SOUTH COW CREEK HABITAT ASSESSMENT

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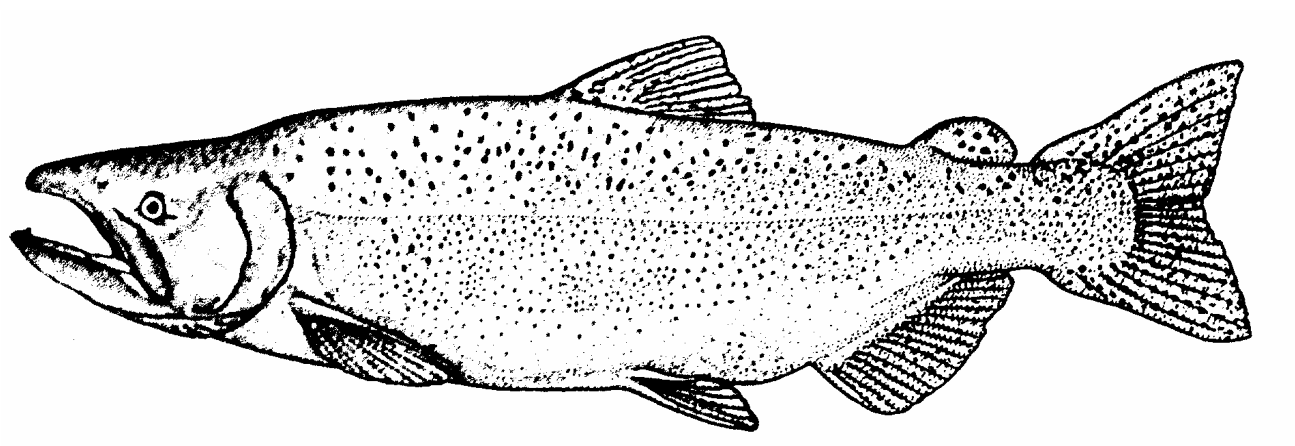

Prepared by staff of
The Restoration and Monitoring Program

PREFACE

The following is the final report, South Cow Creek Habitat Assessment, prepared as part of the Central Valley Project Improvement Act (CVPIA) Instream Flow and Fisheries Investigations, an effort which began in October, 2001.[1] The purpose of this investigation is to provide scientific information to other CVPIA programs to use in planning fisheries restoration actions.

The field work described herein was conducted by Ed Ballard, Mark Gard, Bill Pelle, Kevin Aceituno, Jeremy Redding, Rick Williams, Jacob Cunha, Brenda Olson, and Tricia Bratcher.

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[1] The scope of this program was broadened in FY 2009 to include fisheries investigations. This program is a continuation of a 7-year effort, titled the Central Valley Project Improvement Act Instream Flow Investigations, which ran from February 1995 through September 2001.

INTRODUCTION

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act provided for enactment of all reasonable efforts to double sustainable natural production of anadromous fish stocks including the four races of Chinook salmon (fall, late-fall, winter, and spring), steelhead trout, white and green sturgeon, American shad and striped bass. In June 2001, the Service's Sacramento Fish and Wildlife Office, Energy Planning and Instream Flow Branch prepared a study proposal to use the Service's Instream Flow Incremental Methodology (IFIM) to identify the instream flow requirements for anadromous fish in selected streams within the Central Valley of California. In 2008, South Cow Creek was selected as an additional stream for this type of study.

The South Cow Creek study was originally going to address both steelhead and fall-run Chinook salmon and cover the entire lower 19 miles of South Cow Creek, up to Ponderosa Way Bridge. Information we reviewed in study scoping suggested that the lower portion of this study area was primarily important for fall-run Chinook salmon, while the upper portion of this study area was primarily important for steelhead. Due to landowner access issues in the upper portion of the lower 19 miles of South Cow Creek, and since the focus of restoration activities for Cow Creek is on fall-run Chinook salmon, we reduced the geographic scope of the study to the lower 7.36 miles of South Cow Creek.

The South Cow Creek study was planned to be a 5-year effort quantifying spawning and rearing habitat, and began in October 2008 with habitat mapping and collection of spawning habitat suitability data for fall-run Chinook salmon. Fieldwork was completed on one study site and started on an additional three study sites to determine the relationship between stream flow and physical habitat availability for fry and juvenile rearing fall-run Chinook salmon in FY 2009. Due to funding cuts, the South Cow Creek study was revised to focus on juvenile habitat and one study site was eliminated. The study was finished in FY 2010 with completion of fieldwork on the three remaining juvenile study sites, redd mapping, and preparation of a final report on habitat quantity and quality in South Cow Creek.

METHODS

Hydrology

Regression formulas were generated that could be used to predict flows for South Cow Creek using flow data available on the Internet. Historical U.S. Geological Survey gage flow records for South Cow Creek and Cow Creek were identified that could be used to develop regression formulas to predict flows. Additional flow data were collected as part of the habitat mapping, redd mapping, and study site hydraulic and data collection to corroborate the flow/flow regression equations.

Water Temperature

Regression formulas were generated that could be used to predict water temperatures for South Cow Creek using U.S. Geological Survey Cow Creek flow and U.S. Forest Service Redding air temperature data available on the Internet. We deployed an Optic StowAway probe, manufactured by Onset Corporation, at one of the study sites to record temperature. The thermograph was set up to record water temperatures every hour. The thermograph was deployed on March 2, 2010 and recovered on June 9, 2010. Data were subsequently downloaded from the thermograph. Daily average and daily maximum water temperatures were calculated for the thermograph. We used the data we collected to develop a regression of daily maximum water temperature versus daily maximum air temperature and flow.

Segment Delineation

Stream gradient was calculated from USGS topographic maps. Segments were delineated within the study area of South Cow Creek based on hydrology and other factors, such as gradient, channel type and land use, so that the amount of habitat in the study sites in each segment could be accurately extrapolated to each segment.

Habitat Mapping

Mesohabitat mapping of South Cow Creek was conducted October 27-30, 2008, November 24-26, 2008, and April 16, 2009 at flows of, respectively, 16.3, 22 and 39.6 cfs for the entire study area. Using habitat typing protocols developed by CDFG, the mesohabitat mapping consisted of walking upstream or downstream and delineating the mesohabitat units, such as pool, riffle, run and glide. The location of the upstream and downstream boundaries of habitat units was recorded with a survey-grade Real Time Kinematic (RTK) Global Positioning System (GPS) unit. The mesohabitat units were also delineated on aerial photos. During the habitat mapping, a qualitative assessment was made of the quantity of spawning-sized gravel in each segment.

Following the completion of the mesohabitat mapping on April 16, 2009, the mesohabitat types and number of mesohabitat units of each mesohabitat type in each segment were enumerated. Shapefiles of the mesohabitat units were created in a Geographic Information System (GIS) using the GPS data and aerial photos flown on October 27, 2008. Since we were not able to get permission to access the upper 1.54 miles of the Valley Floor Segment, identification of mesohabitat types and shapefiles for this area was made solely using the October 27, 2008 aerial photos. The area of each mesohabitat unit was computed in GIS from the above shapefiles.

Redd Mapping

Adult Chinook salmon construct redds (nests) where they bury their eggs (Figure 1). Redd mapping of the lower 5.25 miles of South Cow Creek was conducted October 27-30, 2008, November 24-26, 2008 and Nov 16-18, 2009 at flows of, respectively, 16.3, 22 and 17.9-20.7 cfs. Data for redds were collected from an area adjacent to the redd which was judged to have a similar depth and velocity as was present at the redd location prior to redd construction (Gard

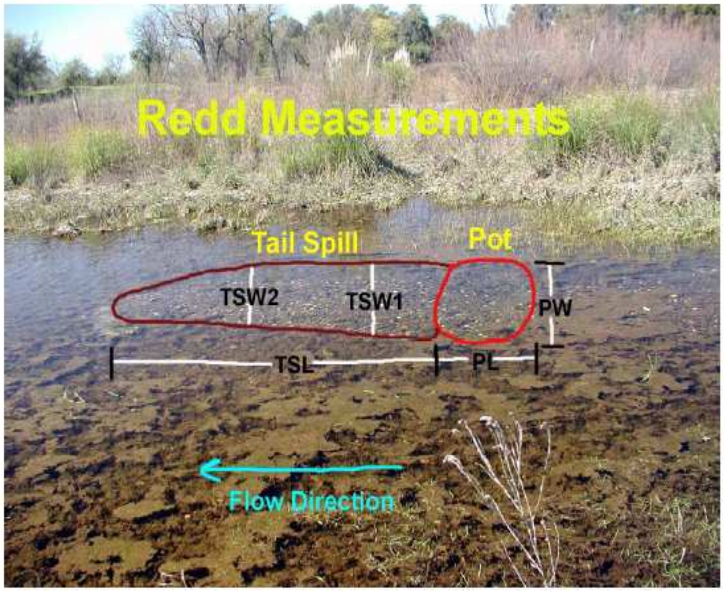

Figure 1
Chinook salmon redd (nest)

1998). Depth was recorded to the nearest 0.1 foot and average water column velocity was recorded to the nearest 0.01 ft/s. Measurements were taken with a wading rod and a Marsh-McBirney^{R} model 2000 velocity meter. Substrate was visually assessed for the dominant particle size range (i.e., range of 1-2 inches) at three locations: 1) in front of the pit; 2) on the sides of the pit; and 3) in the tailspill. The location of each redd was recorded with a survey-grade RTK GPS unit, with the measurement taken at the center of the pit of the redd.

Upstream Passage Assessment

The ability of an adult salmon to move upstream into the entire study area (upstream passage) is a critical factor in the ability to maintain or increase salmonid populations. An upstream fish passage assessment was conducted Nov 16-18, 2009 at flows of 17.9-20.7 cfs. The minimum thalweg (deepest point on a channel cross-section) depth was recorded for each riffle and cascade that was identified for the lower 5.25 miles of South Cow Creek in the mesohabitat mapping. The hydraulic models of the study sites were used to estimate the flow that would allow upstream passage of adult fall-run Chinook salmon. This was done by determining what flow would result in a minimum thalweg depth of 0.8 feet (Thompson 1972) for each of the riffles located in our study sites. A depth of 0.8 feet is the minimum depth needed for successful upstream passage by adult Chinook salmon. There weren't any cascades in our study sites.

Field Reconnaissance and Study Site Selection

Study sites were the focus of intensive data collection to quantify the amount of fry and juvenile habitat for fall-run Chinook salmon. Field reconnaissance in April and May 2009 investigated potential study sites in two segments. The study sites were approximately 500 feet long and included multiple mesohabitat units (Figure 2). Based on the results of the mesohabitat mapping and field reconnaissance, a list of potential study sites in two segments was developed. Using the final list of potential study sites, study sites were selected that represented all of the habitat types found in the two segments. The study sites were randomly selected to insure unbiased selection of the study sites. For the sites selected for modeling, the landowners along both riverbanks were identified and asked to sign temporary entry permits authorizing entry onto their property during the course of the study.

Transect Placement (study site setup)

Five study sites were established April-May 2009. For each study site, a transect was placed at the up- and downstream ends of the site. Transect pins (headpins and tailpins) were marked on each river bank above the 300 cfs water surface level using rebar driven into the ground and/or bolts placed in tree trunks. Survey flagging was used to mark the locations of each pin. We also installed horizontal bench marks that acted as control points for the bed topography data collection when using a robotic total station[2]. After installing the horizontal bench marks, data were collected to establish a precise set of location coordinates for each horizontal bench mark using survey-grade RTK GPS. Vertical benchmarks (lagbolts in trees or bedrock points) were established, and marked with paint and flagging.

Hydraulic and Structural Data Collection

Hydraulic and structural data collection in the study sites began in April 2009 and was completed in March 2010. The data collected at the inflow and outflow transects included: 1) water surface elevations (WSELs) measured to the nearest 0.01 foot at a minimum of three significantly different stream discharges using standard surveying techniques (differential leveling); 2) wetted streambed elevations determined by subtracting the measured depth from the surveyed WSEL at a measured flow; 3) dry ground elevations to points above 300 cfs (the highest flow simulated) surveyed to the nearest 0.1 foot; 4) mean water column velocities measured at a mid-to-high-range flow at the points where bed elevations were taken; and 5) substrate and cover classification at these same locations and also where dry ground elevations were surveyed.

When conditions allowed, WSELs were measured along both banks and in the middle of each transect. Otherwise, the WSELs were measured along both banks. Depth and velocity measurements were made using a wading rod equipped with a Marsh-McBirney[R] model 2000 velocity meter. Data collected between the transects included: 1) bed elevation; 2) northing and easting (horizontal location); 3) substrate; and 4) cover. These parameters were collected at enough points to characterize the bed topography, substrate and cover of the sites. Bed elevation and horizontal location of individual points were obtained with a total station or survey-grade RTK GPS, while the cover and substrate were visually assessed at each point.

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[2] A total station is an electronic/optical instrument used in modern surveying. The total station is an electronic theodolite (transit) integrated with an electronic distance meter (EDM) to read distances from the instrument to a particular point. Data from the total station consist of the horizontal angle, vertical angle and slope distance to each point.

Figure 2
Example South Cow Creek Study Site[3]

Hydraulic Model Construction and Calibration

The topographic data for the 2-D model were first processed using the R2D_Bed software. The resulting data set was then converted into a computational mesh (Figure 3) using the R2D_Mesh software. The resulting mesh was used in River2D to simulate depths and velocities at the flows to be simulated.

To calibrate the River2D model, there are three steps: 1) first WSELs are generated at the upstream and downstream transects using the Physical Habitat Simulation System (PHABSIM) ; 2) the WSEL generated by PHABSIM at the downstream end of each study site is used as an

[3] Letters identify the mesohabitat types (for example, G is main channel glide).

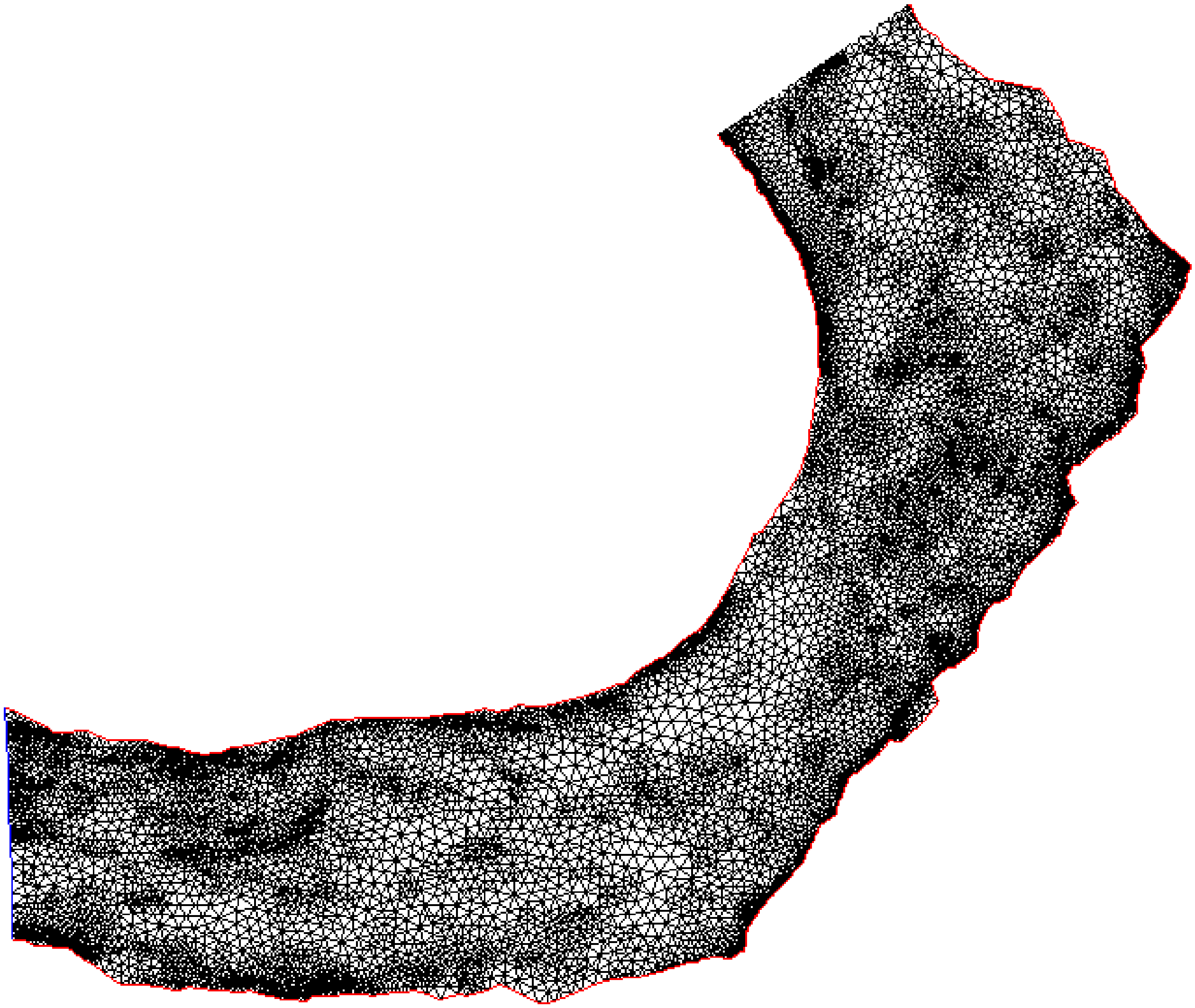

Figure 3
Example South Cow Creek Study Site Computational Mesh

input to the River2D model; and 3) the River2D model is calibrated by changing bed roughnesses so that the WSEL at the upstream end of the study site matches the WSEL generated by PHABSIM. The bed roughness represents a combination of substrate size and cover, and small-scale variation in bed topography that are not captured by the bed topography data. The adjustment of bed roughness accounts for the unmeasured small-scale variations in bed topography. The initial bed roughnesses used by the River2D model were based on the observed substrate sizes and cover types. The River2D model was run at 30 simulation flows, ranging from 10 to 300 cfs, to use in computing habitat.

Habitat Suitability Criteria Development

We used habitat suitability criteria (HSC) developed for the Lower Alluvial Segment of Clear Creek for fall-run fry and juvenile Chinook salmon rearing because: 1) they were developed on a similar nearby stream; and 2) were developed using state of the art methods for developing juvenile HSC (logistic regression, cover and adjacent velocity). Fry are defined as young of the year Chinook salmon less than 60 mm long, while juveniles are defined as young of the year Chinook salmon with a length greater than 60 mm.

Habitat Simulation

Fall-run Chinook salmon fry and juvenile rearing habitat, quantified as Weighted Useable Area (WUA), were computed over a range of discharges (10 to 300 cfs) for the rearing sites in South Cow Creek. Habitat was determined using the fall-run Chinook salmon fry and juvenile rearing HSC developed for the Lower Alluvial Segment of Clear Creek and the hydraulic models of the South Cow Creek study sites. Habitat was extrapolated to the stream segments, based on the mesohabitat mapping data, to compute the total amount of juvenile habitat in each segment.

RESULTS

Hydrology

Table 1 summarizes the historical gage flow records used to develop regression formulas to predict flows, while Table 2 presents the regression formulas. Figure 3 shows the historical gage flows and regression equations, while Figure 4 shows the annual average hydrograph for South Cow Creek, computed from all historical gage flows for Cow Creek and the flow/flow regression equations in Table 2. Annual average flows range from 18 cfs in mid-August to 390 cfs in mid-January. Table 3 summarizes the flow measurements that we made, while Figure 5 shows the measured flows for South Cow Creek relative to the regression equations computed from historical gage data. The website containing the data that were plugged into the regression equations in Table 2 is:
http://waterdata.usgs.gov/nwis/dv?cb_00060=on&format=html&site_no=11374000&referred_module=sw.

Water Temperature

Figure 6 show the results of the water temperature monitoring. Maslin et al. (1996) found that juvenile Chinook salmon were still present in streams at daily maximum water temperatures as high as 74.5 ° F. As a result, we used a daily maximum water temperature of 74.5 ° F as a conservative predictor of when all juvenile fall-run Chinook salmon would die or leave South Cow Creek. The multiple regression did not show a significant effect of Cow Creek flows on South Cow Creek water temperatures ($p = 0.57$). However, when we removed three points with

Table 1
Historical Gage Data Used to Develop Flow/Flow Regressions

Stream	USGS Gage Number	Period of Record
Cow Creek	11374000	10/1/49-present
South Cow Creek	11372200	10/1/56-10/3/72

Table 2
Flow/Flow Regresssions[4]

Cow Creek Flow Range	Regression Equation	R^2
< 50 cfs	South Cow Q = 6.388 + 0.334 x Cow Q	0.61
50-180 cfs	South Cow Q = 15.573 + 0.151 x Cow Q	0.46
181-500 cfs	South Cow Q = 8.642 + 0.188 x Cow Q	0.51
> 500 cfs	South Cow Q = 38.737 + 0.134 x Cow Q	0.88

high leverage[5], there was a significant effect of Cow Creek flows on South Cow Creek water temperatures ($p = 0.045$). Table 4 shows the regression equation we developed from the water temperature data, excluding the three data points with high leverage. Web sites for the flow and air temperature data to plug into the regression equation in Table 4 are given in Table 5.

Study Segment Delineation

The study area of South Cow Creek was divided into three segments: the Boero Segment, Valley Floor Segment, and the Tetrick Segment. The combined distance for these three segments was 7.36 miles. The Tetrick Segment has a significantly steeper gradient than the other two segments (Figure 7). The River Mile (RM) boundaries for each segment are as follows: Boero Segment RM 0 – 1.68; Valley Floor Segment RM 1.68 – 6.79; Tetrick Segment RM 6.79 – 7.36.

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[4] The categories of flow ranges were developed by visual observation of changes in the slope of the relationship between South Cow Creek and Cow Creek flows, with the cutoff points selected where the slope changed, and were used to improve the fit of the regression relationships to the measured data.

[5] In statistics, leverage is a term used in connection with regression analysis and, in particular, in analyses aimed at identifying those observations which have a large effect on the outcome of fitting regression models. Points with high leverage are those observations, if any, made at extreme or outlying values of the independent variables such that the lack of neighbouring observations means that the fitted regression model will pass close to that particular observation. In general, it is appropriate to exclude points with high leverage to best capture the overall relationship between the dependent and independent variables.

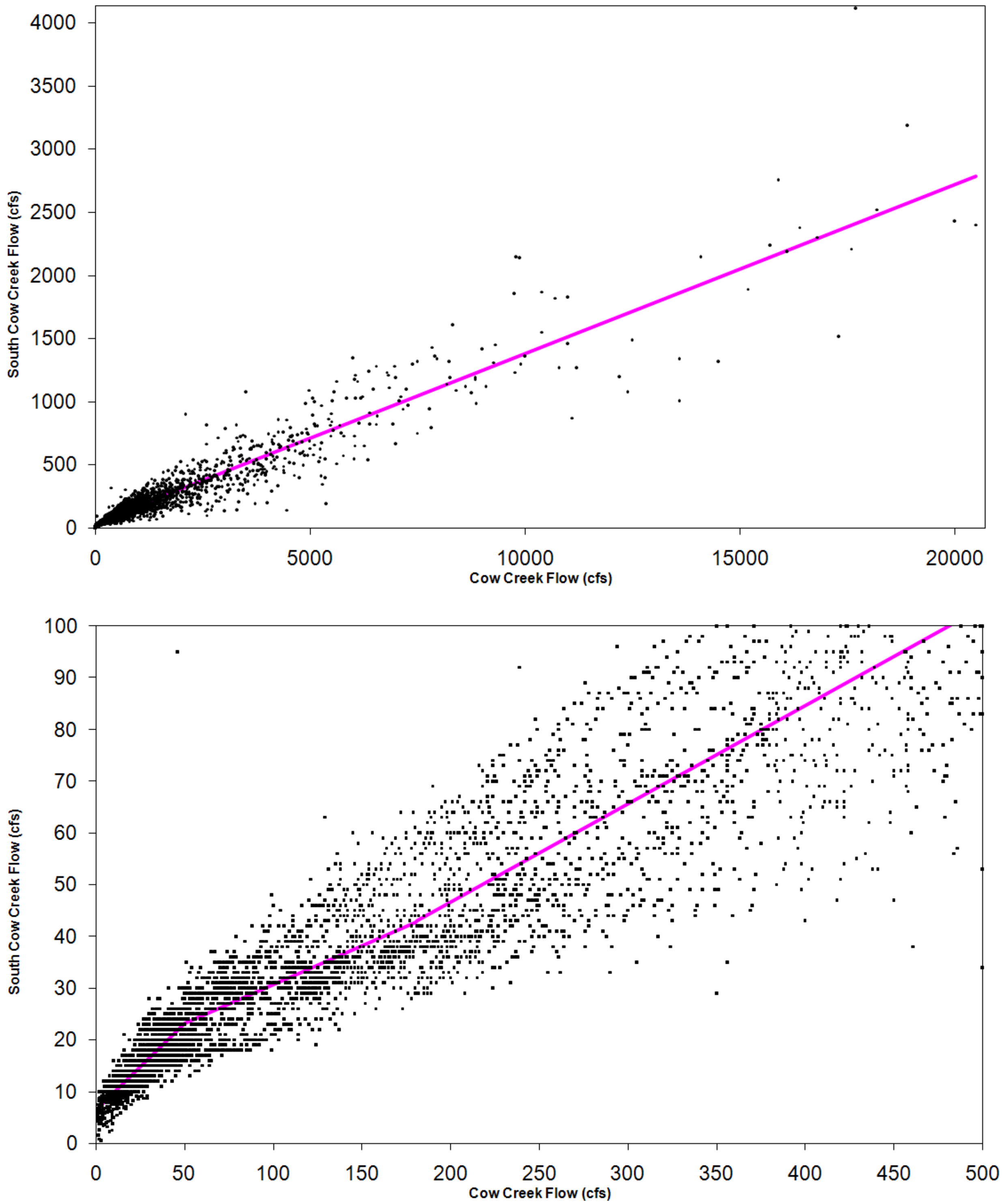

Figure 3
South Cow Creek Flow Data and Regression[6]

[6] The lower graph is an expanded view of the lower-flow portion of the upper graph.

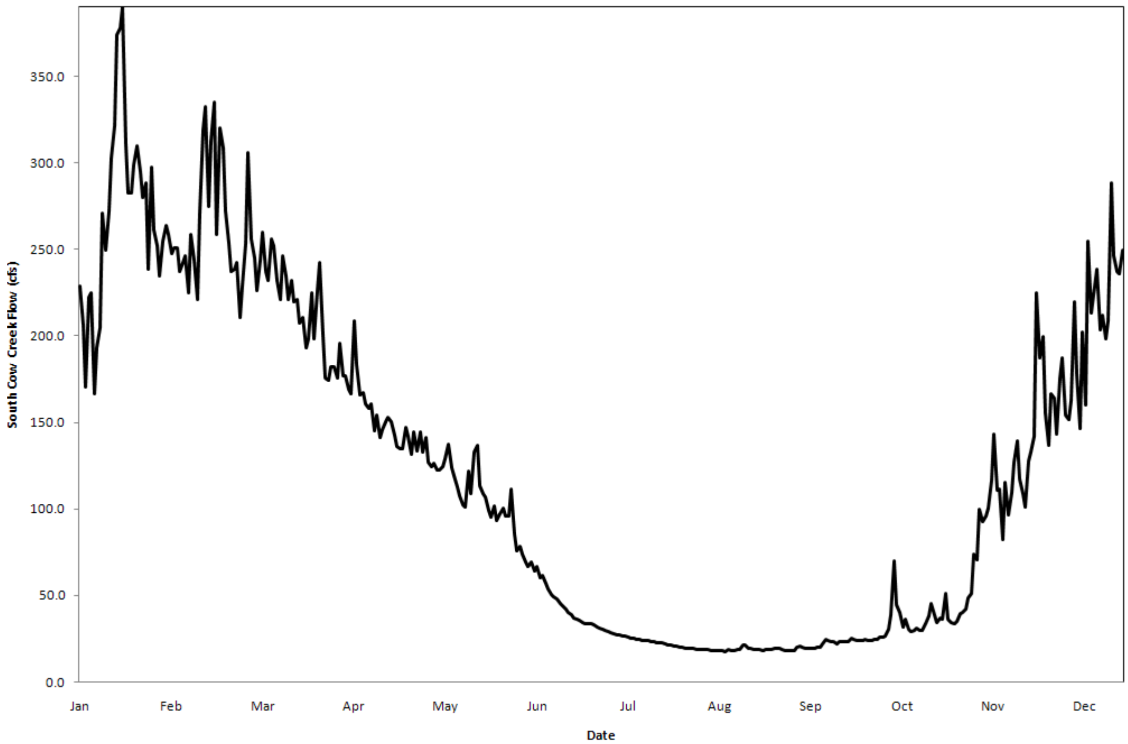

Figure 4
South Cow Creek Average Annual Hydrograph

Table 3
Flow Measurement Data (cfs)

Date	South Cow Creek
10/28/2008	16.3
11/24/2008	22
4/16/2009	39.6
4/17/2009	52.4
4/28/2009	64.5
4/29/2009	64.5
5/12/2009	70
6/22/2009	18.6
7/20/2009	8.2
7/22/2009	7.1
9/3/2009	6.4
9/10/2009	8.2
11/16/2009	17.9
11/17/2009	20.7
11/18/2009	20.5
2/1/2010	122.8

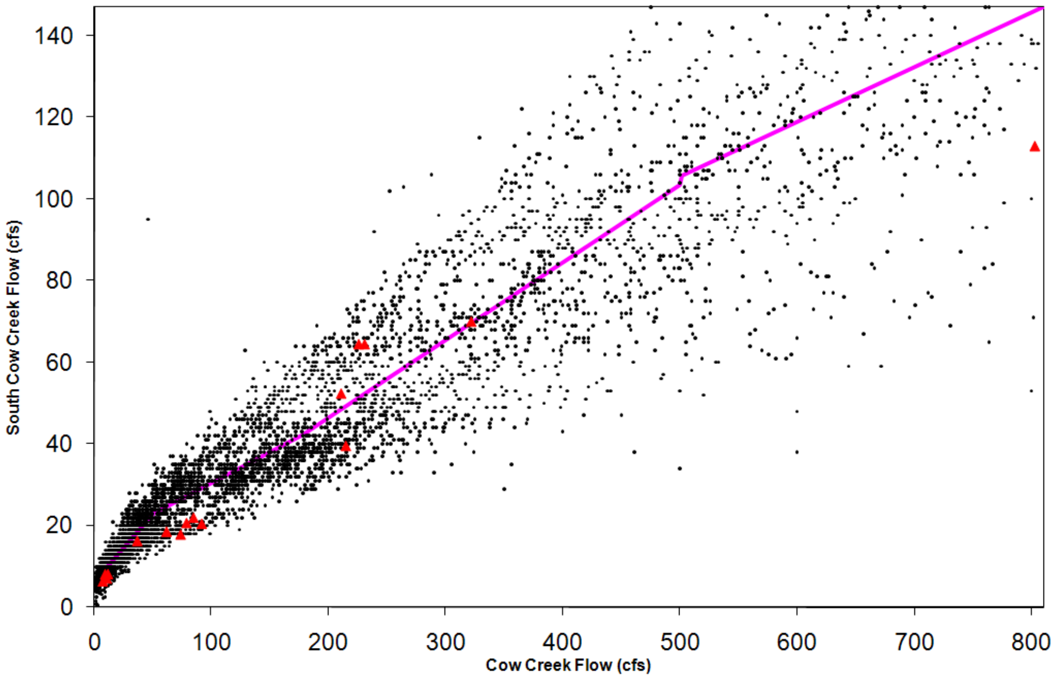

Figure 5
South Cow Creek Flows Measured (Red Triangles) Versus Historic Gage Data (Black Dots) and Flow/Flow Regression Calculated from Historic Gage Data (Purple Line)[7]

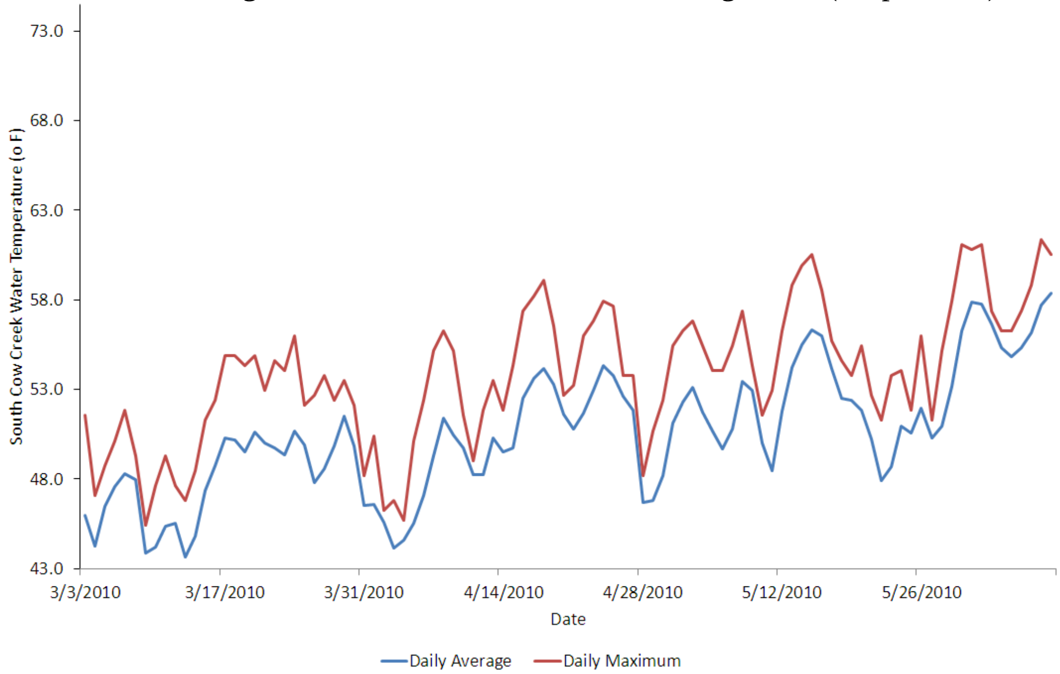

Figure 6
South Cow Creek Water Temperatures Versus 74.5 ° F Threshold For All Juvenile Fall-run Chinook Salmon Leaving South Cow Creek

[7] The discontinuity in the regression line reflects where we switched from one regression to another regression.

Table 4
Water Temperature Regresssions[8]

Regression Equation	R^2
South Cow Creek Water Temp = 34.0 + 0.295 x Air Temp – 0.0016 x Cow Creek Flow	0.746

Table 5
Web Sites for Data to Plug in to Equations in Table 4

Parameter	Web Site
Cow Creek Flows	http://waterdata.usgs.gov/nwis/dv?cb_00060=on&format=html&site_no=11374000&referred_module=sw
Air Temperatures	http://cdec.water.ca.gov/cgi-progs/queryDaily?s=RED

[8] This regression equation was developed without the three points with high leverage.

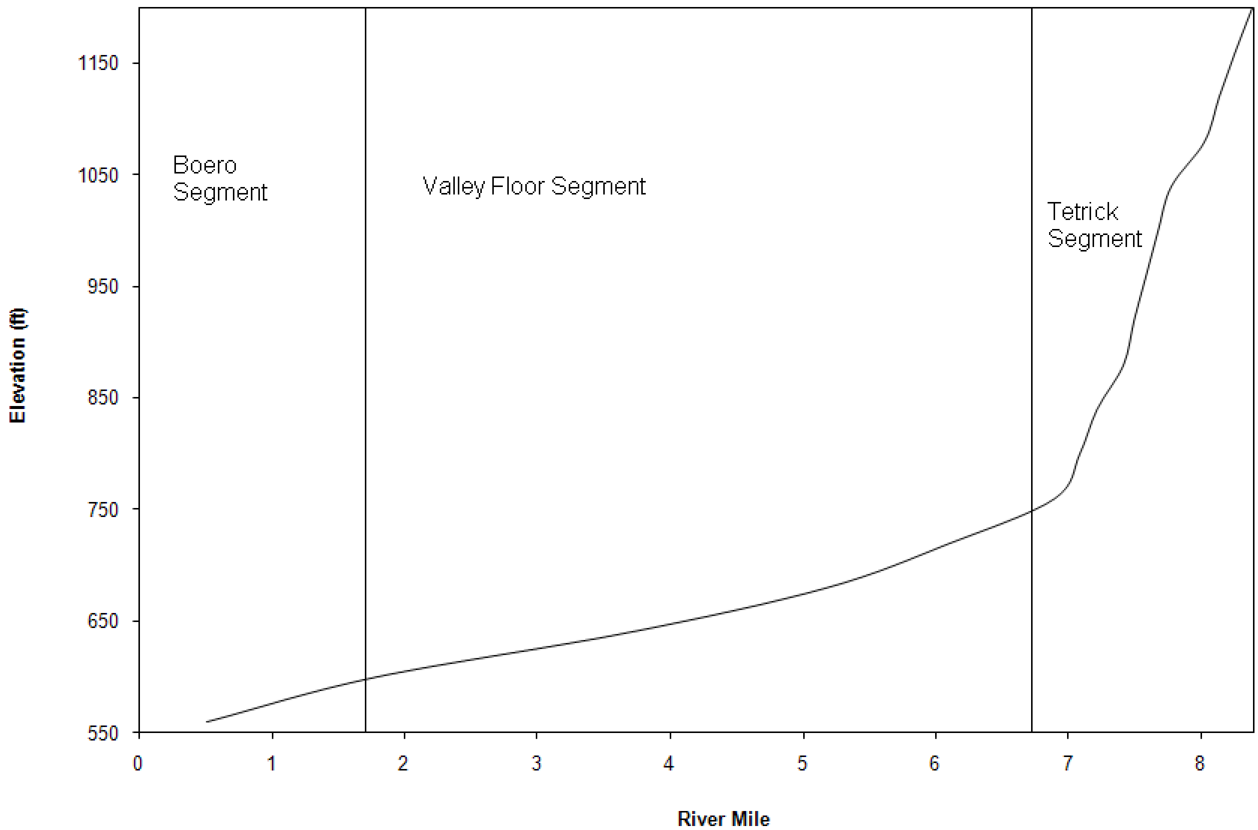

Figure 7
South Cow Creek Stream Gradient[9]

Habitat Mapping

A total of 555 mesohabitat units were mapped for the three segments (Appendix A). Table 6 summarizes the mesohabitat types, area totals and numbers of each type recorded in the Boero and Valley Floor Segments during the habitat mapping process, while Table 7 summarizes the mesohabitat composition of all three segments. Table 6 does not include the Tetrick Segment because juvenile habitat was not modeled for this segment. Much less spawning-sized gravel was observed in the Tetrick Segment than in the Boero and Valley Floor Segments.

Redd Mapping

During the course of conducting the mesohabitat mapping, we also attempted to collect fall-run Chinook salmon spawning HSC. We were only able to locate a total of 27 redds in 2008 and 28 redds in 2009, which were insufficient data for use in developing spawning HSC. These were dry years and what few adult fall-run Chinook salmon there were may have had trouble getting into Cow Creek. As a result, we used the redd mapping data as an index of spawning habitat quality. We mapped redds in 4.05 miles in 2008 and 5.25 miles in 2009, for an overall redd density of 6.7 redds/mile in 2008 and 5.3 redds/mile in 2009. There were 8 redds (30%) in the

[9] River Mile 0 is at the confluence of South Cow and Old Cow Creeks.

Table 6
Boero and Valley Floor Segments Mesohabitat Mapping Results

Mesohabitat Type	South Cow Creek Units Area Totals (ft^2)	Number of Units
Side Channel Pool	51,292	32
Main Channel Pool	697,366	94
Side Channel Riffle	19,584	40
Main Channel Riffle	261,901	124
Side Channel Run	15,277	13
Main Channel Run	234,679	100
Side Channel Glide	1,156	2
Main Channel Glide	138,234	37
Cascade	493	2

Table 7
South Cow Creek Segment Mesohabitat Composition

Mesohabitat Type	Boero Segment	Valley Floor Segment	Tetrick Segment
Side Channel Pool	2.4%	3.9%	1.5%
Main Channel Pool	48.9%	49.2%	28.2%
Side Channel Riffle	0.5%	1.6%	2.8%
Main Channel Riffle	15%	19.3%	33.5%
Side Channel Run	0.09%	1.3%	0.2%
Main Channel Run	20.2%	15.6%	26.8%
Side Channel Glide	0%	0.1%	0%
Main Channel Glide	12.9%	8.9%	2%
Cascade	0.04%	0.03%	5%

Table 8
South Cow Creek Redd Count data

River Mile	2008	2009
0-1	6	8
1-2	5	6
2-3	10	4
3-4	1[10]	5
4-5	5	5
5-5.25	Not sampled	0

Boero Segment in 2008 and 14 (50%) redds in the Boero Segment in 2009. The remaining redds were in the Valley Floor Segment. The Tetrick Segment was not surveyed for redds because of the scarcity of spawning-sized gravel observed during the habitat mapping. Redd count data by river mile is shown in Table 8. We only observed two redds in October 2008; the other 25 redds from 2008 were not observed until November.

Upstream Passage Assessment

The location with the shallowest thalweg depth (0.4 feet at a flow of 20.7 cfs) was a cascade at River Mile 1.35 (Figure 7). Another cascade and 20 riffles had a shallowest thalweg depth of 0.5 feet. These units constituted a very small percentage of the total length and were spread throughout both the Boero and Valley Floor Segments. The shallow thalwegs were generally on the length of 10-20 feet. It is unknown if they were barriers or if they were short enough that burst speed could get adult fall-run Chinook through these areas to deeper water. Three of the 20 riffles were located in our study sites. The hydraulic models for these sites indicated that these riffles had a shallowest thalweg depth of 0.8 feet at 55.6, 32.4 and 64.4 cfs. Therefore, South Cow Creek flows need to be at least 64.4 cfs for upstream passage over all riffles to occur, assuming that the three riffles in the study sites were representative of all riffles in the lower two segments. Based on the flow-flow regression in Table 2, this would be equivalent to a Cow Creek flow of 294 cfs, which on average first occurs on November 9.

[10] This redd was observed in October 2008. In November 2008, we sampled RM 0-3.25 and RM 4.1-4.9. Since we only covered ¼ mile of this mile section in November, we could have missed some redds. Thus, the redd count for this mile section is likely biased low compared to the other mile sections.

Field Reconnaissance and Study Site Selection

Five study sites were selected for modeling fall-run Chinook salmon fry and juvenile rearing habitat in the Boero and Valley Floor Segments (Figure 8). The following are the five study sites, listed in order from upstream to downstream: Jones, Poole, Farrell, Sabanovich and Boero.

Hydraulic and Structural Data Collection

Low, medium and high flow water surface elevations were collected for all five sites. Due to lack of sufficient funds and time constraints, we were unable to collect topographic data on the Sabanovich study site and eliminated it from the study. Distribution of substrate types in the remaining four study sites is given in Appendix B. The Boero study site was dominated by boulders and bedrock, while the other study sites had primarily fines up on the banks and gravel and cobble in the wetted low flow channel. There was considerable variation in substrate distribution between the study sites in the Valley Floor reach.

Hydraulic Model Construction and Calibration

All data for the four fall-run Chinook salmon rearing sites were compiled and checked. At all four sites, we completed PHABSIM calibration, construction and calibration of the 2-D hydraulic models as described above, and ran the hydraulic model for the simulation flows.

Habitat Simulation

Flow-habitat relationships for fry and juvenile fall-run Chinook salmon for the Boero and Valley Floor Segments are shown in Figures 9 and 10. On a per mile basis, there was much more fry and juvenile fall-run Chinook salmon habitat in the Valley Floor Segment than in the Boero Segment.

DISCUSSION

Hydrology

The measured South Cow Creek flows fell within the range of historical gage flows. Thus, it appears likely that the South Cow Creek flow/Cow Creek flow regression still applies to South Cow Creek.

Water Temperature

It should be noted that although water temperatures did not go above 74.5 ° F for the period in which data were collected, the water temperatures recorded could result in adverse sublethal effects on juvenile salmonids. For example, maximum water temperatures toward the end of the monitoring period (i.e. in mid-June) exceeded a 59° F threshold for smolt survival (Mesick 2009). The regression equation does not appear to be accurate to extrapolate beyond the measured data – for example, it predicts that the maximum air temperature would need to be

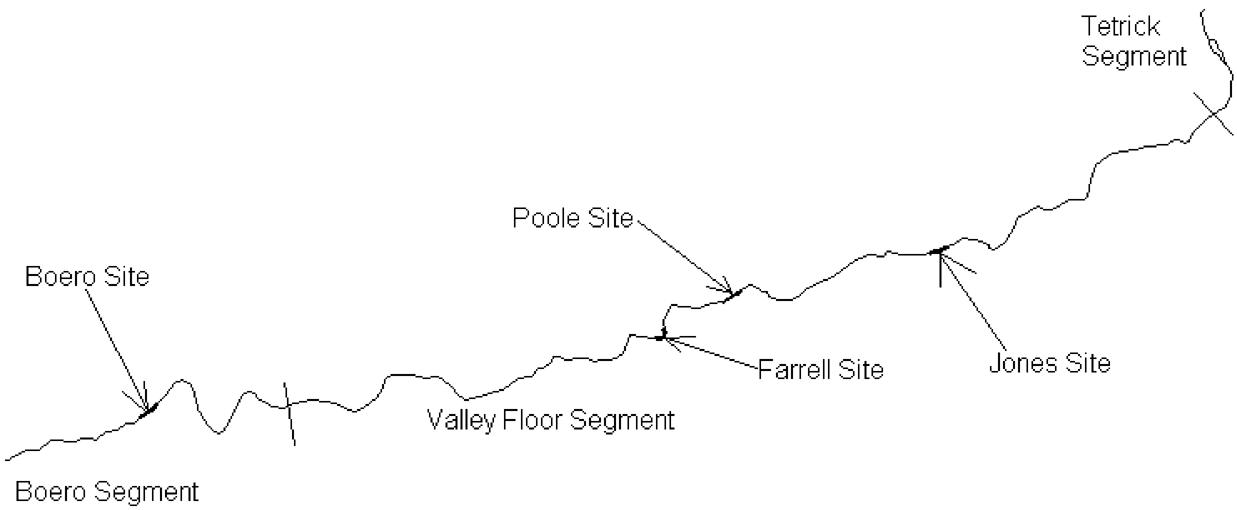

Figure 8
Study Sites and Segments

greater than 120 ° F to result in a daily maximum water temperature of 74.5 ° F. As such, we are unable to predict when water temperatures in South Cow Creek would reach the point where all juvenile fall-run Chinook salmon would leave South Cow Creek. The water temperature regression equation showed a negative relationship between water temperature and flow (i.e. water temperatures were lower at higher flows), and a positive relationship between water and air temperatures. This suggests that, as expected, water temperatures in South Cow Creek will stay in an acceptable range for a longer period in wetter and cooler years, versus warmer and dryer years.

Study Segment Delineation

Based on the scarcity of spawning gravel in the Tetrick Segment, suspected to be due to the high gradient, restoration efforts for fall-run Chinook salmon should be focused on the Boero and Valley Floor Segments.

Habitat Mapping

The Boero and Valley Floor Segments have relatively similar habitat composition. The Tetrick Segment had a very different habitat composition than the Boero and Valley Floor Segments, with more cascades and riffles and less pools, reflecting the higher gradient of the Tetrick Segment. Side channels are important habitats for juvenile Chinook salmon because they have low velocities and greater proportions of woody debris, as compared to main channel habitats, and thus would be a priority for habitat restoration, maintenance and protection. Woody debris is an important habitat parameter for juvenile salmonids, providing refugia from predation. Side channels comprised 3% of the Boero Segment, 6.9% of the Valley Floor Segment and 4.5% of the Tetrick Segment. The side channel habitat units in the Valley Floor Segment were primarily located in a large island complex located at River Mile 1.7-1.9. The side channels were watered year round for the period of the study.

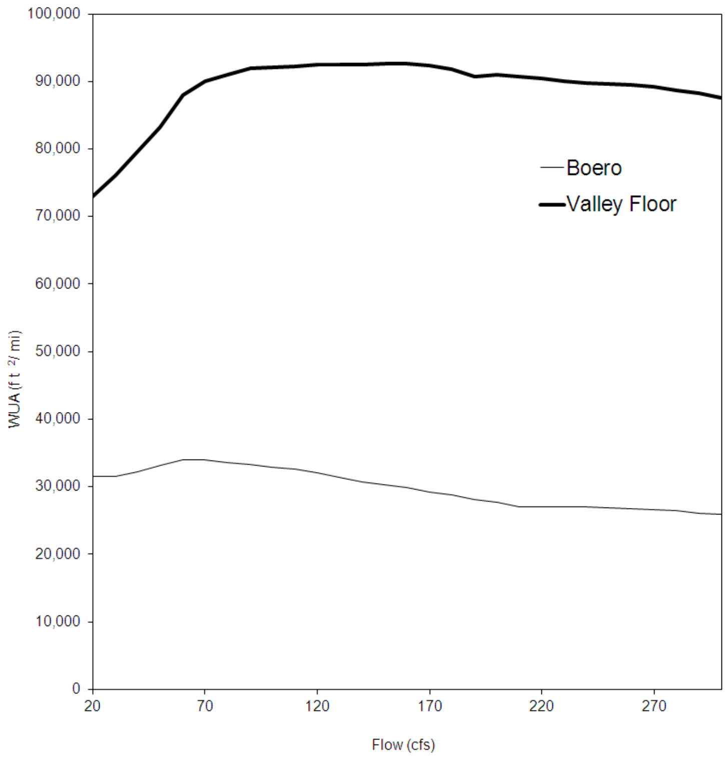

Figure 9
South Cow Creek Fall-run Chinook Salmon Fry Flow-Habitat Relationships

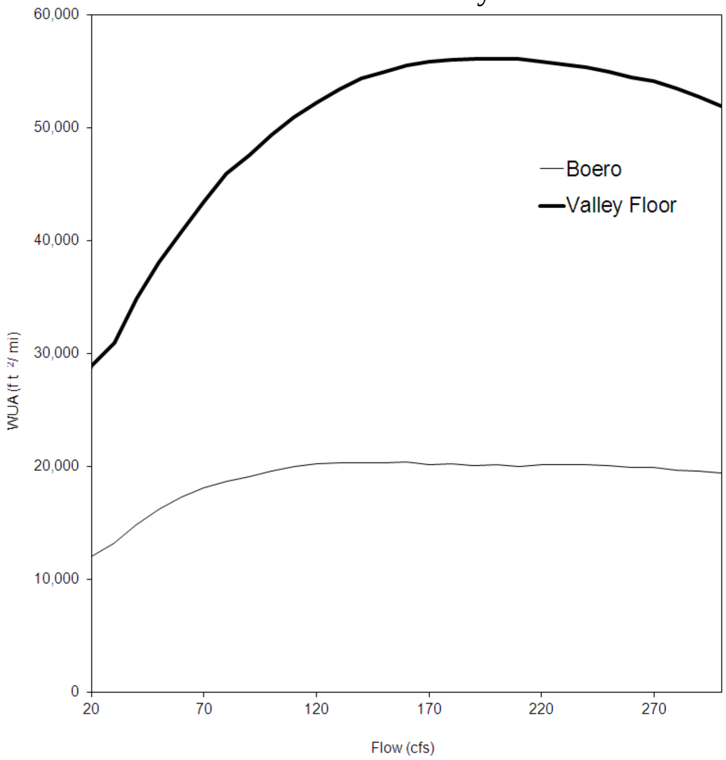

Figure 10
South Cow Creek Fall-run Chinook Salmon Juvenile Flow-Habitat Relationships

Redd Mapping

The spatial distribution of redds was relatively even along the entire length of the Boero and Valley Floor Segments, but varied significantly between years. Based on the limited amount of data, both the Boero and Valley Floor Segments appear to be important for fall-run Chinook salmon spawning. The low numbers of fish in 2008 and 2009 limits our ability to evaluate spawning habitat quality. We were unable to assess the spawning habitat quality of the upper 1.54 miles of the Valley Floor Segment, since we were unable to obtain permission for access. In addition, aerial photography was not effective in detecting redds in South Cow Creek, likely due to the low contrast between disturbed and undisturbed gravel. The two redds that we observed on the ground in October 2008 were not visible at all in the aerial photography taken at the same time as the ground survey, despite the high resolution (3-inch pixel size) of the aerial photography. This is in marked contrast to other streams, such as the American River, where fall-run Chinook salmon redds can be readily identified in aerial photos.

If we assume that the ratio of adult fish to redds is 2:1, our redd count data, which only covers 60-77% of the Boero and Valley Floor reaches, would be equivalent to 54 adults in 2008 and 56 adults in 2009. Based on the total video weir counts of adult Chinook salmon for Cow Creek of 472 prior to November 26, 2008 and 254 prior to November 18, 2009, over 11-22% of fall-run Chinook salmon in the Cow Creek watershed spawned in South Cow Creek in these years. South Cow Creek therefore appears to be an important habitat area for fall-run Chinook salmon within the context of the entire Cow Creek watershed.

Upstream Passage Assessment

Given that flows in South Cow Creek are unregulated with the exception of diversions, upstream passage is dependent on high flows associated with the first substantial rains of the fall and the reduction of diversions. Anecdotal reports from landowners indicate that fall-run Chinook salmon in South Cow Creek start spawning right around Halloween (October 31). However, spawning can be delayed due to late onset of the rainy season, as we saw in 2008, where there were only two redds present October 27-30, but an additional 25 redds present by November 24-26. This is consistent with our upstream passage assessment, since Cow Creek flows first exceeded 294 cfs on November 3, 2008. Upstream passage may limit returns of adult fall-run Chinook salmon in dry years. For example, flows only exceeded 294 cfs for two days in 2008, prior to December 22, 2008. This would give adult fall-run Chinook salmon a very limited window of time to pass the many low flow migration barriers in South Cow Creek.

Hydraulic and Structural Data Collection

All of the bed topography measurements were accurate to 1 foot horizontally and 0.1 foot vertically. We believe that measurement error would have a minimal effect on the final result because of the high degree of accuracy of the measurements.

Habitat Simulation

We attribute the greater amount of fry and juvenile habitat in the Valley Floor Segment, versus the Boero Segment, to the greater proportion of side channel habitat in the Valley Floor Segment, and the alluvial nature of the Valley Floor Segment. In contrast, the Boero Segment, with steeper banks, has less potential for juvenile habitat, since the habitat is concentrated in a narrower bank along the stream banks. Based on the greater amount of fry and juvenile habitat and the potential to improve fry and juvenile habitat conditions in the Valley Floor Segment, the Valley Floor Segment should be the highest priority for habitat restoration. Habitat restoration actions should focus on enhancing woody cover, which is a key aspect of fry and juvenile habitat.

In general, population responses occur by increasing the amount of habitat for the limiting life stage. We were not able to determine what the limiting life stage was. We were not able to assess whether spawning is the limiting life stage because we did not quantify the amount of spawning habitat. We attribute the greater amount of fry habitat in both segments, as compared to juvenile habitat, to the higher suitability of slow adjacent velocities for fry, versus juveniles. Generally speaking for smaller Central Valley tributaries, it is believed that a large number of fry emigrate from the streams and rear in the Sacramento River. This, together with mortality between the fry and juvenile life stages and the larger amount of habitat needed for individual juveniles, compared to individual fry, makes it difficult to assess whether fry or juvenile is the limiting life stage. Therefore, restoration actions should target both fry and juvenile habitat. Since the cover suitability criteria used in this study are similar for fry and juveniles, habitat restoration actions that increase the amount of woody cover will have the same benefits for both fry and juvenile fall-run Chinook salmon in South Cow Creek.

REFERENCES

Gard, M. 1998. Technique for adjusting spawning depth habitat utilization curves for availability. Rivers: 6: 94-102.

Maslin, P.E., W.R. McKinney and T.L. Moore. 1996. Intermittent streams as rearing habitat for Sacramento River Chinook salmon: 1996 update. Department of Biology, California State University Chico, Chico, CA.

Mesick, C.F. 2009. Direct testimony of Carl F. Mesick on behalf of the U.S. Fish and Wildlife Service. Before the U.S. Federal Energy Regulatory Commission Office of Administrative Law Judges. Turlock Irrigation District and Modesto Irrigation District, New Don Pedro Project, FERC Project Nos. 2299-065 and 2299-053. September 11, 2009. U.S. Fish and Wildlife Service: Sacramento, CA.

Thompson, K. 1972. Determining stream flows for fish life. Presented at Pacific Northwest River Basins Commission Instream Flow Requirement Workshop. March 1972. 20 pp.

APPENDIX A
HABITAT MAPPING DATA[11]

[11] Habitat Units 1-118 are in the Boero Segment. Habitat Units 119-443 are in the Valley Floor Segment. Habitat Units 444-555 are in the Tetrick Segment.

Habitat distribution identified in the lower 7.36 miles of South Cow Creek

Mesohabitat Unit #	Mesohabitat Type	Mesohabitat Unit Area (ft^2)	River mile
1	Main Channel Pool	27630	0
2	Main Channel Riffle	4895	
3	Main Channel Run	1343	
4	Main Channel Riffle	4010	
5	Main Channel Run	3203	
6	Main Channel Riffle	799	
7	Main Channel Glide	1628	
8	Main Channel Pool	11117	
9	Main Channel Pool	2868	
10	Main Channel Run	3538	
11	Main Channel Riffle	666	
12	Main Channel Run	1960	
13	Main Channel Riffle	801	
14	Main Channel Pool	5766	
15	Main Channel Run	1570	
16	Main Channel Riffle	1468	
17	Main Channel Glide	2030	
18	Main Channel Pool	1717	
19	Main Channel Run	1079	
20	Main Channel Riffle	739	
21	Main Channel Pool	5487	
22	Main Channel Pool	2881	
23	Main Channel Riffle	1416	
24	Main Channel Pool	2102	
25	Main Channel Glide	877	
26	Main Channel Run	1614	
27	Main Channel Riffle	623	
28	Main Channel Glide	1623	
29	Main Channel Run	549	
30	Side Channel Riffle	237	
31	Side Channel Pool	1219	
32	Main Channel Riffle	2201	
33	Side Channel Riffle	146	
34	Main Channel Glide	2383	
35	Main Channel Run	1775	
36	Main Channel Riffle	1999	
37	Main Channel Glide	3458	
38	Main Channel Run	751	
39	Main Channel Riffle	441	
40	Main Channel Pool	1707	
41	Main Channel Run	710	
42	Main Channel Riffle	372	

Mesohabitat Unit #	Mesohabitat Type	Mesohabitat Unit Area (ft^2)	River mile
43	Main Channel Run	214	
44	Main Channel Riffle	125	
45	Main Channel Run	1625	
46	Side Channel Run	95	
47	Side Channel Riffle	36	
48	Side Channel Run	150	
49	Main Channel Riffle	257	
50	Main Channel Glide	1210	
51	Side Channel Riffle	50	
52	Side Channel Pool	72	
53	Main Channel Run	2328	
54	Main Channel Riffle	521	
55	Main Channel Pool	5279	
56	Main Channel Glide	13202	
57	Main Channel Pool	2903	
58	Main Channel Run	1071	
59	Main Channel Riffle	1390	
60	Main Channel Run	803	
61	Main Channel Riffle	825	
62	Main Channel Pool	2354	
63	Main Channel Run	1749	
64	Main Channel Riffle	2382	
65	Main Channel Pool	6981	
66	Main Channel Riffle	2401	
67	Main Channel Pool	17592	1
68	Main Channel Riffle	1022	
69	Main Channel Pool	2166	
70	Main Channel Glide	2139	
71	Main Channel Riffle	362	
72	Main Channel Run	2320	
73	Main Channel Glide	2837	
74	Main Channel Riffle	445	
75	Main Channel Pool	4986	
76	Main Channel Riffle	295	
77	Main Channel Pool	1737	
78	Main Channel Run	1309	
79	Main Channel Pool	1217	
80	Main Channel Riffle	927	
81	Main Channel Pool	4439	
82	Main Channel Riffle	977	
83	Main Channel Run	1717	
84	Main Channel Pool	4439	
85	Main Channel Riffle	156	
86	Main Channel Run	3692	

Mesohabitat Unit #	Mesohabitat Type	Mesohabitat Unit Area (ft^2)	River mile
87	Main Channel Riffle	769	
88	Main Channel Run	1980	
89	Main Channel Riffle	149	
90	Main Channel Run	1100	
91	Main Channel Pool	1386	
92	Cascade	103	
93	Main Channel Run	1515	
94	Main Channel Riffle	378	
95	Main Channel Pool	2219	
96	Main Channel Run	6248	
97	Main Channel Pool	2050	
98	Main Channel Riffle	2556	
99	Main Channel Run	2791	
100	Main Channel Glide	2703	
101	Main Channel Run	908	
102	Main Channel Riffle	3639	
103	Main Channel Pool	4503	
104	Side Channel Pool	5660	
105	Main Channel Run	2616	
106	Main Channel Pool	3156	
107	Main Channel Run	941	
108	Main Channel Riffle	460	
109	Side Channel Riffle	391	
110	Main Channel Pool	8984	
111	Main Channel Riffle	2007	
112	Main Channel Glide	2864	
113	Main Channel Run	2028	
114	Main Channel Pool	2201	
115	Main Channel Run	1159	
116	Main Channel Riffle	446	
117	Main Channel Run	1494	1.68
118	Side Channel Riffle	546	Boero
119	Main Channel Pool	1954	Valley Floor
120	Side Channel Run	523	
121	Side Channel Riffle	230	
122	Side Channel Pool	1917	
123	Main Channel Riffle	466	
124	Side Channel Pool	609	
125	Side Channel Pool	303	
126	Side Channel Riffle	549	
127	Main Channel Pool	2375	
128	Main Channel Pool	2277	
129	Main Channel Run	1071	
130	Main Channel Pool	985	

Mesohabitat Unit #	Mesohabitat Type	Mesohabitat Unit Area (ft^2)	River mile
131	Main Channel Run	1899	
132	Main Channel Riffle	2608	
133	Side Channel Riffle	814	
134	Side Channel Run	540	
135	Side Channel Riffle	349	
136	Side Channel Run	516	
137	Side Channel Riffle	149	
138	Side Channel Pool	50	
139	Side Channel Riffle	631	
140	Side Channel Pool	1099	
141	Side Channel Riffle	224	
142	Side Channel Riffle	103	
143	Side Channel Run	150	
144	Side Channel Pool	398	
145	Side Channel Pool	715	
146	Main Channel Pool	1201	
147	Main Channel Pool	767	
148	Main Channel Run	810	
149	Main Channel Pool	13230	
150	Main Channel Riffle	358	
151	Main Channel Glide	3055	
152	Main Channel Riffle	1090	
153	Main Channel Pool	778	
154	Cascade	390	
155	Main Channel Pool	7627	
156	Main Channel Run	2439	
157	Main Channel Pool	2559	
158	Main Channel Glide	3170	
159	Main Channel Run	727	
160	Main Channel Riffle	822	
161	Main Channel Pool	13423	
162	Main Channel Riffle	1666	
163	Side Channel Pool	655	
164	Side Channel Glide	801	
165	Main Channel Pool	9321	
166	Main Channel Riffle	1208	
167	Main Channel Pool	16423	2
168	Main Channel Run	679	
169	Main Channel Riffle	438	
170	Main Channel Pool	6640	
171	Main Channel Riffle	2726	
172	Main Channel Pool	24670	
173	Main Channel Run	1912	
174	Main Channel Pool	2685	

Mesohabitat Unit #	Mesohabitat Type	Mesohabitat Unit Area (ft^2)	River mile
175	Main Channel Run	3465	
176	Main Channel Riffle	780	
177	Main Channel Pool	5425	
178	Main Channel Run	1197	
179	Main Channel Pool	7734	
180	Main Channel Run	3002	
181	Main Channel Glide	1938	
182	Main Channel Run	1919	
183	Main Channel Riffle	829	
184	Main Channel Glide	2647	
185	Main Channel Riffle	872	
186	Main Channel Run	1347	
187	Main Channel Riffle	1891	
188	Main Channel Pool	7966	
189	Main Channel Run	2126	
190	Main Channel Riffle	2709	
191	Main Channel Glide	1356	
192	Main Channel Pool	21957	
193	Main Channel Run	1637	
194	Main Channel Riffle	905	
195	Main Channel Pool	2721	
196	Main Channel Riffle	542	
197	Side Channel Pool	366	
198	Side Channel Riffle	523	
199	Side Channel Pool	2163	
200	Side Channel Run	900	
201	Side Channel Riffle	772	
202	Main Channel Pool	11868	
203	Main Channel Riffle	1318	
204	Side Channel Pool	354	
205	Side Channel Riffle	137	
206	Main Channel Pool	14970	
207	Main Channel Riffle	397	
208	Main Channel Run	3751	
209	Main Channel Riffle	795	
210	Main Channel Pool	15786	
211	Main Channel Riffle	9867	
212	Side Channel Riffle	397	
213	Side Channel Glide	355	
214	Main Channel Run	1561	
215	Side Channel Pool	5214	
216	Main Channel Riffle	2511	
217	Side Channel Riffle	666	
218	Main Channel Pool	13522	

Mesohabitat Unit #	Mesohabitat Type	Mesohabitat Unit Area (ft^2)	River mile
219	Main Channel Riffle	2514	
220	Main Channel Run	20053	
221	Main Channel Run	1201	
222	Main Channel Riffle	957	
223	Side Channel Pool	4089	
224	Side Channel Riffle	378	
225	Main Channel Pool	16997	3
226	Main Channel Riffle	1549	
227	Main Channel Riffle	1122	
228	Main Channel Pool	9608	
229	Main Channel Run	1786	
230	Main Channel Riffle	657	
231	Main Channel Pool	9435	
232	Main Channel Riffle	1480	
233	Main Channel Run	6205	
234	Main Channel Pool	2419	
235	Main Channel Riffle	3935	
236	Main Channel Pool	17701	
237	Main Channel Riffle	272	
238	Main Channel Run	759	
239	Main Channel Riffle	703	
240	Side Channel Pool	3305	
241	Side Channel Riffle	895	
242	Main Channel Run	1344	
243	Main Channel Pool	16028	
244	Main Channel Riffle	451	
245	Main Channel Run	5875	
246	Main Channel Glide	4937	
247	Main Channel Riffle	1322	
248	Main Channel Glide	1461	
249	Main Channel Riffle	1328	
250	Main Channel Glide	2635	
251	Main Channel Run	671	
252	Main Channel Riffle	921	
253	Main Channel Run	4401	
254	Main Channel Glide	1405	
255	Main Channel Run	3542	
256	Main Channel Riffle	2594	
257	Main Channel Pool	18152	
258	Main Channel Riffle	669	
259	Main Channel Run	648	
260	Main Channel Pool	733	
261	Main Channel Riffle	1605	
262	Main Channel Pool	2746	

Mesohabitat Unit #	Mesohabitat Type	Mesohabitat Unit Area (ft^2)	River mile
263	Side Channel Riffle	111	
264	Side Channel Pool	304	
265	Side Channel Riffle	963	
266	Main Channel Riffle	1689	
267	Main Channel Glide	1734	
268	Main Channel Pool	11120	
269	Main Channel Pool	6401	
270	Main Channel Riffle	7039	
271	Side Channel Pool	2415	
272	Side Channel Riffle	635	
273	Side Channel Pool	4627	
274	Main Channel Pool	17276	
275	Main Channel Run	1624	
276	Main Channel Riffle	675	
277	Main Channel Run	1776	
278	Main Channel Riffle	388	
279	Main Channel Pool	900	
280	Main Channel Run	1746	
281	Main Channel Pool	10384	
282	Main Channel Run	2850	
283	Main Channel Riffle	1816	
284	Side Channel Pool	988	
285	Side Channel Riffle	490	
286	Main Channel Pool	11726	
287	Main Channel Run	2628	4
288	Main Channel Riffle	1983	
289	Main Channel Glide	2656	
290	Main Channel Run	988	
291	Main Channel Glide	779	
292	Main Channel Pool	7343	
293	Main Channel Run	274	
294	Main Channel Riffle	988	
295	Main Channel Pool	5267	
296	Main Channel Riffle	908	
297	Main Channel Run	804	
298	Side Channel Pool	932	
299	Side Channel Riffle	39	
300	Main Channel Pool	3613	
301	Main Channel Riffle	1084	
302	Main Channel Pool	13033	
303	Main Channel Riffle	1395	
304	Main Channel Run	1659	
305	Side Channel Run	573	
306	Side Channel Riffle	437	

Mesohabitat Unit #	Mesohabitat Type	Mesohabitat Unit Area (ft^2)	River mile
307	Side Channel Pool	182	
308	Side Channel Run	547	
309	Side Channel Riffle	248	
310	Main Channel Pool	3330	
311	Main Channel Riffle	1974	
312	Main Channel Run	1285	
313	Main Channel Riffle	1238	
314	Main Channel Pool	551	
315	Side Channel Pool	1122	
316	Side Channel Riffle	142	
317	Main Channel Pool	10860	
318	Main Channel Riffle	2393	
319	Main Channel Run	2448	
320	Main Channel Riffle	3196	
321	Main Channel Pool	4240	
322	Main Channel Run	1382	
323	Main Channel Riffle	3443	
324	Main Channel Glide	6822	
325	Side Channel Pool	2832	
326	Main Channel Pool	17246	
327	Main Channel Run	992	
328	Main Channel Riffle	2301	
329	Main Channel Pool	18850	
330	Main Channel Run	1827	
331	Side Channel Riffle	420	
332	Main Channel Riffle	676	
333	Main Channel Run	414	
334	Main Channel Riffle	2048	
335	Main Channel Glide	1614	
336	Main Channel Run	3814	
337	Main Channel Riffle	3362	
338	Main Channel Glide	3796	
339	Main Channel Run	1508	
340	Main Channel Pool	11093	
341	Main Channel Riffle	570	
342	Main Channel Run	1571	
343	Main Channel Riffle	229	
344	Main Channel Pool	6961	
345	Main Channel Riffle	1104	
346	Main Channel Run	759	
347	Main Channel Pool	1510	
348	Side Channel Riffle	184	
349	Side Channel Run	577	
350	Side Channel Pool	1277	

Mesohabitat Unit #	Mesohabitat Type	Mesohabitat Unit Area (ft^2)	River mile
351	Side Channel Riffle	365	
352	Side Channel Pool	2090	
353	Side Channel Run	2172	
354	Main Channel Riffle	1312	
355	Main Channel Pool	2198	
356	Main Channel Run	237	
357	Main Channel Glide	1610	
358	Main Channel Run	1035	
359	Main Channel Riffle	250	
360	Side Channel Riffle	180	
361	Main Channel Glide	2575	
362	Main Channel Run	1326	
363	Main Channel Riffle	863	5
364	Main Channel Run	1254	
365	Main Channel Riffle	591	
366	Main Channel Run	3475	
367	Main Channel Riffle	600	
368	Main Channel Run	5693	
369	Main Channel Glide	15587	
370	Main Channel Riffle	1005	
371	Main Channel Run	2015	
372	Main Channel Riffle	894	
373	Main Channel Run	1999	
374	Main Channel Glide	3201	
375	Main Channel Run	2725	
376	Main Channel Riffle	431	
377	Side Channel Riffle	215	
378	Side Channel Pool	770	
379	Main Channel Run	4831	
380	Main Channel Glide	5297	
381	Main Channel Riffle	5883	
382	Side Channel Pool	1009	
383	Side Channel Riffle	314	
384	Main Channel Run	11181	
385	Main Channel Riffle	25104	
386	Side Channel Pool	1631	
387	Side Channel Run	1854	
388	Side Channel Riffle	746	
389	Side Channel Pool	2501	
390	Side Channel Riffle	2431	
391	Main Channel Pool	13141	
392	Main Channel Glide	3876	
393	Main Channel Run	2803	
394	Main Channel Riffle	726	

Mesohabitat Unit #	Mesohabitat Type	Mesohabitat Unit Area (ft^2)	River mile
395	Main Channel Glide	2157	
396	Main Channel Riffle	1952	
397	Main Channel Riffle	3161	
398	Side Channel Run	6681	
399	Main Channel Glide	18464	
400	Main Channel Run	3455	
401	Main Channel Riffle	6372	
402	Main Channel Pool	5087	
403	Main Channel Riffle	6437	
404	Main Channel Pool	7309	
405	Main Channel Riffle	12658	
406	Main Channel Glide	6717	
406	Main Channel Pool	10639	
407	Main Channel Riffle	7187	6
408	Main Channel Run	3744	
409	Main Channel Riffle	7373	
410	Main Channel Run	5908	
411	Main Channel Riffle	4413	
412	Main Channel Glide	1790	
413	Main Channel Pool	4277	
414	Main Channel Riffle	968	
415	Main Channel Run	3050	
416	Main Channel Riffle	1859	
417	Main Channel Pool	9389	
418	Main Channel Riffle	2183	
419	Main Channel Pool	6124	
420	Side Channel Riffle	282	
421	Main Channel Riffle	1957	
422	Main Channel Run	3451	
423	Main Channel Riffle	3020	
424	Side Channel Riffle	3053	
425	Main Channel Run	3384	
426	Main Channel Pool	3680	
427	Main Channel Run	1911	
428	Main Channel Riffle	1639	
429	Main Channel Pool	5005	
430	Main Channel Run	3670	
431	Main Channel Riffle	1913	
432	Main Channel Pool	10968	
433	Main Channel Riffle	7865	
434	Side Channel Pool	428	
435	Side Channel Riffle	106	
436	Main Channel Pool	4798	
437	Main Channel Riffle	4698	

Mesohabitat Unit #	Mesohabitat Type	Mesohabitat Unit Area (ft^2)	River mile
438	Main Channel Run	1413	
439	Main Channel Riffle	5403	
440	Main Channel Pool	7823	
441	Main Channel Run	2041	
442	Main Channel Riffle	2890	
443	Main Channel Pool	2677	
438	Main Channel Run	1413	
439	Main Channel Riffle	5403	
440	Main Channel Pool	7823	
441	Main Channel Run	2041	
442	Main Channel Riffle	2890	6.79
443	Main Channel Pool	2677	Valley Floor
444	Main Channel Riffle	768	Tetrick
445	Main Channel Run	717	
446	Main Channel Riffle	2114	
447	Main Channel Run	2384	
448	Main Channel Glide	798	
449	Main Channel Run	1026	
450	Main Channel Pool	4231	
451	Main Channel Run	1576	
452	Main Channel Pool	1042	
453	Main Channel Run	1774	
454	Main Channel Riffle	5172	
455	Main Channel Pool	1631	
456	Main Channel Run	1226	
457	Main Channel Riffle	358	7
458	Main Channel Run	3363	
459	Cascade	800	
460	Main Channel Run	2781	
461	Main Channel Riffle	3042	
462	Main Channel Pool	807	
463	Main Channel Run	509	
464	Main Channel Riffle	1010	
465	Main Channel Run	908	
466	Main Channel Riffle	153	
467	Main Channel Run	896	
468	Main Channel Riffle	2527	
469	Main Channel Run	935	
470	Main Channel Riffle	287	
471	Main Channel Pool	450	
472	Side Channel Riffle	990	
473	Side Channel Pool	642	
474	Side Channel Riffle	576	
475	Main Channel Riffle	117	

Mesohabitat Unit #	Mesohabitat Type	Mesohabitat Unit Area (ft^2)	River mile
476	Cascade	80	
477	Main Channel Pool	999	
478	Main Channel Pool	1366	
479	Main Channel Run	901	
480	Main Channel Pool	1623	
481	Cascade	101	
482	Main Channel Pool	743	
483	Main Channel Riffle	296	
484	Main Channel Run	591	
485	Main Channel Pool	583	
486	Main Channel Riffle	1829	
487	Main Channel Pool	929	
488	Main Channel Riffle	1670	
489	Side Channel Riffle	823	
490	Side Channel Run	174	
491	Main Channel Pool	743	
492	Cascade	166	
493	Main Channel Pool	536	
494	Main Channel Riffle	1588	
495	Side Channel Pool	429	
496	Main Channel Pool	377	
497	Main Channel Riffle	77	
498	Main Channel Pool	564	
499	Main Channel Riffle	73	
500	Main Channel Pool	468	
501	Side Channel Riffle	73	
502	Side Channel Pool	186	
503	Cascade	76	
504	Main Channel Pool	510	
505	Cascade	259	
506	Main Channel Pool	663	
507	Main Channel Riffle	3060	
508	Main Channel Pool	537	
509	Cascade	437	
510	Main Channel Riffle	201	
511	Cascade	177	
512	Main Channel Riffle	145	
513	Cascade	356	
514	Main Channel Pool	1349	
515	Main Channel Pool	284	
516	Main Channel Pool	1372	
517	Main Channel Riffle	856	
518	Cascade	163	
519	Main Channel Pool	121	

Mesohabitat Unit #	Mesohabitat Type	Mesohabitat Unit Area (ft^2)	River mile
520	Main Channel Run	170	
521	Main Channel Riffle	359	
522	Cascade	238	
523	Cascade	267	
524	Main Channel Pool	302	
525	Main Channel Riffle	100	
526	Main Channel Pool	111	
527	Main Channel Pool	176	
528	Main Channel Riffle	96	
529	Cascade	101	
530	Main Channel Pool	323	
531	Main Channel Pool	200	
532	Main Channel Pool	560	
533	Cascade	448	
534	Main Channel Run	273	
535	Main Channel Riffle	682	
536	Main Channel Run	708	
537	Main Channel Glide	896	
538	Main Channel Run	975	
539	Main Channel Riffle	287	
540	Cascade	168	
541	Main Channel Pool	353	
542	Main Channel Riffle	182	
543	Main Channel Pool	174	
544	Main Channel Riffle	692	
545	Cascade	290	
546	Main Channel Run	503	
547	Cascade	105	
548	Main Channel Run	771	
549	Cascade	109	
550	Main Channel Riffle	406	
551	Main Channel Run	190	
552	Main Channel Pool	267	
553	Main Channel Riffle	838	7.36

Shapefiles for the above mesohabitat units are available in electronic format upon request from:

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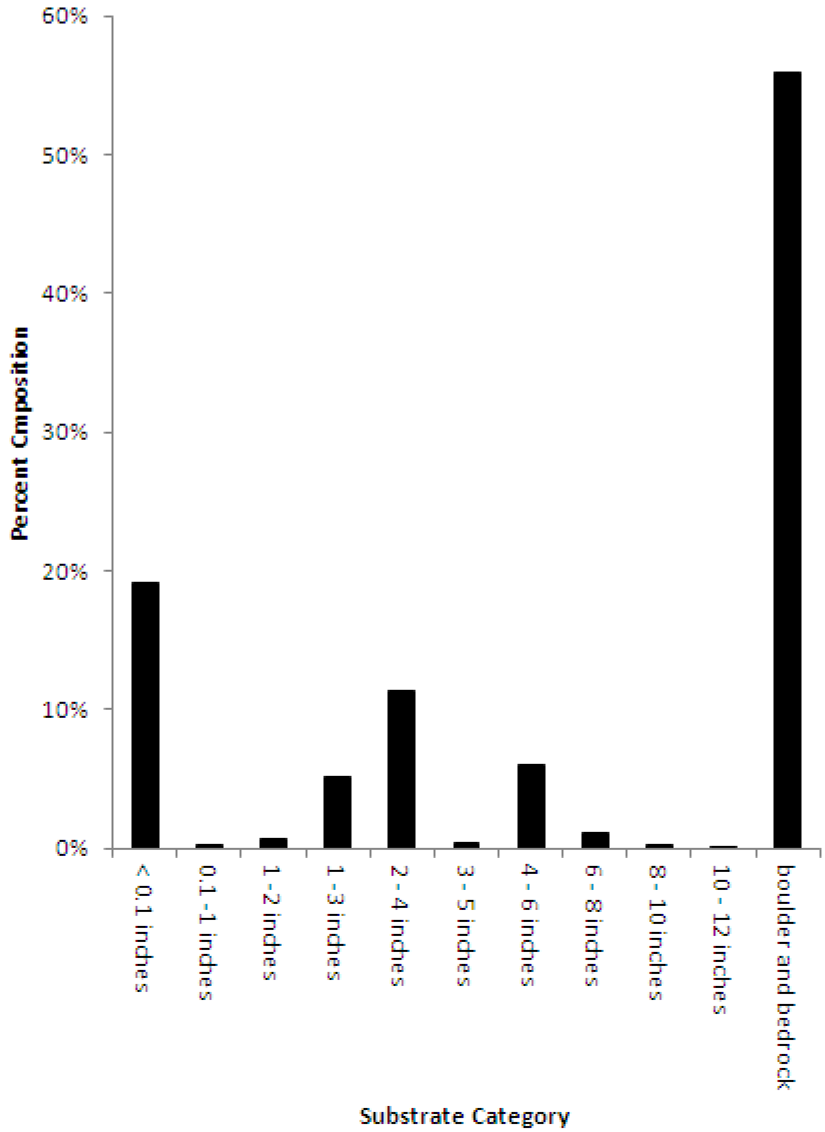
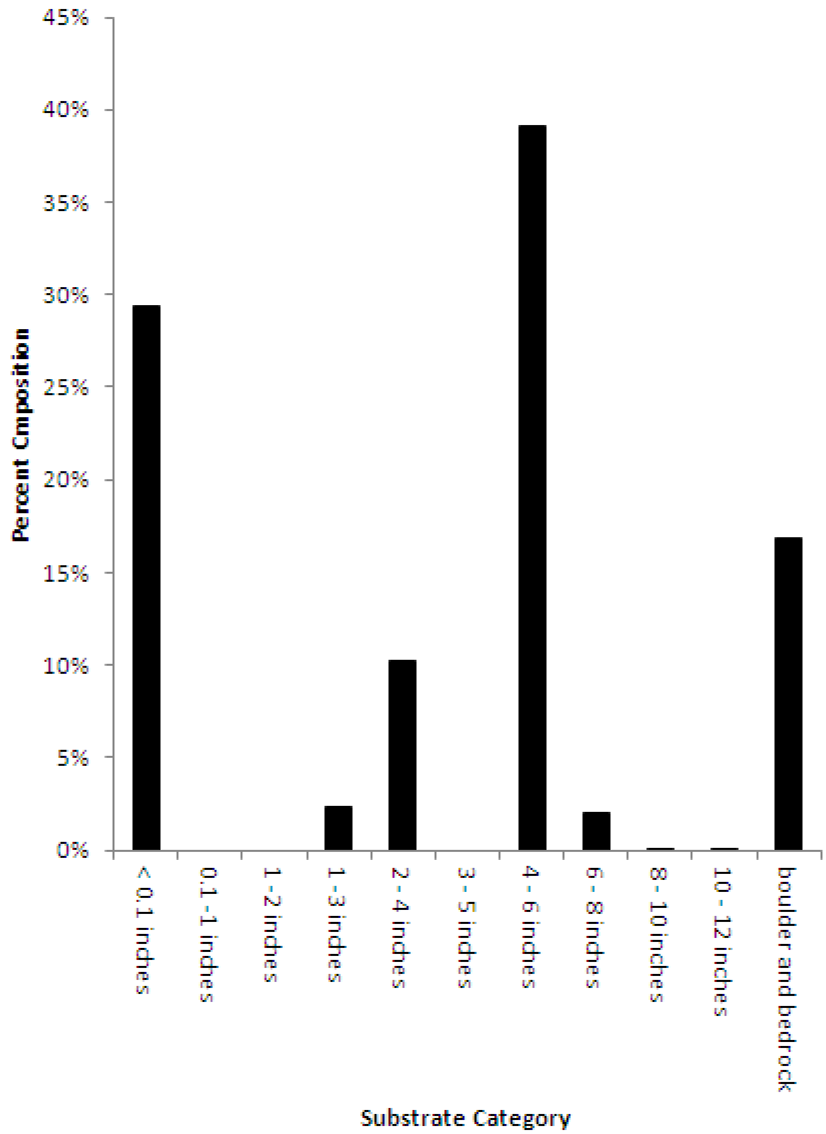
Restoration and Monitoring Program
U.S. Fish and Wildlife Service
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, CA 95825
Mark_Gard@fws.gov

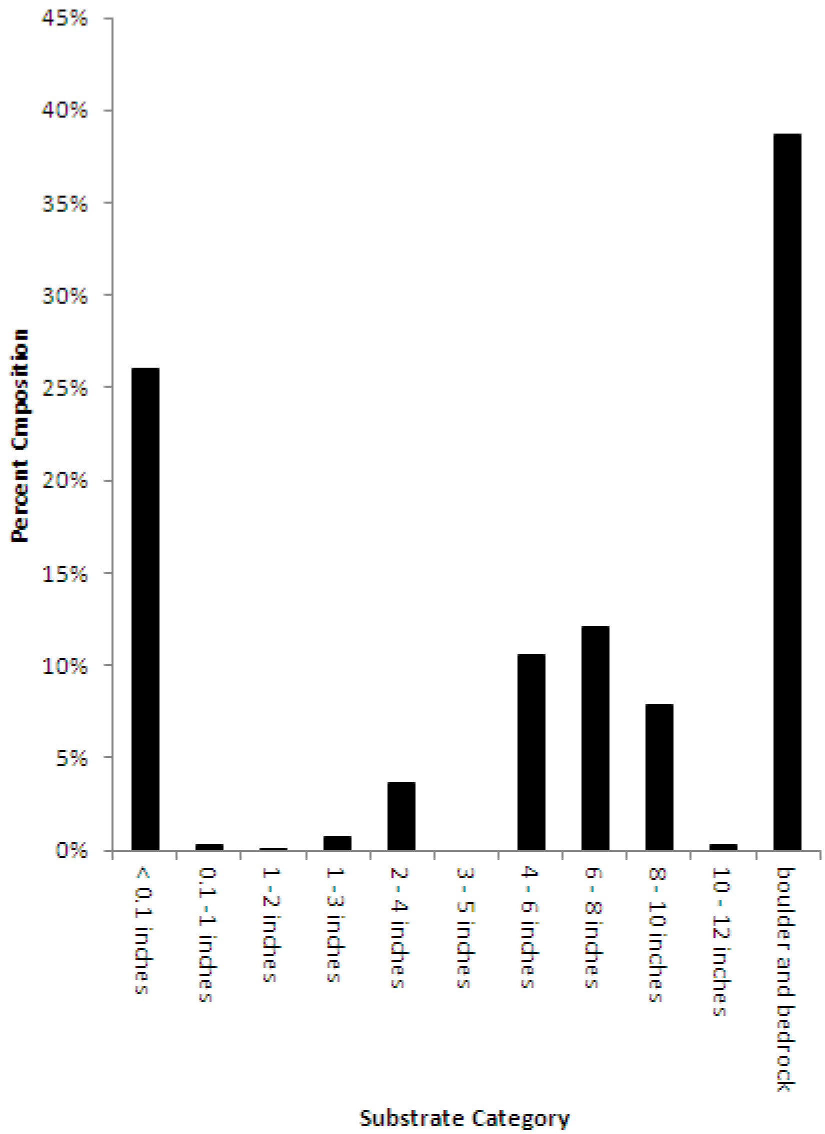
APPENDIX B
SUBSTRATE DISTRIBUTION DATA IN STUDY SITES



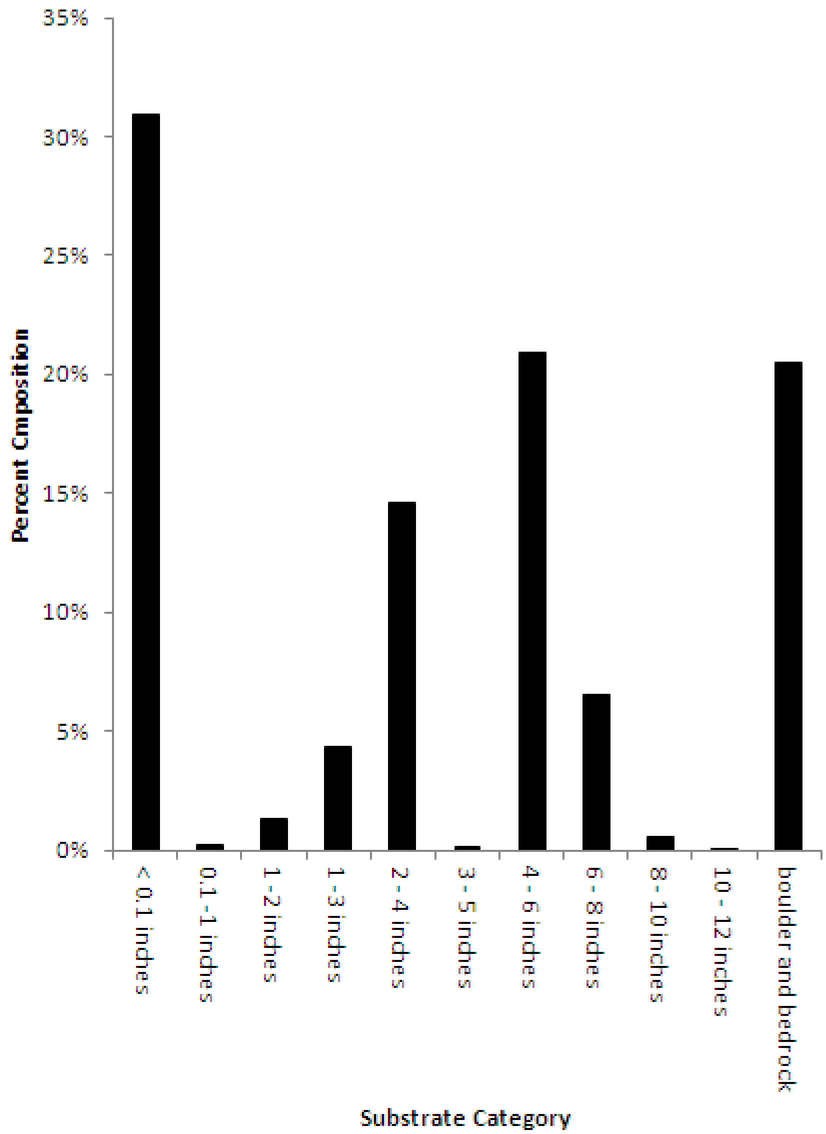
Boero Site Substrate Distribution



Farrell Site Substrate Distribution



Jones Site Substrate Distribution



Poole Site Substrate Distribution