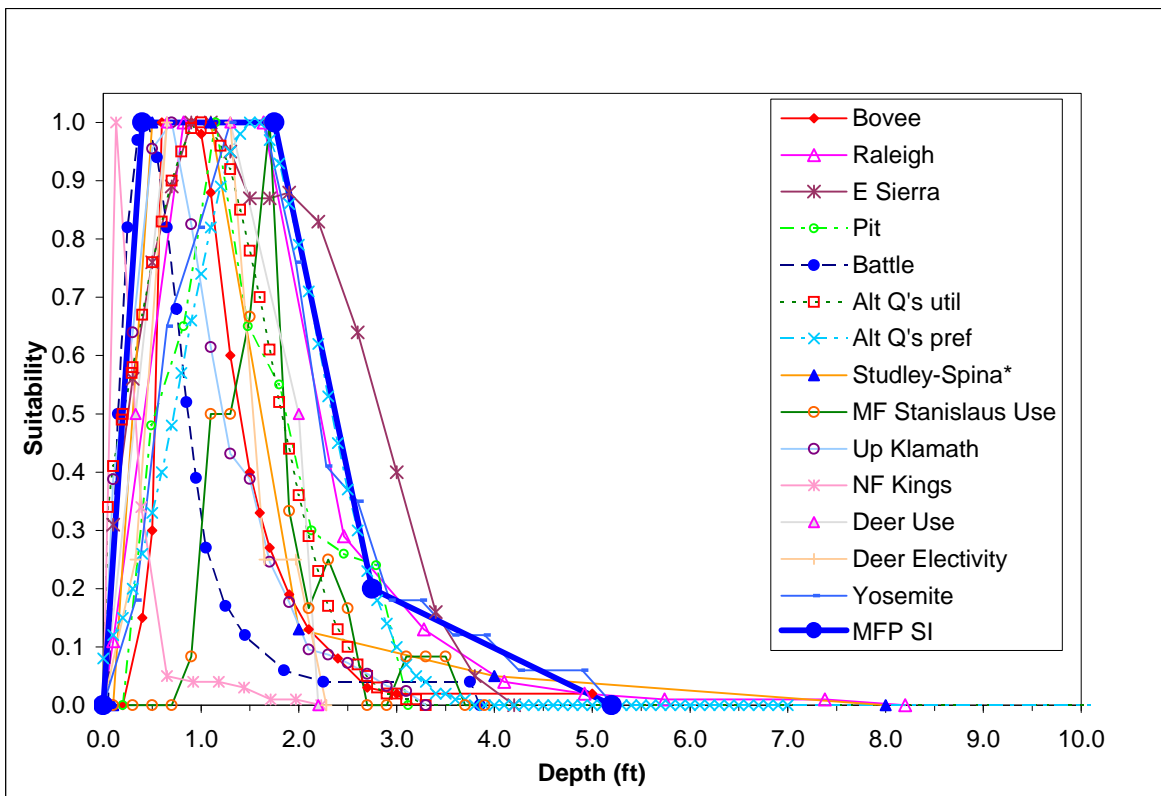
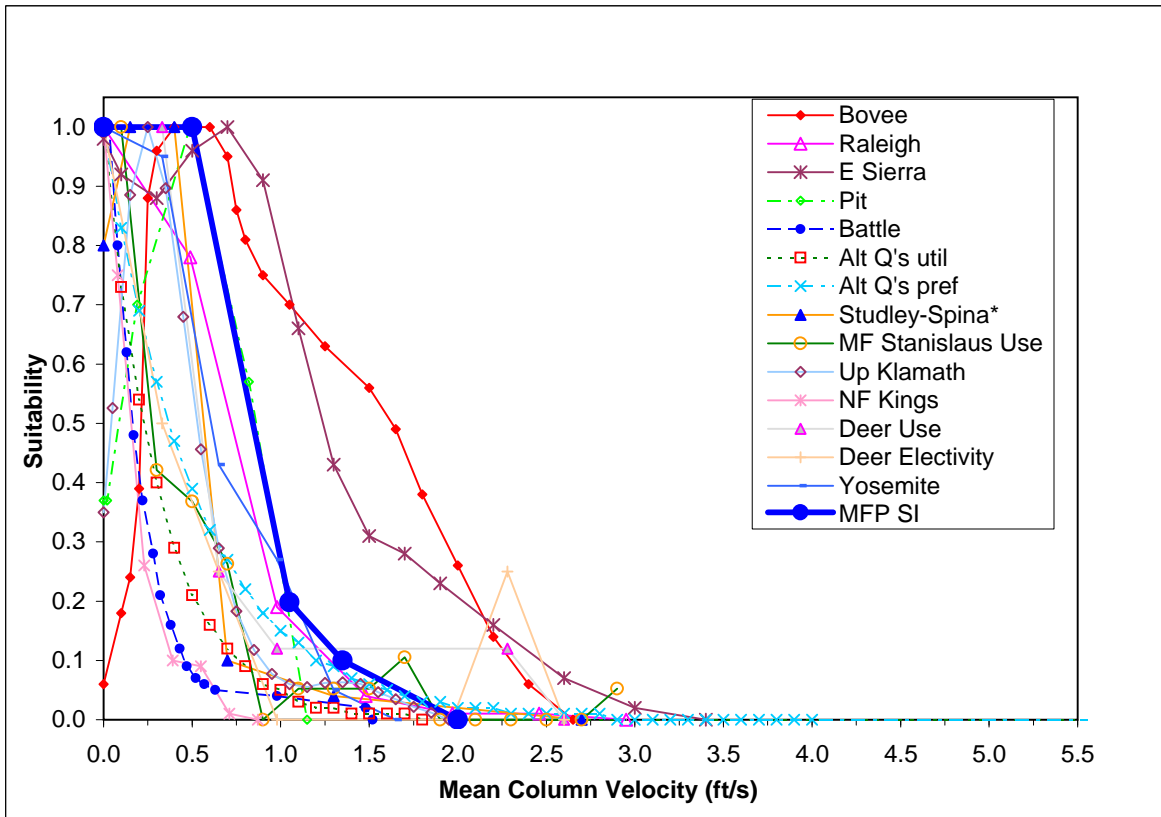


Figure B-3. Hardhead Juvenile Habitat Suitability Curve Data Sets Used to Develop the MFP Habitat Suitability Criteria.

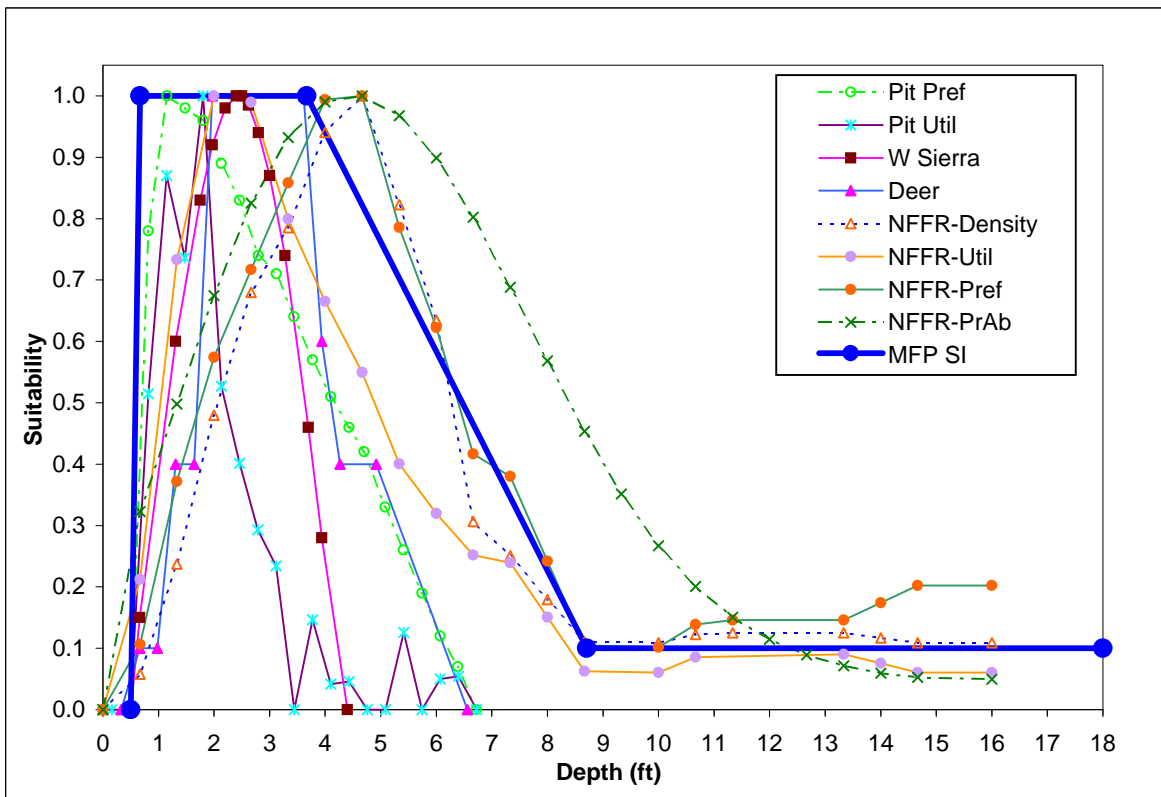
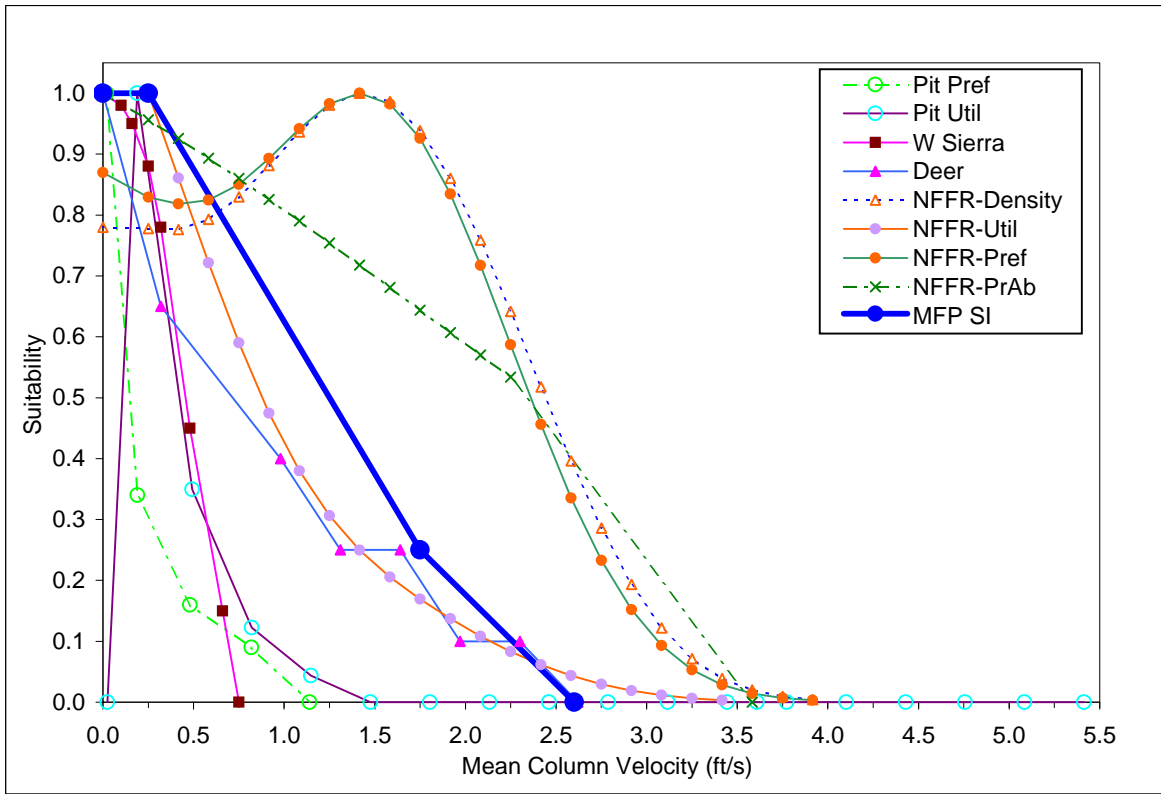


Figure B-4. Hardhead Adult Habitat Suitability Curve Data Sets Used to Develop the MFP Habitat Suitability Criteria.

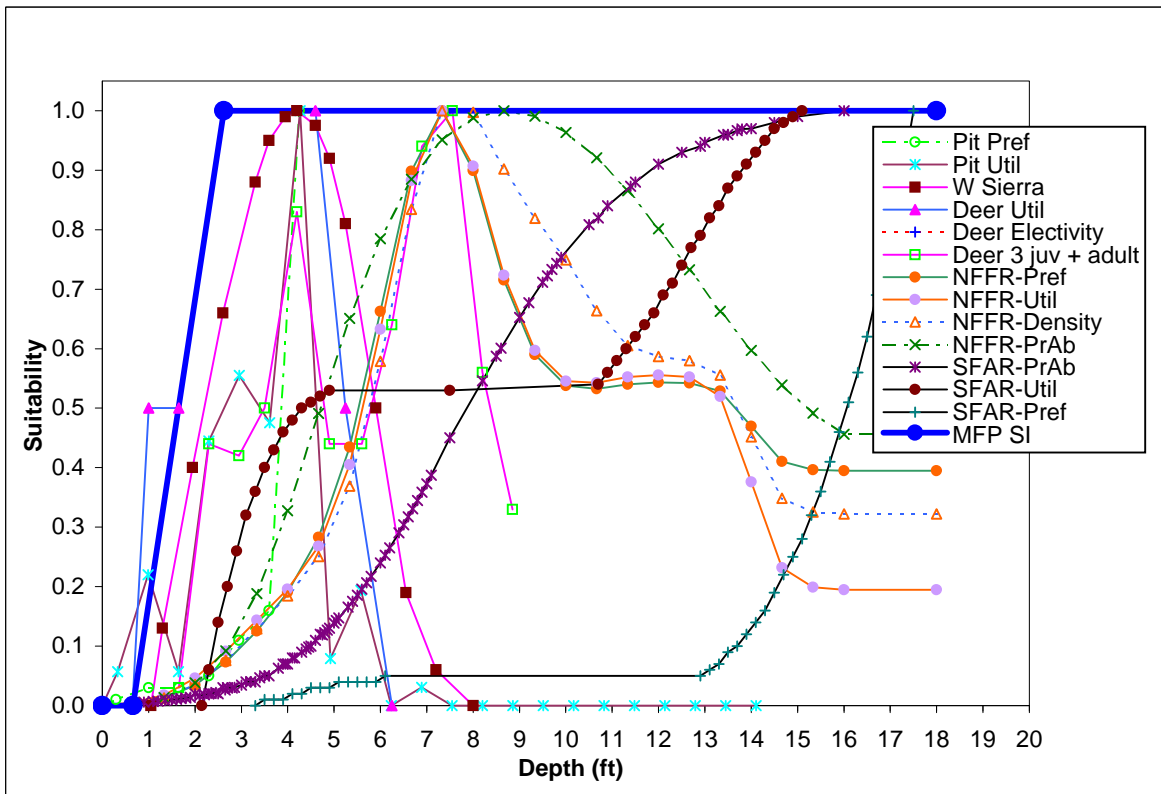
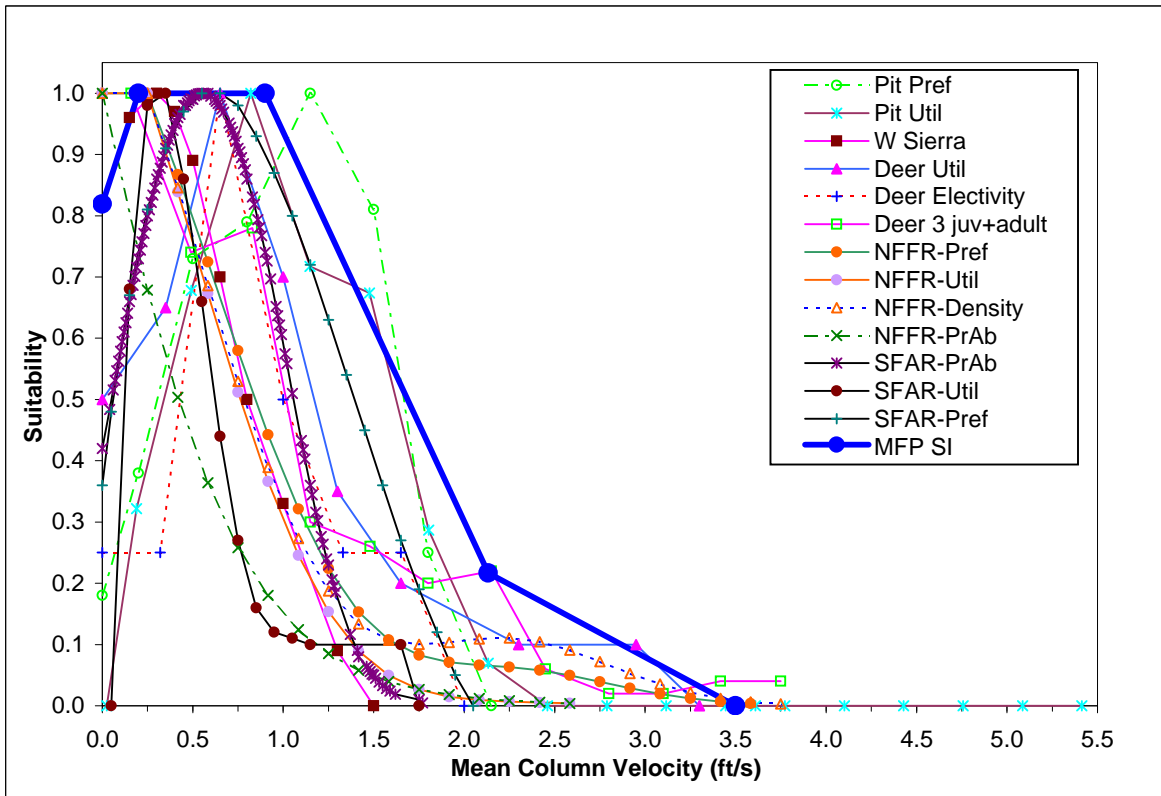


Figure B-5. Sacramento Pikeminnow Juvenile Habitat Suitability Curve Data Sets Used to Develop the MFP Habitat Suitability Criteria.

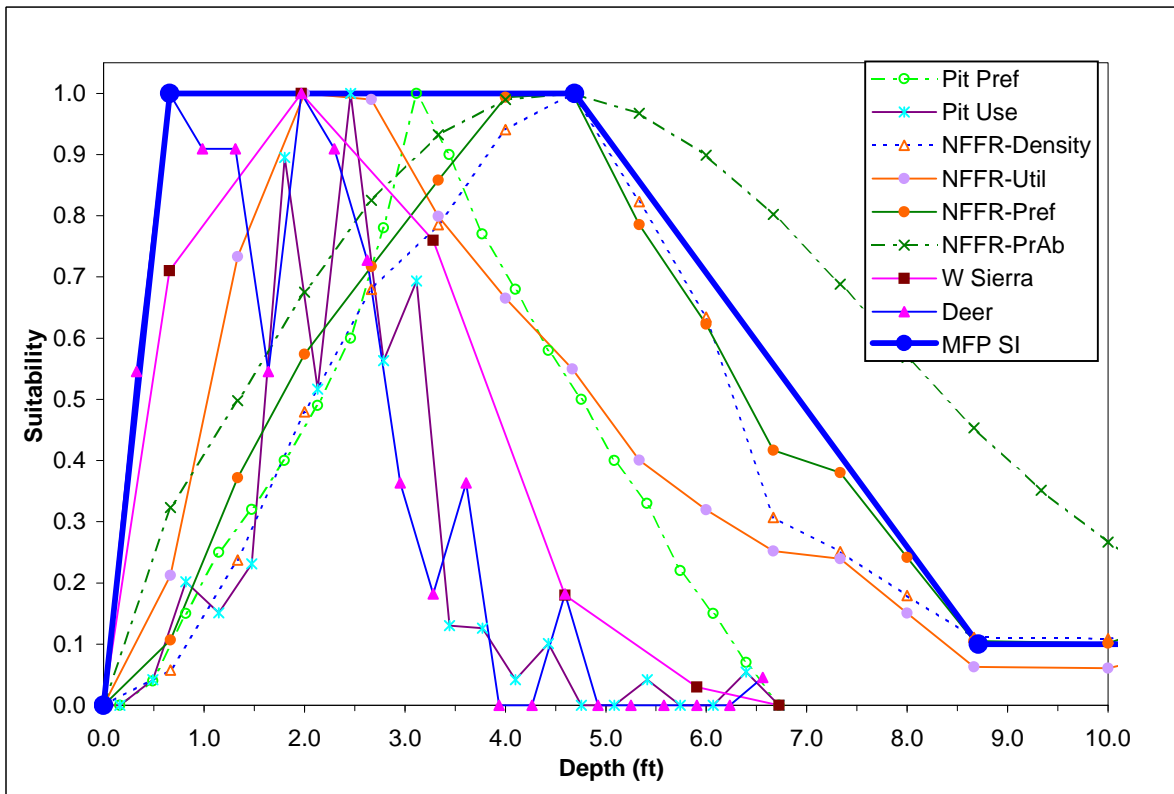
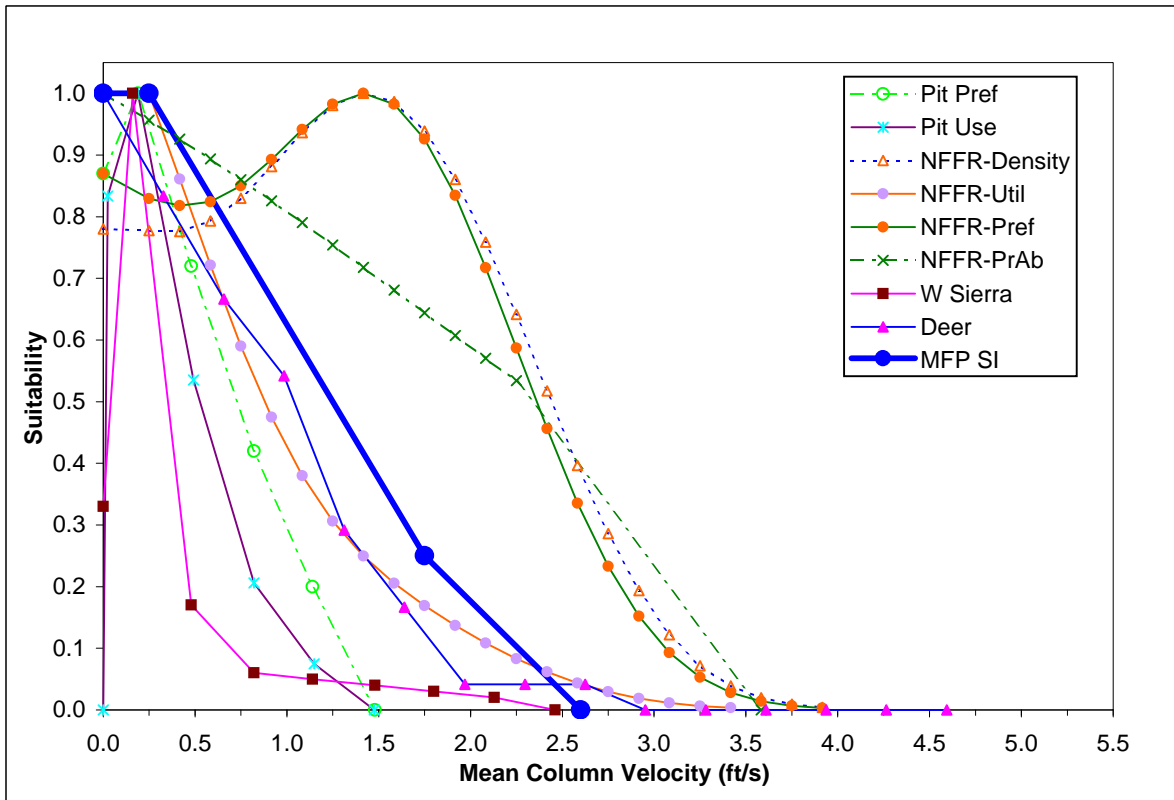


Figure B-6. Sacramento Pikeminnow Adult Habitat Suitability Curve Data Sets Used to Develop the MFP Habitat Suitability Criteria.

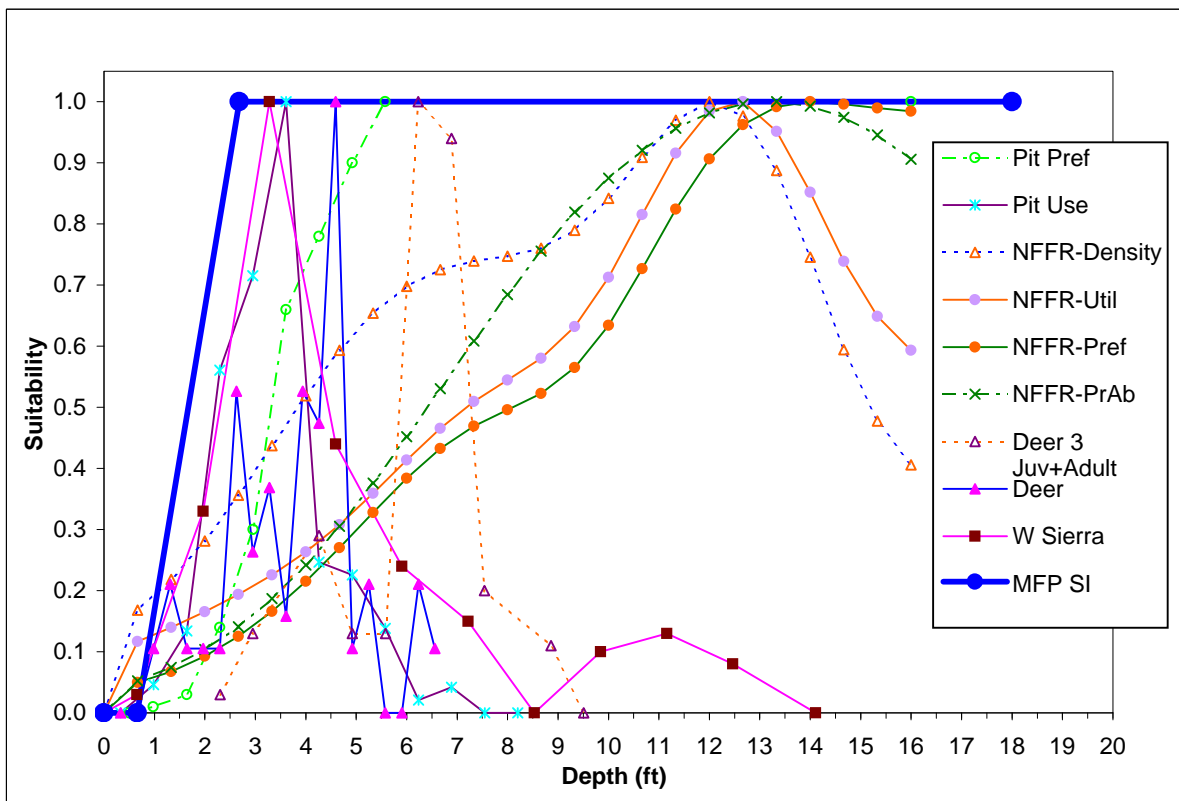
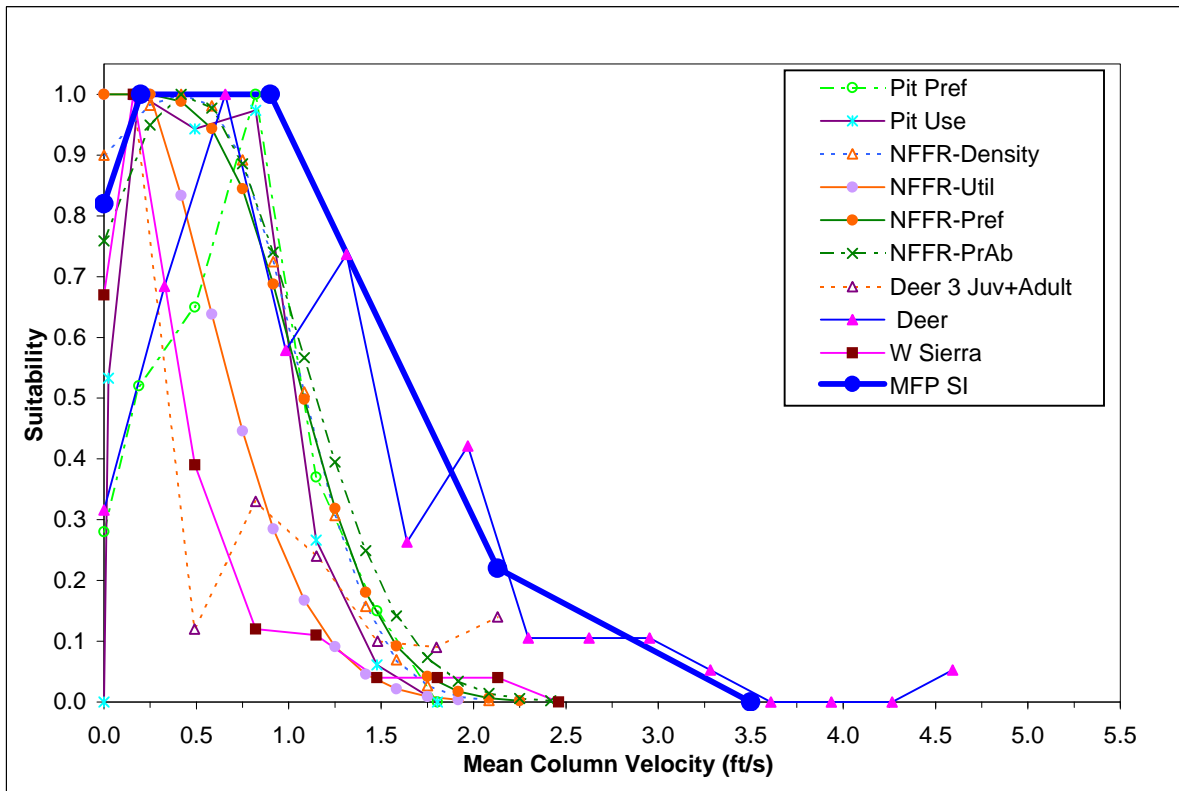


Figure B-7. Sacramento Sucker Juvenile Habitat Suitability Curve Data Sets Used to Develop the MFP Habitat Suitability Criteria.

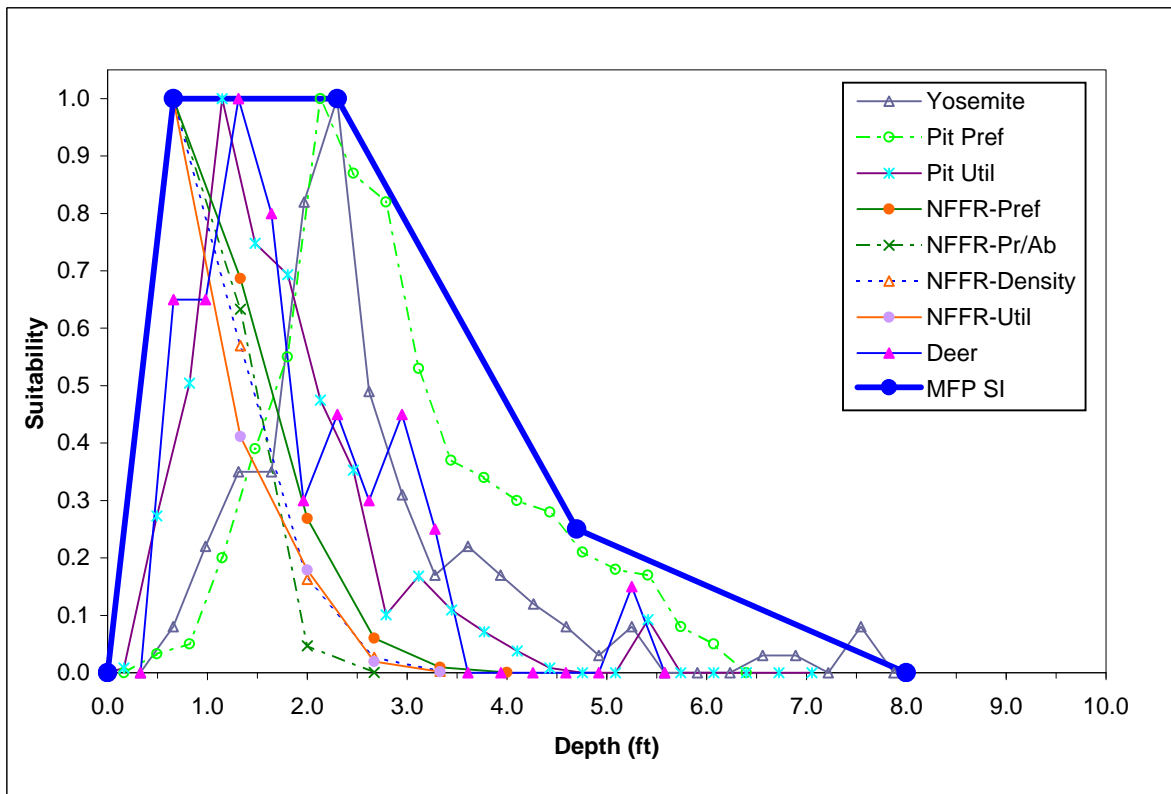
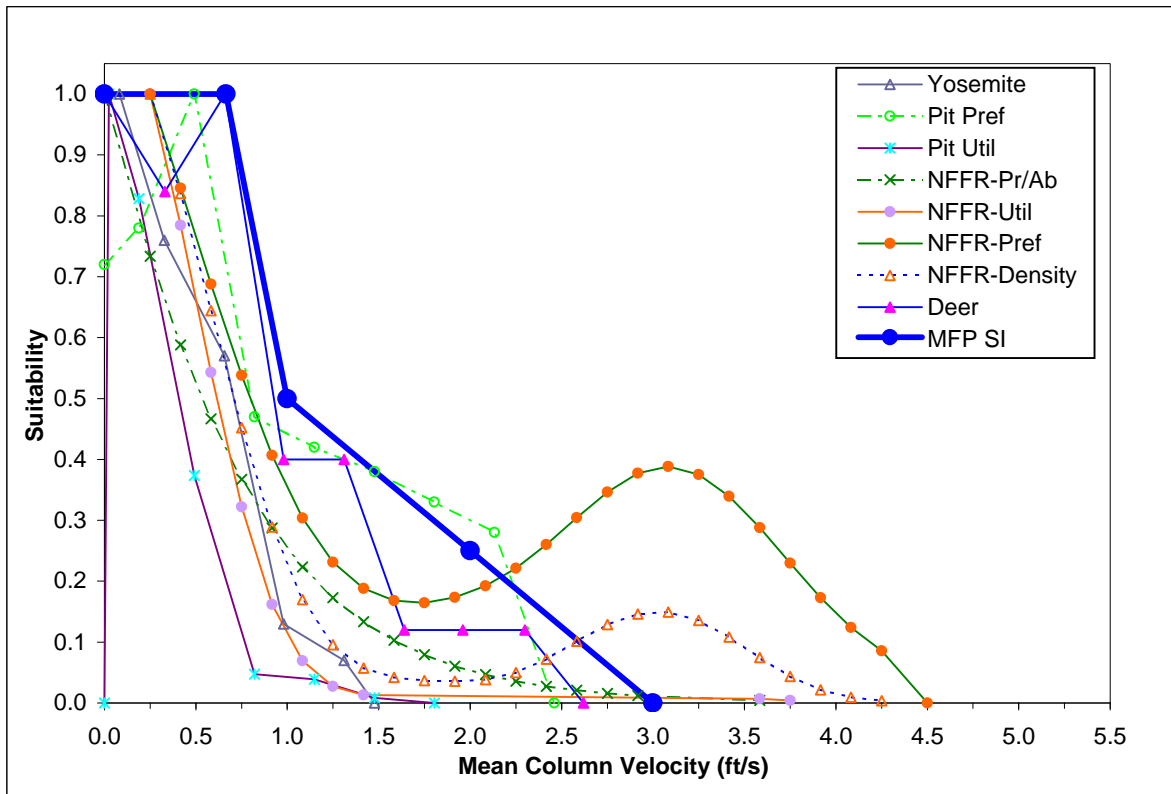
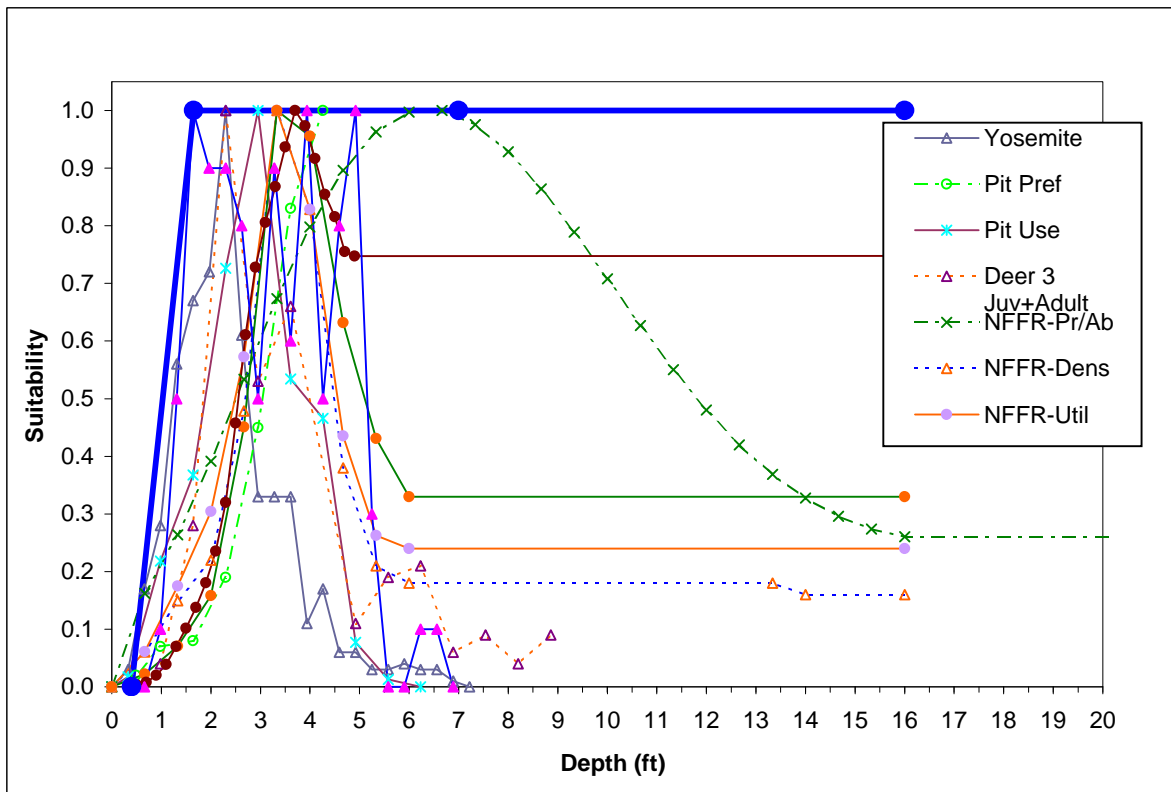
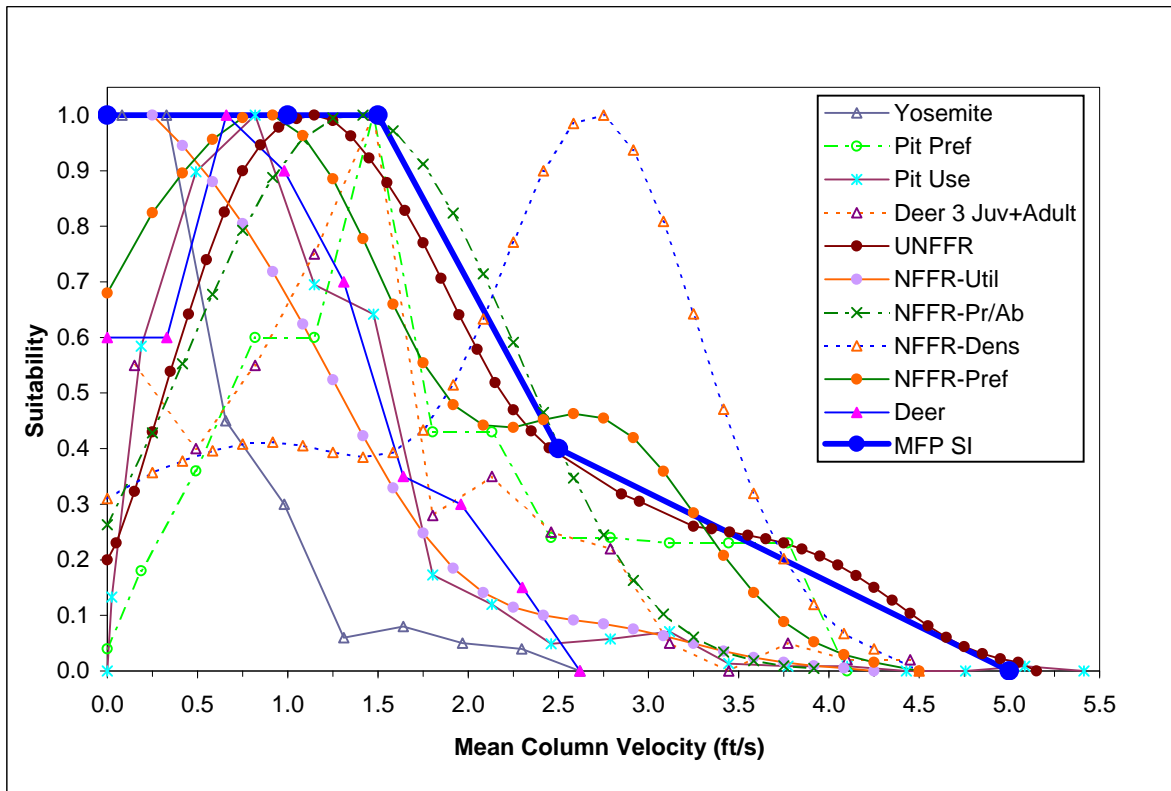


Figure B-8. Sacramento Sucker Adult Habitat Suitability Curve Data Sets Used to Develop the MFP Habitat Suitability Criteria.



**APPENDIX C**

**Foothill Yellow-Legged Frog Habitat Suitability Criteria**

**List of Tables**

- Table C-1. *R.boylii* egg mass habitat suitability criteria justification. Criteria shown are for MFP and Lind & Yarnell 2007 data combined.
- Table C-2. *R.boylii* tadpole habitat suitability criteria and biological justification. Criteria shown are for MFP and Lind & Yarnell 2007 data combined.
- Table C-3. *Rana boylii* egg mass habitat suitability criteria. n = valid sample size for depth/velocity/substrate; 0 = not suitable, 0.1 = marginally suitable, 1 = suitable
- Table C-4. *Rana boylii* tadpole habitat suitability criteria. n = valid sample size for depth/velocity/substrate; 0 = not suitable, 0.1 = marginally suitable, 1 = suitable.
- Table C-5. Frequency data for *Rana boylii* egg mass attachment substrate and tadpole group habitat substrate. Highlighted cells represent the ranked (highest to lowest) substrate types used to reach a total of 90% of the observations for each dataset. Data are from Lind and Yarnell (2007), MFP, and All Rivers combined.

**List of Figures**

- Figure C-1. Velocity, depth, and substrate habitat suitability criteria for egg masses and tadpoles.
- Figure C-2a. Distribution of observed mean-column velocity at egg masses in MFP large river sites, Lind and Yarnell (2007), and All River data combined. Suitability criteria color overlays from All Rivers (top) and just MFP data (bottom).
- Figure C-2b. Distribution of observed depth at egg masses in MFP large river sites, Lind and Yarnell (2007), and All River data combined. Suitability criteria color overlays from All Rivers (top) and just MFP data (bottom).
- Figure C-3a. Distribution of observed mean-column velocity at tadpoles in MFP large river sites, Lind and Yarnell (2007), Eel River, and All River data combined (excluding Eel River). Suitability criteria color overlays from All Rivers (top) and just MFP data (bottom).
- Figure C-3b. Distribution of observed depth at tadpoles in MFP large river sites, Lind and Yarnell (2007), Eel River, and All River data combined (excluding Eel River). Suitability criteria color overlays from All Rivers (top) and just MFP data (bottom).

**List of Attachments**

- Attachment A. Summary of Experimental Data for Tadpoles from Kupferberg et al. 2007.

**TABLES**

**Table C-1. *R.boylii* egg mass habitat suitability criteria justification. Criteria shown are for MFP and Lind & Yarnell 2007 data combined.**

Habitat Parameter	Habitat Suitability	Parameter Range	Biological Justification
<b>Mean-column Water Velocity (cm/s) Suitability</b>	<b>0</b>	>25	Criteria based on habitat utilization, no egg masses were observed at greater than 25 cm/s. Limited experimental data from the Pit River <sup>1</sup> during a flow increase indicated that scouring of egg masses occurred in this velocity range.
	<b>0.1</b>	>11 – 25	Criteria based on habitat utilization in the field, less than 10% of egg masses were observed between 11 and 25 cm/s. Limited experimental data from the Pit River <sup>1</sup> during a flow increase indicated that scouring of some egg masses occurred in this velocity range.
	<b>1.0</b>	0 – 11 cm/s	Criteria based on habitat utilization, 90% of egg masses were observed at 11cm/s or less. Limited experimental data from the Pit River <sup>1</sup> during a flow increase indicated that minimal scouring of egg masses occurred in this velocity range.
<b>Total Depth (cm) Suitability</b>	<b>0</b>	<2, >110	Criteria based on observed habitat utilization data; no experimental data on preferred depths exists.
	<b>0.1</b>	2 - <7, >53 - 110	
	<b>1.0</b>	7 – 53	
<b>Substrate Suitability<sup>2</sup></b>	<b>0</b>	7	Criteria based on observed habitat utilization data; no experimental data on preferred substrates exists.
	<b>0.1</b>	1,2,3,6	
	<b>1.0</b>	4,5	

<sup>1</sup>Spring Rivers Ecological Sciences, LLC. 2002. Foothill Yellow-legged Frog (*Rana boylii*) Studies in 2002 for PG&E's Pit 3, 4 and 5 Hydroelectric Project (FERC No. 233). Prepared for Pacific Gas and Electric Company, San Ramon, California. 62pp.

<sup>2</sup>See Table C-5 for substrate codes.

**Table C-2. *R. boylii* tadpole habitat suitability criteria and biological justification. Criteria shown are for MFP and Lind & Yarnell 2007 data combined.**

Habitat Parameter	Habitat Suitability	Parameter Range	Biological Justification
<b>Mean-column Water Velocity (cm/s) Suitability</b>	<b>0</b>	> 28	Criteria based on habitat utilization in the field, no individuals were observed at greater than 28cm/s. Experimental data indicate that direct negative effects occur to most if not all individuals. These range from 65-70% of individuals swept downstream at 30cm/s to 100% of individuals swept downstream at 40-50 cm/s.
	<b>0.1</b>	>6 -28	Criteria based on habitat utilization in the field, less than 10% of individuals were observed at greater than 6 cm/s. Experimental data indicate that negative effects occur to a majority of individuals. These range from modified behavior (i.e. sheltering in substrate) and increased predation risk and decreased growth and development while sheltering at 5-10cm/s to 50-70% of individuals swept downstream at 25-30cm/s.
	<b>1.0</b>	0 - 6	Criteria based on habitat utilization in the field, 90% of individuals were observed at 6 cm/s or less. Experimental data indicate that there are is no observable velocity effects below 3cm/s, and that observed behavior changes (i.e., sheltering in substrate) for some individuals at 5cm/s.
<b>Total Depth (cm) Suitability</b>	<b>0</b>	<2, >100	Criteria based on observed habitat utilization data; no experimental data on preferred depths exists.
	<b>0.1</b>	>40 -.100	
	<b>1.0</b>	2 - 40	
<b>Substrate Suitability<sup>1</sup></b>	<b>0</b>	7	Criteria based on observed habitat utilization data; no experimental data on preferred substrates exists.
	<b>0.1</b>	1,2	
	<b>1.0</b>	3,4,5,6	

<sup>1</sup>See Table C-5 for substrate codes.

**Table C-3. *Rana boylei* egg mass habitat suitability criteria. n = valid sample size for depth/velocity/substrate; 0 = not suitable, 0.1 = marginally suitable, 1 = suitable.**

River	n	Total Depth (cm) Suitability <sup>1</sup>			Mid-column Water Velocity (cm/sec) Suitability <sup>2</sup>			Substrate Suitability <sup>2,3</sup>		
		0	0.1	1	0	0.1	1	0	0.1	1
All Rivers Combined	330,296,376	<2, >110	2-<7, >53-110	7-53	>25	>11-25	0-11	7	1,2,3,6	4,5
MFP Rivers	110,104,128	<5, >110	5-<12, >59-110	12-59	>23	>11-23	0-11	1,2,3,7	6	4,5
L&Y 2007 All Rivers Combined	223,192,248	<2, >90	2-5, 48-90	6-47	>25	10-25	0-9	3	1,2,6	3,4,5
Butte Creek	59,59	<2, >64	2-4	5-64	>7	6-7	0-5			
West Branch Feather River	49,49	<9, >90	65-90	10-64	>17	13-17	0-12			
South Fork Feather	28,28	na	na	na	>25	14-25	0-13			
Pit River	114,80	<6, >49	6-9, 32-49	10-31	>15	10-15	0-9			

<sup>1</sup>L&Y 2007 for total depth = Butte Creek, West Branch Feather River, and Pit River.

<sup>2</sup>L&Y 2007 for mid-column water velocity and substrate = South Fork Feather River, Butte Creek, West Branch Feather River, Pit River.

<sup>3</sup>See Table C-5 for the substrate codes.

**Table C-4. *Rana boylei* tadpole habitat suitability criteria. n = valid sample size for depth/velocity/substrate; 0 = not suitable, 0.1 = marginally suitable, 1 = suitable.**

River	N	Total Depth (cm) Suitability <sup>1</sup>			Mid-column Water Velocity (cm/sec) Suitability <sup>1</sup>			Substrate Suitability <sup>1,2</sup>		
		0	0.1	1	0	0.1	1	0	0.1	1
All Rivers Combined	323,315,361	<2,>100	>40-100	2-40	>28	>6-28	0-6	7	1,2	3,4,5,6
MFP Rivers	169,169,206	<2,>76	>21-76	2-21	> 27	>3-27	0-3	1,2,7	3,6	4,5
L&Y 2007 All Rivers Combined	154,145,155	<2,>100	45-100	2-44	>28	12-28	0-11	7	1,5	2,3,4,6
Butte Creek	114,105	<2,>100	45-100	2-44	>28	9-28	0-8			
West Branch Feather River	40,40	<5,>100	36-100	5-35	>24	11-24	0-10			
South Fork Eel River	184,184	<1,>70	21-70	1-20	>8	4-8	0-3			

<sup>1</sup>All Rivers = Butte, West Branch Feather (South Fork Eel **not** included)

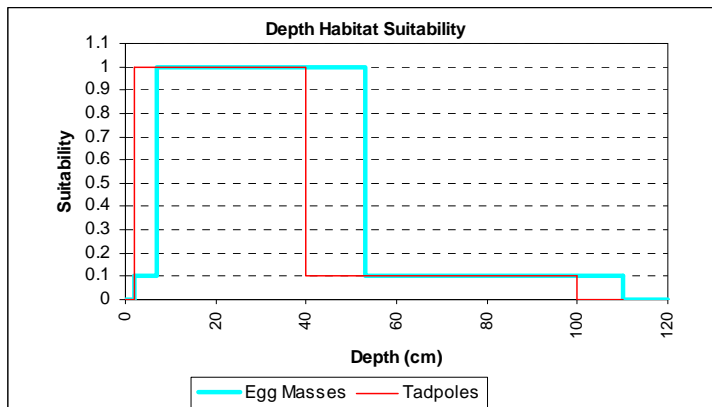
<sup>2</sup>See Table C-5 for the substrate codes.

**Table C-5. Frequency data for *Rana boylei* egg mass attachment substrate and tadpole group habitat substrate. Highlighted cells represent the ranked (highest to lowest) substrate types used to reach a total of 90% of the observations for each dataset. Data are from Lind and Yarnell (2007), MFP, and All Rivers combined.**

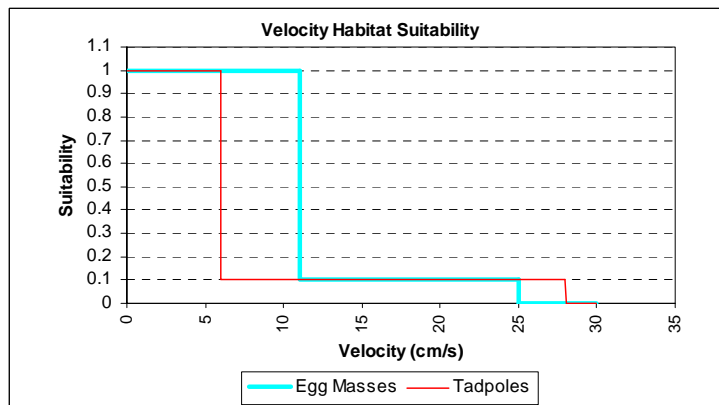
Substrate Category	Code	All Rivers Egg Masses (%)	All Rivers Tadpole Groups (%)	MFP Egg Masses (%)	MFP Tadpole Groups (%)	L&Y 2007 Egg Masses (%)	L&Y 2007 Tadpole Groups (%)
Silt/Clay/Mud	1	0.3	1.1	0.0	0.0	0.4	2.6
Sand (<2mm)	2	0.5	4.4	0.0	0.0	0.8	10.3
Gravel (2-64mm)	3	7.2	13.3	0.0	6.3	10.9	22.6
Cobble (64-128mm)	4	66.0	65.6	53.1	84.5	72.6	40.6
Boulder (>128mm)	5	24.7	7.8	46.1	8.3	13.7	7.1
Bedrock	6	1.3	7.8	0.8	1.0	1.6	16.8
Other	7	0	0	0	0	0	0
n =		376	361	128	206	248	155

**FIGURES**

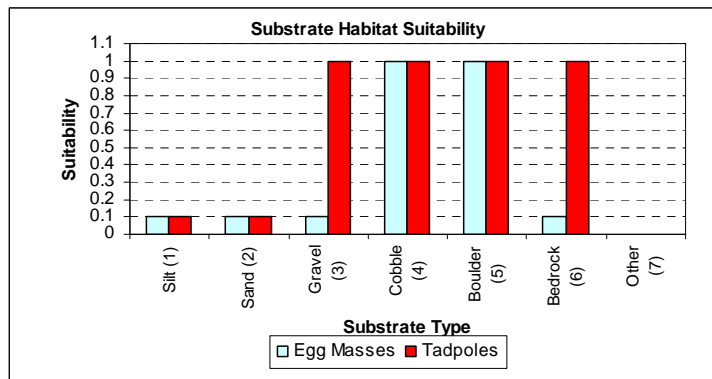
Figure C-1. Velocity, depth, and substrate habitat suitability criteria for egg masses and tadpoles.



Egg Masses		Tadpoles	
Depth (cm)	SI	Depth (cm)	SI
0	0	0	0
1.99	0	1.99	0
2	0.1	2	1
6.99	0.1	40	1
7	1	40.01	0.1
53	1	100	0.1
53.01	0.1	100.01	0
110	0.1	110	0
110.01	0		
120	0		

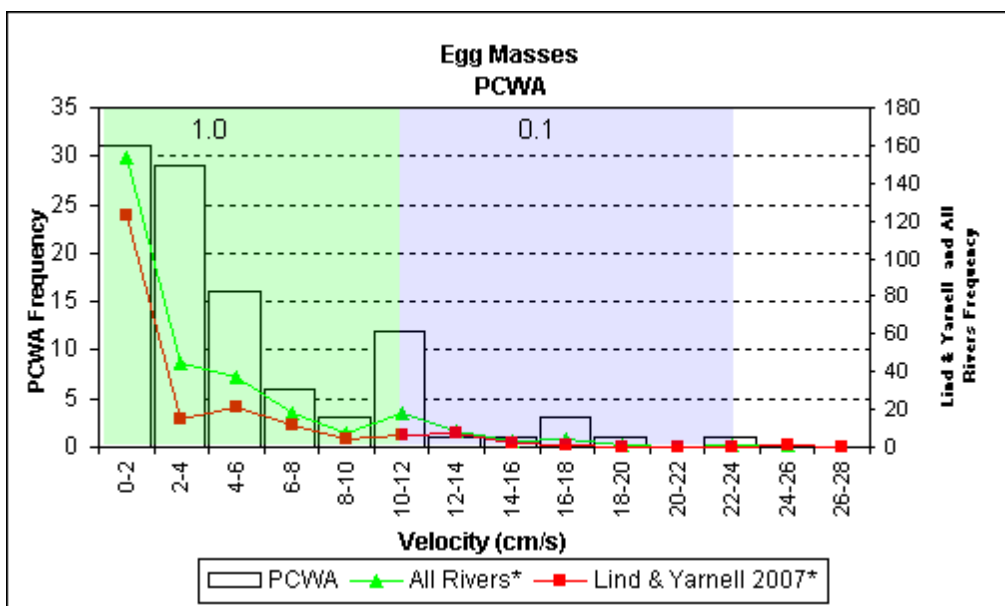
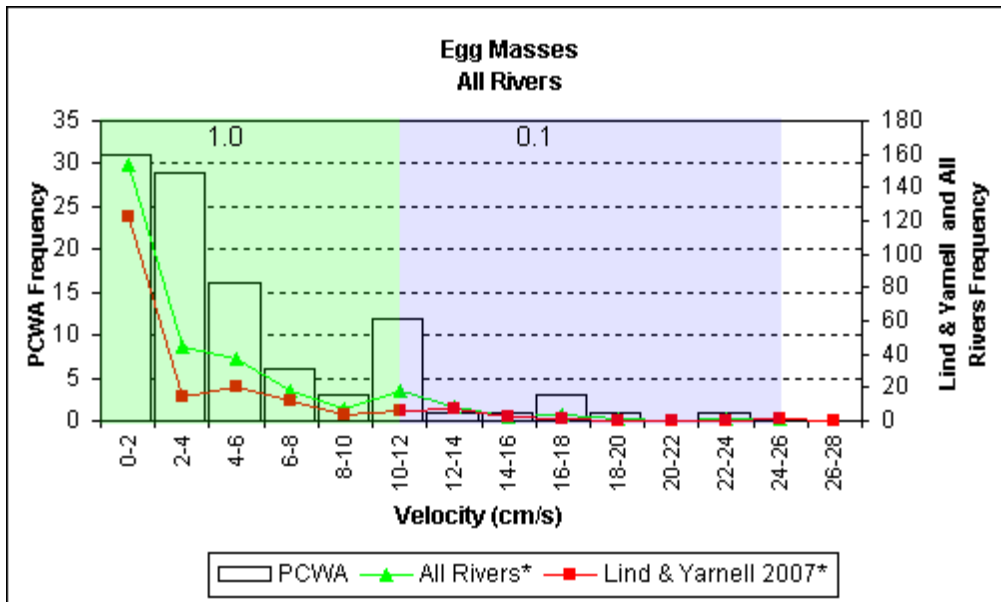


Egg Masses		Tadpoles	
Vel (cm/s)	SI	Vel (cm/s)	SI
0	1	0	1
11	1	6	1
11.01	0.1	6.01	0.1
25	0.1	28	0.1
25.01	0	28.01	0
30	0	30	0



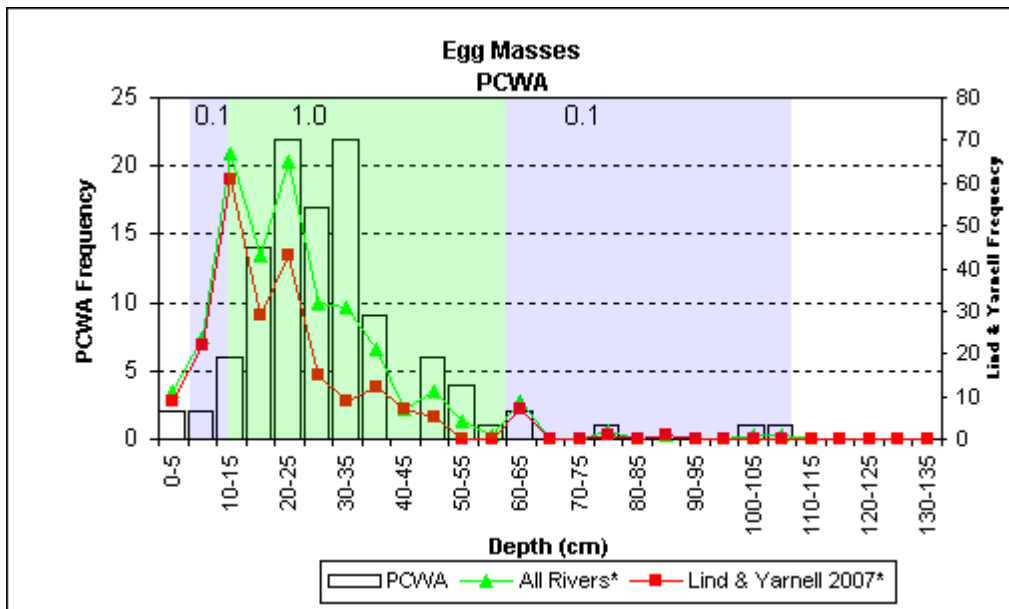
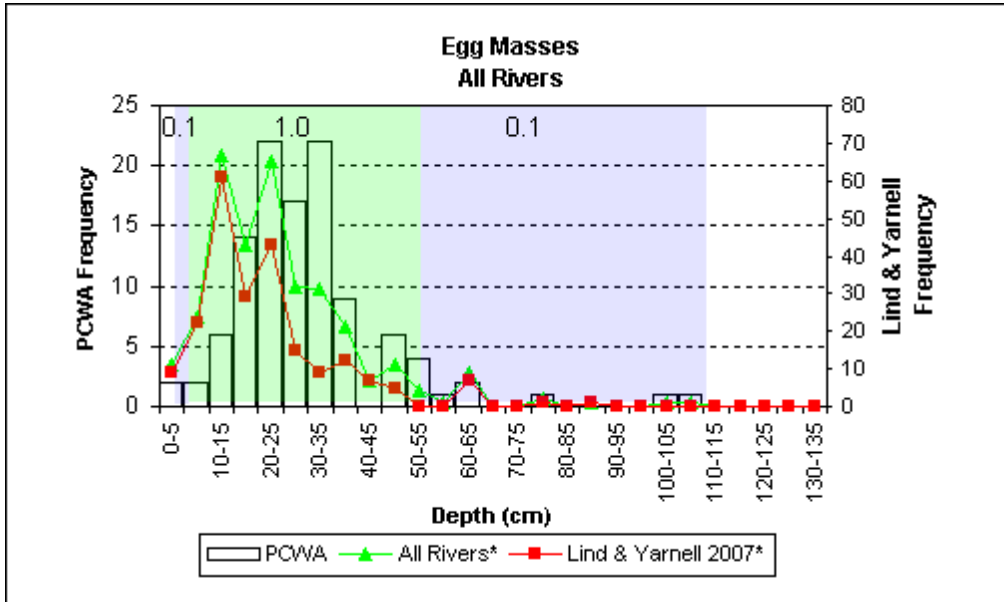
Substrate (code)	Egg Masses	Tadpoles
Silt (1)	0.1	0.1
Sand (2)	0.1	0.1
Gravel (3)	0.1	1
Cobble (4)	1	1
Boulder (5)	1	1
Bedrock (6)	0.1	1
Other (7)	0	0

Figure C-2a. Distribution of observed mean-column velocity at egg masses in MFP large river sites, Lind and Yarnell (2007), and All River data combined. Suitability criteria color overlays from All Rivers (top) and just MFP data (bottom).



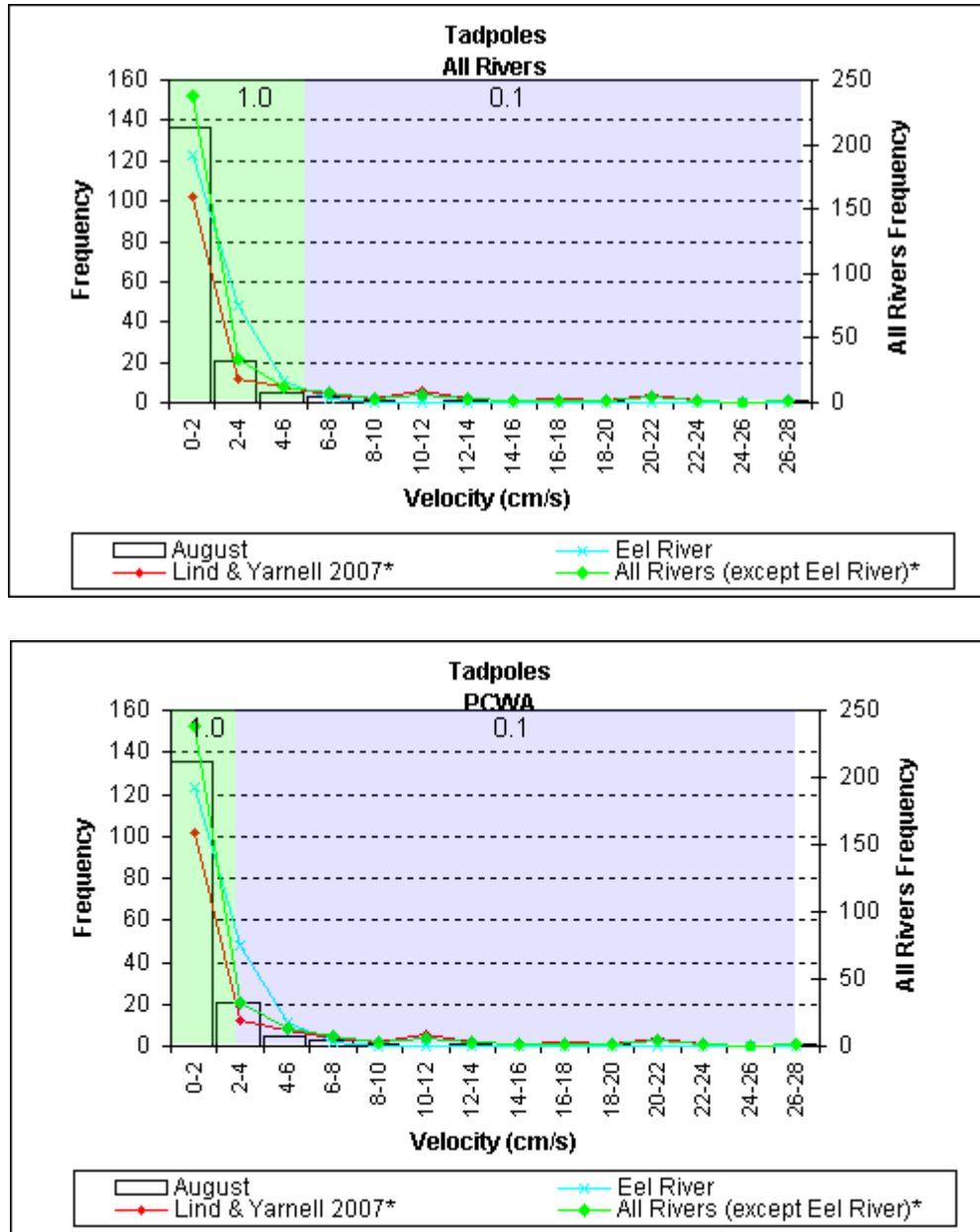
\*All Rivers is MFP data and Lind and Yarnell (2007). Lind and Yarnell (2007) data are from a combined data set from the West Branch Feather River (2006), Butte Creek (2006), the South Fork Feather River (2005) and the Pit River (2002-2004). Note: the scales on the two x-axes are different.

Figure C-2b. Distribution of observed depth at egg masses in MFP large river sites, Lind and Yarnell (2007), and All River data combined. Suitability criteria color overlays from All Rivers (top) and just MFP data (bottom).



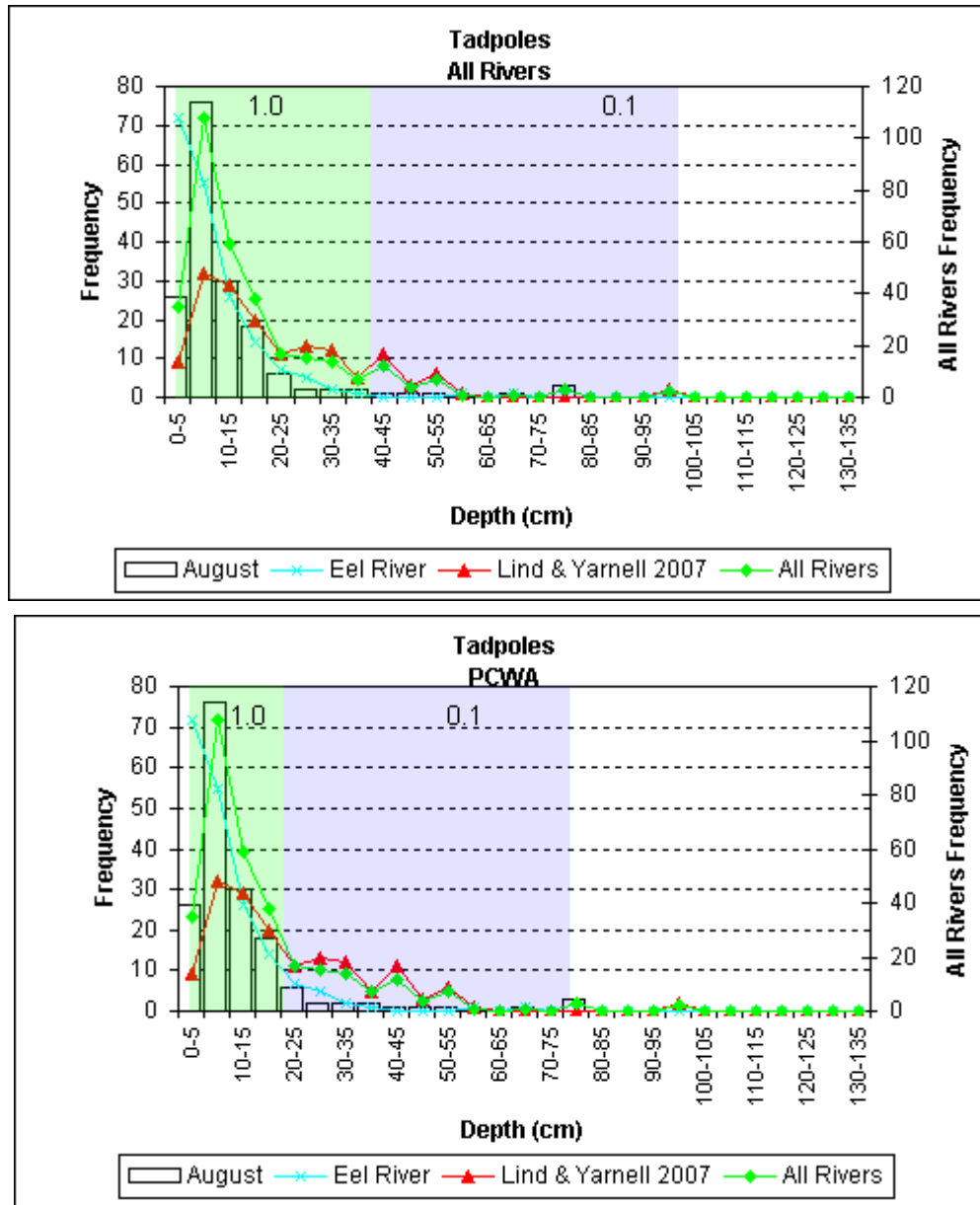
\*All Rivers is MFP data and Lind and Yarnell (2007). Lind and Yarnell (2007) data are from a combined data set from the West Branch Feather River (2006), Butte Creek (2006), and the Pit River (2002-2004). Note: the scales on the two x-axes are different.

**Figure C-3a. Distribution of observed mean-column velocity at tadpoles in MFP large river sites, Lind and Yarnell (2007), Eel River, and All River data combined (excluding Eel River). Suitability criteria color overlays from All Rivers (top) and just MFP data (bottom).**



\*All Rivers is MFP data and Lind and Yarnell (2007). Lind and Yarnell (2007) data are from a combined data set from the West Branch Feather River (2006) and Butte Creek (2006). Eel River data (S. Kupferberg, unpublished) are plotted, but not combined in the other river data sets.

**Figure C-3b. Distribution of observed depth at tadpoles in MFP large river sites, Lind and Yarnell (2007), Eel River, and All River data combined (excluding Eel River). Suitability criteria color overlays from All Rivers (top) and just MFP data (bottom).**



\*All Rivers is MFP data and Lind and Yarnell (2007). Lind and Yarnell (2007) data are from a combined data set from the West Branch Feather River (2006) and Butte Creek (2006). Eel River data (S. Kupferberg, unpublished) are plotted, but not combined in the other river data sets.

**ATTACHMENT A**

**Summary of Experimental Data for Tadpoles from Kupferberg et al. 2007**

Velocity effects on *R.boylii* tadpoles summarized from experiments and discussion in Kupferberg et al 2007.

Velocity Range	Experiment	Results
0-2 cm/s	Artificial channel in circular flume (Arcata lab)	~60% of tadpoles active with normal behavior (foraging on substrate, swimming, not sheltering in substrate)
0-2 cm/s	Instream rearing experiments	Baseflow or 'control' conditions with normal behavior, growth and development observed
5-8 cm/s (3-10cm/s)	Artificial channel in circular flume (Arcata lab)	~45% of tadpoles active with normal behavior; lower emigration from patch (i.e. greater number sheltering in substrate)
5-10 cm/s	Instream drift fence experiment	52% and 80% (in 2 trials) of tadpoles swept downstream or disappear
8-10 cm/s	Instream rearing experiments	Smaller, less developed tadpoles; direct mortality of recently hatched tadpoles (<2 wks old); lower survival rate of older tadpoles (~40% mortality when predators present)
10 cm/s	Brett chamber (UCD lab)	25% of all tadpoles exhausted; Mean critical velocity (velocity at which tadpoles exhausted) for late stage tadpoles (39-42 Gosner stage)
10-30 cm/s (mean vel = 16 cm/s)	Instream flume box	40% of tadpoles displaced from flume box over 18 hrs
10-30 cm/s (mean vel = 21 cm/s)	Instream flume box	70% of tadpoles displaced from flume box over 18 hrs
16-22 cm/s	Artificial channel in circular flume (Arcata lab)	39% of tadpoles displaced; remainder sheltering in substrate
25 cm/s	Brett chamber (UCD lab)	Mean critical velocity for all tadpoles tested and for mid-stage tadpoles (35-38 Gosner stage)
30 cm/s	Brett chamber (UCD lab)	66% of all tadpoles exhausted; Mean critical velocity for early stage tadpoles (27-30 Gosner stage)
40-50 cm/s	Artificial channel in circular flume (Arcata lab)	100% of tadpoles displaced
50 cm/s	Brett chamber (UCD lab)	100% of all tadpoles exhausted

Summary conclusions regarding velocity effects on *R.boylii* tadpoles excerpted from Kupferberg et al 2007 chapter 4:

- *R. boylii* tadpoles across a wide ontogenetic sequence seek refuge in substrate as soon as velocity increases and behavioral responses and performances were consistent among experimental venues. The sheltering response became apparent at velocities as low as 5 cm/sec.

- In a laboratory flume (Brett chamber), tadpoles could no longer shelter under rocks at a mean critical velocity of  $20.9 \pm 1.6$  cm/s.
- Critical velocity varied negatively with tadpole size and developmental stage, with velocities as low as 10 cm/s causing 25% of tadpoles to be displaced. The most easily displaced individuals are the largest, especially those closest to metamorphosis.
- For recently hatched tadpoles in the field, there were direct lethal effects of velocities as low as 10 cm/s.
- In flow refugia, there are lethal effects of predation. For tadpoles < 6 weeks old, mortality risk in rearing enclosures was doubled with a mean increase of approximately 7 cm/sec.

### **Literature Cited**

Kupferberg, S., Lind, A., Mount, J., and Yarnell, S. 2007. Pulsed flow effects on the Foothill Yellow-Legged Frog (*Rana boylei*): Integration of empirical, experimental and hydrodynamic modeling approaches. Final Report. California Energy Commission, PIER. Publication number TBD.

**APPENDIX D**  
**Instream Flow Study Site Selection Data**

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**TABLES**

**Table D-1. Duncan Creek D8.3 Mesohabitat Unit Location and Type<sup>1</sup>.**

Unit #	River Mile Start	Unit Length (ft)	McCain Channel Type	Instream Flow Habitat Type	Instream Flow Transects	Notes
10	8.53	46.3	HGR	HGR		
11	8.52	39.7	MCP	Pool		
12	8.51	40.2	MCP	Pool		
13	8.50	73.1	MCP	Pool		
14	8.49	26.4	MCP	Pool		
15	8.49	76.7	LGR	LGR		
16	8.47	44.5	HGR	HGR		
17	8.46	35.8	STP	Pool		
18	8.46	38.4	HGR	HGR		
18.1		40	HGR	HGR		
18.2		35.6	MCP	Pool		
18.3		21.6	CAS	CAS		
18.4		19.1	MCP	Pool		
19	8.45	44.6	LGR	LGR		
20	8.44	76.3	HGR	HGR		
21	8.43	97.7	HGR	HGR		
22	8.41	19.2	MCP	Pool		
23	8.41	66.3	MCP	Pool		
24	8.40	45.4	MCP	Pool		
25	8.39	127.7	MCP	Pool		
26	8.37	36.4	TRN	Run		
27	8.36	48.1	SRN	Run		
28	8.35	25.9	TRN	Run		
29	8.35	33.8	MCP	Pool		
30	8.34	52.2	STP	Pool		
31	8.33	43.3	HGR	HGR		
32	8.33	32.4	CAS	CAS		
33	8.32	95.5	STP	Pool	1	XS for gravel transport <sup>2</sup> .
34	8.30	76.9	HGR	HGR		
35	8.29	27.3	MCP	Pool		
36	8.29	61.9	CAS	CAS		
37	8.27	43.9	MCP	Pool		
38	8.27	39.2	RUN	Run		
39	8.26	78.3	HGR	HGR		
40	8.25	35	RUN	Run		
41	8.24	75	HGR	HGR		
42	8.23	85.7	STP	Pool	1	XS for gravel transport <sup>2</sup> .
43	8.21	21.3	HGR	HGR		
44	8.21	75.1	STP	Pool		
45	8.20	61.7	LGR	LGR		
46	8.18	40.8	TRN	Run		
47	8.18	26.1	CAS	CAS		
48	8.17	75	MCP	Pool		
49	8.16	46	TRN	Run		
50	8.15	194	STP	Pool	1	XS for gravel transport <sup>2</sup> .
51	8.12	54.4	HGR	HGR		
52	8.11	74.1	MCP	Pool		
53	8.10	30.5	HGR	HGR		
54	8.10	20	CAS	CAS		
55	8.09	111	STP	Pool		
56	8.07	99	HGR	HGR		
57	8.05	90	MCP	Pool		
58	8.03	118.4	SRN	Run		
59	8.02	52.6	CAS	CAS		

<sup>1</sup>Rosgen Channel Type B/F.

<sup>2</sup>Special purpose transect.

Table D-2. Duncan Creek D6.3 Mesohabitat Unit Location and Type<sup>1</sup>.

Unit #	River Mile Start	Unit Length (ft)	McCain Channel Type	Instream Flow Habitat Type	Instream Flow Transects	Notes
171	6.53	23.7	CAS	CAS		
172	6.52	63.2	RUN	Run		
173	6.51	137.4	HGR	HGR		
174	6.49	16.4	CAS	CAS		
175	6.48	58.8	MCP	Pool		
176	6.47	91	RUN	Run		
177	6.46	77.9	HGR	HGR		LGR and Run included in unit.
178	6.45	54.5	RUN	Run		
179	6.44	61.9	POW	Run	2	Crossflow.
180	6.43	42	LGR	LGR		
181	6.42	59.5	STP	Pool		QSS T1.
182	6.41	27	CAS	CAS		
183	6.40	63.3	MCP	Pool		Bottom LGR.
184	6.39	39.9	MCP	Pool		
185	6.39	97.2	HGR	HGR	2	Crossflows.
186	6.37	19.3	MCP	Pool		
187	6.37	27.9	LGR	LGR		
188	6.36	95.7	STP	Pool	3	Head, body, tail in upstream pool. <b>Gravels in tail.</b>
189	6.34	44.8	SRN	Run		2 steps.
190	6.34	17.7	CAS	CAS		
191	6.33	28.6	RUN	Run		
192	6.33	141.3	STP	Pool	3	Head, body, tail. QSS T2.
193	6.30	91.8	MCP	Pool	3	Head, body, tail. <b>Gravels in body.</b> Small backwater.
194	6.29	24.8	HGR	HGR		
195	6.28	48.8	PLP	Pool		Long with multiple pockets.
196	6.28	40.1	CAS	CAS		
197	6.27	27.7	MCP	Pool		
198	6.26	65.4	HGR	HGR	1	XS is in LGR at top of unit.
199	6.25	54.9	LGR	LGR	1	RUN-like.
200	6.24	113.8	HGR	HGR	2	RUN-like.
201	6.22	78.9	RUN	Run	2	Bottom XS is QSS T3. MCP at bottom.
202	6.21	42.1	CAS	CAS		
203	6.20	43.5	MCP	Pool	3	<b>Gravels at head.</b>
204	6.20	32.1	POW	Run		
205	6.19	33.4	CAS	CAS		
206	6.18	99	MCP	Pool		
207	6.16	47	HGR	HGR		XS for gravel transport <sup>2</sup> .
208	6.15	58	TRN	Run		
209	6.14	110	LSP	Pool		

<sup>1</sup>Rosgen Channel Type B/F.

Table D-3. North Fork Long Canyon Creek NFLC1.9 Mesohabitat Unit Location and Type<sup>1</sup>.

Unit #	River Mile Start	Unit Length (ft)	McCain Channel Type	Instream Flow Habitat Type	Instream Flow Transects	Notes
93	2.06	137	SRN	Run	1	Pocket gravel.
94	2.05	30	HGR	HGR		
95	2.05	25	MCP	Pool		
96	2.04	47	POW	Run	1	Wide, slow.
97	2.03	59	STP	Pool		
98	2.02	47	HGR	HGR		
99	2.01	55	LSP	Pool		LWD over unit.
100	2.01	44	HGR	HGR		Complex. Top of unit is LGR.
101	1.99	80	STP	Pool		Tree cover. Downstream is shallow.
102	1.98	42	HGR	HGR		Pocket pools.
103	1.98	23	LSP	Pool	2	Small pool. XS in body and tail. <b>Tail with gravels.</b>
104	1.98	28	LGR	LGR	1	Wide, shallow.
105	1.97	29	LSP	Pool		Shallow.
106	1.97	28	HGR	HGR		No habitat.
107	1.96	58	MCP	Pool	3	Head, body, tail. Head difficult. Tree cover.
108	1.95	64	HGR	HGR		RUN at top. No habitat in HGR. Split.
109	1.94	80	STP	Pool	1	XS is tailout. <b>Has gravels on bank.</b>
110	1.93	43	HGR	HGR		
111	1.90	160	STP	Pool		Shallow.
112	1.89	91	HGR	HGR	2	1XS in pocket, 1XS in fast water. RUN at top.
113	1.88	45	MCP	Pool		
114	1.87	29	HGR	HGR	1	XS used for LGR.
115	1.86	53	MCP	Pool	3	Head, body, tail. Tail is QSS T0. Coarse gravel.
116	1.85	62	HGR	HGR	1	XS is for RUN. Perched gravels.
117	1.84	77	STP	Pool		Top is RUN. Small pocket gravel.
118	1.82	84	HGR	HGR	1	QSS T1.
119	1.81	39	MCP	Pool		Coarse gravel in pockets.
120	1.80	31	LGR	LGR		
121	1.79	24	LSP	Pool		
122	1.78	44	RUN	Run		
123	1.77	27	STP	Pool		
124	1.75	89	HGR	HGR	1	QSS T2. Use XS for LGR.
125	1.74	59	LSP	Pool		
126	1.74	34	BRS	CAS		
127	1.74	27	TRN	Run		
128	1.72	131	STP	Pool		
129	1.72	41	HGR	HGR		XS for gravel transport.
130	1.71	103	TRN	Run		
131	1.70	50	STP	Pool		
132	1.70	24	HGR	HGR		
133	1.67	106	TRN	Run		
134	1.66	55	MCP	Pool		
135	1.66	31	LGR	LGR		

<sup>1</sup>Rosgen Channel Type B.

Table D-4. South Fork Long Canyon Creek SFLC2.3 Mesohabitat Unit Location and Type<sup>1</sup>.

Unit #	River Mile Start	Unit Length (ft)	McCain Channel Type	Instream Flow Habitat Type	Instream Flow Transects	Notes
72	2.57	93.8	MCP	Pool		
73	2.56	31.5	LGR	LGR		Part HGR.
74	2.55	11.5	MCP	Pool		
75	2.55	64.5	SRN	Run		Wide/shallow.
76	2.54	76.8	STP	Pool		
77	2.53	39.1	SRN	Run	2	<b>Gravels at upstream xs.</b> Shallow.
78	2.52	66.9	STP	Pool		
79	2.51	28.6	LGR	LGR		
80	2.51	23.6	MCP	Pool		Part LGR.
81	2.50	55.1	LGR	LGR		Part HGR.
82	2.49	37.7	STP	Pool		
83	2.49	38	LGR	LGR		
84	2.48	27.9	MCP	Pool		
85	2.48	138.5	LGR	LGR		RUN in middle.
86	2.45	103.7	LSP	Pool		
87	2.44	52.1	LGR	LGR		Part HGR.
88	2.43	10.7	MCP	Pool		
89	2.43	90.2	HGR	HGR	1	Step with pockets/run.
90	2.41	34.5	RUN	Run		Narrow.
91	2.41	61.2	LGR	LGR	1	Narrow.
92	2.40	45.3	RUN	Run	2	
93	2.39	131.9	LSP	Pool	1	<b>XS is tail with gravels.</b>
94	2.37	46	TRN	Run		
95	2.36	45.3	MCP	Pool		
96	2.35	54.9	LGR	LGR		RUN-like in lower half.
97	2.34	91.4	MCP	Pool	3	Head, body, tail. <b>Gravels at tail.</b>
98	2.33	105	HGR	HGR	1	Steep, narrow.
99	2.31	53.2	LSP	Pool		
100	2.30	68.1	HGR	HGR		
101	2.29	46.9	MCP	Pool		
102	2.29	43.6	RUN	Run	1	QSS T2 as XS. Pool-like.
103	2.28	110.5	LGR	LGR		CAS within. Small pool DS of CAS.
104	2.26	102.2	MCP	Pool	2	No head.
105	2.24	74	LGR	LGR		Combine with LGR below.
106	2.23	46.1	LGR	LGR	2	1XS is QSS T1.
107	2.22	102.2	MCP	Pool	3	Head, body, tail.
108	2.21	127.8	LGR	LGR		XS for gravel transport <sup>2</sup> .
109	2.18	31	LSP	Pool		

<sup>1</sup>Rosgen Channel Type B.

Table D-5. Long Canyon Creek LC9.0 Mesohabitat Unit Location and Type<sup>1</sup>.

Unit #	River Mile Start	Unit Length (ft)	McCain Channel Type	Instream Flow Habitat Type	Instream Flow Transects	Notes
120	9.21	258.7	SRN	Run		
121	9.16	70.6	HGR	HGR		
122	9.15	66.6	MCP	Pool		
123	9.13	224.5	LGR	LGR		Sections of HGR.
124	9.09	58.7	MCP	Pool	1	Deep, bedrock.
125	9.08	38.5	CAS	CAS		Pool in middle. Upstream barrier.
126	9.08	90.9	STP	Pool	2	<b>1XS in downstream pool with gravels</b> , QSS T1 is head. 1XS in top pool.
127	9.06	243	HGR	HGR	2	
128	9.02	78.9	MCP	Pool	3	Head, body, tail.
129	9.00	85.6	HGR	HGR		
130	8.99	34.5	MCP	Pool		
131	8.98	293.4	LGR	LGR	2	1XS is QSS T2 . DS XS is RUN-like. Short HGR at bottom.
132	8.93	134.6	RUN	Run	2	Small pool at upstream end.
133	8.90	125.5	LGR	LGR		Steps of HGR.
134	8.88	98.6	MCP	Pool	3	Head, body, tail. <b>Gravels at tail out.</b> Long, shallow tailout.
135	8.86	132.2	LGR	LGR	2	RUN at downstream end. Nearly HGR.
136	8.84	97.9	RUN	Run	1	Small step, almost SRN. <b>Pocket gravels.</b>
137	8.82	93.9	MCP	Pool		
138	8.80	259	LGR	LGR		
139	8.76	33.6	BRS	CAS		
140	8.75	129.4	STP	Pool		
141	8.73	35.7	BRS	CAS		

<sup>1</sup>Rosgen Channel Type F.

Table D-6. Middle Fork American River MF44.7 Mesohabitat Unit Location and Type<sup>1</sup>.

Unit #	River Mile Start	Unit Length (ft)	McCain Channel Type	Instream Flow Habitat Type	Instream Flow Transects	Notes
707	44.66	50	CAS	CAS		Access downstream difficult at high flows.
708	44.67	176	STP	Pool		QSS T1 and T2 in unit. Confined bedrock.
709	44.70	23	CAS	CAS		
710	44.71	50	PLP	Pool		
711	44.72	33	CAS	CAS		
712	44.72	55	LGR	LGR		Unique LGR.
713	44.73	186	MCP	Pool		Access difficult at high flows.
714	44.77	52	CAS	CAS		
715	44.77	102	HGR	HGR		Complex, split channel.
716	44.79	31	MCP	Pool		Side pool.
717	44.80	156	MCP	Pool	4	QSS T0 is downstream of tailout. <b>2nd flag going u/s has gravels.</b>
718	44.83	34	MCP	Pool		Short, deep.
719	44.83	56	HGR	HGR	1	Little fish habitat, one short section of level flow.
720	44.84	104	SRN	Run		Wide, difficult to model. Split channel.
721	44.86	144	MCP	Pool	4	Gravels in body and tailout. Backwater. <b>2nd flag going u/s has gravels</b>
722	44.89	113	STP	Pool		Hard access up step. CAS at top and at step.
724	44.90	66	MCP	Pool		
725	44.91	52	LGR	LGR	1	RUN-like, wide.
726	44.92	55	RUN	Run	1	Pool-like on margin, eddies, wide.
727	44.93	62	HGR	HGR		Too complex to model.
728	44.94	209	STP	Pool	6	3XS in pool, 1XS in step pool. 2XS in HGR. <b>Mid-pool gravels RB-XS 5 or 6</b>
729	44.97	31	HGR	HGR		Complex, some CAS.
730	44.98	86	RUN	Run	2	Deep, slow run. Narrow at top, LGR-like.
731	44.99	49	LGR	LGR		Nearly HGR.
732	45.00	71	MCP	Pool		Split head.
733	45.01	56	LGR	LGR		Side pool. Access difficult above at high flows.
734	45.02	63	PLP	Pool		
735	45.03	18	CAS	CAS		
736	45.03	157	STP	Pool		HGR between units.
737	45.05	100	SRN	Run		HGR-like.
738	45.07	67	MCP	Pool		
739	45.08	34	HGR	HGR		Complex.
740	45.09	55	RUN	Run		
741	45.10	49	LGR	LGR		HGR or POW-like.
742	45.11	167	MCP	Pool		Complex tail.

<sup>1</sup>Rosgen Channel Type Ba/Fb.

Table D-7. Middle Fork American River MF36.2 Mesohabitat Unit Location and Type<sup>1</sup>.

Unit #	River Mile Start	Unit Length (ft)	McCain Channel Type	Instream Flow Habitat Type	Instream Flow Transects	Notes
<b>Interbay Reservoir</b>						
685	35.98	225	MCP	Pool		
686	36.02	224	HGR	HGR	2	Upstream XS is LGR, Downstream XS is HGR.
687	36.06	87	LSP	Pool	3	Head, body, tail. Gauge.
688	36.08	74	RUN	Run	1	
689	36.09	98	HGR	HGR	3	2XS in HGR, 1XS in Run.
690	36.11	197	MCP	Pool	3	1XS in body, 2XS in tail. <b>Gravels in body and tail</b>
691	36.15	80	MCP	Pool	1	XS near head, deep and fast water.
692	36.16	43	CAS	CAS		
693	36.17	43	HGR	HGR	1	Little habitat, hard to model.
694	36.17	55	RUN	Run	1	<b>Gravels.</b>
695	36.18	163	STP	Pool	2	2XS in Pool. 1XS at T1, 1XS at T2.
<b>No access beyond this point.</b>						

<sup>1</sup>Rosgen Channel Type Ba/Fb.

Table D-8. Middle Fork American River MF26.2 Mesohabitat Unit Location and Type<sup>1</sup>.

Unit #	River Mile Start	Unit Length (ft)	McCain Channel Type	Side Channel Type	Instream Flow Habitat Type	Instream Flow Transects	Notes
317	pow Reservoir		DPL				
318	25.94	292	MCP		Pool		Not as representative, alternate pool.
319	25.99	186	LGR		LGR	(2D)	Split channel (FYLF 2D site #1, upstream portion of unit included in modeling).
320	26.02	232	MCP		Pool	3 (2D)	Head, body, tail. USGS Gage. (FYLF 2D site #1).
320.1		105		LGR	LGR		Split channel.
321	26.07	41	MCP		Pool		Split channel.
322	26.07	46	RUN		Run		Split channel (Potential 2D site #2).
323	26.08	187	LGR		LGR	1	Wide LGR. In short section between split channels.
323.1		270		LGR	LGR	(2D)	Split channel (Potential FYLF 2D site #2) <sup>2</sup> .
324	26.12	107	RUN		Run		Split channel.
325	26.14	91	MCP		Pool		Split channel.
326	26.15	130	HGR		HGR	1 (2D)	Split channel (Potentially model with 2D).
327	26.18	188	POW		Run	3 (2D)	Split channel (FYLF 2D site #2). <b>Gravels.</b>
328	26.21	42	LGR		LGR	1	Short, narrow LGR.
329	26.22	63	RUN		Run	1	Short run.
330	26.23	92	HGR		HGR	2	Lower gradient HGR <sup>3</sup> . <b>Gravels.</b>
331	26.25	190	SRN		Run	3	1XS wide, 1XS narrow, and 1XS deep.
332	26.28	99	POW		Run		Complex, multiple levels.
333	26.30	125	MCP		Pool	3	Head, body, tail. Small split near head of pool.
334	26.32	293	HGR		HGR	2	1XS wide, 1XS narrow. Complex at bottom of unit. <b>Gravels.</b>
335	26.36	140	STP		Pool	3	Some backwater.
336	26.38	48	CAS		CAS		
337	26.39	172	PLP		Pool	1	XS at tailout. Difficult access to pool body and head.
338	26.42	47	CAS		CAS		No access beyond this point.

<sup>1</sup>Rosgen Channel Type Bc/F.<sup>2</sup>Extent of 2D modeling dependent on FYLF egg mass oviposition locations.<sup>3</sup>One HGR transect is alternative, potentially replaces transect in unit #326.

**Table D-9. Middle Fork American River MF14.1 Mesohabitat Unit Location and Type<sup>1</sup>.**

Unit #	River Mile Start	Unit Length (ft)	McCain Channel Type	Side Channel Type	Instream Flow Habitat Type	Proposed 2D Subset	Notes
174	13.32	597	MCP		Pool		
175	13.44	231	RUN		Run		
176	13.48	754	MCP		Pool		
177	13.64	846	SRN		Run		Gravels on RB split.
178.1		868		LGR	LGR		
178	13.78	700	MCP		Pool	2D	
179	13.92	564	RUN		Run	2D	
180	14.03	276	HGR		HGR	2D	
181	14.08	581	MCP		Pool	2D	
182	14.16	206	LGR		LGR	2D	
183	14.20	573	MCP		Pool	2D	Gravels.
184	14.31	303	LSP		Pool	2D	
185	14.38	133	LGR		LGR	2D	
186	14.44	520	RUN		Run	2D	
187	14.50	148	LGR		LGR	2D	Gravels.
188	14.52	160	RUN		Run		
189	14.55	70	LGR		LGR		
190	14.58	166	RUN		Run		
191.1		343		RUN	RUN		
191.2		263		LGR	LGR		
191	14.69	1267	MCP		Pool		
192	14.94	135	HGR		HGR		
193	14.96	194	RUN		Run		

<sup>1</sup>Rosgen Channel Type Bc/F.

**Table D-10. Middle Fork American River MF4.8 Mesohabitat Unit Location and Type<sup>1</sup>.**

Unit #	River Mile Start	Unit Length (ft)	McCain Channel Type	Side Channel Type	Instream Flow Habitat Type	Proposed 2D Subset	Notes
67	3.66	156	HGR		HGR		
68	3.69	99	MCP		Pool		
69	3.70	790	MCP		Pool		
70	3.85	133	RUN		Run		
71	3.87	304	LGR		LGR		
72	3.93	1030	GLD		Run		
73	4.13	218	LGR		LGR	2D	
74	4.17	474	MCP		Pool	2D	
75	4.26	190	RUN		Run	2D	
76	4.30	132	LGR		LGR	2D	
77	4.32	170	LSP		Pool	2D	
78	4.35	456	RUN		Run	2D	
79	4.44	621	MCP		Pool	2D	<b>Gravels.</b>
80	4.56	257	GLD		Run	2D	
81	4.61	439	MCP		Pool	2D	<b>Gravels.</b>
82	4.69	167	LGR		LGR	2D	
83	4.72	514	SRN		Run	2D	<b>Gravels.</b>
84	4.82	538	MCP		Pool	2D	
85	4.92	687	RUN		Run		
86	5.05	313	MCP		Pool		
87	5.11	292	RUN		Run		
88	5.17	1079	LSP		Pool		

<sup>1</sup>Rosgen Channel Type Bc/F.

**Table D-11. Rubicon River R25.7 Mesohabitat Unit Location and Type<sup>1</sup>.**

Unit #	River Mile Start	Unit Length (ft)	McCain Channel Type	Instream Flow Habitat Type	Instream Flow Transects	Notes
794	25.14	305.7	GLD	Run		
795	25.20	349.5	LGR	LGR		<b>Gravels in tailout (not modeled).</b>
796	25.26	84.1	MCP	Pool		
797	25.28	236.7	MCP	Pool		
798	25.32	98.8	HGR	HGR		
799	25.34	180.5	LGR	LGR		RUN-like. Split.
800	25.37	135.1	MCP	Pool		Split.
801	25.39	225.5	HGR	HGR		
802	25.43	68.1	RUN	Run		
803	25.44	104.1	HGR	HGR		Lower gradient.
804	25.46	191.0	MCP	Pool		RUN-tailout.
805	25.50	220.1	LGR	LGR	1	QSS T1. HGR-like.
806	25.54	545.3	MCP	Pool		Glide-tailout.
807	25.63	237.2	LSP	Pool	4	Head, body, tail. <b>Gravels in tailout.</b>
808	25.67	196.7	LGR	LGR	1	XS for watersurface at QSS 2 <sup>2</sup> .
809	25.71	216.3	MCP	Pool	3	Head, body, tail. Deep, short.
810	25.75	24.5	HGR	HGR		
811	25.75	34.8	MCP	Pool		
812	25.76	56.4	HGR	HGR		
813	25.77	110.0	RUN	Run	2	Deep.
814	25.78	57.3	LGR	LGR	1	Short unit.
815	35.80	90.0	RUN	Run	2	Deep, slow.
816	25.81	216.5	MCP	Pool		Glide-like.
817	25.85	200.0	HGR	HGR	2	
818	25.88	92.3	LGR	LGR	2	
819	25.90	89.4	RUN	Run	2	Shallow, wide. DS XS may be LGR.
820	25.92	439.7	MCP	Pool	4	Head, 2 in body, tail. Small split in body. <b>Gravels in tail.</b>
821	26.00	284.0	HGR	HGR	2	Longer, some complex habitat.
822	26.05	178.3	RUN	Run		
823	26.08	262.6	HGR	HGR		
824	26.13	193.9	RUN	Run		

<sup>1</sup>Rosgen Channel Type C.<sup>2</sup>Special purpose transect.

Table D-12. Rubicon River R20.9 Mesohabitat Unit Location and Type<sup>1</sup>.

Unit #	River Mile Start	Unit Length (ft)	McCain Channel Type	Instream Flow Habitat Type	Instream Flow Transects	Notes
657	20.22	98.3	HGR	HGR		
658	20.23	241.5	MCP	Pool		Alternate pool.
659	20.28	440.0	SRN	Run		Alternate run.
660	20.36	77.5	HGR	HGR		Alternate HGR.
661	20.37	181.2	RUN	Run		Short LGR at top, shallow.
662	20.40	320.6	MCP	Pool	3	Head, body, tail. Angled tailout. <b>Gravels in tail out.</b>
663	20.46	125.8	RUN	Run	1	Medium width run.
664	20.48	157.1	HGR	HGR	1	Wider, less steep section. Difficult to model.
665	20.51	606.3	RUN	Run	1	Slow wide run. <b>Gravels in XS.</b>
666	20.62	156.1	RUN	Run	1	Nearly pool.
667	20.64	74.9	SRN	Run		
668	20.66	92.0	HGR	HGR	1	Some SRN near top.
669	20.67	98.0	SRN	Run	1	Deep, fast run. Bottom step is HGR.
670	20.69	63.0	MCP	Pool	1	Deep, slow. Some run components.
671	20.70	227.0	MCP	Pool	4	Head, body, tail.
672	20.74	18.0	HGR	HGR		
673	20.75	71.0	RUN	Run		
674	20.76	115.0	MCP	Pool		Split.
675	20.78	76.0	HGR	HGR		Part CAS.
676	20.79	334.0	RUN	Run		Wide.
677	20.85	77.0	LGR	LGR		Split. QSS T2, collect water surface elev. data.
678	20.86	56.0	RUN	Run		Wide.
679	20.87	199.0	MCP	Pool	3	Head, body, tail. <b>Gravels in tailout of split channel.</b> Small split.
680	20.91	43.0	LGR	LGR	1	
681	20.92	187.0	SRN	Run	2	1XS in narrow RUN, 1XS in HGR (step).
682	20.95	117.0	MCP	Pool		Split head. Nearly run.
683	20.97	112.0	CAS	CAS		
684	20.99	86.0	HGR	HGR	2	1XS wide, 1XS narrow.
685	21.01	542.0	MCP	Pool		Ellicott Bridge

<sup>1</sup>Rosgen Channel Type B/Fb.

Table D-13. Rubicon River R3.5 Mesohabitat Unit Location and Type<sup>1</sup>.

Unit #	River Mile Start	Unit Length (ft)	McCain Channel Type	Instream Flow Habitat Type	Instream Flow Transects	Notes
56	2.63	62.0	LGR	LGR		
57	2.64	50.0	RUN	Run		
58	2.65	143.0	MCP	Pool		
59	2.68	98.0	CAS	CAS		
60	2.70	135.0	RUN	Run		
61	2.72	102.0	MCP	Pool		
62	2.74	84.0	HGR	HGR		
63	2.75	84.0	RUN	Run		
64	2.77	149.0	LSP	Pool		Step pool.
65	2.79	245.0	LSP	Pool		Step pool.
66	2.83	111.0	HGR	HGR		
67	2.85	265.0	MCP	Pool		
68	2.90	150.0	HGR	HGR	2	
69	2.96	70.0	LGR	LGR	1	
70	2.97	350.0	RUN	Run	2	
71	3.02	150.0	LSP	Pool	3	<b>Gravels at middle xs.</b>
72	3.05	75.0	LSP	Pool		Short pool.
73	3.07	75.0	LGR	LGR		
74	3.08	134.0	LSP	Pool		
75	3.11	68.0	LGR	LGR	1	Short unit.
76	3.12	501.0	MCP	Pool	4	Multiple scours. <b>Coarse gravels in tail.</b>
77	3.22	145.0	CAS	CAS		Side run.
78	3.24	186.0	SRN	Run	1	Three short runs.
79	3.28	124.0	HGR	HGR		Complex.
80	3.30	52.0	RUN	Run		
81	3.31	151.0	MCP	Pool	1	<b>XS in tailout for gravels.</b> Split tailout with egg masses.
82	3.34	288.0	SRN	Run	2	Three short runs with CAS and LGR between.
83	3.39	326.0	HGR	HGR	2	Some gravels. Upstream XS is LGR.
84	3.45	257.0	LSP	Pool	2D	Backwater, FYLF Site #1 (Downstream end of pool only)
85	3.50	152.0	LGR	LGR		
86	3.53	50.0	RUN	Run		
86.1		150.0	TRN	Run		Split channel.
87	3.54	467.0	LSP	Pool		Long Canyon enters at head. QSS T1 at tailout.
88	3.62	105.0	HGR	HGR		
89	3.64	110.0	RUN	Run	2D	Pool-like, lateral scour. FYLF Site #2 cont. (Upstream part of run to be modeled).
90	3.66	353.0	MCP	Pool	3 (2D)	Amph HSC site. Backwater, long glide-like tailout. FYLF Site #2.

<sup>1</sup>Rosgen Channel Type Bc/F

**APPENDIX E**  
**Large Pool Habitat Use Modeling Validation**

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Figure E-3. Range of Velocities Minnows Were Observed Utilizing in Pools During Snorkeling Observations Compared to Hardhead Habitat Suitability Criteria.

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**Table E-1. Rubicon River and Middle Fork American River Fish Habitat Use in Pools.**

<b>Rubicon River - July 26, 2007</b>				
<b>Pool #1</b>				
<b>Species and Age Class</b>	<b>Pool Spatial Location Observed</b>	<b>Depth (ft)</b>	<b>Velocity (ft/sec)</b>	<b>Observation Notes</b>
<b>Morning Sample</b>				
Adult Trout	Head	2 - 4	1.3 - 2.6	Observed feeding in turbulent water at interface between pool and riffle.
Juvenile Minnow	Body, tail, along river margin	2 - 6	0 - 0.83	Observed in submerged willow habitat along the scoured banks.
Young-of-the-year Minnow	Body	<1.5	0 - 0.1	In small schools along a cobble bar near the tail of the pool.
<b>Afternoon Sample</b>				
Adult Trout	Head and body	2 (head), 12 (body)	1.3 - 2.6 (head), 0 (body)	One trout was observed feeding at the head of the pool, the remainder (5) were near the bottom of the body of the pool.
Adult Pikeminnow	Head	2	0	Observed behind boulder near the head of the pool.
Juvenile Minnow	Head, body, tail, along river margin	2 - 6	0 - 0.83	Observed in submerged willow habitat along the scoured banks. One adult pikeminnow was observed near the head of the pool behind a large bolder.
Young-of-the-year Minnow	Body	< 1.5	0 - 0.1	In small schools along a cobble bar near the tail of the pool.
<b>Pool #2</b>				
<b>Species and Age Class</b>	<b>Pool Spatial Location Observed</b>	<b>Depth (ft)</b>	<b>Velocity (ft/sec)</b>	<b>Observation Notes</b>
<b>Morning Sample</b>				
Adult Trout	Head	4-6	0.35 - 1.2	Two adult trout were observed in swift water feeding at the head, one trout was observed in deeper, moderate velocity water feeding at the head.
Adult Minnow	Body, along river margin	< 2	0 - 0.25	
Juvenile Minnow	Body, along river margin	< 2	0 - 0.25	Most juvenile minnow were observed in slow water along the river margin. Some observed near the head in moderate velocity feeding on drift.
Young-of-the-year Minnow	Body, tail, along river margin	< 1	0 - 0.25	Observed along river margins in slow to zero velocity water.
<b>Afternoon Sample</b>				
Adult Trout	Head	4-6	0.35 - 1.2	Two adult trout were observed in swift water feeding at the head, one trout was observed in deeper, moderate velocity water feeding at the head.
Adult Minnow	Body, along river margin	< 2	0 - 0.25	
Juvenile Minnow	Body, along river margin	2 - 3	0 - 0.25	Most juvenile minnow were observed in slow water along the river margin. Some observed near the head in moderate velocity feeding on drift.
Young-of-the-year Minnow	Body, tail, along river margin	< 1	0 - 0.25	Observed along river margins in slow to zero velocity water.
Adult California Roach	Body, tail, along river margin	4 - 6	0 - 0.20	Observed along river margins in slow to zero velocity water.

**Table E-1. Rubicon River and Middle Fork American River Fish Habitat Use in Pools (continued).**

<b>Rubicon River - July 26, 2007</b>				
<b>Pool #3</b>				
<b>Species and Age Class</b>	<b>Pool Spatial Location Observed</b>	<b>Depth (ft)</b>	<b>Velocity (ft/sec)</b>	<b>Observation Notes</b>
<b>Morning Sample</b>				
Adult Trout	Body	1, 20	1 - 2.2, 0	One rainbow trout was observed in the body of the pool at 1' depth, 5 were observed cruising near the bottom at 20' deep.
Adult Minnow	Body	4 - 10	0 - 1.2	
<b>Afternoon Sample</b>				
Adult Trout	Head and body	0 - 4 (head), 20 (body)	2.3 - 3.1 (head), 0 (body)	Two of the eight trout observed were actively feeding at the head, the remaining 6 were cruising near the bottom in the body of the pool. One adult hardhead was observed near the bottom in the body of the pool. Small schools observed actively feeding near the surface along the margins of the river.
Adult Minnow	Body	20	0 - 1.2	
Juvenile Minnow	Tail, river margin	0-6	0 - 1.2	

Table E-1. Rubicon River and Middle Fork American River Fish Habitat Use in Pools (continued).

<b>Middle Fork American River - August 18-19, 2007</b>				
<b>Pool #1</b>				
<b>Species and Age Class</b>	<b>Pool Spatial Location Observed</b>	<b>Depth (ft)</b>	<b>Velocity (ft/sec)</b>	<b>Observation Notes</b>
<b>Morning Sample</b>				
Adult California Roach	Body, tail, along river margin	< 2.5	< 0.3	Observed along river margins near submerged vegetation and algae mats.
Juvenile Minnow	Body, tail, along river margin	< 2.5	< 0.3	Observed along river margins near submerged vegetation and algae mats.
<b>Afternoon Sample</b>				
Adult California Roach	Body, tail, along river margin	< 2.5	< 0.3	Observed along river margins near submerged vegetation and algae mats.
Juvenile Minnow	Body, tail, along river margin	< 2.5	< 0.3	Observed along river margins near submerged vegetation and algae mats.
<b>Pool #2</b>				
<b>Species and Age Class</b>	<b>Pool Spatial Location Observed</b>	<b>Depth (ft)</b>	<b>Velocity (ft/sec)</b>	<b>Observation Notes</b>
<b>Morning Sample</b>				
Adult Trout	Head	4 - 5	0.85	Five adult trout observed feeding on drift at the head of the pool.
Juvenile Minnow	Body, along river margin	< 2.0	< 0.2	Observed along river margins near submerged vegetation and algae mats.
<b>Afternoon Sample</b>				
Adult Trout	Head and body	7	< 0.2	Five adult trout observed in the deepest part of the pool, near the head.
Juvenile Minnow	Body, river margin	< 2.0	< 0.2	Observed along river margins near submerged vegetation and algae mats.
<b>Pool #3</b>				
<b>Species and Age Class</b>	<b>Pool Spatial Location Observed</b>	<b>Depth (ft)</b>	<b>Velocity (ft/sec)</b>	<b>Observation Notes</b>
<b>Morning Sample</b>				
Adult Trout	Head and body	3- 6 (head), 5 (body)	0.19 - 0.37 (head), 0.0 (body)	Six adult trout were observed feeding on drift at the head of the pool, 1 adult trout was observed in the body near the bottom.
Juvenile Minnow	Body, river margin	2 - 4	< 0.3	Schools of mixed minnow were observed along the margins of the river in submerged vegetation.
<b>Afternoon Sample</b>				
Adult Trout	Head and body	3 - 6	0.19 - 0.37	Seven adult trout were observed feeding on drift at the head of the pool.
Juvenile Minnow	Body, river margin	2 - 4	< 0.3	Schools of mixed minnow were observed along the margins of the river in submerged vegetation.

**Table E-1. Rubicon River and Middle Fork American River Fish Habitat Use in Pools (continued).**

<b>Middle Fork American River - August 18-19, 2007</b>				
<b>Pool #4</b>				
<b>Species and Age Class</b>	<b>Pool Spatial Location Observed</b>	<b>Depth (ft)</b>	<b>Velocity (ft/sec)</b>	<b>Observation Notes</b>
<b>Morning Sample</b>				
Adult Trout	Head and body	6 - 10	0.3 - 0.7	Approximately 20 adult trout were observed swimming between the head and body. Most appeared to be feeding on benthic invertebrates.
Juvenile Trout	Body and tail	< 2.5	0.2	Juvenile brown and rainbow trout were observed in cobble and boulders along the margin of the pool in near zero velocity water.
Juvenile Minnow	Tail, river margin	0-6	0.3 - 0.7	Small schools observed actively feeding near the surface along the margins of the river.
<b>Afternoon Sample</b>				
Adult Trout	Head and body	6 - 10	0.3 - 0.7	Approximately 20 adult trout were observed swimming between the head and body. Most appeared to be feeding on benthic invertebrates.
Juvenile Trout	Body and tail	< 2.5	Slow	Juvenile brown and rainbow trout were observed in cobble and boulders along the margin of the pool in near zero velocity water.
Juvenile Minnow	Tail, river margin	0-6	Moderate-slow	Small schools observed actively feeding near the surface along the margins of the river.

**FIGURES**

**Figure E-1. Range of Velocities Trout Were Observed Utilizing in Pools During Snorkeling Observations Compared to Rainbow Trout Habitat Suitability Criteria.**

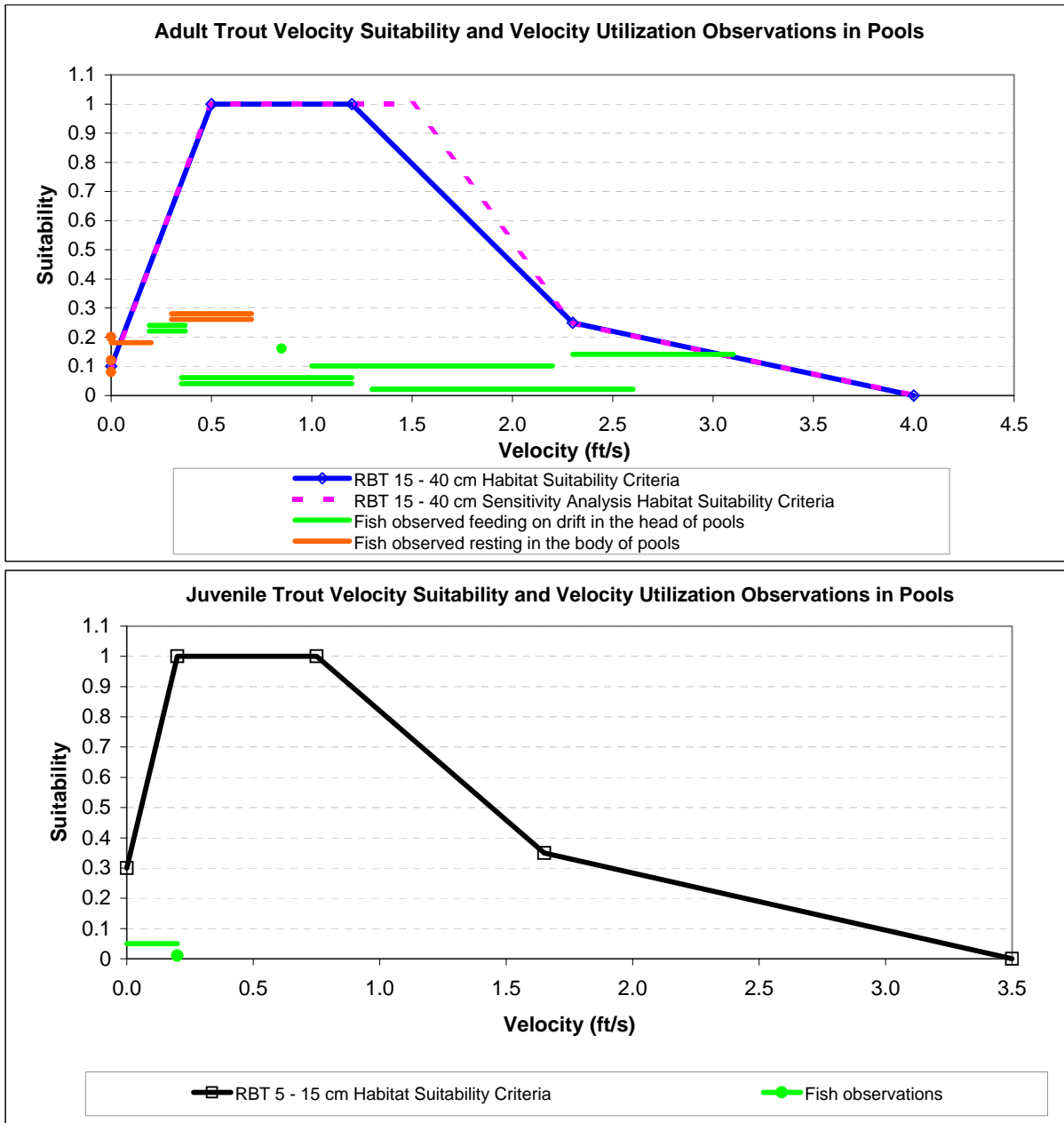


Figure E-2. Range of Depths Trout Were Observed Utilizing in Pools During Snorkeling Observations Compared to Rainbow Trout Habitat Suitability Criteria.

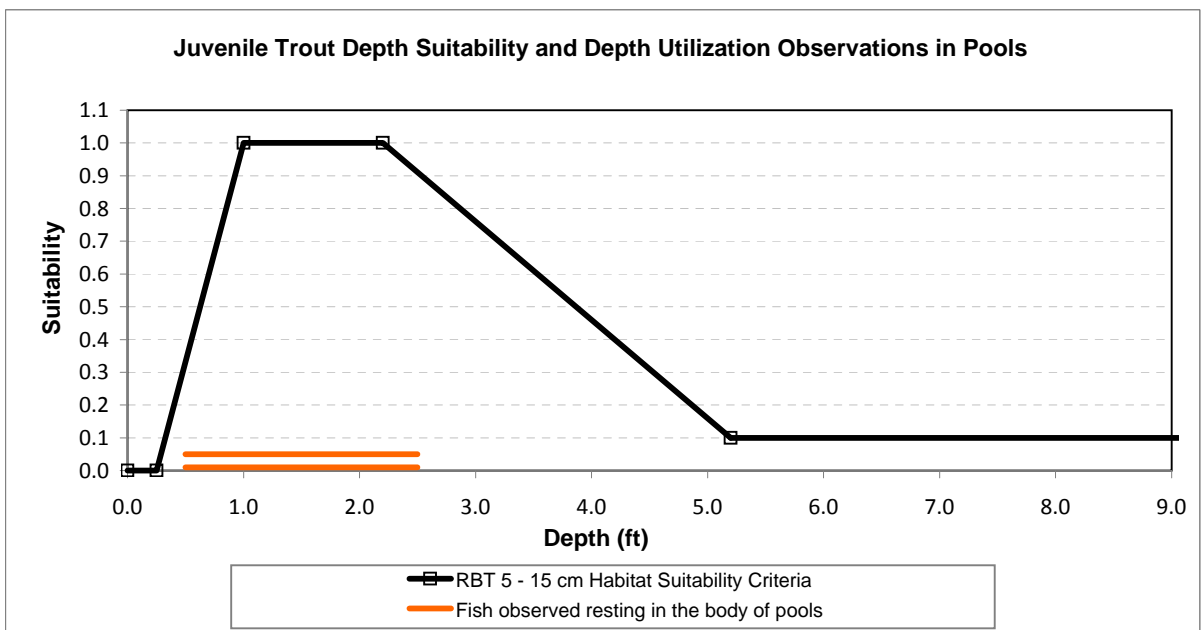
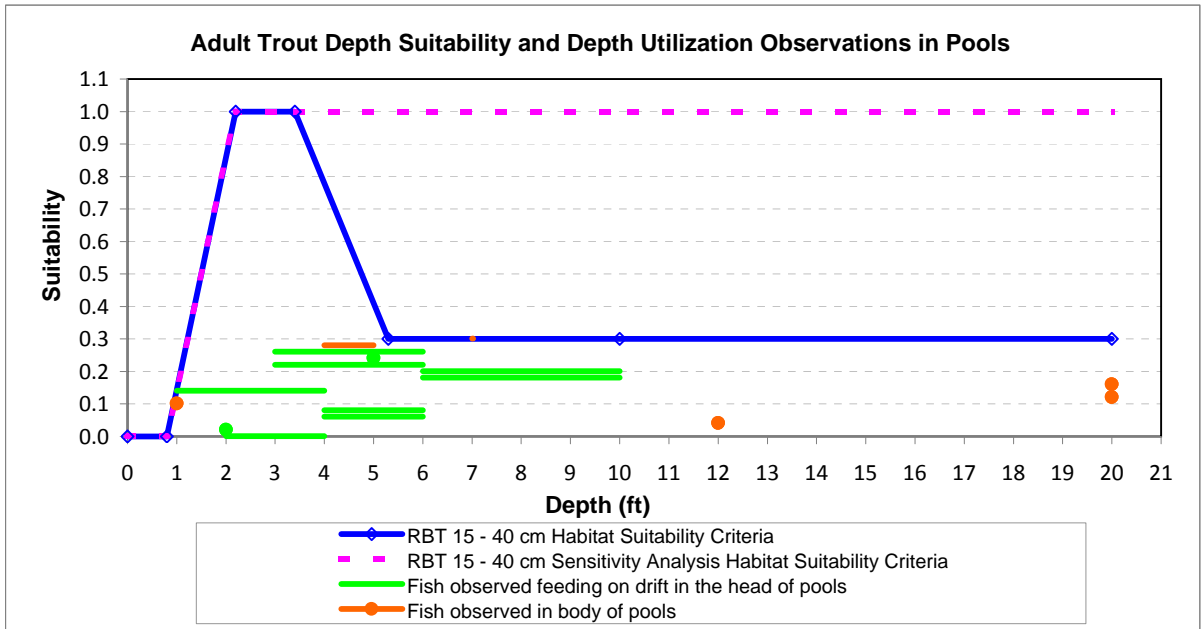


Figure E-3. Range of Velocities Minnows Were Observed Utilizing in Pools During Snorkeling Observations Compared to Hardhead Habitat Suitability Criteria.

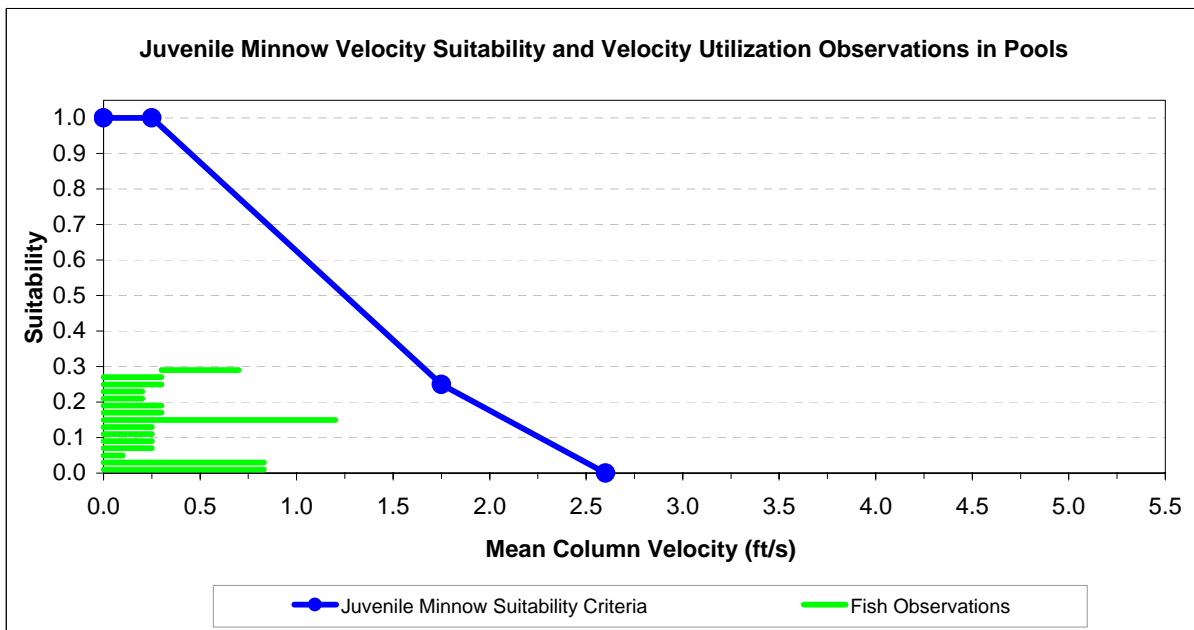
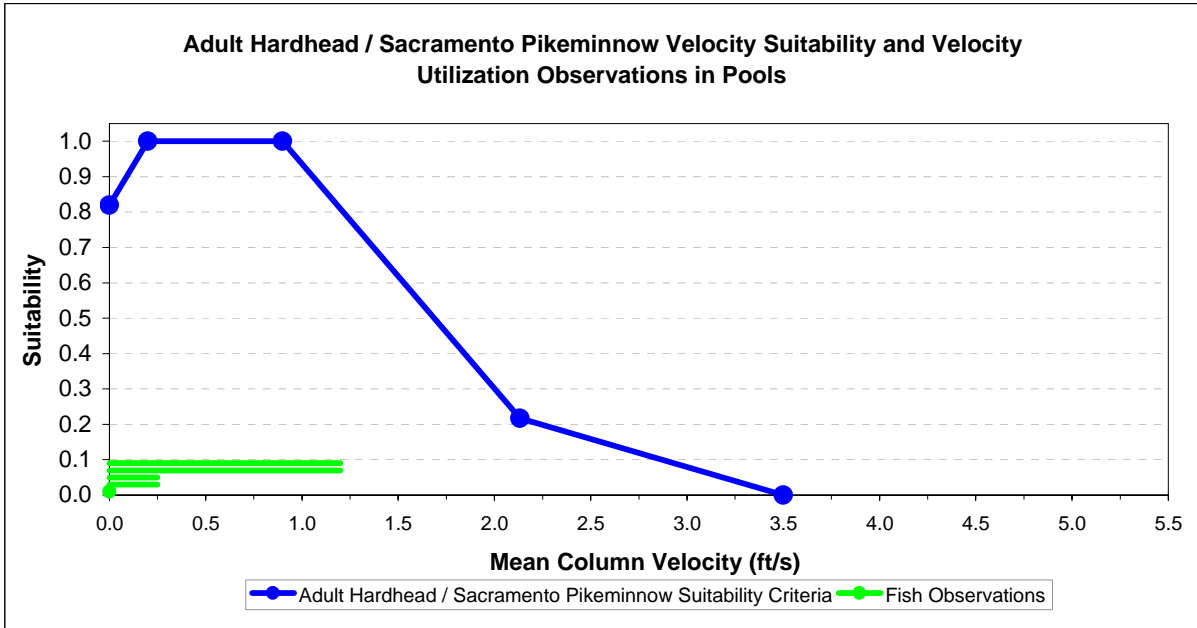
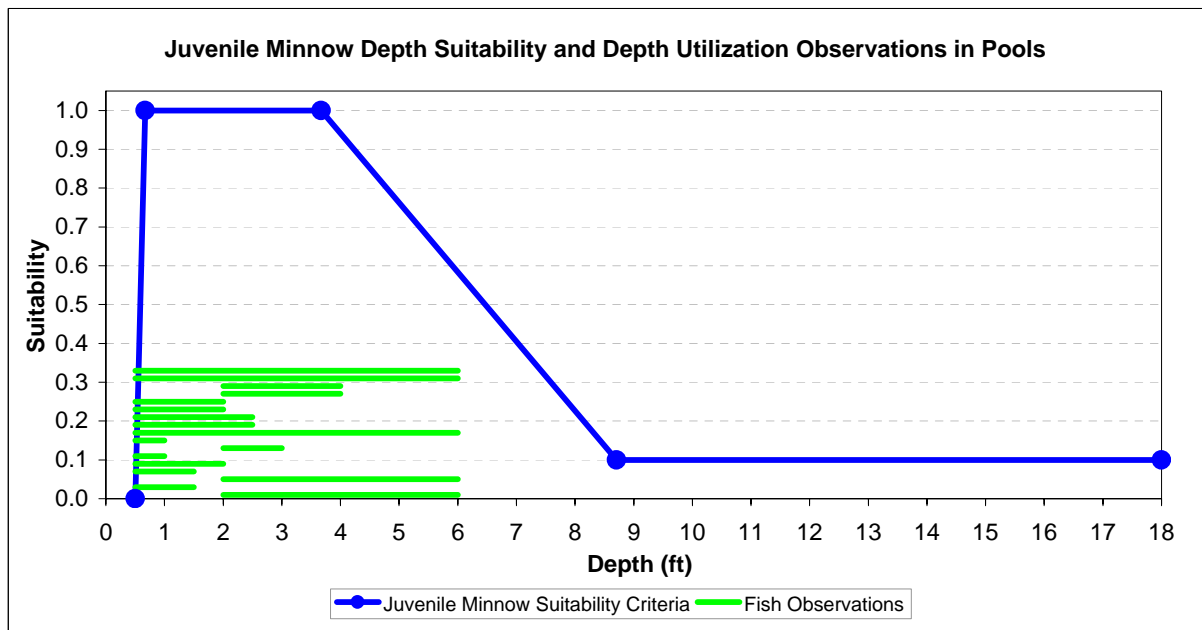
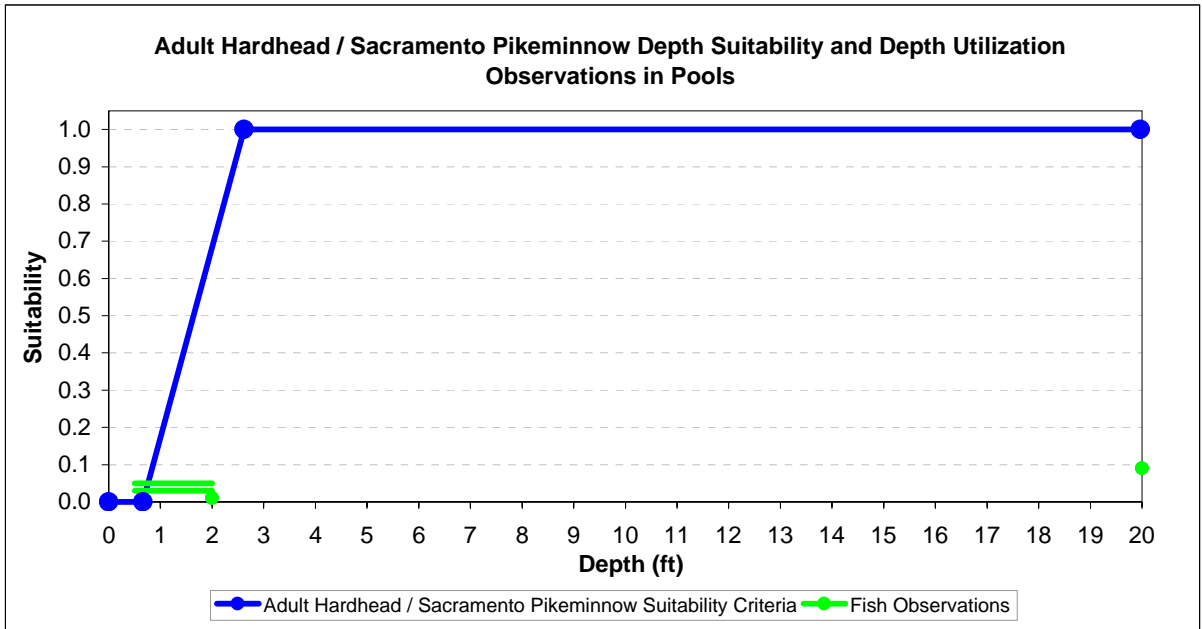


Figure E-4. Range of Depths Minnows Were Observed Utilizing in Pools During Snorkeling Observations Compared to Hardhead Habitat Suitability Criteria.



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**Empirical Stranding Study**

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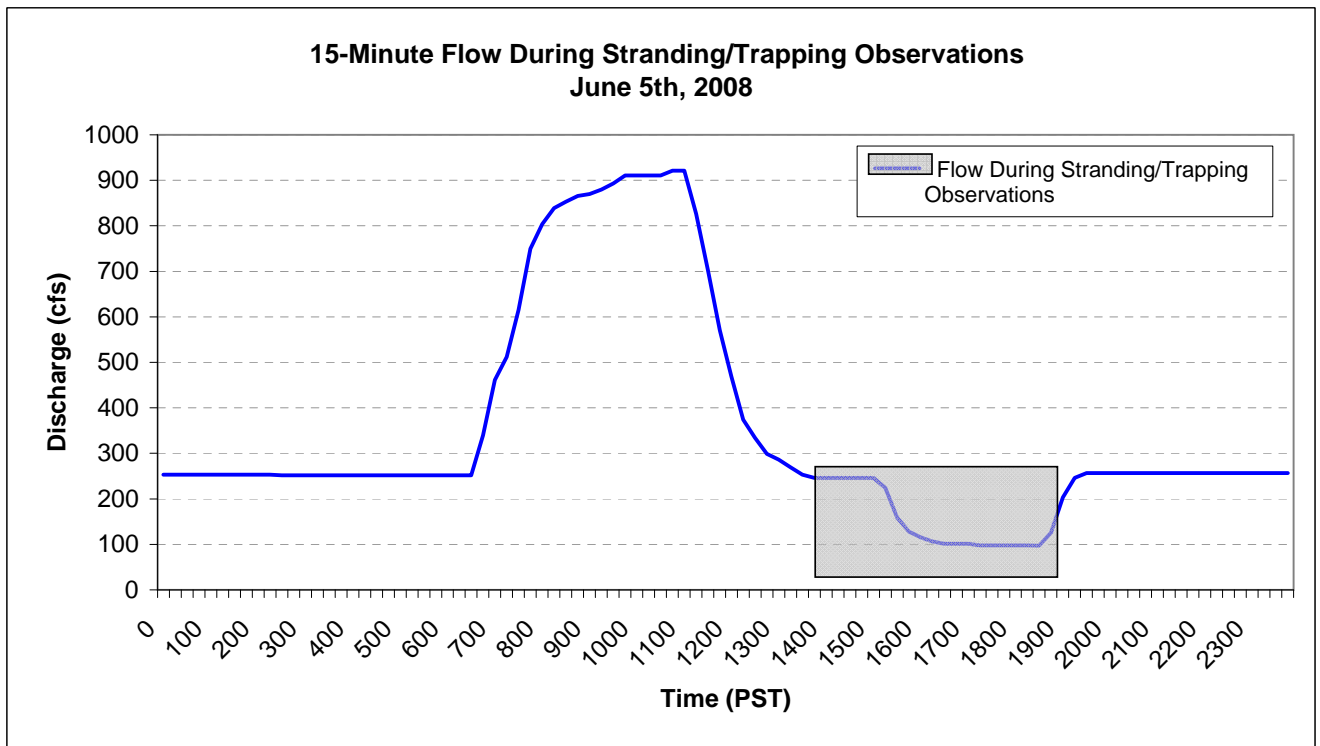
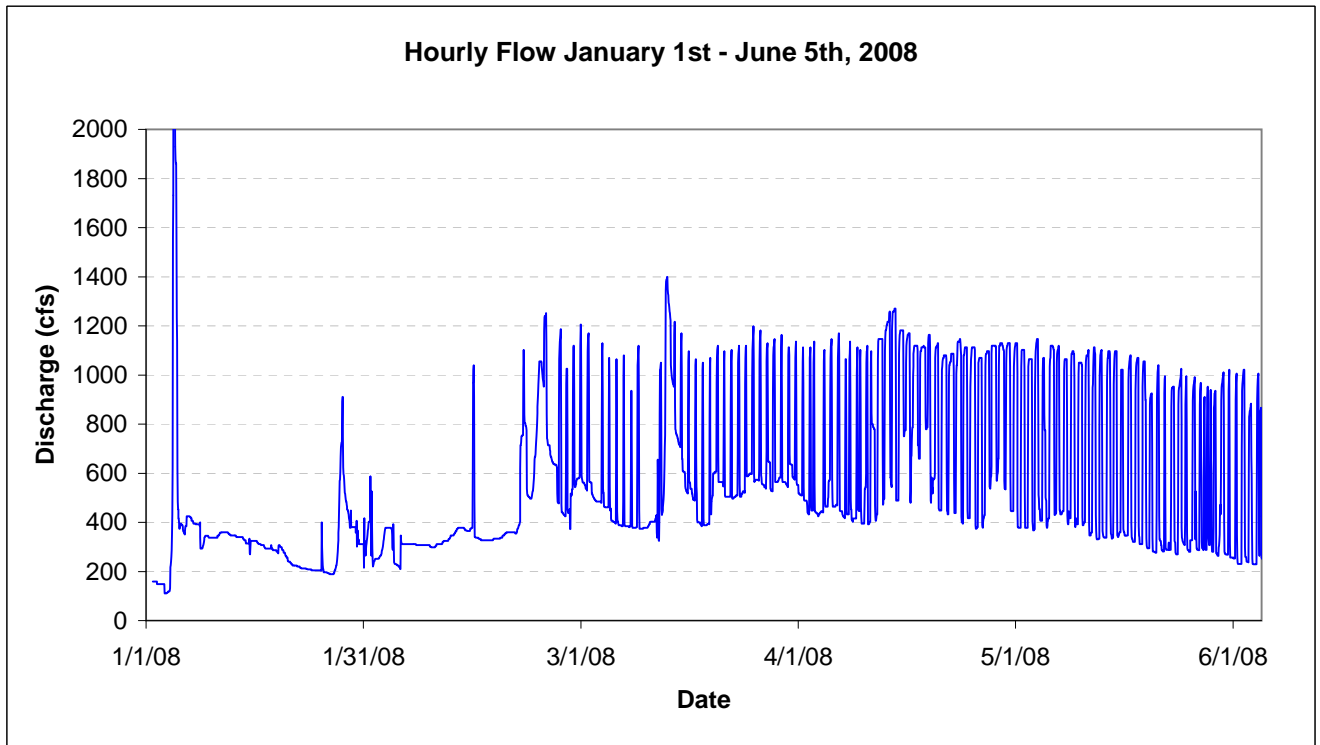
**TABLES**

Table F-1. Fish Stranding and Trapping / Isolation Observed in the Middle Fork American River Peaking Reach.

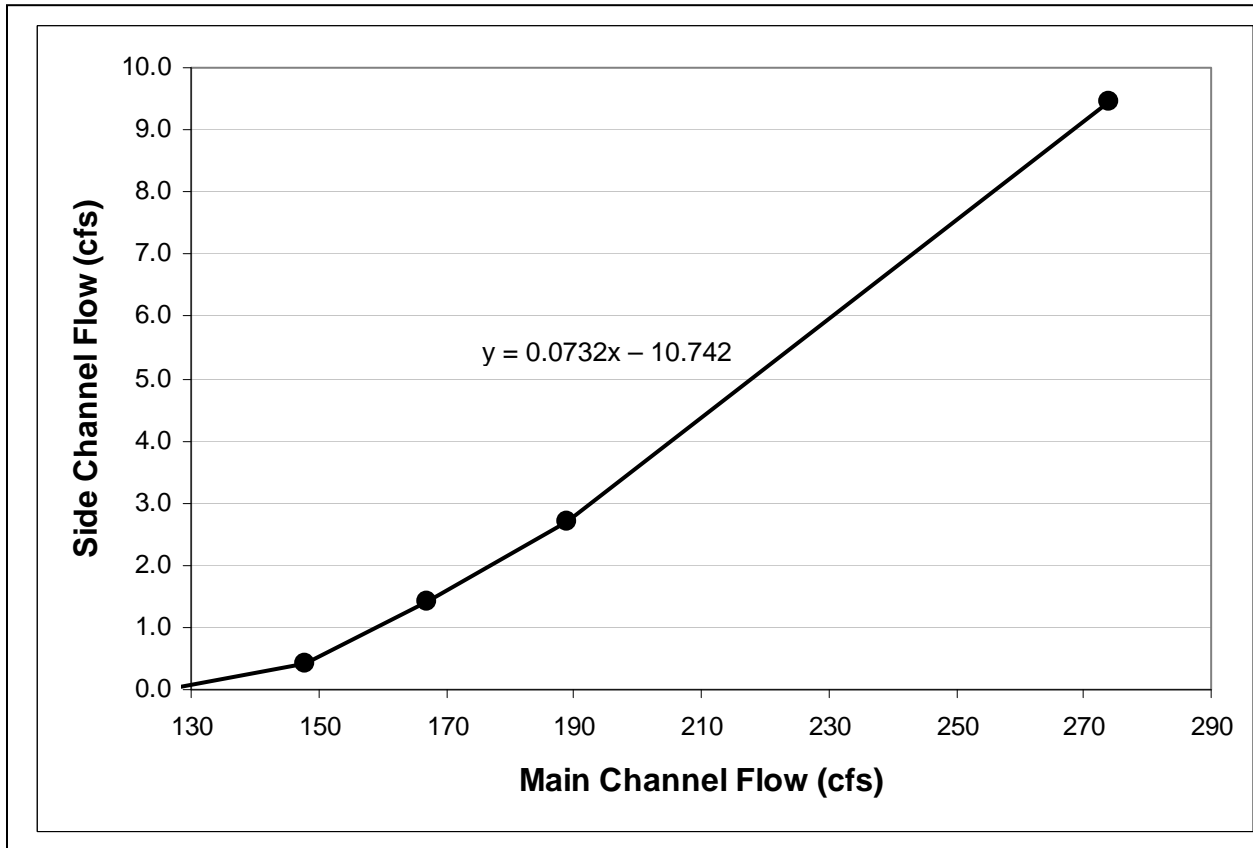
Gray Eagle Bar - American Bar (RM 22.3 - 22.8, 23.1 - 23.8)							
Date: June 5th, 2008 Time: 14:00 - 17:00 Flow: 98 - 246 cfs Total Length: 1.2 miles							
Potential Stranding/Trapping Areas	Area (sq. ft.)	Number of Fish Observed			Species Observed	Notes	Photograph Number
		Stranding	Temporary Trapping	Permanent Trapping			
A	44685	0	0	0		Seven small stranding pools.	AB-A
B	43076	0	0	0		Large, broad flat area.	AB-B1, AB-B2
C	5942	0	~250	0	Mixed hardhead, Sacramento pikeminnow, California roach, sculpin	14" deep dredge hole on the margin of the river, all fish fry or young-of-the-year. All fish alive.	AB-C
D	22675	0	35	0	10 Sculpin, 25 mixed minnow / trout fry	Isolated pools with some flow. All fish alive, swimming between pools.	AB-D1, AB-D2
E	21632	0	3-5	0	Trout	Four small isolated pools with some flow. Trout fry observed swimming between pools.	AB-E
Fords Bar (RM 13.6 - 14.5)							
Date: June 5th, 2008 Time: 17:30 - 20:00 Flow: 98 - 246 cfs Total Length: 0.9 miles							
Potential Stranding/Trapping Areas	Area (sq. ft.)	Number of Fish Observed			Species Observed	Notes	Photograph Number
		Stranding	Temporary Trapping	Permanent Trapping			
A	4060	1	0	0	Sculpin	One stranded sculpin observed (dead).	FB-A1, FB-A2
B	1569	0	0	0			FB-B
C	2709	0	0	0			FB-C
D	4485	0	0	0		Small stranded pool in bedrock, no fish observed.	FB-D1, FB-D2
E	4122	0	0	0			FB-E
F	3091	0	0	0			FB-F
G	6117	0	0	0			FB-G
H	5412	0	0	0			FB-H
I	1779	0	0	0			FB-I
J	4706	0	0	0			FB-J
K	1841	0	0	0			FB-K
L	3187	0	0	0			FB-L
M	1942	0	0	0			FB-M
N	8173	0	0	0			FB-N
O	5483	0	0	0			FB-O
P	6500	0	0	0			FB-P
Q	1782	0	0	0			FB-Q
R	2748	0	0	0			FB-R

**FIGURES**

Figure F-1. Hydrograph of the Middle Fork American River Peaking Reach from January 1st, 2008 to June 5th, 2008 (top) and during June 5th, 2008 Stranding Observations (bottom).



**Figure F-2. Relationship between Middle Fork American River Mean Channel Flow and Side Channel Flow at Gray Eagle Bar.**



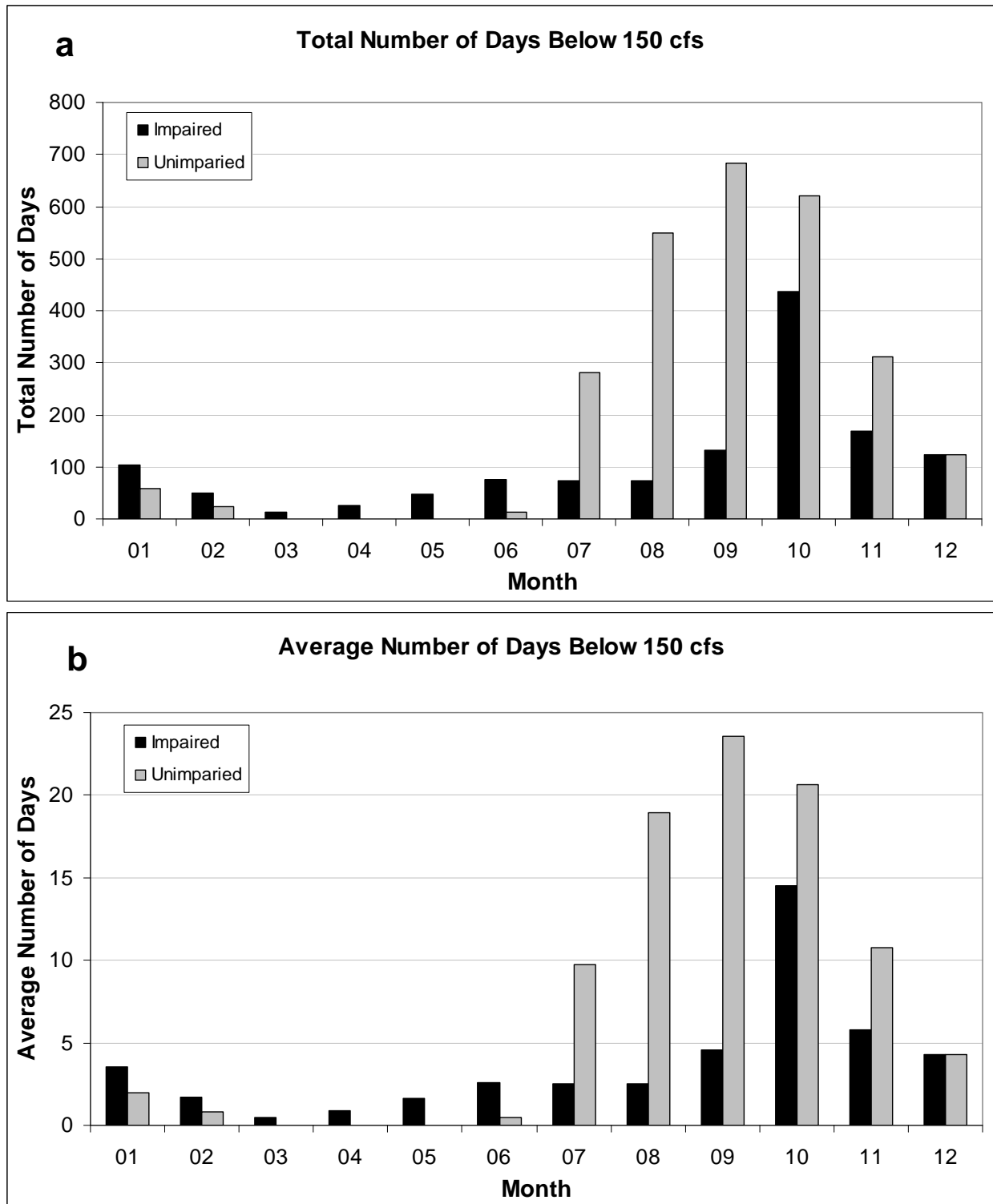
Measurement Date	Main Channel Flow <sup>1</sup> (cfs)	Side Channel Flow (cfs)
11/13/2008	274	9.5
11/13/2008	189	2.7
11/14/2008	167	1.4
11/17/2008	148	0.4
11/21/2008 <sup>2</sup>	126	0 <sup>3</sup>

<sup>1</sup> Flows within the Middle Fork American River main channel were measured at the Middle Fork American River Nr. Oxbow PH gage (OXB).

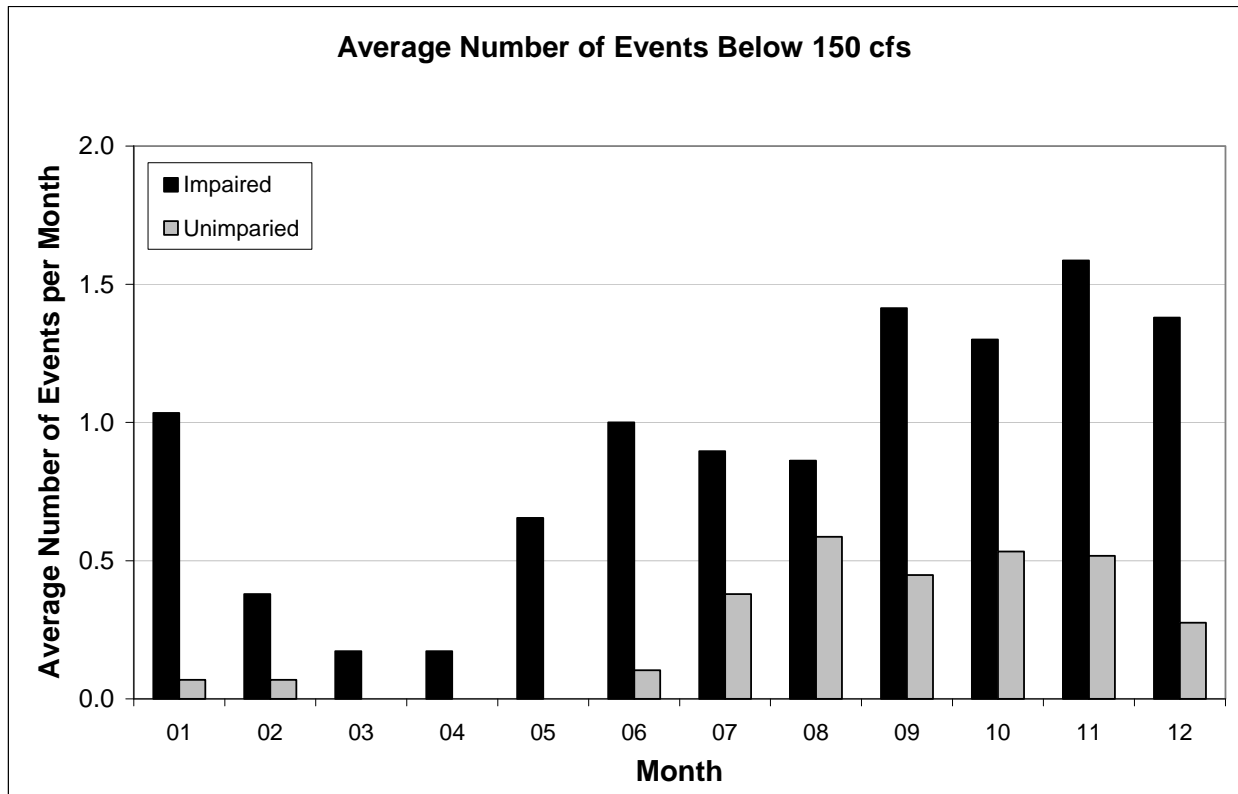
<sup>2</sup> At the lowest flow observed, discharge in the side channel was not measured. Field observation suggested flow into the side channel was essentially zero cfs.

<sup>3</sup>Subsurface flow likely but not measured during site visits.

**Figure F-3. Comparison of the Total (a) and Average (b) Number of Days by Month (1975 – 2003) that Flow within the Middle Fork American River was Less Than 150 cfs for Impaired and Unimpaired Flows.**



**Figure F-4. Average Number of Events<sup>1</sup> by Month (1975 – 2003) that Flow within the Middle Fork American River was Less Than 150 cfs for Impaired and Unimpaired Flows.**



<sup>1</sup> Multiple continuous days equals one event.

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**Stranding Study Area Photographs**

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**Potential Stranding/Trapping Areas Surveyed at Gray Eagle Bar – American Bar.**

AB-A



AB-B1



AB-B2



**Potential Stranding/Trapping Areas Surveyed at Gray Eagle Bar – American Bar.**

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AB-C



AB-D1



AB-D2



AB-E



**Potential Stranding/Trapping Areas Surveyed at Fords Bar.**

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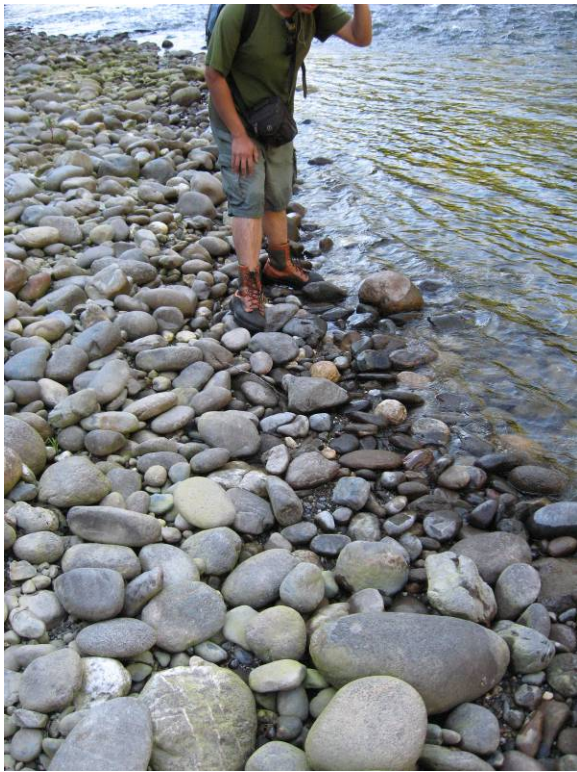
FB-A1



FB-A2



FB-B



FB-C



**Potential Stranding/Trapping Areas Surveyed at Fords Bar.**

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FB-D1



FB-D2



FB-E



FB-F



**Potential Stranding/Trapping Areas Surveyed at Fords Bar.**

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FB-G



FB-H



FB-I



FB-J



**Potential Stranding/Trapping Areas Surveyed at Fords Bar.**

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FB-K



FB-L



FB-M



FB-N



**Potential Stranding/Trapping Areas Surveyed at Fords Bar.**

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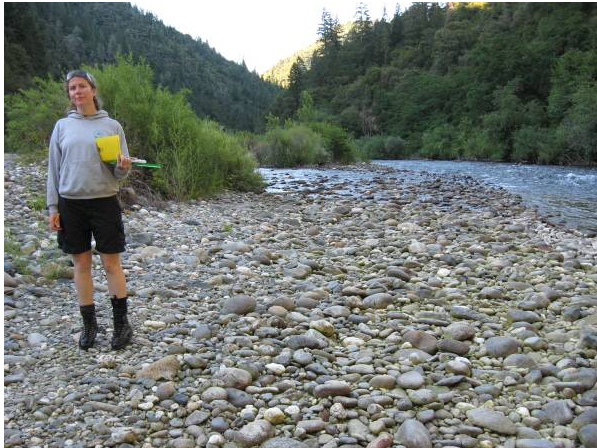
FB-O



FB-P



FB-Q



FB-R



**ATTACHMENT B**  
**Gray Eagle Bar Side Channel Observations**

Below are photographs of habitat conditions in the side channel at 167 cfs and 148 cfs (11/17/08 and 11/14/08, respectively) in the Middle Fork American River main channel.

**Flow into the Top of the Side Channel**

**Main Channel Flow: 167 cfs  
Side Channel Flow: 1.4 cfs**



**Main Channel Flow: 148 cfs  
Side Channel Flow: 0.4 cfs**



At a discharge of 148 cfs, a little flow (0.4 cfs) flowed within the side channel; although the large riffle in the mid-section of the bar and the riffle at the downstream end of the bar were dewatered creating disconnected pool habitat.

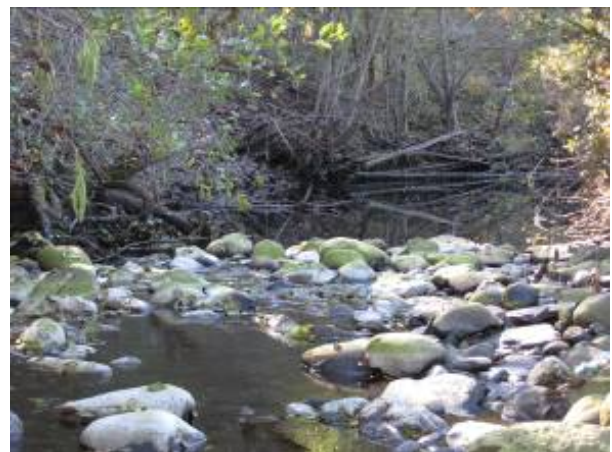
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**Looking Downstream at the Head of the First Major Pool in the Side Channel**

**167 cfs**



**148 cfs**



**Gray Eagle Bar Side Channel Observations (continued)**

**Long Riffle Habitat in the Mid-section of the Side Channel**

167 cfs



148 cfs



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**Looking Downstream at the Downstream Pool in the Side Channel  
Disconnected from Main Channel**

167 cfs

No photo

148 cfs



**Gray Eagle Bar Side Channel Observations (continued)**

**Hydraulic Control in Main Channel and Side Channel at 167 cfs**

**Main Channel**



**Side Channel**



**APPENDIX G**  
**Evaluation of Sediment Transport Conditions**

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Figure G-5. Flow for Twenty-five Percent Gravel Motion Versus the Impaired 1.5 Year (Top), 2.0 Year<sup>1</sup> (Middle), and 5.0 Year (Bottom) Recurrence Interval Flow at All MFP Sites.  
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### **Shear Stress Calculation**

Calculation of the stream's bed shear stress ( $\tau_0$ ), or tangential force per unit bed area, is necessary to understand flow intensity and its ability to mobilize and transport sediment particles resting on the bed. Bedload transport rates (e.g., gravel transport) are steep and non-linear, which means relatively small changes in shear stress can create large changes in sediment transport. Therefore, obtaining accurate shear stress estimates is critical in calculating sediment transport.

For steady, uniform flow the momentum equation states a balance must exist between shear forces (resisting forces) and gravity component (driving forces)

$$\tau_0 P_w \Delta s = \rho g A \Delta s S$$

or

$$\tau_0 = \rho g R S$$

where  $\tau_0$  is bottom shear stress,  $P_w$  is wetted perimeter,  $\Delta s$  is length of control volume,  $\rho$  is fluid density,  $g$  is gravity acceleration,  $A$  is cross-section area,  $S$  is the bed slope, and  $R$  is the hydraulic radius.

To calculate bed shear stress for steady, gradually varied flow conditions common to most streams, the friction slope  $S_f$  is often substituted for the bed slope  $S$ . And for relatively wide channels where the hydraulic radius and mean flow depth are approximately similar, the "depth\*slope" product is used to calculate the mean cross-sectionally averaged boundary shear stress

$$\tau_0 = \rho g H S_f$$

where  $H$  is mean flow depth.

The mean boundary shear stress, however, includes forces acting on debris jams, vegetation, channel banks, bar forms, and other features that add resistance and increase flow depth. Research has shown that the actual bed shear stress available for sediment transport (effective shear stress) is often a third to a half the mean boundary shear stress (Dietrich 1987). To gain a better estimate of only the portion of the shear stress that is acting on the sediment grains and available to transport sediment, a local estimate of shear stress directly above the area of the bed of interest is required. This local estimate is often referred to as a grain stress.

The following section describes the method used in this study to calculate local bed shear stress.

Time averaged fluid shear stress in a streamflow is defined as the rate of change of downstream momentum per unit cross-sectional area

$$\tau = -\rho \overline{u'v'}$$

where  $\tau$  is turbulent shear stress,  $\rho$  is fluid density,  $u'$  is downstream velocity, and  $v'$  is vertical velocity.

Determining the vertical variation in flow velocity in turbulent flow requires knowledge of the mixing length  $l$ , or the vertical distance over which a fluid parcel's momentum changes. By equating the mixing length to

$$u' = -l \left( \frac{d\bar{u}}{dy} \right) \quad \text{and} \quad v' = l \left( \frac{d\bar{u}}{dy} \right)$$

then turbulent shear stress is

$$\tau = -\rho \overline{u'v'} = \rho l^2 \left( \frac{d\bar{u}}{dy} \right)^2$$

By assuming that: (1) the fluid shear is approximately equal to the bed shear near the streambed; and (2) mixing length increases linearly with distance from the bed, the law of the wall equation for determining the velocity gradient near the streambed (i.e., "wall") is calculated from

$$\frac{\bar{u}}{u^*} = \frac{1}{\kappa} \ln \left( \frac{y}{y_0} \right)$$

where  $\kappa$  is Von Karman's constant (commonly set at 0.41),  $\bar{u}$  is time averaged velocity at flow depth  $y$  above the bed, and  $y_0$  is the flow depth where flow velocity equals zero. The shear velocity,  $u^*$ , is a measure of the velocity gradient near the bed, from which local bed shear stress can be calculated

$$\tau_0 = u^{*2} \rho$$

In reality, flow velocity is only zero where  $y = 0$ . Therefore, in order to solve the equation for hydraulically rough flows,  $y_0$  is related to the equivalent roughness height,  $k_s$ , by

$$y_0 = \frac{k_s}{30}$$

And  $k_s$  is based on the dominant coarse bed substrate, such as the  $D_{84}$  (the particle size in which 84% of the bed surface is finer).

Integration of the law of the wall equation above over the entire flow depth ( $h$ ) shows that the mean flow velocity occurs at a distance of  $0.368h$  from the bed. By inserting the  $0.368h$  and  $k_s$  values into the law of the wall equation above, the local shear velocity, and thus local shear stress related to grain-induced resistance can be determined from mean channel velocity ( $U$ ) using Keulegan's (1938) resistance law for rough flow:

$$\frac{U}{u^*} = \frac{1}{\kappa} \ln\left(\frac{h}{k_s}\right) + 6$$

This equation, or variations of it, is commonly used to calculate local shear stress values for use in incipient motion and sediment transport analysis.

The following equation (from Wilcock 1996) was used to calculate local grain stress in this study:

$$\frac{U}{u^*} = \frac{1}{\kappa} \ln\left(\frac{h}{ez_0}\right)$$

where  $z_0$  (the bed roughness length where flow velocity ( $u$ ) is 0) is calculated from

$$z_0 = \frac{3D_{84}}{30}$$

### **Initiation of Motion Calculation**

Whether or not a particle on the stream bed will be entrained by the flow or remain in place depends on: (1) randomness (grain placement and turbulence); and (2) balance of driving fluid drag ( $F_D$ ) and resisting gravity forces ( $F_G$ )

$$F_D \propto \tau_0 D^2, \text{ and } F_G \propto (\rho_s - \rho)gD^3$$

and

$$\frac{F_D}{F_G} \propto \frac{\tau_0}{(\rho_s - \rho)gD} = \Theta = \tau^*$$

where  $D$  is grain diameter and  $\rho_s$  is sediment density. The dimensionless bed shear stress ( $\Theta$ , commonly called the Shields number, or  $\tau^*$ ) is a measure of sediment mobility. If  $\tau^*$  is greater than the threshold required for sediment motion ( $\tau_c^*$ , critical dimensionless bed shear stress), then sediment motion is predicted to occur.

Much research continues in the field of sediment movement initiation and the selection of appropriate  $\tau_c^*$ . Figure G-1 shows initiation of motion curves from which  $\tau_c^*$  is

determined from the particle Reynolds number ( $R_{ep}$ ). If the  $\tau^*_c$  value plots above the curve, then sediment motion is predicted to occur; whereas if the value is under the curve, then no motion is predicted to occur. Both curves show that as particle size increases from coarse sand to gravel, the increased resistance to movement from the weight of the particle exceeds the additional drag exerted on the particle, and thus the critical dimensionless shear stress required for movement increases. The curves flatten out as particle size approaches coarse gravel (32-64 mm) and coarser particles. Several researchers have shown the original Shields curve (in blue) values for initiation of motion are too high, and thus predict too much shear stress is required for sediment movement. Therefore, Figure G-1 shows a modified curve (in red) in which the initiation of motion curve flattens out around 0.045 instead of 0.06.

The same two original and modified Shields curves are plotted in dimensional units in Figure G-2. From this plot, the amount of shear stress (Pascal units) needed to initiate motion of a given particle size (mm units) can be determined.

### **Initiation of Motion for Sediment Mixtures**

The initiation of motion curves in Figures G-1 and G-2 represent critical shear stress values needed to mobilize sediment of a uniform size resting on a nearly flat channel bed. The curves do not consider how the relative variability of grain sizes in a sediment mixture influence initiation of motion values for individual particle sizes ( $D_i$ ) within the mixture. For sediment mixtures of coarse and fine particles, the coarser particles (e.g., gravel) in the mixture can be relatively easier to mobilize than if all the sediment was the same size because the coarser grains protrude higher into the flow where flow velocities are greater, and they have relatively lower pivoting angles. By contrast, the smaller particles in the sediment mixture have higher pivot angles, and are shielded from the higher flow velocities by the larger particles. Therefore, the finer (e.g., sand) particles in a mixture can be relatively harder to mobilize than if all the sediment was the same size.

Additionally, research has shown the importance of the percentage of sand in a sediment mixture on the critical shear stress needed to mobilize both sand and gravel particles (Wilcock 1998; Wilcock and Crowe 2003). As the sand content increases on the bed to larger percentages, the gravel particles become less constrained by other gravel particles, and thus more of the particle is exposed to fluid drag since it is becoming larger than its surroundings. Once the gravel particle is entrained, it moves faster over the relatively smooth, mobile bed created by the sand than it would over other gravel particles, and it may move a greater distance because potential resting areas are filled with sand. At even higher percentages of sand, gravel particles can be mobilized through undercutting of the underlying sand, and once mobilized the gravel keeps going over the relatively smooth sand bed. Figure G-3<sup>1</sup> shows how variations in bed surface sand content influence the critical dimensionless shear stress needed to

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<sup>1</sup> The reference shear stress values presented in Wilcock and Crowe (2003) were converted to critical shear stress values by reducing the reference shear stress by 10%, per Wilcock 1998.

initiate motion of a sediment mixtures mean particle size ( $D_m$ ) (Wilcock and Crowe 2003). Figure G-4 is the same plot but with dimensional critical shear stress values for different  $D_m$  values. The plots show that as surface sand content increases from 0 to 20%, the shear stress needed to mobilize the  $D_m$  decreases. Sand content increases greater than 20% have little influence on the critical shear stress needed for sediment initiation.

The Wilcock and Crowe (2003) method for calculating the critical shear stress needed to initiate sediment movement for mixed-size sediment was used for this study. This method was chosen since it considers how relative particle size variation within the sediment mixture and sand content influence sediment mobility.

## References

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- Keulegan, G. H. 1938. Laws of turbulent flow in open channels. *Journal of Research of the National Bureau of Standards* 21(Paper RP1151): 707-741.
- Wilcock, P. R. 1996. Estimating local bed shear stress from velocity observations. *Water Resources Research* 32(11): 3361-3366.
- Wilcock, P. R. 1998. Two-fraction model of initial sediment motion in gravel-bed rivers. *Science* 280: 410-412.
- Wilcock, P. R. and J. C. Crowe. 2003. Surface-based transport model for mixed-size sediment. *Journal of Hydraulic Engineering* 129(2): 120-128.

**TABLES**

**Table G-1. Summary of Flows Required to Move Twenty-five Percent of Suitable Gravels<sup>1</sup> within the High Calibration Flow Wetted Channel.**

Site	Transect #	Unit Type	Impaired and Unimpaired Hydrology Recurrence Intervals (cfs)					25% Gravel Initiation Flow (cfs)		
			Hydrology Node	Q1.5 Unimpaired	Q1.5 Impaired	Q2.0 Impaired	Q5.0 Impaired	Measured Site Average Q25%	Measured Transect Q25%	Regression Q25% <sup>2</sup>
D8.3 <sup>3</sup>	T1 <sup>4</sup>	Pool	800.804	253	90	164	774	425	--	149
	T2 <sup>4</sup>	Pool		253	90	164	774		--	
	T3	Pool		253	90	164	774		425	
NFLC1.9	T10 <sup>5</sup>	Step Pool	817.819	50	19	32	225	11	--	29
	T15	Pool Tail		50	19	32	225		14.5	
	T18	Run		50	19	32	225		8	
SFLC2.3	T10	Pool Tail	820.822	77	29	44	396	36	27	40
	T13	Pool Tail		77	29	44	396		55	
	T19	Run		77	29	44	396		25	
LC9.0	T1 <sup>5</sup>	Run	825.828	202	181	216	1,144	100	--	197
	T4	Pool Tail		202	181	216	1,144		180	
	T10	Low Gradient Riffle		202	181	216	1,144		80	
	T16	Pool tail		202	181	216	1,144		40	
MF44.7	T2	Pool DS body	530.802	965	25	34	632	343	330	343 <sup>6</sup>
	T7	Pool DS body		965	25	34	632		475	
	T16	Pool body		965	25	34	632		225	
MF36.2	T10	Pool Tail	806.810	1324	466	771	1,758	763	530	702
	T11	Pool		1324	466	771	1,758		1500	
	T15	Run		1324	466	771	1,758		260	
MF26.2	2D-T6	Run	813.845	1938	369	584	2,970	568	675	532
	T4 <sup>7</sup>	High Gradient Riffle		1938	369	584	2,970		--	
	T14	Pool Tail		1938	369	584	2,970		460	
MF14.1	Full Site	Various	860.863	6483	3383	7,332	19,789	5372	5372	6674
MF4.8	Full Site	Various	866.868	6590	3476	7,467	20,241	8000	8000	6797
R25.7	T2	Pool Tail	832.835	2012	87	173	1,922	500	500	500 <sup>6</sup>
	T21	Pool Tail		2012	87	173	1,922		500	
R20.9	T1	Pool tail	834.836	2259	322	745	4,479	530	260	678
	T6	Run		2259	322	745	4,479		1100	
	T15	Pool Tail		2259	322	745	4,479		230	
R3.5	6	Pool Tail	842.815	3234	1168	2,415	11,341	2300	1100	2198
	10	Pool Tail		3234	1168	2,415	11,341		2100	
	15	Pool		3234	1168	2,415	11,341		3700	

<sup>1</sup>Suitable for rainbow trout spawning according to the MFP RBT spawning substrate HSC.

<sup>2</sup>Predicted flow to move 25% of gravels based on Q2.0 impaired regression (see Figure G-1).

<sup>3</sup>Used representative bulk gravel sample from Duncan 6.3 site to characterize gravel at this site.

<sup>4</sup>Gravels movement occurs at extremely high flows greater than the modeled flow range.

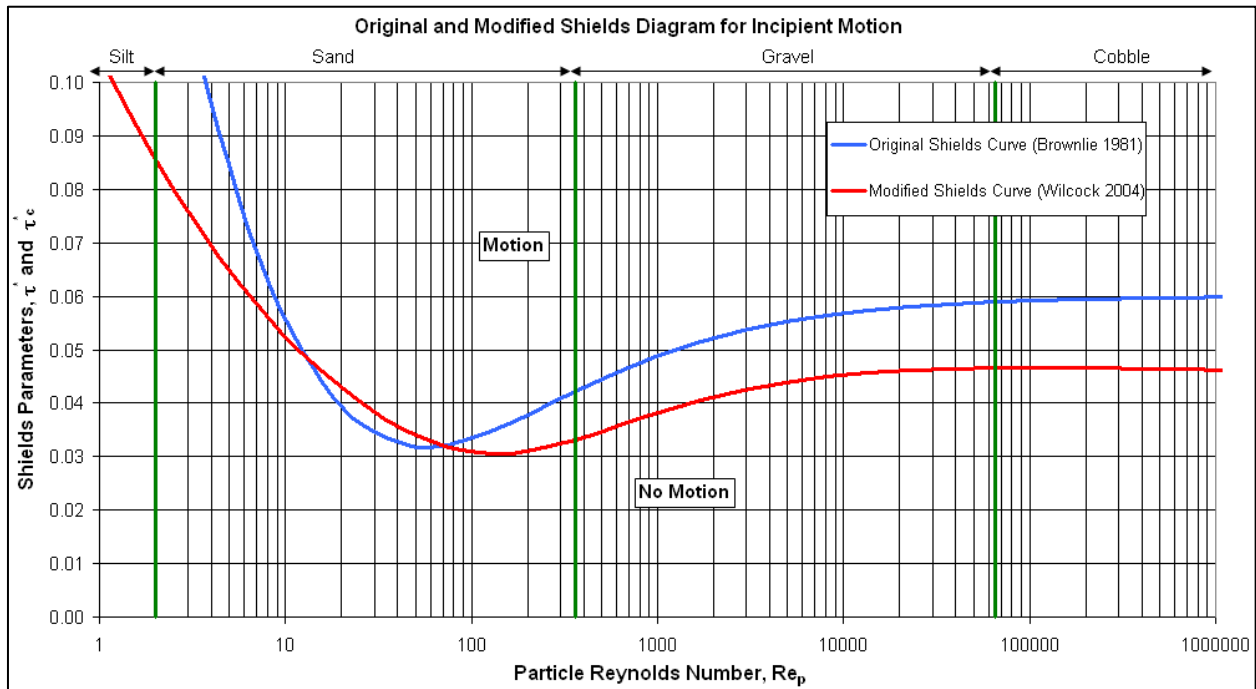
<sup>5</sup>Substrate sizes in bulk gravel sample at this location larger than suitable for RBT spawning.

<sup>6</sup>Measured data used at these sites, Q2.0 impaired regression not used. The Q2.0 impaired recurrence interval flows at this site are relatively low. Gravel movement at these sites is most likely initiated by lower frequency (Q5.0) large spill events.

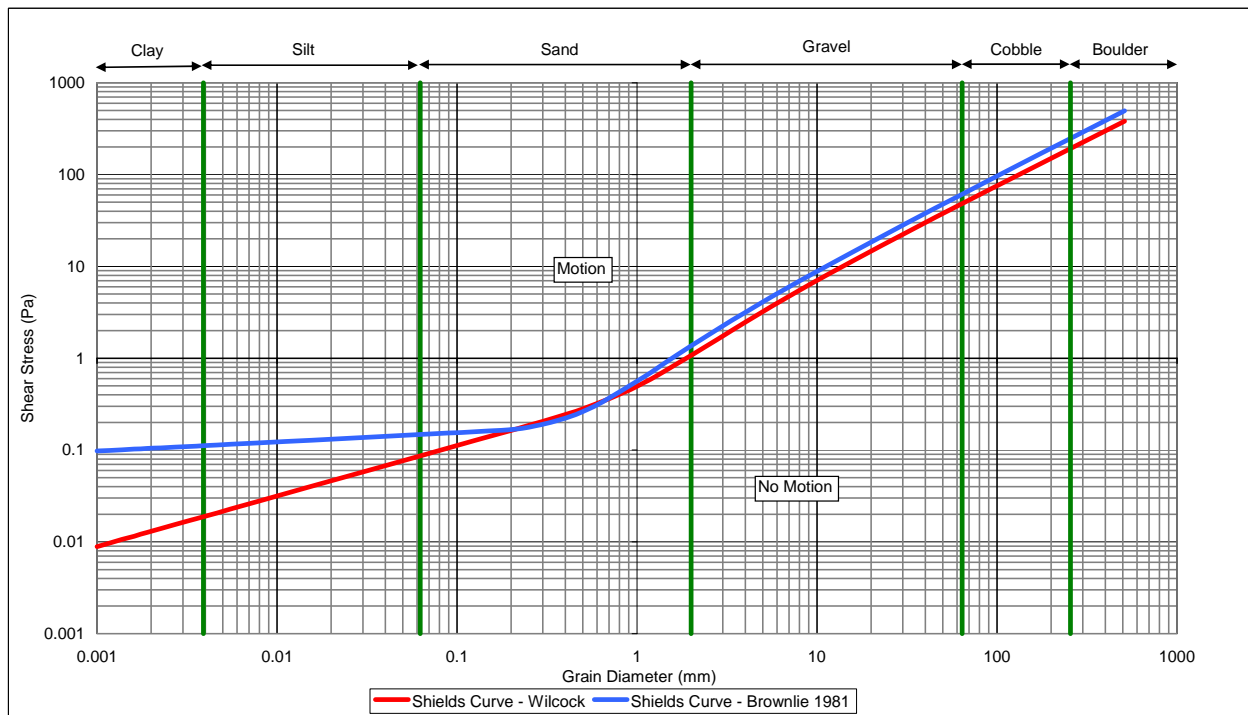
<sup>7</sup>Gravels present at this site were outside of target high calibration wetted channel for this transect.

**FIGURES**

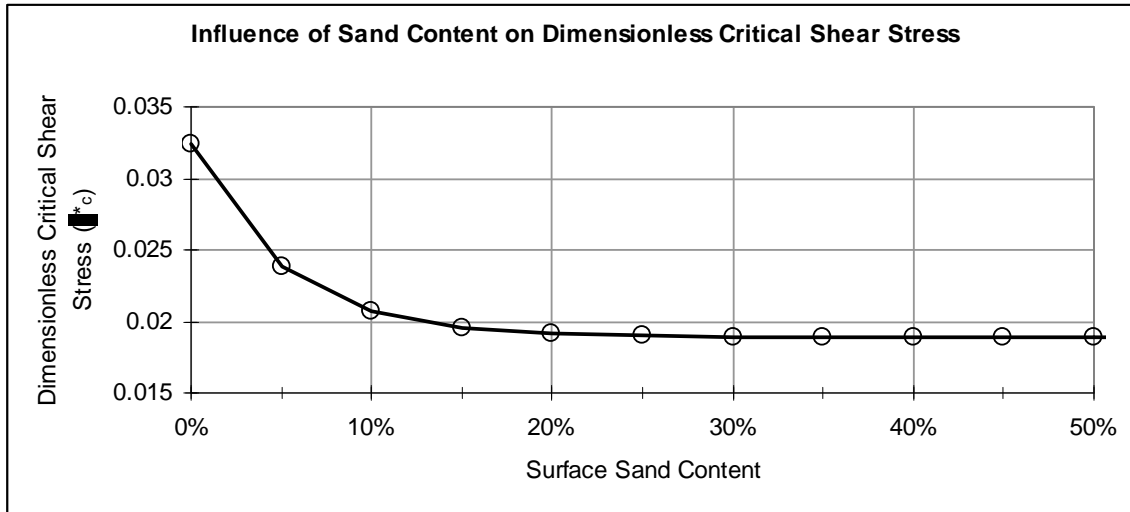
**Figure G-1. Dimensionless initiation of motion curves.**



**Figure G-2. Dimensional initiation of motion curves.**



**Figure G-3. Influence of bed surface sand content on the dimensionless critical shear stress value of the bed surface sediment mixture mean particle size.**



**Figure G-4. Influence of bed surface sand content on the critical shear stress value of selected bed surface sediment mixtures mean particle sizes.**

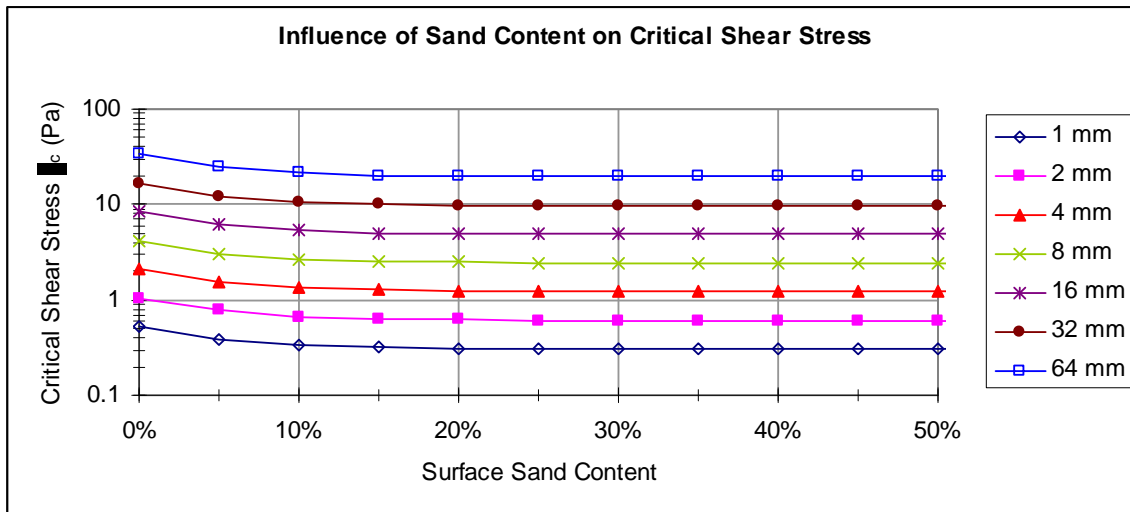
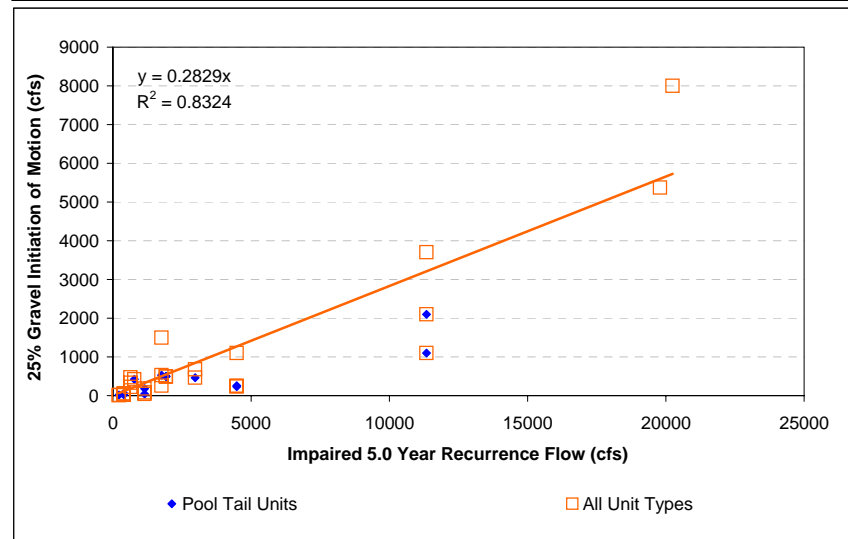
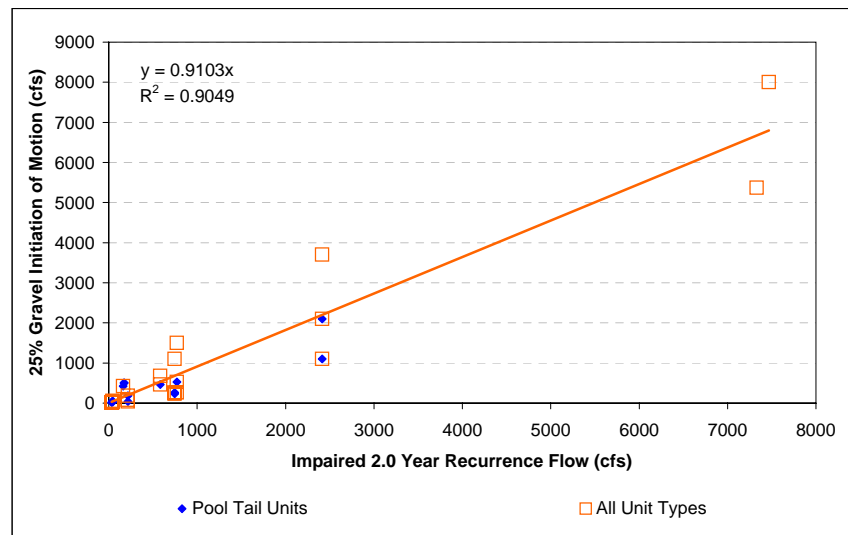
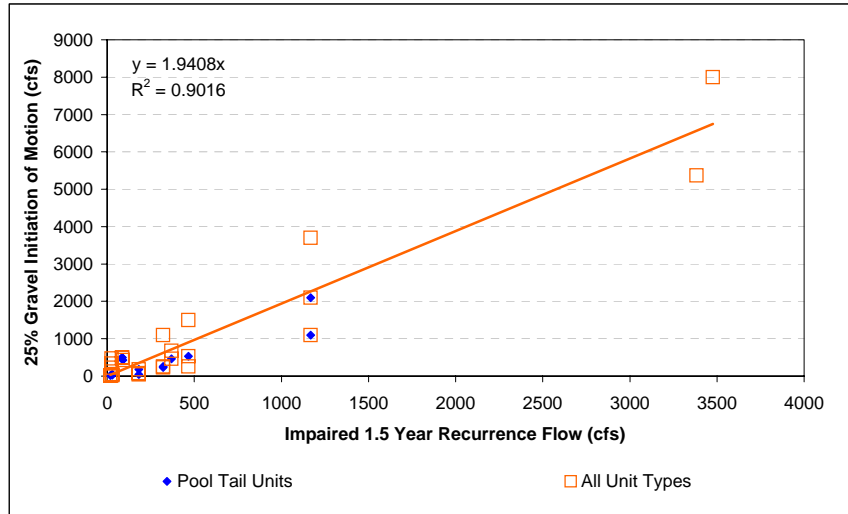
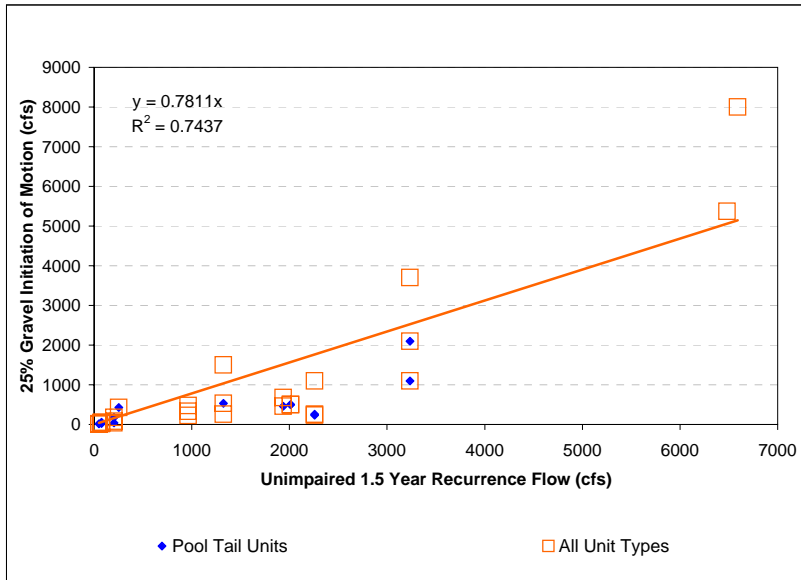


Figure G-5. Flow for Twenty-five Percent Gravel Motion Versus the Impaired 1.5 Year (Top), 2.0 Year<sup>1</sup> (Middle), and 5.0 Year (Bottom) Recurrence Interval Flow at All MFP Sites.



<sup>1</sup>MF44.7 and R25.7 data are not included in the 2.0 Year Regression. See Table G-1.

Figure G-6. Flow for Twenty-five Percent Gravel Motion Versus the Unimpaired 1.5 Year Recurrence Interval Flow at All MFP Sites.



**APPENDIX H**  
**Algae Study**

**List of Tables**

- Table H-1. Presence/Absence of *Didymosphenia geminata*.  
Table H-2. Summary Results From Algae Abundance Surveys.  
Table H-3. Detailed Results From Algae Abundance Surveys.

**List of Attachments**

- Attachment A. Representative Algae Abundance Photographs at Instream Flow Study Sites.

**TABLES**

**Table H-1. Presence / Absence of *Didymosphenia geminata*.**

Instream Flow Study Reaches / Sites		Presence/Absence	Supplemental Lab Samples <sup>1</sup>	Comments <sup>2</sup>
Duncan Creek				
Duncan Creek below Diversion	D6.3	Present	Present	Dominant, microscope photo taken
North Fork Long Canyon Creek				
North Fork Long Canyon Creek below Diversion	NFLC1.9	Absent	NA	
South Fork Long Canyon Creek				
South Fork Long Canyon Creek above Diversion	SFLC4.2	Present	NA	Rare
South Fork Long Canyon Creek below Diversion	SFLC2.3	Absent	NA	
Long Canyon Creek				
Long Canyon Creek below North and South Fork Long Canyon Creek	LC9.0	Present	NA	Rare
Middle Fork American River Upstream of Middle Fork Interbay				
Middle Fork American River below French Meadows Reservoir	MF44.7	Present	Present	Dominant, microscope photo taken
Middle Fork American River Immediately above Middle Fork Interbay	MF36.2	Present	NA	Rare
Middle Fork American River from Middle Fork Interbay to Ralston Afterbay				
Middle Fork American River between Middle Fork Interbay and Ralston Afterbay	MF26.2	Present	NA	Dominant
Middle Fork American River Downstream of Ralston Afterbay				
Middle Fork American River below Ralston Afterbay at Horseshoe Bar	MF23.5	Present	NA	Dominant
Middle Fork American River below Ralston Afterbay	MF14.1	Present	Present	Abundant
Middle Fork American River above North Fork American River confluence	MF4.8	Present	Present	Dominant
Rubicon River				
Rubicon River below Hell Hole Reservoir	R25.7	Present	Present	Abundant
Rubicon River Near Ellicott Bridge	R20.9	Present	Absent; masses of <i>Cymbella</i> sp. present	Abundant
Rubicon River Near Ralston Afterbay	R3.5	Absent	NA	
Other Tributaries				
North Fork American River	NF31.3	Absent	NA	

<sup>1</sup>At some sites additional algae samples were also collected and sent to Sarah Spaulding's Lab for identification.

<sup>2</sup>Rare = only one cell/fragment in scan, Abundant = >25 cells per field-of-view, Dominant= too numerous to count

Table H-2. Summary Results From Algae Abundance Surveys.

Instream Flow Study Reaches / Sites	Site ID	Algae Coverage			Substrate Type	Percent of Substrate Available for Algae Attachment <sup>3</sup>
		Macro <sup>1</sup>	Micro <sup>2</sup>	None		
<b>Duncan Creek</b>						
Duncan Creek below Diversion	D6.3	68.7%	12.9%	18.4%	boulder/cobble/gravel	90.6%
<b>North Fork Long Canyon Creek</b>						
North Fork Long Canyon Creek below Diversion	NFLC1.9	5.0%	20.4%	74.6%	boulder/cobble/gravel/sand	76.1%
<b>South Fork Long Canyon Creek</b>						
South Fork Long Canyon Creek below Diversion	SFLC2.3	24.0%	14.5%	61.5%	boulder/cobble/gravel/sand	88.9%
<b>Long Canyon Creek</b>						
Long Canyon Creek below North and South Fork Long Canyon Creek	LC9.0	2.3%	68.3%	29.5%	boulder/cobble/gravel	83.9%
<b>Middle Fork American River Upstream of Middle Fork Interbay</b>						
Middle Fork American River below French Meadows Reservoir	MF44.7	51.2%	0.0%	48.8%	bedrock/boulder/gravel	100.0%
Middle Fork American River Immediately above Middle Fork Interbay	MF36.2	10.9%	6.8%	82.3%	boulder/cobble/gravel	100.0%
<b>Middle Fork American River from Middle Fork Interbay to Ralston Afterbay</b>						
Middle Fork American River between Middle Fork Interbay and Ralston Afterbay	MF26.2	21.3%	12.7%	66.0%	boulder/cobble/gravel	97.8%
<b>Middle Fork American River Downstream of Ralston Afterbay</b>						
Middle Fork American River below Ralston Afterbay (Horseshoe Bar)	MF23.5	79.6%	5.9%	14.5%	boulder/cobble	100.0%
Middle Fork American River below Ralston Afterbay	MF14.1	37.4%	5.9%	56.7%	cobble/gravel/sand	83.4%
Middle Fork American River above North Fork American River confluence	MF4.8	47.8%	12.7%	39.5%	boulder/cobble/gravel	97.8%
<b>Rubicon River</b>						
Rubicon River below Hell Hole Reservoir	R25.7	69.4%	7.3%	23.4%	boulder/cobble/sand	76.7%
Rubicon River Near Ellicott Bridge	R20.9	7.5%	3.2%	89.3%	boulder/cobble/gravel	100.0%
Rubicon River Near Ralston Afterbay	R3.5	16.1%	17.2%	66.7%	boulder/cobble	100.0%
<b>Other Tributaries</b>						
North Fork American River	NF31.3	31.5%	10.9%	57.6%	cobble/gravel	100.0%

<sup>1</sup>Macroalgae is visible without magnification, i.e. filamentous algae.<sup>2</sup>Microalgae, typically diatoms or blue-green algae, is only visible with magnification.<sup>3</sup>Substrates >0.8 inches in diameter (within the small gravel category in the MFP substrate code) are available for attachment (Barbour et al. 1999).

Table H-3. Detailed Results From Algae Abundance Surveys.

## Duncan Creek

D6.3				
Location on Transect	Algae Type <sup>1</sup>	Coverage <sup>2</sup>	Substrate	Percent of Substrate Available for Algae Attachment <sup>3</sup>
<b>Transect 1</b>				
River Left	macro	30	cobble	90
	micro	4		
River Center	macro	20	60 cobble/ 40 gravel	95
	micro	9		
River Right	macro	40	coarse gravel	90
	micro	6		
<b>Transect 2</b>				
River Left	macro	30	cobble	45
	micro	10		
River Center	macro	23	cobble	95
	micro	11		
River Right	macro	49	boulder	100
	micro	0		
<b>Transect 3</b>				
River Left	macro	49	60 cobble/ 40 gravel	100
	micro	0		
River Center	macro	13	boulder	100
	micro	17		
River Right	macro	49	cobble	100
	micro	0		

## North Fork Long Canyon Creek

NFLC 1.9				
Location on Transect	Algae Type <sup>1</sup>	Coverage <sup>2</sup>	Substrate	Percent of Substrate Available for Algae Attachment <sup>3</sup>
<b>Transect 1</b>				
River Left	macro	0	sand/gravel/cobble	40
	micro	0		
River Center	macro	0	sand/gravel/cobble	80
	micro	14		
River Right	macro	0	med cobble	95
	micro	0		
<b>Transect 2</b>				
River Left	macro	0	cobble/sand	50
	micro	7		
River Center	macro	0	cobble/gravel	85
	micro	7		
River Right	macro	0	sml boulder/lrg cobble	100
	micro	7		
<b>Transect 3</b>				
River Left	macro	8	cobble/sml gravel	95
	micro	7		
River Center	macro	6	cobble/boulder	90
	micro	41		
River Right	macro	8	gravel	50
	micro	7		

Table H-3. Detailed Results From Algae Abundance Surveys (continued).

South Fork Long Canyon Creek

<b>SFLC 2.3</b>				
Location on Transect	Algae Type <sup>1</sup>	Coverage <sup>2</sup>	Substrate	Percent of Substrate Available for Algae Attachment <sup>3</sup>
<b>Transect 1</b>				
River Left	macro	19	cobble/gravel mix	85
	micro	5		
River Center	macro	0	boulder	100
	micro	25		
River Right	macro	2	gravels range	70
	micro	15		
<b>Transect 2</b>				
River Left	macro	25	cobble/gravel mix	95
	micro	4		
River Center	macro	28	sml boulder	100
	micro	4		
River Right	macro	4	lrg cobble	100
	micro	0		
<b>Transect 3</b>				
River Left	macro	0	sml boulder	100
	micro	4		
River Center	macro	18	cobble/gravel/sand mi	75
	micro	3		
River Right	macro	10	cobble/gravel/sand mi	75
	micro	4		

Long Canyon Creek

<b>LC9.0</b>				
Location on Transect	Algae Type <sup>1</sup>	Coverage <sup>2</sup>	Substrate	Percent of Substrate Available for Algae Attachment <sup>3</sup>
<b>Transect 1</b>				
River Left	macro	0	cobble	50
	micro	0		
River Center	macro	0	sml boulder	100
	micro	49		
River Right	macro	0	cobble	80
	micro	0		
<b>Transect 2</b>				
River Left	macro	0	large gravel	50
	micro	21		
River Center	macro	0	boulder	100
	micro	49		
River Right	macro	10	large cobble	100
	micro	49		
<b>Transect 3</b>				
River Left	macro	0	large gravel	75
	micro	35		
River Center	macro	0	boulder	100
	micro	49		
River Right	macro	0	boulder	100
	micro	49		

Table H-3. Detailed Results From Algae Abundance Surveys (continued).

Middle Fork American River

<b>MF44.7</b>				
<b>Location on Transect</b>	<b>Algae Type<sup>1</sup></b>	<b>Coverage<sup>2</sup></b>	<b>Substrate</b>	<b>Percent of Substrate Available for Algae Attachment<sup>3</sup></b>
<b>Transect 1</b>				
River Left	macro	23	boulder	100
	micro	0		
River Center	macro	5	boulder	100
	micro	0		
River Right	macro	34	boulder	100
	micro	0		
<b>Transect 2</b>				
River Left	macro	45	lrg. gravel	100
	micro	0		
River Center	macro	15	gravel	100
	micro	0		
River Right	macro	28	gravel	100
	micro	0		
<b>Transect 3</b>				
River Left	macro	16	bedrock	100
	micro	0		
River Center	macro	36	bedrock	100
	micro	0		
River Right	macro	24	gravel	100
	micro	0		
<b>MF36.2</b>				
<b>Location on Transect</b>	<b>Algae Type<sup>1</sup></b>	<b>Coverage<sup>2</sup></b>	<b>Substrate</b>	<b>Percent of Substrate Available for Algae Attachment<sup>3</sup></b>
<b>Transect 1</b>				
River Left	macro	0	cobble	100
	micro	11		
River Center	macro	11	boulder/gravel	100
	micro	0		
River Right	macro	6	boulder/gravel	100
	micro	5		
<b>Transect 2</b>				
River Left	macro	10	UNK	100
	micro	0		
River Center	macro	0	boulder	100
	micro	3		
River Right	macro	8	boulder	100
	micro	6		
<b>Transect 3</b>				
River Left	macro	10	cobble	100
	micro	0		
River Center	macro	0	boulder	100
	micro	0		
River Right	macro	3	cobble	100
	micro	5		

Table H-3. Detailed Results From Algae Abundance Surveys (continued).

<b>MF26.2</b>				
<b>Location on Transect</b>	<b>Algae Type<sup>1</sup></b>	<b>Coverage<sup>2</sup></b>	<b>Substrate</b>	<b>Percent of Substrate Available for Algae Attachment<sup>3</sup></b>
<b>Transect 1</b>				
River Left	macro	0	gravel mix	90
	micro	5		
River Center	macro	18	boulder	100
	micro	0		
River Right	macro	0	boulder	100
	micro	0		
<b>Transect 2</b>				
River Left	macro	0	boulder	100
	micro	25		
River Center	macro	40	cobble	90
	micro	0		
River Right	macro	19	boulder	100
	micro	0		
<b>Transect 3</b>				
River Left	macro	0	boulder	100
	micro	26		
River Center	macro	11	cobble	100
	micro	0		
River Right	macro	6	boulder	100
	micro	0		
<b>MF23.5</b>				
<b>Location on Transect</b>	<b>Algae Type<sup>1</sup></b>	<b>Coverage<sup>2</sup></b>	<b>Substrate</b>	<b>Percent of Substrate Available for Algae Attachment<sup>3</sup></b>
<b>Transect 1</b>				
River Left	macro	40	cobble/boulder	100
	micro	6		
River Center	macro	21	cobble/boulder	100
	micro	20		
River Right	macro	45	cobble/boulder	100
	micro	0		
<b>Transect 2</b>				
River Left	macro	44	cobble/boulder	100
	micro	0		
River Center	macro	22	cobble/boulder	100
	micro	0		
River Right	macro	49		100
	micro	0		
<b>Transect 3</b>				
River Left	macro	49	cobble/boulder	100
	micro	0		
River Center	macro	49	cobble/boulder	100
	micro	0		
River Right	macro	32	cobble/boulder	100
	micro	0		

Table H-3. Detailed Results From Algae Abundance Surveys (continued).

<b>MF14.1</b>				
<b>Location on Transect</b>	<b>Algae Type<sup>1</sup></b>	<b>Coverage<sup>2</sup></b>	<b>Substrate</b>	<b>Percent of Substrate Available for Algae Attachment<sup>3</sup></b>
<b>Transect 1</b>				
River Left	macro	37	gravel	85
	micro	0		
River Center	macro	25	gravel	80
	micro	0		
River Right	macro	41	gravel	85
	micro	0		
<b>Transect 2</b>				
River Left	macro	0	gravel	85
	micro	21		
River Center	macro	3	gravel/sand	60
	micro	5		
River Right	macro	0	cobble/small gravel	76
	micro	0		
<b>Transect 3</b>				
River Left	macro	40	cobble	90
	micro	0		
River Right <sup>4</sup>	macro	10	cobble	100
	micro	0		
River Right	macro	9	cobble	90
	micro	0		
<b>MF4.8</b>				
<b>Location on Transect</b>	<b>Algae Type<sup>1</sup></b>	<b>Coverage<sup>2</sup></b>	<b>Substrate Type</b>	<b>Percent of Substrate Available for Algae Attachment<sup>3</sup></b>
<b>Transect 1</b>				
River Left	macro	39	cobble	100
	micro	0		
River Center	macro	0	boulder	100
	micro	49		
River Left <sup>4</sup>	macro	47	gravel/cobble	90
	micro	0		
<b>Transect 2</b>				
River Left	macro	19	cobble	100
	micro	0		
River Center	macro	32	cobble	100
	micro	7		
River Right	macro	49	cobble	100
	micro	0		
<b>Transect 3</b>				
River Left	macro	4	gravel/cobble	90
	micro	0		
River Center	macro	14	cobble	100
	micro	0		
River Right	macro	7	gravel/cobble	100
	micro	0		

Table H-3. Detailed Results From Algae Abundance Surveys (continued).

Rubicon River

<b>R25.7</b>				
<b>Location on Transect</b>	<b>Algae Type<sup>1</sup></b>	<b>Coverage<sup>2</sup></b>	<b>Substrate</b>	<b>Percent of Substrate Available for Algae Attachment<sup>3</sup></b>
<b>Transect 1</b>				
River Left	macro	18	boulder	100
	micro	5		
River Center	macro	45	boulder	100
	micro	0		
River Right	macro	40	boulder	100
	micro	10		
<b>Transect 2</b>				
River Left	macro	32	small cobble	30
	micro	0		
River Center	macro	14	small boulder	100
	micro	8		
River Right	macro	49	large cobble	100
	micro	0		
<b>Transect 3</b>				
River Left	macro	34	medium cobble	10
	micro	6		
River Center	macro	37	small cobble	80
	micro	3		
River Right	macro	37	bld, large cobble, sand	70
	micro	0		
<b>R20.9</b>				
<b>Location on Transect</b>	<b>Algae Type<sup>1</sup></b>	<b>Coverage<sup>2</sup></b>	<b>Substrate</b>	<b>Percent of Substrate Available for Algae Attachment<sup>3</sup></b>
<b>Transect 1</b>				
River Left	macro	2	bedrock/boulder	100
	micro	2		
River Center	macro	16	boulder	100
	micro	2		
River Right	macro	0	bedrock/cobble	100
	micro	4		
<b>Transect 2</b>				
River Left	macro	4	cobble/gravel	100
	micro	0		
River Center	macro	0	boulder/cobble	100
	micro	0		
River Right	macro	0	boulder/cobble	100
	micro	2		
<b>Transect 3</b>				
River Left	macro	11	boulder	100
	micro	0		
River Center	macro	0	cobble	100
	micro	4		
River Right	macro	0	cobble	100
	micro	0		

**Table H-3. Detailed Results From Algae Abundance Surveys (continued).**

<b>R3.5</b>				
<b>Location on Transect</b>	<b>Algae Type<sup>1</sup></b>	<b>Coverage<sup>2</sup></b>	<b>Substrate</b>	<b>Percent of Substrate Available for Algae Attachment<sup>3</sup></b>
<b>Transect 1</b>				
River Left	macro	0	cobble	100
	micro	22		
River Center	macro	11	boulder	100
	micro	0		
River Right	macro	5	cobble	100
	micro	0		
<b>Transect 2</b>				
River Left	macro	6	cobble	100
	micro	4		
River Center	macro	0	cobble	100
	micro	40		
River Right	macro	15	cobble	100
	micro	0		
<b>Transect 3</b>				
River Left	macro	4	cobble	100
	micro	0		
River Center	macro	23	boulder	100
	micro	4		
River Right	macro	7	cobble	100
	micro	6		

**North Fork American River**

<b>NF31.3</b>				
<b>Location on Transect</b>	<b>Algae Type<sup>1</sup></b>	<b>Coverage<sup>2</sup></b>	<b>Substrate</b>	<b>Percent of Substrate Available for Algae Attachment<sup>3</sup></b>
<b>Transect 1</b>				
River Left	macro	0	cobble	100
	micro	10		
River Center	macro	0	cobble	100
	micro	0		
River Right	macro	50	cobble	100
	micro	0		
<b>Transect 2</b>				
River Left	macro	16	cobble	100
	micro	8		
River Center	macro	0	cobble	100
	micro	12		
River Right	macro	12	cobble	100
	micro	15		
<b>Transect 3</b>				
River Left	macro	16	gravel/cobble mix	100
	micro	0		
River Center	macro	0	gravel/cobble mix	100
	micro	3		
River Right	macro	45	cobble	100
	micro	0		

<sup>1</sup>Macroalgae is visible without magnification, i.e. filamentous algae. Microalgae, typically diatoms or blue-green algae, is only visible with magnification.

<sup>2</sup>Coverage out of 49 possible delineated units from the field-based rapid periphyton survey protocol detailed in the Environmental Protection Agencies' Rapid Bioassessment Protocol For Use in Streams and Wadeable Rivers (Barbour et al. 1999).

<sup>3</sup>Substrates >0.8 inches in diameter (within the small gravel category in the MFP substrate code) are available for attachment (Barbour et al. 1999).

<sup>4</sup>Due to water velocity during time of survey one section could not be viewed. A duplicate measurement was taken on an accessible channel margin.

**ATTACHMENT A**

**Representative Algae Abundance Photographs at Instream Flow Study Sites**

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## Representative Algae Abundance Photographs at Instream Flow Study Sites

Duncan Creek D6.3



North Fork Long Canyon Creek NFLC1.9



## Representative Algae Abundance Photographs at Instream Flow Study Sites

### South Fork Long Canyon Creek SFLC2.3



## Representative Algae Abundance Photographs at Instream Flow Study Sites

Long Canyon Creek LC9.0



Middle Fork American River MF44.7

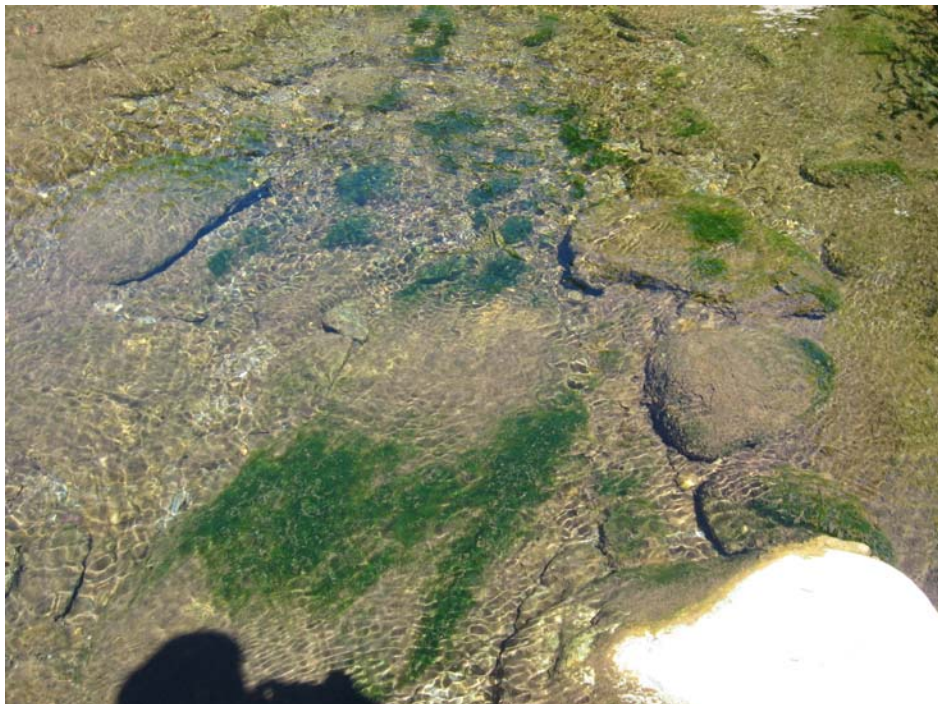


## Representative Algae Abundance Photographs at Instream Flow Study Sites

Middle Fork American River MF36.2



Middle Fork American River MF26.2



**Representative Algae Abundance Photographs at Instream Flow Study Sites**

Middle Fork American River MF23.5

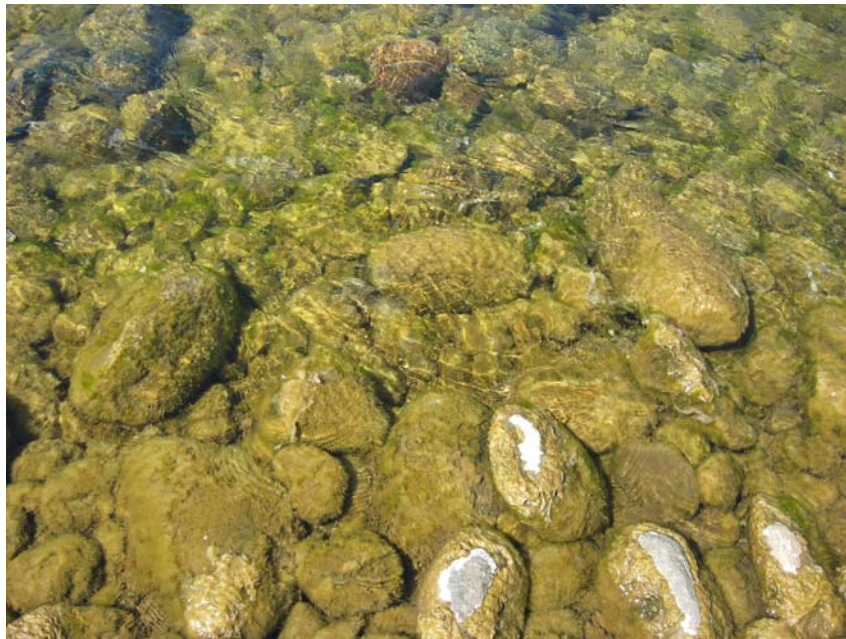


## Representative Algae Abundance Photographs at Instream Flow Study Sites

Middle Fork American River MF14.1



Middle Fork American River MF4.8



## Representative Algae Abundance Photographs at Instream Flow Study Sites

Rubicon River R25.7



Rubicon River R20.9



Rubicon River R3.5



**Representative Algae Abundance Photographs at Instream Flow Study Sites**

North Fork American River NF31.3



**APPENDIX I**

**1D Study Site Topography, Substrate, and Velocity Data**

(See Attached Electronic Media)

**TABLE OF CONTENTS**

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Topography, Substrate, and Velocity Data by Cross Section for Each 1D Study Site

<b><u>Study Site</u></b>	<b><u>File Name</u></b>
Duncan Creek Below Diversion.....	01_D6.3 Topo Sub Vel Data.xls
North Fork Long Canyon Creek Below Diversion.....	02_NFLC1.9 Topo Sub Vel Data.xls
South Fork Long Canyon Creek Below Diversion .....	03_SFLC2.3 Topo Sub Vel Data.xls
Long Canyon Creek Above Ramsey Crossing .....	04_LC9.0 Topo Sub Vel Data.xls
Middle Fork American River Below French Meadows..	05_MF44.7 Topo Sub Vel Data.xls
Middle Fork American River Above Interbay .....	06_MF36.2 Topo Sub Vel Data.xls
Middle Fork American River Above Ralston Afterbay..	07_MF26.2 Topo Sub Vel Data.xls
Rubicon River Above Parsley Bar (Helicopter Site) .....	08_R25.7 Topo Sub Vel Data.xls
Rubicon River Below Ellicott Bridge .....	09_R20.9 Topo Sub Vel Data.xls
Rubicon River at Confluence with Long Canyon Creek...	10_R3.5 Topo Sub Vel Data.xls

**APPENDIX J**

**1D Study Site Velocity Sensitivity Analysis and Hydraulic Calibration Results**

(See Attached Electronic Media)

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- Figure J-1. Duncan Creek - D6.3 Weighted Usable Area Results by Species/Lifestage from Velocity Modeling Sensitivity Analysis Comparing Original (O) and Revised (R) Modeled Velocities. Negative Velocities Removed from Revised Set.
- Figure J-2. Long Canyon Creek - LC9.0 Weighted Usable Area Results by Species/Lifestage from Velocity Modeling Sensitivity Analysis Comparing Original (O) and Revised (R) Modeled Velocities. Negative Velocities Removed from Revised Set.
- Figure J-3. Middle Fork of the American River - MF44.7 Weighted Usable Area Results by Species/Lifestage from Velocity Modeling Sensitivity Analysis Comparing Original (O) and Revised (R) Modeled Velocities. Negative Velocities Removed from Revised Set.
- Figure J-4. Rubicon River - R25.7 Weighted Usable Area Results by Species/Lifestage from Velocity Modeling Sensitivity Analysis Comparing Original (O) and Revised (R) Modeled Velocities. Negative Velocities Removed from Revised Set.
- Figure J-5. Rubicon River - R20.9 Weighted Usable Area Results by Species/Lifestage from Velocity Modeling Sensitivity Analysis Comparing Original (O) and Revised (R) Modeled Velocities. Negative Velocities Removed from Revised Set.
- Figure J-6. Rubicon River – R3.5 Weighted Usable Area Results by Species/Lifestage from Velocity Modeling Sensitivity Analysis Comparing Original (O) and Revised (R) Modeled Velocities. Negative Velocities Removed from Revised Set.

**List of Attachments**

Attachment A - 1D Hydraulics Calibration Results by Cross Section for Each 1D Study Site (AQ - 1 Instream Flow) and Special Purpose 1D Modeling Sites (AQ – 9 Geomorphology, AQ – 10 Riparian Resources and AQ – 12 Special-Status Amphibian and Aquatic Reptile):

**AQ – 1 Instream Flow Study Sites****File Name**

Duncan Creek Below Diversion.....01\_D6.3\_calibration\_report.xls  
 North Fork Long Canyon Creek Below Diversion ..... 02\_NFLC1.9\_calibration\_report.xls  
 South Fork Long Canyon Creek Below Diversion ..... 03\_SFCLC2.3\_calibration\_report.xls

AQ – 1 Instream Flow Study Sites (continued)

File Name

Long Canyon Creek Above Ramsey Crossing .....04\_LC9.0\_calibration\_report.xls  
Middle Fork American River Below French Meadows .. 05\_MF44.7\_calibration\_report.xls  
Middle Fork American River Above Interbay ..... 06\_MF36.2\_calibration\_report.xls  
Middle Fork American River Above Ralston Afterbay... 07\_MF26.2\_calibration\_report.xls  
Rubicon River Above Parsley Bar (Helicopter Site) .....08\_R25.7\_calibration\_report.xls  
Rubicon River Below Ellicott Bridge .....09\_R20.9\_calibration\_report.xls  
Rubicon River at Confluence with Long Canyon Creek..... 10\_R3.5\_calibration\_report.xls

*SPECIAL PURPOSE MODELING*

AQ – 9 Geomorphology Study Sites

Duncan Creek below Diversion.....11\_D8.3\_calibration\_report.xls

AQ – 10 Riparian Resources Study Sites

Duncan Creek Above Diversion.....12\_D9.0\_calibration\_report.xls  
South Fork Long Canyon Creek Above Diversion ..... 13\_SFLC4.2\_calibration\_report.xls  
North Fork of the Middle Fork (3 Transects)..... 14\_NFMF2.3\_calibration\_report.xls  
North Fork American River at Ponderosa Bridge.....15\_NF31.3\_calibration\_report.xls  
North Fork American River (Helicopter Site).....16\_NF53.7\_calibration\_report.xls

AQ – 12 Special-Status Amphibian and Aquatic Reptile Study Sites

North Fork of the Middle Fork (One Transect).....See 14 Above  
North Fork American River at Shirrtial Creek...17\_NF35.7\_Shirttail\_calibration\_report.xls  
Shirrtail Creek.....See 17 Above

**FIGURES**

Figure J-1. Duncan Creek - D6.3 Weighted Usable Area Results by Species/Lifestage from Velocity Modeling Sensitivity Analysis Comparing Original (O) and Revised (R) Modeled Velocities. Negative Velocities Removed from Revised Set.

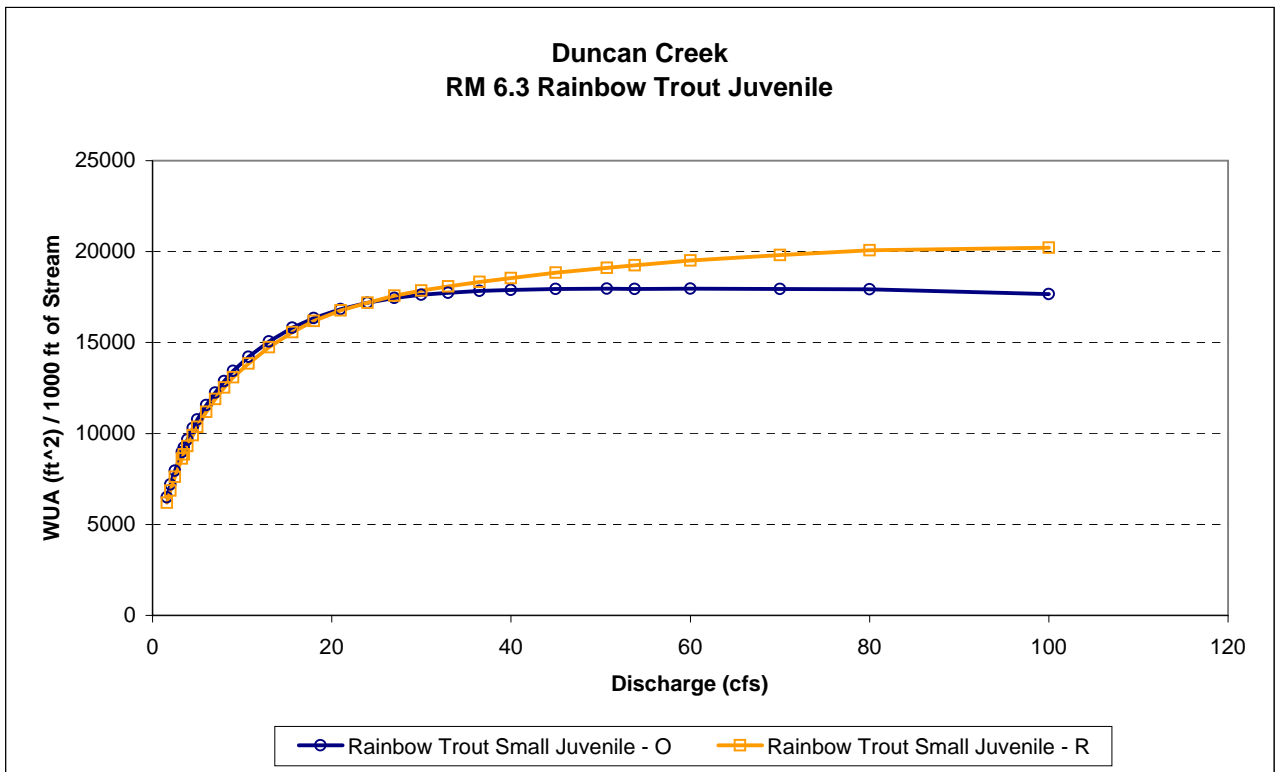
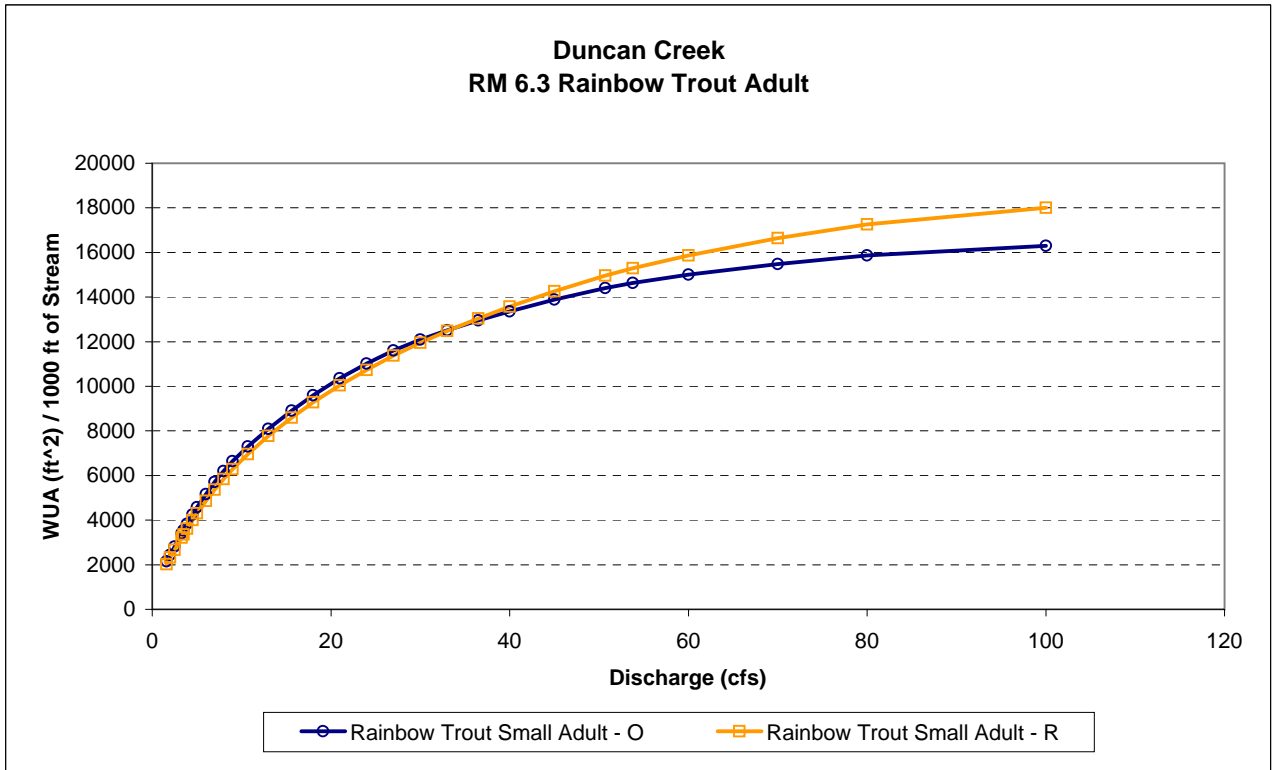


Figure J-1. Duncan Creek - D6.3 Weighted Usable Area Results by Species/Lifestage from Velocity Modeling Sensitivity Analysis Comparing Original (O) and Revised (R) Modeled Velocities. Negative Velocities Removed from Revised Set (continued).

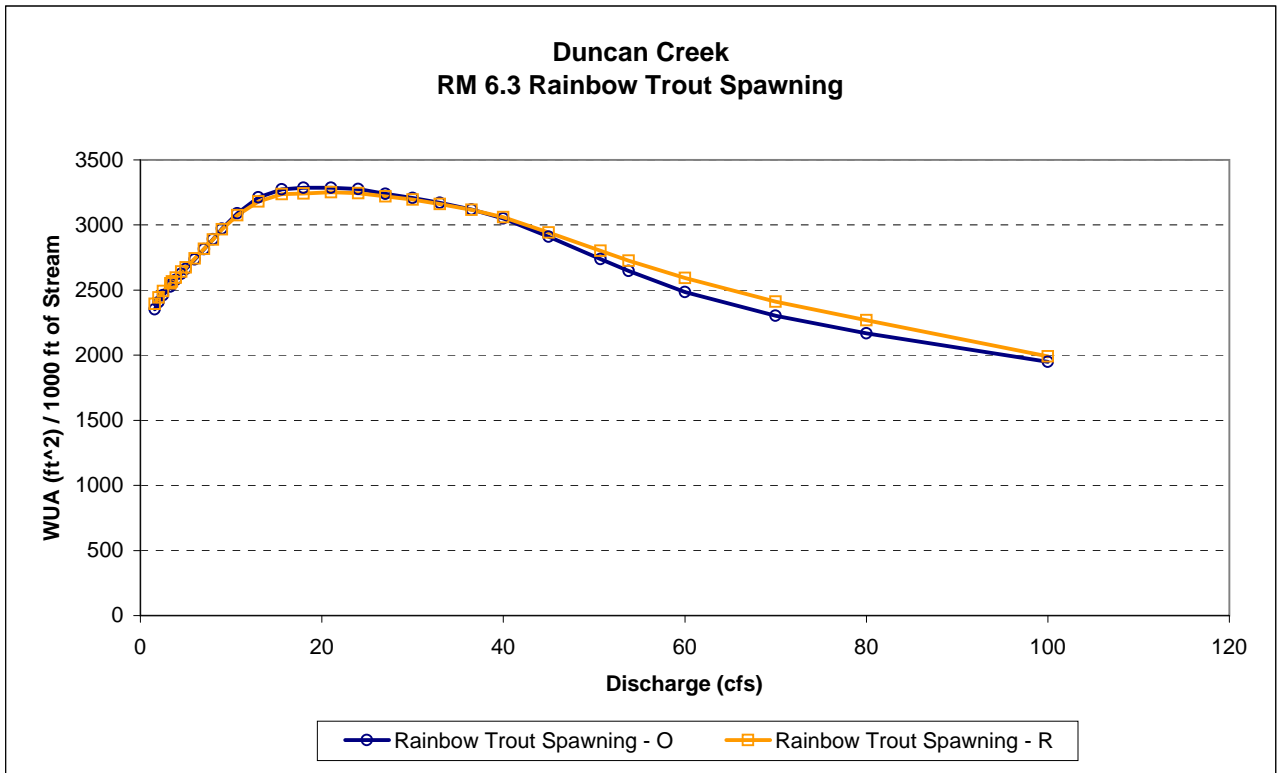
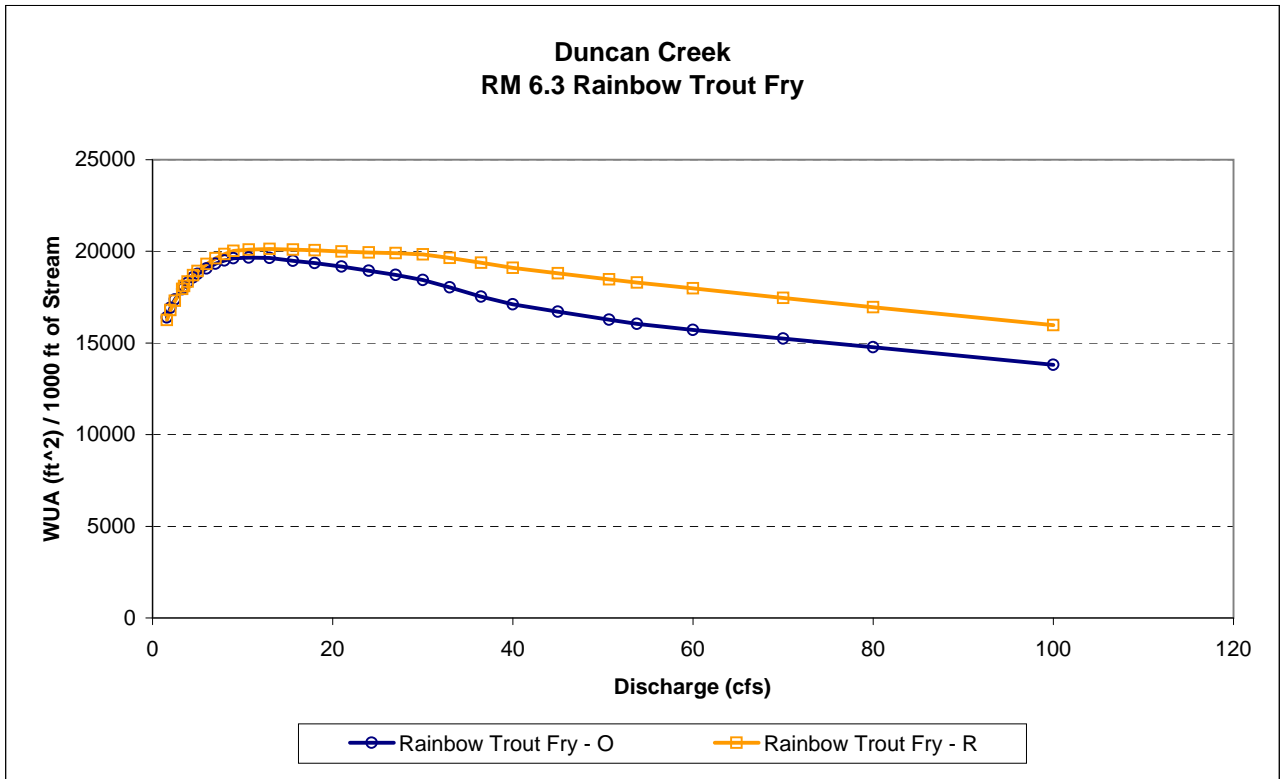


Figure J-2. Long Canyon Creek - LC9.0 Weighted Usable Area Results by Species/Lifestage from Velocity Modeling Sensitivity Analysis Comparing Original (O) and Revised (R) Modeled Velocities. Negative Velocities Removed from Revised Set.

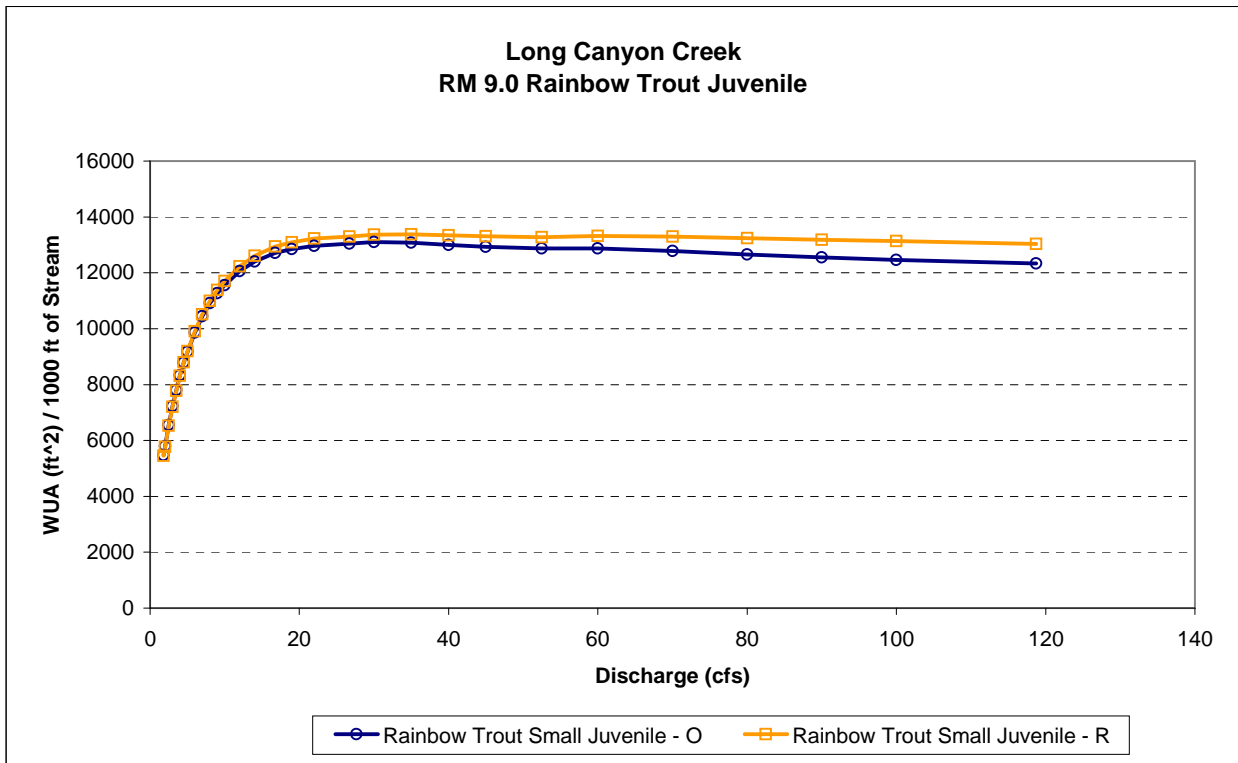
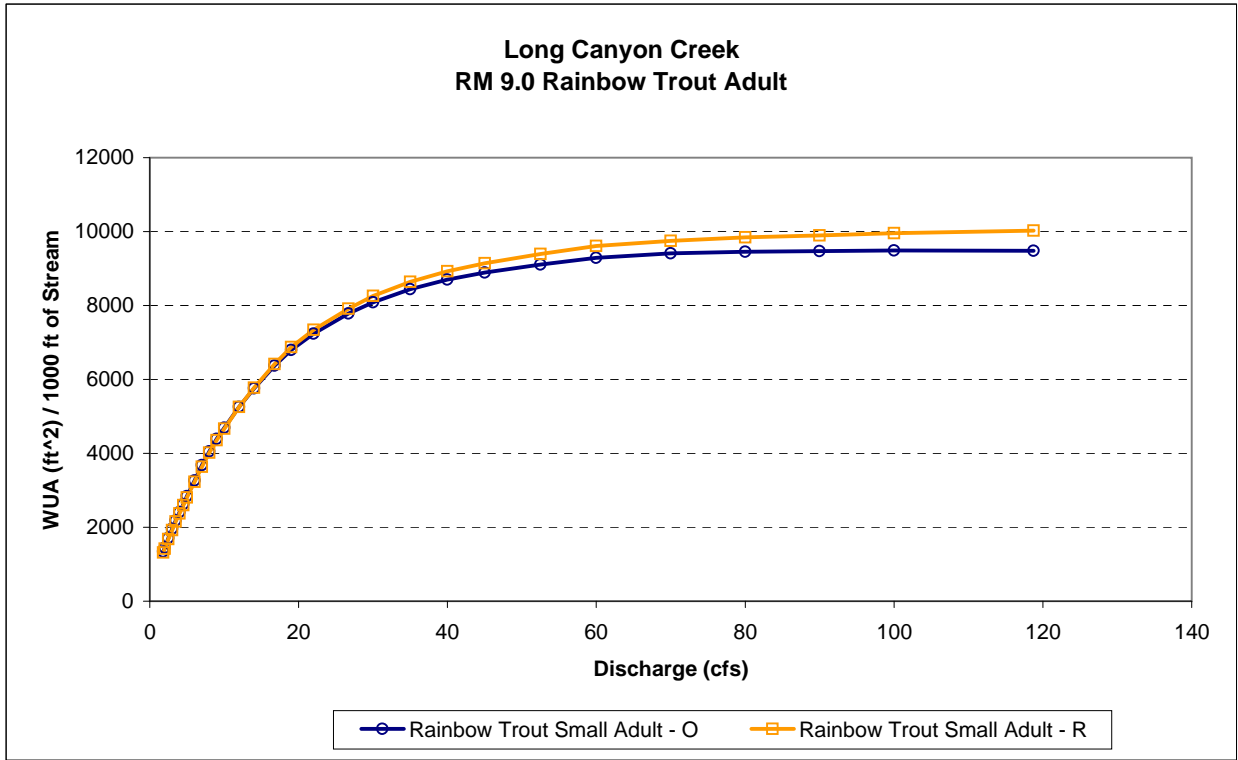


Figure J-2. Long Canyon Creek - LC9.0 Weighted Usable Area Results by Species/Lifestage from Velocity Modeling Sensitivity Analysis Comparing Original (O) and Revised (R) Modeled Velocities. Negative Velocities Removed from Revised Set (continued).

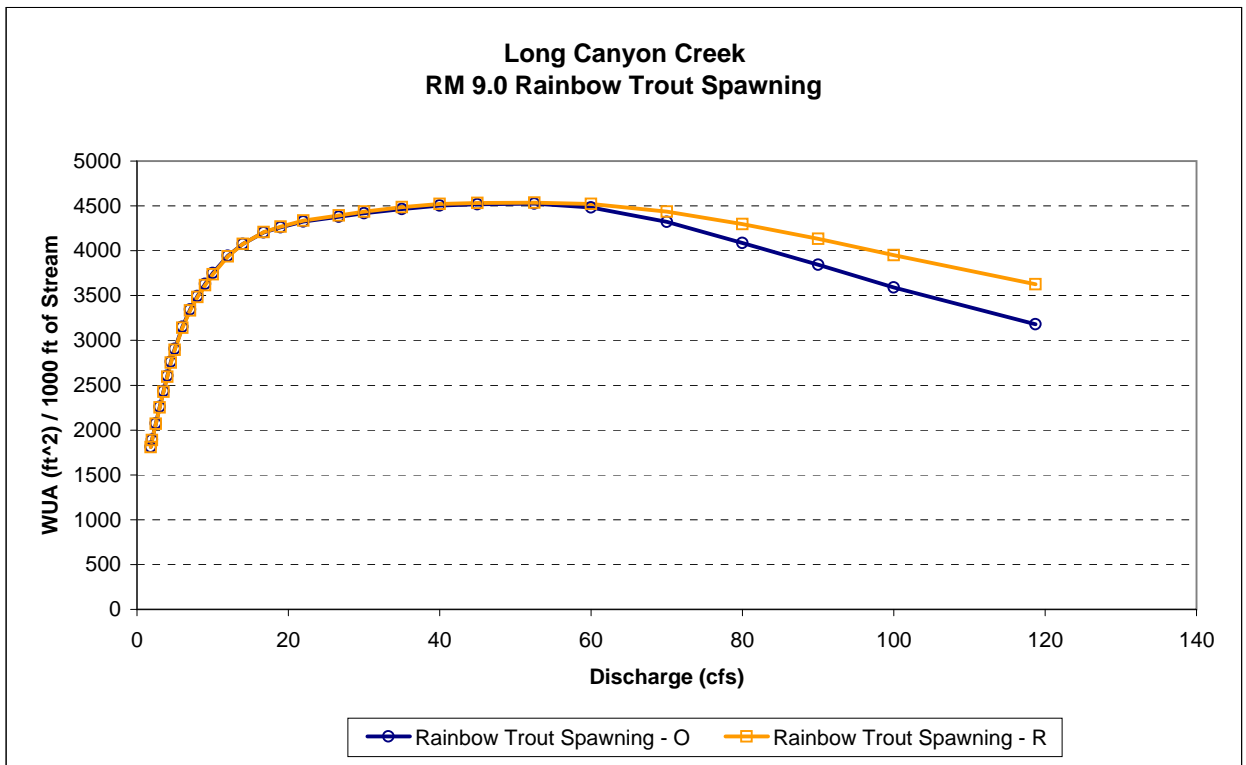
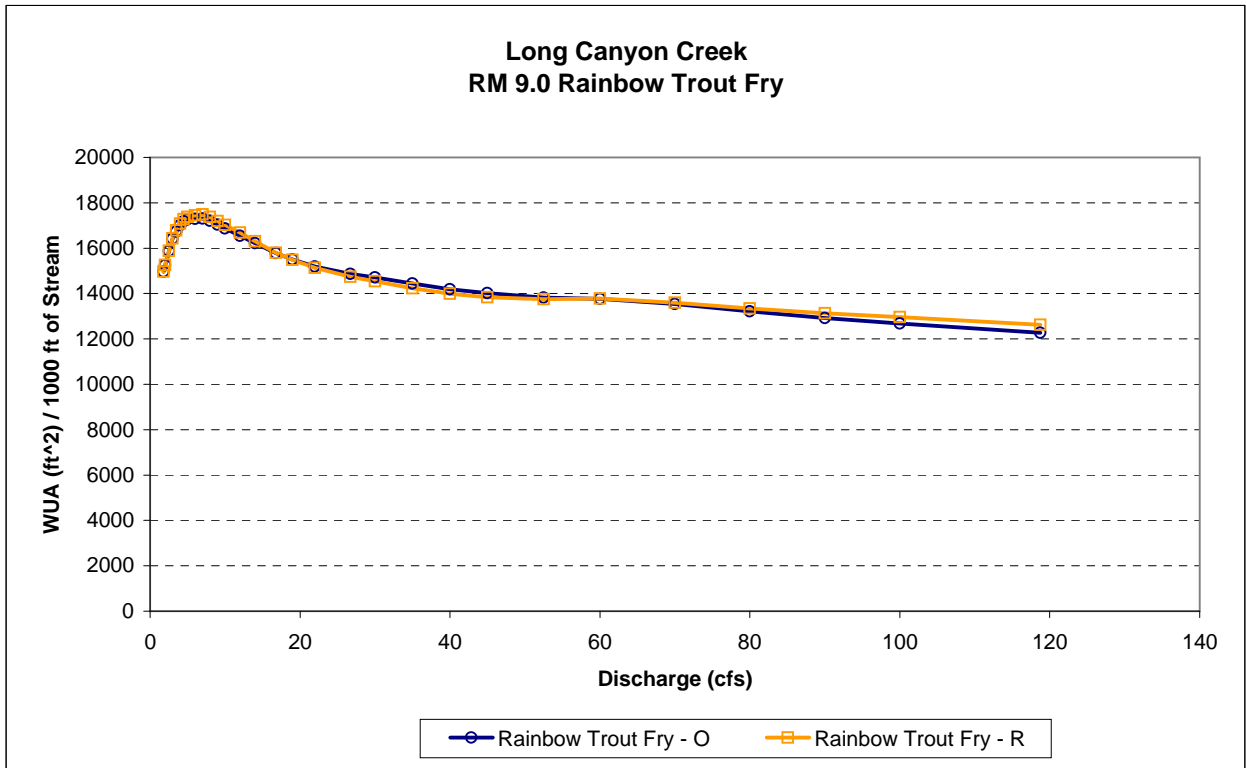


Figure J-3. Middle Fork of the American River - MF44.7 Weighted Usable Area Results by Species/Lifestage from Velocity Modeling Sensitivity Analysis Comparing Original (O) and Revised (R) Modeled Velocities. Negative Velocities Removed from Revised Set.

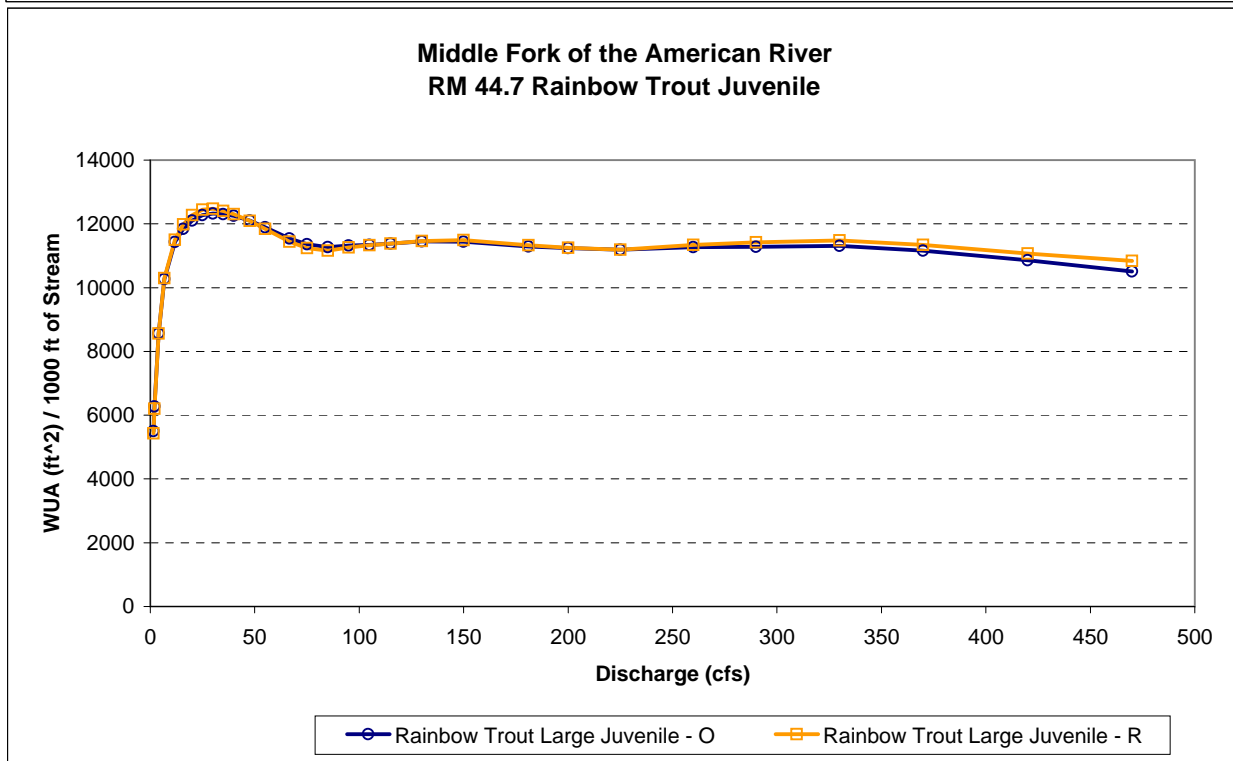
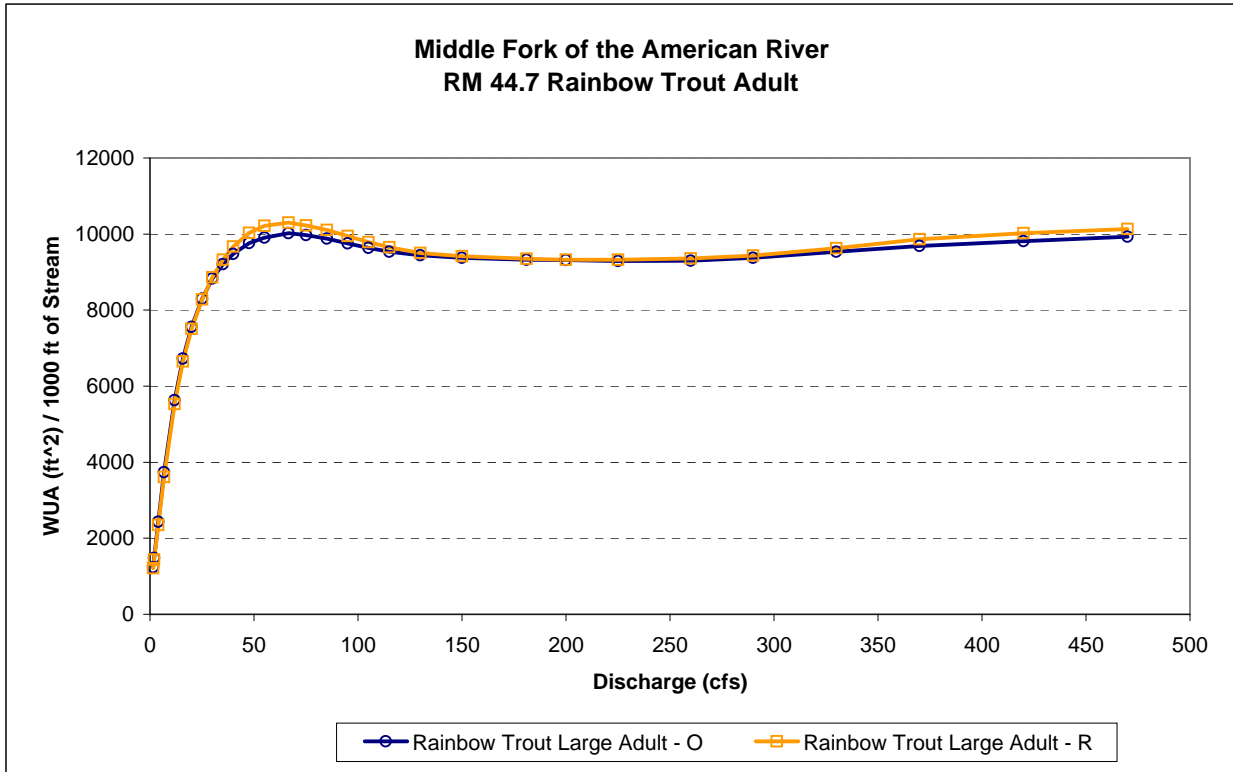
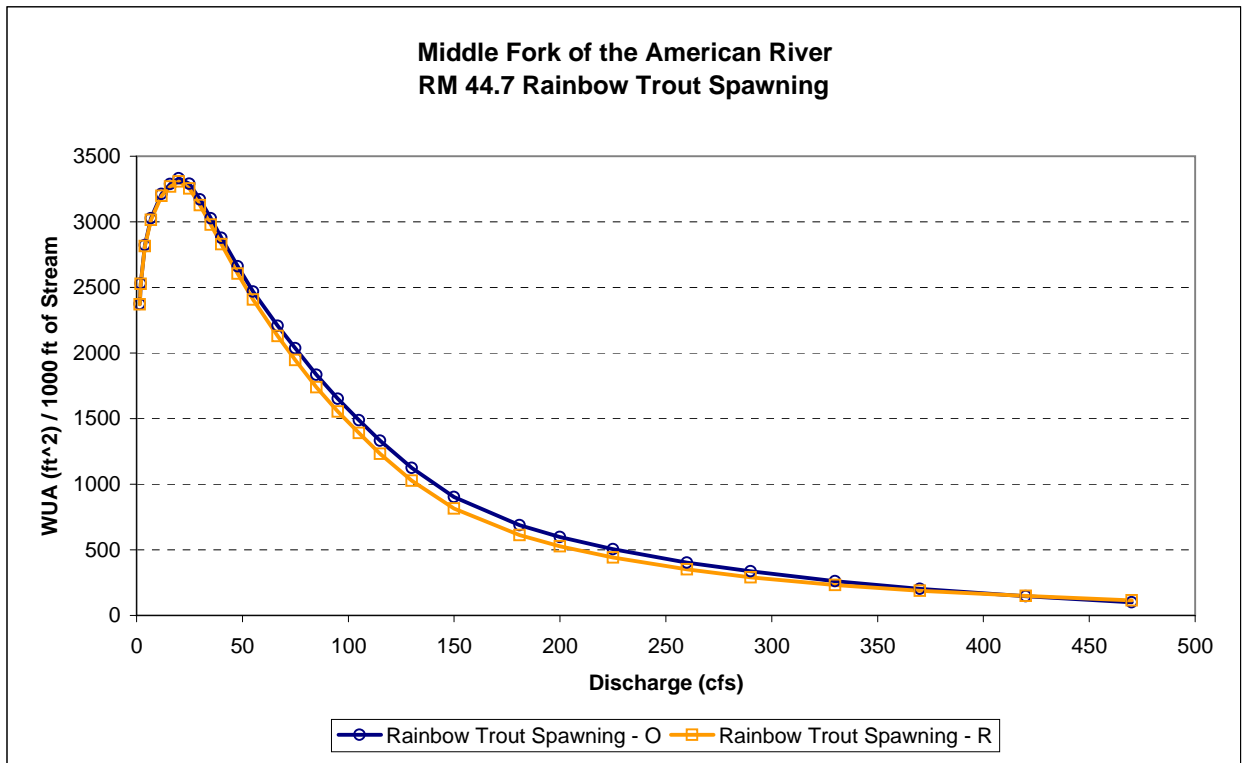
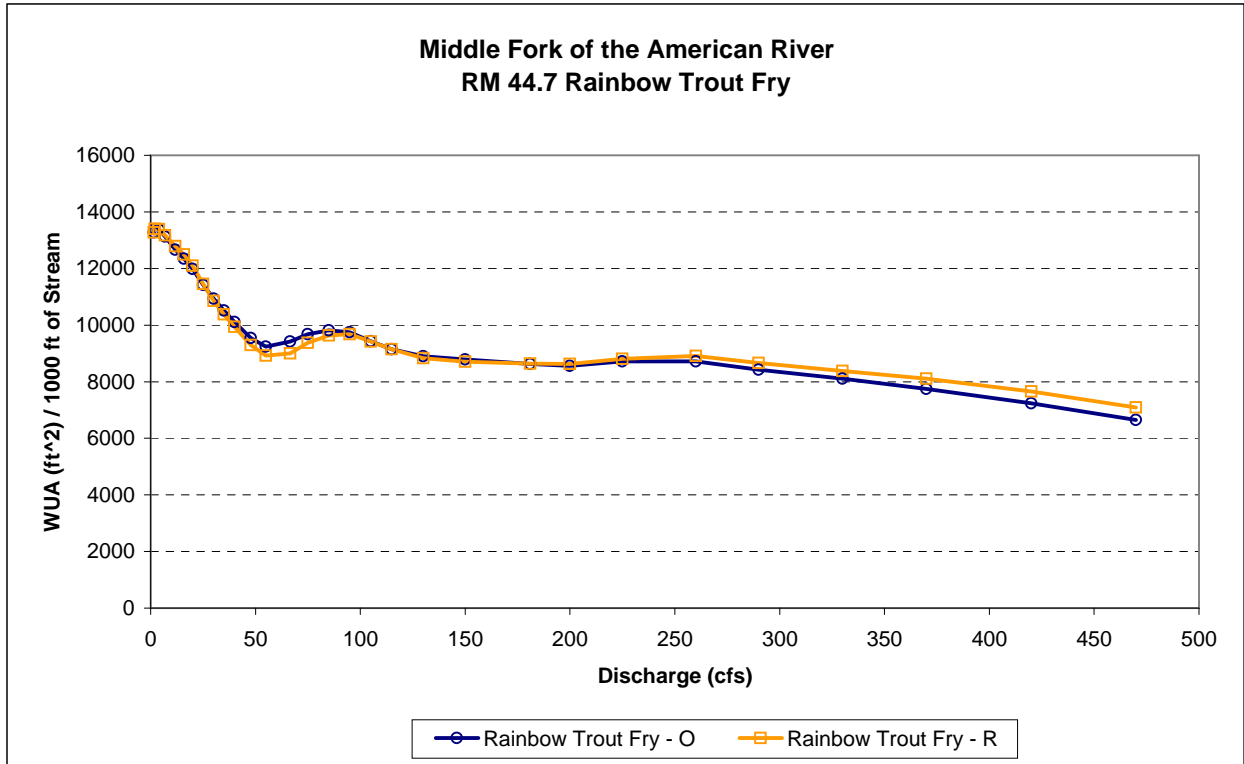
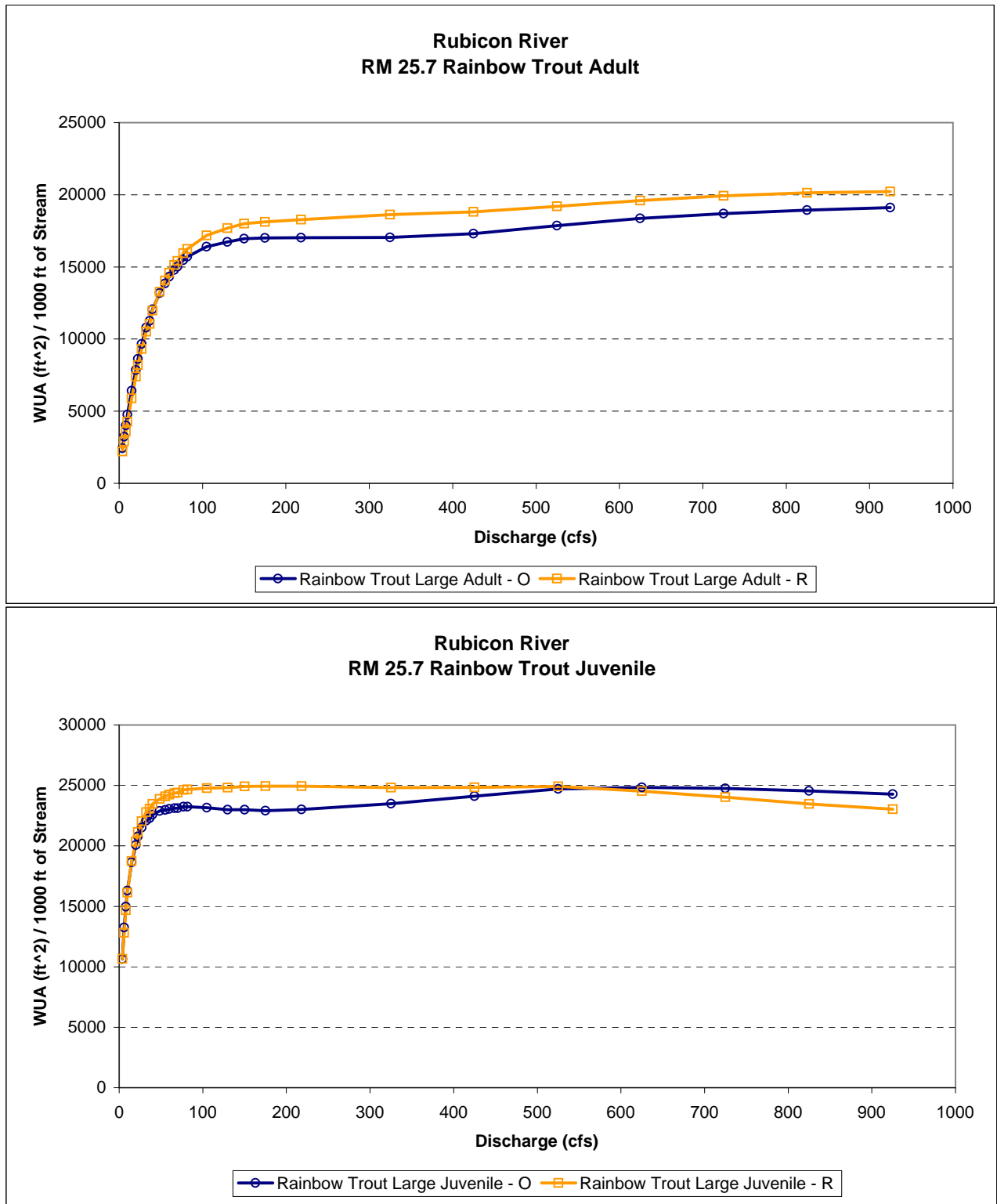


Figure J-3. Middle Fork of the American River - MF44.7 Weighted Usable Area Results by Species/Lifestage from Velocity Modeling Sensitivity Analysis Comparing Original (O) and Revised (R) Modeled Velocities. Negative Velocities Removed from Revised Set (continued).



**Figure J-4. Rubicon River - R25.7 Weighted Usable Area Results by Species/Lifestage from Velocity Modeling Sensitivity Analysis Comparing Original (O) and Revised (R) Modeled Velocities. Negative Velocities Removed from Revised Set.**



**Figure J-4. Rubicon River - R25.7 Weighted Usable Area Results by Species/Lifestage from Velocity Modeling Sensitivity Analysis Comparing Original (O) and Revised (R) Modeled Velocities. Negative Velocities Removed from Revised Set (continued).**

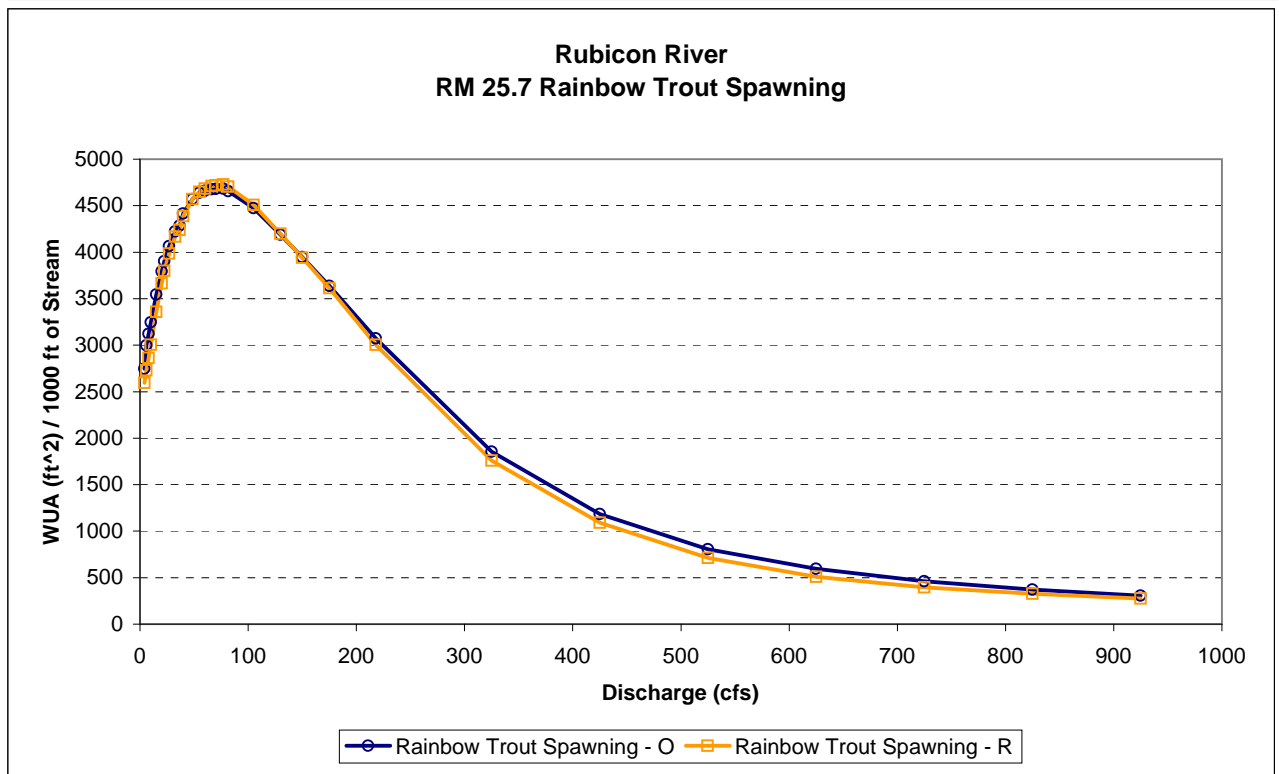
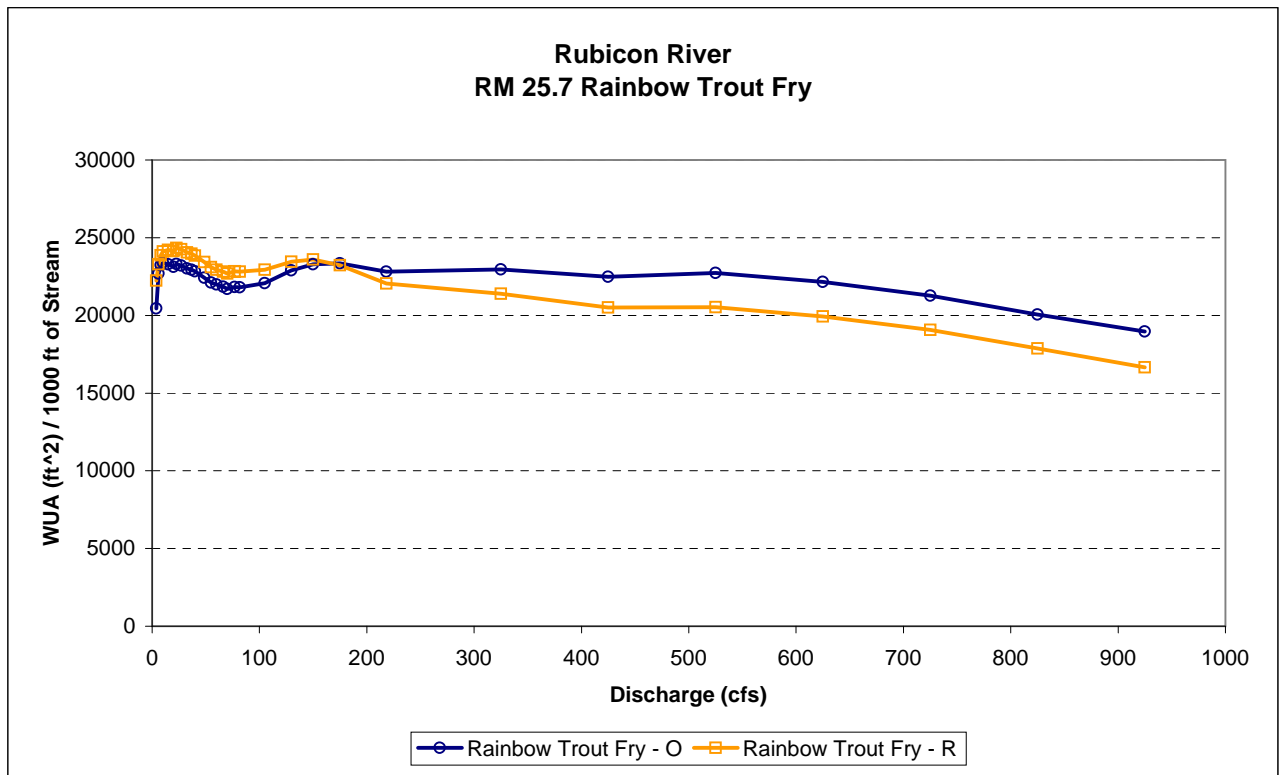


Figure J-5. Rubicon River - R20.9 Weighted Usable Area Results by Species/Lifestage from Velocity Modeling Sensitivity Analysis Comparing Original (O) and Revised (R) Modeled Velocities. Negative Velocities Removed from Revised Set.

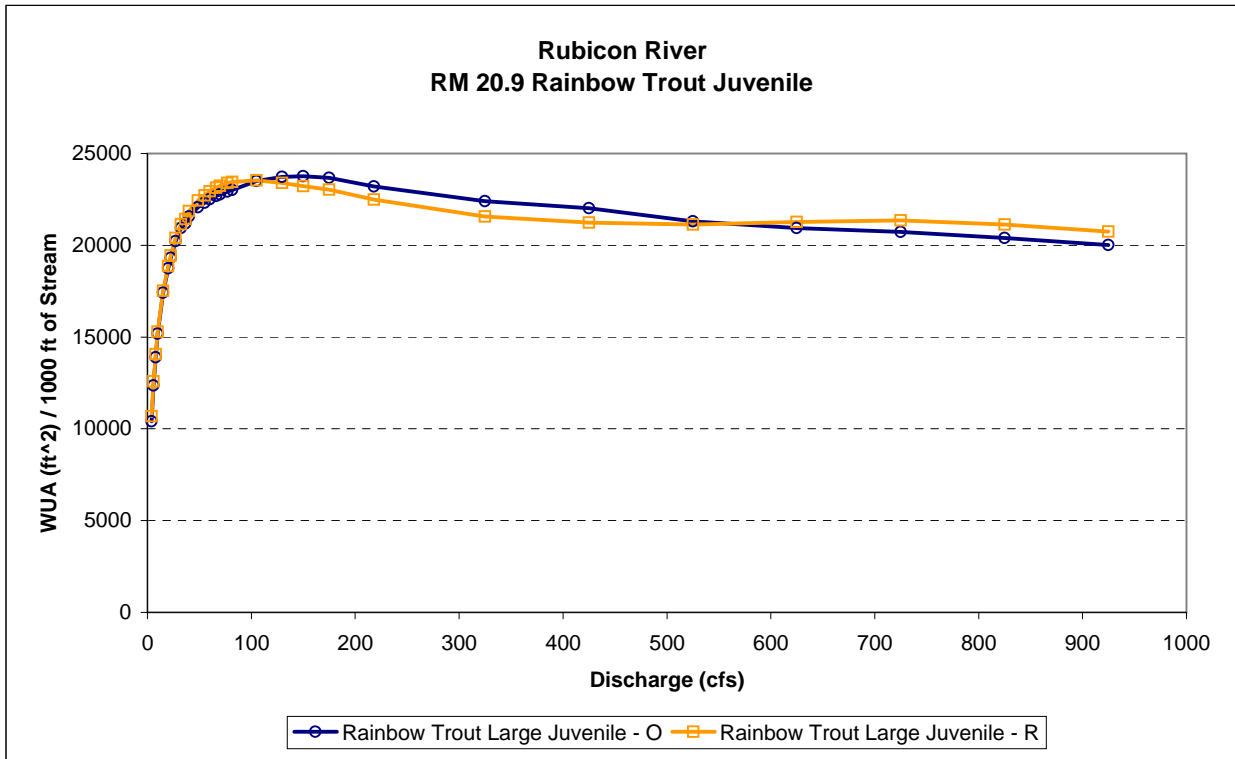
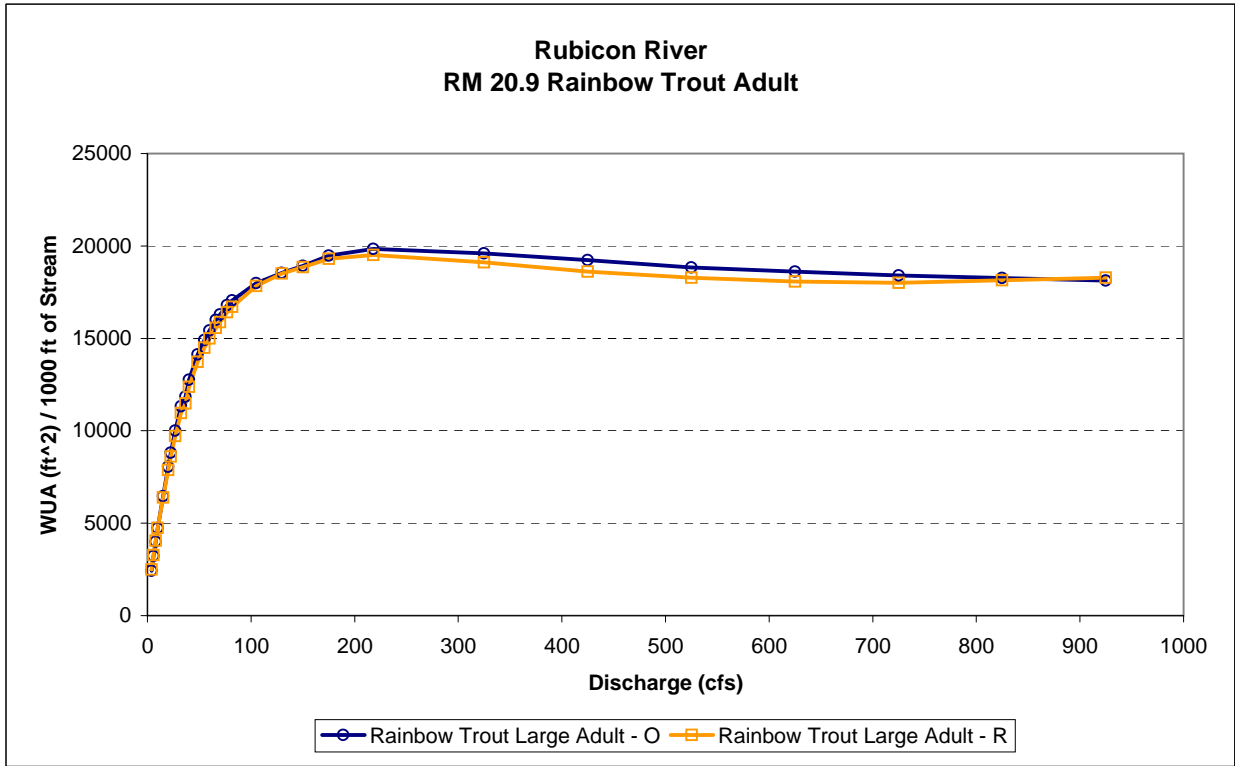


Figure J-5. Rubicon River - R20.9 Weighted Usable Area Results by Species/Lifestage from Velocity Modeling Sensitivity Analysis Comparing Original (O) and Revised (R) Modeled Velocities. Negative Velocities Removed from Revised Set (continued).

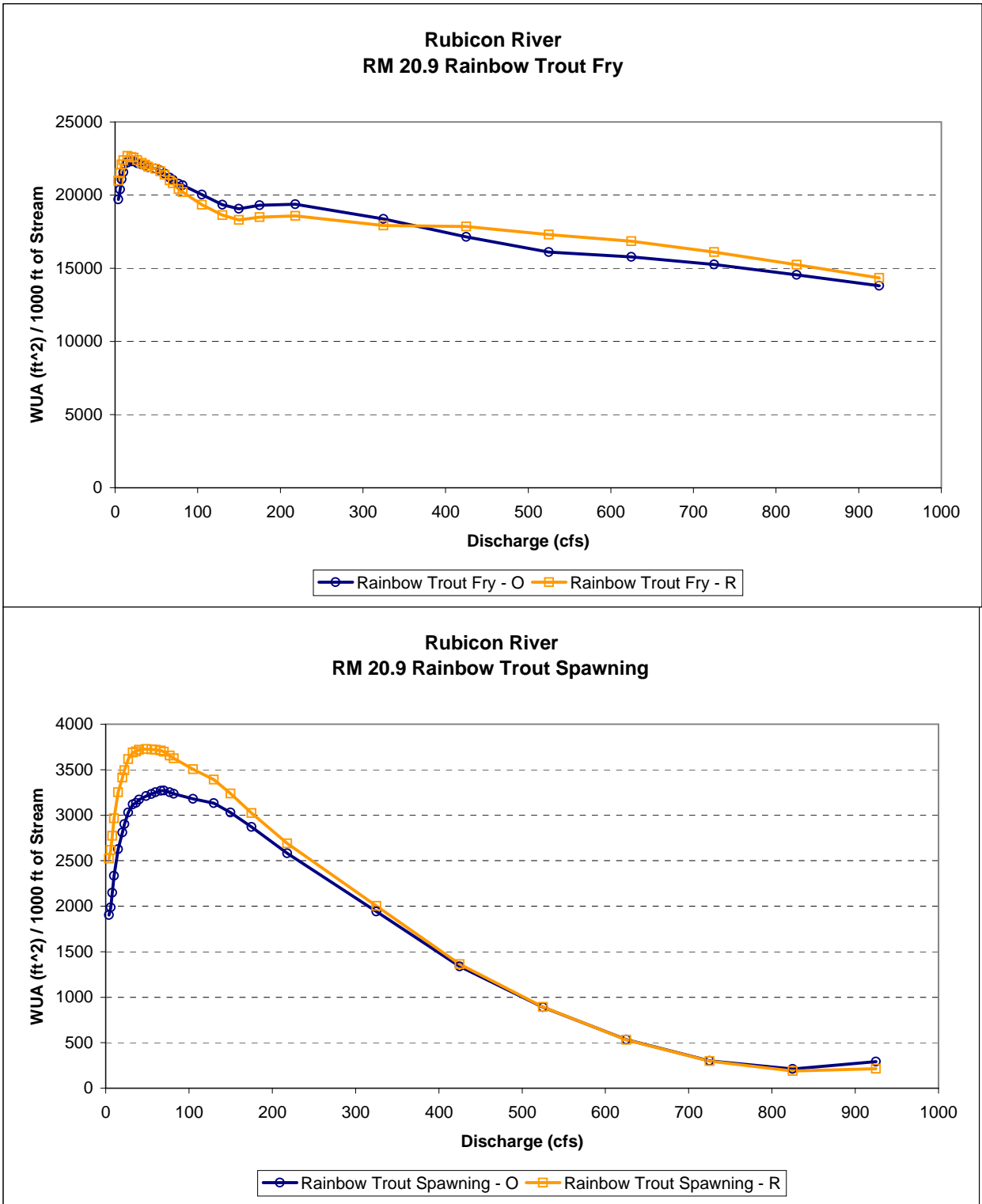


Figure J-5. Rubicon River - R20.9 Weighted Usable Area Results by Species/Lifestage from Velocity Modeling Sensitivity Analysis Comparing Original (O) and Revised (R) Modeled Velocities. Negative Velocities Removed from Revised Set (continued).

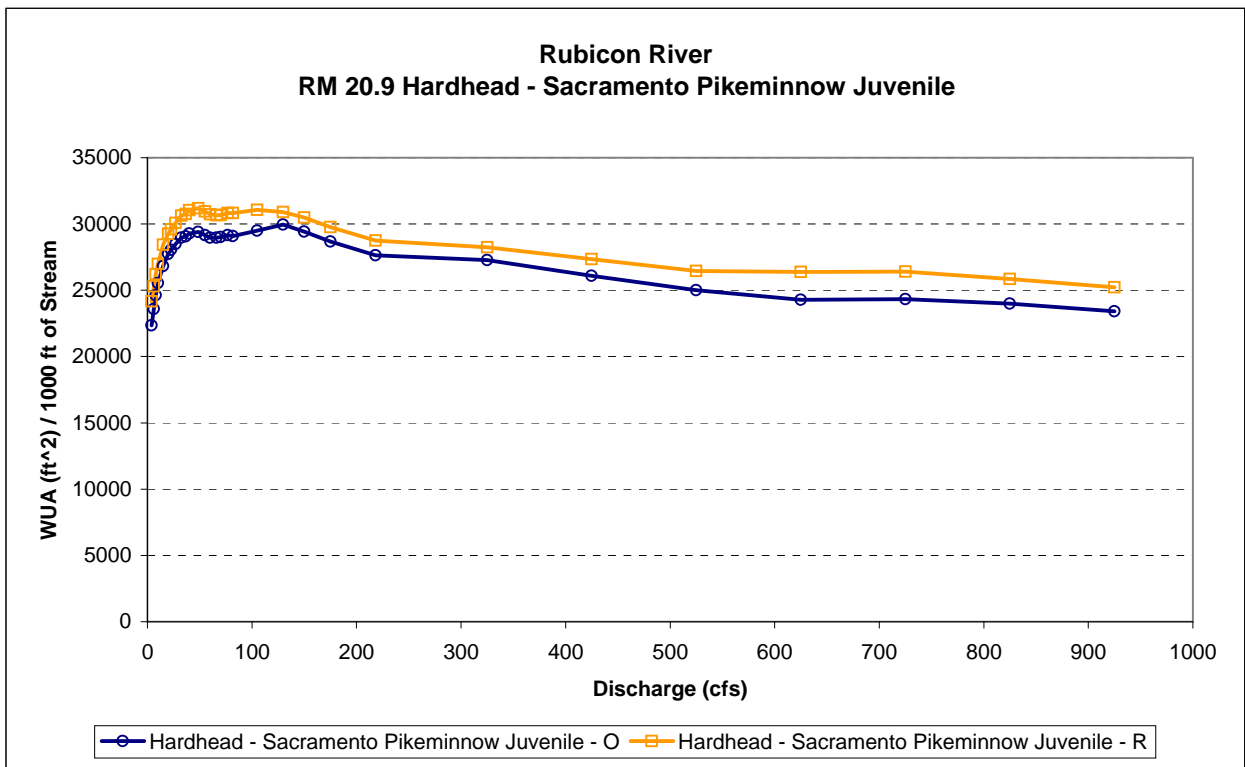
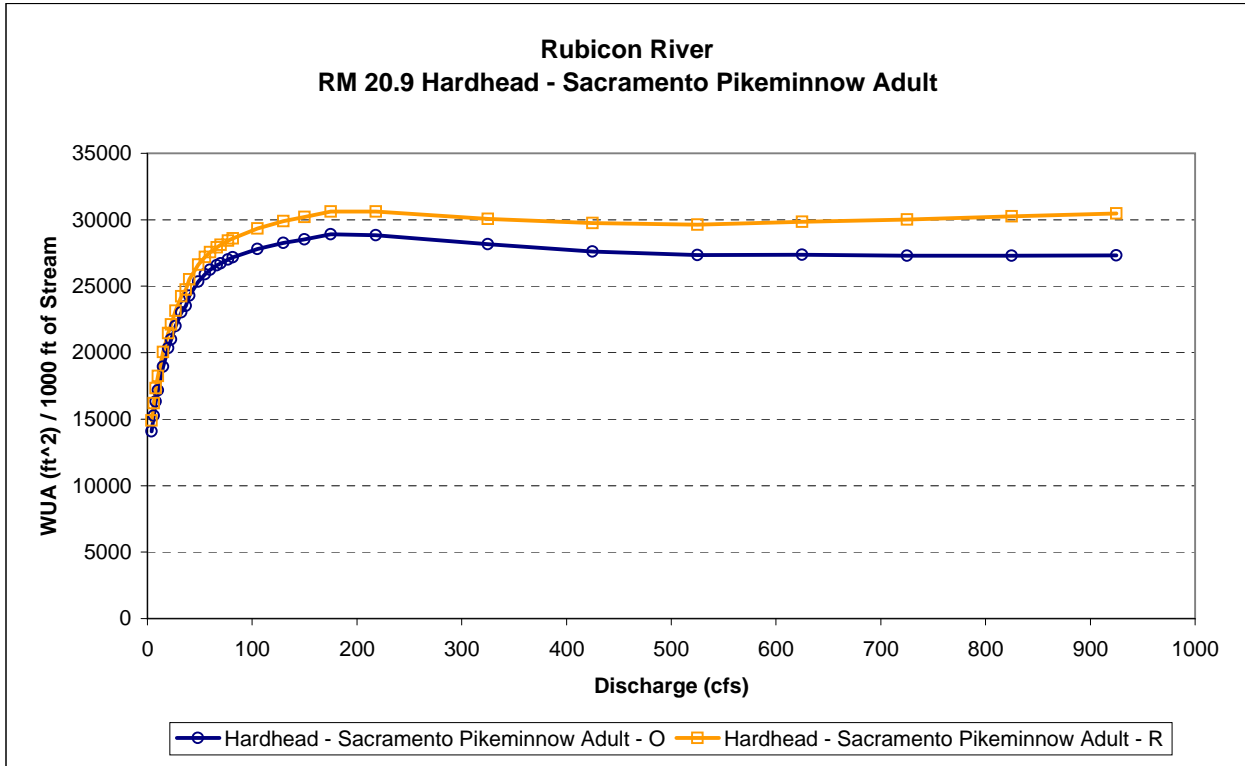


Figure J-6. Rubicon River – R3.5 Weighted Usable Area Results by Species/Lifestage from Velocity Modeling Sensitivity Analysis Comparing Original (O) and Revised (R) Modeled Velocities. Negative Velocities Removed from Revised Set.

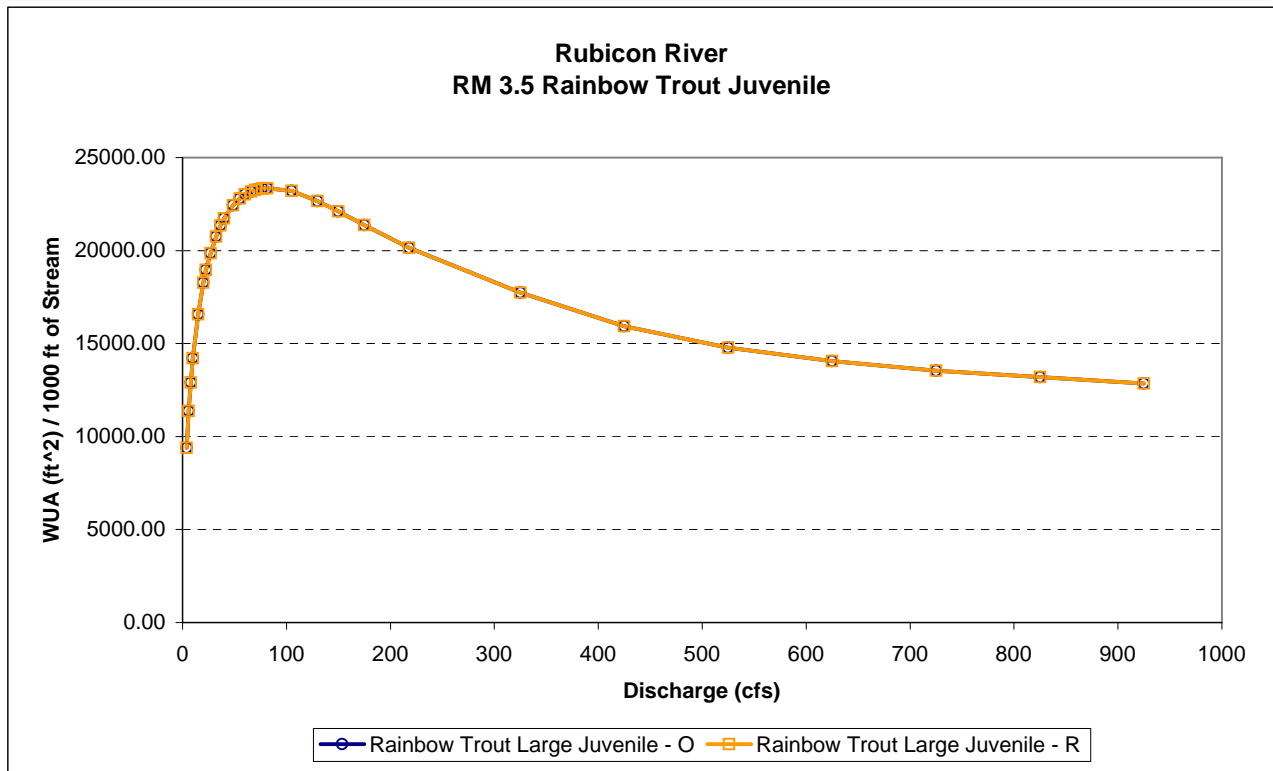
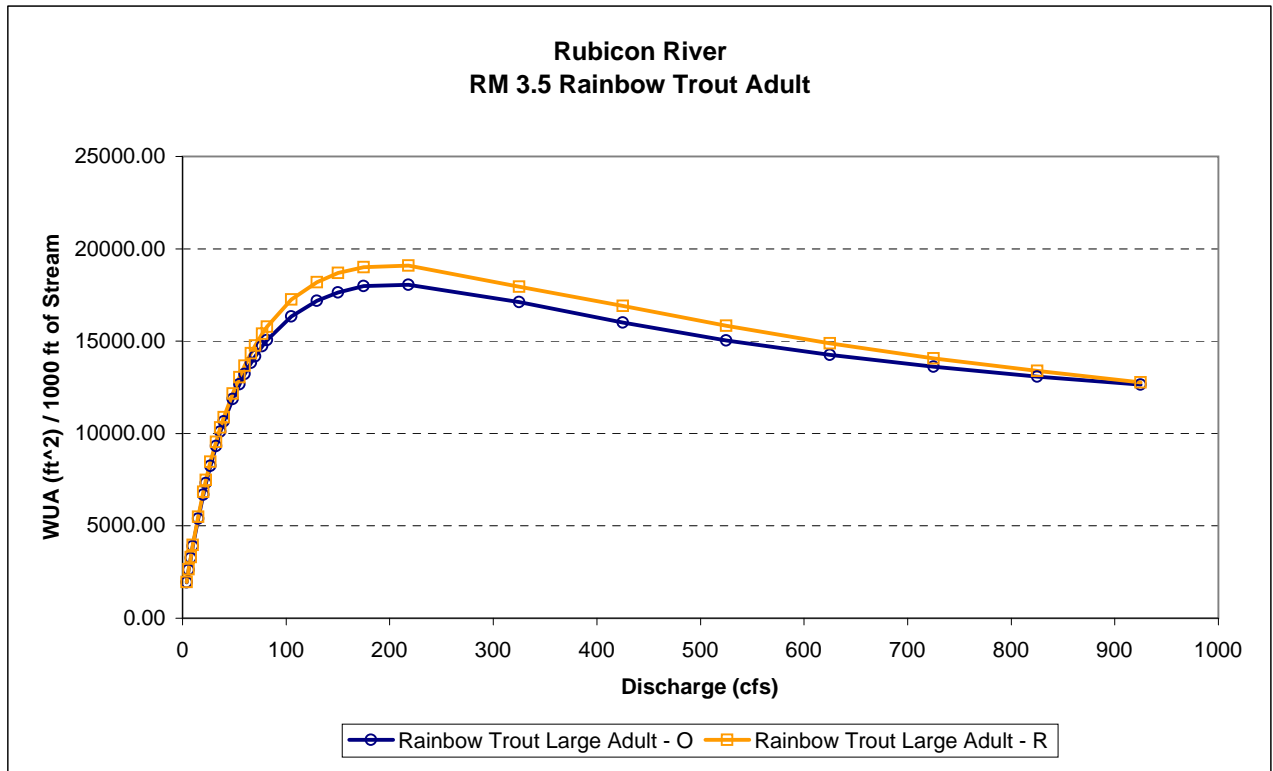


Figure J-6. Rubicon River – R3.5 Weighted Usable Area Results by Species/Lifestage from Velocity Modeling Sensitivity Analysis Comparing Original (O) and Revised (R) Modeled Velocities. Negative Velocities Removed from Revised Set (continued).

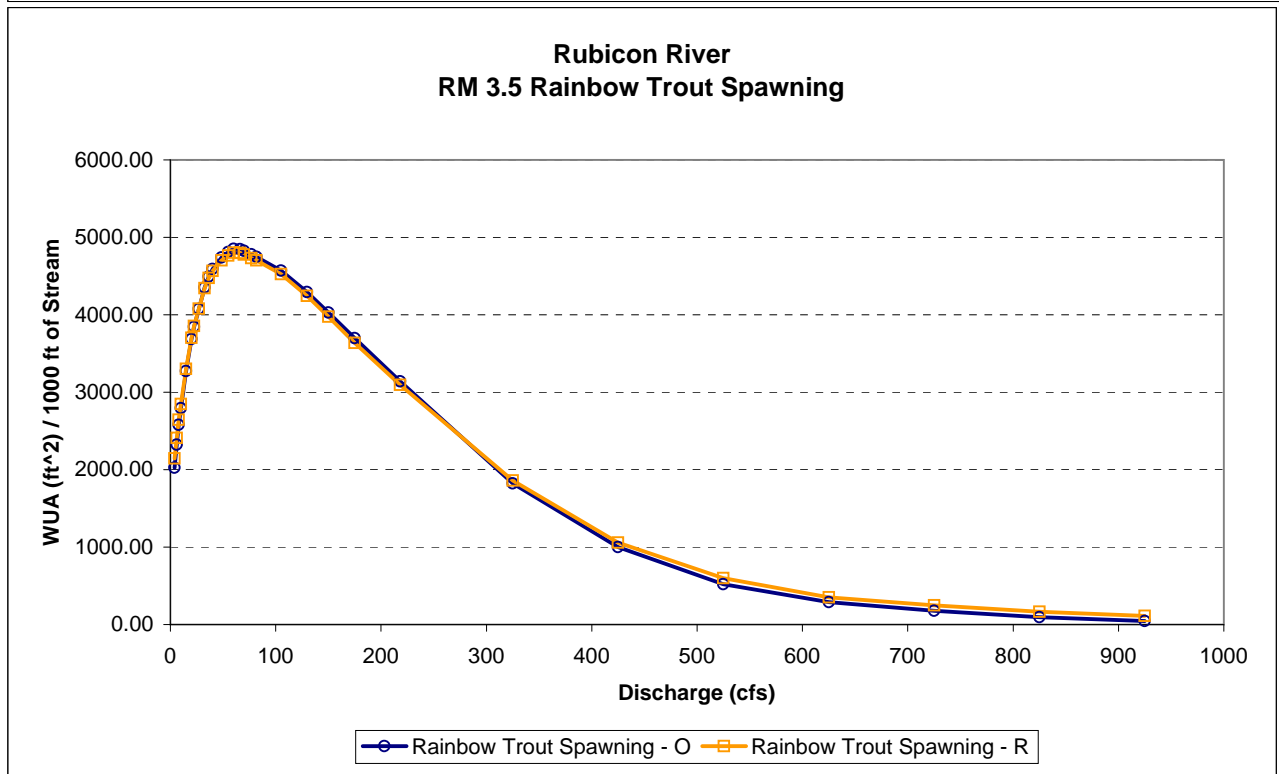
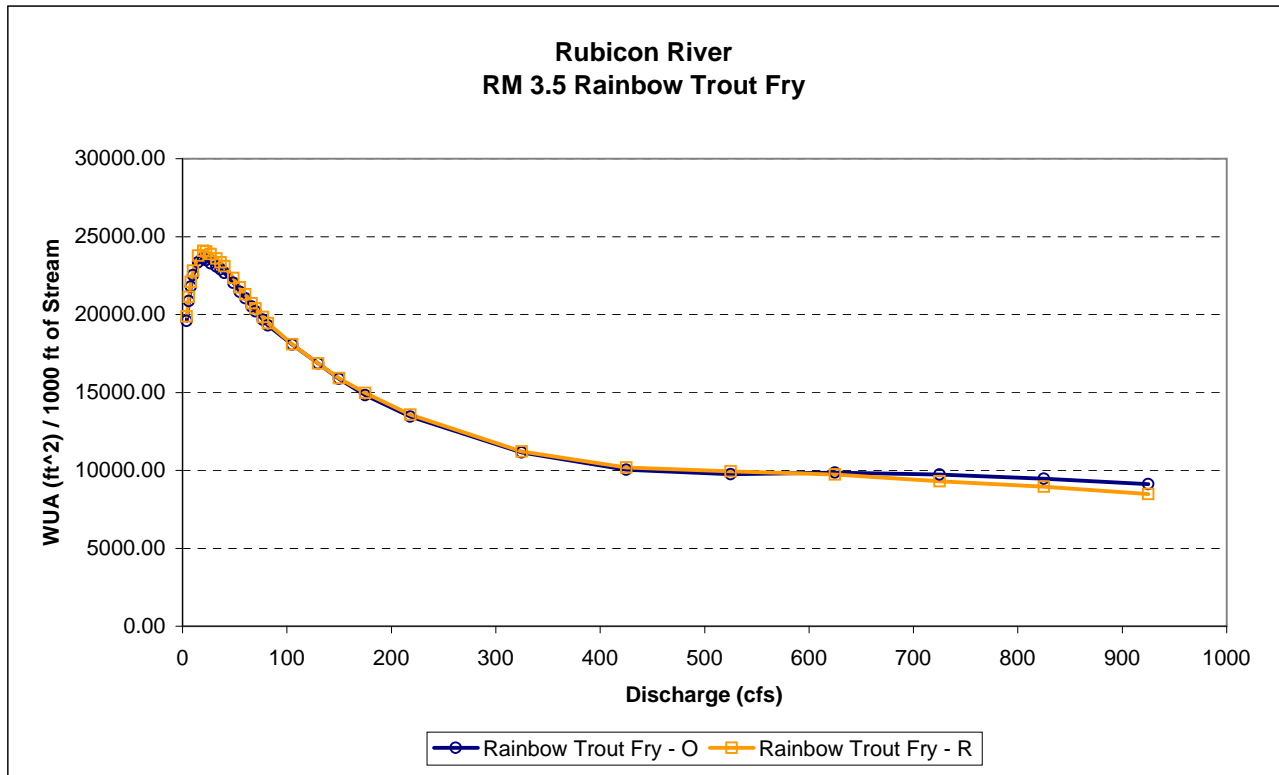
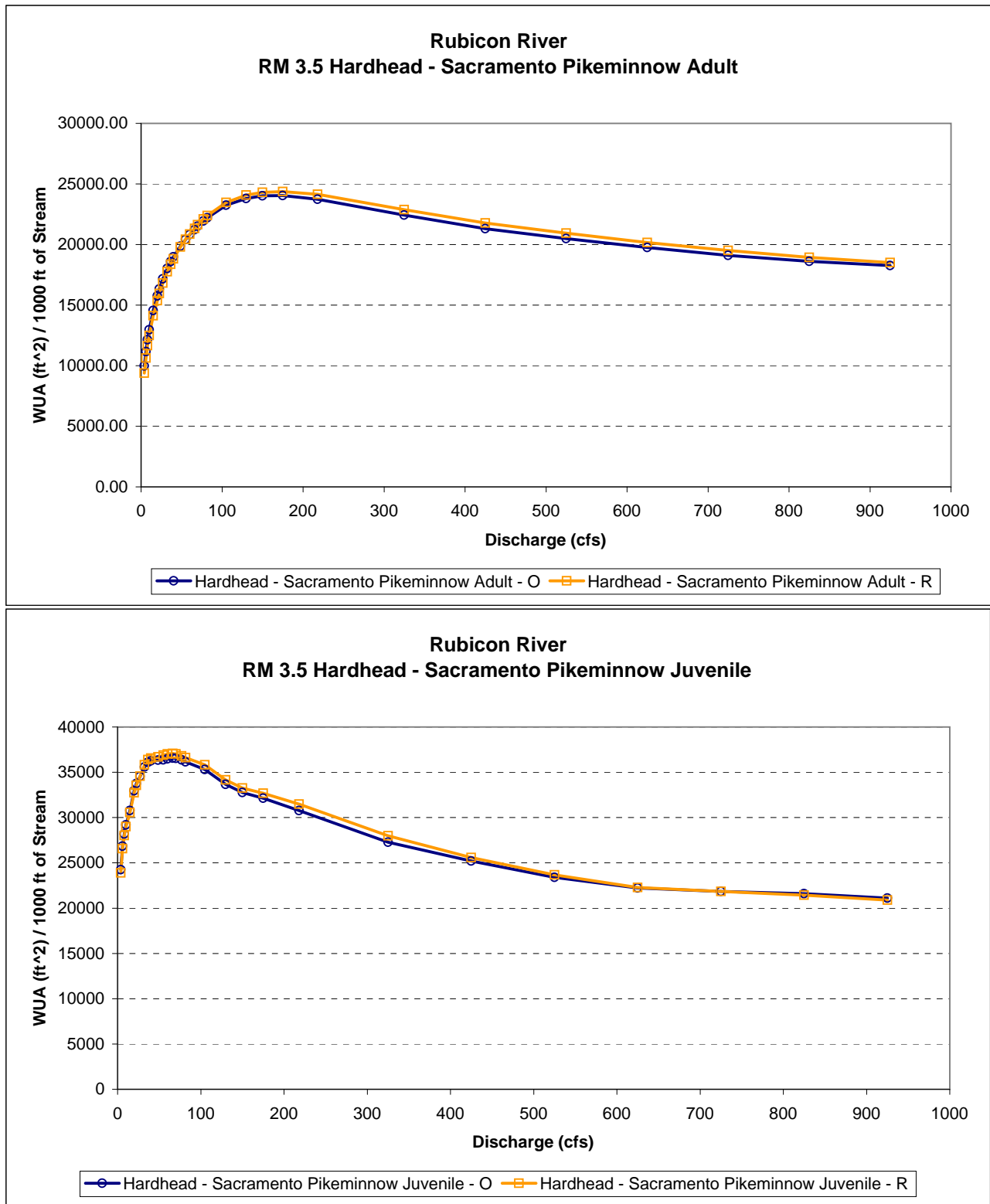


Figure J-6. Rubicon River – R3.5 Weighted Usable Area Results by Species/Lifestage from Velocity Modeling Sensitivity Analysis Comparing Original (O) and Revised (R) Modeled Velocities. Negative Velocities Removed from Revised Set (continued).



**ATTACHMENT A**

**1D Hydraulics Calibration Results by Cross Section for each 1D Study Site (AQ - 1 Instream Flow) and Special Purpose 1D Modeling Sites (AQ - 9 Geomorphology, AQ - 10 Riparian Resources and AQ - 12 Special-Status Amphibian And Aquatic Reptile)**

(See Attached Electronic Media)

**APPENDIX K**

**2D Study Site Topography, Substrate, Depth and Velocity Data**

(See Attached Electronic Media)

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- Figure K-1. Middle Fork American River 26.2 Upstream Site Bed Topography (0.25 m Contours).
- Figure K-2. Middle Fork American River 26.2 Downstream Site Bed Topography (0.25 m Contours).
- Figure K-3. Rubicon River 3.5 Upstream Site Bed Topography (0.25 m Contours).
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- Figure K-5. Middle Fork American River 14.1 – Fords Bar Whole Site Bed Topography (2.5 m Contours).
- Figure K-6. Middle Fork American River 14.1 – Fords Bar Upstream Bed Topography (0.5 m Contours).
- Figure K-7. Middle Fork American River 4.8 – Buckeye Bar Whole Site Bed Topography (0.75 m Contours).
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- Map K-2. Substrate Delineations by Trout Spawning Code. Middle Fork American River 26.2 Upstream Site.
- Map K-3. Substrate Delineations by FYLF Egg Mass Code. Middle Fork American River 26.2 Upstream Site.
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**Middle Fork American River 26.2 Downstream Site**

- Map K-5. Substrate Delineations by Field Data Collection Code. Middle Fork American River 26.2 Downstream Site.
- Map K-6. Substrate Delineations by Trout Spawning Code. Middle Fork American River 26.2 Downstream Site.
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- Map K-8. Substrate Delineations by FYLF Tadpole Code. Middle Fork American River 26.2 Downstream Site.

Rubicon River 3.5 Upstream Site

- Map K-9. Substrate Delineations by Field Data Collection Code. Rubicon River 3.5 Upstream Site.
- Map K-10. Substrate Delineations by Trout Spawning Code. Rubicon River 3.5 Upstream Site.
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- Map K-12. Substrate Delineations by FYLF Tadpole Code. Rubicon River 3.5 Upstream Site.

Rubicon River 3.5 Downstream Site

- Map K-13. Substrate Delineations by Field Data Collection Code. Rubicon River 3.5 Downstream Site.
- Map K-14. Substrate Delineations by Trout Spawning Code. Rubicon River 3.5 Downstream Site.
- Map K-15. Substrate Delineations by FYLF Egg Mass Code. Rubicon River 3.5 Downstream Site.
- Map K-16. Substrate Delineations by FYLF Tadpole Code. Rubicon River 3.5 Downstream Site.

Middle Fork American River 14.1 at Fords Bar

- Map K-17. Substrate Delineations by Field Data Collection Code. Fords Bar. (3 Sheet Series)
- Map K-18. Substrate Delineations by Trout Spawning Code. Fords Bar. (3 Sheet Series)
- Map K-19. Substrate Delineations by FYLF Egg Mass Code. Fords Bar. (3 Sheet Series)
- Map K-20. Substrate Delineations by FYLF Tadpole Code. Fords Bar. (3 Sheet Series)
- Map K-21. Riparian Vegetation Delineations by Dominance. Fords Bar. (3 Sheet Series)

Middle Fork American River 4.8 at Buckeye Bar

- Map K-22. Substrate Delineations by Field Data Collection Code. Buckeye Bar. (3 Sheet Series)
- Map K-23. Substrate Delineations by Trout Spawning Code. Buckeye Bar. (3 Sheet Series)
- Map K-24. Substrate Delineations by FYLF Egg Mass Code. Buckeye Bar. (3 Sheet Series)
- Map K-25. Substrate Delineations by FYLF Tadpole Code. Buckeye Bar. (3 Sheet Series)
- Map K-26. Riparian Vegetation Delineations by Dominance. Buckeye Bar. (3 Sheet Series)

**List of Attachments**

Attachment A. 2D Hydrodynamics Depth and Velocity AVIs by Site

**AQ – 1 Instream Flow Study Sites File**

Name

Middle Fork American River 26.2 Upstream Site	1_MF26.2_US_Depth.ppt 2_MF26.2_US_Velocity.ppt
Middle Fork American River 26.2 Downstream Site	3_MF26.2_DS_Depth.ppt 4_MF 26.2_DS_Velocity.ppt
Rubicon River 3.5 Upstream Site	5_R3.5_US_Depth.ppt 6_R3.5_US_Velocity.ppt
Rubicon River 3.5 Downstream Site	7_R3.5_DS_Depth.ppt 8_R3.5_DS_Velocity.ppt
Middle Fork American River 14.1 at Fords Bar	9_MF14.1_Depth.ppt 10_MF14.1_Velocity.ppt
Middle Fork American River 4.8 ay Buckeye Bar	11_MF4.8_Depth.ppt 12_MF4.8_Velocity.ppt

**FIGURES**

**Figure K-1. Middle Fork American River 26.2 Upstream Site Bed Topography (0.25 m Contours).**

Bed Elevation

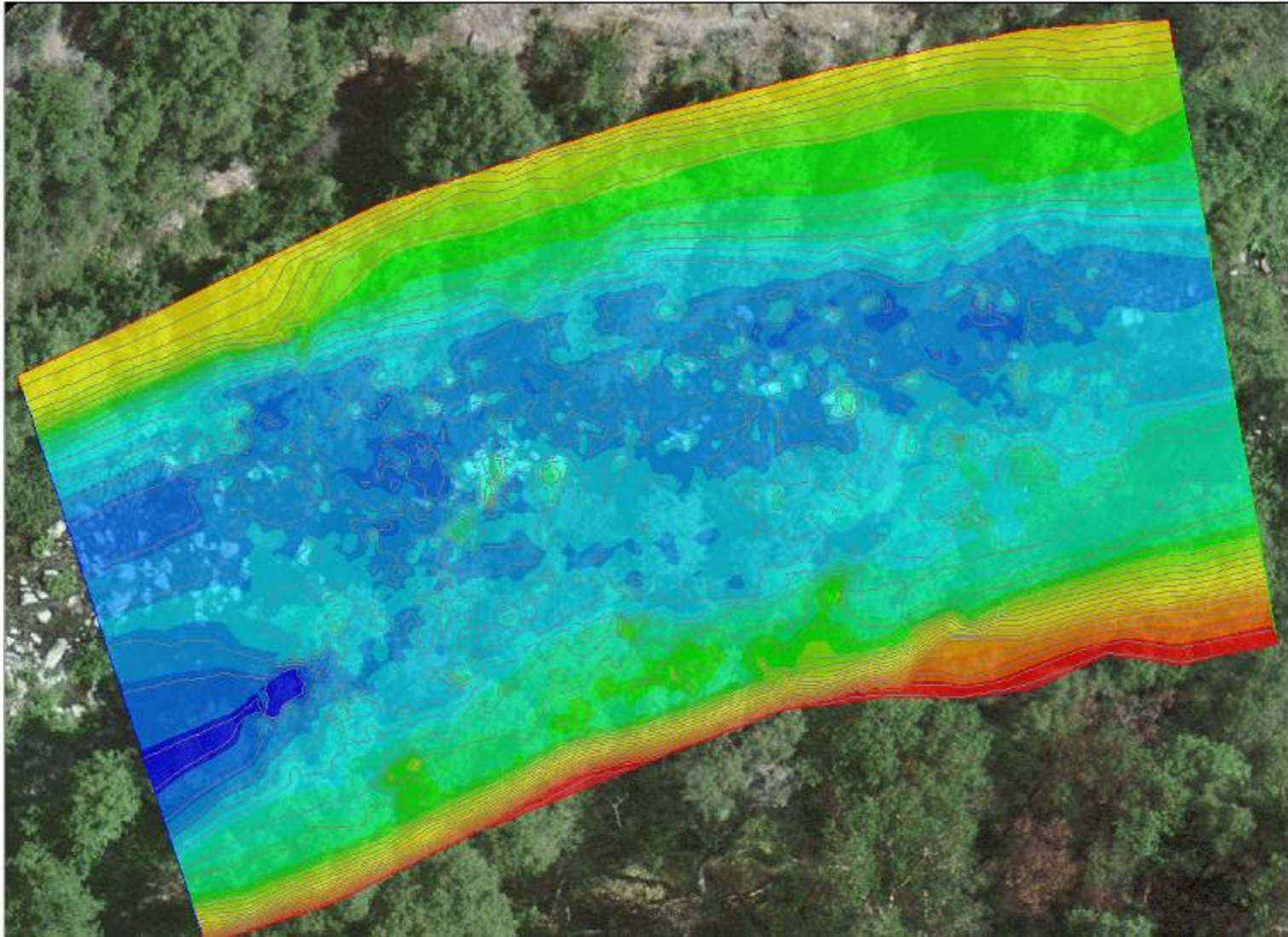
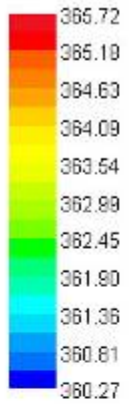
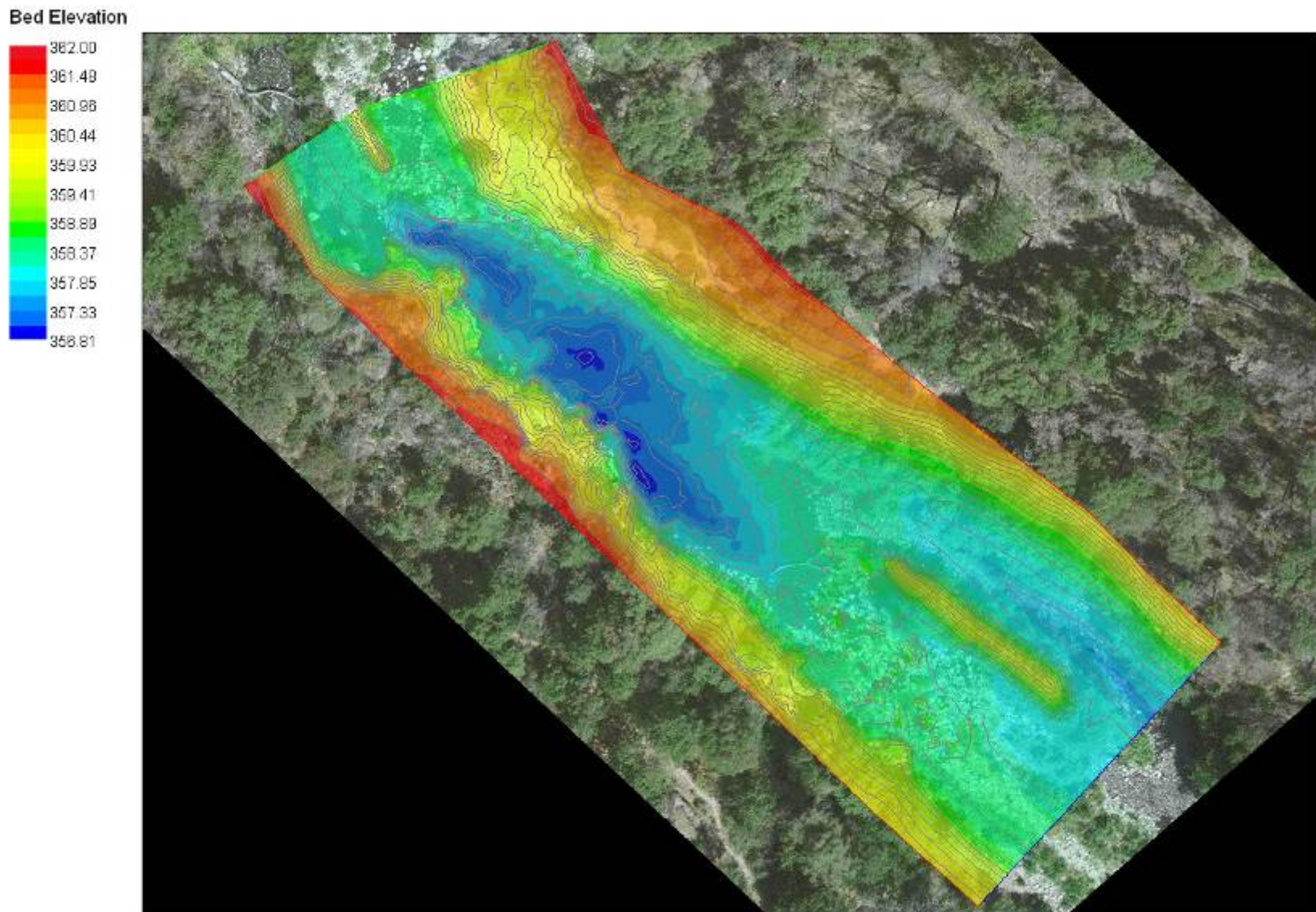
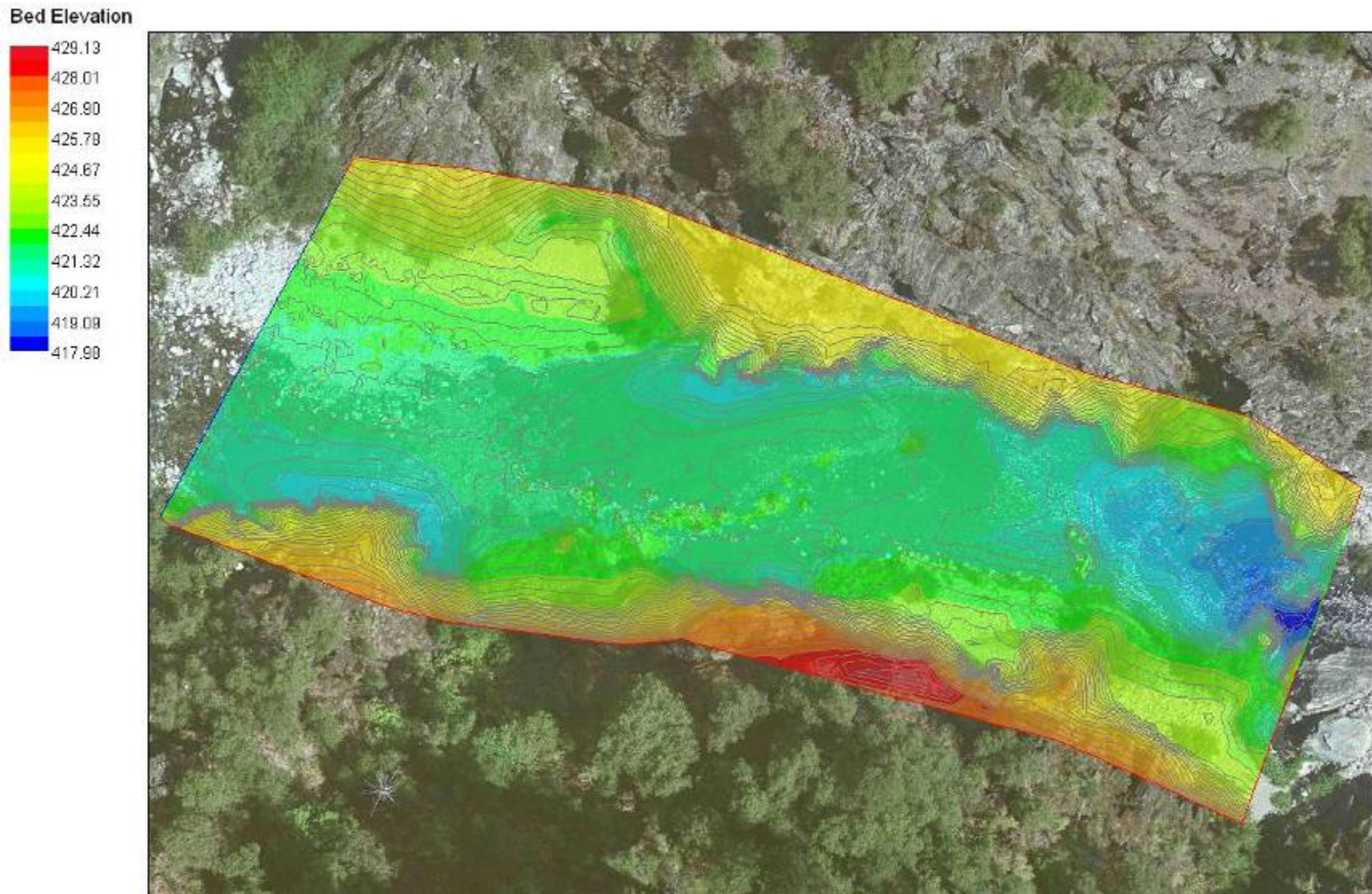


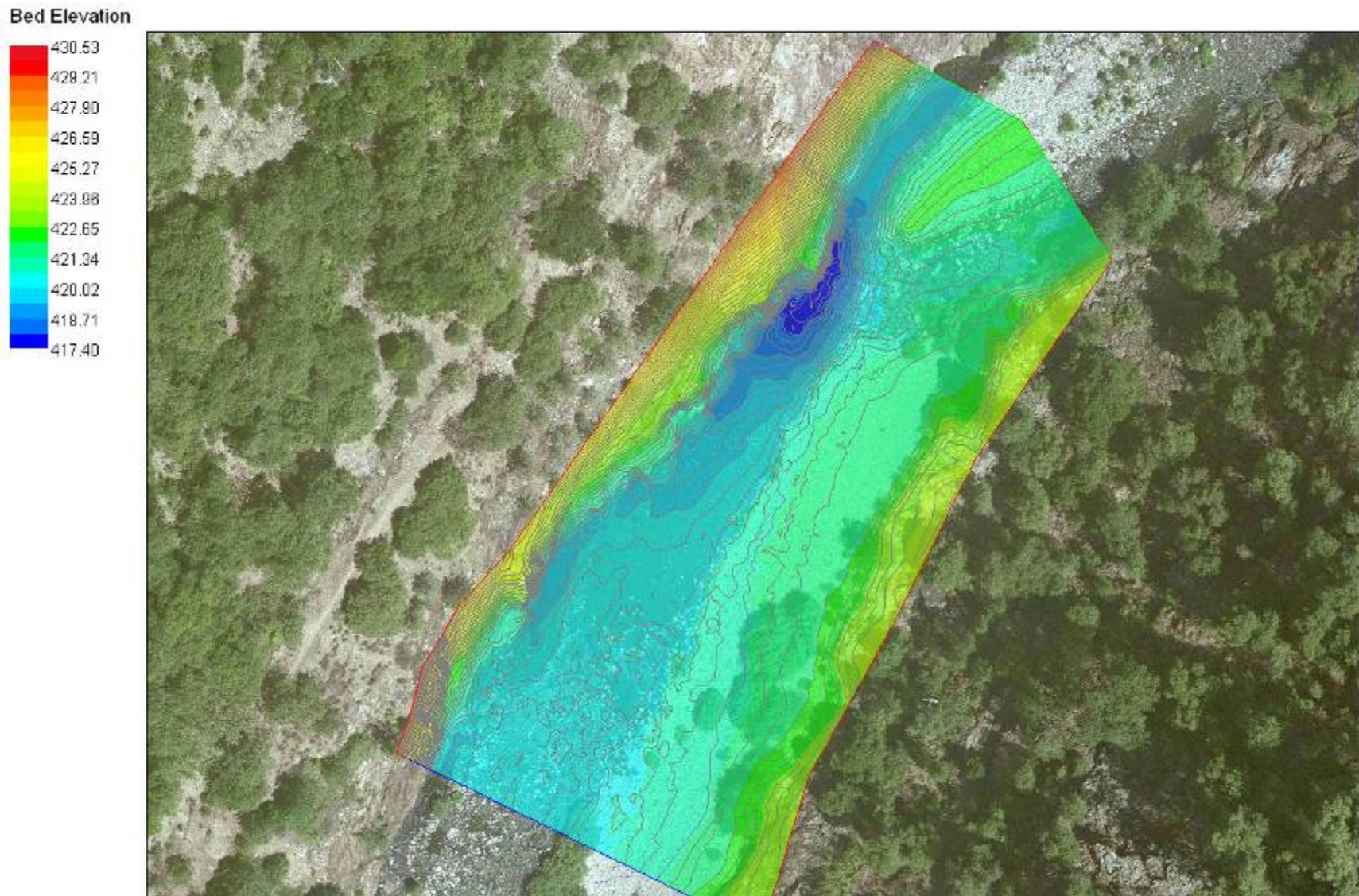
Figure K-2. Middle Fork American River 26.2 Downstream Site Bed Topography (0.25 m Contours).



**Figure K-3. Rubicon River 3.5 Upstream Site Bed Topography (0.25 m Contours).**



**Figure K-4. Rubicon River 3.5 Downstream Site Bed Topography (0.25 m Contours).**



**Figure K-5. Middle Fork American River 14.1 – Fords Bar Whole Site Bed Topography (2.5 m Contours).**

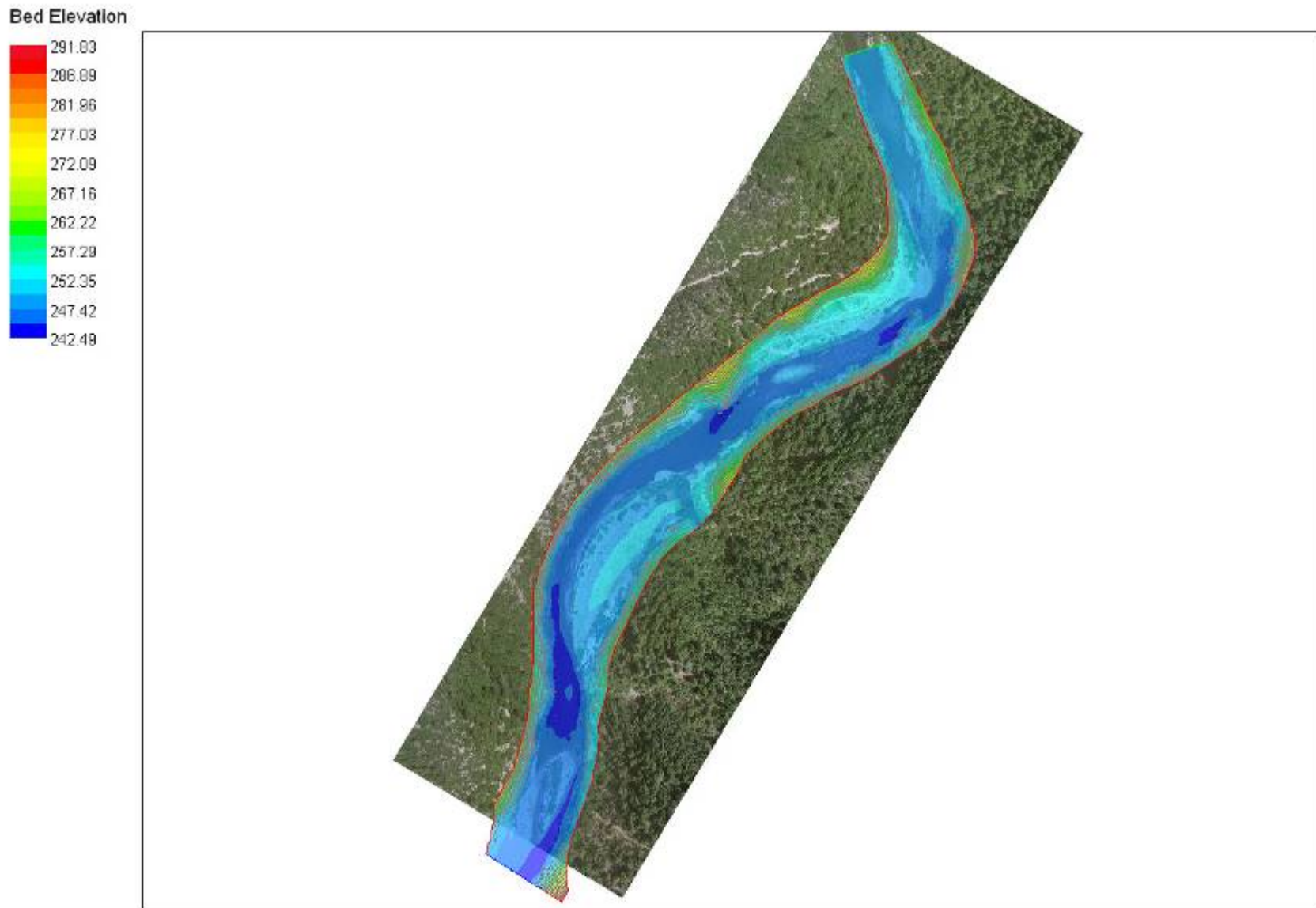


Figure K-6. Middle Fork American River 14.1 – Fords Bar Upstream Bed Topography (0.5 m Contours).

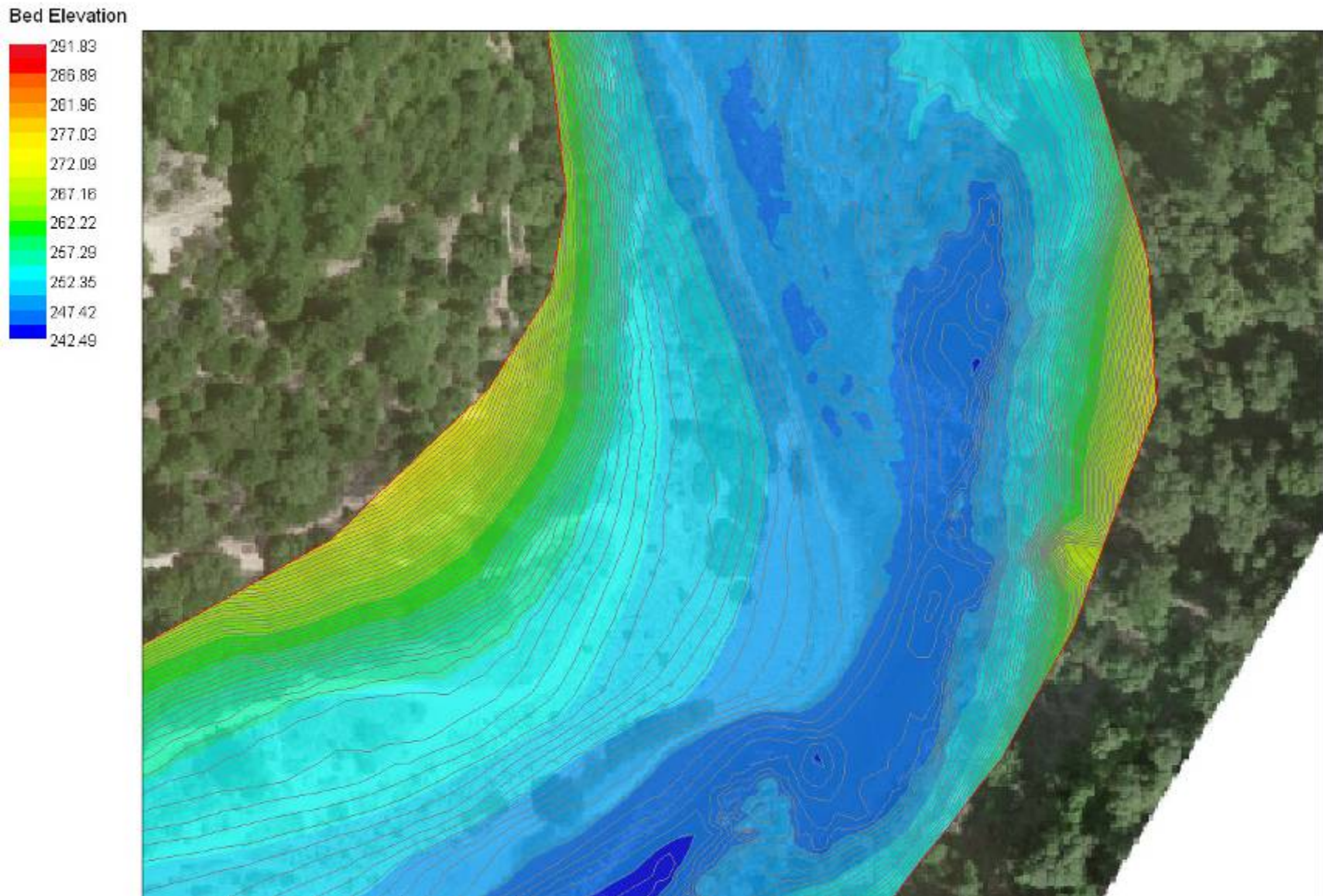


Figure K-7. Middle Fork American River 4.8 – Buckeye Bar Whole Site Bed Topography (0.75 m Contours).

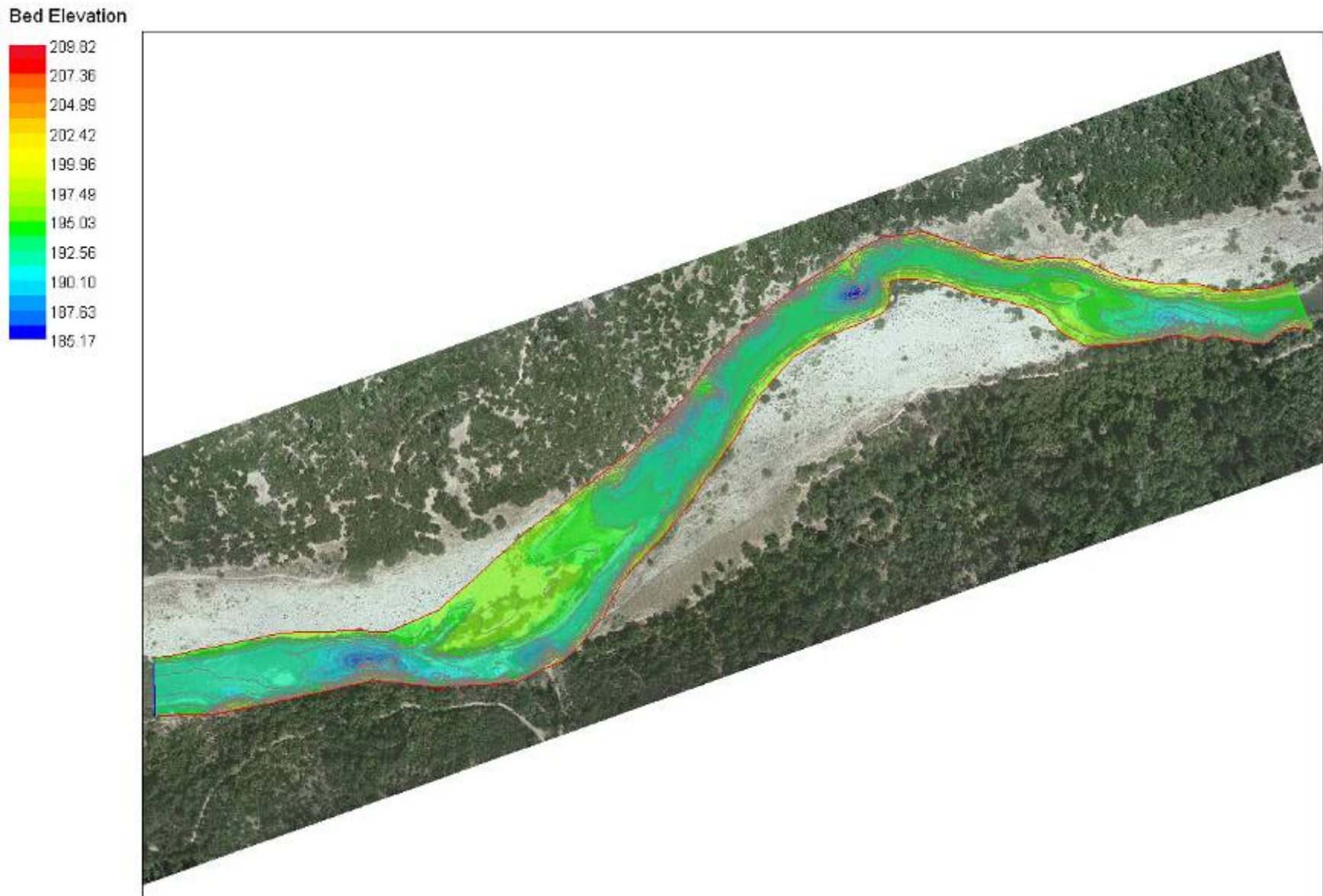
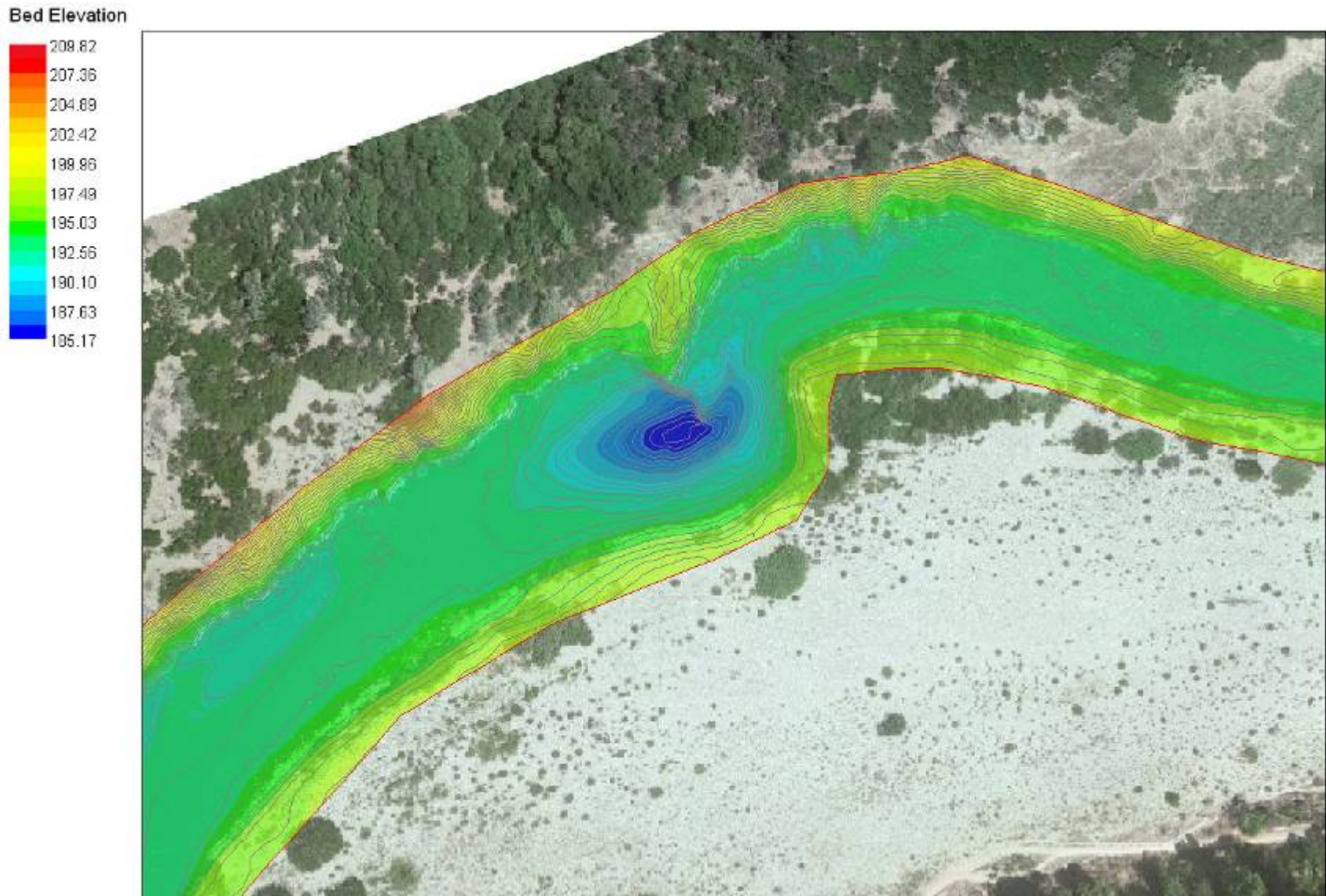


Figure K-8. Middle Fork American River 4.8 – Buckeye Bar Upstream Bed Topography (0.5 m Contours).



**MAPS**

**ATTACHMENT A**

**2D Hydrodynamics Depth and Velocity AVIS by Site**

(See Attached Electronic Media)

**APPENDIX L**  
**2D Study Site Hydrodynamics Calibration Results**

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- Table L-1. Summary of Error Between Measured and Modeled Water Surface Elevations for Validation of 2D Hydrodynamics.

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- Figure L-2. Stage-Discharge Regression for 2D Hydrodynamics Modeling at Rubicon River Mile 3.5, (Top) Upstream Site and (Bottom) Downstream Site.
- Figure L-3. Stage-Discharge Regression for 2D Hydrodynamics Modeling at Middle Fork American River Mile 14.1, Fords Bar.
- Figure L-4. Stage-Discharge Regression for 2D Hydrodynamics Modeling at Middle Fork American River Mile 4.8, Buckeye Bar.

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- Figure L-6. Modeled Velocity and Depth Validations for Buckeye Bar (Top) Transect 3 and (Bottom) Transect 4 at the Mid Calibration Flow 452 cfs. Velocities Measured by ADP Method.
- Figure L-7. Modeled Velocity and Depth Validations for Buckeye Bar (Top) Transect 5 (Wading Method) and (Bottom) Transect 6 (ADP Method) at the Mid Calibration Flow 452 cfs.
- Figure L-8. Modeled Velocity and Depth Validations for Fords Bar (Top) Approximate Transect 1 Location at the Mid Calibration Flow 407.6 cfs (Wading Method) and Approximate Transect 2 Location at the High Calibration Flow 1018 cfs (ADP Method)
- Figure L-9. Modeled Velocity and Depth Validations for Fords Bar (Top) Approximate Transect 3 Location at the High Calibration Flow 1018 cfs (ADP Method) and Approximate Transect 4 Location at the Mid Calibration Flow 407.6 cfs (Wading Method).

Scatter Plots of Velocity Validation Data

- Figure L-10. Modeled versus Measured Depth and Velocity for the Middle Fork American River Mile 26.2, Downstream Site.
- Figure L-11. Modeled versus Measured Depth and Velocity for the Rubicon River Mile 3.5, Upstream Site.
- Figure L-12. Modeled versus Measured and Velocity for the Middle Fork American River Mile 26.2, Upstream Site.
- Figure L-13. Modeled versus Measured Depth and Velocity for the Rubicon River Mile 3.5, Downstream Site.

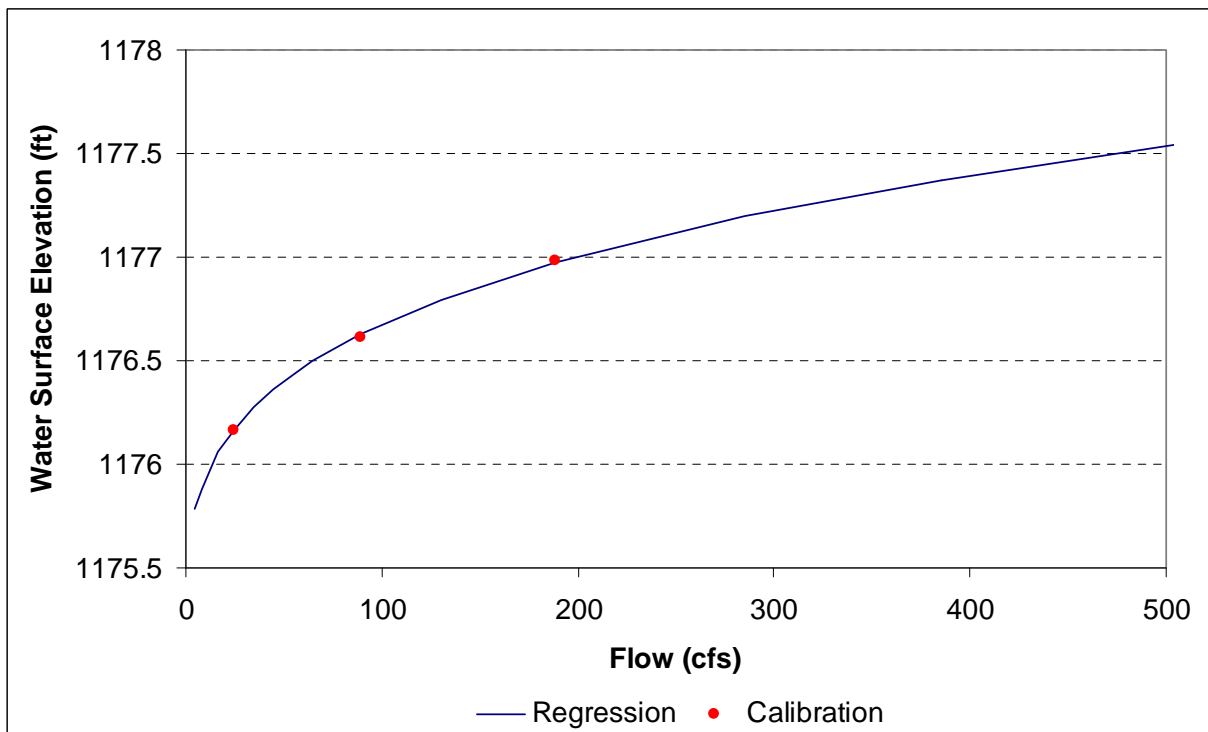
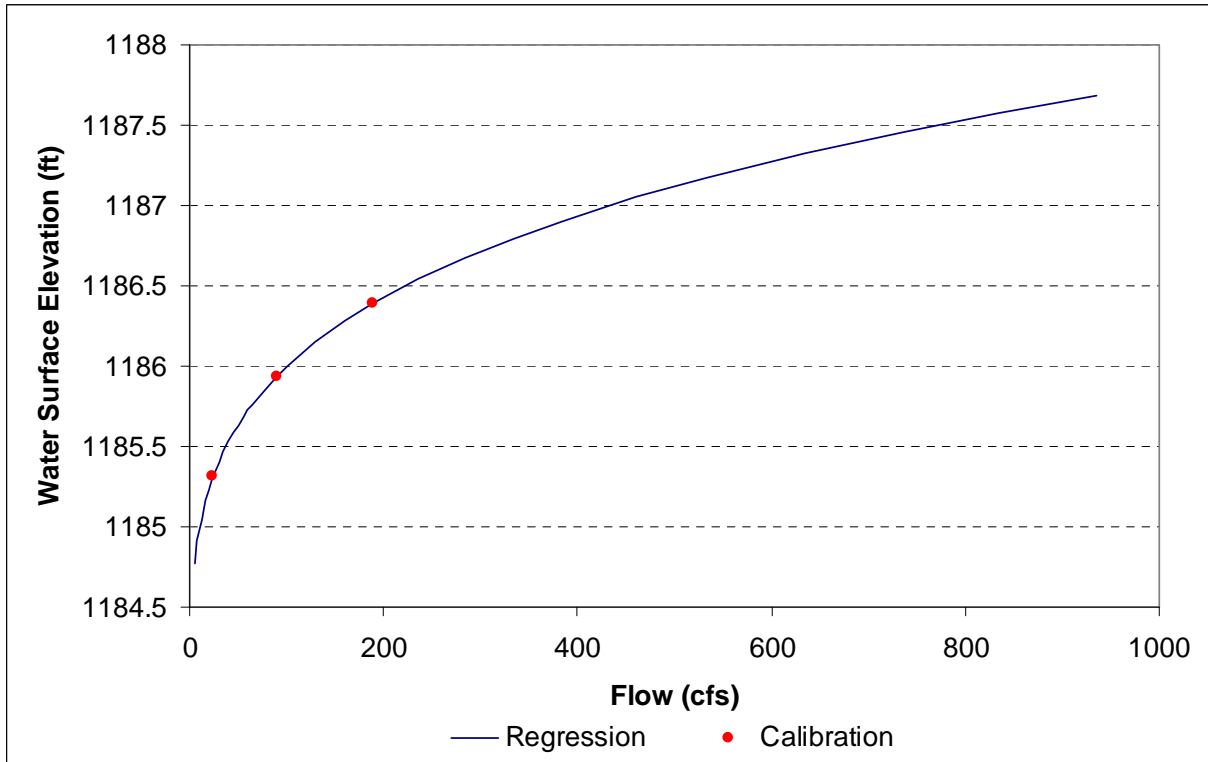
**TABLE**

**Table L-1. Summary of Error Between Measured and Modeled Water Surface Elevations for Validation of 2D Hydrodynamics.**

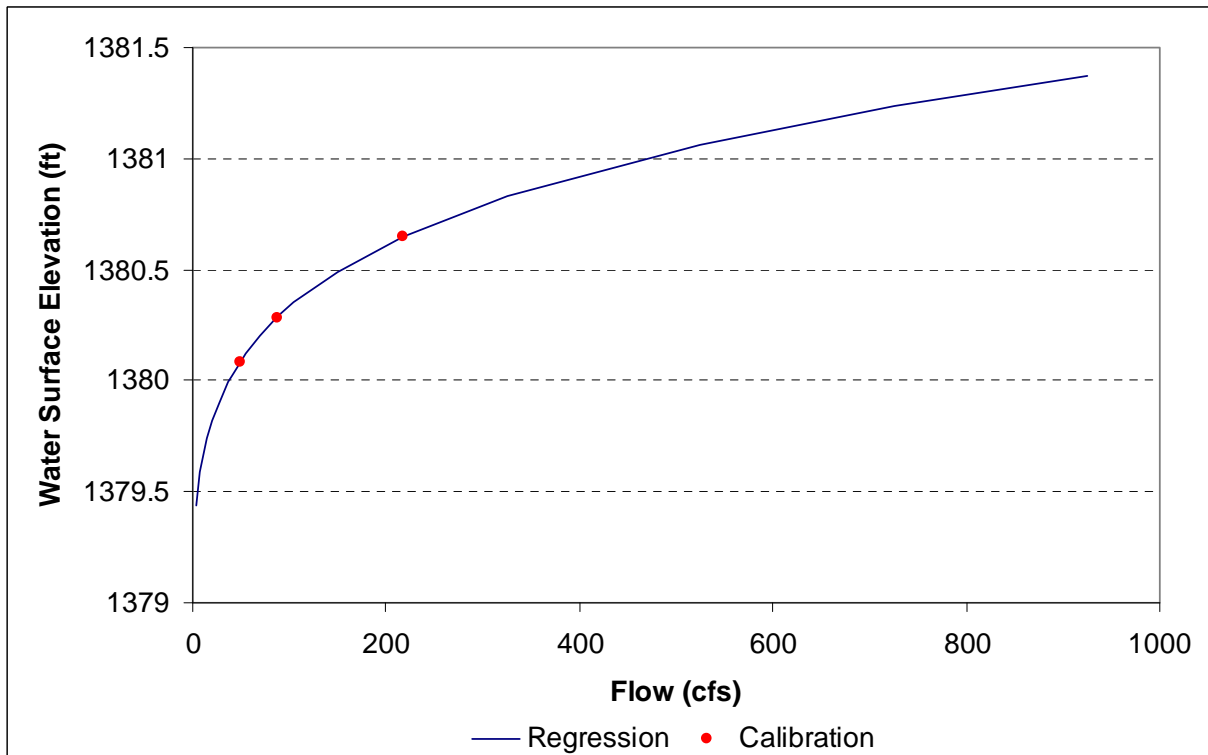
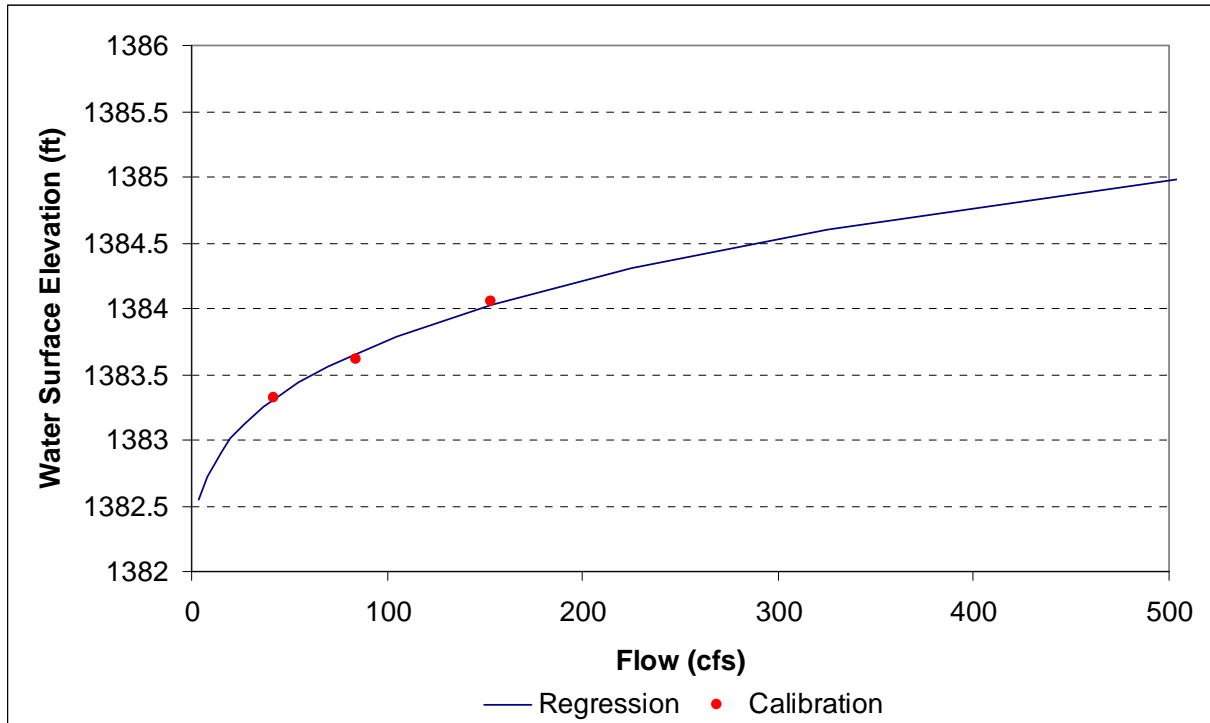
Site	Calibration Flow (cfs)	n	Average Error Modeled - Measured (ft)	Root Mean Square Error (ft)
MF26.2 Upstream	188.4	6	0.01	0.07
	89.6	6	-0.05	0.11
	24.2	6	-0.1	0.11
MF26.2 Downstream	188.4	6	0.05	0.06
	89.6	6	0.02	0.05
	24.2	6	-0.03	0.04
R3.5 Upstream	153.1	9	-0.07	0.11
	84	37	-0.04	0.08
	41.7	56	-0.05	0.10
R3.5 Downstream	218.1	7	-0.08	0.10
	88.5	33	-0.04	0.07
	48.6	80	-0.10	0.13
Fords Bar	1018	58	0.02	0.13
	407.6	73	-0.02	0.14
	101.3	128	-0.01	0.15
Buckeye Bar	911	53	0.06	0.14
	452	160	-0.03	0.12
	111	117	-0.06	0.14

**FIGURES**

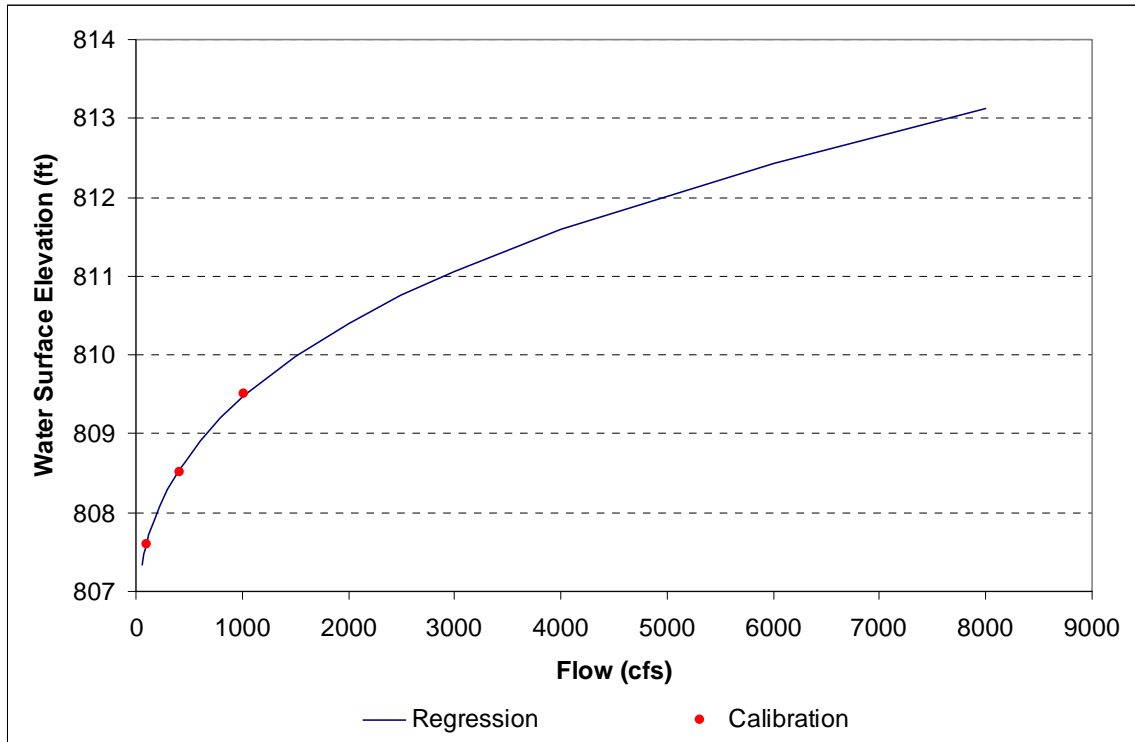
**Figure L-1. Stage-Discharge Regression for 2D Hydrodynamics Modeling at Middle Fork American River Mile 26.2 above Ralston Afterbay, (Top) Upstream Site and (Bottom) Downstream Site.**



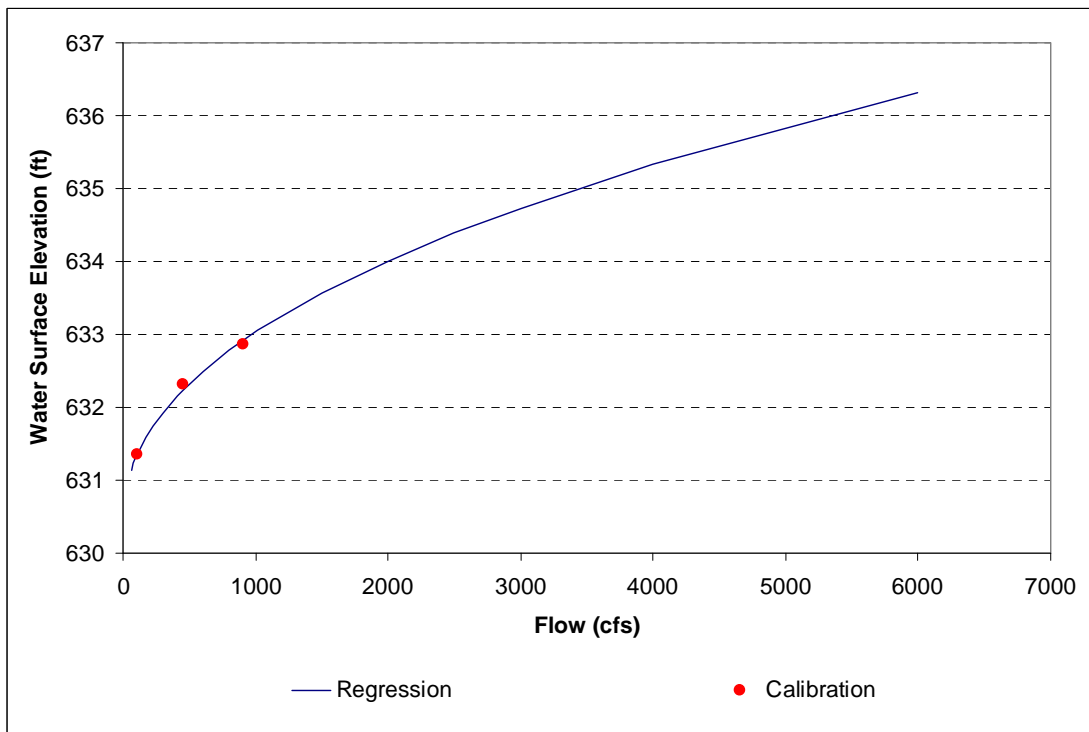
**Figure L-2. Stage-Discharge Regression for 2D Hydrodynamics Modeling at Rubicon River Mile 3.5, (Top) Upstream Site and (Bottom) Downstream Site.**



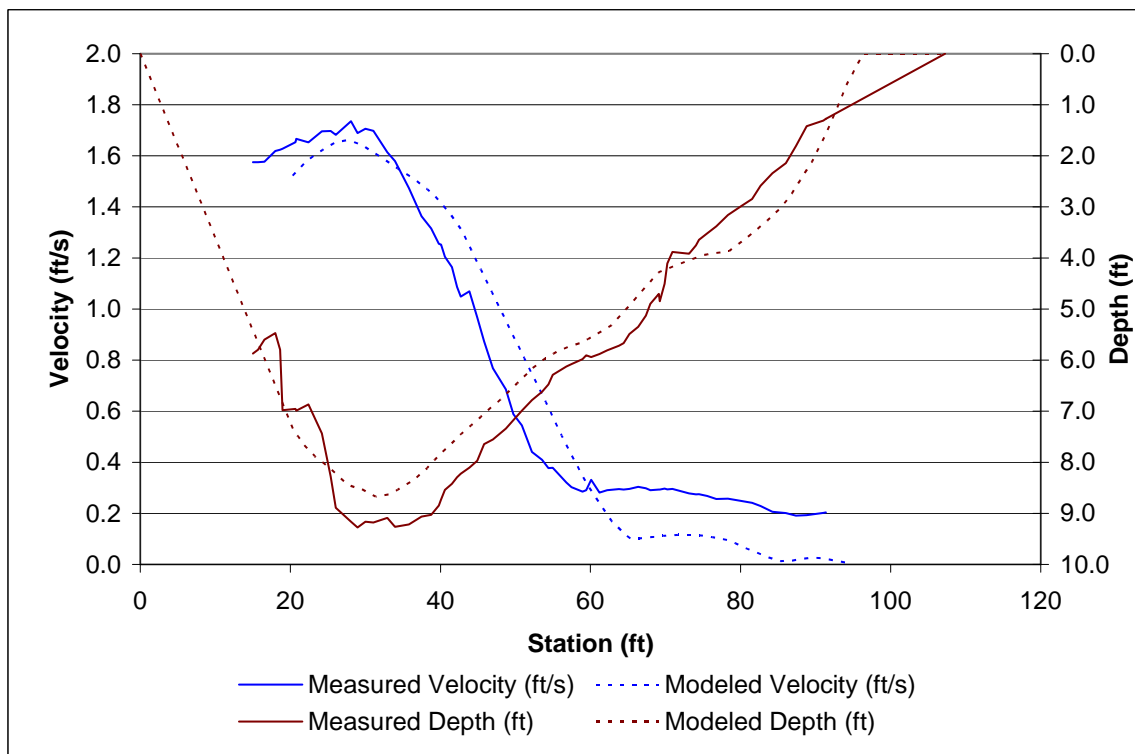
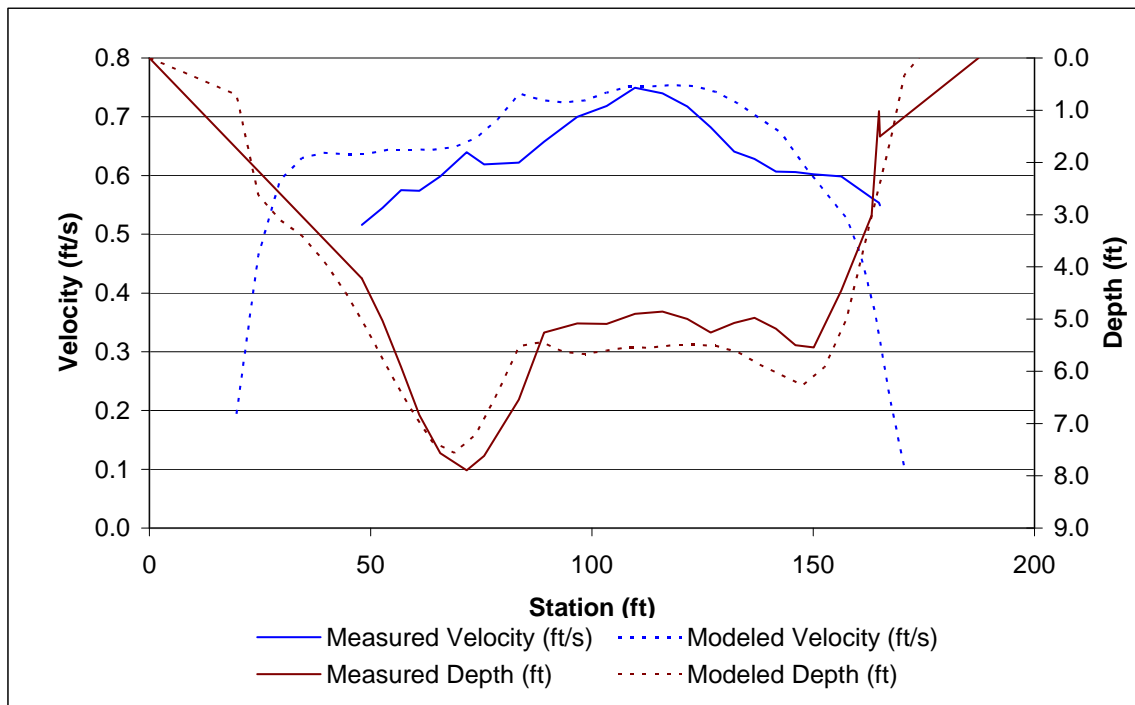
**Figure L-3. Stage-Discharge Regression for 2D Hydrodynamics Modeling at Middle Fork American River Mile 14.1, Fords Bar.**



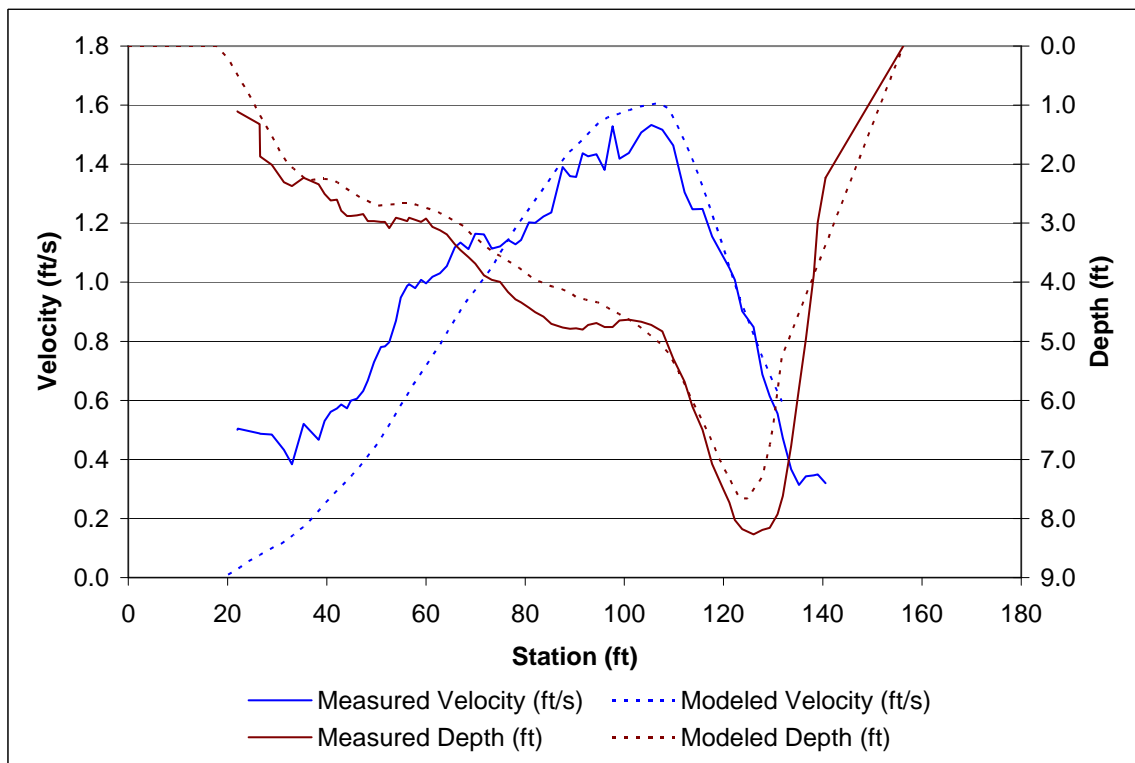
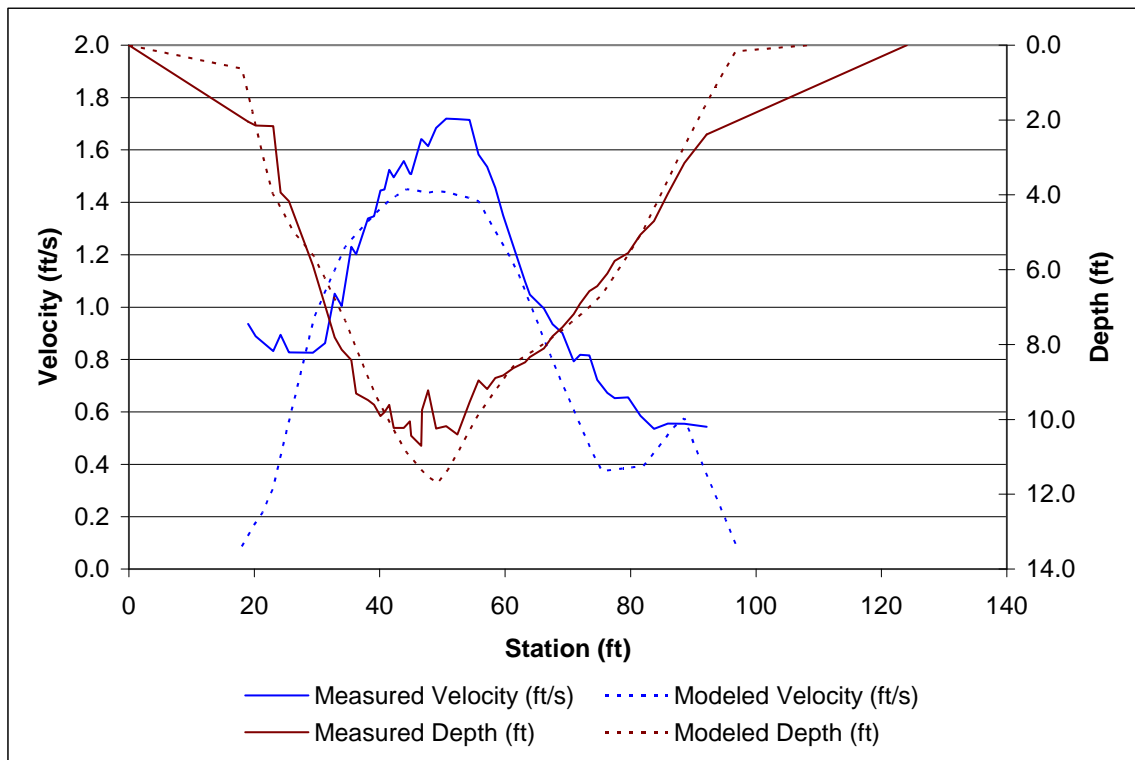
**Figure L-4. Stage-Discharge Regression for 2D Hydrodynamics Modeling at Middle Fork American River Mile 4.8, Buckeye Bar.**



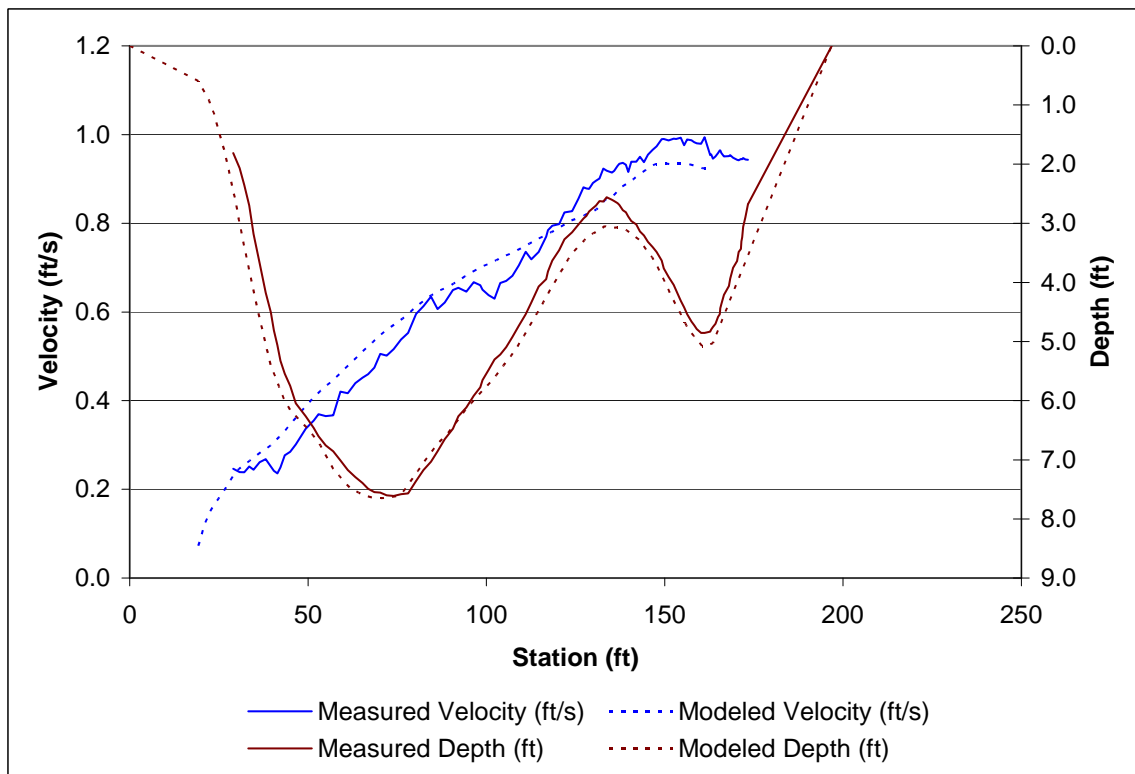
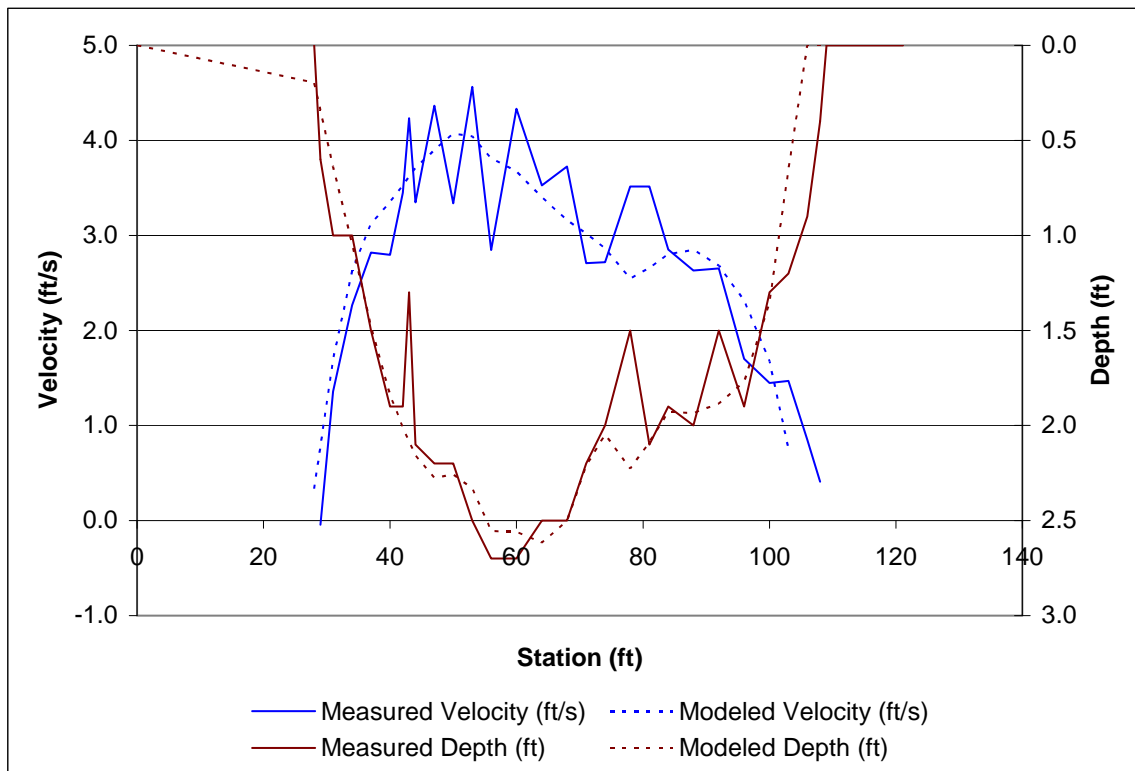
**Figure L-5. Modeled Velocity and Depth Validations for Buckeye Bar (Top) Transect 1 and (Bottom) Transect 2 at the Mid Calibration Flow 452 cfs. Velocities Measured by Acoustic Doppler Profiler (ADP) Method.**



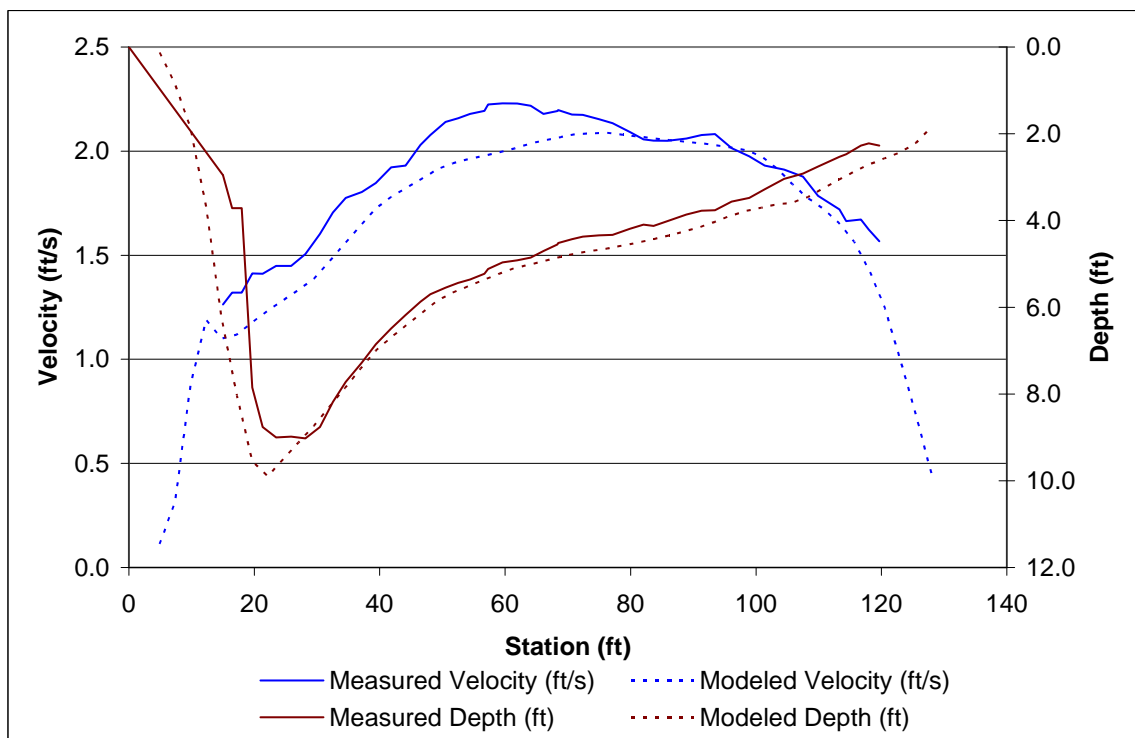
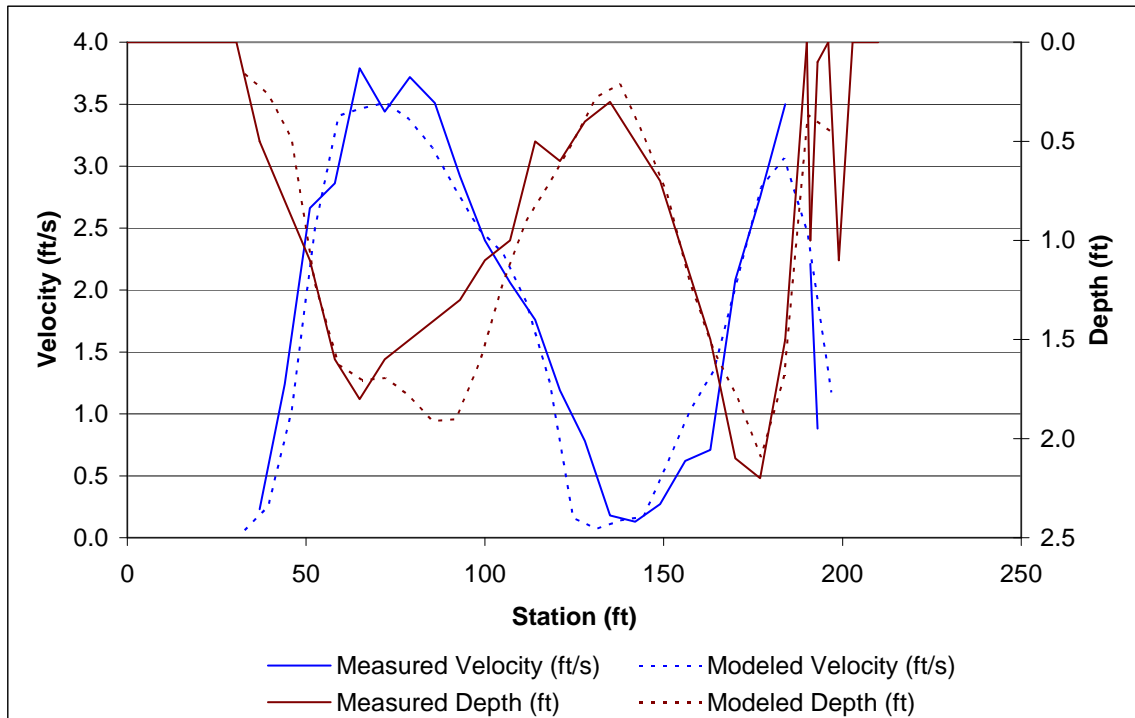
**Figure L-6. Modeled Velocity and Depth Validations for Buckeye Bar (Top) Transect 3 and (Bottom) Transect 4 at the Mid Calibration Flow 452 cfs. Velocities Measured by Acoustic Doppler Profiler (ADP) Method.**



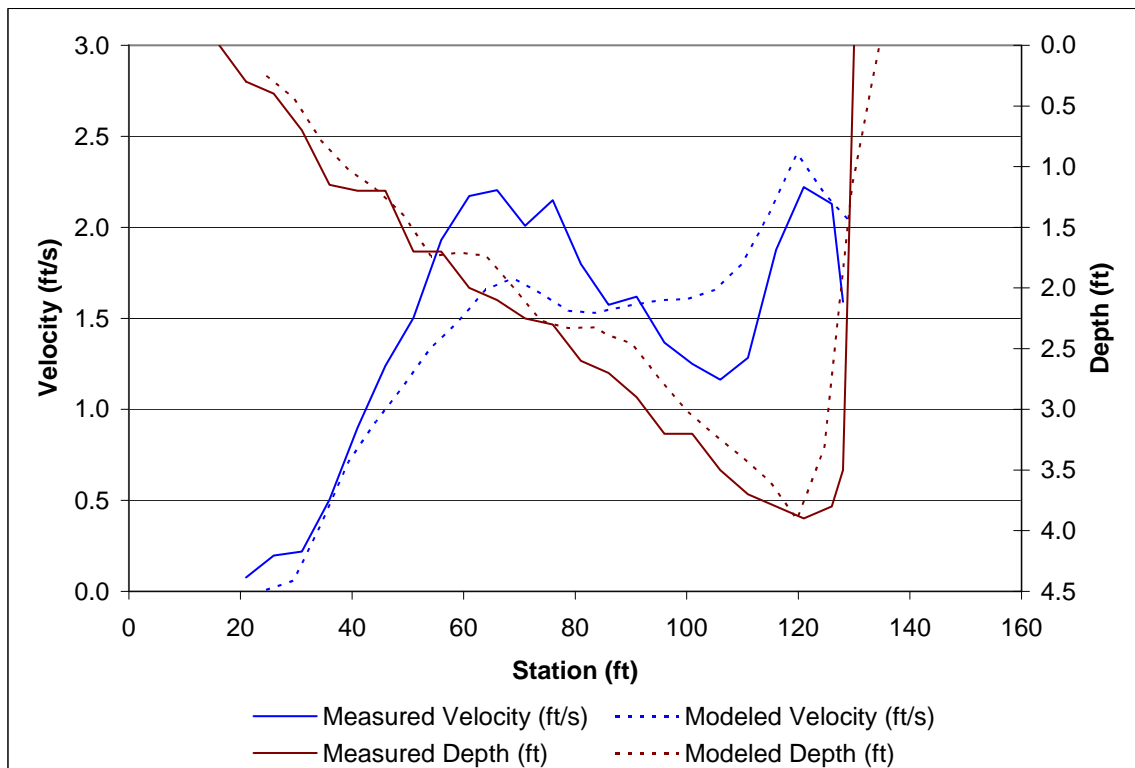
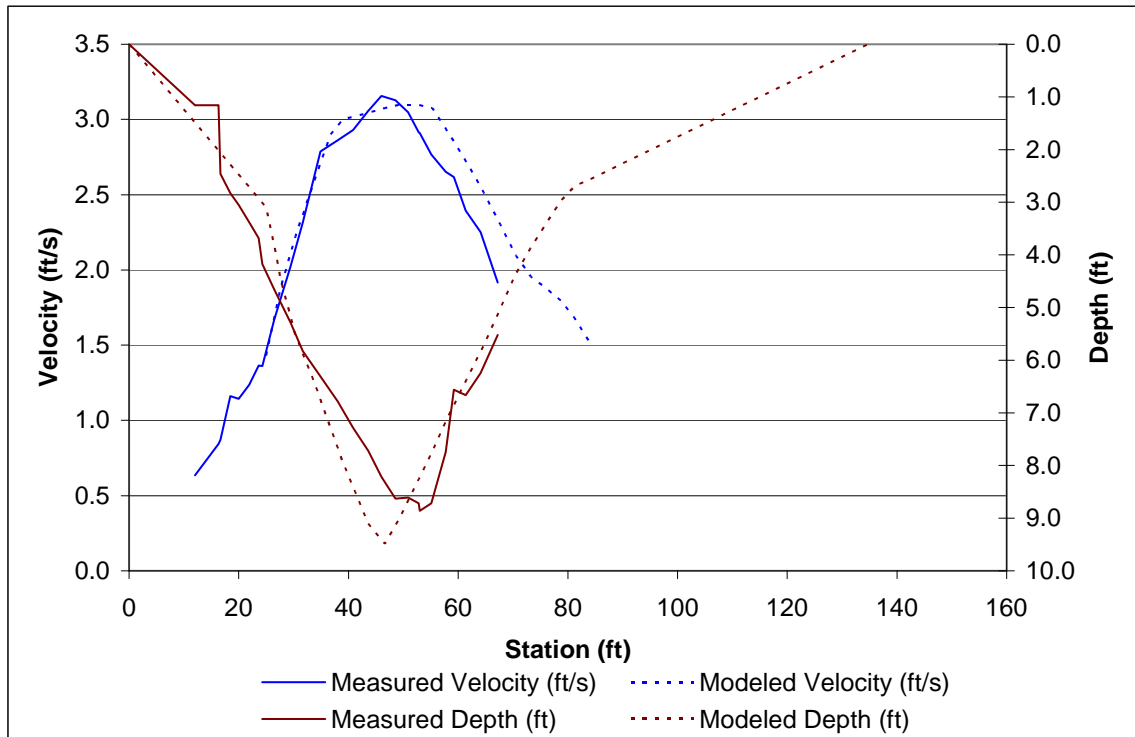
**Figure L-7. Modeled Velocity and Depth Validations for Buckeye Bar (Top) Transect 5 (Wading Method) and (Bottom) Transect 6 (ADP Method) at the Mid Calibration Flow 452 cfs.**



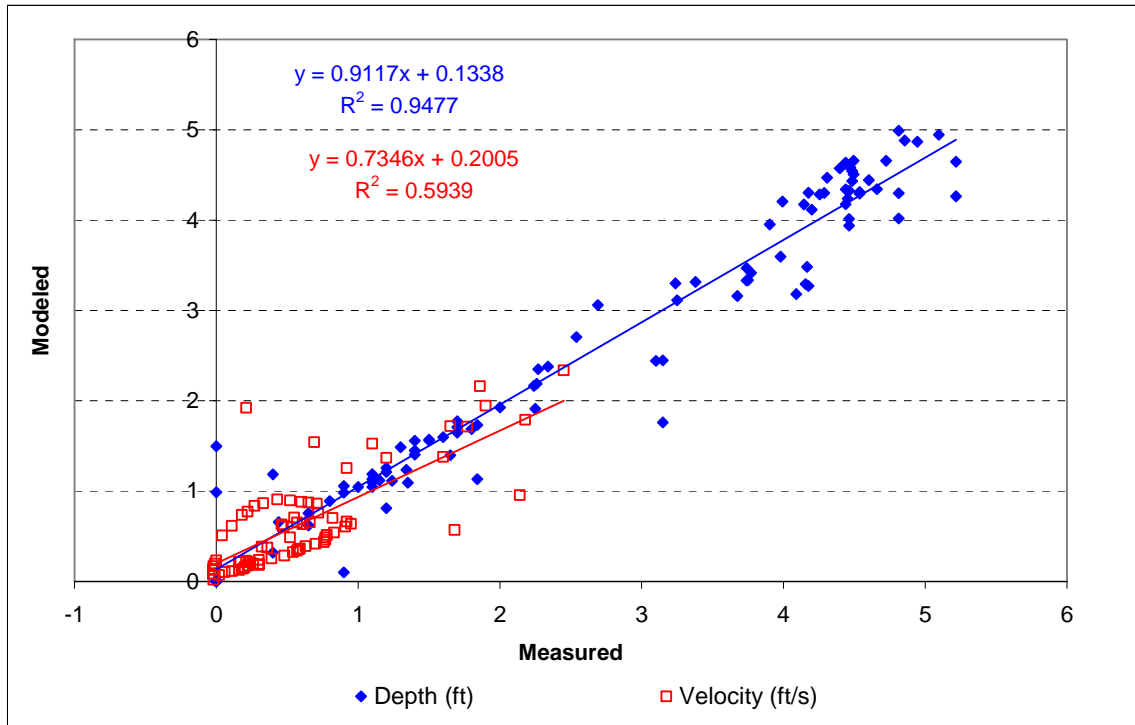
**Figure L-8. Modeled Velocity and Depth Validations for Fords Bar (Top) Approximate Transect 1 Location at the Mid Calibration Flow 407.6 cfs (Wading Method) and Approximate Transect 2 Location at the High Calibration Flow 1018 cfs (ADP Method).**



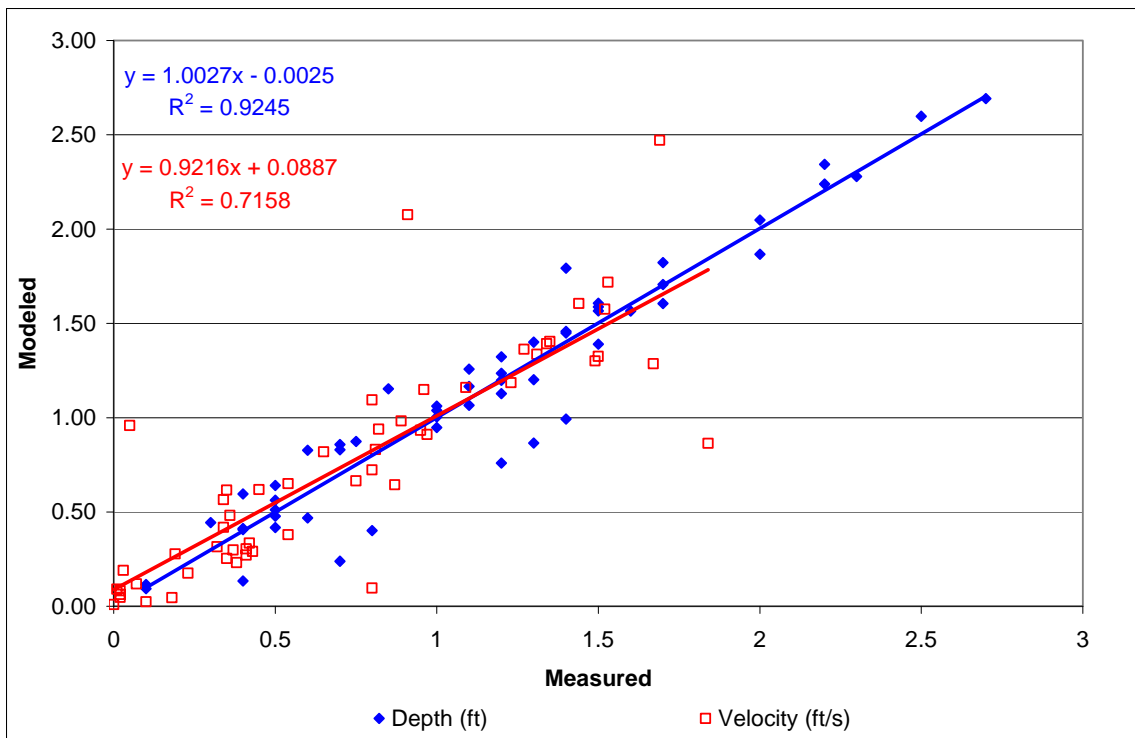
**Figure L-9. Modeled Velocity and Depth Validations for Fords Bar (Top) Approximate Transect 3 Location at the High Calibration Flow 1018 cfs (ADP Method) and Approximate Transect 4 Location at the Mid Calibration Flow 407.6 cfs (Wading Method).**



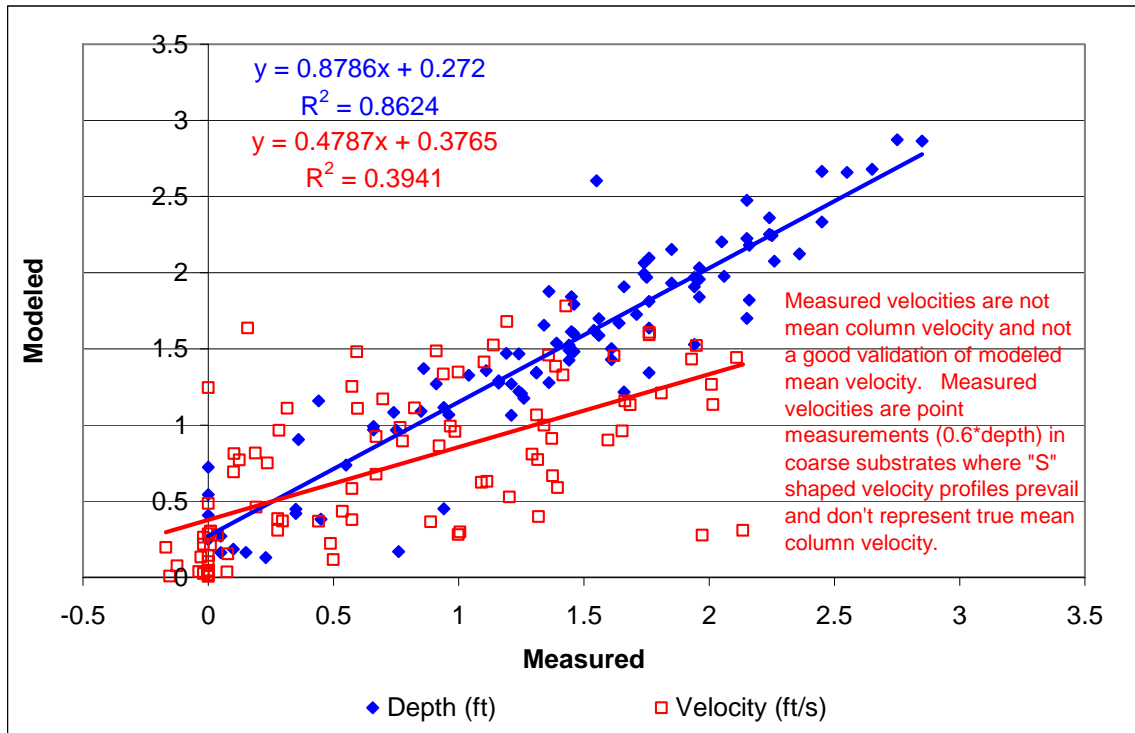
**Figure L-10. Modeled versus Measured Depth and Velocity for the Middle Fork American River Mile 26.2, Downstream Site.**



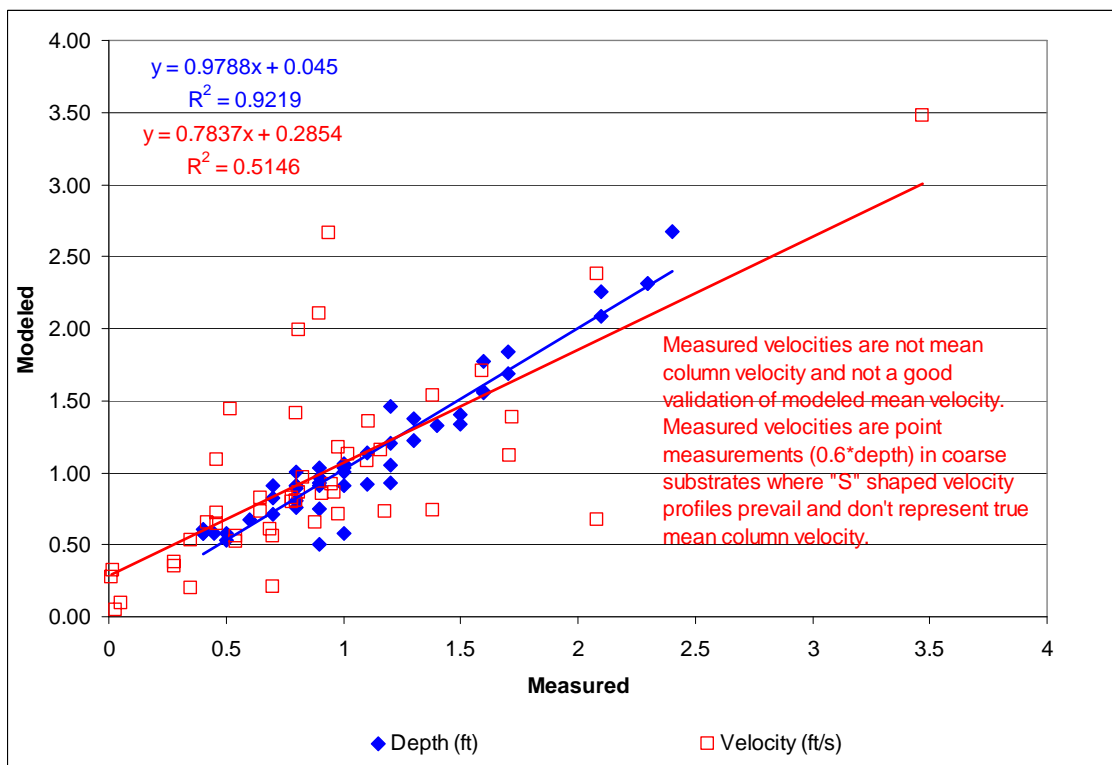
**Figure L-11. Modeled versus Measured Depth and Velocity for the Rubicon River Mile 3.5, Upstream Site.**



**Figure L-12. Modeled versus Measured and Velocity for the Middle Fork American River Mile 26.2, Upstream Site.**



**Figure L-13. Modeled versus Measured Depth and Velocity for the Rubicon River Mile 3.5, Downstream Site.**



**APPENDIX M**

**Habitat Area Versus Flow Relationships**

(See Attached Electronic Media)

**List of Attachments**

Attachment A. Database of Habitat Versus Flow Relationship Development for Each Site

**Duncan Creek D6.3**

Figure M-1. Duncan Creek – D6.3 Weighted Usable Area (top) and Percent of Maximum Weighted Usable Area (bottom).

Table M-1A. Duncan Creek – D6.3 Weighted Usable Area.

Table M-1B. Duncan Creek – D6.3 Percent of Maximum Weighted Usable Area.

Figure M-2. Duncan Creek – D6.3 Spatial Niche Area by Individual Niche (top) and by Cumulative Area (bottom).

Figure M-3. Duncan Creek – D6.3 Wetted Perimeter.

**North Fork Long Canyon Creek NFLC1.9**

Figure M-4. North Fork Long Canyon Creek – NFLC1.9 Weighted Usable Area (top) and Percent of Maximum Weighted Usable Area (bottom).

Table M-2A. North Fork Long Canyon Creek – NFLC1.9 Weighted Usable Area.

Table M-2B. North Fork Long Canyon Creek – NFLC1.9 Percent of Maximum Weighted Usable Area.

Figure M-5. North Fork Long Canyon Creek – NFLC1.9 Spatial Niche Area by Individual Niche (top) and by Cumulative Area (bottom).

Figure M-6. North Fork Long Canyon Creek – NFLC1.9 Wetted Perimeter.

**South Fork Long Canyon Creek SFLC2.3**

Figure M-7. South Fork Long Canyon Creek – SFLC2.3 Weighted Usable Area (top) and Percent of Maximum Weighted Usable Area (bottom).

Table M-3A. South Fork Long Canyon Creek – SFLC2.3 Weighted Usable Area.

Table M-3B. South Fork Long Canyon Creek – SFLC2.3 Percent of Maximum Weighted Usable Area.

Figure M-8. South Fork Long Canyon Creek – SFLC2.3 Spatial Niche Area by Individual Niche (top) and by Cumulative Area (bottom).

Figure M-9. South Fork Long Canyon Creek – SFLC2.3 Wetted Perimeter.

**Long Canyon Creek – LC9.0**

Figure M-10. Long Canyon Creek – LC9.0 Weighted Usable Area (top) and Percent of Maximum Weighted Usable Area (bottom).

Table M-4A. Long Canyon Creek – LC9.0 Weighted Usable Area.

Table M-4B. Long Canyon Creek – LC9.0 Percent of Maximum Weighted Usable Area.

Figure M-11. Long Canyon Creek – LC9.0 Spatial Niche Area by Individual Niche (top) and by Cumulative Area (bottom).

Figure M-12. Long Canyon Creek – LC9.0 Wetted Perimeter.

Middle Fork of the American River MF44.7

Figure M-13. Middle Fork of the American River – MF44.7 Weighted Usable Area (top) and Percent of Maximum Weighted Usable Area (bottom).

Table M-5A. Middle Fork of the American River – MF44.7 Weighted Usable Area.

Table M-5B. Middle Fork of the American River – MF44.7 Percent of Maximum Weighted Usable Area.

Figure M-14. Middle Fork of the American River – MF44.7 Spatial Niche Area by Individual Niche (top) and by Cumulative Area (bottom).

Figure M-15. Middle Fork of the American River – MF44.7 Wetted Perimeter.

Middle Fork of the American River MF36.2

Figure M-16. Middle Fork of the American River – MF36.2 Weighted Usable Area (top) and Percent of Maximum Weighted Usable Area (bottom).

Table M-6A. Middle Fork of the American River – MF36.2 Weighted Usable Area.

Table M-6B. Middle Fork of the American River – MF36.2 Percent of Maximum Weighted Usable Area.

Figure M-17. Middle Fork of the American River – MF36.2 Spatial Niche Area by Individual Niche (top) and by Cumulative Area (bottom).

Figure M-18. Middle Fork of the American River – MF36.2 Wetted Perimeter.

Middle Fork of the American River 26.2

Figure M-19. Middle Fork of the American River – MF26.2 Weighted Usable Area (top) and Percent of Maximum Weighted Usable Area (bottom).

Table M-7A. Middle Fork of the American River – MF26.2 Weighted Usable Area.

Table M-7B. Middle Fork of the American River – MF26.2 Percent of Maximum Weighted Usable Area.

Figure M-20. Middle Fork of the American River – MF26.2 Spatial Niche Area by Individual Niche (top) and by Cumulative Area (bottom).

Figure M-21. Middle Fork of the American River – MF26.2 Wetted Perimeter.

Rubicon River R25.7

Figure M-22. Rubicon River – R25.7 Weighted Usable Area (top) and Percent of Maximum Weighted Usable Area (bottom).

Table M-8A. Rubicon River – R25.7 Weighted Usable Area.

Table M-8B. Rubicon River – R25.7 Percent of Maximum Weighted Usable Area.

Figure M-23. Rubicon River – R25.7 Spatial Niche Area by Individual Niche (top) and by Cumulative Area (bottom).

Figure M-24. Rubicon River – R25.7 Wetted Perimeter.

### Rubicon River R20.9

- Figure M-25. Rubicon River – R20.9 Weighted Usable Area (top) and Percent of Maximum Weighted Usable Area (bottom).
- Table M-9A. Rubicon River – R20.9 Weighted Usable Area.
- Table M-9B. Rubicon River – R20.9 Percent of Maximum Weighted Usable Area.
- Figure M-26. Rubicon River – R20.9 Spatial Niche Area by Individual Niche (top) and by Cumulative Area (bottom).
- Figure M-27. Rubicon River – R20.9 Wetted Perimeter.

### Rubicon River R3.5

- Figure M-28. Rubicon River – R3.5 Weighted Usable Area (top) and Percent of Maximum Weighted Usable Area (bottom).
- Table M-10A. Rubicon River – R3.5 Weighted Usable Area.
- Table M-10B. Rubicon River – R3.5 Percent of Maximum Weighted Usable Area.
- Figure M-29. Rubicon River – R3.5 Spatial Niche Area by Individual Niche (top) and by Cumulative Area (bottom).
- Figure M-30. Rubicon River – R3.5 Wetted Perimeter.

### Middle Fork American River MF14.1

- Figure M-31. Middle Fork American River - MF14.1 Weighted Usable Area (top) and Percent of Maximum Weighted Usable Area (bottom).
- Table M-11A. Middle Fork American River - MF14.1 Weighted Usable Area.
- Table M-11B. Middle Fork American River - MF14.1 Percent of Maximum Weighted Usable Area.
- Figure M-32. Middle Fork American River - MF14.1 Spatial Niche Area by Individual Niche (top) and by Cumulative Area (bottom).
- Figure M-33. Middle Fork American River - MF14.1 Wetted Bed and Food Production by Flow.

### Middle Fork American River MF4.8

- Figure M-34. Middle Fork American River – MF4.8 Weighted Usable Area (top) and Percent of Maximum Weighted Usable Area (bottom).
- Table M-12A. Middle Fork American River – MF4.8 Weighted Usable Area.
- Table M-12B. Middle Fork American River – MF4.8 Percent of Maximum Weighted Usable Area.
- Figure M-35. Middle Fork American River – MF4.8 Spatial Niche Area by Individual Niche (top) and by Cumulative Area (bottom).
- Figure M-36. Middle Fork American River – MF4.8 Wetted Bed and Food Production by Flow.

**ATTACHMENT A**

**Database of Habitat Versus Flow Relationship Development for Each Site**

(See Attached Electronic Media)

**APPENDIX N**

**Habitat Time Series Relationships**

(See Attached Electronic Media)

**List of Attachments**

Attachment A: Database of Habitat Time Series Relationship Development for Each Site

**Duncan Creek Below Diversion – Top of Reach**

Figure N1A – 1A. Duncan Creek – D6.3 Rainbow Trout Spawning Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 800.804 (Top of Reach).

Figure N1A – 1B. Duncan Creek – D6.3 Rainbow Trout Spawning Depth Sensitivity Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 800.804 (Top of Reach).

Figure N1A – 2A. Duncan Creek – D6.3 Rainbow Trout Small Stream Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 800.804 (Top of Reach).

Figure N1A – 2B. Duncan Creek – D6.3 Rainbow Trout Small Stream Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 800.804 (Top of Reach).

Figure N1A – 2C. Duncan Creek – D6.3 Rainbow Trout Fry Summer (June - August) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 800.804 (Top of Reach).

**Duncan Creek Below Diversion – Bottom of Reach**

Figure N1B – 1A. Duncan Creek – D6.3 Rainbow Trout Spawning Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 805.806 (Bottom of Reach).

Figure N1B – 1B. Duncan Creek – D6.3 Rainbow Trout Spawning Depth Sensitivity Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 805.806 (Bottom of Reach).

Figure N1B – 2A. Duncan Creek – D6.3 Rainbow Trout Small Stream Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above

- Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 805.806 (Bottom of Reach).
- Figure N1B – 2B. Duncan Creek – D6.3 Rainbow Trout Small Stream Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 805.806 (Bottom of Reach).
- Figure N1B – 2C. Duncan Creek – D6.3 Rainbow Trout Fry Summer (June - August) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 805.806 (Bottom of Reach).

#### North Fork Long Canyon Creek Below Diversion

- Figure N2 – 1A. North Fork Long Canyon – NFLC1.9 Rainbow Trout Spawning Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 817.819.
- Figure N2 – 1B. North Fork Long Canyon – NFLC1.9 Rainbow Trout Spawning Depth Sensitivity Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 817.819.
- Figure N2 – 2A. North Fork Long Canyon – NFLC1.9 Rainbow Trout Small Stream Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 817.819.
- Figure N2 – 2B. North Fork Long Canyon – NFLC1.9 Rainbow Trout Small Stream Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 817.819.
- Figure N2 – 2C. North Fork Long Canyon – NFLC1.9 Rainbow Trout Fry Summer (June - August) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 817.819.

#### South Fork Long Canyon Creek Below Diversion

- Figure N3 – 1A. South Fork Long Canyon – SFLC2.3 Rainbow Trout Spawning Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 820.822.

- Figure N3 – 1B. South Fork Long Canyon – SFLC2.3 Rainbow Trout Spawning Depth Sensitivity Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 820.822.
- Figure N3 – 2A. South Fork Long Canyon – SFLC2.3 Rainbow Trout Small Stream Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 820.822.
- Figure N3 – 2B. South Fork Long Canyon – SFLC2.3 Rainbow Trout Small Stream Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 820.822.
- Figure N3 – 2C. South Fork Long Canyon – SFLC2.3 Rainbow Trout Fry Summer (June - August) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 820.822.

#### Long Canyon Creek Above Ramsey Crossing – Top of Reach

- Figure N4A – 1A. Long Canyon – LC9.0 Rainbow Trout Spawning Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 825.828 (Top of Reach).
- Figure N4A – 1B. Long Canyon – LC9.0 Rainbow Trout Spawning Depth Sensitivity Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 825.828 (Top of Reach).
- Figure N4A – 2A. Long Canyon – LC9.0 Rainbow Trout Small Stream Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 825.828 (Top of Reach).
- Figure N4A – 2B. Long Canyon – LC9.0 Rainbow Trout Small Stream Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 825.828 (Top of Reach).
- Figure N4A – 2C. Long Canyon – LC9.0 Rainbow Trout Fry Summer (June - August) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 825.828 (Top of Reach).

Long Canyon Creek Above Ramsey Crossing – Bottom of Reach

- Figure N4B – 1A. Long Canyon – LC9.0 Rainbow Trout Spawning Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 830.842 (Bottom of Reach).
- Figure N4B – 1B. Long Canyon – LC9.0 Rainbow Trout Spawning Depth Sensitivity Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 830.842 (Bottom of Reach).
- Figure N4B – 2A. Long Canyon – LC9.0 Rainbow Trout Small Stream Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 830.842 (Bottom of Reach).
- Figure N4B – 2B. Long Canyon – LC9.0 Rainbow Trout Small Stream Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 830.842 (Bottom of Reach).
- Figure N4B – 2C. Long Canyon – LC9.0 Rainbow Trout Fry Summer (June - August) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 830.842 (Bottom of Reach).

Middle Fork American River Below French Meadows – Top of Reach

- Figure N5A – 1A. Middle Fork of the American River – MF44.7 Rainbow Trout Spawning Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 530.802 (Top of Reach).
- Figure N5A – 1B. Middle Fork of the American River – MF44.7 Rainbow Trout Spawning Depth Sensitivity Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 530.802 (Top of Reach).
- Figure N5A – 2A. Middle Fork of the American River – MF44.7 Rainbow Trout Large Stream Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 530.802 (Top of Reach).

Figure N5A – 2B. Middle Fork of the American River – MF44.7 Rainbow Trout Large Stream Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 530.802 (Top of Reach).

Figure N5A – 2C. Middle Fork of the American River – MF44.7 Rainbow Trout Fry Summer (June - August) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 530.802 (Top of Reach).

Middle Fork American River Below French Meadows – Bottom of Reach

Figure N5B – 1A. Middle Fork of the American River – MF44.7 Rainbow Trout Spawning Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 802.806 + 806 Accretion (Bottom of Reach).

Figure N5B – 1B. Middle Fork of the American River – MF44.7 Rainbow Trout Spawning Depth Sensitivity Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 802.806 + 806 Accretion (Bottom of Reach).

Figure N5B – 2A. Middle Fork of the American River – MF44.7 Rainbow Trout Large Stream Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 802.806 + 806 Accretion (Bottom of Reach).

Figure N5B – 2B. Middle Fork of the American River – MF44.7 Rainbow Trout Large Stream Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 802.806 + 806 Accretion (Bottom of Reach).

Figure N5B – 2C. Middle Fork of the American River – MF44.7 Rainbow Trout Fry Summer (June - August) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 802.806 + 806 Accretion (Bottom of Reach).

Middle Fork American River Above Interbay – Top of Reach

Figure N6A – 1A. Middle Fork of the American River – MF36.2 Rainbow Trout Spawning Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 806.810 (Top of Reach).

- Figure N6A – 1B. Middle Fork of the American River – MF36.2 Rainbow Trout Spawning Depth Sensitivity Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 806.810 (Top of Reach).
- Figure N6A – 2A. Middle Fork of the American River – MF36.2 Rainbow Trout Large Stream Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 806.810 (Top of Reach).
- Figure N6A – 2B. Middle Fork of the American River – MF36.2 Rainbow Trout Large Stream Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 806.810 (Top of Reach).
- Figure N6A – 2C. Middle Fork of the American River – MF36.2 Rainbow Trout Fry Summer (June - August) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 806.810 (Top of Reach).

Middle Fork American River Above Interbay – Bottom of Reach

- Figure N6B – 1A. Middle Fork of the American River – MF36.2 Rainbow Trout Spawning Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 806.810 + 810 Accretion (Bottom of Reach).
- Figure N6B – 1B. Middle Fork of the American River – MF36.2 Rainbow Trout Spawning Depth Sensitivity Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 806.810 + 810 Accretion (Bottom of Reach).
- Figure N6B – 2A. Middle Fork of the American River – MF36.2 Rainbow Trout Large Stream Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 806.810 + 810 Accretion (Bottom of Reach).
- Figure N6B – 2B. Middle Fork of the American River – MF36.2 Rainbow Trout Large Stream Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 806.810 + 810 Accretion (Bottom of Reach).

Figure N6B – 2C. Middle Fork of the American River – MF36.2 Rainbow Trout Fry Summer (June - August) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 806.810 + 810 Accretion (Bottom of Reach).

Middle Fork American River Above Ralston Afterbay – Top of Reach

Figure N7A – 1A. Middle Fork of the American River – MF26.2 Rainbow Trout Spawning Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 810.812 (Top of Reach).

Figure N7A – 1B. Middle Fork of the American River – MF26.2 Rainbow Trout Spawning Depth Sensitivity Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 810.812 (Top of Reach).

Figure N7A – 1C. Middle Fork of the American River – MF26.2 Foothill Yellow-Legged Frog Breeding Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 810.812 (Top of Reach).

Figure N7A – 2A. Middle Fork of the American River – MF26.2 Rainbow Trout Large Stream Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 810.812 (Top of Reach).

Figure N7A – 2B. Middle Fork of the American River – MF26.2 Rainbow Trout Large Stream Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 810.812 (Top of Reach).

Figure N7A – 2C. Middle Fork of the American River – MF26.2 Rainbow Trout Fry Summer (June - August) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 810.812 (Top of Reach).

Figure N7A – 2D. Middle Fork of the American River – MF26.2 Hardhead/Sacramento Pikeminnow Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 810.812 (Top of Reach).

- Figure N7A – 2E. Middle Fork of the American River – MF26.2 Hardhead/Sacramento Pikeminnow Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 810.812 (Top of Reach).
- Figure N7A – 2F. Middle Fork of the American River – MF26.2 Foothill Yellow-Legged Frog Tadpole Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 810.812 (Top of Reach).

#### Middle Fork American River Above Ralston Afterbay – Bottom of Reach

- Figure N7B – 1A. Middle Fork of the American River – MF26.2 Rainbow Trout Spawning Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 813.845 (Bottom of Reach).
- Figure N7B – 1B. Middle Fork of the American River – MF26.2 Rainbow Trout Spawning Depth Sensitivity Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 813.845 (Bottom of Reach).
- Figure N7B – 1C. Middle Fork of the American River – MF26.2 Foothill Yellow-Legged Frog Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 813.845 (Bottom of Reach).
- Figure N7B – 2A. Middle Fork of the American River – MF26.2 Rainbow Trout Large Stream Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 813.845 (Bottom of Reach).
- Figure N7B – 2B. Middle Fork of the American River – MF26.2 Rainbow Trout Large Stream Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 813.845 (Bottom of Reach).
- Figure N7B – 2C. Middle Fork of the American River – MF26.2 Rainbow Trout Fry Summer (June - August) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 813.845 (Bottom of Reach).

- Figure N7B – 2D. Middle Fork of the American River – MF26.2 Hardhead/Sacramento Pikeminnow Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 813.845 (Bottom of Reach).
- Figure N7B – 2E. Middle Fork of the American River – MF26.2 Hardhead/Sacramento Pikeminnow Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 813.845 (Bottom of Reach).
- Figure N7B – 2F. Middle Fork of the American River – MF26.2 Foothill Yellow-Legged Frog Tadpole Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 813.845 (Bottom of Reach).

Rubicon River Above Parsley Bar (Helicopter Site) – Top of Reach

- Figure N8A – 1A. Rubicon River – R25.7 Rainbow Trout Spawning Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 540.832 (Top of Reach).
- Figure N8A – 1B. Rubicon River – R25.7 Rainbow Trout Spawning Depth Sensitivity Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 540.832 (Top of Reach).
- Figure N8A – 2A. Rubicon River – R25.7 Rainbow Trout Large Stream Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 540.832 (Top of Reach).
- Figure N8A – 2B. Rubicon River – R25.7 Rainbow Trout Large Stream Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 540.832 (Top of Reach).
- Figure N8A – 2C. Rubicon River – R25.7 Rainbow Trout Fry Summer (June - August) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 540.832 (Top of Reach).

Rubicon River Above Parsley Bar (Helicopter Site) – Bottom of Reach

- Figure N8B – 1A. Rubicon River – R25.7 Rainbow Trout Spawning Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 832.835 (Bottom of Reach).

- Figure N8B – 1B. Rubicon River – R25.7 Rainbow Trout Spawning Depth Sensitivity Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 832.835 (Bottom of Reach).
- Figure N8B – 2A. Rubicon River – R25.7 Rainbow Trout Large Stream Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 832.835 (Bottom of Reach).
- Figure N8B – 2B. Rubicon River – R25.7 Rainbow Trout Large Stream Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 832.835 (Bottom of Reach).
- Figure N8B – 2C. Rubicon River – R25.7 Rainbow Trout Fry Summer (June - August) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 832.835 (Bottom of Reach).

#### Rubicon River Below Ellicott Bridge – Top of Reach

- Figure N9A – 1A. Rubicon River – R20.9 Rainbow Trout Spawning Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 834.836 (Top of Reach).
- Figure N9A – 1B. Rubicon River – R20.9 Rainbow Trout Spawning Depth Sensitivity Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 834.836 (Top of Reach).
- Figure N9A – 2A. Rubicon River – R20.9 Rainbow Trout Large Stream Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 834.836 (Top of Reach).
- Figure N9A – 2B. Rubicon River – R20.9 Rainbow Trout Large Stream Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 834.836 (Top of Reach).
- Figure N9A – 2C. Rubicon River – R20.9 Rainbow Trout Fry Summer (June - August) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 834.836 (Top of Reach).

Figure N9A – 2D. Rubicon River – R20.9 Hardhead/Sacramento Pikeminnow Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 834.836 (Top of Reach).

Figure N9A – 2E. Rubicon River – R20.9 Hardhead/Sacramento Pikeminnow Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 834.836 (Top of Reach).

Rubicon River Below Ellicott Bridge – Bottom of Reach

Figure N9B – 1A. Rubicon River – R20.9 Rainbow Trout Spawning Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 840.842 + 842 Accretion (Bottom of Reach).

Figure N9B – 1B. Rubicon River – R20.9 Rainbow Trout Spawning Depth Sensitivity Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 840.842 + 842 Accretion (Bottom of Reach).

Figure N9B – 2A. Rubicon River – R20.9 Rainbow Trout Large Stream Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 840.842 + 842 Accretion (Bottom of Reach).

Figure N9B – 2B. Rubicon River – R20.9 Rainbow Trout Large Stream Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 840.842 + 842 Accretion (Bottom of Reach).

Figure N9B – 2C. Rubicon River – R20.9 Rainbow Trout Fry Summer (June - August) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 840.842 + 842 Accretion (Bottom of Reach).

Figure N9B – 2D. Rubicon River – R20.9 Hardhead/Sacramento Pikeminnow Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 840.842 + 842 Accretion (Bottom of Reach).

Figure N9B – 2E. Rubicon River – R20.9 Hardhead/Sacramento Pikeminnow Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 840.842 + 842 Accretion (Bottom of Reach).

Rubicon River at Confluence with Long Canyon Creek – Top of Reach

Figure N10A – 1A. Rubicon River – R3.5 Rainbow Trout Spawning Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 842.815 (Top of Reach).

Figure N10A – 1B. Rubicon River – R3.5 Rainbow Trout Spawning Depth Sensitivity Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 842.815 (Top of Reach).

Figure N10A – 1C. Rubicon River – R3.5 Foothill Yellow-Legged Frog Breeding Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 842.815 (Top of Reach).

Figure N10A – 2A. Rubicon River – R3.5 Rainbow Trout Large Stream Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 842.815 (Top of Reach).

Figure N10A – 2B. Rubicon River – R3.5 Rainbow Trout Large Stream Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 842.815 (Top of Reach).

Figure N10A – 2C. Rubicon River – R3.5 Rainbow Trout Fry Summer (June - August) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 842.815 (Top of Reach).

Figure N10A – 2D. Rubicon River – R3.5 Hardhead/Sacramento Pikeminnow Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 842.815 (Top of Reach).

Figure N10A – 2E. Rubicon River – R3.5 Hardhead/Sacramento Pikeminnow Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 842.815 (Top of Reach).

Figure N10A – 2F. Rubicon River – R3.5 Foothill Yellow-Legged Frog Tadpole Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 842.815 (Top of Reach).

Rubicon River at Confluence with Long Canyon Creek – Bottom of Reach

Figure N10B – 1A. Rubicon River – R3.5 Rainbow Trout Spawning Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 842.815 + 815 Accretion (Bottom of Reach).

Figure N10B – 1B. Rubicon River – R3.5 Rainbow Trout Spawning Depth Sensitivity Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 842.815 + 815 Accretion (Bottom of Reach).

Figure N10B – 1C. Rubicon River – R3.5 Foothill Yellow-Legged Frog Breeding Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 842.815 + 815 Accretion (Bottom of Reach).

Figure N10B – 2A. Rubicon River – R3.5 Rainbow Trout Large Stream Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 842.815 + 815 Accretion (Bottom of Reach).

Figure N10B – 2B. Rubicon River – R3.5 Rainbow Trout Large Stream Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 842.815 + 815 Accretion (Bottom of Reach).

Figure N10B – 2C. Rubicon River – R3.5 Rainbow Trout Fry Summer (June - August) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 842.815 + 815 Accretion (Bottom of Reach).

Figure N10B – 2D. Rubicon River – R3.5 Hardhead/Sacramento Pikeminnow Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 842.815 + 815 Accretion (Bottom of Reach).

Figure N10B – 2E. Rubicon River – R3.5 Hardhead/Sacramento Pikeminnow Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 842.815 + 815 Accretion (Bottom of Reach).

Figure N10B – 2F. Rubicon River – R3.5 Foothill Yellow-Legged Frog Tadpole Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 842.815 + 815 Accretion (Bottom of Reach).

Middle Fork of the American River – MF14.1 at Fords Bar (15-Minute Data)

Figure N11 – 1A. Middle Fork of the American River – MF14.1 Rainbow Trout Spawning Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 855.857 (15-Minute Data).

Figure N11 – 1B. Middle Fork of the American River – MF14.1 Rainbow Trout Spawning Depth Sensitivity Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model 855.857 (15-Minute Data).

Figure N11 – 1C. Middle Fork of the American River – MF14.1 Foothill Yellow-Legged Frog Breeding Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 855.857 (15-Minute Data).

Figure N11 – 2A. Middle Fork of the American River – MF14.1 Rainbow Trout Large Stream Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 855.857 (15-Minute Data).

Figure N11 – 2B. Middle Fork of the American River – MF14.1 Rainbow Trout Large Stream Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 855.857 (15-Minute Data).

Figure N11 – 2C. Middle Fork of the American River – MF14.1 Rainbow Trout Fry Summer (June - August) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 855.857 (15-Minute Data).

Figure N11 – 2D. Middle Fork of the American River – MF14.1 Hardhead/Sacramento Pikeminnow Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 855.857 (15-Minute Data).

Figure N11 – 2E. Middle Fork of the American River – MF14.1 Hardhead/Sacramento Pikeminnow Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type

- Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 855.857 (15-Minute Data).
- Figure N11 – 2F. Middle Fork of the American River – MF14.1 Foothill Yellow-Legged Frog Tadpole Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 855.857 (15-Minute Data).

Middle Fork of the American River – MF4.8 at Buckeye Bar (15-Minute Data)

- Figure N12 – 1A. Middle Fork of the American River – MF14.1 Rainbow Trout Spawning Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 855.857 (15-Minute Data).
- Figure N12 – 1B. Middle Fork of the American River – MF14.1 Rainbow Trout Spawning Depth Sensitivity Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model 855.857 (15-Minute Data).
- Figure N12 – 1C. Middle Fork of the American River – MF14.1 Foothill Yellow-Legged Frog Breeding Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 855.857 (15-Minute Data).
- Figure N12 – 2A. Middle Fork of the American River – MF14.1 Rainbow Trout Large Stream Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 855.857 (15-Minute Data).
- Figure N12 – 2B. Middle Fork of the American River – MF14.1 Rainbow Trout Large Stream Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 855.857 (15-Minute Data).
- Figure N12 – 2C. Middle Fork of the American River – MF14.1 Rainbow Trout Fry Summer (June - August) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 855.857 (15-Minute Data).
- Figure N11 – 2D. Middle Fork of the American River – MF14.1 Hardhead/Sacramento Pikeminnow Juvenile Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 855.857 (15-Minute Data).

Figure N12 – 2E. Middle Fork of the American River – MF14.1 Hardhead/Sacramento Pikeminnow Adult Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 855.857 (15-Minute Data).

Figure N12 – 2F. Middle Fork of the American River – MF14.1 Foothill Yellow-Legged Frog Tadpole Summer Through Fall (June - October) Habitat Exceedance Plots for All Water Years and each Water Year Type Separately (Wet, Above Normal, Below Normal, Dry, Critically Dry). Hydrology Model Node 855.857 (15-Minute Data).

**ATTACHMENT A**

**Database of Habitat Time Series Relationship Development for Each Site**

(See Attached Electronic Media)

**APPENDIX O**  
**Effective Habitat Analyses**

**List of Figures**Middle Fork American River – MF26.2

- Figure O-1. Middle Fork American River MF26.2 Upper Effective FYLF Egg Mass Habitat Matrix.
- Figure O-2. Middle Fork American River MF26.2 Upper Effective FYLF Tadpole Habitat Matrix.
- Figure O-3. Middle Fork American River MF26.2 Lower Effective FYLF Egg Mass Habitat Matrix.
- Figure O-4. Middle Fork American River MF26.2 Lower Effective FYLF Tadpole Habitat Matrix.

Rubicon River – R3.5

- Figure O-5. Rubicon River R3.5 Upper Effective FYLF Egg Mass Habitat Matrix.
- Figure O-6. Rubicon River R3.5 Upper Effective FYLF Tadpole Habitat Matrix.
- Figure O-7. Rubicon River R3.5 Lower Effective FYLF Egg Mass Habitat Matrix.
- Figure O-8. Rubicon River R3.5 Lower Effective FYLF Tadpole Habitat Matrix.

Middle Fork American River at Fords Bar – MF14.1*Effective Habitat Matrices*

- Figure O-9. Middle Fork American River MF14.1 Effective Rainbow Trout Spawning Habitat Matrix.
- Figure O-10. Middle Fork American River MF14.1 Effective Rainbow Trout Incubation Habitat Matrix.
- Figure O-11. Middle Fork American River MF14.1 Effective Rainbow Trout Spawning Depth Sensitivity Habitat Matrix.
- Figure O-12. Middle Fork American River MF14.1 Effective Rainbow Trout Depth Sensitivity Incubation Habitat Matrix.
- Figure O-13. Middle Fork American River MF14.1 Effective FYLF Egg Mass Habitat Matrix.
- Figure O-14. Middle Fork American River MF14.1 Effective FYLF Tadpole Habitat Matrix.
- Figure O-15. Middle Fork American River MF14.1 Effective Food Production Habitat Matrix.

*Effective Habitat Time Series*

- Figure O-16. Fords Bar MF14.1 Effective Habitat Time Series. (Top) Effective Rainbow Trout Spawning (Average of Eight Weekly Spawning Periods May–April) and Subsequent Incubation and (Bottom) Effective Foothill Yellow-Legged Frog Breeding Habitat (Average of Three 10–11 Day Breeding Periods (May 10–June 15) (see text for details).
- Figure O-17. Fords Bar MF14.1 Effective Rainbow Trout Spawning Habitat. Maximum, Minimum, and 25% and 75% Exceedance of Eight Weekly Spawning Periods (March–April) and Subsequent Incubation (see text for details).

Middle Fork American River at Buckeye Bar – MF4.8

*Effective Habitat Matrices*

- Figure O-18. Middle Fork American River MF4.8 Effective Rainbow Trout Spawning Habitat Matrix.
- Figure O-19. Middle Fork American River MF4.8 Effective Rainbow Trout Incubation Habitat Matrix.
- Figure O-20. Middle Fork American River MF4.8 Effective Rainbow Trout Spawning Depth Sensitivity Habitat Matrix.
- Figure O-21. Middle Fork American River MF4.8 Effective Rainbow Trout Depth Sensitivity Incubation Habitat Matrix.
- Figure O-22. Middle Fork American River MF4.8 Effective FYLF Egg Mass Habitat Matrix.
- Figure O-23. Middle Fork American River MF4.8 Effective FYLF Tadpole Habitat Matrix.
- Figure O-24. Middle Fork American River MF4.8 Effective Food Production Habitat Matrix.

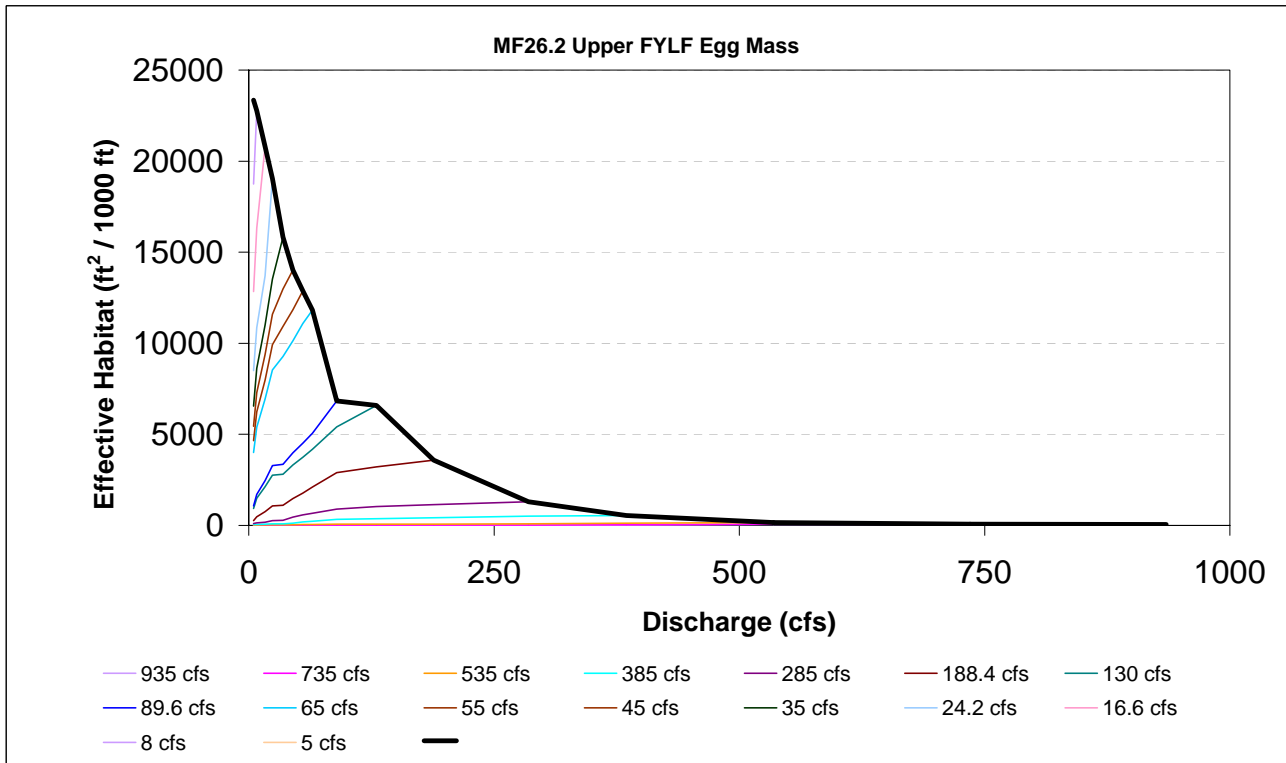
*Effective Habitat Time Series*

- Figure O-25. Buckeye Bar MF4.8 Effective Habitat Time Series. (Top) Effective Rainbow Trout Spawning Habitat (Average of Eight Weekly Spawning Periods March–April) and Subsequent Incubation and (Bottom) Effective Foothill Yellow-Legged Frog Breeding Habitat (Average of Three 10–11 Day Breeding Periods (May 10–June 15) (see text for details).
- Figure O-26. Buckeye Bar MF4.8 Effective Rainbow Trout Spawning Habitat. Maximum, Minimum, and 25% and 75% Exceedance of Eight Weekly Spawning Periods (March–April) and Subsequent Incubation (see text for details).

**FIGURES**

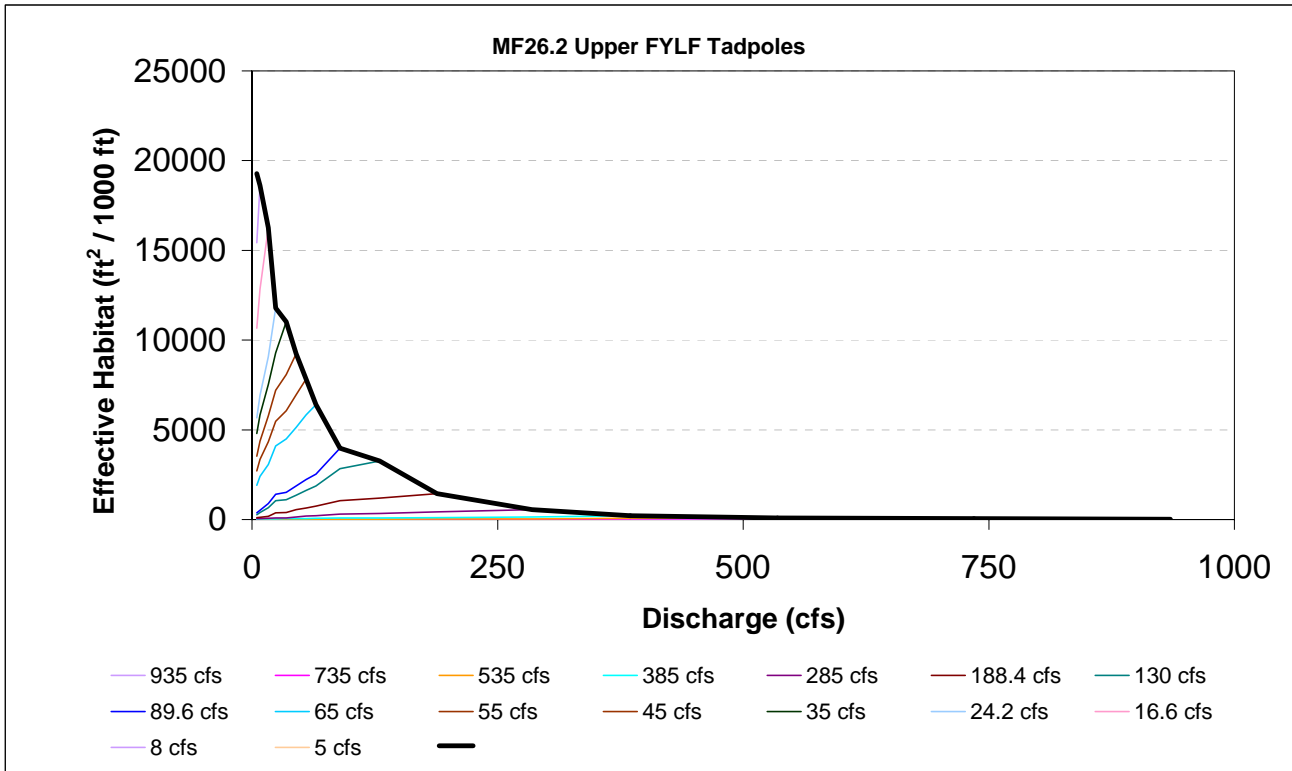
**Figure O-1. Middle Fork American River MF26.2 Upper Effective FYLF Egg Mass Habitat Matrix.**

Starting Discharge (cfs)	Ending Discharge (cfs)																Initial Habitat vs Flow Relationship	
	935	735	535	385	285	188	130	90	65	55	45	35	24	17	8	5		
935 cfs	52	45	45	23	3	1	1	1	1	1	1	1	1	1	1	1	1	52
735 cfs		70	64	43	23	19	17	17	15	15	13	13	13	12	10	9		70
535 cfs			154	126	83	77	73	69	61	44	42	36	34	29	25	24		154
385 cfs				551	501	419	373	329	226	194	124	94	91	68	54	50		551
285 cfs					1305	1142	1042	891	661	585	461	284	258	169	134	105		1305
188.4 cfs						3576	3208	2907	2106	1772	1481	1100	1068	761	475	259		3576
130 cfs							6590	5403	4176	3736	3312	2803	2759	2122	1487	925		6590
89.6 cfs								6829	5064	4510	3995	3357	3293	2454	1706	1073		6829
65 cfs									11828	11089	10140	9279	8538	6938	5389	4003		11828
55 cfs										12879	11836	10921	9932	7978	6230	4651		12879
45 cfs											14028	12984	11595	9381	7289	5452		14028
35 cfs												15831	13527	11004	8618	6546		15831
24.2 cfs													19036	13698	10856	8504		19036
16.6 cfs														20801	16327	12845		20801
8 cfs															22771	18750		22771
5 cfs																23346		23346



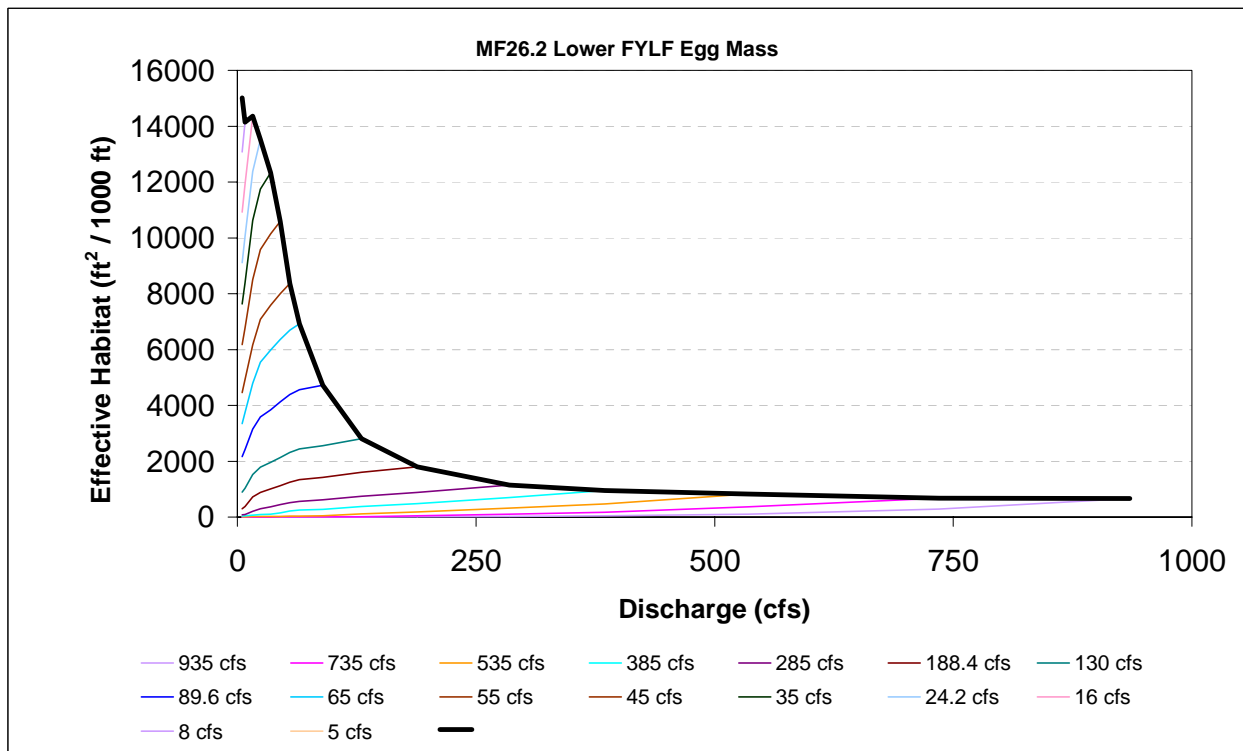
**Figure O-2. Middle Fork American River MF26.2 Upper Effective FYLF Tadpole Habitat Matrix.**

Starting Discharge (cfs)	Ending Discharge (cfs)															Initial Habitat vs Flow Relationship		
	935	735	535	385	285	188	130	90	65	55	45	35	24	17	8		5	
935 cfs	26	24	24	6	2	2	1	1	1	1	1	1	1	1	1	1	0	26
735 cfs		51	50	33	9	5	5	5	4	4	4	4	3	2	2	2	2	51
535 cfs			87	63	37	32	26	25	20	19	17	16	16	13	10	10	10	87
385 cfs				215	144	113	96	88	66	62	53	45	42	35	29	26	26	215
285 cfs					549	423	339	299	220	197	143	97	88	68	57	51	51	549
188.4 cfs						1440	1192	1060	750	647	546	397	380	172	132	114	114	1440
130 cfs							3264	2834	1868	1624	1363	1103	1046	651	395	261	261	3264
89.6 cfs								3979	2537	2233	1866	1507	1412	899	525	381	381	3979
65 cfs									6410	5834	5135	4491	4108	3071	2408	1902	1902	6410
55 cfs										7837	6948	6064	5481	4331	3355	2719	2719	7837
45 cfs											9229	8076	7212	5772	4368	3537	3537	9229
35 cfs												11028	9286	7531	5837	4803	4803	11028
24.2 cfs													11784	9085	6925	5668	5668	11784
16.6 cfs														16269	12834	10656	10656	16269
8 cfs															18623	15419	15419	18623
5 cfs																19269	19269	19269



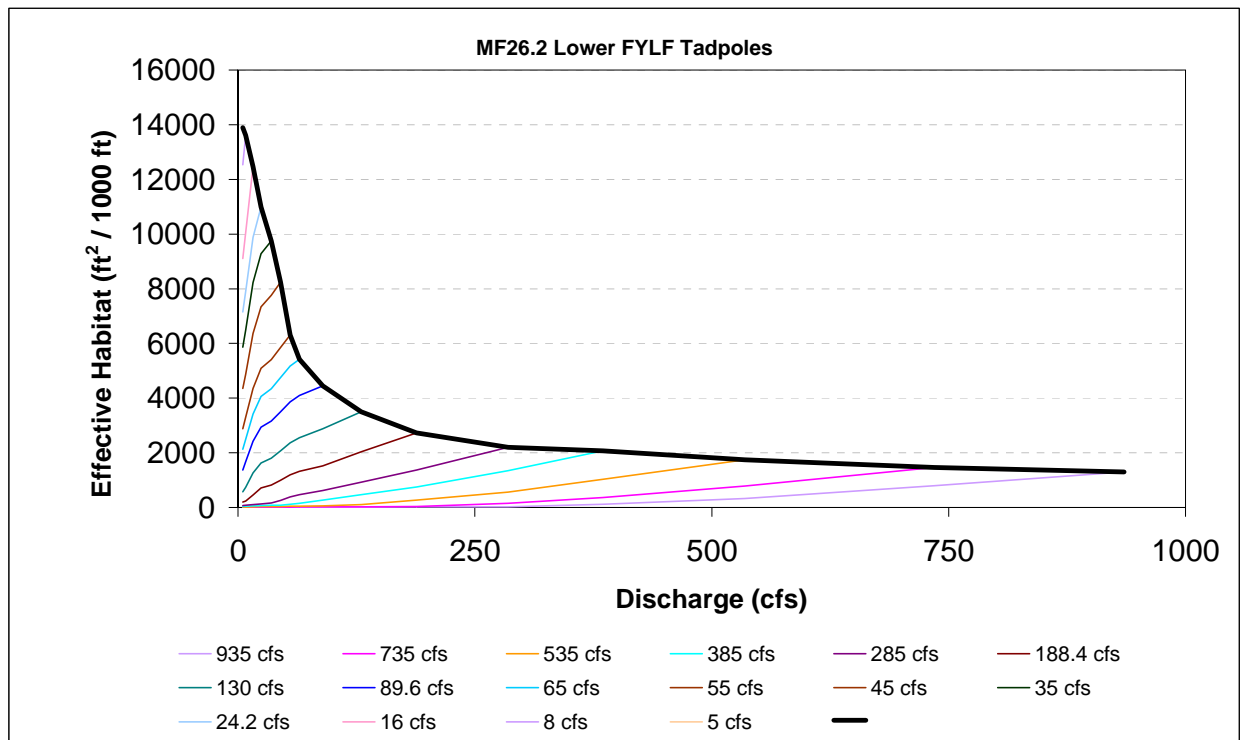
**Figure O-3. Middle Fork American River MF26.2 Lower Effective FYLF Egg Mass Habitat Matrix.**

Starting Discharge (cfs)	Ending Discharge (cfs)																Initial Habitat vs Flow Relationship
	935	735	535	385	285	188	130	90	65	55	45	35	24	16	8	5	
935 cfs	662	283	104	46	23	6	4	3	2	2	2	2	2	1	1	1	662
735 cfs		671	371	169	98	43	15	10	8	7	6	5	5	4	3	2	671
535 cfs			830	471	325	180	112	48	34	30	26	22	20	18	13	11	830
385 cfs				952	705	478	373	281	247	216	154	107	91	64	44	39	952
285 cfs					1141	880	741	621	566	518	442	368	301	210	97	84	1141
188.4 cfs						1799	1601	1421	1337	1252	1123	1009	888	725	374	303	1799
130 cfs							2812	2552	2437	2316	2137	1964	1792	1530	1032	893	2812
89.6 cfs								4719	4559	4391	4127	3845	3584	3157	2413	2168	4719
65 cfs									6921	6688	6365	5985	5545	4789	3748	3346	6921
55 cfs										8365	8005	7583	7080	6163	4925	4453	8365
45 cfs											10587	10140	9586	8502	6776	6177	10587
35 cfs												12338	11752	10621	8392	7635	12338
24.2 cfs													13524	12376	10054	9111	13524
16 cfs														14359	11917	10924	14359
8 cfs															14146	13074	14146
5 cfs																15017	15017



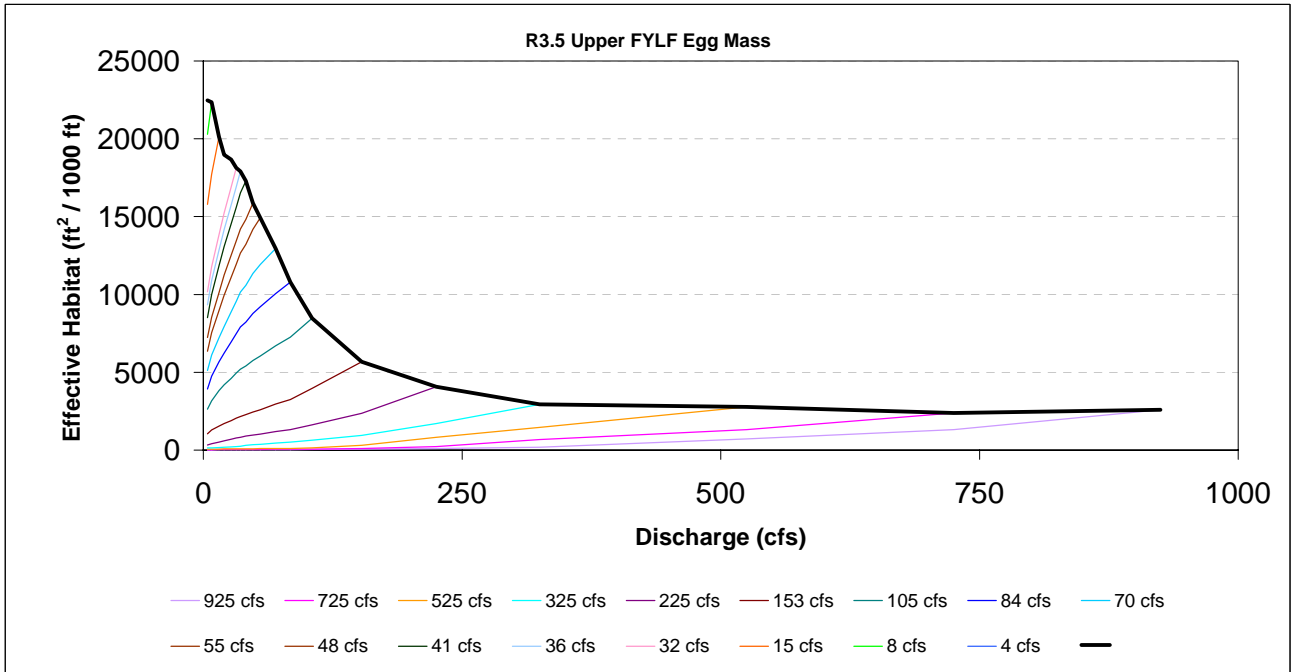
**Figure O-4. Middle Fork American River MF26.2 Lower Effective FYLF Tadpole Habitat Matrix.**

Starting Discharge (cfs)	Ending Discharge (cfs)																Initial Habitat vs Flow Relationship
	935	735	535	385	285	188	130	90	65	55	45	35	24	16	8	5	
935 cfs	1303	796	330	121	28	19	14	10	8	7	7	5	5	3	1	1	1303
735 cfs		1467	788	367	157	39	28	22	18	16	14	12	11	8	4	4	1467
535 cfs			1745	1028	561	270	102	58	47	45	39	35	33	28	17	15	1745
385 cfs				2076	1349	755	464	267	156	112	86	78	74	63	44	40	2076
285 cfs					2198	1374	923	618	470	384	258	161	129	107	79	73	2198
188.4 cfs						2730	2038	1522	1319	1197	996	819	717	460	238	198	2730
130 cfs							3504	2880	2553	2362	2071	1799	1632	1269	743	579	3504
89.6 cfs								4449	4096	3863	3494	3161	2938	2426	1670	1365	4449
65 cfs									5415	5171	4755	4342	4057	3422	2495	2133	5415
55 cfs										6307	5851	5407	5088	4355	3299	2883	6307
45 cfs											8240	7763	7334	6366	4875	4357	8240
35 cfs												9745	9282	8226	6487	5867	9745
24.2 cfs													10991	9881	7896	7149	10991
16 cfs														12471	10059	9110	12471
8 cfs															13618	12536	13618
5 cfs																13894	13894



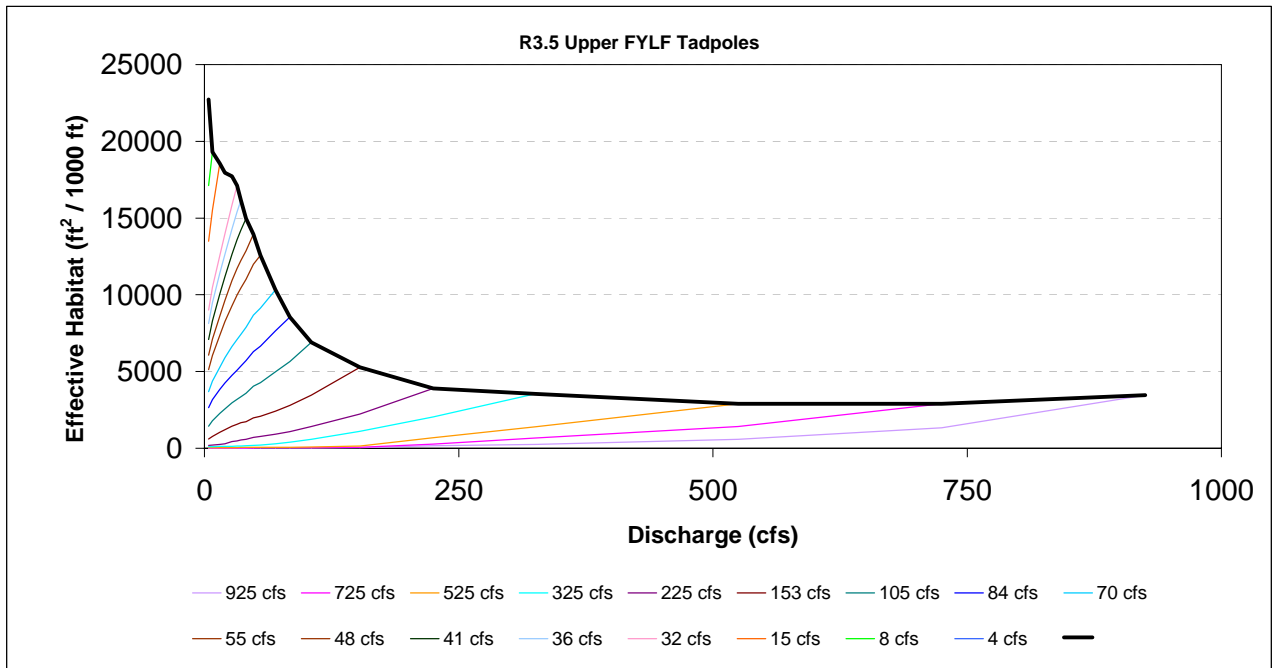
**Figure O-5. Rubicon River R3.5 Upper Effective FYLF Egg Mass Habitat Matrix.**

Starting Discharge (cfs)	Ending Discharge (cfs)																		Initial Habitat vs Flow Relationship	
	925	725	525	325	225	153	105	84	70	55	48	41	36	32	27	20	15	8		4
925 cfs	2583	1309	716	185	105	55	33	29	27	25	24	20	19	17	16	13	12	10	9	2583
725 cfs		2381	1326	672	223	94	63	56	53	49	48	44	42	41	39	35	33	30	27	2381
525 cfs			2778	1456	828	307	139	109	98	93	90	86	84	82	80	74	71	67	64	2778
325 cfs				2932	1717	952	638	512	444	374	342	303	256	233	201	187	167	148	141	2932
225 cfs					4070	2367	1628	1311	1186	1035	970	906	826	772	701	600	523	411	338	4070
153 cfs						5676	3967	3241	2952	2586	2438	2285	2161	2053	1896	1709	1544	1296	1058	5676
105 cfs							8464	7253	6707	6050	5754	5407	5203	4946	4610	4188	3816	3165	2632	8464
84 cfs								10802	10062	9207	8770	8219	7905	7486	6954	6232	5678	4748	3937	10802
70 cfs									12950	11927	11344	10593	10150	9564	8880	7946	7218	6115	5129	12950
55 cfs										14931	14185	13216	12655	11945	11108	9944	8958	7549	6344	14931
48 cfs											15878	14822	14199	13436	12517	11249	10117	8533	7229	15878
41 cfs												17289	16524	15606	14526	13084	11837	9994	8508	17289
36 cfs													17902	16924	15744	14168	12855	10894	9337	17902
32 cfs														18135	16891	15231	13843	11785	10174	18135
27 cfs															18668	16816	15363	13188	11443	18668
20 cfs																18977	17363	15057	13194	18977
15 cfs																	20135	17714	15786	20135
8 cfs																		22354	20288	22354
4 cfs																			22476	22476



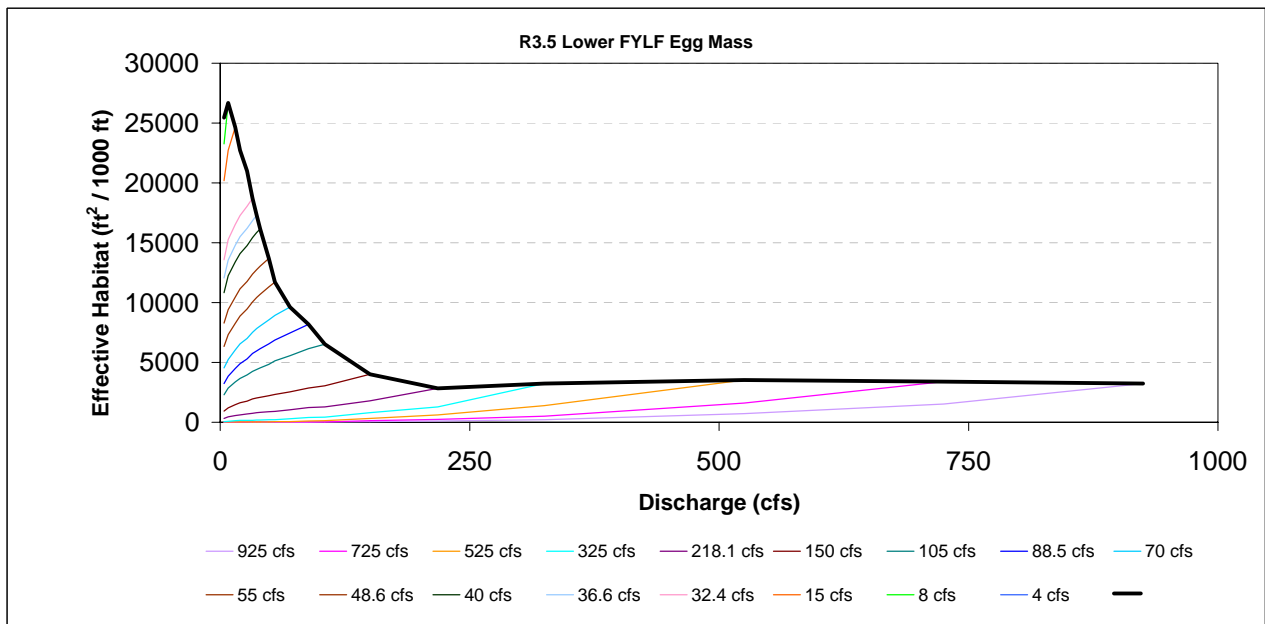
**Figure O-6. Rubicon River R3.5 Upper Effective FYLF Tadpole Habitat Matrix.**

Starting Discharge (cfs)	Ending Discharge (cfs)																		Initial Habitat vs Flow Relationship	
	925	725	525	325	225	153	105	84	70	55	48	41	36	32	27	20	15	8		4
925 cfs	3463	1339	583	252	164	45	28	21	18	15	13	10	9	8	7	5	4	2	2	3463
725 cfs		2903	1420	677	266	68	49	39	36	32	30	27	25	24	23	19	18	14	12	2903
525 cfs			2893	1389	679	138	84	73	68	62	59	55	52	50	47	43	40	36	33	2893
325 cfs				3550	2036	1099	574	406	297	215	192	160	145	139	134	125	119	108	102	3550
225 cfs					3899	2235	1412	1092	926	768	701	587	540	486	429	300	252	211	190	3899
153 cfs						5274	3452	2799	2429	2088	1977	1738	1675	1561	1444	1218	1048	762	599	5274
105 cfs							6907	5652	4973	4271	4044	3590	3361	3182	2964	2573	2267	1789	1435	6907
84 cfs								8552	7648	6655	6291	5708	5354	5088	4761	4257	3828	3168	2645	8552
70 cfs									10319	9139	8667	7880	7427	7082	6633	5894	5282	4375	3687	10319
55 cfs										12575	11985	11006	10438	9992	9272	8247	7368	6054	5137	12575
48 cfs											13951	12863	12232	11720	10922	9630	8602	7109	6058	13951
41 cfs												14969	14224	13591	12635	11166	10048	8306	7084	14969
36 cfs													16164	15402	14275	12642	11405	9492	8133	16164
32 cfs														17119	15836	13961	12555	10491	9006	17119
27 cfs															17715	15527	13959	11654	10038	17715
20 cfs																17949	16195	13518	11664	17949
15 cfs																	18563	15519	13487	18563
8 cfs																		19311	17112	19311
4 cfs																			22735	22735



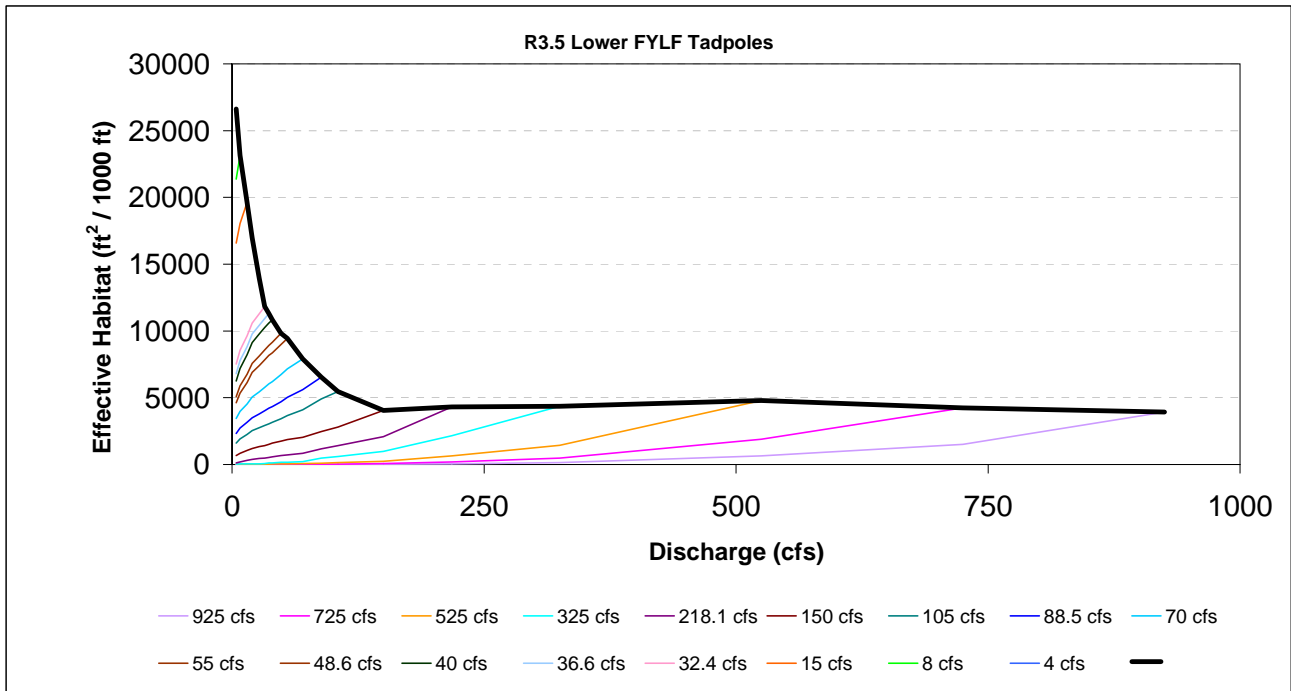
**Figure O-7. Rubicon River R3.5 Lower Effective FYLF Egg Mass Habitat Matrix.**

Starting Discharge (cfs)	Ending Discharge (cfs)																			Initial Habitat vs Flow Relationship
	925	725	525	325	218	150	105	89	70	55	49	40	37	32	27	20	15	8	4	
925 cfs	3226	1522	734	209	98	42	20	13	11	11	10	10	10	8	8	8	8	8	6	3226
725 cfs		3389	1604	506	240	128	38	28	19	17	17	17	15	14	13	12	11	11	9	3389
525 cfs			3530	1394	616	325	128	98	52	44	37	33	26	25	25	23	23	22	21	3530
325 cfs				3240	1289	794	424	390	301	216	206	196	174	170	166	154	126	70	57	3240
218.1 cfs					2829	1797	1291	1228	1046	911	873	832	793	746	694	622	566	456	327	2829
150 cfs						4009	3039	2859	2529	2316	2226	2098	2021	1951	1764	1638	1472	1200	937	4009
105 cfs							6531	6153	5573	5128	4844	4552	4410	4262	3955	3663	3360	2858	2302	6531
88.5 cfs								8173	7457	6881	6554	6160	5972	5739	5288	4894	4479	3858	3236	8173
70 cfs									9638	8929	8544	8050	7844	7524	7017	6556	6032	5252	4549	9638
55 cfs										11718	11315	10695	10437	10066	9472	8890	8263	7321	6328	11718
48.6 cfs											13684	13038	12764	12377	11764	11137	10466	9409	8281	13684
40 cfs												16141	15864	15416	14771	14095	13407	12235	10824	16141
36.6 cfs													17300	16850	16205	15500	14784	13568	12072	17300
32.4 cfs														18705	18044	17265	16531	15256	13595	18705
27 cfs															20997	20156	19297	17873	15991	20997
20 cfs																22721	21803	20101	17974	22721
15 cfs																	24644	22719	20175	24644
8 cfs																		26689	23258	26689
4 cfs																			25459	25459



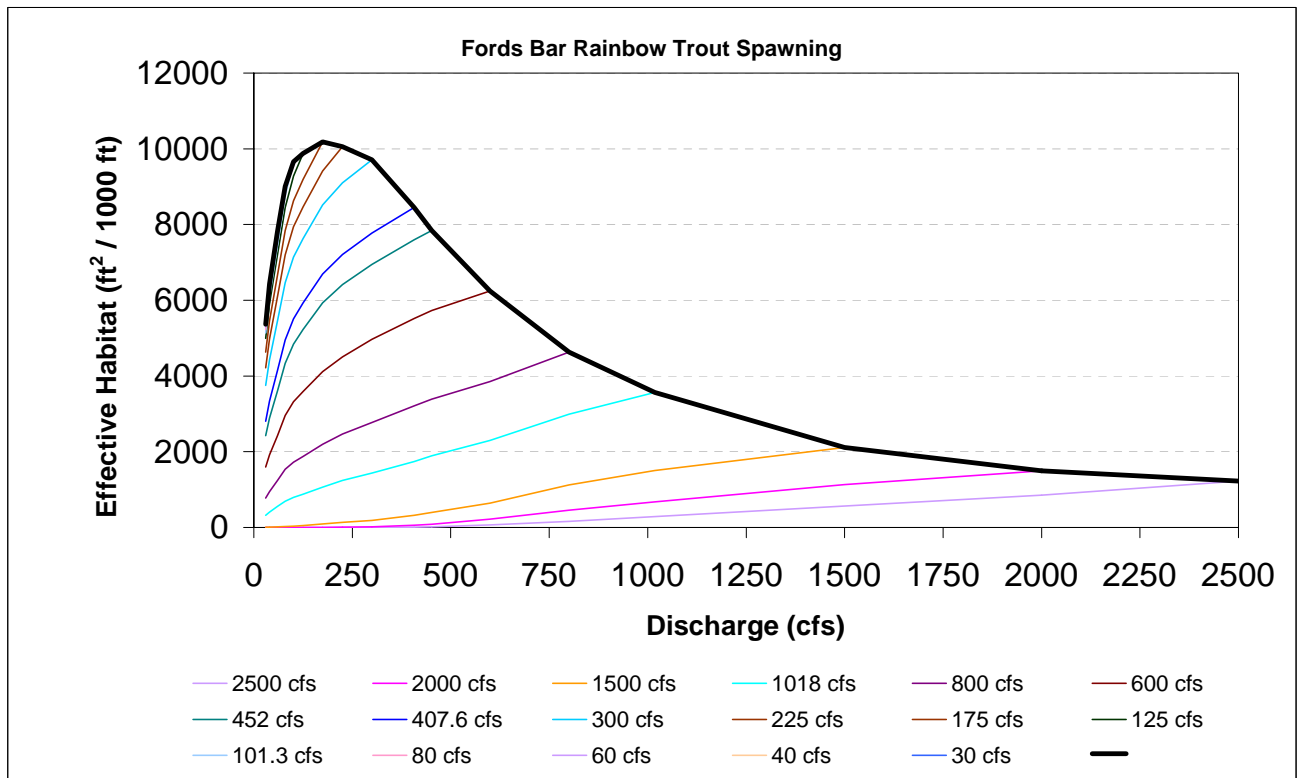
**Figure O-8. Rubicon River R3.5 Lower Effective FYLF Tadpole Habitat Matrix.**

Starting Discharge (cfs)	Ending Discharge (cfs)																		Initial Habitat vs Flow Relationship	
	925	725	525	325	218	150	105	89	70	55	49	40	37	32	27	20	15	8		4
925 cfs	3934	1505	658	141	37	20	14	9	8	8	7	7	7	7	6	6	6	5	4	3934
725 cfs		4233	1896	471	193	81	32	21	15	13	12	12	10	8	8	8	7	7	6	4233
525 cfs			4781	1431	659	247	144	102	70	52	50	49	33	17	17	16	14	13	13	4781
325 cfs				4354	2161	979	603	475	212	167	157	132	109	73	59	51	46	40	35	4354
218.1 cfs					4318	2091	1412	1177	836	716	678	568	526	480	448	381	317	201	125	4318
150 cfs						4058	2799	2470	2045	1859	1744	1599	1519	1417	1331	1209	1049	834	681	4058
105 cfs							5455	4911	4106	3660	3422	3153	3043	2920	2751	2533	2264	1919	1599	5455
88.5 cfs								6543	5606	5029	4703	4332	4206	4027	3784	3507	3163	2726	2320	6543
70 cfs									7907	7169	6738	6218	6034	5767	5443	5044	4527	3969	3448	7907
55 cfs										9438	8979	8372	8160	7835	7396	6896	6130	5350	4621	9438
48.6 cfs											9833	9151	8910	8585	8131	7571	6760	5903	5085	9833
40 cfs												10842	10585	10247	9776	9128	8217	7198	6259	10842
36.6 cfs													11299	10932	10430	9777	8826	7787	6804	11299
32.4 cfs														11826	11292	10595	9626	8546	7518	11826
27 cfs															13938	13178	12117	10957	9813	13938
20 cfs																16956	15829	14508	13172	16956
15 cfs																	19617	18037	16581	19617
8 cfs																		23141	21367	23141
4 cfs																			26622	26622



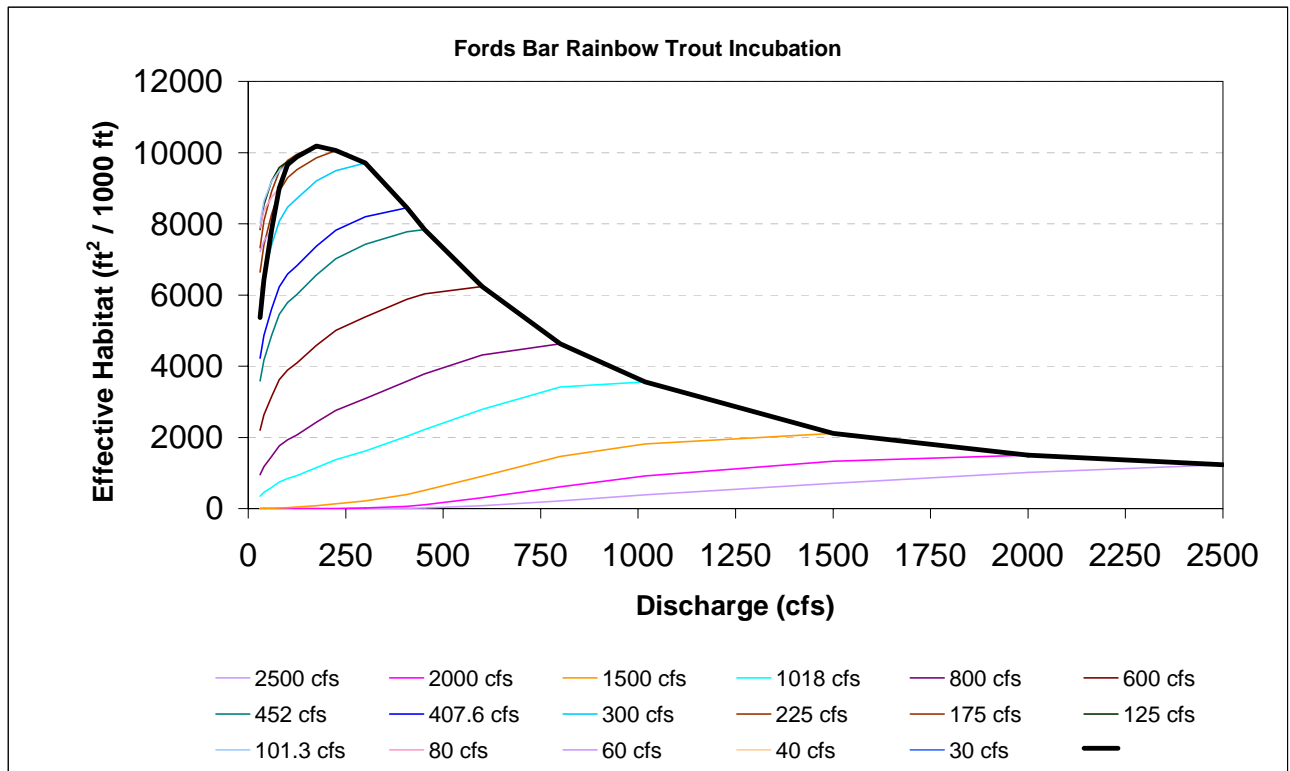
**Figure O-9. Middle Fork American River MF14.1 Effective Rainbow Trout Spawning Habitat Matrix.**

Starting Discharge (cfs)	Ending Discharge (cfs)																Initial Habitat vs Flow Relationship	
	2500	2000	1500	1018	800	600	452	407	300	225	175	125	101	80	60	40		30
2500 cfs	1227	852	564	283	163	67	20	12	4	1	1	0	0	0	0	0	0	1227
2000 cfs		1499	1134	672	458	221	89	58	15	5	2	0	0	0	0	0	0	1499
1500 cfs			2111	1505	1121	644	396	322	187	135	95	48	35	25	15	7	4	2111
1018 cfs				3563	2990	2296	1893	1745	1438	1243	1067	876	792	694	559	410	321	3563
800 cfs					4632	3857	3390	3208	2775	2466	2193	1876	1724	1535	1245	947	774	4632
600 cfs						6242	5725	5519	4966	4506	4112	3591	3322	2957	2427	1916	1595	6242
452 cfs							7839	7600	6948	6412	5930	5229	4844	4331	3610	2891	2424	7839
407.6 cfs								8453	7771	7209	6697	5936	5513	4948	4145	3337	2809	8453
300 cfs									9708	9104	8518	7635	7141	6462	5459	4427	3749	9708
225 cfs										10057	9415	8468	7940	7201	6100	4974	4215	10057
175 cfs											10186	9195	8630	7841	6667	5456	4628	10186
125 cfs												9883	9283	8452	7210	5904	4992	9883
101.3 cfs													9660	8764	7455	6096	5140	9660
80 cfs														9006	7649	6235	5235	9006
60 cfs															7826	6334	5293	7826
40 cfs																6431	5346	6431
30 cfs																	5367	5367



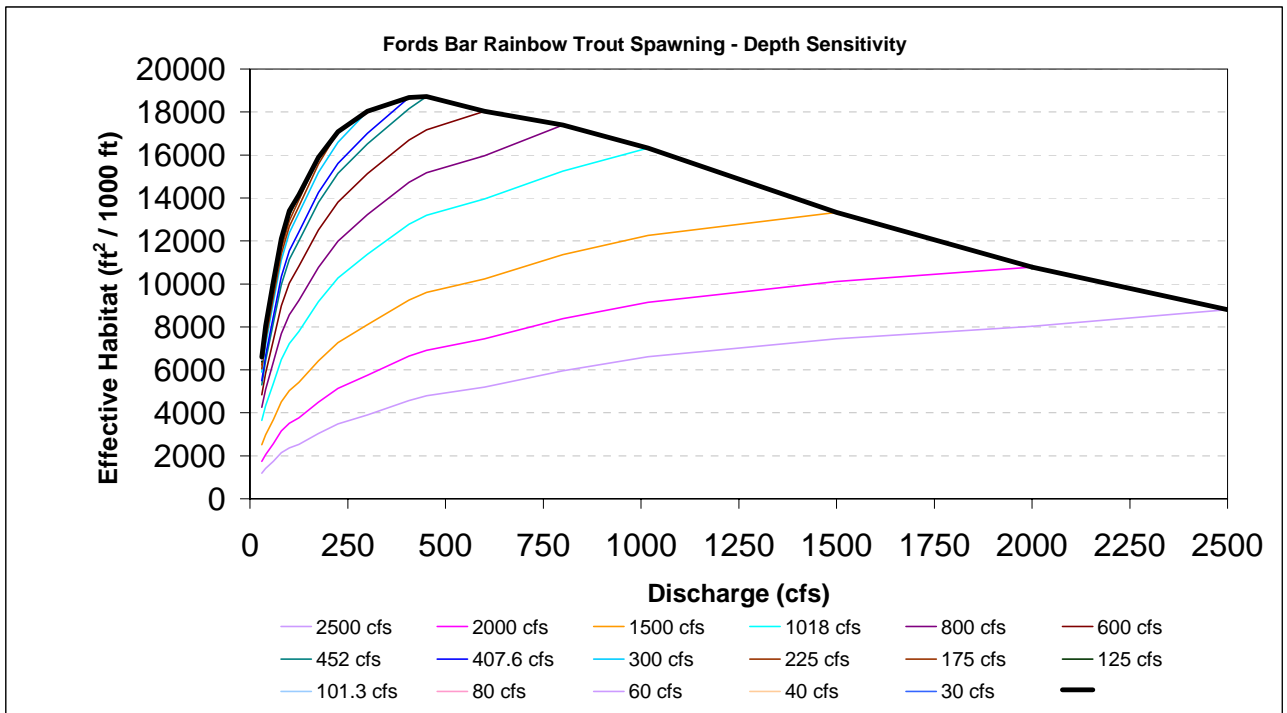
**Figure O-10. Middle Fork American River MF14.1 Effective Rainbow Trout Incubation Habitat Matrix.**

Starting Discharge (cfs)	Ending Discharge (cfs)																	Initial Habitat vs Flow Relationship
	2500	2000	1500	1018	800	600	452	407	300	225	175	125	101	80	60	40	30	
2500 cfs	1227	1014	712	387	217	81	20	13	7	1	1	1	0	0	0	0	0	1227
2000 cfs		1499	1329	918	615	303	109	64	19	4	2	2	0	0	0	0	0	1499
1500 cfs			2111	1813	1465	906	509	392	212	133	83	45	30	22	12	6	3	2111
1018 cfs				3563	3417	2783	2220	2030	1617	1373	1148	924	844	747	597	460	354	3563
800 cfs					4632	4318	3782	3579	3090	2757	2425	2064	1932	1758	1468	1178	950	4632
600 cfs						6242	6031	5880	5389	5004	4580	4091	3895	3621	3145	2629	2206	6242
452 cfs							7839	7778	7428	7016	6558	6015	5788	5456	4865	4172	3587	7839
407.6 cfs								8453	8200	7820	7370	6823	6586	6232	5612	4863	4223	8453
300 cfs									9708	9494	9205	8713	8464	8076	7406	6561	5826	9708
225 cfs										10057	9849	9523	9293	8916	8271	7411	6647	10057
175 cfs											10186	9946	9780	9471	8907	8083	7328	10186
125 cfs												9883	9752	9580	9201	8526	7842	9883
101.3 cfs													9660	9484	9198	8641	8015	9660
80 cfs														9006	8744	8365	7882	9006
60 cfs															7826	7519	7214	7826
40 cfs																6431	6144	6431
30 cfs																	5367	5367



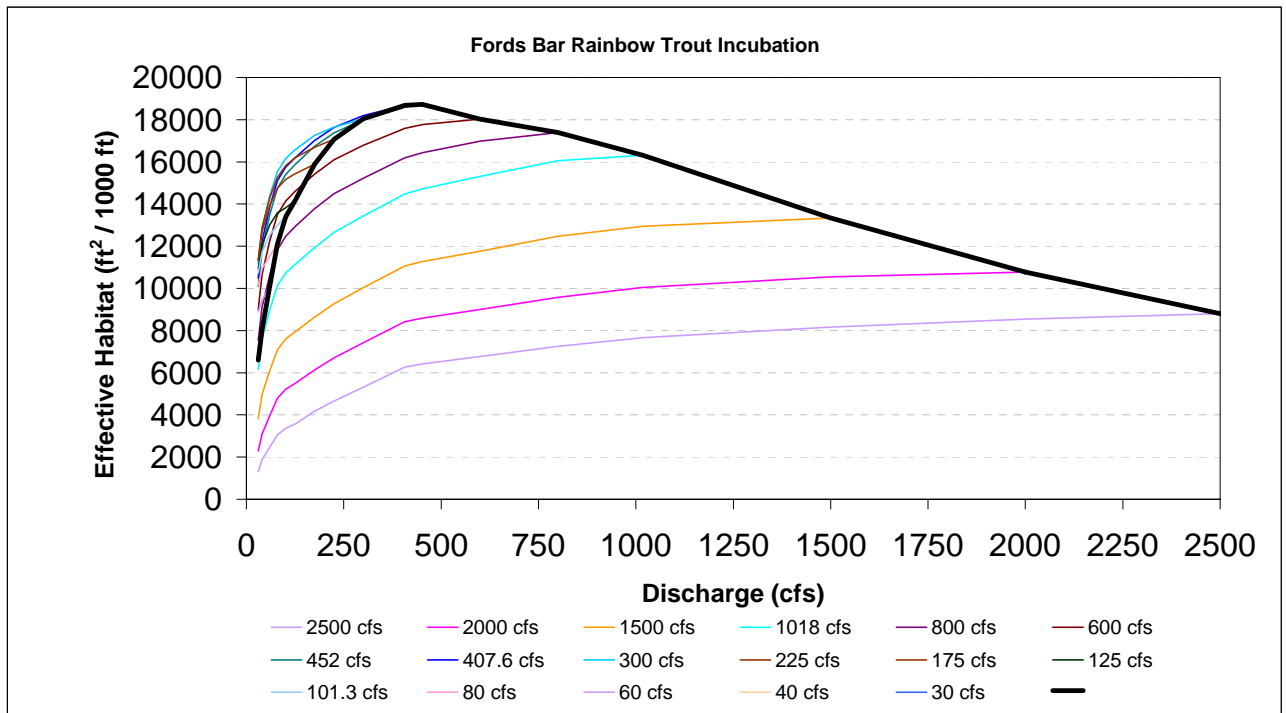
**Figure O-11. Middle Fork American River MF14.1 Effective Rainbow Trout Depth Sensitivity Spawning Habitat Matrix.**

Starting Discharge (cfs)	Ending Discharge (cfs)																	Initial Habitat vs Flow Relationship
	2500	2000	1500	1018	800	600	452	407	300	225	175	125	101	80	60	40	30	
2500 cfs	8801	8024	7446	6609	5950	5198	4789	4569	3909	3489	3033	2538	2370	2137	1749	1417	1196	8801
2000 cfs		10776	10115	9149	8387	7443	6908	6635	5751	5137	4503	3770	3508	3150	2557	2059	1736	10776
1500 cfs			13332	12250	11356	10236	9599	9255	8106	7269	6413	5419	5038	4509	3672	2972	2522	13332
1018 cfs				16318	15248	13951	13193	12781	11375	10278	9166	7792	7218	6475	5361	4334	3651	16318
800 cfs					17392	15972	15168	14730	13228	11981	10764	9235	8561	7682	6357	5099	4264	17392
600 cfs						18030	17171	16700	15127	13799	12507	10822	10036	8977	7373	5857	4844	18030
452 cfs							18720	18155	16513	15141	13797	12003	11146	9967	8170	6436	5303	18720
407.6 cfs								18681	17014	15613	14251	12424	11546	10340	8479	6668	5488	18681
300 cfs									18036	16584	15186	13292	12370	11110	9137	7168	5893	18036
225 cfs										17077	15575	13618	12672	11391	9378	7365	6047	17077
175 cfs											15890	13908	12945	11649	9611	7570	6227	15890
125 cfs												14151	13173	11868	9814	7748	6378	14151
101.3 cfs													13396	12010	9921	7839	6454	13396
80 cfs														12113	10003	7903	6499	12113
60 cfs															10104	7959	6535	10104
40 cfs																8039	6581	8039
30 cfs																	6597	6597



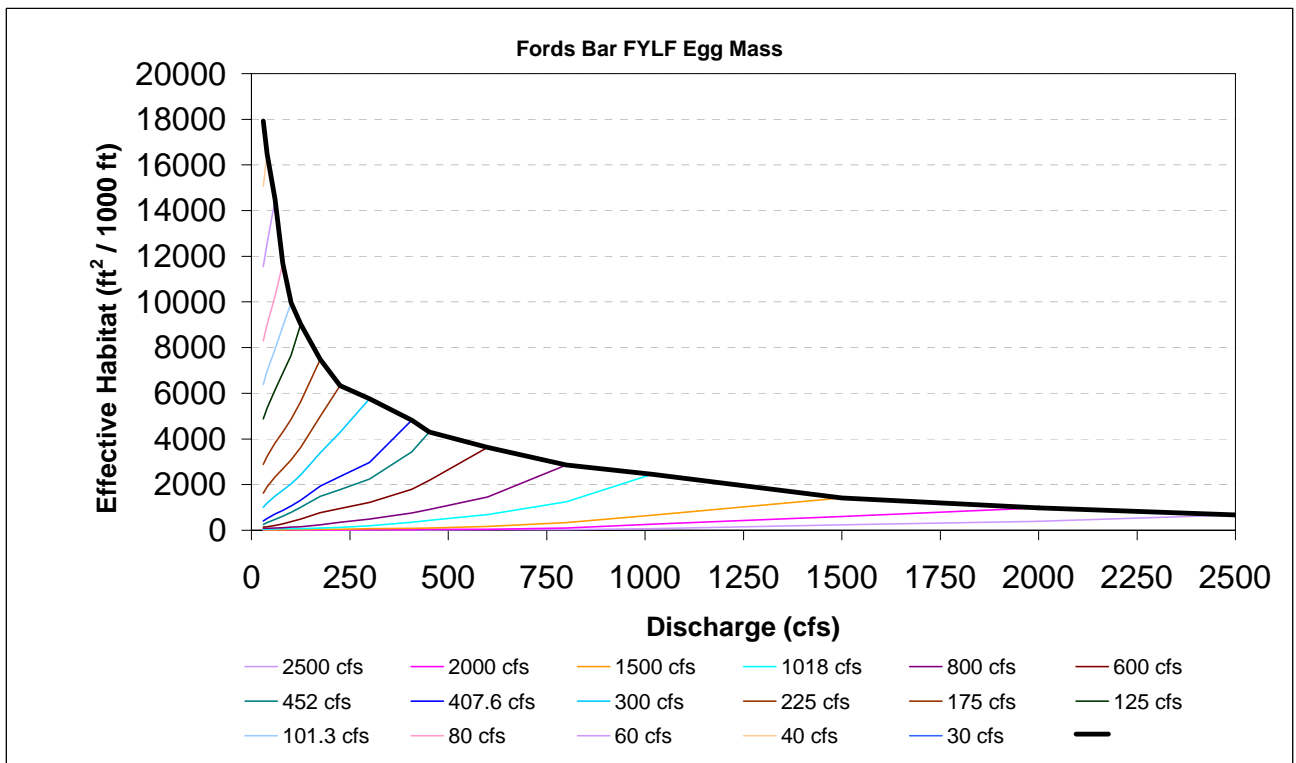
**Figure O-12. Middle Fork American River MF14.1 Effective Rainbow Trout Spawning Depth Sensitivity Incubation Habitat Matrix.**

Starting Discharge (cfs)	Ending Discharge (cfs)																	Initial Habitat vs Flow Relationship
	2500	2000	1500	1018	800	600	452	407	300	225	175	125	101	80	60	40	30	
2500 cfs	8801	8542	8157	7658	7253	6761	6425	6269	5304	4663	4168	3572	3367	3055	2476	1884	1307	8801
2000 cfs		10776	10550	10048	9579	9003	8589	8415	7415	6708	6138	5496	5217	4796	3966	3099	2284	10776
1500 cfs			13332	12945	12467	11757	11271	11062	10025	9275	8638	7933	7605	7092	6100	4972	3830	13332
1018 cfs				16318	16055	15307	14718	14475	13432	12652	11934	11134	10732	10131	8984	7608	6158	16318
800 cfs					17392	16980	16429	16190	15226	14486	13782	12928	12480	11832	10615	9116	7540	17392
600 cfs						18030	17772	17594	16782	16103	15424	14593	14144	13503	12261	10670	9003	18030
452 cfs							18720	18588	18000	17374	16731	15865	15396	14748	13498	11841	10089	18720
407.6 cfs								18681	18194	17631	17014	16198	15755	15109	13867	12229	10480	18681
300 cfs									18036	17642	17249	16564	16165	15546	14401	12855	11183	18036
225 cfs										17077	16696	16189	15823	15270	14289	12889	11350	17077
175 cfs											15890	15432	15172	14744	13933	12698	11324	15890
125 cfs												14151	13829	13576	13019	12059	10930	14151
101.3 cfs													13396	12989	12541	11732	10722	13396
80 cfs														12113	11540	10946	10139	12113
60 cfs															10104	9436	8891	10104
40 cfs																8039	7290	8039
30 cfs																	6597	6597



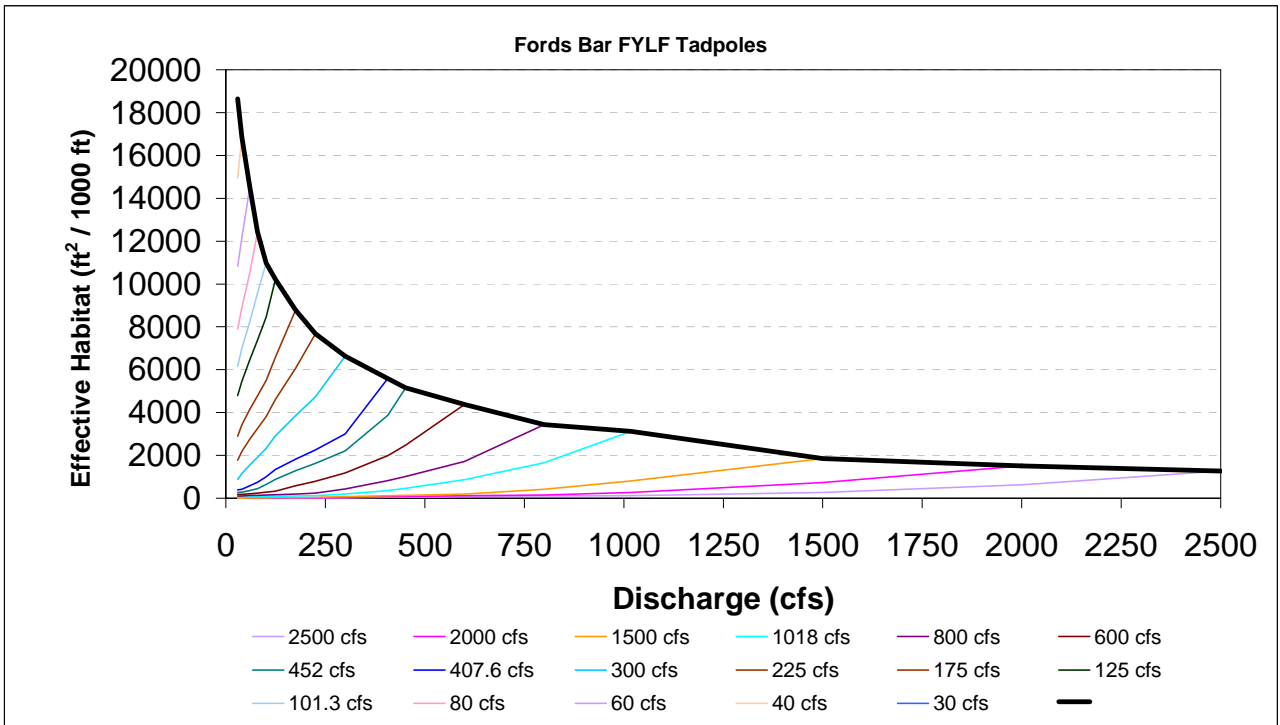
**Figure O-13. Middle Fork American River MF14.1 Effective FYLF Egg Mass Habitat Matrix.**

Starting Discharge (cfs)	Ending Discharge (cfs)																Initial Habitat vs Flow Relationship	
	2500	2000	1500	1018	800	600	452	407	300	225	175	125	101	80	60	40		30
2500 cfs	668	399	239	74	33	25	20	15	11	7	6	3	2	1	1	1	1	668
2000 cfs		985	601	265	101	48	35	30	22	15	13	8	6	5	3	2	2	985
1500 cfs			1418	655	331	173	96	84	72	41	37	26	24	21	18	13	12	1418
1018 cfs				2451	1254	690	430	351	200	122	99	74	70	63	53	42	40	2451
800 cfs					2857	1457	914	757	490	347	238	160	136	117	97	82	77	2857
600 cfs						3627	2193	1791	1226	959	771	494	381	281	204	150	139	3627
452 cfs							4300	3429	2238	1781	1483	1003	790	619	481	335	259	4300
407.6 cfs								4820	2977	2357	1930	1323	1069	872	712	523	402	4820
300 cfs									5759	4289	3395	2429	2031	1752	1506	1191	1008	5759
225 cfs										6339	4996	3626	3083	2688	2343	1899	1630	6339
175 cfs											7491	5638	4864	4297	3823	3243	2884	7491
125 cfs												9021	7662	6878	6157	5357	4871	9021
101.3 cfs													9970	8923	7931	6984	6395	9970
80 cfs														11687	10256	9016	8291	11687
60 cfs															14472	12565	11548	14472
40 cfs																16476	15066	16476
30 cfs																	17926	17926



**Figure O-14. Middle Fork American River MF14.1 Effective FYLF Tadpole Habitat Matrix**

Starting Discharge (cfs)	Ending Discharge (cfs)																	Initial Habitat vs Flow Relationship	
	2500	2000	1500	1018	800	600	452	407	300	225	175	125	101	80	60	40	30		
2500 cfs	1264	626	263	116	102	87	52	49	18	2	1	0	0	0	0	0	0	0	1264
2000 cfs		1512	724	274	148	118	77	70	30	11	9	5	4	3	1	1	1	1	1512
1500 cfs			1858	801	412	189	132	121	71	39	33	25	21	18	15	7	6	6	1858
1018 cfs				3125	1665	872	468	356	190	125	111	93	86	79	73	59	55	55	3125
800 cfs					3437	1718	1023	818	440	232	195	163	152	138	128	111	104	104	3437
600 cfs						4379	2483	1986	1179	793	578	333	282	236	217	186	177	177	4379
452 cfs							5153	3861	2209	1623	1278	888	639	450	355	285	270	270	5153
407.6 cfs								5589	3005	2254	1820	1338	1006	752	576	423	381	381	5589
300 cfs									6639	4732	3849	2918	2333	1906	1558	1157	884	884	6639
225 cfs										7682	6072	4617	3807	3263	2763	2188	1784	1784	7682
175 cfs											8780	6591	5495	4773	4159	3420	2902	2902	8780
125 cfs												10222	8454	7379	6467	5457	4797	4797	10222
101.3 cfs														10972	9580	8248	6984	6164	10972
80 cfs															12423	10529	8885	7907	12423
60 cfs																14520	12157	10833	14520
40 cfs																	16857	14957	16857
30 cfs																		18640	18640



**Figure O-15. Middle Fork American River MF14.1 Effective Food Production Habitat Matrix**

Starting Discharge (cfs)	Ending Discharge (cfs)																Initial Habitat vs Flow Relationship	
	2500	2000	1500	1018	800	600	452	407	300	225	175	125	101	80	60	40		30
2500 cfs	82078	75359	69776	62262	56087	50125	45857	43702	38740	33765	29679	24269	19538	13730	7722	4545	2991	82078
2000 cfs		95204	89029	80958	74435	67745	62485	59653	53125	47537	42921	36110	29840	22754	15214	10075	7229	95204
1500 cfs			103390	94561	87679	80521	74838	71687	64269	57964	52757	45277	38412	30878	22524	16130	12019	103390
1018 cfs				107696	100096	92600	86482	83084	74980	68155	62509	54447	47017	38860	29565	21977	17005	107696
800 cfs					107013	98431	92093	88533	80072	73036	67171	58926	51346	43003	33328	25361	19976	107013
600 cfs						106258	99025	95302	86446	79204	73224	64848	57162	48698	38772	30516	24884	106258
452 cfs							103990	99247	90064	82633	76597	68134	60383	51856	41834	33422	27649	103990
407.6 cfs								101210	91371	83587	77487	68985	61160	52619	42553	34120	28320	101210
300 cfs									93632	85023	78704	70164	62286	53696	43567	35103	29276	93632
225 cfs										87534	80338	71248	62925	54098	43804	35334	29500	87534
175 cfs											81336	71735	63317	54467	44130	35655	29817	81336
125 cfs												72341	63646	54711	44308	35831	29993	72341
101.3 cfs													64643	55156	44488	35991	30148	64643
80 cfs														55640	44680	36124	30233	55640
60 cfs															45736	36479	30365	45736
40 cfs																36791	30472	36791
30 cfs																	30672	30672

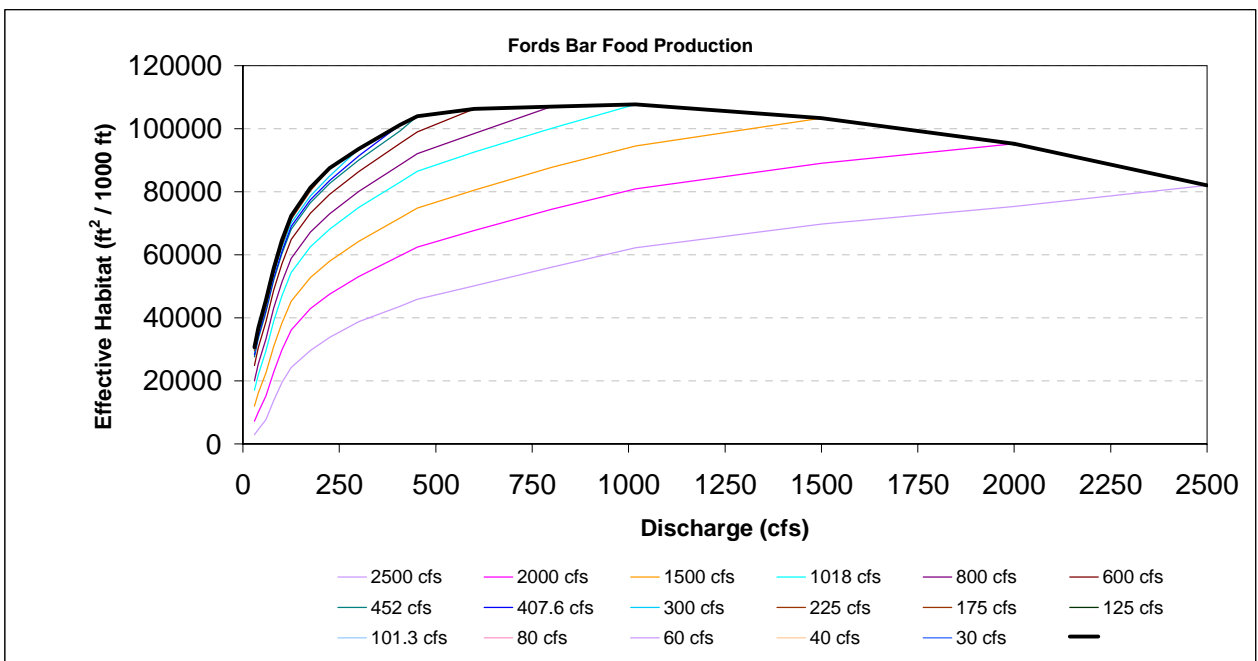


Figure O-16. Fords Bar MF14.1 Effective Habitat Time Series. (Top) Effective Rainbow Trout Spawning (Average of Eight Weekly Spawning Periods May–April) and Subsequent Incubation and (Bottom) Effective Foothill Yellow-Legged Frog Breeding Habitat (Average of Three 10–11 Day Breeding Periods (May 10–June 15) (see text for details).

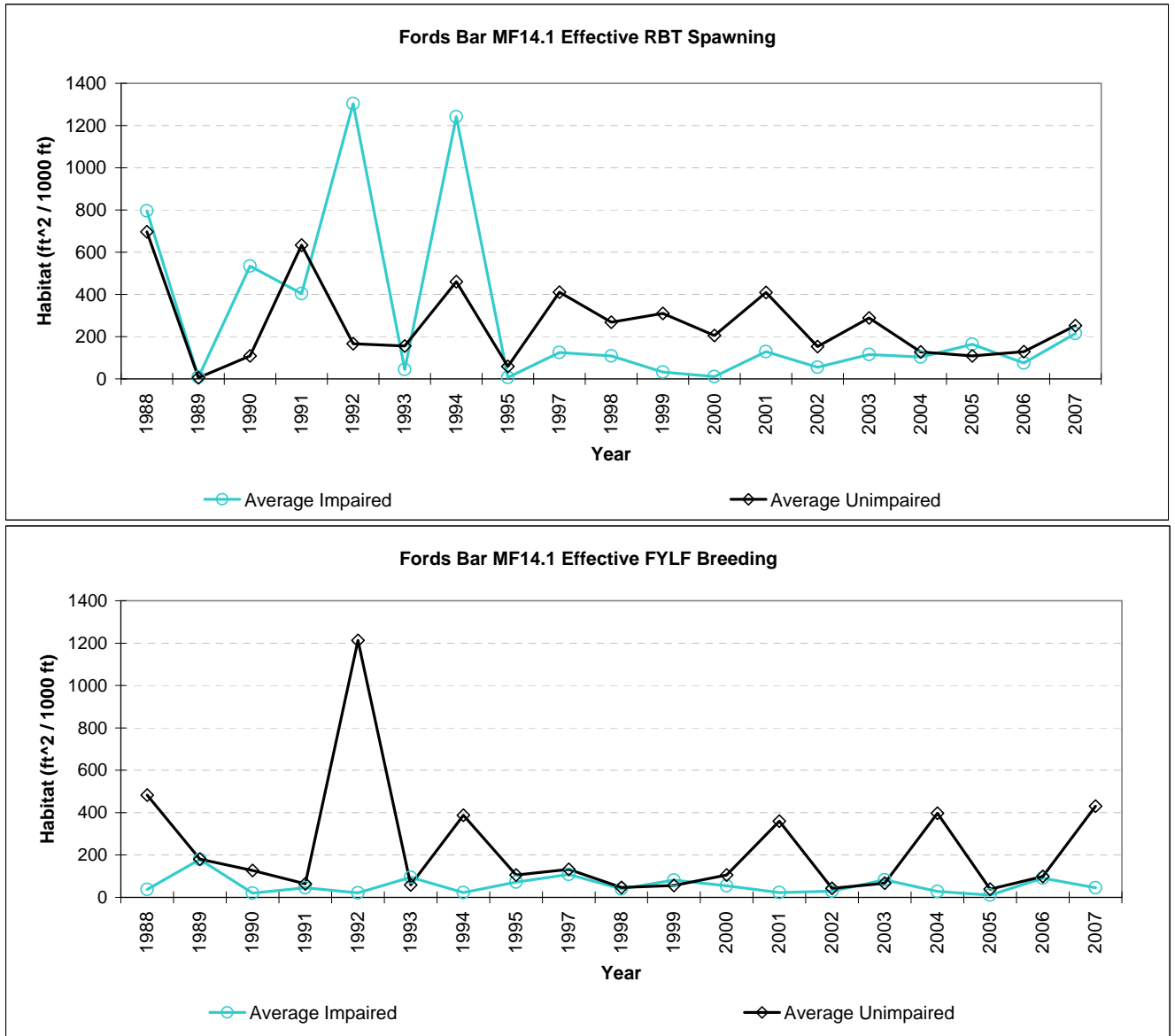
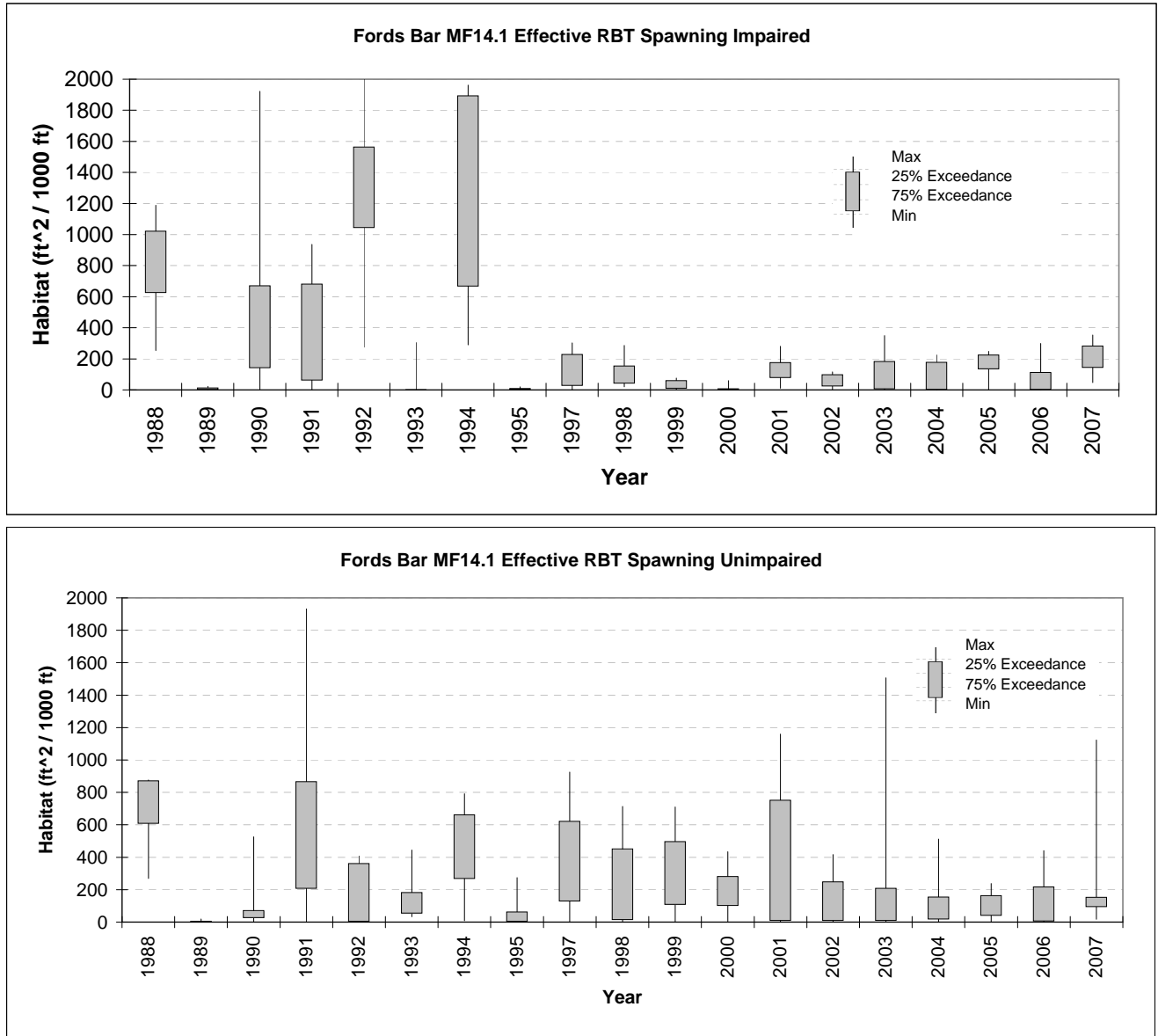
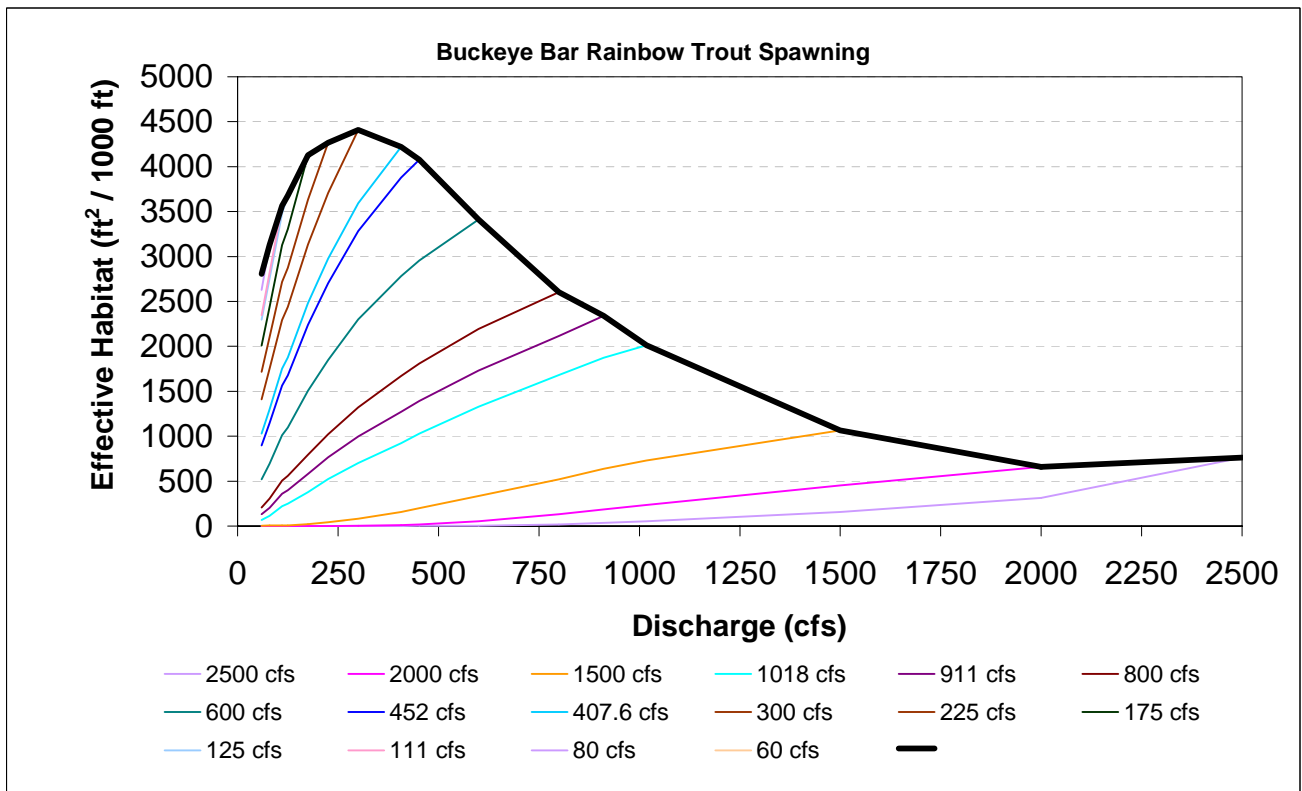


Figure O-17. Fords Bar MF14.1 Effective Rainbow Trout Spawning Habitat. Maximum, Minimum, and 25% and 75% Exceedance of Eight Weekly Spawning Periods (March-April) and Subsequent Incubation (see text for details).



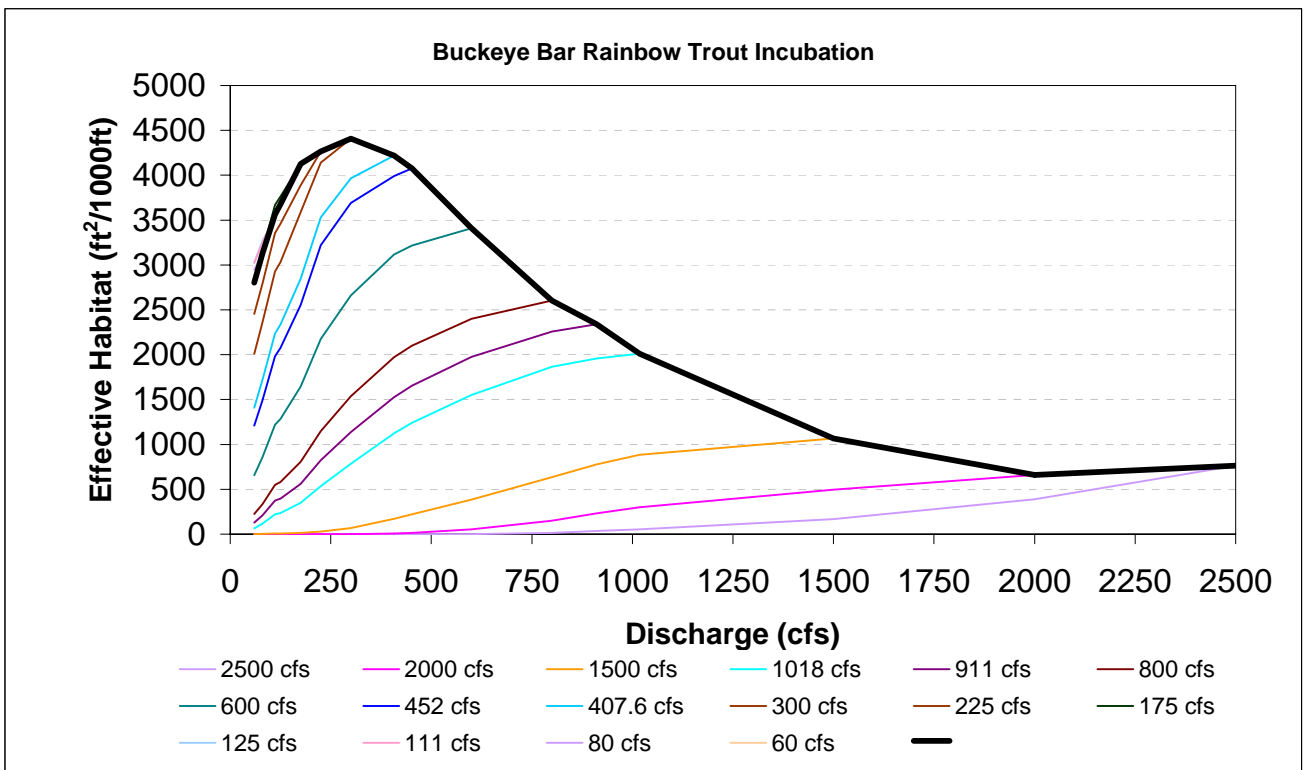
**Figure O-18. Middle Fork American River MF4.8 Effective Rainbow Trout Spawning Habitat Matrix.**

Starting Discharge (cfs)	Ending Discharge (cfs)																Initial Habitat vs Flow Relationship
	2500	2000	1500	1018	911	800	600	452	407	300	225	175	125	111	80	60	
2500 cfs	764	315	155	54	34	18	4	2	1	0	0	0	0	0	0	0	764
2000 cfs		658	453	235	186	132	54	19	12	2	1	0	0	0	0	0	658
1500 cfs			1067	728	639	518	333	198	156	83	44	23	8	7	6	3	1067
1018 cfs				2011	1874	1680	1329	1030	921	701	522	376	248	222	115	69	2011
911 cfs					2341	2114	1730	1392	1270	998	766	580	398	359	204	131	2341
800 cfs						2602	2193	1808	1670	1322	1022	793	557	505	306	205	2602
600 cfs							3411	2957	2782	2302	1850	1505	1099	1012	696	519	3411
452 cfs								4076	3878	3282	2705	2241	1678	1563	1147	899	4076
407.6 cfs									4221	3594	2978	2482	1876	1753	1301	1030	4221
300 cfs										4409	3706	3134	2439	2295	1752	1410	4409
225 cfs											4265	3632	2875	2716	2105	1716	4265
175 cfs												4128	3305	3126	2441	2010	4128
125 cfs													3678	3478	2758	2296	3678
111 cfs														3564	2820	2346	3564
80 cfs															3130	2629	3130
60 cfs																2805	2805



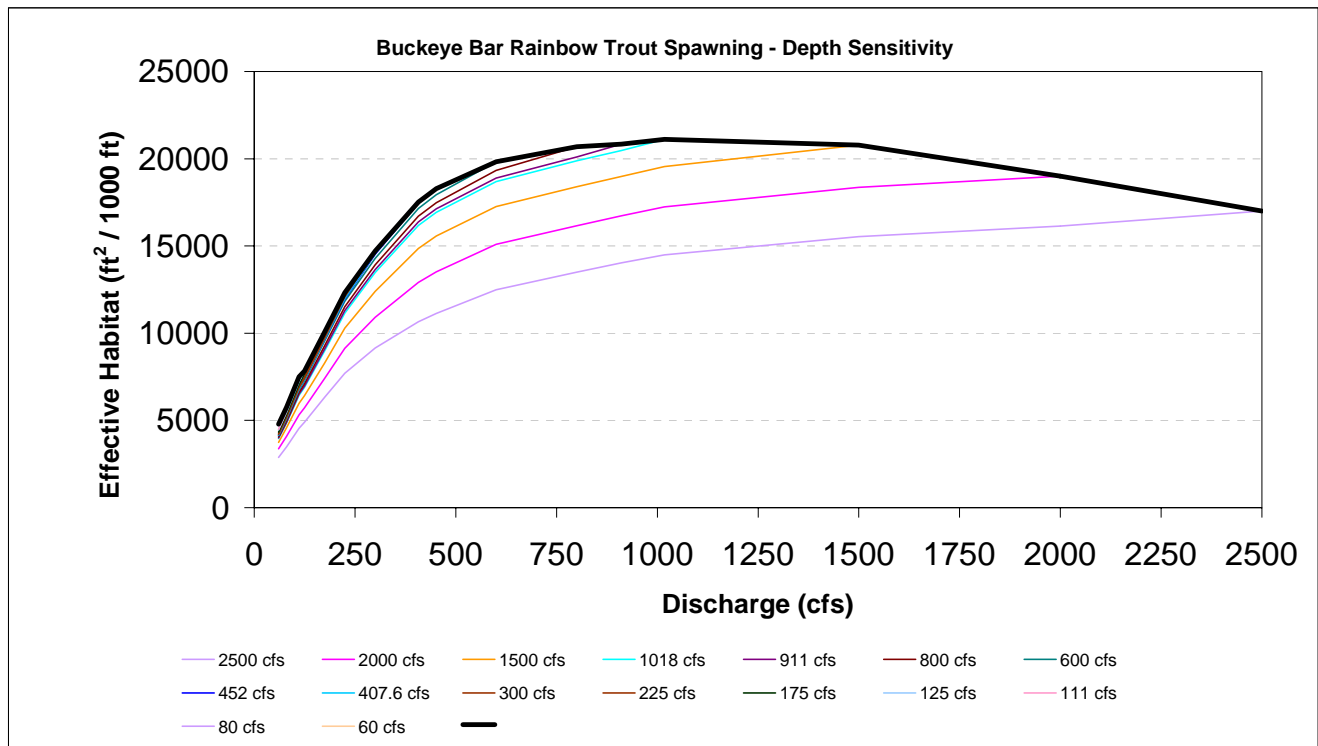
**Figure O-19. Middle Fork American River MF4.8 Effective Rainbow Trout Incubation Habitat Matrix.**

Starting Discharge (cfs)	Ending Discharge (cfs)																Initial Habitat vs Flow Relationship
	2500	2000	1500	1018	911	800	600	452	407	300	225	175	125	111	80	60	
2500 cfs	764	389	167	55	36	15	2	1	0	0	0	0	0	0	0	0	764
2000 cfs		658	496	298	232	150	53	16	7	0	0	0	0	0	0	0	658
1500 cfs			1067	884	776	633	384	222	172	68	30	16	6	6	5	1	1067
1018 cfs				2011	1957	1866	1551	1241	1122	783	536	350	234	221	117	65	2011
911 cfs					2341	2259	1976	1654	1527	1138	824	561	395	374	212	129	2341
800 cfs						2602	2401	2100	1972	1537	1150	805	581	551	337	223	2602
600 cfs							3411	3217	3116	2662	2176	1644	1283	1219	861	658	3411
452 cfs								4076	3990	3691	3219	2552	2075	1982	1495	1208	4076
407.6 cfs									4221	3964	3531	2848	2336	2237	1721	1409	4221
300 cfs										4409	4140	3586	3033	2926	2366	2007	4409
225 cfs											4265	3889	3459	3356	2796	2452	4265
175 cfs												4128	3761	3670	3163	2849	4128
125 cfs													3678	3517	3270	3025	3678
111 cfs														3564	3253	3023	3564
80 cfs															3130	2946	3130
60 cfs																2805	2805



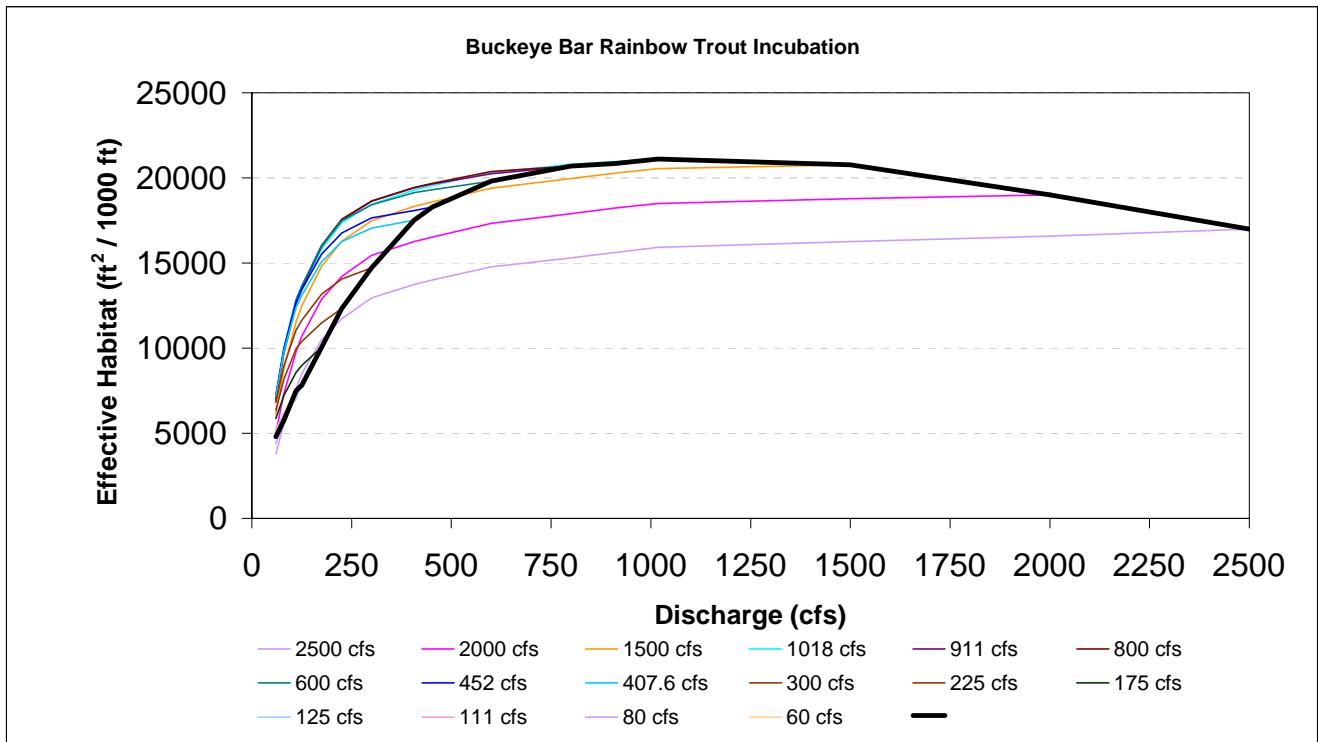
**Figure O-20. Middle Fork American River MF4.8 Effective Rainbow Trout Depth Sensitivity Spawning Habitat Matrix.**

Starting Discharge (cfs)	Ending Discharge (cfs)																Initial Habitat vs Flow Relationship
	2500	2000	1500	1018	911	800	600	452	407	300	225	175	125	111	80	60	
2500 cfs	16998	16140	15535	14483	14030	13506	12495	11126	10650	9150	7702	6327	4903	4544	3476	2878	16998
2000 cfs		18998	18366	17250	16728	16168	15087	13525	12917	10910	9143	7404	5720	5321	4096	3382	18998
1500 cfs			20774	19558	18977	18391	17251	15576	14853	12398	10283	8284	6416	5981	4577	3741	20774
1018 cfs				21107	20474	19876	18684	16932	16178	13474	11143	8981	6898	6432	4860	3955	21107
911 cfs					20840	20095	18894	17130	16373	13644	11293	9102	6978	6505	4905	3991	20840
800 cfs						20688	19332	17478	16711	13926	11518	9282	7096	6611	4978	4048	20688
600 cfs							19820	17933	17144	14296	11834	9547	7261	6757	5084	4125	19820
452 cfs								18284	17462	14531	11966	9642	7329	6819	5134	4161	18284
407.6 cfs									17522	14580	11997	9662	7342	6830	5142	4168	17522
300 cfs										14709	12085	9723	7390	6875	5181	4202	14709
225 cfs											12329	9830	7479	6961	5254	4264	12329
175 cfs												10063	7640	7065	5330	4328	10063
125 cfs													7825	7224	5472	4453	7825
111 cfs														7499	5526	4496	7499
80 cfs															5758	4688	5758
60 cfs																4796	4796



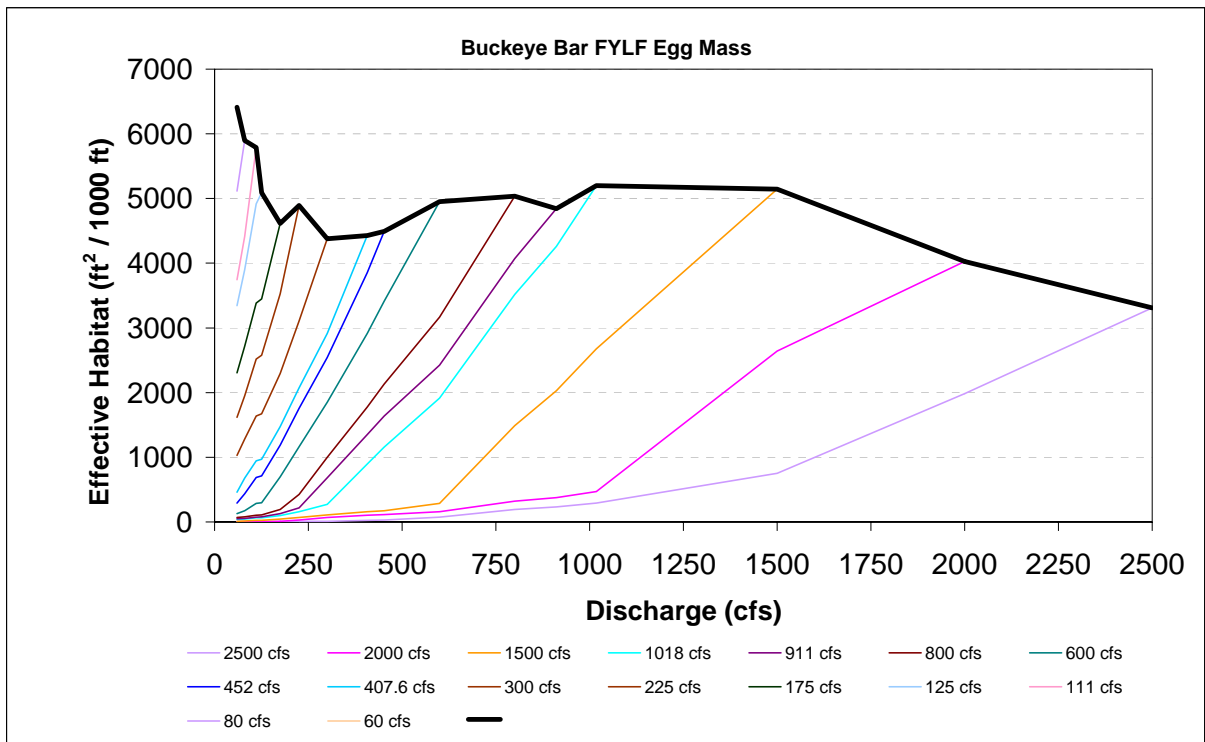
**Figure O-21. Middle Fork American River MF4.8 Effective Rainbow Trout Spawning Depth Sensitivity Incubation Habitat Matrix.**

Starting Discharge (cfs)	Ending Discharge (cfs)																Initial Habitat vs Flow Relationship
	2500	2000	1500	1018	911	800	600	452	407	300	225	175	125	111	80	60	
2500 cfs	16998	16581	16255	15922	15614	15299	14774	14001	13747	12954	11723	10487	8501	7611	5595	3776	16998
2000 cfs		18998	18783	18492	18225	17897	17339	16521	16263	15449	14217	12868	10699	9779	7329	5012	18998
1500 cfs			20774	20541	20288	19969	19404	18590	18324	17486	16278	14805	12476	11543	8800	6135	20774
1018 cfs				21107	20957	20795	20317	19550	19293	18461	17378	15819	13385	12499	9630	6821	21107
911 cfs					20840	20674	20251	19646	19415	18625	17509	15980	13533	12623	9740	6919	20840
800 cfs						20688	20371	19677	19445	18641	17581	16029	13595	12749	9875	7062	20688
600 cfs							19820	19312	19141	18430	17475	16010	13663	12854	10003	7224	19820
452 cfs								18284	18076	17641	16774	15518	13438	12678	9951	7212	18284
407.6 cfs									17522	17054	16252	15075	13106	12393	9808	7163	17522
300 cfs										14709	14051	13181	11638	11061	8975	6821	14709
225 cfs											12329	11486	10393	9960	8170	6353	12329
175 cfs												10063	8980	8563	7219	5869	10063
125 cfs													7825	7012	6198	5225	7825
111 cfs														7499	6105	5101	7499
80 cfs															5758	4379	5758
60 cfs																4796	4796



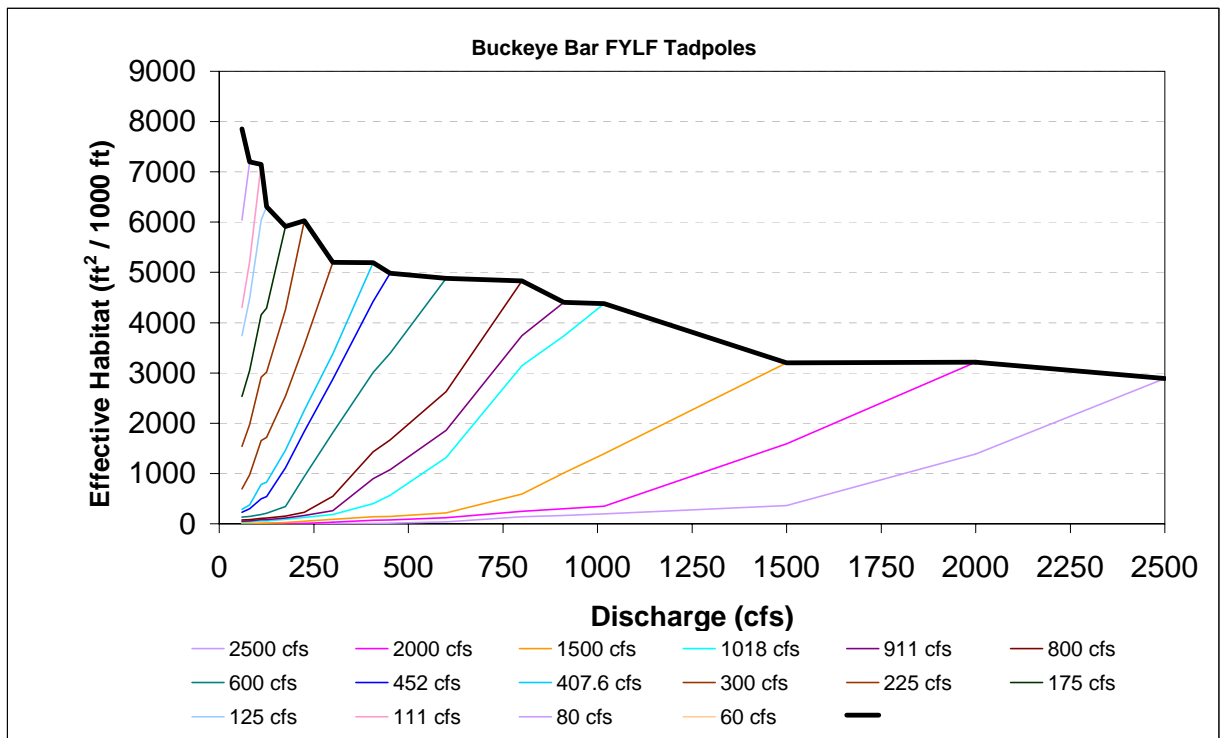
**Figure O-22. Middle Fork American River MF4.8 Effective FYLF Egg Mass Habitat Matrix.**

Starting Discharge (cfs)	Ending Discharge (cfs)																Initial Habitat vs Flow Relationship
	2500	2000	1500	1018	911	800	600	452	407	300	225	175	125	111	80	60	
2500 cfs	3309	1985	751	291	233	195	72	32	26	11	10	5	3	2	1	0	3309
2000 cfs		4029	2641	468	375	321	161	115	106	68	30	10	6	5	4	3	4029
1500 cfs			5145	2676	2028	1489	285	174	157	110	69	44	24	23	14	11	5145
1018 cfs				5202	4260	3518	1913	1159	895	272	157	97	66	63	45	40	5202
911 cfs					4842	4070	2425	1639	1349	684	218	128	78	75	55	48	4842
800 cfs						5036	3165	2134	1775	999	428	192	110	104	78	69	5036
600 cfs							4951	3412	2913	1852	1161	697	295	285	175	127	4951
452 cfs								4493	3855	2541	1755	1186	710	686	433	293	4493
407.6 cfs									4425	2912	2073	1474	970	944	676	461	4425
300 cfs										4380	3105	2297	1671	1637	1284	1029	4380
225 cfs											4894	3525	2577	2518	1951	1618	4894
175 cfs												4615	3450	3383	2714	2306	4615
125 cfs													5088	4919	3899	3344	5088
111 cfs														5790	4412	3747	5790
80 cfs															5898	5116	5898
60 cfs																6413	6413



**Figure O-23. Middle Fork American River MF4.8 Effective FYLF Tadpole Habitat Matrix.**

Starting Discharge (cfs)	Ending Discharge (cfs)																Initial Habitat vs Flow Relationship
	2500	2000	1500	1018	911	800	600	452	407	300	225	175	125	111	80	60	
2500 cfs	2892	1385	363	194	167	140	36	10	9	6	5	1	1	0	0	0	2892
2000 cfs		3211	1593	347	298	247	121	76	69	33	9	4	3	2	2	1	3211
1500 cfs			3202	1396	1009	594	213	148	137	92	49	27	15	14	7	6	3202
1018 cfs				4380	3736	3146	1321	568	404	187	127	88	59	58	40	35	4380
911 cfs					4402	3741	1857	1075	898	261	164	116	82	81	58	52	4402
800 cfs						4831	2628	1665	1431	546	227	154	114	111	83	75	4831
600 cfs							4883	3389	3011	1815	942	346	210	187	147	133	4883
452 cfs								4985	4422	2877	1841	1113	540	499	296	231	4985
407.6 cfs									5191	3378	2261	1466	831	783	372	287	5191
300 cfs										5203	3558	2541	1720	1653	974	696	5203
225 cfs											6030	4257	3020	2914	1975	1543	6030
175 cfs												5915	4293	4159	3048	2532	5915
125 cfs													6308	6037	4478	3741	6308
111 cfs														7150	5213	4305	7150
80 cfs															7200	6039	7200
60 cfs																7856	7856



**Figure O-24. Middle Fork American River MF4.8 Effective Food Production Habitat Matrix**

Starting Discharge (cfs)	Ending Discharge (cfs)																Initial Habitat vs Flow Relationship
	2500	2000	1500	1018	911	800	600	452	407	300	225	175	125	111	80	60	
2500 cfs	94386	87594	81657	73449	71476	67927	62685	57763	55986	49601	41510	32140	21472	19456	11620	8995	94386
2000 cfs		94191	87787	79050	76344	72470	66875	61623	59700	52944	44265	34735	23680	21525	12895	9826	94191
1500 cfs			93796	84480	80996	77039	71228	65705	63660	56565	47363	37634	26276	23856	14712	10992	93796
1018 cfs				90811	87111	83130	77198	71498	69391	62012	52457	42567	30896	28153	18513	14424	90811
911 cfs					90275	84841	78856	73096	70966	63477	53820	43885	32162	29394	19681	15524	90275
800 cfs						88394	81700	75458	73306	65736	55946	45899	34050	31203	21425	17163	88394
600 cfs							86248	79817	77655	70029	60062	49796	37700	34759	24891	20513	86248
452 cfs								83693	81189	73163	62928	52443	40149	37164	27224	22789	83693
407.6 cfs									82057	73954	63667	53158	40829	37845	27882	23422	82057
300 cfs										75891	65434	54858	42480	39480	29494	24976	75891
225 cfs											66817	56008	43621	40616	30625	26093	66817
175 cfs												57403	44664	41506	31412	26772	57403
125 cfs													45641	42223	31996	27235	45641
111 cfs														44190	32091	27313	44190
80 cfs															33184	28109	33184
60 cfs																28269	28269

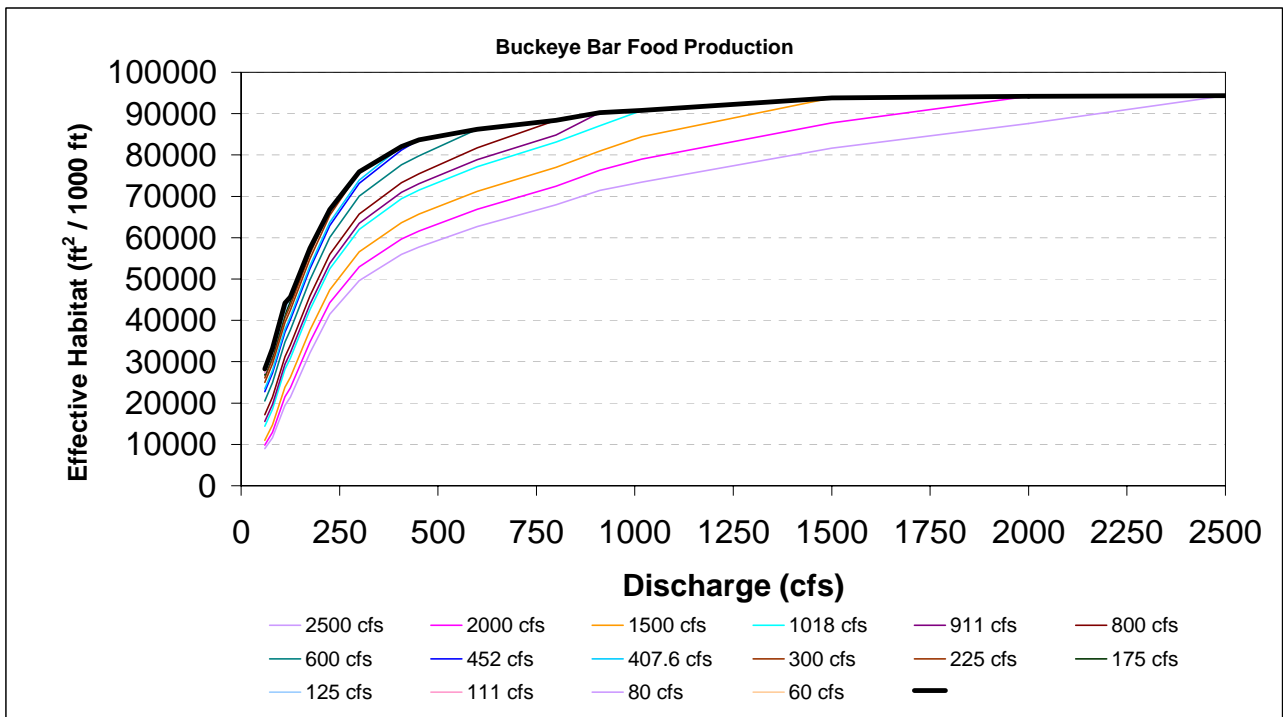


Figure O-25. Buckeye Bar MF4.8 Effective Habitat Time Series. (Top) Effective Rainbow Trout Spawning Habitat (Average of Eight Weekly Spawning Periods March–April) and Subsequent Incubation and (Bottom) Effective Foothill Yellow-Legged Frog Breeding Habitat (Average of Three 10–11 Day Breeding Periods (May 10–June 15) (see text for details).

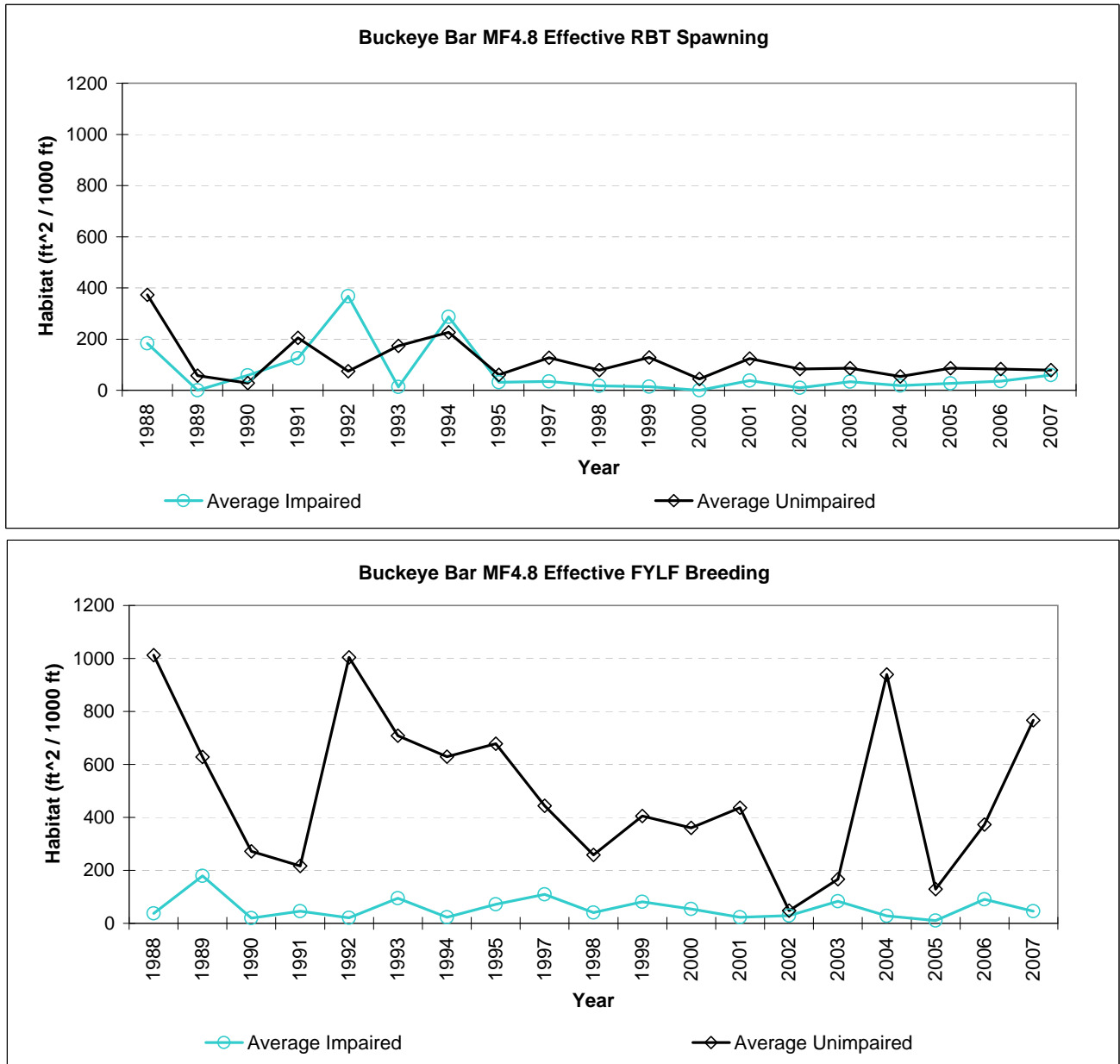
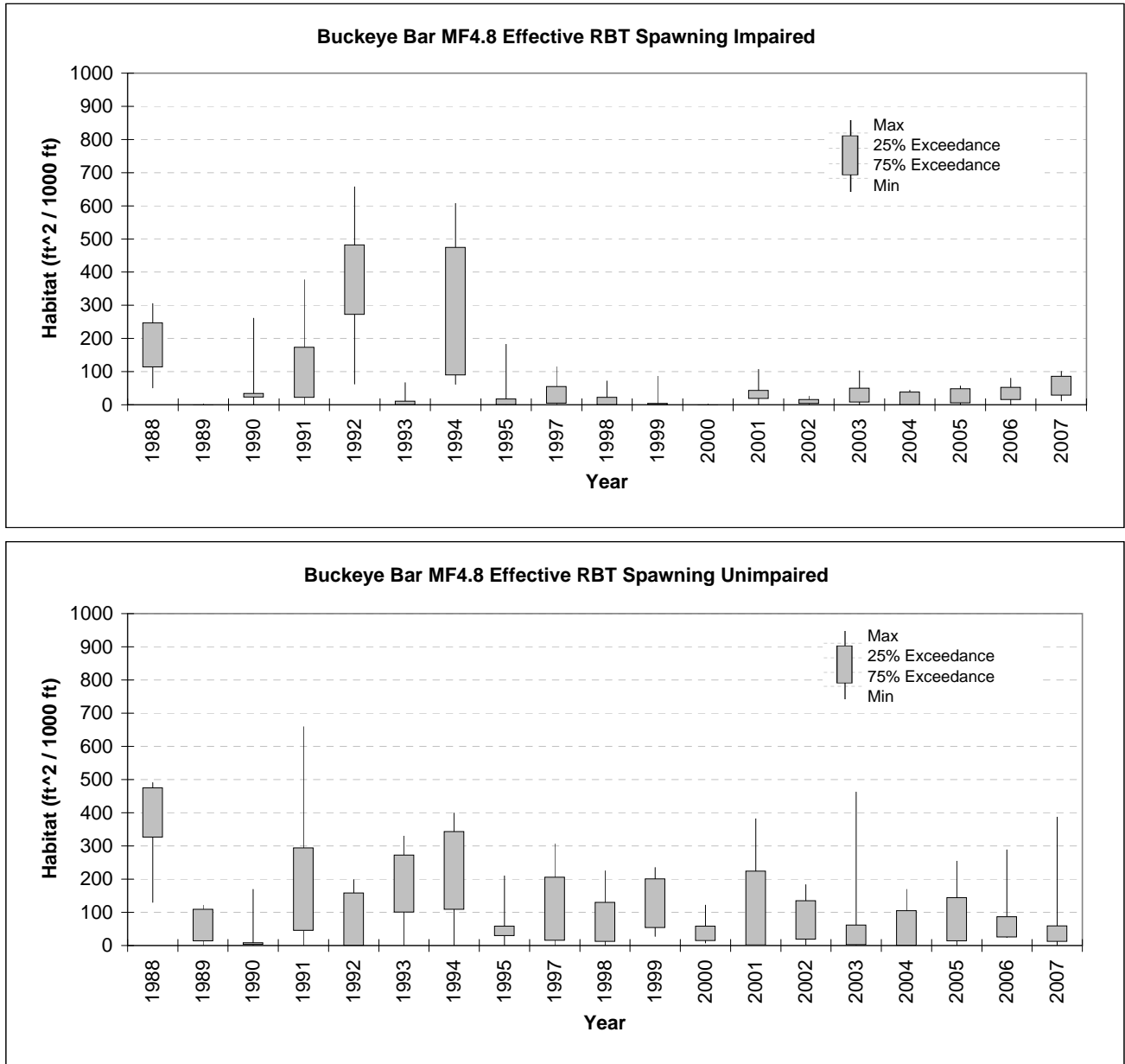


Figure O-26. Buckeye Bar MF4.8 Effective Rainbow Trout Spawning Habitat. Maximum, Minimum, and 25% and 75% Exceedance of Eight Weekly Spawning Periods (March-April) and Subsequent Incubation (see text for details).



**APPENDIX P**

**Foothill Yellow-Legged Frog Habitat Model Validation Data**

(See Attached Electronic Media)

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Table P-1. Comparison of Modeled versus Measured Conditions for Validation of Foothill Yellow-Legged Frog Breeding and Tadpole Habitat by Site.

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Map P-2. Substrate Polygon Delineation with Observed FYLF Egg Mass and Tadpole Locations. Middle Fork American River 26.2 Downstream Site.

Map P-3. Substrate Polygon Delineation with Observed FYLF Egg Mass Locations. Rubicon River 3.5 Upstream Site.

Map P-4. Substrate Polygon Delineation with Observed FYLF Tadpole Locations. Rubicon River 3.5 Upstream Site.

Map P-5. Substrate Polygon Delineation with Observed FYLF Egg Mass Locations. Rubicon River 3.5 Downstream Site.

**List of Attachments**

Attachment A - Foothill Yellow-Legged Frog Validation Data Slideshows

**AQ – 1 Instream Flow Study Sites**

**File Name**

Middle Fork American River 26.2 .....	1_MF26.2US_FYLF_EggsLocations_35cfs.ppt
.....	2_MF 26.2DS_FYLF_EggsLocations_30cfs.ppt
.....	3_MF 26.2DS_FYLF_TadpoleLocations_30cfs.ppt
Rubicon River 3.5.....	4_R3.5US_FYLF_EggsLocations_55cfs.ppt
.....	5_R3.5US_FYLF_TadsLocations_36cfs.ppt
.....	6_R3.5DS_FYLF_EggsLocations_125cfs.ppt
.....	7_R3.5DS_FYLF_EggsLocations_88.5cfs.ppt

**TABLES**

**Table P-1. Comparison of Modeled versus Measured Conditions for Validation of Foothill Yellow-Legged Frog Breeding and Tadpole Habitat by Site.**

Site/I.D.	Model Match	Criteria				
		Depth	Velocity		Substrate	
		Match	Match	Note	Inaccuracy	Match
<b>Rubicon R3.5 Upstream Site</b>						
EGG MASS D	Yes	Good	Good			Good
EGG MASS E	Yes	Good	Good			Good
EGG MASS F G	Yes	Good	Good			Good
EGG MASS H	Yes	Good	Good			Good
EGG MASS I	Yes	Good	Good			Good
EGG MASS N	Yes	Good	Good			Good
EGG MASS O	No	Good	Poor	Modeled as >0.11 m/s, measured as 0.0 m/s	Model	Good
EGG MASS P	No	Good	Poor	Modeled as >0.11 m/s, measured as 0.16 m/s	HSC	Good
EGG MASS Q	No	Good	Poor	Modeled as >0.11 m/s, measured as 0.14 m/s	HSC	Good
EGG MASS S	Yes	Good	Good			Good
EGG MASS T	No	Good	Poor	Modeled as >0.11 m/s, measured as -0.04 m/s	Model	Good
EGG MASS V	Yes	Good	Good			Good
EGG MASS X	Yes	Good	Good			Good
EGG MASS Y	Yes	Good	Good			Good
EGG MASS Z	Yes	Good	Good			Good
EGG MASS AA	No	Good	Poor	Modeled as >0.11 m/s, measured as 0.02 m/s	Model	Good
EGG MASS 99	Yes <sup>1</sup>	Good	Good			Poor <sup>1</sup>
EGG MASS 88	Yes <sup>1</sup>	Good	Good			Poor <sup>1</sup>
TADS 01	Yes	Good	Good			Good
TADS 02	Yes	Good	Good			Good
TADS 04	Yes	Good	Good			Good
TADS 05	Yes	Good	Good			Good
TADS 06	Yes	Good	Good			Good
TADS 07	Yes	Good	Good			Good
TADS 08	Yes	Good	Good			Good
TADS 09	Yes	Good	Good			Good
TADS 11	Yes	Good	Good			Good
TADS 12	Yes	Good	Good			Good
TADS 13	Yes	Good	Good			Good
TADS 14	Yes	Good	Good			Good
TADS 15	Yes	Good	Good			Good
TADS 16	No	Good	Poor	Modeled as >0.06 m/s, measured as 0.0 m/s	Model	Good
TADS 17	Yes	Good	Good			Good
TADS 18	Yes	Good	Good			Good
TADS 19	Yes	Good	Good			Good
TADS 20	Yes	Good	Good			Good
TADS 31	Yes	Good	Good			Good
TADS 48	Yes	Good	Good			Good
TADS 49	Yes	Good	Good			Good
TADS 52	Yes	Good	Good			Good
TADS 55	Yes	Good	Good			Good
TADS 58	Yes	Good	Good			Good
TADS 62	Yes	Good	Good			Good
TADS D	Yes	Good	Good			Good
TADS E	Yes	Good	Good			Good
TADS F	No	Good	Poor	Modeled as >0.06 m/s, measured as 0.0 m/s	Model	Good
TADS G	No	Good	Poor	Modeled as >0.06 m/s, measured as 0.02 m/s	Model	Good
TADS H	No	Good	Poor	Modeled as >0.06 m/s, measured as 0.0 m/s	Model	Good
TADS I	Yes	Good	Good			Good
TADS J	Yes	Good	Good			Good
TADS K	Yes	Good	Good			Good
TADS L	Yes	Good	Good			Good
TADS M	Yes	Good	Good			Good
TADS N	Yes	Good	Good			Good
TADS O	Yes	Good	Good			Good
TADS P	Yes	Good	Good			Good
<b>Rubicon R3.5 Downstream Site</b>						
EGG MASS J	No	Good	Poor	Modeled as >0.25 m/s, measured as 0.11 m/s	Model, HSC	Good
EGG MASS A	No	Good	Poor	Modeled as >0.11 m/s, measured as 0.03 m/s	Model	Good
EGG MASS W	Yes	Good	Good			Good
EGG MASS B	Yes	Good	Good			Good
<b>Middle Fork American River MF26.2 Upstream Site</b>						
EGG MASS A	Yes	Good	Good			Good
EGG MASS B	No	Good	Poor	Modeled as >0.25 m/s, measured as 0.07 m/s	Model	Good
<b>Middle Fork American River MF26.2 Downstream Site</b>						
EGG MASS C	No	Good	Poor	Modeled as >0.11 m/s, measured as 0.13 m/s	HSC	Good
TADS	No	Good	Poor	Modeled as >0.06 m/s, measured as 0.13 m/s	HSC	Good

<sup>1</sup>Substrate was modeled as bedrock, but could have easily, and likely should have been, classified as a boulder with regard to FYLF breeding suitability.

**MAPS**

**ATTACHMENT A**

**Foothill Yellow-Legged Frog Validation Data Slideshows**

(See Attached Electronic Media)

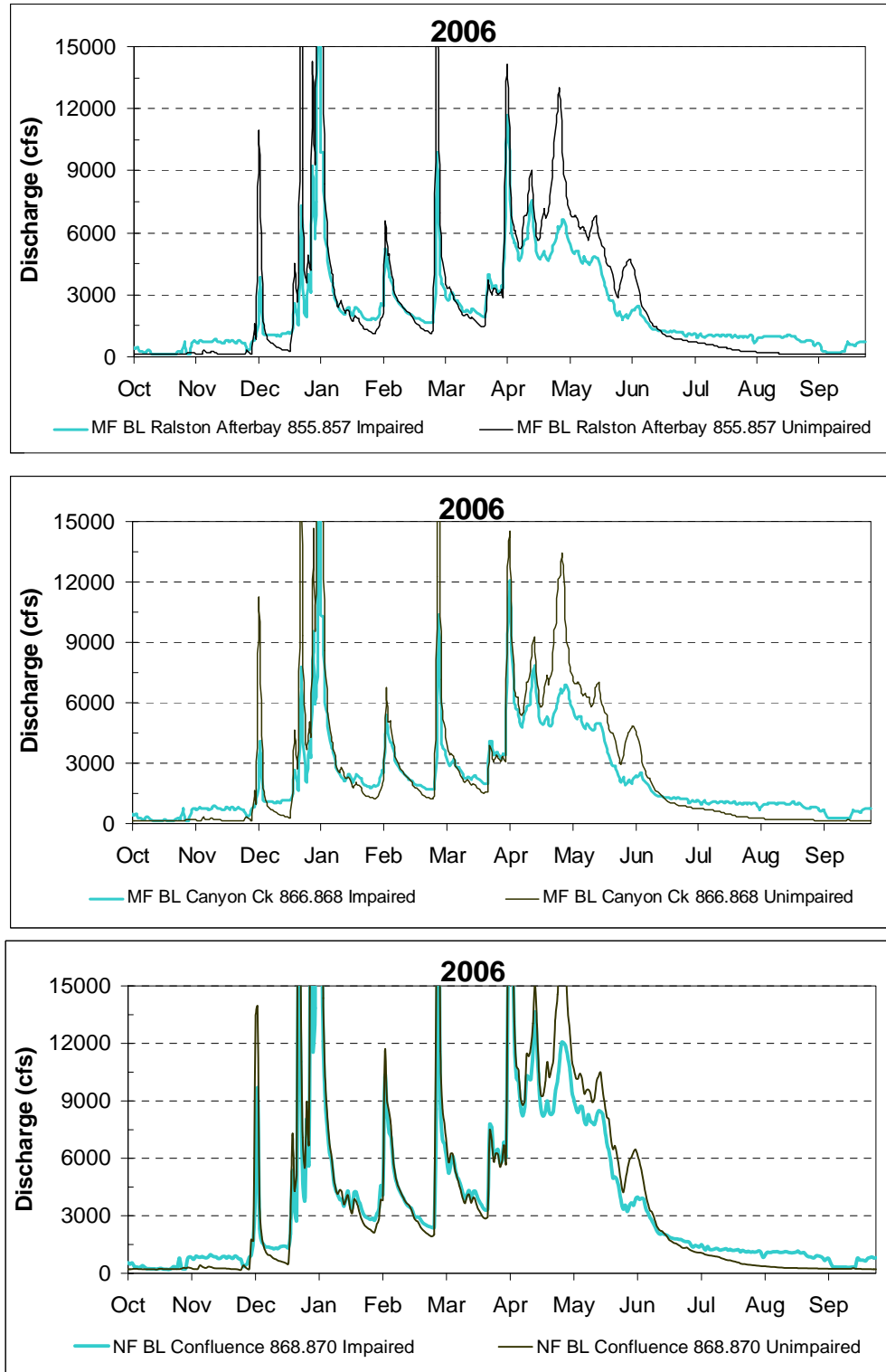
**APPENDIX Q**  
**Peaking Reach Mean Daily Flow Hydrology**

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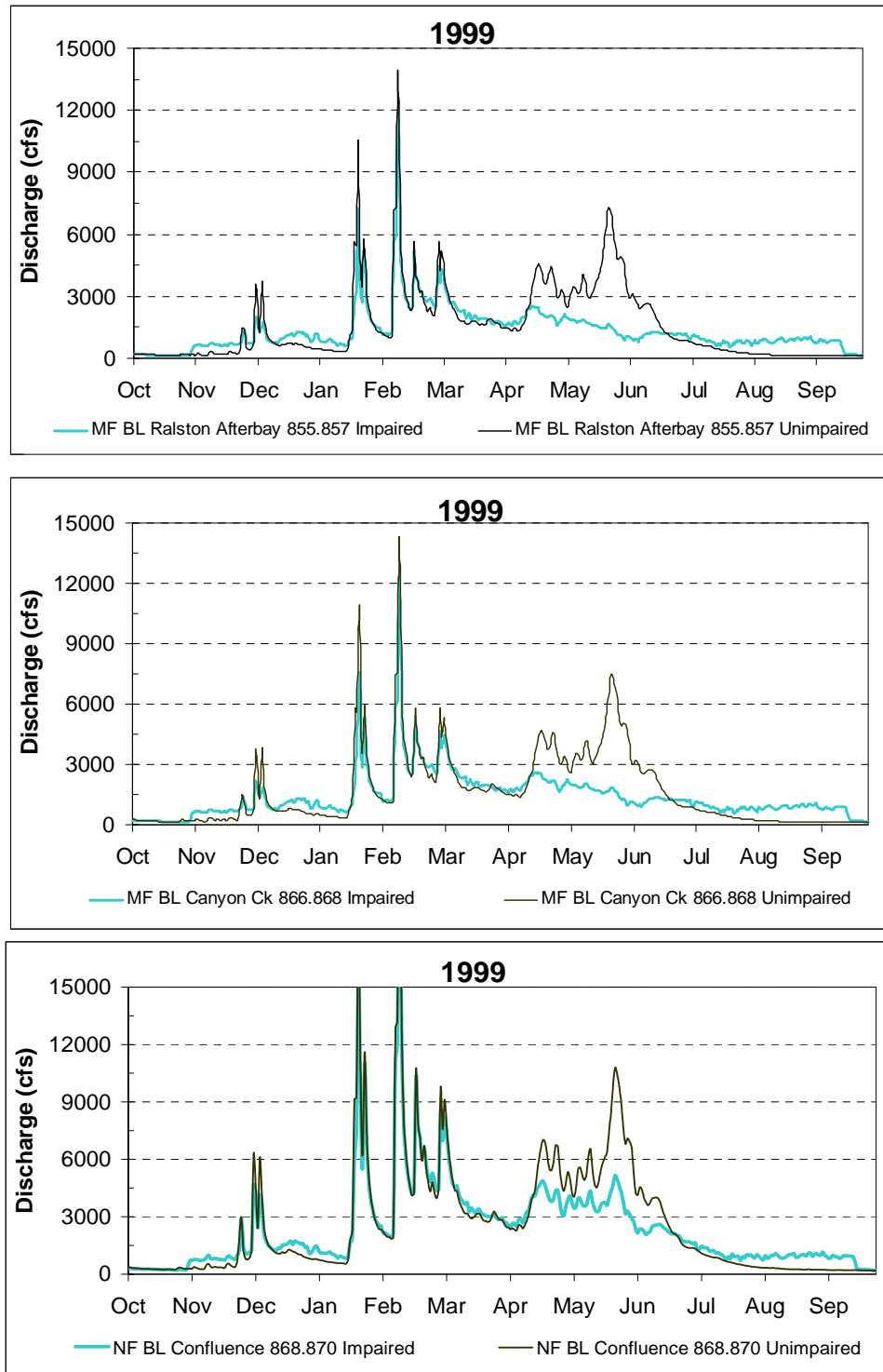
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Figure Q-2. Above Normal Water Year (1999) flows in the Middle Fork American River below Ralston Afterbay (top), Middle Fork American River downstream of Canyon Creek (middle), and the North Fork American River below the Middle Fork American River Confluence (bottom). .....	Q-2
Figure Q-3. Below Normal Water Year (2003) flows in the Middle Fork American River below Ralston Afterbay (top), Middle Fork American River downstream of Canyon Creek (middle), and the North Fork American River below the Middle Fork American River Confluence (bottom). .....	Q-3
Figure Q-4. Dry Water Year (2001) flows in the Middle Fork American River below Ralston Afterbay (top), Middle Fork American River downstream of Canyon Creek (middle), and the North Fork American River below the Middle Fork American River Confluence (bottom). .....	Q-4
Figure Q-5. Critical Dry Water Year (1999) flows in the Middle Fork American River below Ralston Afterbay (top), Middle Fork American River downstream of Canyon Creek (middle), and the North Fork American River below the Middle Fork American River Confluence (bottom). .....	Q-5

**FIGURES**

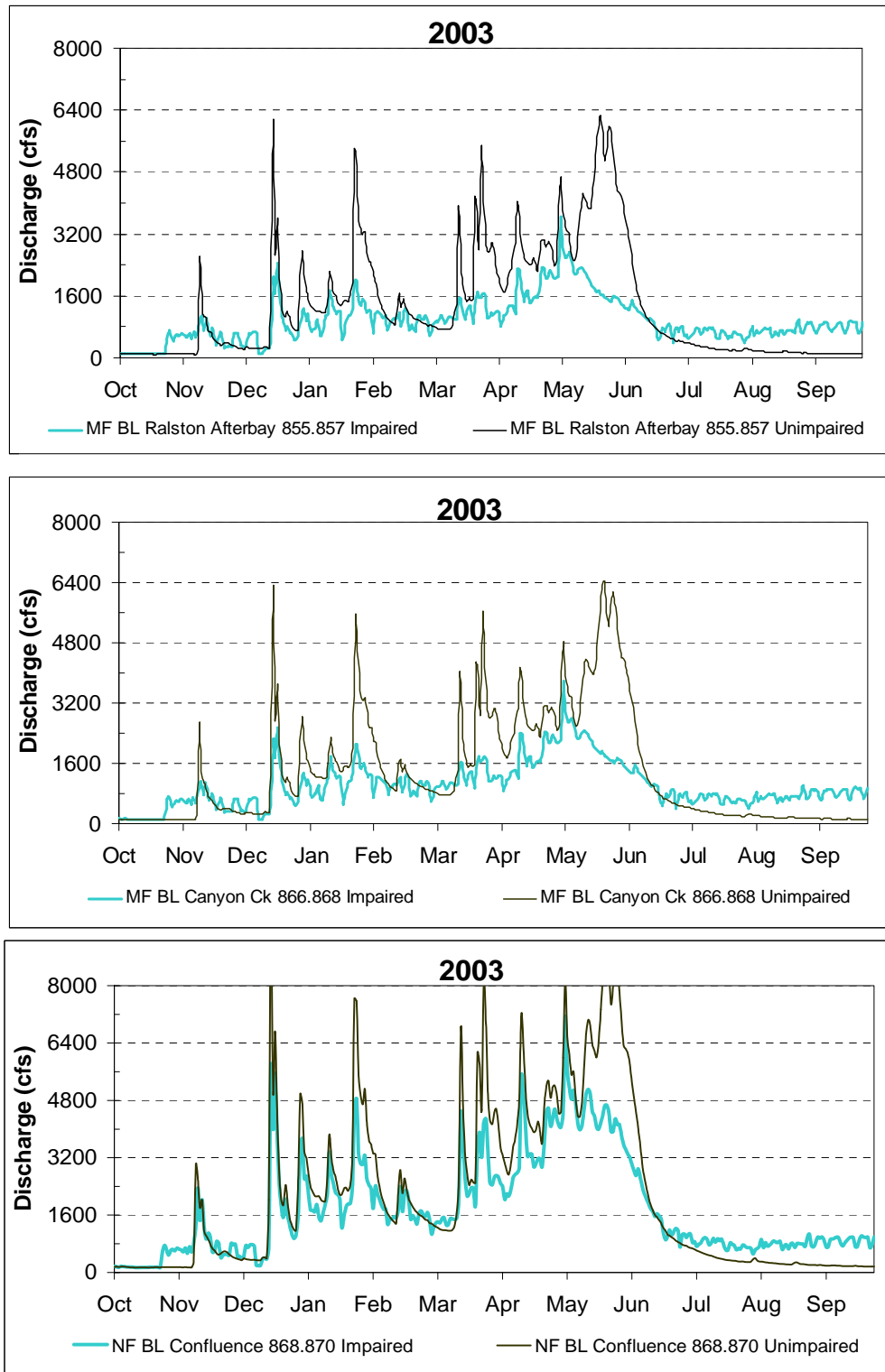
**Figure Q-1. Wet Water Year (2006) flows in the Middle Fork American River below Ralston Afterbay (top), Middle Fork American River downstream of Canyon Creek (middle), and the North Fork American River below the Middle Fork American River Confluence (bottom).**



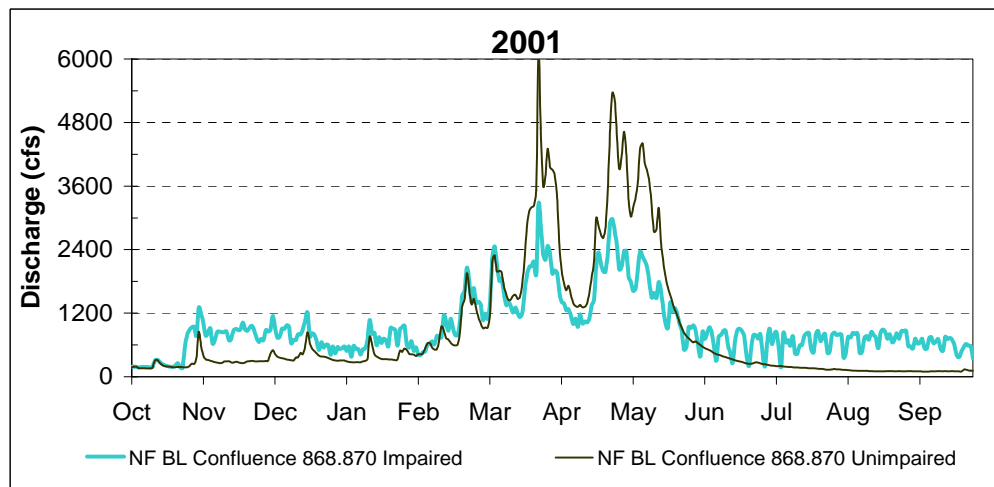
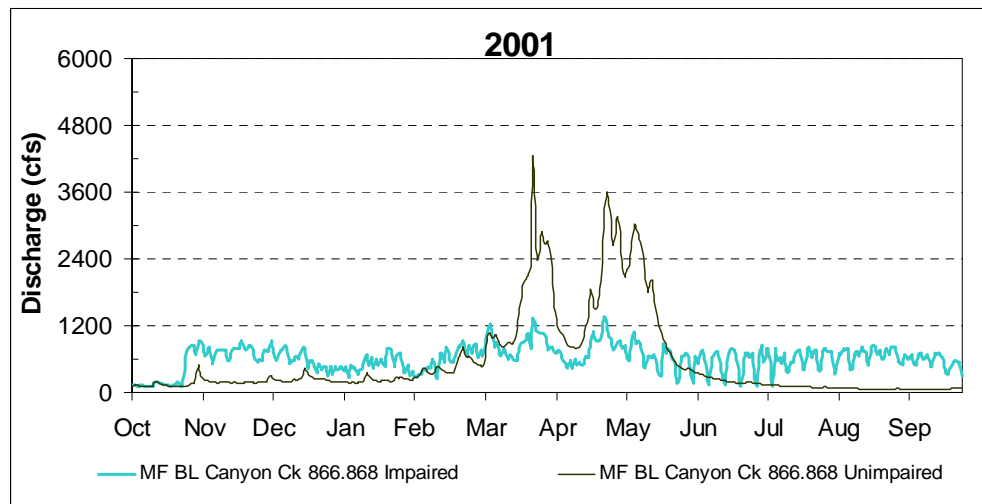
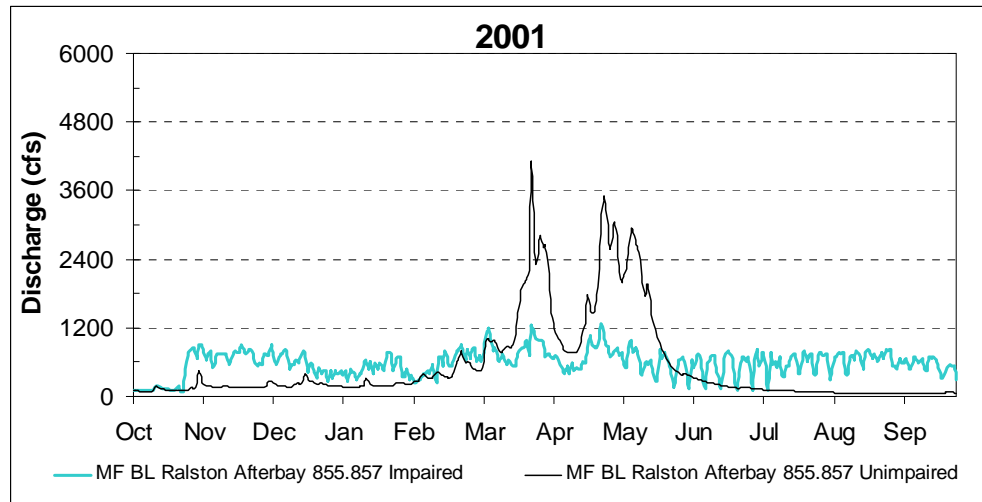
**Figure Q-2. Above Normal Water Year (1999) flows in the Middle Fork American River below Ralston Afterbay (top), Middle Fork American River downstream of Canyon Creek (middle), and the North Fork American River below the Middle Fork American River Confluence (bottom).**



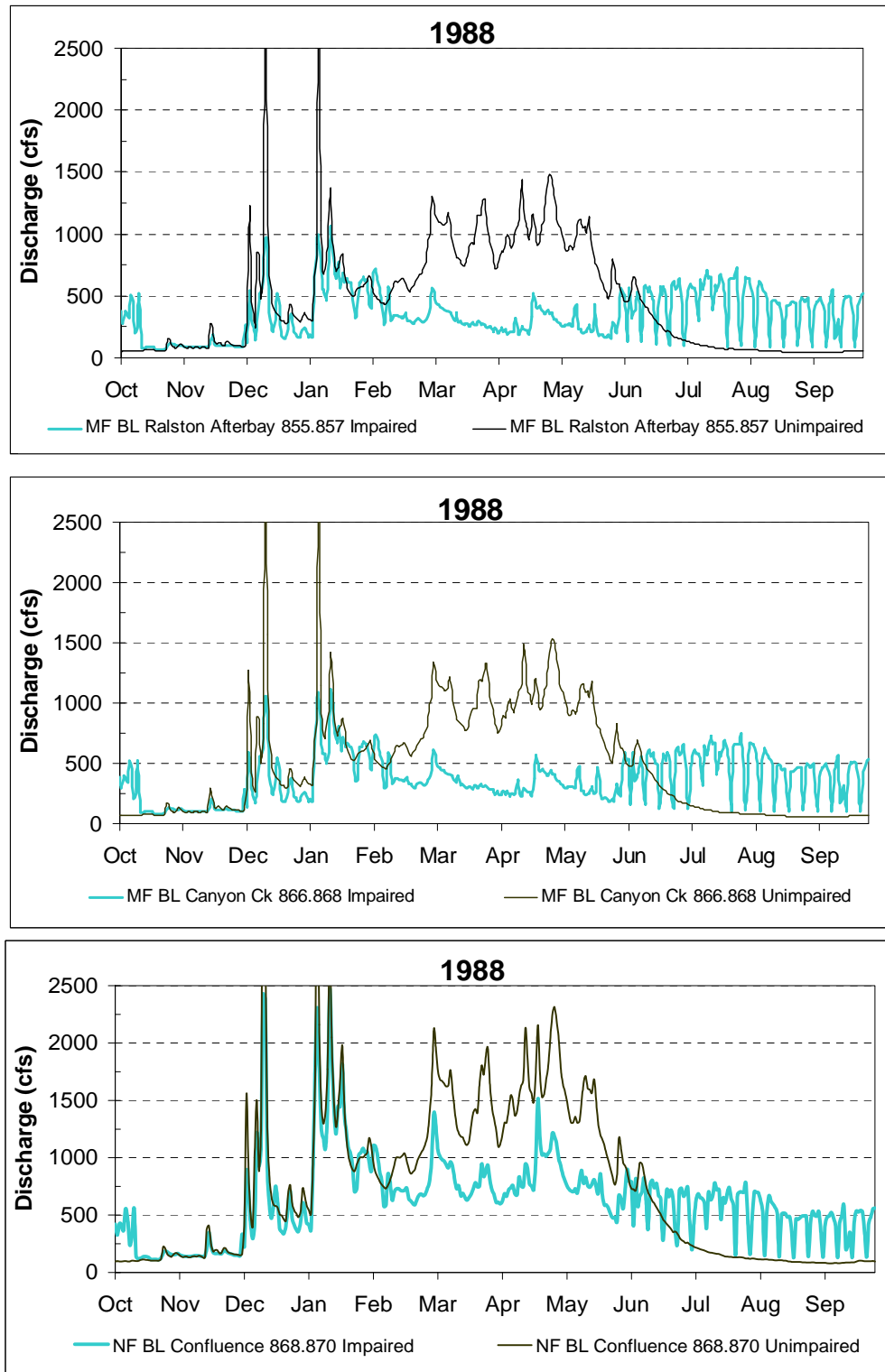
**Figure Q-3. Below Normal Water Year (2003) flows in the Middle Fork American River below Ralston Afterbay (top), Middle Fork American River downstream of Canyon Creek (middle), and the North Fork American River below the Middle Fork American River Confluence (bottom).**



**Figure Q-4. Dry Water Year (2001) flows in the Middle Fork American River below Ralston Afterbay (top), Middle Fork American River downstream of Canyon Creek (middle), and the North Fork American River below the Middle Fork American River Confluence (bottom).**



**Figure Q-5. Critical Dry Water Year (1999) flows in the Middle Fork American River below Ralston Afterbay (top), Middle Fork American River downstream of Canyon Creek (middle), and the North Fork American River below the Middle Fork American River Confluence (bottom).**



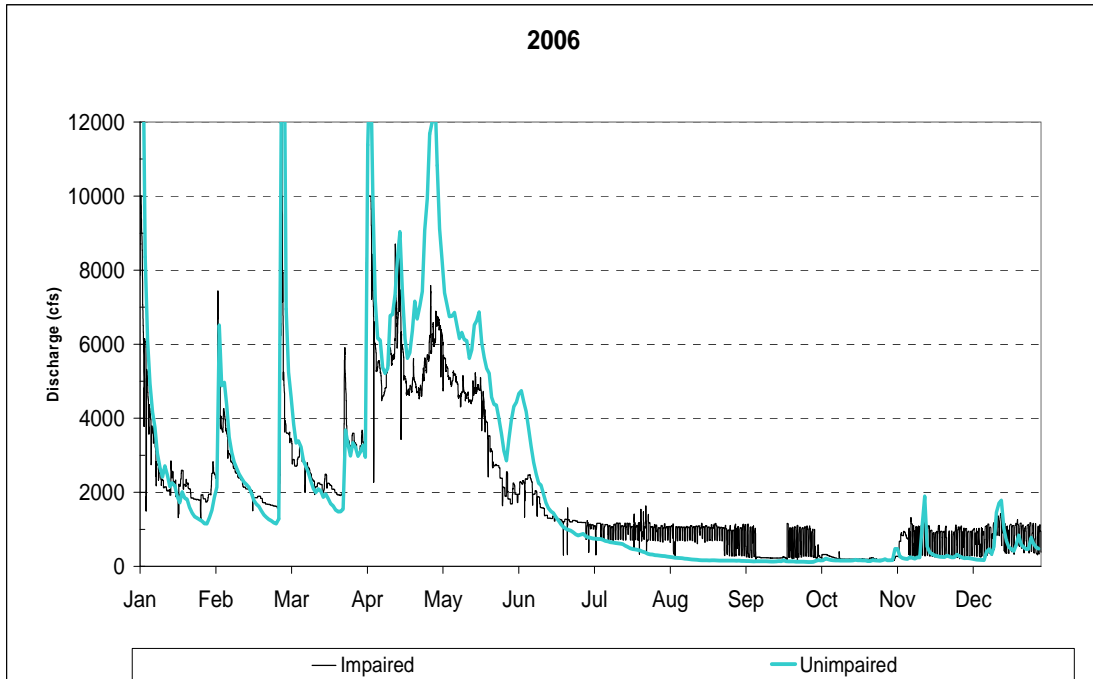
**APPENDIX R**  
**Peaking Reach 15-Minute Hydrology**

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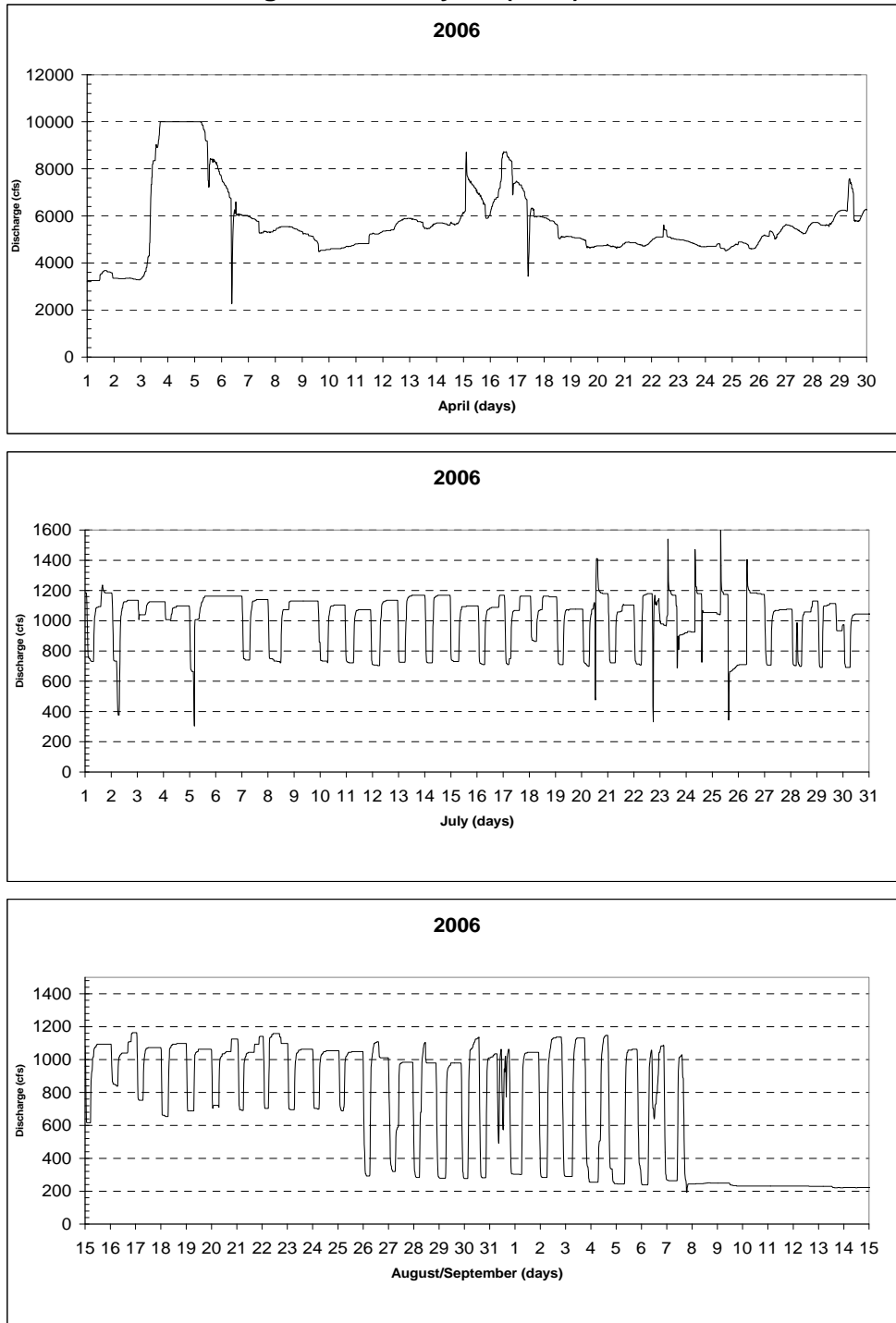
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**FIGURES**

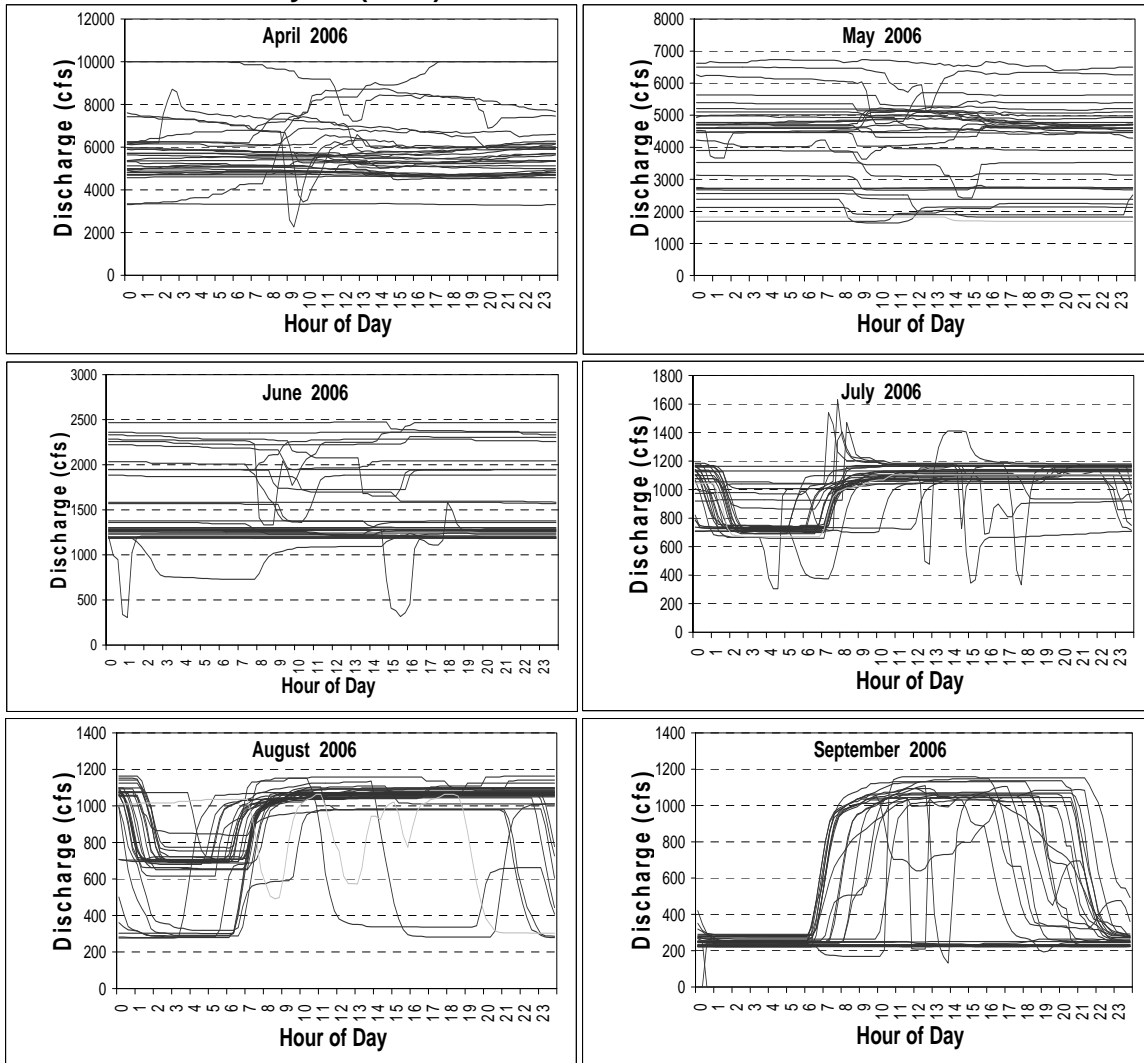
**Figure R-1. Unimpaired and impaired (existing) flow time series in the peaking reach at Middle Fork American River Gage below Oxbow Powerhouse during a wet water year (2006).**



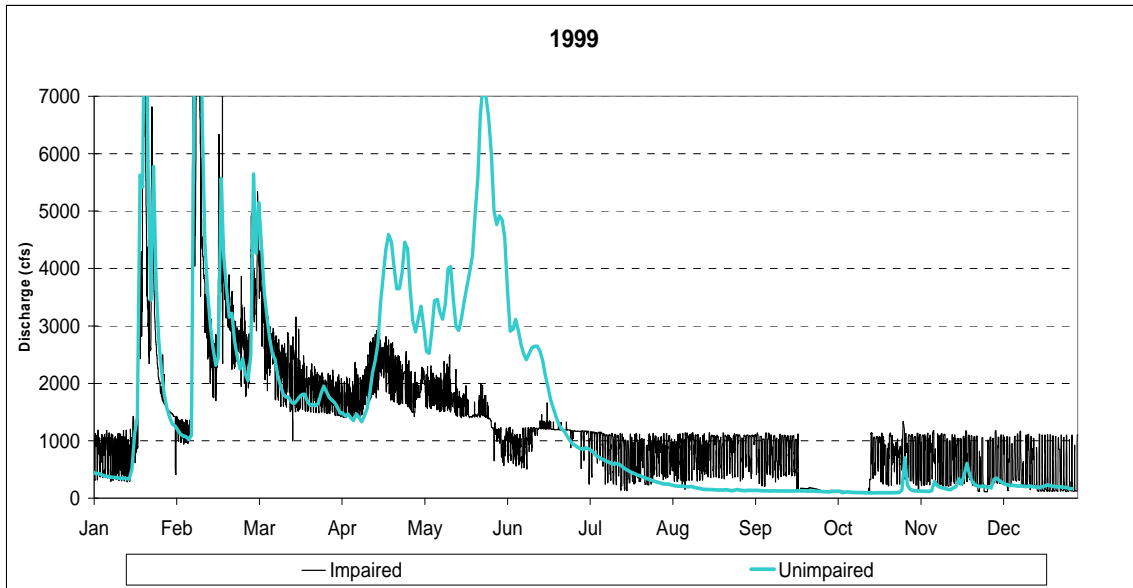
**Figure R-2. April, July, and August/September flow time series (15 min) in the peaking reach at Middle Fork American River Gage below Oxbow Powerhouse during a wet water year (2006).**



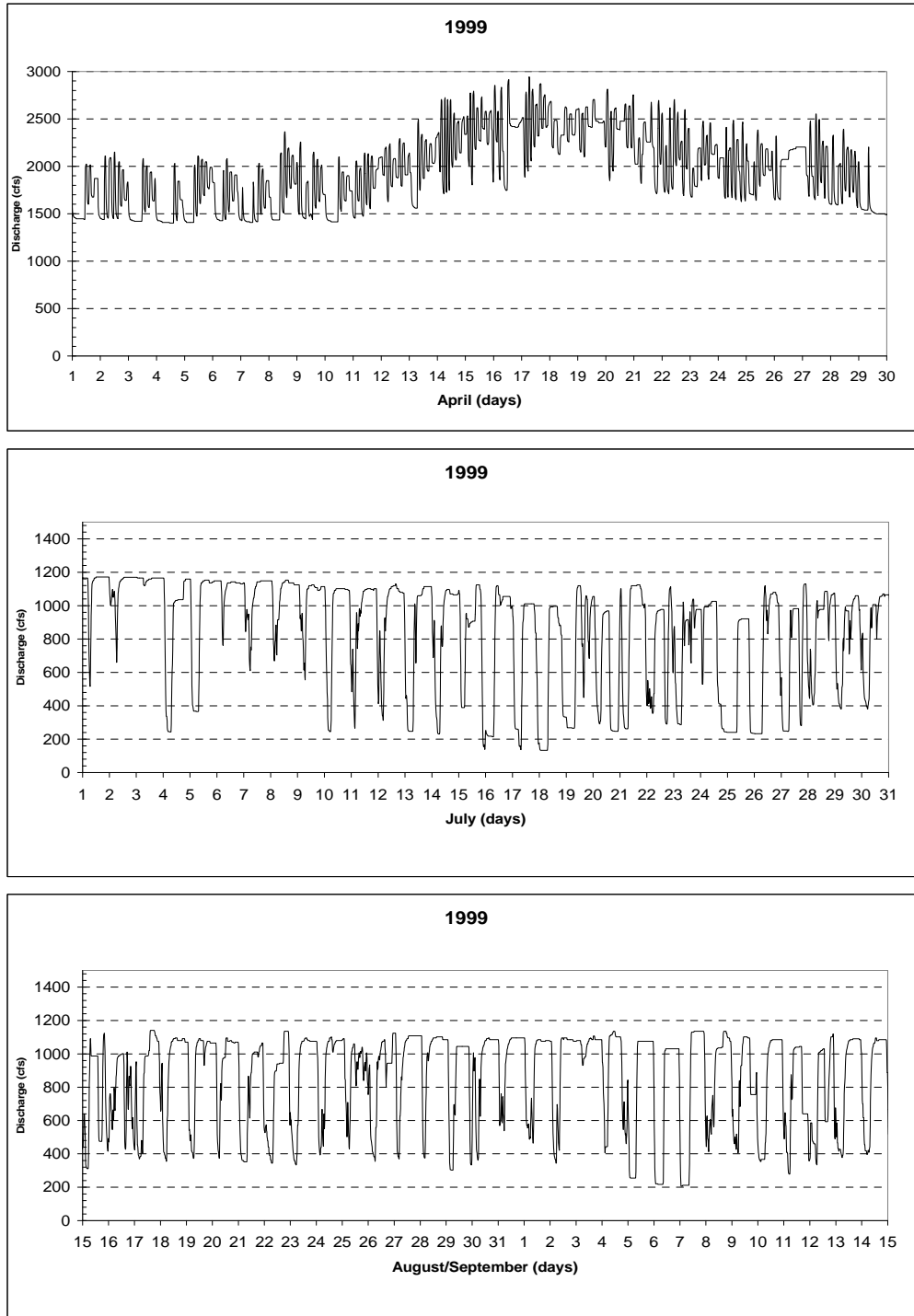
**Figure R-3. Daily peaking events for the months of April through September of a wet water year (2006).**



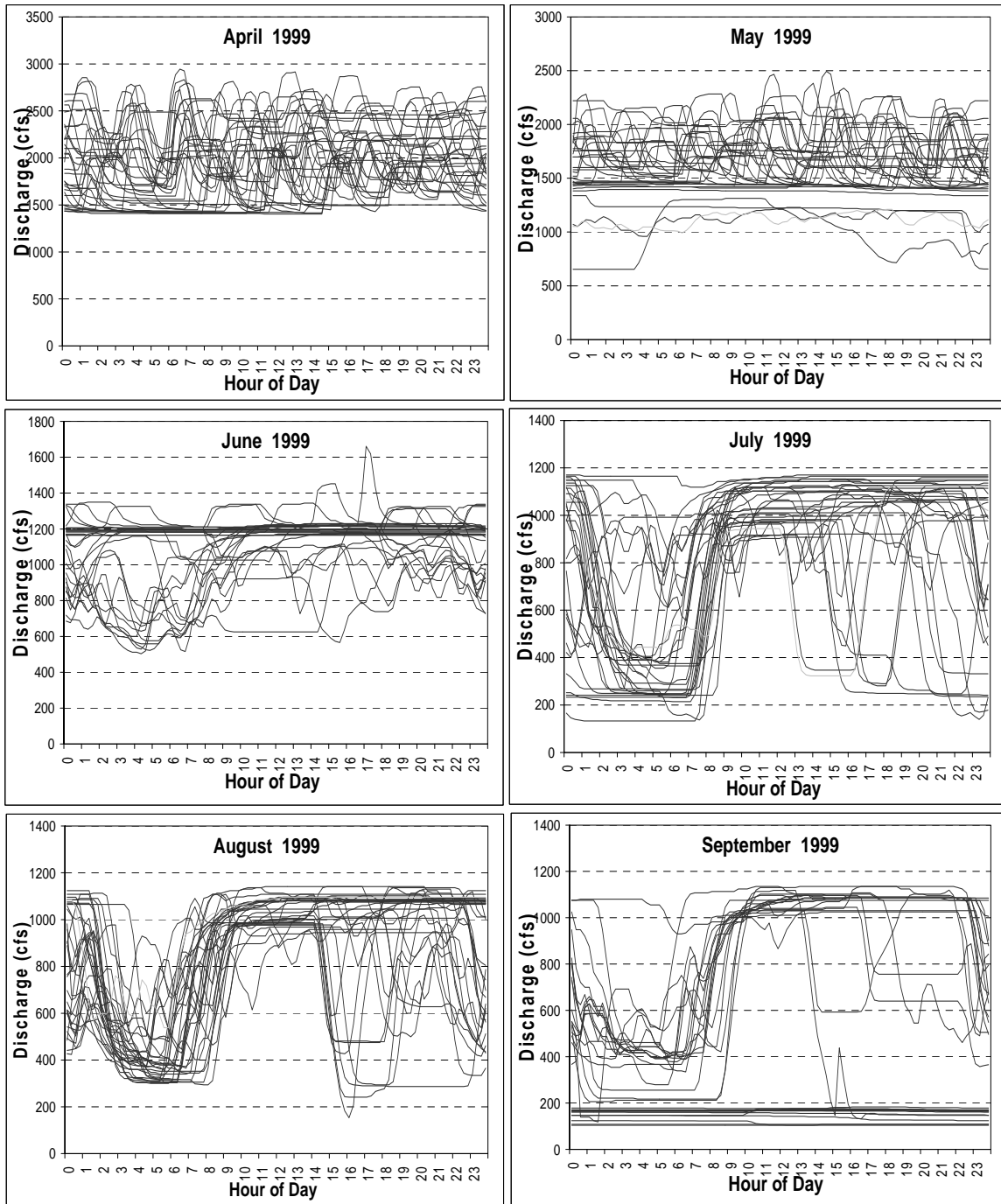
**Figure R-4. Unimpaired and impaired (existing) flow time series in the peaking reach at Middle Fork American River Gage below Oxbow Powerhouse during an above normal water year (1999).**



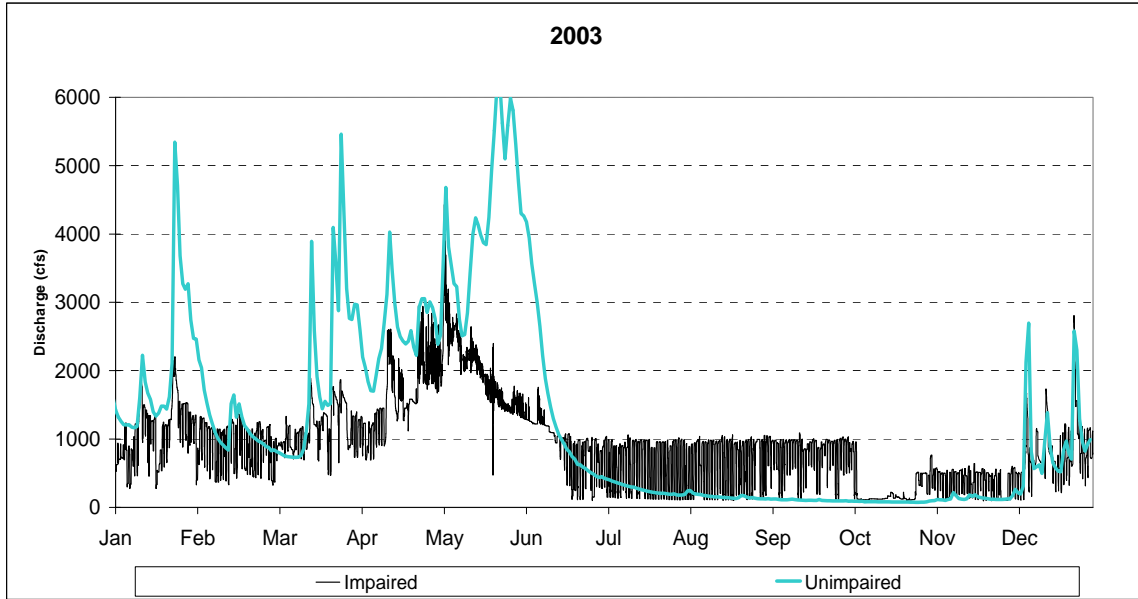
**Figure R-5. April, July, and August/September flow time series (15 min) in the peaking reach at Middle Fork American River Gage below Oxbow Powerhouse during an above normal water year (1999).**



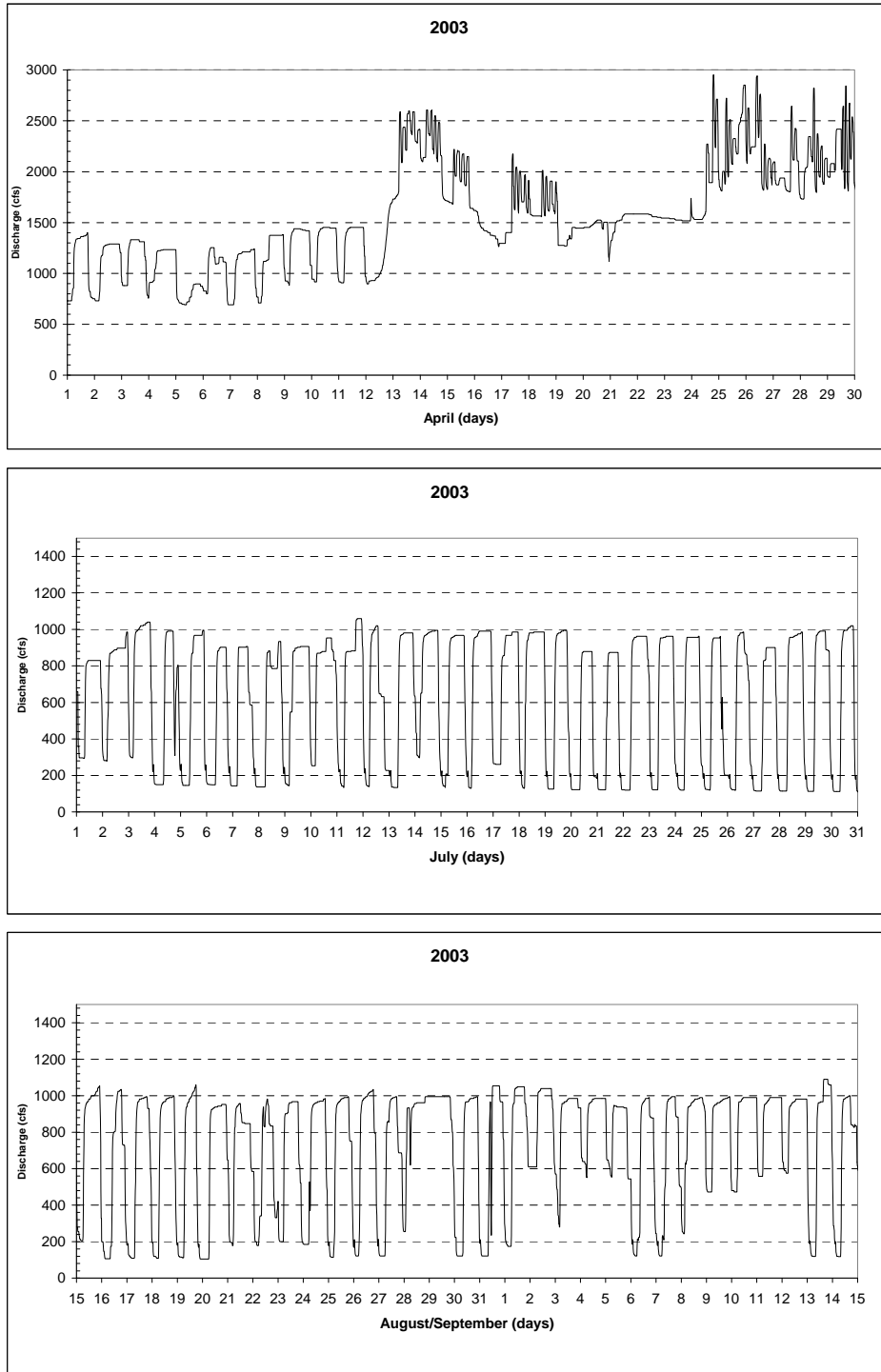
**Figure R-6. Daily peaking events for the months of April through September of an above normal water year (1999).**



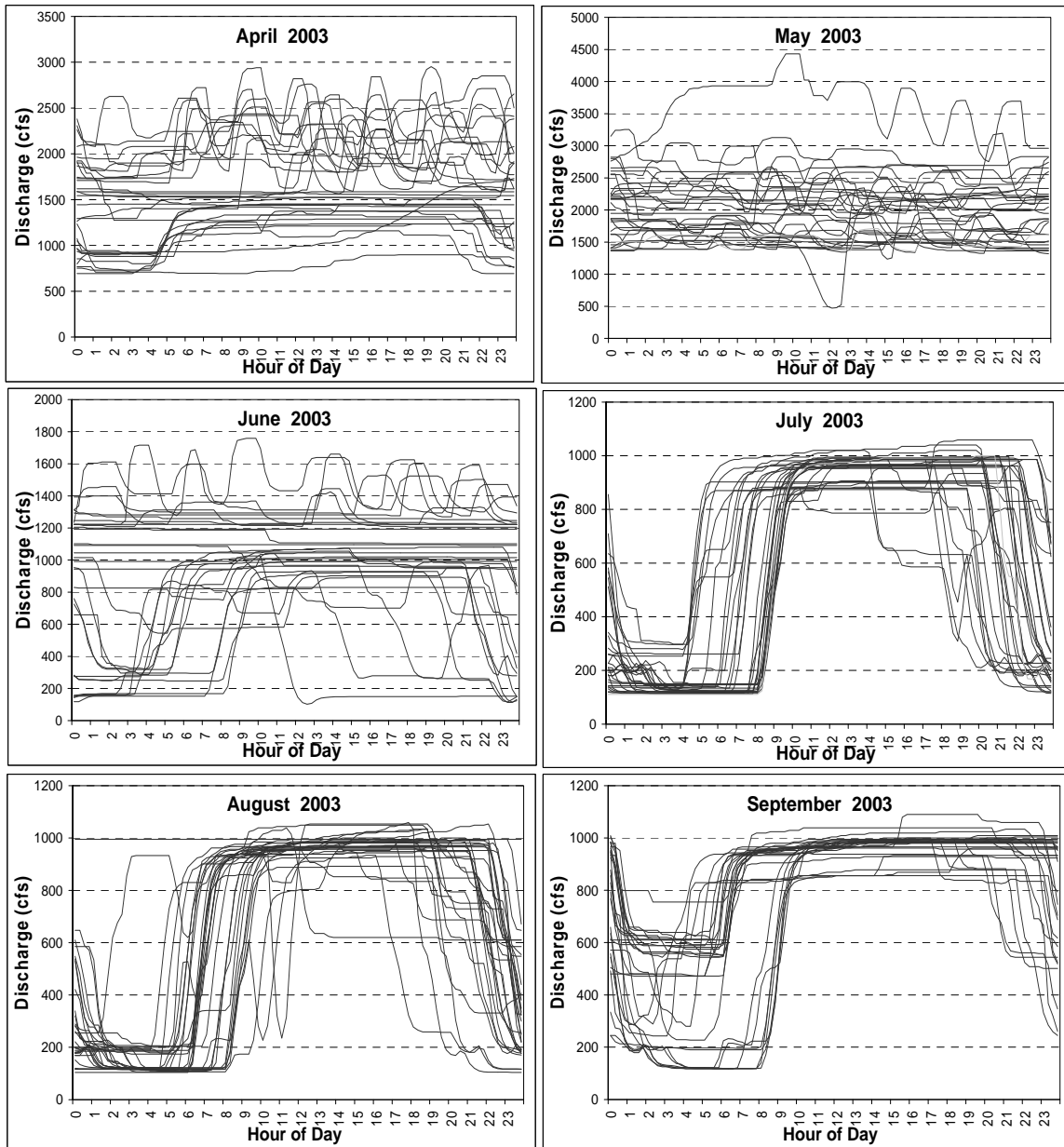
**Figure R-7. Unimpaired and impaired (existing) flow time series in the peaking reach at Middle Fork American River Gage below Oxbow Powerhouse during a below normal water year (2003).**



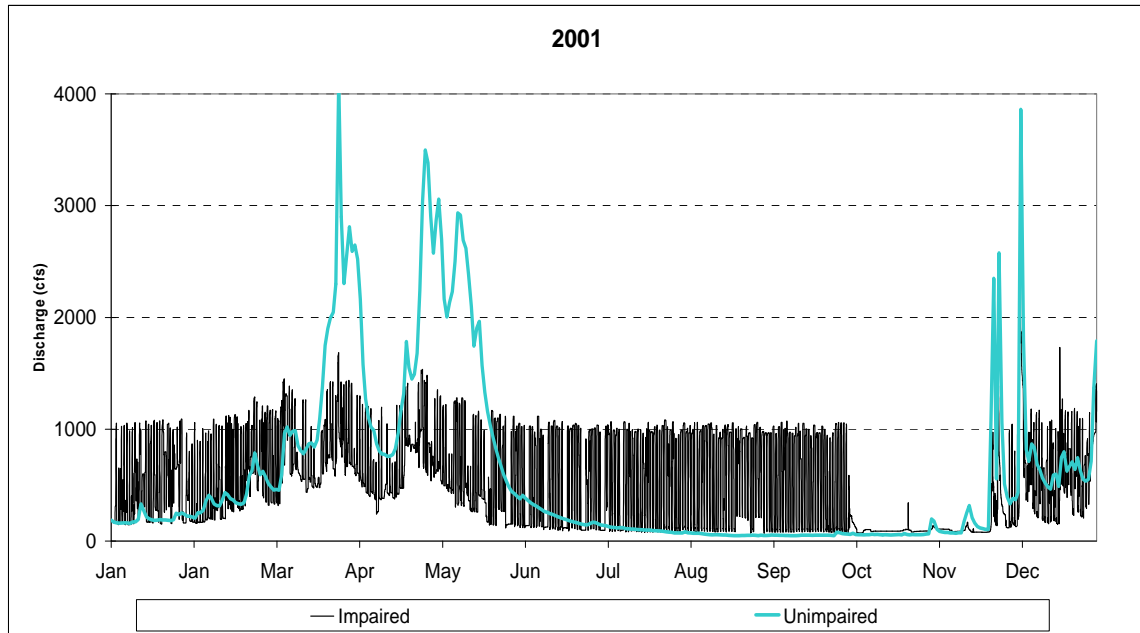
**Figure R-8. April, July, and August/September flow time series (15 min) in the peaking reach at Middle Fork American River Gage below Oxbow Powerhouse during a below normal water year (2003).**



**Figure R-9. Daily peaking events for the months of April through September of a below normal water year (2003).**



**Figure R-10. Unimpaired and impaired (existing) flow time series in the peaking reach at Middle Fork American River Gage below Oxbow Powerhouse during a dry water year (2001).**



**Figure R-11. April, July, and August/September flow time series (15 min) in the peaking reach at Middle Fork American River Gage below Oxbow Powerhouse during a dry water year (2001).**

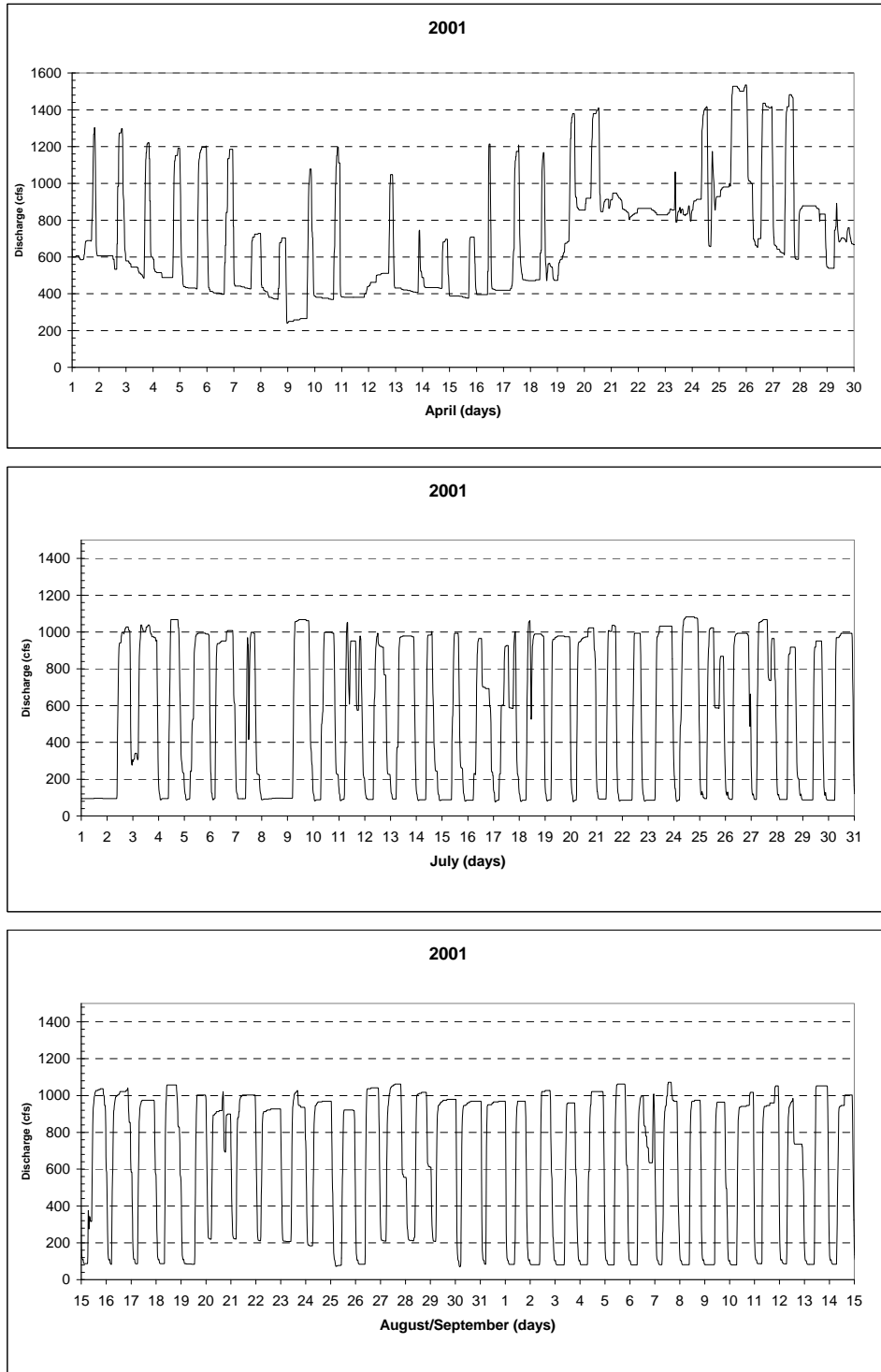
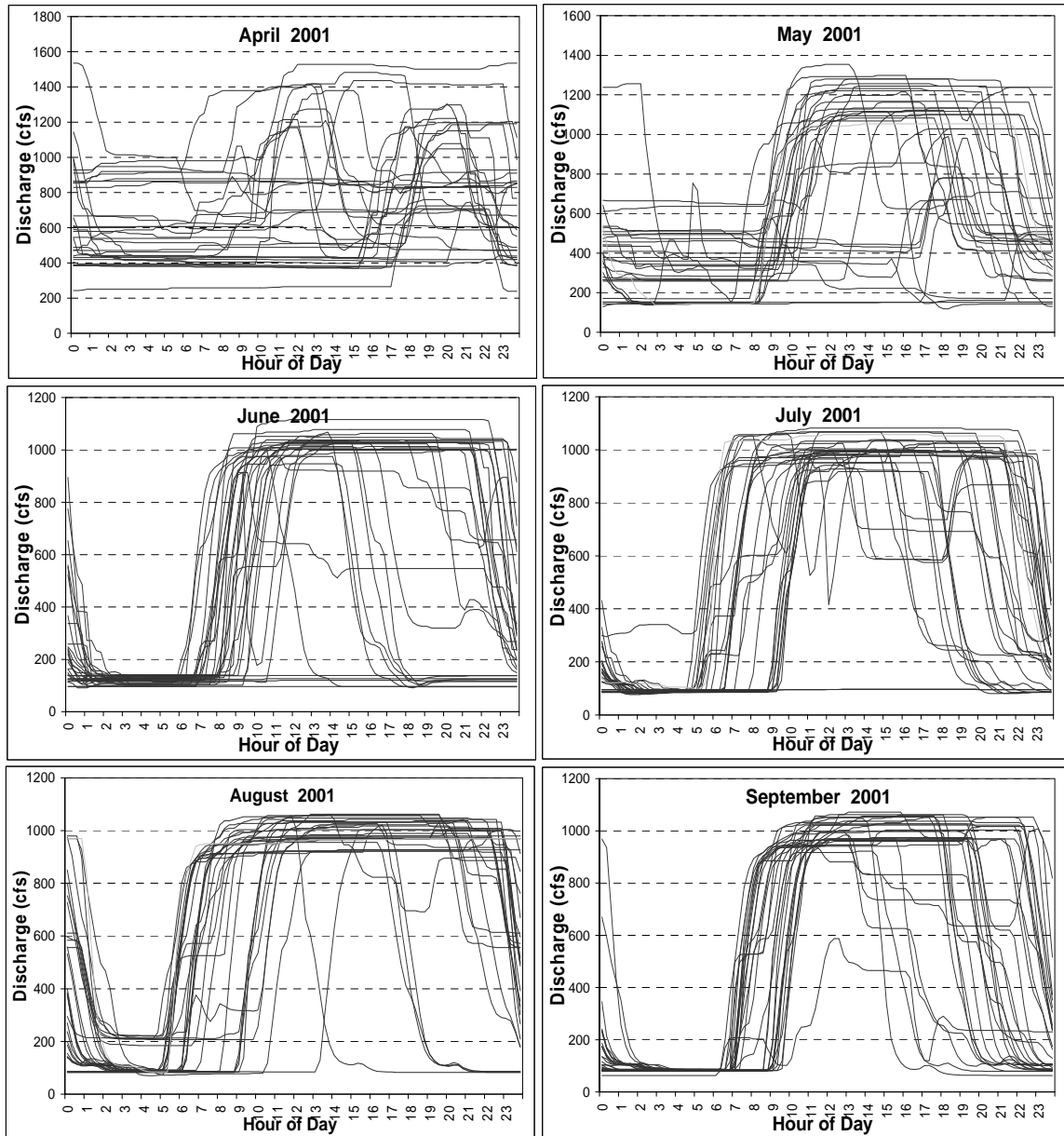
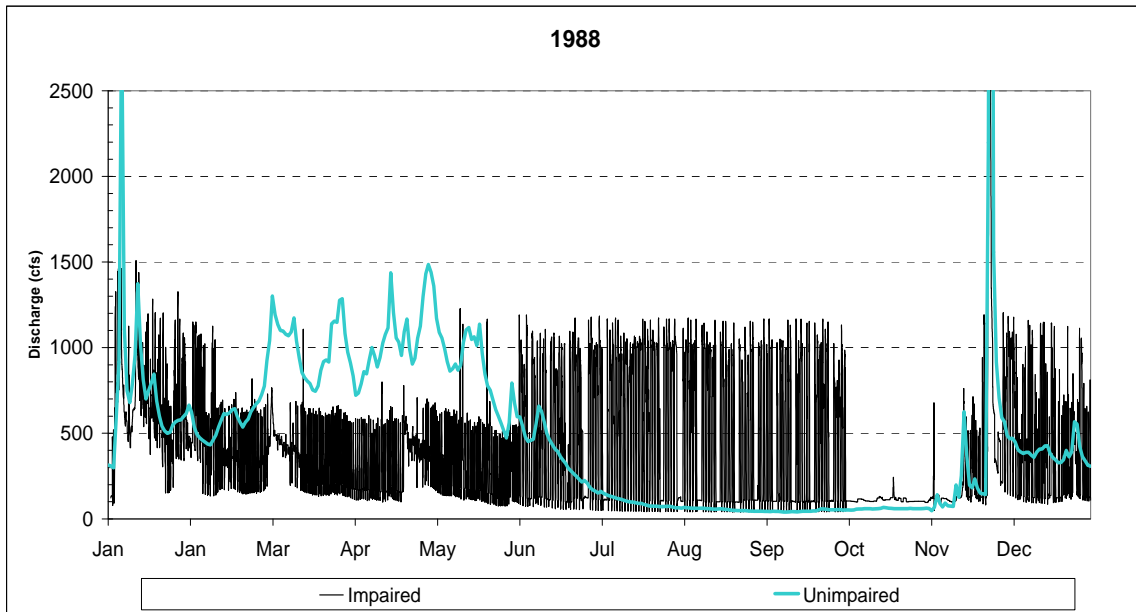


Figure R-12. Daily peaking events for the months of April through September of a dry water year (2001).



**Figure R-13. Unimpaired and impaired (existing) flow time series in the peaking reach at Middle Fork American River Gage below Oxbow Powerhouse during a critically dry water year (1988).**



**Figure R-14. April, July, and August/September flow time series (15 min) in the peaking reach at Middle Fork American River Gage below Oxbow Powerhouse during a critically dry water year (1988).**

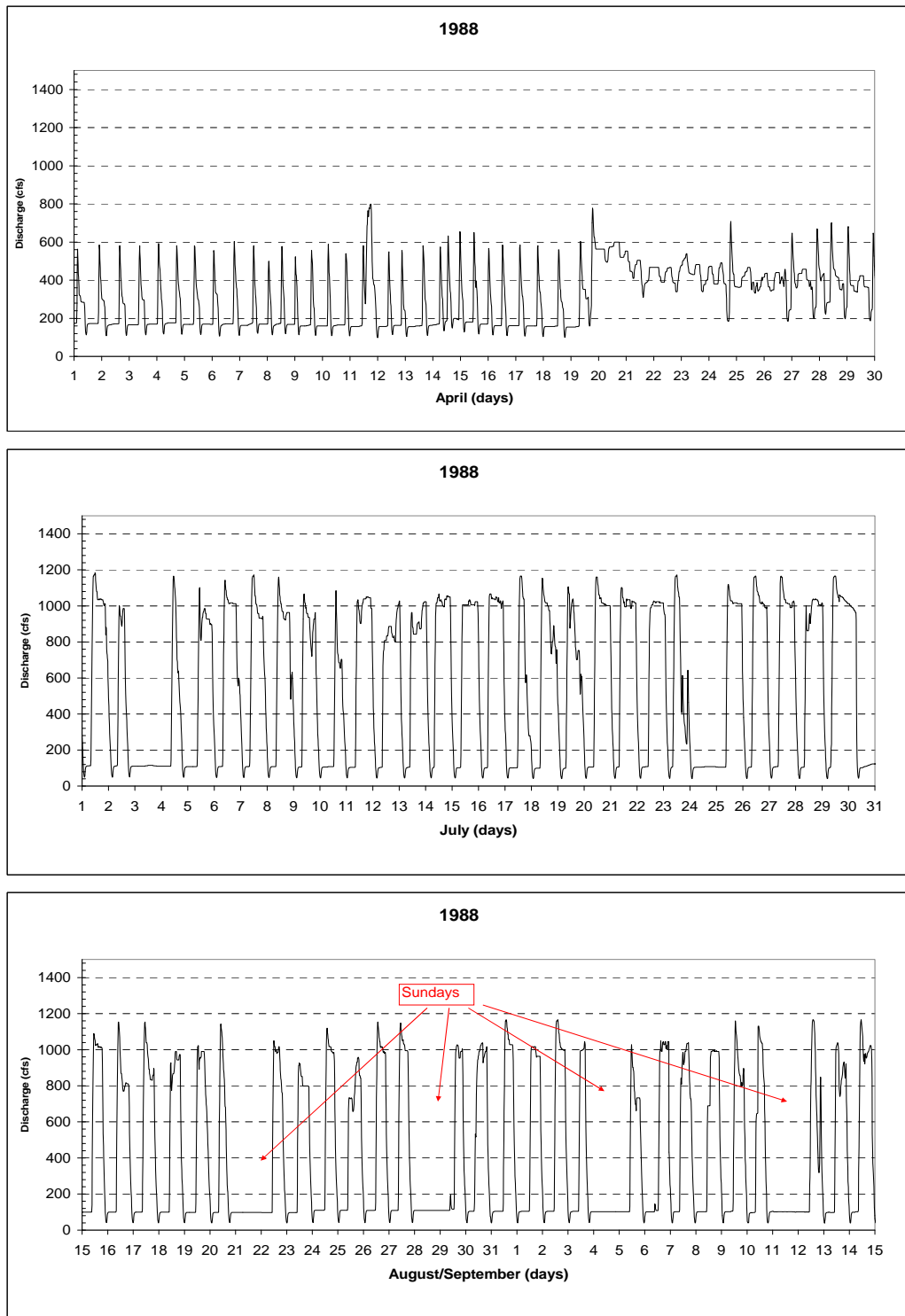
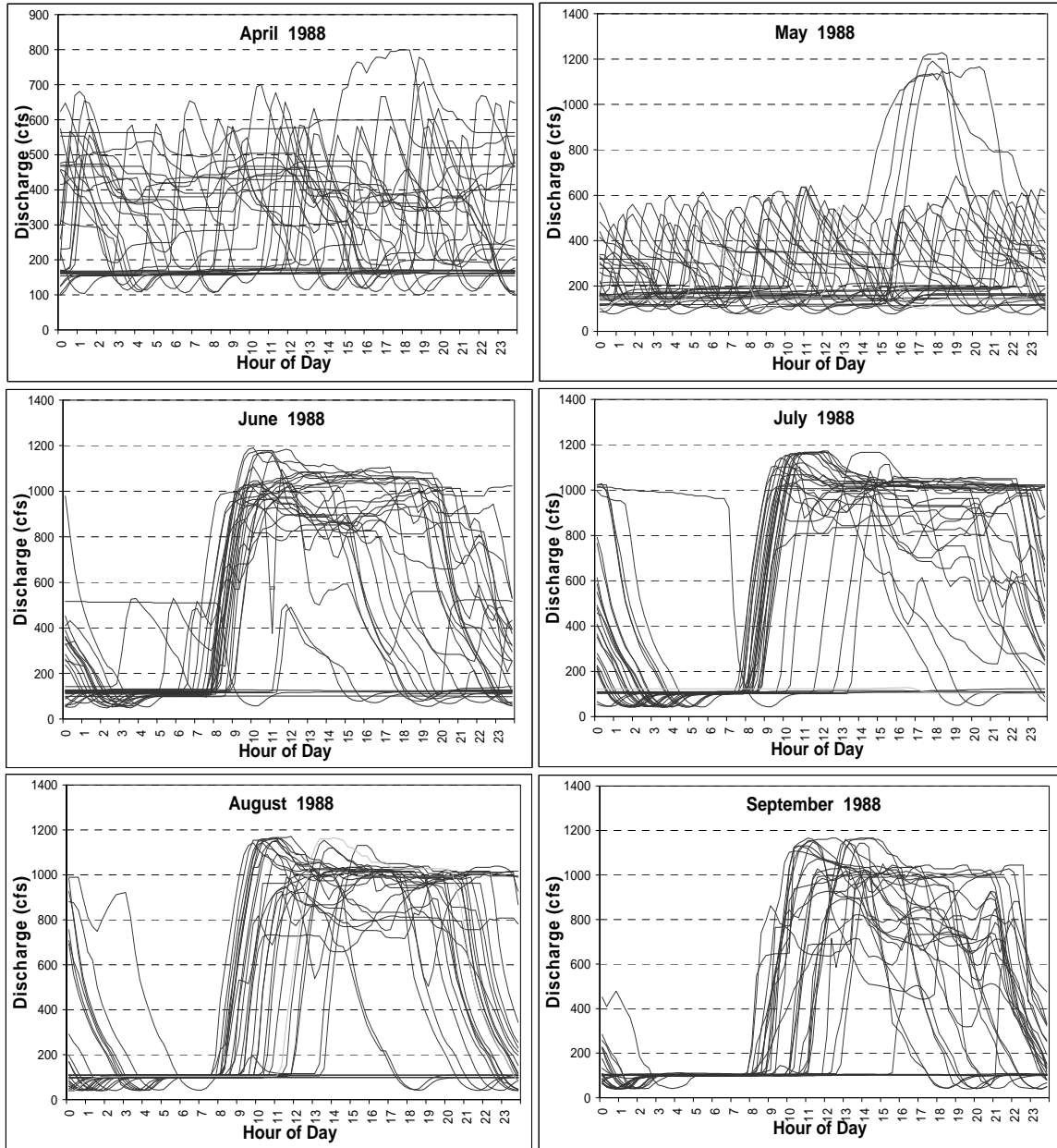


Figure R-15. Daily peaking events for the months of April through September of a critically dry water year (1988).



**ATTACHMENT A**

**AQ1 – Instream Flow Technical Study Report  
Comment Letter and PCWA Response**

**Attachment A. AQ1 Instream Flow Technical Study Report Response to Comments Table.**

Comment Number	Comment	Response
<b>Foothills Water Network (FWN) (March 20, 2010)</b>		
1	<p>The Instream Flow Study Report (IFIM Study) should include: Habitat Suitability Curves for Chinook and a desktop analysis of Chinook passage and instream flow relationship from Folsom Reservoir up to Ralston Reservoir. In our flow negotiations, we would like to discuss instream flows to enhance the planted and spawning Chinook fish population in Folsom Reservoir. As currently drafted, PCWA's IFIM Study does not include Chinook.</p>	<p><b>Clarification:</b> Anadromous fish, either chinook salmon or steelhead trout, are no longer present in the American River upstream of Nimbus Dam/Folsom Dam complex. Nimbus Dam was constructed in 1955 and has completely blocked upstream migration of all anadromous fish for the last 54 years. Nimbus Dam is owned and operated by the Bureau of Reclamation (BOR) and is located approximately 24.4 miles downstream of the nearest Middle Fork American River Project (MFP) facility. Historically hatchery chinook salmon have been stocked in Folsom Reservoir as a put-and-take sport fish. Currently, it is our understanding that this practice has been discontinued. Chinook salmon was not identified as a management species by the resource agencies (e.g., California Department of Fish and Game [CDFG]) in the MFP nor were any chinook salmon observed during the three years of fish sampling in the MFP. Regarding fish passage, the fish passage report, AQ 6 Fish Passage Technical Study Report (AQ 6 – TSR), identifies the potential barriers to upstream fish movement in the MFP. Two large barriers exist in the reach of river from Folsom Reservoir to Ralston Afterbay--Ruck-a-Chucky Falls (water fall) and Tunnel Chute (water fall created by historic mining) (see PCWA 2008)</p> <p><b>Response:</b> Development of habitat suitability curves or a desktop analysis of Chinook passage and instream flow relationships in the MFP is not necessary for development of new license conditions based on the current resource management objectives of the MFP and, therefore, was not included in the AQ 1 Instream Flow Report (AQ 1 – TSR).</p>

**Attachment A. AQ1 Instream Flow Technical Study Report Response to Comments Table. (continued)**

Comment Number	Comment	Response
<b>Foothills Water Network (FWN) (March 20, 2010)</b>		
2	<p>The Instream Flow Study Report (IFIM Study) should include: Winter-spawning <i>O. mykiss</i> in the analysis of weighted usable area (WUA) for spawning at different times of year. For winter-spawning <i>O. mykiss</i>, this analysis should inform management decisions for winter spawning flows, winter base flows and flows during fall and winter outage periods for the bypass and peaking reaches. In addition, the WUA analysis should inform management of flows for juvenile rearing habitat, for winter-spawning <i>O. mykiss</i>, which takes place earlier than for spring spawning <i>O. mykiss</i>. As currently written, PCWA's Draft IFIM Study Report does not analyze flows for winter-spawning <i>O. mykiss</i>.</p>	<p><b>Clarification:</b> Rainbow trout spawning habitat versus flow relationships developed in the AQ1 – TSR are applicable to any time of the year. These relationships show the amount of habitat for different discharges and are independent of time of the year. Stakeholders can use these relationships to assess suitability of flows and spawning habitat during any time period.</p> <p>In the AQ1 – TSR a secondary time series analysis was also included to compare fish habitat between impaired and unimpaired flows during several different seasons. The management period identified for spawning rainbow trout was spring. The comparative time series analysis focused on this time period.</p> <p><b>Response:</b> The rainbow trout spawning habitat versus flow relationship will be the primary tool that will be used to develop new license conditions regarding spawning flows; therefore, a time series comparison of rainbow trout spawning habitat for impaired and unimpaired flow was not included in the AQ1 – TSR for any time period other than spring.</p>

**LITERATURE CITED**

PCWA. 2008. DRAFT AQ 6 – Fish Passage Technical Study Report (TSR) – 2008. PCWA Middle Fork American River Project (FERC Project No. 2079). July 2009.



March 20, 2010

### **RE: Comments on PCWA's Draft Instream Flow Study Results**

Dear Mr. Andy Fecko,

In response to request for comments on PCWA's Draft Instream Flow Study Results, the Foothills Water Network is submitting this comment letter.

The Instream Flow Study Report (IFIM Study) should include:

1. Habitat Suitability Curves for Chinook and a desktop analysis of Chinook passage and instream flow relationship from Folsom Reservoir up to Ralston Reservoir. In our flow negotiations, we would like to discuss instream flows to enhance the planted and spawning Chinook fish population in Folsom Reservoir. As currently drafted, PCWA's IFIM Study does not include Chinook.

2. Winter-spawning O. mykiss in the analysis of weighted usable area (WUA) for spawning at different times of year. For winter-spawning O. mykiss, this analysis should inform management decisions for winter spawning flows, winter base flows and flows during fall and winter outage periods for the bypass and peaking reaches. In addition, the WUA analysis should inform management of flows for juvenile rearing habitat, for winter-spawning O. mykiss, which takes place earlier than for spring spawning O. mykiss. As currently written, PCWA's Draft IFIM Study Report does not analyze flows for winter-spawning O. mykiss.

#### **Chinook**

In a Bob Simms Outdoor Show podcast on February 21, 2010, Mickey Thomas reported catching a "King" on Folsom Reservoir with Jay Rowan, Reservoir Biologist for CDFG. Rowan took a scale sample and later confirmed that the fish was a 1-year juvenile Chinook. The ImHooked.com blog receives regular posts about catching 12-14 inch Chinook in Folsom Reservoir (see: <http://www.imhooked.com/cgi-bin/forumsyabb/YaBB.pl?board=kokes> .) The size of the Chinooks indicate that the Chinook originally planted by DFG are spawning. Individual angler reports of catching and sighting other Chinook at Mammoth Bar in the late

summer to early fall of 2008 seem to indicate that the Chinook are migrating up the Middle Fork American River. As stated above, the Network members are interested in managing flows that provide migration and spawning habitat for these Chinook.

### **Winter-spawning O. mykiss**

With this letter, we are submitting new evidence to support our contention that winter-spawning O. mykiss should be included as a target species for relicensing negotiations on the Middle Fork American and the Rubicon Rivers. The new evidence includes:

- Photos of winter-caught O. mykiss with roe. (Appendix A)
- Reports supporting the concept that habitat and remnant steelhead populations exist in the Upper American River.

PCWA responded on July 21, 2009 to a comment letter from the Foothills Water Network on the Draft Fish Passage Study, which requested PCWA to take into account the winter-spawning O. mykiss as a target species during license negotiations. In PCWA's response letter, Mr. Fecko cites statements attributed to Mr. Stafford Lehr of the California Department of Fish & Game stating that the specimens referred to as remnant steelhead or winter-spawning O. mykiss by members of the Foothills Water Network were either brown trout or remnant planted fish.<sup>1</sup> According to Mr. Fecko, Lehr stated that the trout were from the Coleman strain of fall-spawning rainbows planted in Folsom Reservoir by CADFG.

We agree that fall-spawning trout could be derived from the Coleman strain planted in Folsom Reservoir though DFG has not yet been able to produce planting records to confirm this. However, the existence of the planted Coleman strain does not preclude the existence of a remnant population of steelhead that are winter-spawning O. mykiss in the Middle Fork American and the Rubicon reaches.

Members of the Foothills Water Network have observed and caught the winter-spawning O. mykiss on the Rubicon and Middle Fork American Rivers. These anglers have caught and landed these winter-spawning O. mykiss containing eggs from October to January. The anglers do not believe these fish to be either "brown trout" or "planted" fish. Please see the photos in Appendix A.

In addition to this first-hand evidence of the winter-spawning O. mykiss, the following reports establish that within the Upper American River watershed, including the Middle Fork drainage, there is habitat suitable for winter-spawning O. mykiss or remnant steelhead, and that the watershed supported populations of these fish prior to the construction of migration barriers that

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<sup>1</sup> These statements, if indeed made by Mr. Lehr, do not appear in the study report, and no reference or citation to them in the record is specified by Mr. Fecko.

now exist. It is our position, based upon actual angler observations that it is likely that winter-spawning *O. mykiss* populations exist within the watershed.

1. D.R. McEwan, 2001, Central Valley Steelhead, Fish bulletin 179, volume 1.
2. Gerstung, Eric, 2002, Fishes and Fishing in the Forks of the American River: Then and Now; p.302-305 in Protect American River Canyons, 2002, The American River: a Recreational Guide Book, 336 p.
3. J. L. Nielsen, et al, 2005, Genetics of Central Valley *O. mykiss* populations: Drainage and watershed scale analyses, San Francisco Estuary and Watershed Science, Vol. 3, Iss. 2 (September, 2005) Art 3.
4. J.C. Garza, D.E. Pearse, 2009, Final Report for California Department of Fish and Game Contract #P0485303.

Specifically, Nielsen et al. in their paper “Genetic Analyses of Central Valley Trout PopulationsL1999-2003” concluded the following:

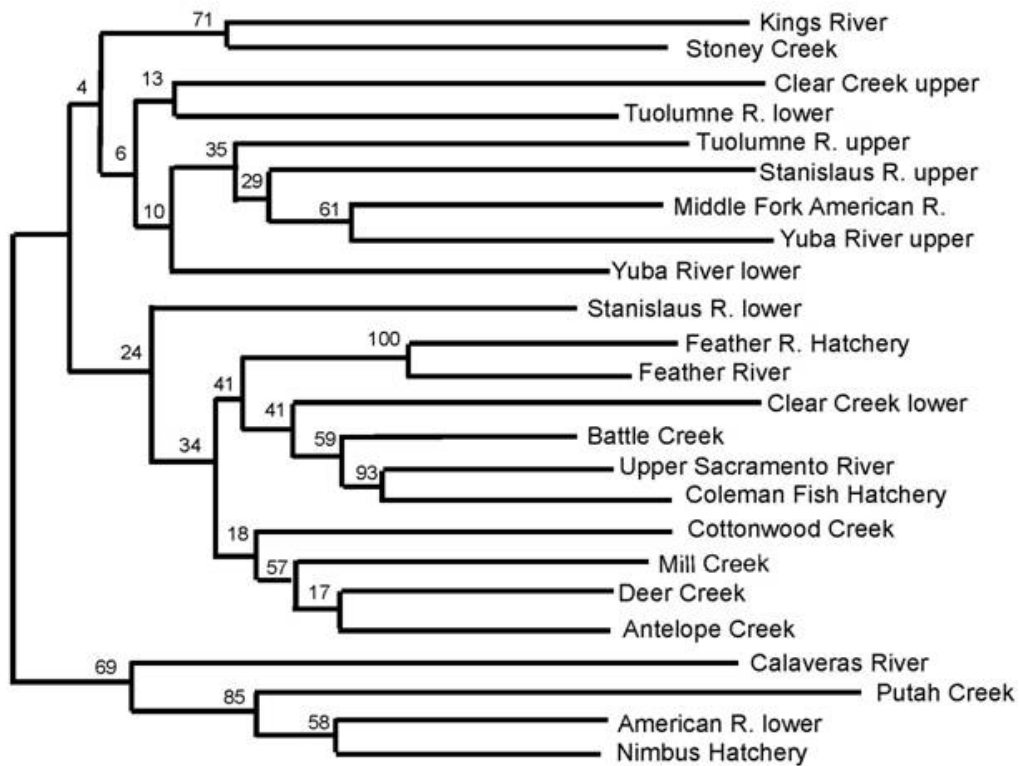
Significant allelic differences were found in trout collected above and below impassable dams on the American, Yuba, Stanislaus and Tuolumne rivers.... These data suggest that significant genetic population structure remains for steelhead populations within the Central Valley, and careful consideration of this genetic diversity should be part of future conservation and restoration efforts.

Statements such as the above citation in published reports, provide sufficient scientific basis that would require a genetic study to preclude the existence of such winter-spawning *O. mykiss* or remnant steelhead. In the absence of such a study, and taking into account the photo evidence of winter-spawning rainbows, the IFIM study analysis should take into account spawning and juvenile rearing flows for this fish population.

The figure set forth below, supports the proposition that remnant steelhead populations are likely to exist irrespective of whether fish were planted within the watershed. There is no evidence in Mr. Fecko’s letter or in the PCWA relicensing studies that Middle Fork American River winter-spawning *O. mykiss* are only derived from a hatchery stock.<sup>2</sup> In the absence of genetic studies, the relicensing process needs to consider the winter-spawning *O. mykiss* as a possible target species for management under PCWA’s FERC license.

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<sup>2</sup> The figure was taken from the Nielsen report entitled “Genetic Analyses of Central Valley Trout PopulationsL1999-2003.”



The population of winter-spawning *O. mykiss* were not referenced in the Fish Population, Fish Passage, nor Instream Flow Studies. In addition, no data on young of the year for the winter-spawning *O. mykiss* appears in the Fish Population Study Results.

The Network would like PCWA to develop the requested desktop analyses in order to inform ongoing flow negotiations. The Network would like to consider these two fish populations as stakeholders collaboratively develop flow regimes and objectives for PCWA's Middle Fork American Hydroelectric Project.

Sincerely,  
 Julie Leimbach  
 Foothills Water Network

Middle Fork Working Group

Bill Carnazzo, Spring Creek Guide Service, Upper American River Foundation, and Northern California Federation of Flyfishers

Bill Templin, Upper American River Foundation

Chris Shutes, California Sportfishing Protection Alliance

Monte Hendricks, Angler

Grant Fraser, Upper American River Foundation

Tom Bartos, Horseshoe Bar Preserve

Dan Crandall, Current Adventures

Ty Gorre, Save Sierra Salmon

Gary Estes, Protect American River Canyons