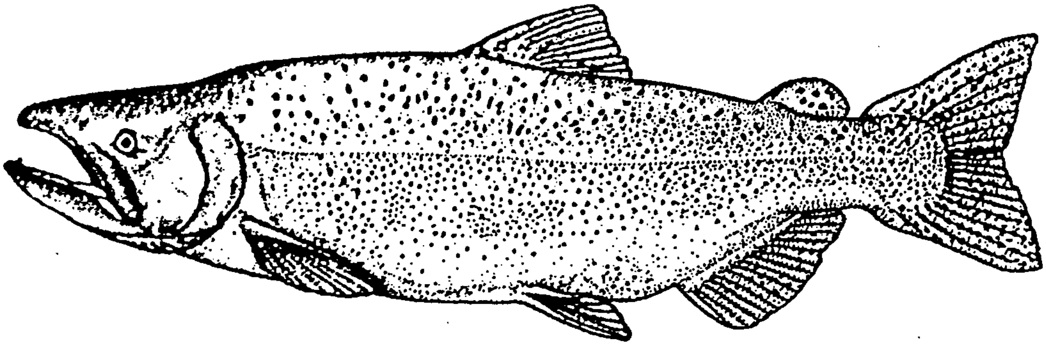
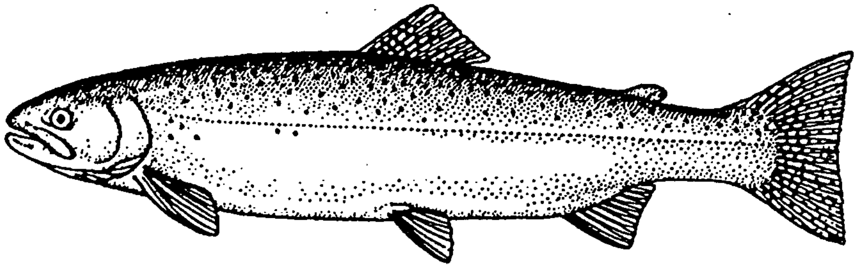
IDENTIFICATION OF THE INSTREAM FLOW REQUIREMENTS FOR STEELHEAD AND FALL-RUN CHINOOK SALMON SPAWNING IN THE LOWER AMERICAN RIVER





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The Instream Flow Assessments Branch

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PREFACE

The following is the final report for the U.S. Fish and Wildlife Service's investigations on the Lower American River, part of the Anadromous Doubling Plan Instream Flow Investigations, a 5-year effort which began in February, 1995. Title 34, Section 3406(b)(1)(B) of the Central Valley Project Improvement Act, P.L. 102-575, requires the Secretary of the Interior to determine instream flow needs for anadromous fish for all Central Valley Project controlled streams and rivers, based on recommendations of the U.S. Fish and Wildlife Service after consultation with the California Department of Fish and Game (CDFG). The purpose of these investigations is to provide reliable scientific information to the U.S. Fish and Wildlife Service Central Valley Anadromous Fish Restoration Program to be used to develop such recommendations for Central Valley rivers.

To those who are interested, comments and information regarding this report are welcomed. Written comments or information can be submitted to:

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The field work for this study was conducted by Jeff Thomas, Mark Gard, Sean Gallagher, Rick Williams, Paul Zedonis and Ken Bovee. Data analysis and report preparation were performed by Mark Gard and Jeff Thomas. Technical assistance on the hydraulic modeling was provided by Terry Waddle.

ANADROMOUS DOUBLING PLAN INSTREAM FLOW INVESTIGATIONS LOWER AMERICAN RIVER STEELHEAD AND FALL-RUN CHINOOK SPAWNING

I. INTRODUCTION

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act requires the doubling of the natural production of anadromous fish stocks, including the four races of chinook salmon (fall, late-fall, winter and spring runs), steelhead, and white and green sturgeon. For the Lower American River, the Central Valley Project Improvement Act Anadromous Doubling Plan calls for October through February (during fall-run chinook salmon spawning) flows at the H Street Bridge ranging from 1,750 cfs in critically dry years to 2,500 cfs in wet years. In December 1994, the U.S. Fish and Wildlife Service prepared a study proposal to identify the instream flow requirements for anadromous fish in certain streams within the Central Valley of California, including the Lower American River. The purpose of the Lower American River study was to produce a habitat model predicting physical habitat availability over a range of streamflows for spawning fall-run chinook salmon and steelhead trout. The Physical Habitat Simulation (PHABSIM) component of the Instream Flow Incremental Methodology (IFIM) was used in this modeling effort. The results of this study are intended to supplement data which has been collected by CDFG for several years to produce comprehensive instream flow recommendations. These results will be submitted to them for enclosure in their final report on the Lower American River.

II. METHODS

Field Techniques

Staff met in February 1995 with representatives from CDFG to review aerial redd survey photographs, redd count data, and habitat maps which they had collected over the last four years. From this information, ten study sites (Table 1) were selected for collection of hydraulic data to construct the necessary hydraulic models. These study sites were some of the areas which had been used most extensively for spawning by fall-run chinook salmon based on CDFG data. Shortly thereafter the river was reconnoitered at a streamflow of approximately 6000 cfs to assess study logistics (i.e., access points, property ownership, recreational use, study site boundaries, possible surveying complications). In March, two transects were placed in each site (Appendix A) to represent the hydraulic conditions present[1]. The transects were placed to go

[1] The only exception was for the Sailor Bar site, where three transects were initially established. However, one of these transects was subsequently discarded because the hydraulics of this transect were too complex to be modeled with the PHABSIM programs. Transects were numbered such that XS1 was always downstream of XS2.

across the portion of the mesohabitat unit which had the heaviest chinook salmon redd concentration in 1993 based on aerial redd survey photographs and ground truthing. Transects were established above the 6000 cfs waters edge on each side of the river using 9 mm diameter rebar driven into the ground or lag bolts placed in tree trunks. Permanent benchmarks, one primary and one secondary, were also established at each site to be used as reference elevations during the course of the study. The primary benchmarks were assigned an elevation of 100.00 feet.

Table 1
Lower American River Sites

Site Name	CDFG Site ID #	Mesohabitat Type	Flows Measured (cfs)[2]
Sailor Bar	5/10	Flatwater Glide/Bar-Complex Run	1000, 4000, 5000, 2500* (xsec 1), 2750* (xsec 2)
Above Sunrise (14)	14	Flatwater Glide	1000, 2500*, 4000, 5000
Above Sunrise (16)	16	Bar-Complex Riffle	115, 497*, 966*, 1367[3]
Above Sunrise (23)	23	Bar-Complex Run	1000, 2500*, 4000, 5000
Sunrise Bridge (26)	26	Bar-Complex Riffle	1000, 2250*, 3000, 4000, 5000
Below Sunrise (29)	29	Flatwater Glide	1000, 2500, 3000*, 4000, 5000 (xsec 2 only)
Below Sunrise (30)	30	Bar-Complex Riffle	1000, 2250, 2750*, 4000, 5000
El Manto	42	Flatwater Glide	1000, 2250, 2750*, 4000, 5000
Rossmoor 2	65	Flatwater Glide	1000, 2250, 2750*, 4000, 5000
Rossmoor 1	66	Bar-Complex Run	1000, 2250, 2750*, 4000, 5000 (xsec 1 only)

Hydraulic and structural data collection on established transects was begun in early April and completed in October for input into the hydraulic and habitat simulation models within PHABSIM using the procedures outlined in Trihey and Wegner, 1981. Lateral cell boundaries

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[2] Flows at which water velocities were measured are indicated by *

[3] These are measured side channel flows corresponding to total Lower American River flows of, respectively, 1000, 2250, 4000 and 5000 cfs.

(measurement verticals) were established across each transect at systematic intervals or where significant differences in bed elevations, water velocity, or substrate composition were observed. At least 20 verticals were established across the wetted width with no more than 10 percent (5 percent in most cases) of total stream discharge passing through any one cell. Data collected at each lateral cell boundary included bed elevation, mean column velocity and substrate classification. Bed elevations for verticals on dry land were surveyed to the nearest 0.1 foot by differential leveling with reference to the primary benchmark elevation. Water surface elevations (WSELs), also referenced to the primary benchmark, were surveyed to the nearest 0.01 foot. Bed elevations for verticals in the water were calculated by subtracting the measured water depth from the water surface elevation. For wadeable verticals, depths were measured to the nearest 0.1 foot with a top-setting wading rod. For unwadeable verticals, depths were measured with a bomb and cable assembly mounted on a jet boat. Mean water column velocities at each vertical were measured at 0.6 of the total depth using a Price AA water velocity meter, attached to either the wading rod or the bomb, equipped with a Current Meter Digitizer.

The horizontal distances of measurement verticals from the transect headpin were measured to the nearest foot using a tape or a Leitz/Sokkisha model SDM3FR total station. For short distances near the headpin bank, a field technician positioned on the transect line by the data recorder stretched and held a tape tied at 0.0 feet to the headpin. For longer distances where the tape became difficult to manage, the technician held a prism for signal reflection back to the total station which was positioned over the headpin. When wading became impossible, the prism was mounted on the bow of the boat and the surveyor instructed the boat operator through constant radio contact as to his position on the transect line, the boat was held in place while data were taken, and the measured distance was recorded. This methodology was developed to address two problems frequently encountered when taking measurements on large rivers: 1) the width of the river greatly exceeded the length of available tapes (300 feet), and; 2) stretching steel or kevlar cable across the river, as is often done, was inherently unsafe given the heavy recreational raft traffic.

WSELs were measured at all transects on April 5 and 6, 1995 at a river discharge of 5000 cfs[4]. River flows remained at this level or higher until July 17 when Folsom Dam spillway gate #3 failed and flows increased from 6500 cfs to 42,000 cfs in four hours, then slowly declined to about 12,000 cfs a week later. Data collection resumed in mid-August after flows had stabilized at just above 2000 cfs. Specifically, WSELs were collected on August 17 and 18 at 2250 cfs, on August 28 and 29 and October 19 at 2500 cfs, on August 30 and 31 at 2750 cfs, on September 1

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[4] Transect 2 for Rossmoor 1 and Transect 1 for Below Sunrise (29) were moved after April because it was apparent at lower flows that they were not representative of the mesohabitat unit. Thus water surface elevations are not available for these two transects at 5000 cfs. All 5000 cfs measurements were subsequently excluded from the modelling for reasons discussed in the next section of this report (Hydraulic Model Construction and Calibration).

at 3000 cfs, on September 19 at 4000 cfs, and on October 10 at 1000 cfs (see Table 1 for flows at which data were taken for each transect). Depths and velocities were measured once for all transects from August 17 through September 1 at streamflows between 2250 and 3000 cfs. Velocities were also measured on the transects at the Above Sunrise (16) study site on September 19 at a discharge of 4000 cfs. This site was located in a side-channel; therefore, two additional discharge measurements (at 1000 and 5000 cfs) were made to develop an empirical relationship between side-channel and main-channel discharge. The dominant substrate particle size was described according to a modified Brusven index (Table 2) and recorded at the same time as velocities were measured for all transects.

Table 2
Substrate Descriptors and Codes

Code	Type	Particle Size (inches)
0	Sand/Silt	< 0.1
1	Small Gravel	0.1 - 1
1.2	Medium Gravel	1 - 2
2.3	Large Gravel	2 - 3
2.4	Gravel/Cobble	2 - 4
3.4	Cobble	3 - 4
3.5	Cobble	3 - 5
4.5	Cobble	4 - 5
4.6	Cobble	4 - 6
6.8	Cobble	6 - 8
8	Cobble	8 - 12
9	Boulder	12 - 24
10	Boulder	> 24
11	Bedrock	

Hydraulic Model Construction and Calibration

All data were compiled and checked before entry into PHABSIM data decks. A separate deck was constructed for each study site. The completed decks were then carefully examined using the *CKI4* program to insure no data entry errors had occurred. The stage of zero flow (SZF), an important parameter in calibrating the stage-discharge relationship, was determined for each transect and entered. In habitat types with no backwater effects present (e.g., riffles and runs), this value generally represents the lowest point in the streambed across that transect. However, if a transect directly upstream contains a lower bed elevation than the adjacent downstream transect, the SZF for the downstream transect applies to both.

The first step in the calibration procedure was to determine the best approach for WSEL simulation. Initially, the *IFG4* hydraulic model (Milhous *et al.*, 1989) was run on each deck to compare predicted WSELs with those that had been measured. This model produces a stage-discharge relationship using a log-log linear rating curve calculated from at least three sets of measurements taken at different flows. The results of these runs showed differences in the measured versus predicted WSELs which were unacceptable on virtually every transect. Differences of 0.1 foot were not uncommon with even greater differences in the 5000 cfs WSELs. An iterative process was begun wherein different combinations of the four-to-five measurements taken on each transect were tried to reduce these errors. The results were unusual and unexpected. On all but two transects (Sailor Bar XS1 and Above Sunrise (23) XS1), discarding the 5000 cfs calibration measurement produced a good log-log stage-discharge relationship up to 4000 cfs, but the predicted WSELs at 5000 cfs were consistently a quarter to a third of a foot lower than those measured. This consistent trend indicated a possible systematic surveying error resulting in all of the 5000 cfs WSEL measurements being too high by this increment. Examination of the velocity adjustment factors (VAFs) confirmed that, when the 5000 cfs measurements were used in developing the rating curve, WSELs at high flows were being overpredicted. VAFs typically increase monotonically with increasing flows as higher flows produce higher water velocities. These VAFs, by contrast, showed a consistently decreasing pattern. The model, in mass balancing, was obviously decreasing water velocities at high flows so that the known discharge would pass through the increased cross-sectional area.

Surveying error was subsequently rejected as a possibility for the apparent incorrect measurements at 5000 cfs. The experienced field crew which made the measurements would not have made so many mistakes of such magnitude, and with such consistency. The study sites were independent of one another, each with an independent primary benchmark and a secondary benchmark tied to the primary for confirming elevations on each site visit. This precluded the possibility that a single, significant surveying error could be carried from site to site. Also excluded from consideration was the possibility that the river discharge recorded for the measurements was in error. The 5000 cfs Nimbus Dam release was confirmed with a discharge measurement taken at the furthest downstream site (Rossmoor 1).

Further investigation revealed two other possible cases for the errant relationships. The first was channel characteristics which form hydraulic controls at some flows but not at others (compound controls), thus affecting upstream water elevations. However, compound controls are unlikely to significantly affect WSELs in the habitat types where study sites were located in this study (riffles and runs) and certainly not at every transect. The final possible explanation was changes in channel morphology due to the sudden high flows in late July when the spillway gate failed. In fact, CDFG personnel did notice substantial changes in channel morphology in some locations following this event (Kris Vyverberg, personal communication). Since only the 5000 cfs measurements had been taken prior to this, it was decided that this data should not be used. The river did not reach flow levels of 5000 cfs or greater again in 1995 leaving 4000 cfs as the highest flow at which WSEL data were collected and used in modeling.

All of the WSEL measurements taken from 1000 to 4000 cfs main channel discharge were used to produce the stage-discharge relationship at each transect for WSEL simulation (Appendix B). Besides *IFG4*, two other hydraulic models are available within PHABSIM to predict the stage-discharge relationship, enabling the modeler to predict water depths for flows at which WSELs were not measured. These models are: 1) *MANSQ*, which operates under the assumption that the condition of the channel and the nature of the streambed controls the WSELs; and 2) *WSP*, the water surface profile model, which calculates the energy loss between transects to determine WSELs. *MANSQ*, like *IFG4*, evaluates each transect independently. *WSP* must, by nature, link at least two adjacent transects. *IFG4*, the most versatile of these models, is considered to have worked well if the following standards are met: 1) the beta value (a measure of the change in channel roughness with changes in streamflow) is between 2.0 and 4.5; 2) the mean error in calculated versus given discharges is less than 10%; 3) there is no more than a 25% difference for any calculated versus given discharge; and 4) there is no more than a 0.1 foot difference between measured and simulated WSELs. For most of the transects, *IFG4* met the above standards (Appendix B), the only exceptions being Sailor Bar XS1 and Above Sunrise (23) XS1. Across both of these transects there were large differences in measured WSELs at low flows. For the Above Sunrise (23) XS 1 transect, three measurements of the WSEL across the transect at 1000 cfs were averaged to improve the calibration, but there was still a 0.12 foot difference between the measured and simulated WSEL at 2500 cfs. *WSP* could not be used for this transect because there was no downstream transect and *MANSQ* did not calibrate as well as *IFG4* after repeated attempts. Accordingly, the *IFG4* model was used, even though the last standard above was slightly violated.

Sailor Bar XS1 was successfully modeled by splitting the transect into a left and right channel, on either side of a central bar (the cause of the difference in WSELs across the transect at lower flows). The first step was to add an artificial vertical at the top of the bar with an elevation above the 6000 cfs level; this vertical was offset 0.1 foot horizontally from the actual measured vertical at the top of the bar. For the 2500 cfs flow, where there were velocity measurements across the entire channel, the flow was split by calculating the flow in a spreadsheet for the total channel and each half of the channel; and then adjusting the flow in each half of the channel by an appropriate Velocity Adjustment Factor (VAF), so that the total flow was 2500 cfs. For the other two flows (1000 and 4000 cfs), where there was no measurement of the discharge at the cross-section, the flow was split by: 1) calculating values of Manning's n for each vertical at 2500 cfs, where:

$$n = 1.486\,(S^{.5})(d^{.667})/V$$

S = slope
d = depth at 2500 cfs
V = velocity at 2500 cfs;

2) calculating depths for each half of the channel at 1000 and 4000 cfs using the bed elevations and the measured WSELs in each half of the channel; 3) calculating the velocities at 1000 and 4000 cfs using Manning's equation with the depths at 1000 and 4000 cfs and the N values calculated at 2500 cfs; 4) calculating the flow in each half of the channel and the total flow at 1000 and 4000 cfs; 5) dividing 1000 or 4000 cfs by the total calculated flow to get a VAF; and 6) multiplying the calculated flow in each half of the channel at 1000 and 4000 cfs by the VAF. This is the same method used in *IFG4* to simulate velocities at unmeasured flows. The major assumption of this procedure is that the VAF for each half of the channel is the same at the same total flow. Decks were then set up for each half of the channel with the calculated flows for each half of the channel (Appendix B) and the measured WSELs for each half of the channel. While *IFG4* worked for the right channel, *MANSQ* was required for the left channel to get simulated WSELs within 0.1 foot of measured WSELs.

Log-log regressions were performed to develop relationships between the flow in each half of Sailor Bar XS1 and the total river flow, and between the flow for the Above Sunrise (16) transects (which were located on a side channel) and the total river flow. These regression equations were then used to produce flows for each half of Sailor Bar XS1 and Above Sunrise (16) for each of the river flows to be simulated (1000 to 6000 cfs, by 200 cfs increments).

WSELs were simulated at the flows for which available habitat was to be calculated for all sites. These WSELs were then checked for each site for a breakdown in calibration (i.e., higher WSELs at XS1 than XS2). This occurred for Rossmoor 2 at flows between 5400 and 6000 cfs and at Sailor Bar at flows between 1200 and 2600 cfs, although the magnitude was very small (less than 0.1 foot). This problem was solved by using a *WSP*-type method, where the WSEL values for Rossmoor 2 XS2 for 5400 to 6000 cfs were set equal to the WSEL values for Rossmoor 2 XS1, and the WSEL values for Sailor Bar XS2 at 1200 to 2600 cfs were set equal to the corresponding WSEL values for the right channel of Sailor Bar XS1.

Velocity calibration is the final step in the preparation of the hydraulic models to be used in simulating habitat at unmeasured flows. A single *IFG4* input deck was prepared for all sites except Above Sunrise (16), since this is the only site for which there was still more than one velocity set available. For Above Sunrise (16) two decks were set up, one (a low-flow deck) using the 497 cfs velocity set, and the other (a high-flow deck) using the 966 cfs velocity set. For all decks, VAFs were examined for all of the simulated flows, and velocity statistics were computed for the lowest and highest flows and the flow for which there was a velocity set (Appendix C). Only Sunrise Bridge (26) XS1 deviated from the expected pattern of VAFs, and even this transect did not deviate significantly. In addition, the VAF values (ranging from 0.633 to 1.592) were all within an acceptable range and the velocity statistics were acceptable. Based on the velocity calibration, it was decided that the Above Sunrise (16) low-flow deck should be used to simulate side-channel flows up to 800 cfs, and the high-flow deck should be used to simulate side-channel flows at 600 cfs and greater, with differences between the two decks for side-channel flows of 600-800 cfs resolved at the habitat modeling stage.

Habitat Suitability Curves

Habitat suitability criteria (HSC or HSI Curves) are used within PHABSIM to translate hydraulic and structural elements of rivers into indices of habitat quality (Bovee 1994). A total of seven sets of HSC were used in this study - five for chinook salmon spawning and two for steelhead trout spawning (Figures 1 through 6, Appendix D).

Five of the criteria sets were site-specific criteria developed for fall-run chinook salmon spawning in the Yuba (Beak Consultants Inc. 1990), Feather (California Department of Water Resources 1994) and Upper Sacramento (Gard 1995) Rivers, and for both fall-run chinook salmon and steelhead spawning in the Trinity River (Hampton 1988). The HSC for the Upper Sacramento, Yuba and Feather Rivers would be most likely transferable to the Lower American River since all four rivers are in the Sacramento River Basin and all have flows in the same order of magnitude (annual average flows for the Upper Sacramento, Yuba and Feather Rivers are, respectively, 10,000-12,000 cfs, 2,600 cfs and 4,600 cfs, while the annual average flows for the Lower American River are 3,700 cfs). In contrast, the Trinity River, located in the Klamath River Basin, has an annual average flow of only 470 cfs. The substrate HSC for these curve sets were adapted for use with the data decks for this study (Figures 3 and 6) by translating the substrate size classes used in these criteria to the substrate classes in Table 2. For the Feather River criteria, the depth curve with no decrease in suitability for deep waters was used, and for the Yuba River criteria, the depth curve was modified to have no decrease in suitability for deeper waters. In contrast, the Trinity River depth curves were not modified, so that suitability decreased to zero for deep waters (Figure 2).

The other two sets of criteria (one each for chinook salmon and steelhead trout) were site-specific criteria, developed as follows, using depth and velocity measurements made by CDFG on redds in the Lower American River. Data was available for a total of 118 measurements of fall-run

Figure 1

Fall-run Chinook Salmon HSI Curves

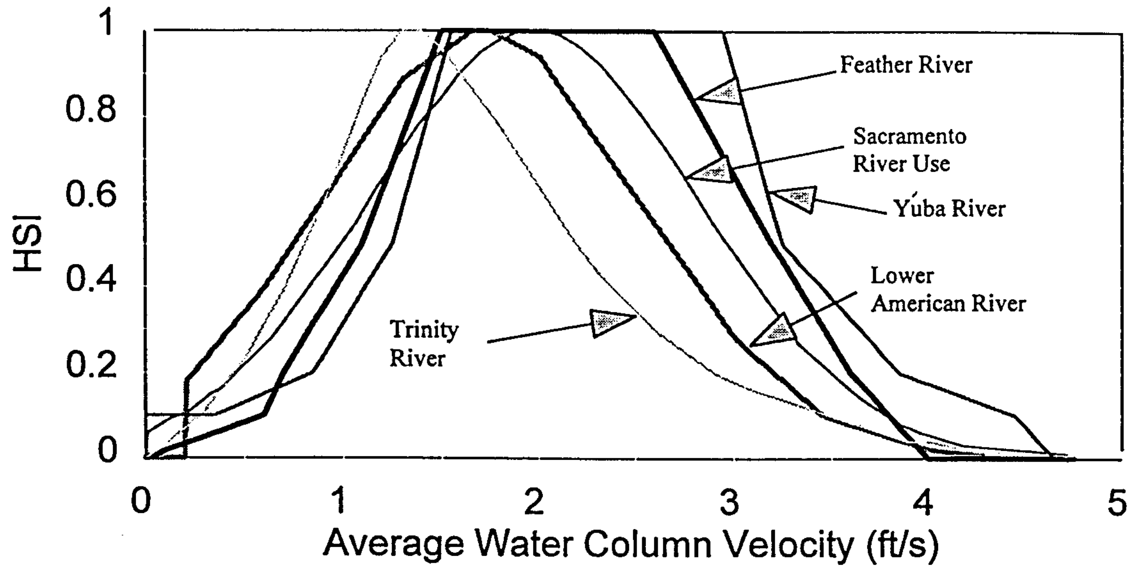


Figure 2

Fall-run Chinook Salmon HSI Curves

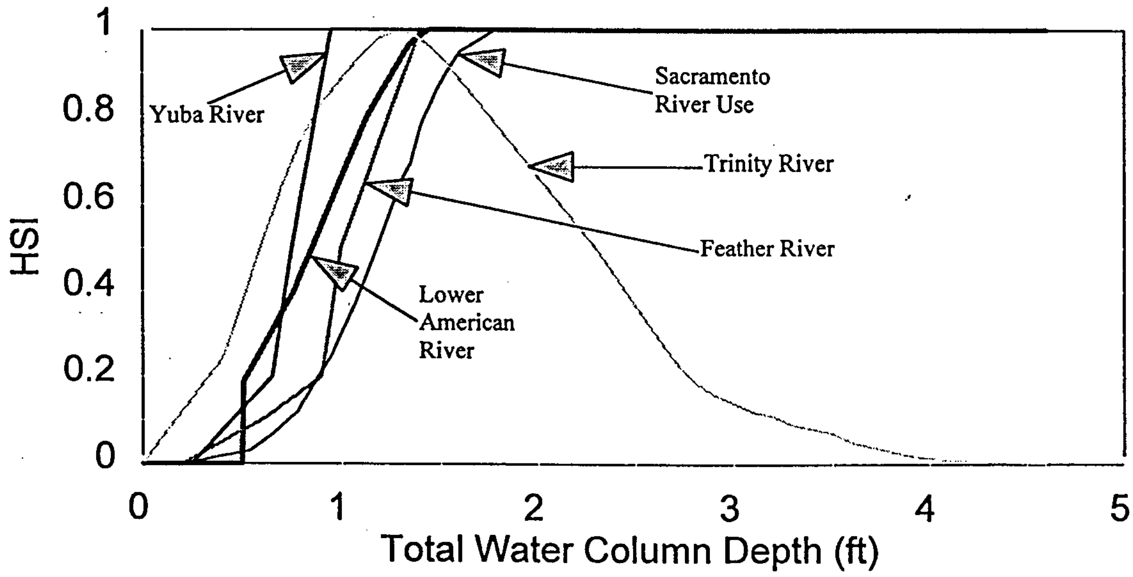


Figure 3

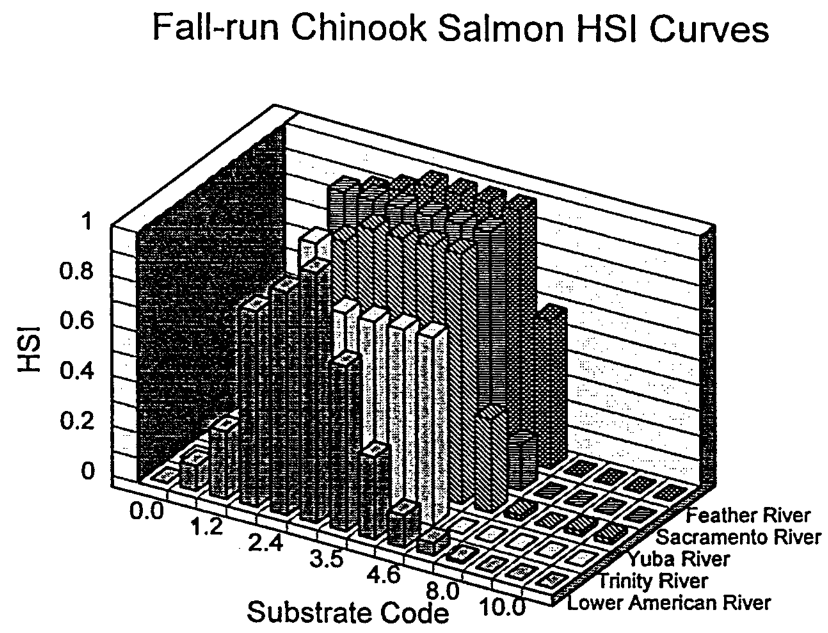


Figure 4

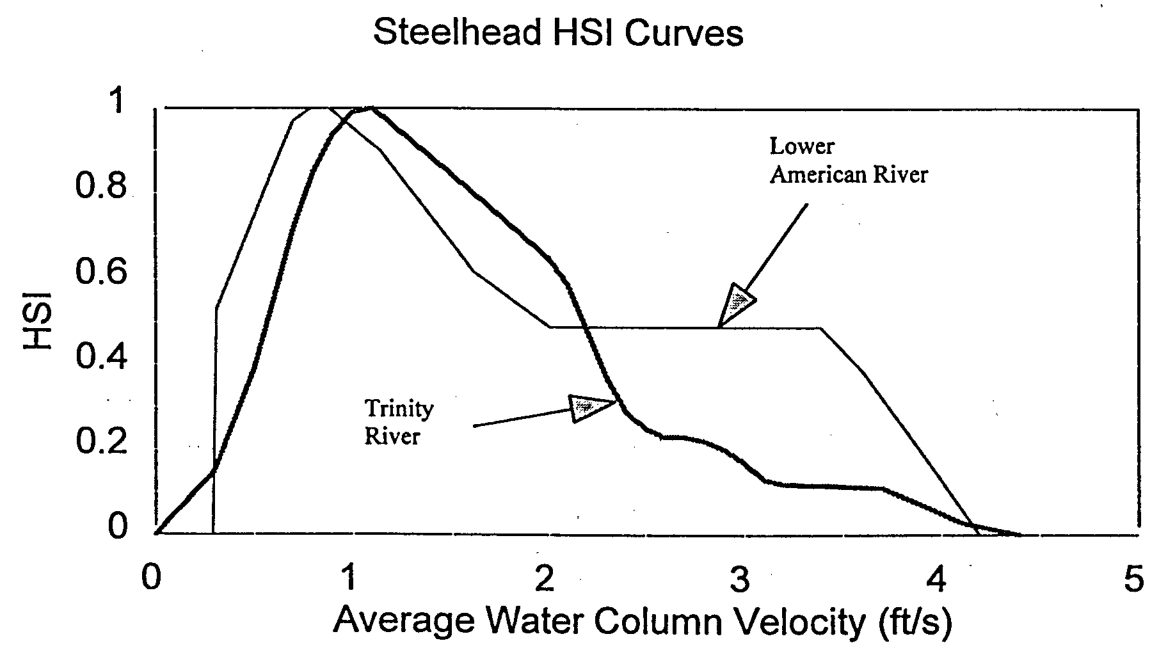


Figure 5

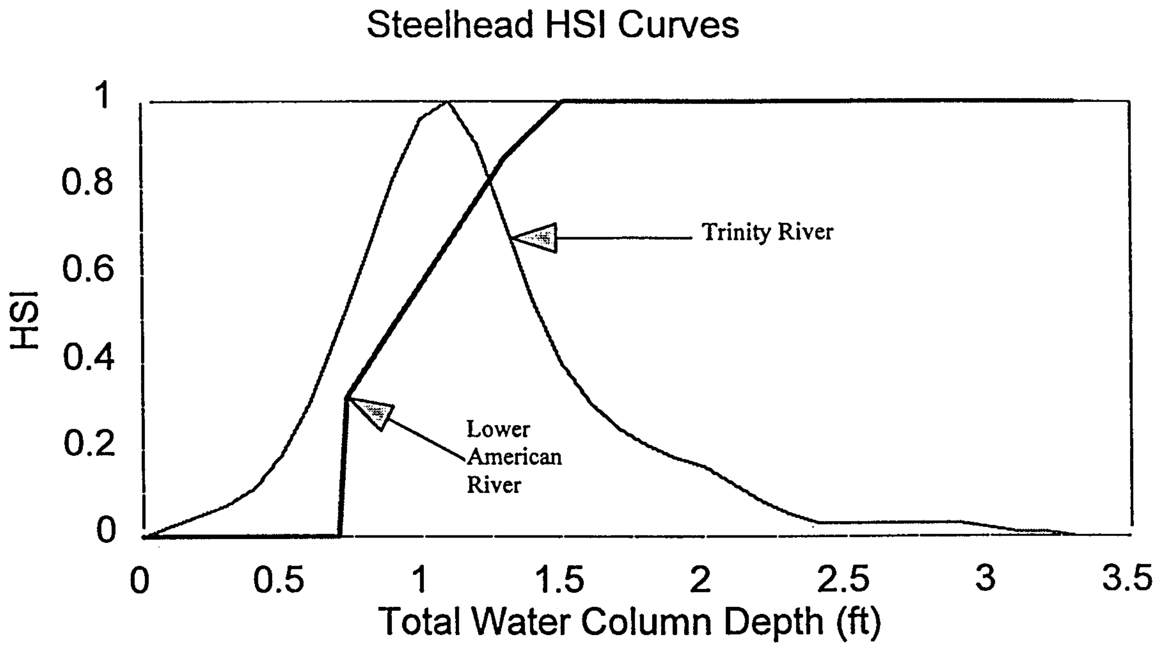
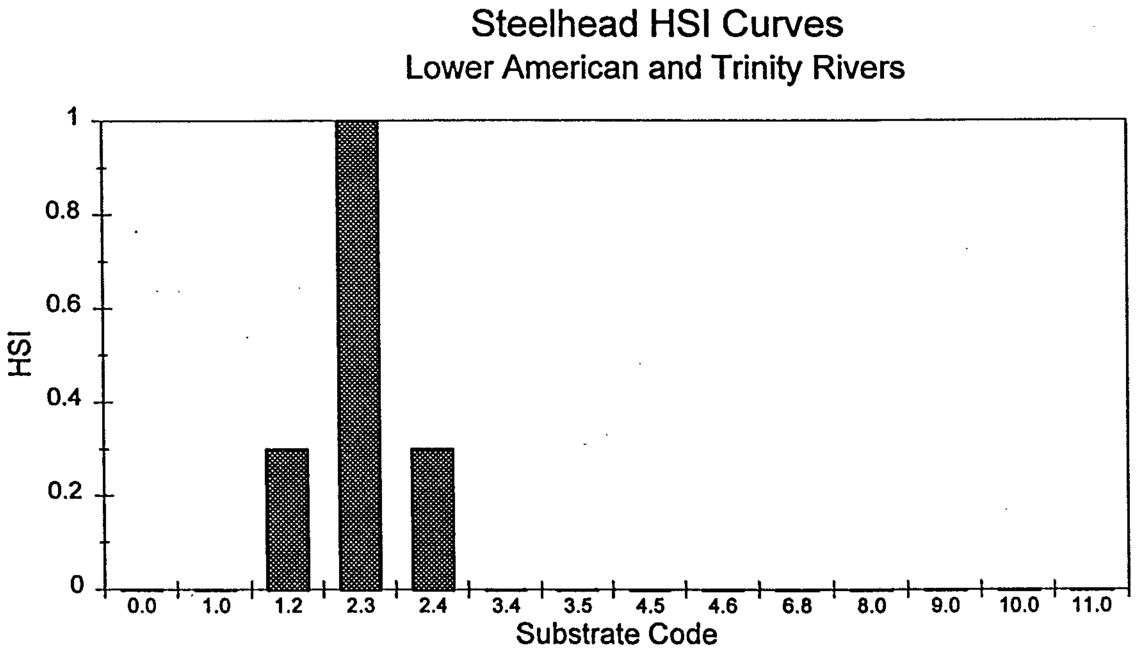


Figure 6



chinook salmon redds and 27 measurements of steelhead redds. Frequency distributions were calculated for depth and velocity for each species in a spreadsheet and input into the PHABSIM suitability index curve development program (CURVE). HSI curves were then computed using exponential smoothing (second order for chinook salmon depth and velocity and for steelhead depth, fourth order for steelhead velocity). The curves generated were exported into a spreadsheet and modified as follows: 1) the curves were truncated at the lower end, so that the lowest observed value had a SI value of zero; 2) velocity curves were extrapolated linearly beyond the highest point generated by CURVE until the HSI value reached zero; 3) the curves were simplified by eliminating all points not needed to capture the basic shape of the curves; and 4) the depth curves were modified to stay at an HSI value of one after the depth where the curve first reached an HSI value of one. The last modification was made because the sampling methodology used by CDFG (wading) restricted the collection of data to redds in relatively shallow water. As a result, the depth curves generated did not represent the actual distribution of depths of redds. For example, the depth curve for chinook salmon spawning reached zero at 2.9 feet, even though CDFG personnel observed chinook salmon redds in water up to 6 feet deep (Kris Vyverberg, CDFG, personal communication). Chinook salmon spawning substrate criteria were developed as follows: 1) the portion of the verticals for the transects which were in areas of high spawning activity were determined based on aerial photos of spawning activity; 2) the number of the verticals determined in step 1 with each substrate type was determined; 3) the numbers from step 2 were treated as frequencies to calculate HSI values for each substrate type. After the initial calculation of HSI values, HSI values for two substrate categories were recalculated to make the HSI values internally consistent, so as to correct for sampling biases. Specifically, the HSI value for substrate type 2.4 was calculated as the average of the HSI values for substrate types 2.3 and 3.4, while the HSI value for substrate type 3.5 was calculated as the average of HSI values for substrate types 3.4 and 4.5. No information was available for substrate for steelhead spawning for the Lower American River. Accordingly, the Trinity River steelhead spawning substrate HSC were also used for the Lower American River steelhead spawning criteria.

Habitat Simulation

The final step in the process was to simulate available habitat for each transect. An input file was created containing the digitized HSC in Appendix E. The HABTAE program was used to compute WUA for each transect over the desired range of flows (1000 to 6000 cfs by 200 cfs increments). For the Upper Sunrise 16 site, a composite WUA curve was developed from the WUA generated in HABTAE using the low-flow and high-flow decks by switching from the low-flow deck to the high-flow deck at the flow where there was the smallest difference in WUA values between the two decks. The flow at which we switched from the low-flow to the high-flow deck was different for different criteria sets.

III. RESULTS

The WUA values calculated for each transect and criteria set are contained in Appendix E.

IV. REFERENCES

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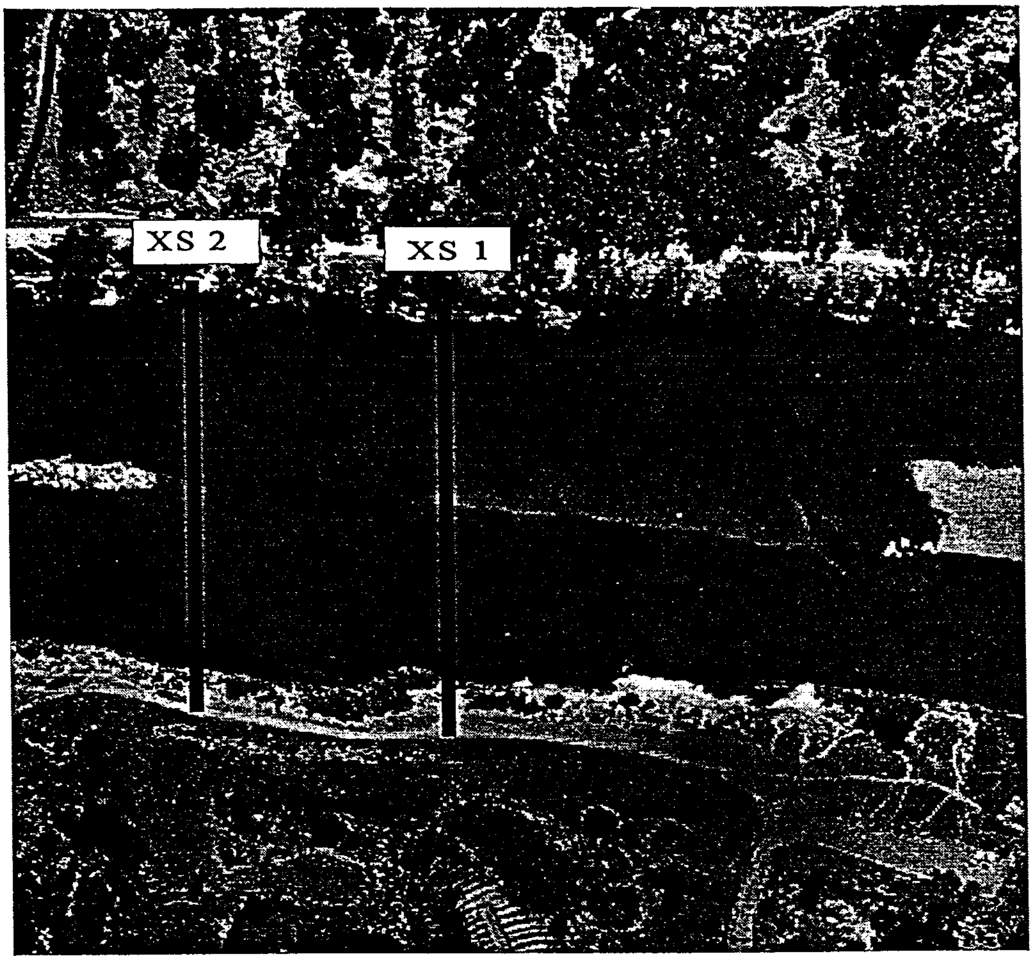
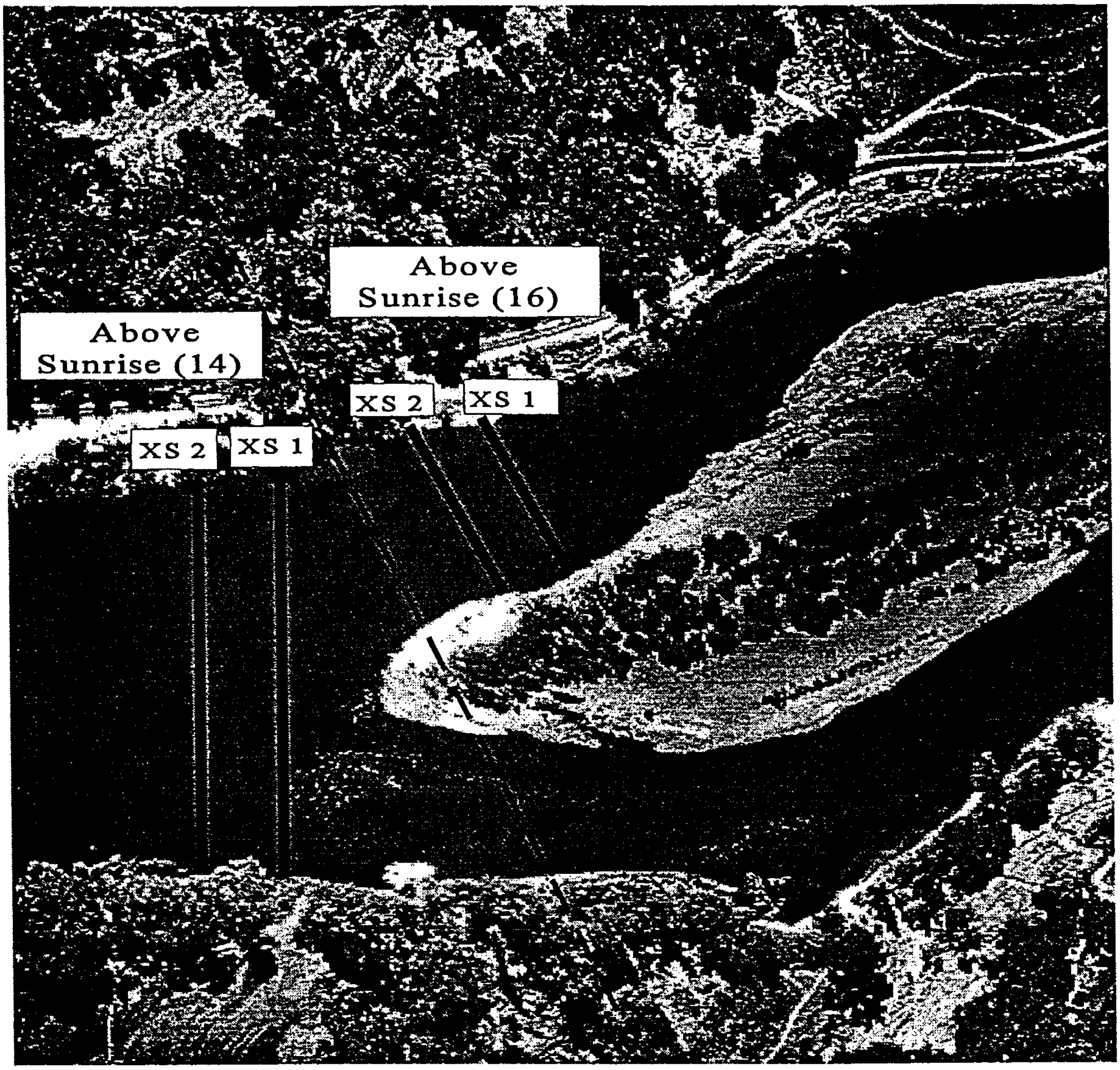
APPENDIX A
STUDY SITE AND TRANSECT LOCATIONS

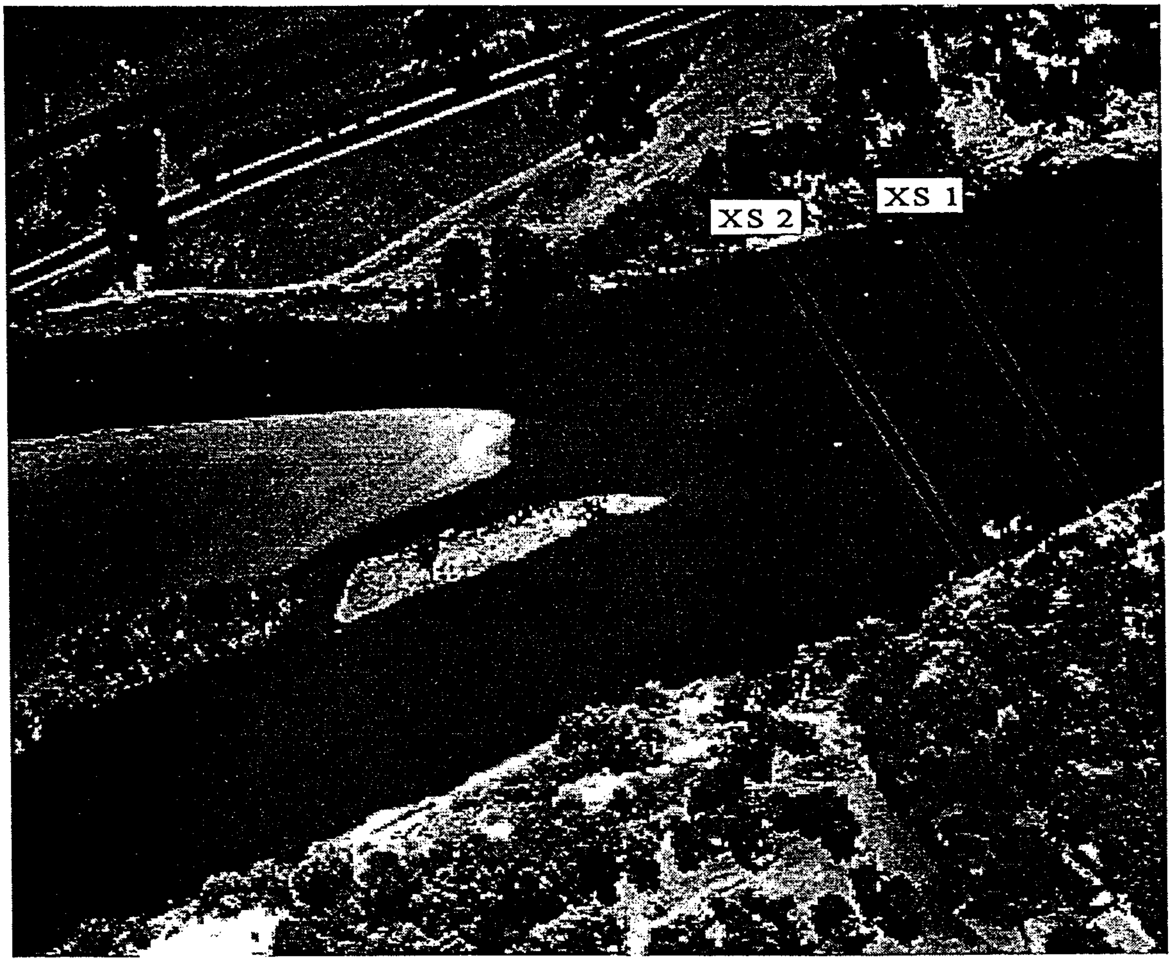
Sailor Bar Study Site



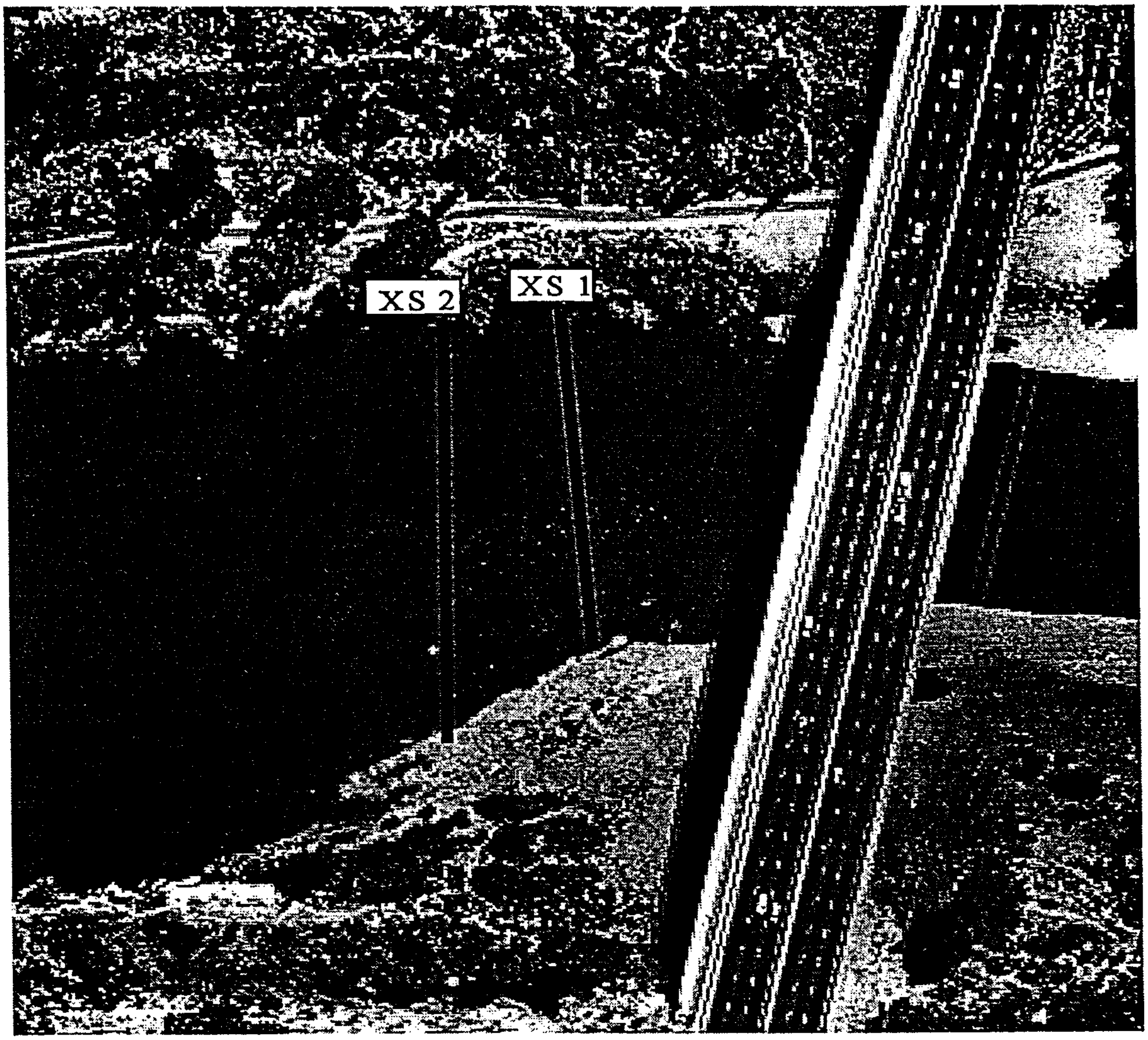
Above Sunrise (14) and (16) Study Sites



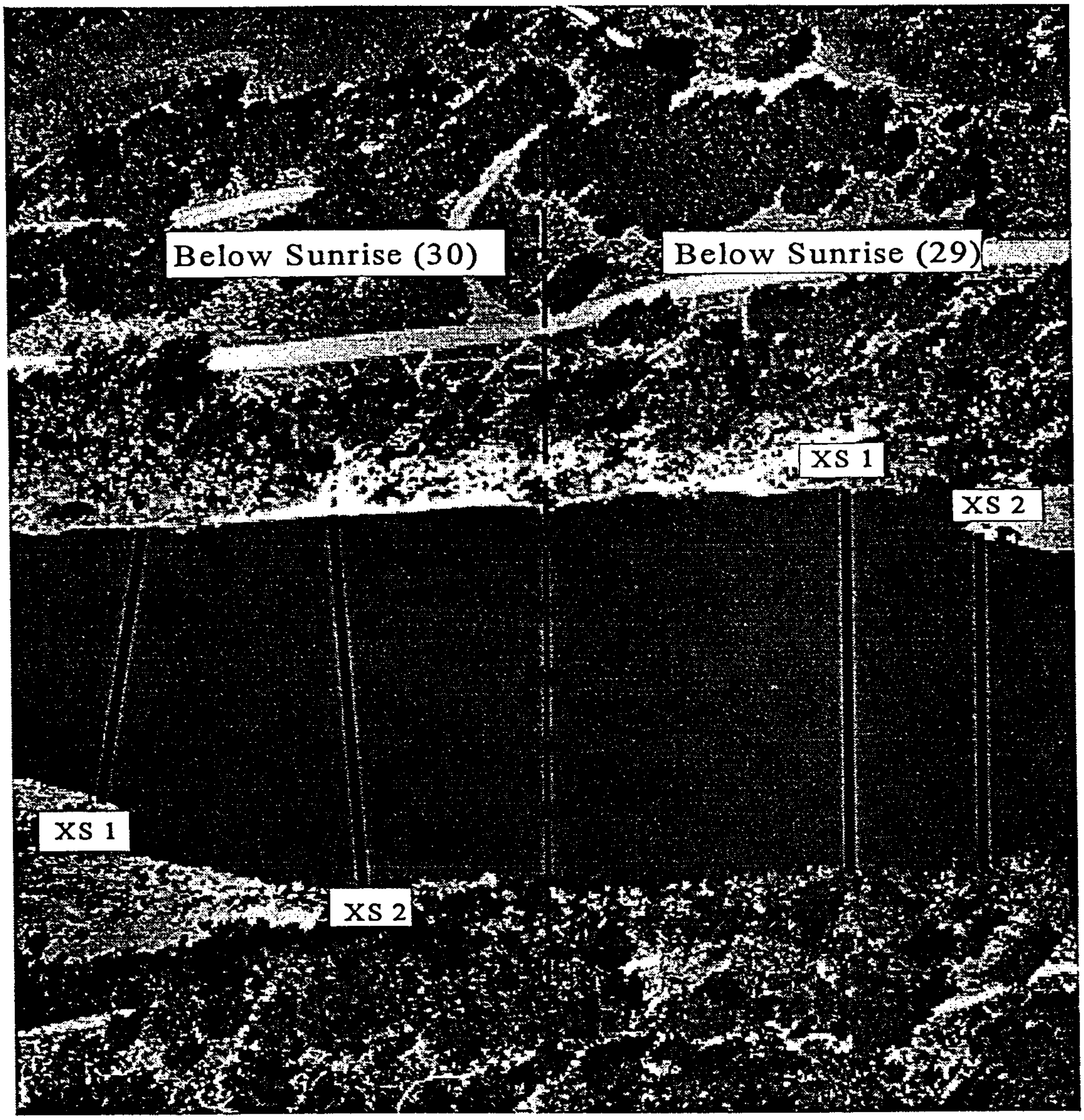
Above Sunrise (23) Study Site



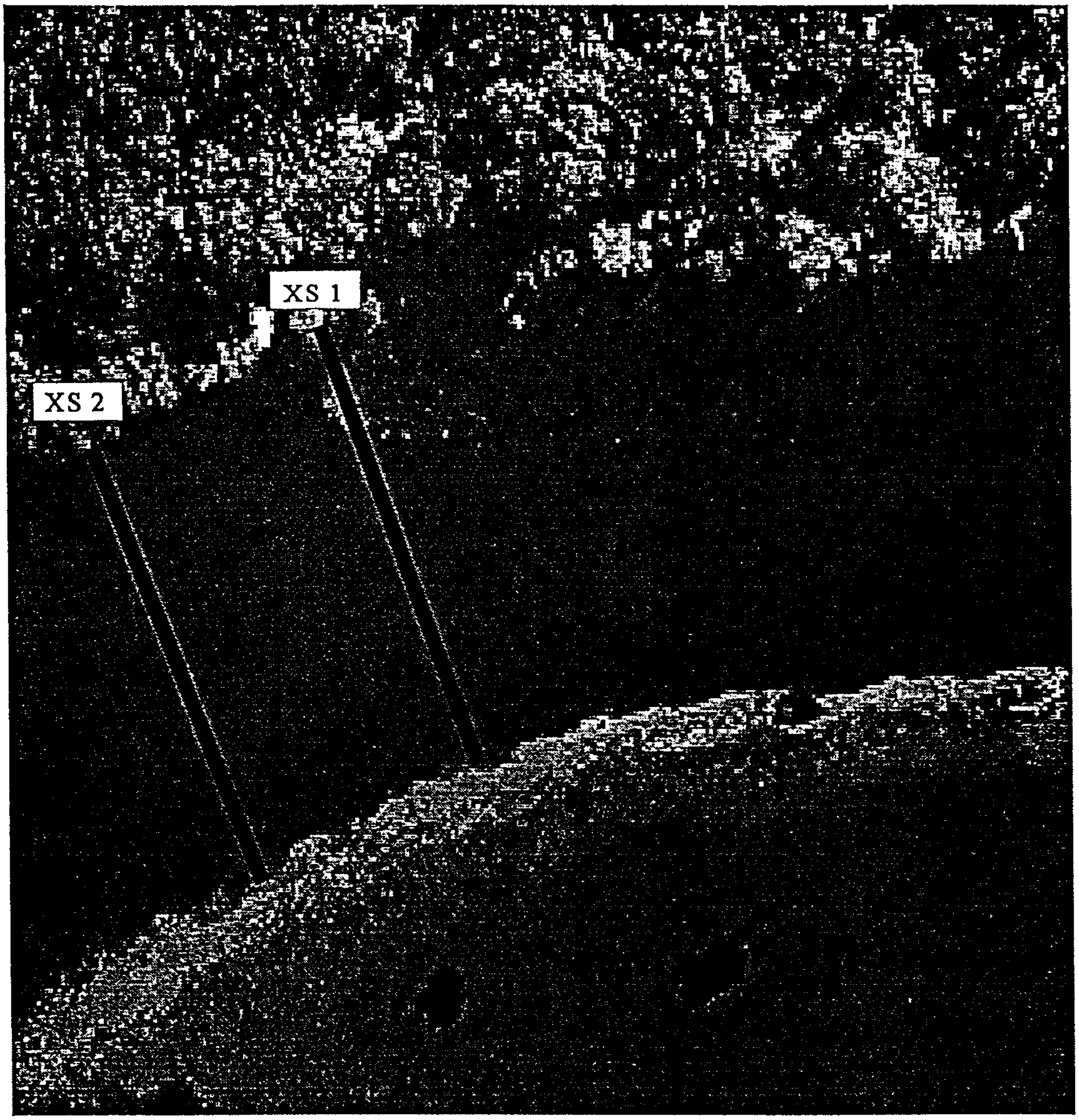
At Sunrise (26) Study Site



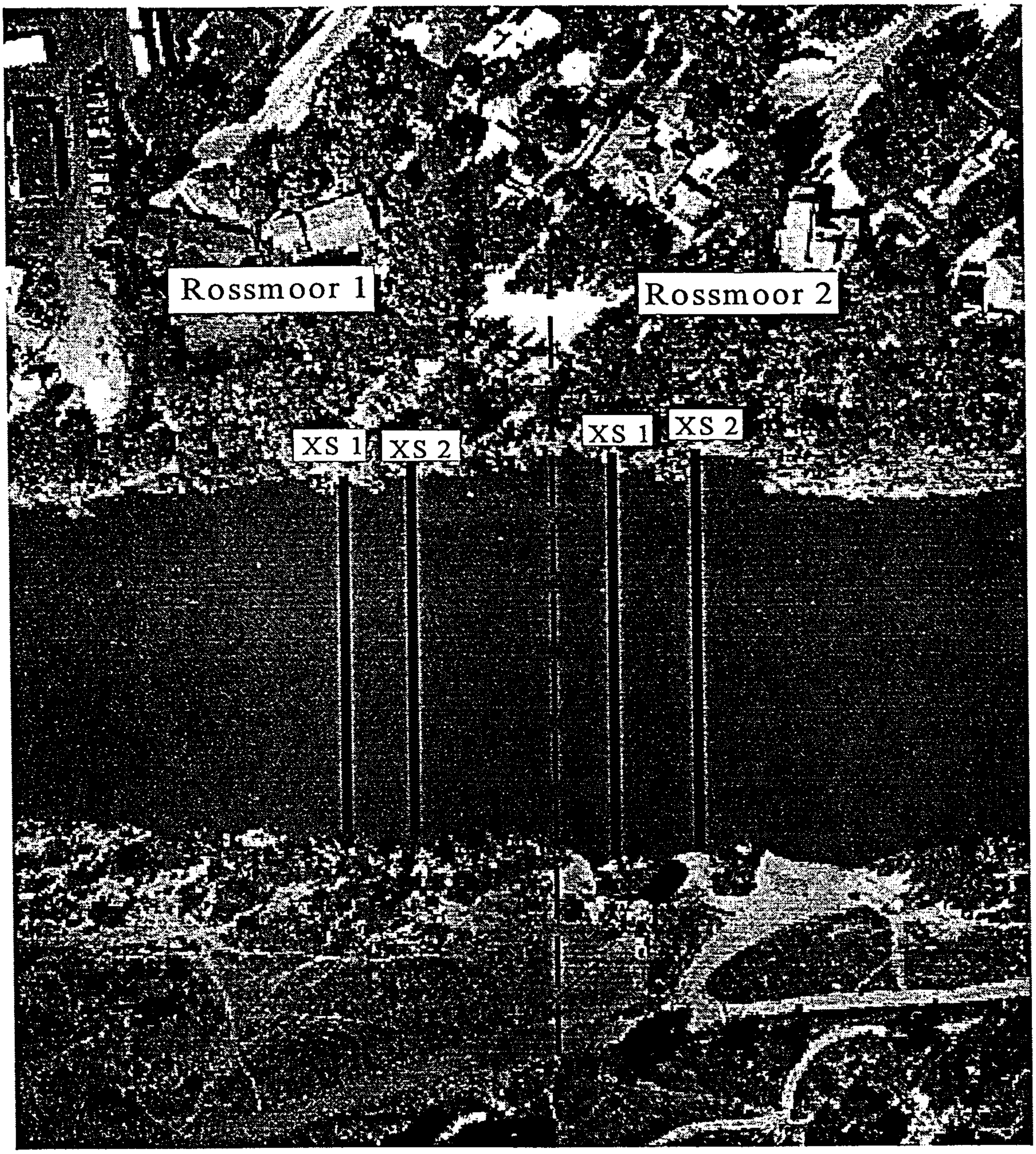
Below Sunrise (29) and (30) Study Sites



El Manto Study Site



Rossmoor 1 and 2 Study Sites



APPENDIX B
WSEL CALIBRATION

Calibration Methods and Parameters Used

Study Site	XS #	Flow Range	Calibration Flows	Method	Parameters
Sailor Bar	1 RC	477.3-1370.6	477.3, 905.2, 1174	IFG4	---
Sailor Bar	1 LC	522.7-4629	522.7, 1594.8, 2826	MANSQ	$\beta = 0.15$, CALQ = 2826
Sailor Bar	2	1000-6000	1000, 2750, 4000	IFG4	---
Above Sunrise (14)	1	1000-6000	1000, 2500, 4000	IFG4	---
Above Sunrise (14)	2	1000-6000	1000, 2500, 4000	IFG4	---
Above Sunrise (16)	1	100-1650	115, 497, 966	IFG4	---
Above Sunrise (16)	2	100-1650	115, 497, 966	IFG4	---
Above Sunrise (23)	1	1000-6000	1000, 2500, 4000	IFG4	---
Above Sunrise (23)	2	1000-6000	1000, 2500, 4000	IFG4	---
Sunrise Bridge (26)	1	1000-6000	1000, 2250, 3000, 4000	IFG4	---
Sunrise Bridge (26)	2	1000-6000	1000, 2250, 3000, 4000	IFG4	---
Below Sunrise (29)	1	1000-6000	1000, 2500, 3000, 4000	IFG4	---
Below Sunrise (29)	2	1000-6000	1000, 2500, 3000, 4000	IFG4	---
Below Sunrise (30)	1	1000-6000	1000, 2250, 2750, 4000	IFG4	---
Below Sunrise (30)	2	1000-6000	1000, 2250, 2750, 4000	IFG4	---
El Manto	1	1000-6000	1000, 2250, 2750, 4000	IFG4	---
El Manto	2	1000-6000	1000, 2250, 2750, 4000	IFG4	---
Rossmoor 2	1	1000-6000	1000, 2250, 2750, 4000	IFG4	---
Rossmoor 2	2	1000-6000	1000, 2250, 2750, 4000	IFG4	---
Rossmoor 1	1	1000-6000	1000, 2250, 2750, 4000	IFG4	---
Rossmoor 1	2	1000-6000	1000, 2250, 2750, 4000	IFG4	---

SAILOR BAR STUDY SITE - XS 1, LEFT CHANNEL

BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 1594.8 cfs	Difference (measured vs. pred. WSELs) 522.7 cfs	1594.8 cfs	2826 cfs
----	----	----	0.06	0.05	None

SAILOR BAR STUDY SITE - XS 1, RIGHT CHANNEL

BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 905.2 cfs	Difference (measured vs. pred. WSELs) 477.3 cfs	905.2 cfs	1174 cfs
2.77	3.69	5.4	0.01	0.08	0.07

SAILOR BAR STUDY SITE - XS 2

BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 2750 cfs	Difference (measured vs. pred. WSELs) 1000 cfs	2750 cfs	4000 cfs
4.00	2.62	3.1	0.01	0.04	0.03

ABOVE SUNRISE (14) STUDY SITE

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 2500 cfs	Difference (measured vs. pred. WSELs) 1000 cfs	2500 cfs	4000 cfs
1	3.42	1.17	1.8	None	0.02	0.01
2	3.46	0.94	1.4	None	0.01	0.01

ABOVE SUNRISE (16) STUDY SITE

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 497 cfs	966 cfs	Difference (measured vs. pred. WSELs) 115 cfs	497 cfs	966 cfs
1	2.63	4.02	2.7	1.1	0.01	0.05	0.04
2	2.83	7.74	4.7	0.6	0.02	0.08	0.06

ABOVE SUNRISE (23) STUDY SITE

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 2500 cfs	Difference (measured vs. pred. WSELs) 1000 cfs	2500 cfs	4000 cfs
1	2.63	7.15	5.7	0.04	0.12	0.08
2	2.88	3.72	3.3	0.02	0.06	0.04

SUNRISE BRIDGE (26) STUDY SITE

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 2250 cfs	Difference (measured vs. pred. WSELs) 1000 cfs	2250 cfs	3000 cfs	4000 cfs
1	2.43	0.93	1.4	0.01	0.02	0.01	0.02
2	2.52	3.38	5.3	0.03	0.07	0.02	0.06

BELOW SUNRISE (29) STUDY SITE

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 3000 cfs	Difference (measured vs. pred. WSELs) 1000 cfs	2500 cfs	3000 cfs	4000 cfs
1	3.74	2.87	0.6	0.02	0.04	0.01	0.06
2	3.29	1.89	2.1	0.01	0.05	None	0.03

BELOW SUNRISE (30) STUDY SITE

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 2750 cfs	Difference (measured vs. pred. WSELs) 1000 cfs	2250 cfs	2750 cfs	4000 cfs
1	4.16	1.06	0.1	None	0.01	0.03	0.02
2	4.06	0.72	0.1	None	0.01	0.02	0.01

EL MANTO STUDY SITE

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 2750 cfs	Difference (measured vs. pred. WSELs) 1000 cfs	2250 cfs	2750 cfs	4000 cfs
1	4.12	0.12	1.2	None	None	None	None
2	3.94	1.58	2.8	None	0.03	0.04	None

ROSSMOOR 2 STUDY SITE

XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 2750 cfs	Difference (measured vs. pred. WSELs) 1000 cfs	2250 cfs	2750 cfs	4000 cfs
1	2.38	2.29	0.8	0.02	0.06	0.01	0.03
2	2.62	1.97	0.8	0.01	0.04	0.01	0.03

ROSSMOOR 1 STUDY SITE

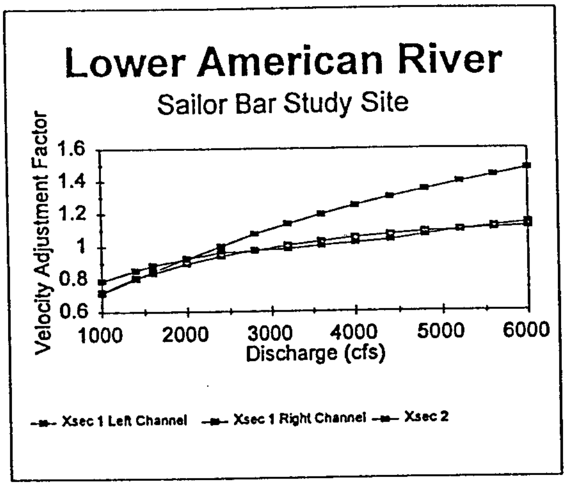
XSEC	BETA COEFF.	%MEAN ERROR	Calculated vs. Given Disch. (%) 2750 cfs	Difference (measured vs. pred. WSELs) 1000 cfs	2250 cfs	2750 cfs	4000 cfs
1	2.77	1.06	1.9	0.01	None	0.04	0.03
2	3.03	0.43	0.3	None	0.01	0.01	0.01

APPENDIX C
VELOCITY CALIBRATION

LOWER AMERICAN RIVER
SAILOR BAR STUDY SITE

VELOCITY CALIBRATION

Discharge	Velocity Adjustment Factors Xsec 1 Left Channel	Xsec 1 Right Channel	Xsec 2
1000	0.791	0.714	0.724
1400	0.854	0.802	0.81
1600	0.885	0.837	0.847
2000	0.923	0.894	0.927
2400	0.964	0.94	1.001
2800	0.973	0.976	1.076
3200	0.986	1.007	1.137
3600	1.004	1.032	1.194
4000	1.022	1.054	1.248
4400	1.039	1.072	1.3
4800	1.068	1.088	1.346
5200	1.097	1.1	1.393
5600	1.123	1.111	1.435
6000	1.144	1.12	1.479



CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

Sailor Bar Study Site

2500/2750 CFS VELOCITY SET USED

TRANSECT 1 LEFT CHANNEL

	meas 2500	sim 1000	sim 2500	sim 6000
avg	3.84	2.12	3.80	5.59
std dev	1.46	0.88	1.44	2.93
max	5.48	3.23	5.43	9.35
avg diff			**0.04**	
+/-			**-0.99**	
max diff			**0.08**	

TRANSECT 1 RIGHT CHANNEL

	meas 2500	sim 1000	sim 2500	sim 6000
avg	1.35	0.84	1.37	1.63
std dev	0.55	0.36	0.39	0.59
max	2.18	1.43	2.06	2.56
avg diff			**0.09**	
+/-			**-1.13**	
max diff			**0.12**	

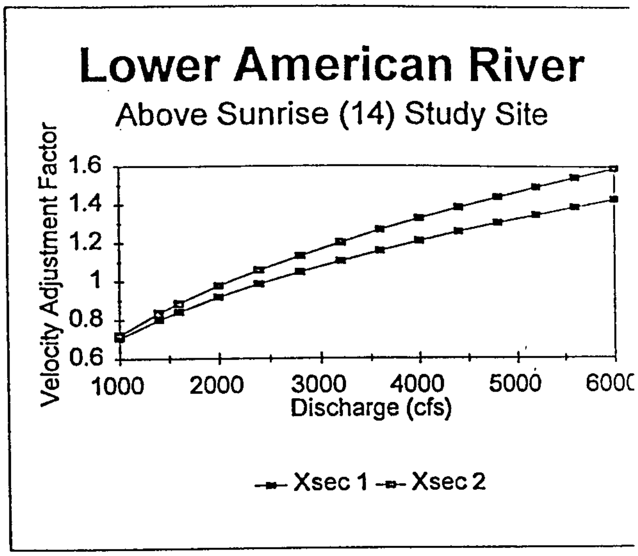
TRANSECT 2

	meas 2750	sim 1000	sim 2750	sim 6000
avg	2.19	1.17	2.32	3.81
std dev	0.65	0.34	0.68	1.35
max	3.26	1.75	3.45	5.80
avg diff			**0.13**	
+/-			**6.46**	
max diff			**0.19**	

LOWER AMERICAN RIVER VELOCITY CALIBRATION

ABOVE SUNRISE (14) STUDY SITE

Discharge	Velocity Adjustment Factors Xsec 1	Xsec 2
1000	0.707	0.723
1400	0.801	0.836
1600	0.843	0.886
2000	0.918	0.977
2400	0.986	1.059
2800	1.048	1.133
3200	1.106	1.202
3600	1.16	1.267
4000	1.21	1.328
4400	1.259	1.385
4800	1.305	1.44
5200	1.349	1.493
5600	1.391	1.544
6000	1.432	1.592



CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

Above Sunrise (14) Study Site 2500 CFS VELOCITY SET USED

TRANSECT 1

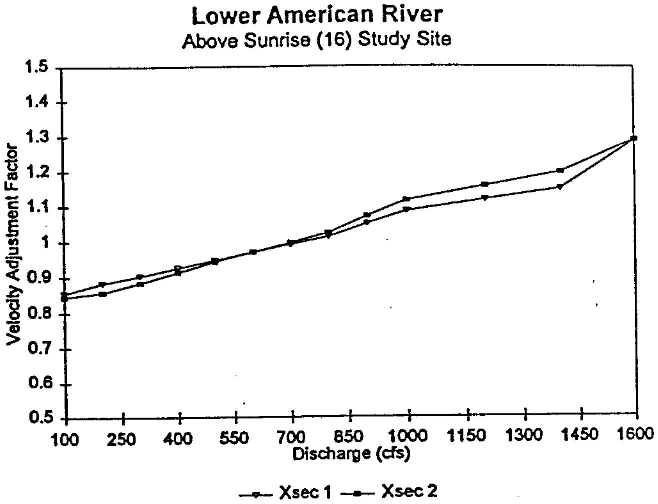
	meas 2500	sim 1000	sim 2500	sim 6000
avg	1.94	1.00	1.95	2.99
std dev	0.82	0.55	0.82	1.76
max	3.26	1.81	3.28	5.82
avg diff			**0.02**	
+/-			**0.41**	
max diff			**0.05**	

TRANSECT 2

	meas 2500	sim 1000	sim 2500	sim 6000
avg	1.84	1.04	1.99	3.56
std dev	0.63	0.41	0.68	1.27
max	2.74	1.57	2.97	5.50
avg diff			**0.15**	
+/-			**4.50**	
max diff			**0.23**	

LOWER AMERICAN RIVER VELOCITY CALIBRATION
ABOVE SUNRISE (16) Side-Channel STUDY SITE

Discharge	Velocity Adjustment Factors Xsec 1	Xsec 2
100	0.855	0.845
200	0.884	0.858
300	0.904	0.885
400	0.927	0.914
500	0.949	0.943
600	0.971	0.971
700	0.992	0.998
800	1.013	1.024
900	1.05	1.071
1000	1.085	1.116
1200	1.117	1.156
1400	1.148	1.195
1600	1.285	1.287



CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

966 CFS VELOCITY SET USED

TRANSECT 1

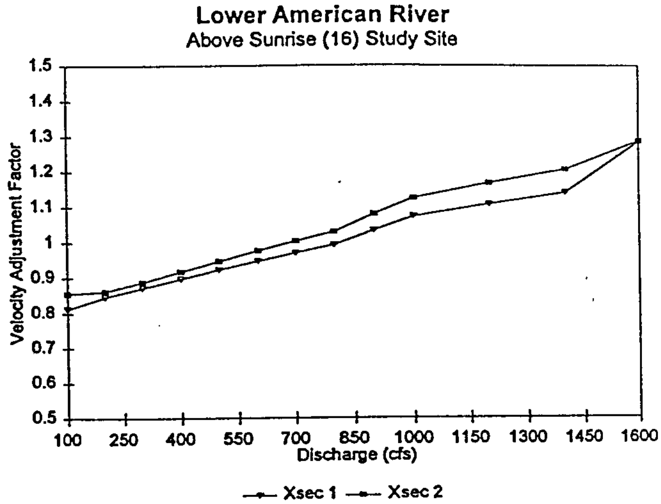
	meas. 497	meas. 966	sim. 115	sim. 497	sim. 966	sim. 1500
avg	2.11	2.5	1.01	2.07	2.58	3.08
std dev	0.88	1.06	0.57	0.64	1.1	1.45
max	3.28	3.71	1.78	2.92	3.83	4.67
avg diff				**0.33**	**0.07**	
+/-				**-0.99**	**2.12**	
max diff				**1.75**	**0.12**	

TRANSECT 2

	meas. 497	meas. 966	sim. 115	sim. 497	sim. 966	sim. 1500
avg	1.96	2.44	1.03	1.95	2.53	3.04
std dev	0.84	1.09	0.42	0.69	1.14	1.56
max	3.54	3.85	1.47	2.85	4	5.07
avg diff				**0.22**	**0.09**	
+/-				**-0.32**	**2.88**	
max diff				**0.77**	**0.15**	

LOWER AMERICAN RIVER VELOCITY CALIBRATION
ABOVE SUNRISE (16) Side-Channel STUDY SITE

	Velocity Adjustment Factors	
Discharge	Xsec 1	Xsec 2
100	0.813	0.856
200	0.847	0.863
300	0.872	0.889
400	0.898	0.918
500	0.924	0.948
600	0.948	0.977
700	0.971	1.004
800	0.993	1.03
900	1.034	1.079
1000	1.072	1.124
1200	1.106	1.166
1400	1.139	1.205
1600	1.285	1.287



CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

467 CFS VELOCITY SET USED

TRANSECT 1

	meas.	meas.	sim.	sim.	sim.	sim.
	497	966	115	497	966	1500
avg	2.11	2.5	0.98	1.99	2.45	2.92
std dev	0.88	1.06	0.6	0.82	1.35	1.76
max	3.28	3.71	1.89	3.07	4.05	4.95
avg diff				**0.12**	**0.43**	
+/-				**-2.92**	**-1.41**	
max diff				**0.21**	**2.61**	

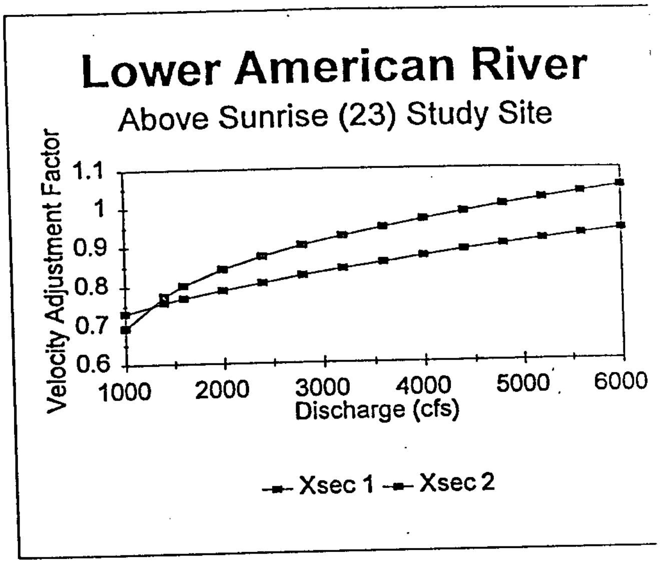
TRANSECT 2

	meas.	meas.	sim.	sim.	sim.	sim.
	497	966	115	497	966	1500
avg	1.96	2.44	1.03	1.94	2.52	3.03
std dev	0.84	1.09	0.44	0.81	1.32	1.77
max	3.54	3.85	1.73	3.49	4.92	6.23
avg diff				**0.03**	**0.33**	
+/-				**-0.49**	**2.57**	
max diff				**0.07**	**1.35**	

LOWER AMERICAN RIVER
ABOVE SUNRISE (23) STUDY SITE

VELOCITY CALIBRATION

Discharge	Velocity Adjustment Factors Xsec 1	Xsec 2
1000	0.732	0.694
1400	0.758	0.775
1600	0.769	0.802
2000	0.789	0.843
2400	0.808	0.875
2800	0.826	0.902
3200	0.842	0.926
3600	0.858	0.948
4000	0.874	0.968
4400	0.889	0.987
4800	0.903	1.005
5200	0.917	1.022
5600	0.93	1.038
6000	0.943	1.054



CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

Above Sunrise (23) Study Site

2500 CFS VELOCITY SET USED

TRANSECT 1

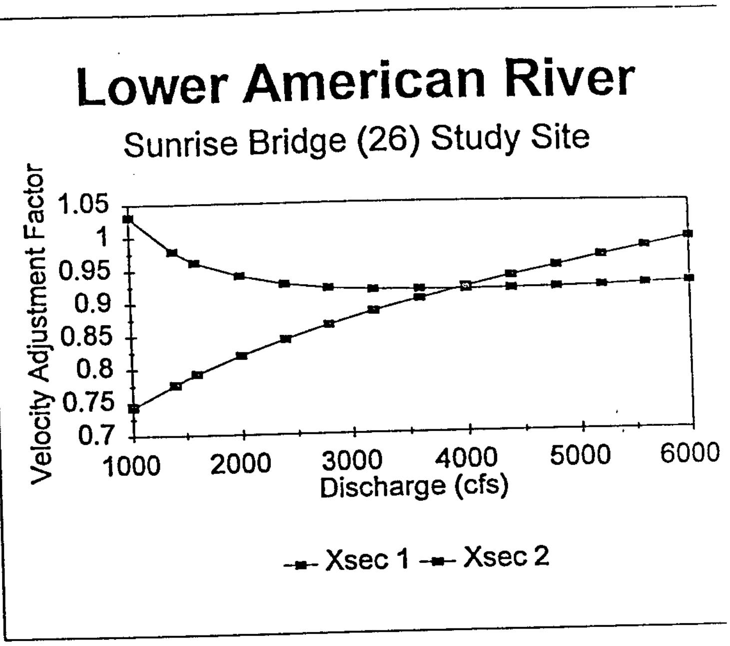
	meas 2500	sim 1000	sim 2500	sim 6000
avg	3.10	1.61	2.64	3.95
std dev	1.54	1.04	1.27	1.98
max	6.54	3.87	5.47	7.97
avg diff			**0.46**	
+/-			**-19.38**	
max diff			**1.07**	

TRANSECT 2

	meas 2500	sim 1000	sim 2500	sim 6000
avg	3.11	1.50	2.83	4.45
std dev	1.33	0.94	1.18	2.18
max	4.93	2.91	4.40	7.84
avg diff			**0.28**	
+/-			**-7.95**	
max diff			**0.53**	

SUNRISE BRIDGE (26) STUDY SITE

Discharge	Velocity Adjustment Factors Xsec 1	Xsec 2
1000	1.031	0.743
1400	0.979	0.776
1600	0.962	0.792
2000	0.941	0.82
2400	0.928	0.844
2800	0.921	0.865
3200	0.918	0.885
3600	0.917	0.903
4000	0.917	0.921
4400	0.918	0.937
4800	0.919	0.952
5200	0.921	0.967
5600	0.924	0.981
6000	0.927	0.995



CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

Sunrise Bridge (26) Study Site 3000 CFS VELOCITY SET USED

TRANSECT 1

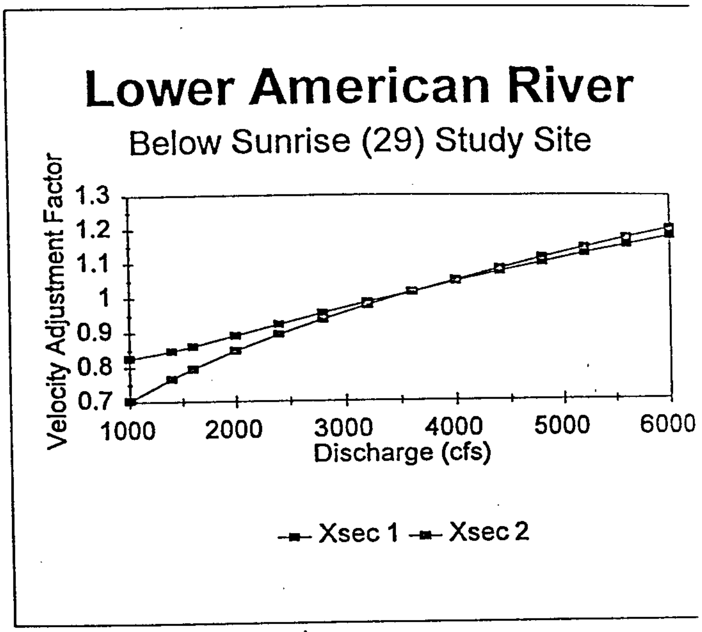
	meas 3000	sim 1000	sim 3000	sim 6000
avg	3.12	1.99	2.98	3.55
std dev	1.10	0.71	0.91	1.60
max	4.56	3.08	4.20	6.00
avg diff			**0.25**	
+/-			**-10.61**	
max diff			**0.36**	

TRANSECT 2

	meas 3000	sim 1000	sim 3000	sim 6000
avg	2.71	1.59	2.39	3.30
std dev	1.09	0.38	0.95	1.41
max	3.97	2.00	3.50	5.11
avg diff			**0.32**	
+/-			**-17.32**	
max diff			**0.47**	

LOWER AMERICAN RIVER VELOCITY CALIBRATION
BELOW SUNRISE (29) STUDY SITE

Discharge	Velocity Adjustment Factors Xsec 1	Xsec 2
1000	0.826	0.703
1400	0.847	0.767
1600	0.861	0.796
2000	0.892	0.848
2400	0.924	0.895
2800	0.956	0.938
3200	0.987	0.978
3600	1.017	1.016
4000	1.046	1.051
4400	1.075	1.084
4800	1.102	1.116
5200	1.129	1.146
5600	1.154	1.175
6000	1.18	1.203



CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

Below Sunrise (29) Study Site 3000 CFS VELOCITY SET USED

TRANSECT 1

	meas 3000	sim 1000	sim 3000	sim 6000
avg	2.51	1.42	2.44	3.51
std dev	0.80	0.44	0.78	1.26
max	3.43	1.92	3.34	4.98
avg diff			**0.07**	
+/-			**-3.15**	
max diff			**0.09**	

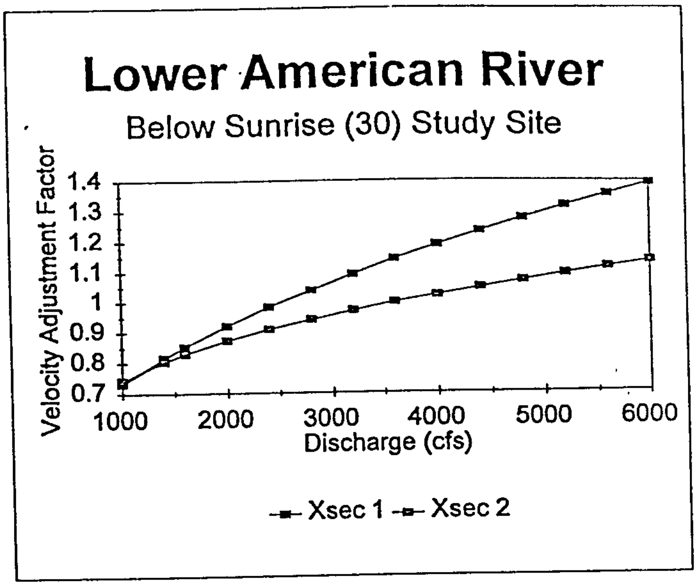
TRANSECT 2

	meas 3000	sim 1000	sim 3000	sim 6000
avg	2.76	1.44	2.64	3.76
std dev	0.78	0.45	0.75	1.33
max	3.73	1.96	3.57	5.52
avg diff			**0.12**	
+/-			**-4.50**	
max diff			**0.16**	

LOWER AMERICAN RIVER
BELOW SUNRISE (30) STUDY SITE

VELOCITY CALIBRATION

Discharge	Velocity Adjustment Factors Xsec 1	Xsec 2
1000	0.732	0.743
1400	0.816	0.804
1600	0.853	0.829
2000	0.921	0.873
2400	0.983	0.91
2800	1.039	0.942
3200	1.092	0.971
3600	1.142	0.998
4000	1.189	1.023
4400	1.234	1.048
4800	1.276	1.071
5200	1.317	1.094
5600	1.355	1.116
6000	1.392	1.137



CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

Below Sunrise (30) Study Site

2750 CFS VELOCITY SET USED

TRANSECT 1

	meas 2750	sim 1000	sim 2750	sim 6000
avg	2.62	1.51	2.69	3.79
std dev	1.33	0.82	1.37	2.37
max	5.08	3.05	5.22	8.14
avg diff			**0.07**	
+/-			**1.93**	
max diff			**0.14**	

TRANSECT 2

	meas 2750	sim 1000	sim 2750	sim 6000
avg	2.51	1.56	2.34	3.59
std dev	1.26	0.72	1.18	1.74
max	4.90	3.01	4.59	6.40
avg diff			**0.17**	
+/-			**-6.69**	
max diff			**0.31**	

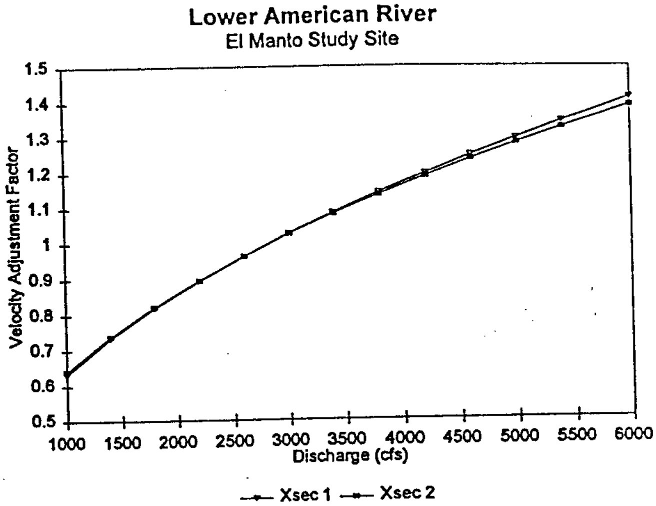
LOWER AMERICAN RIVER

EL MANTO STUDY SITE

VELOCITY CALIBRATION

ELMANTO.IN4

Discharge	Velocity Adjustment Factors Xsec 1	Xsec 2
1000	0.633	0.641
1400	0.733	0.739
1800	0.819	0.823
2200	0.895	0.897
2600	0.964	0.964
3000	1.028	1.026
3400	1.087	1.083
3800	1.144	1.137
4200	1.197	1.188
4600	1.248	1.237
5000	1.297	1.283
5400	1.344	1.327
6000	1.411	1.39



CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

El Manto Study Site

2750 CFS VELOCITY SET USED

TRANSECT 1

	meas. 2750	sim. 1000	sim. 2750	sim. 6000
avg	2.73	1.5	2.69	4.2
std dev	1.3	0.7	1.29	2.25
max	4.96	2.63	4.9	8
avg diff			**0.03**	
+/-			**-1.06**	
max diff			**0.06**	

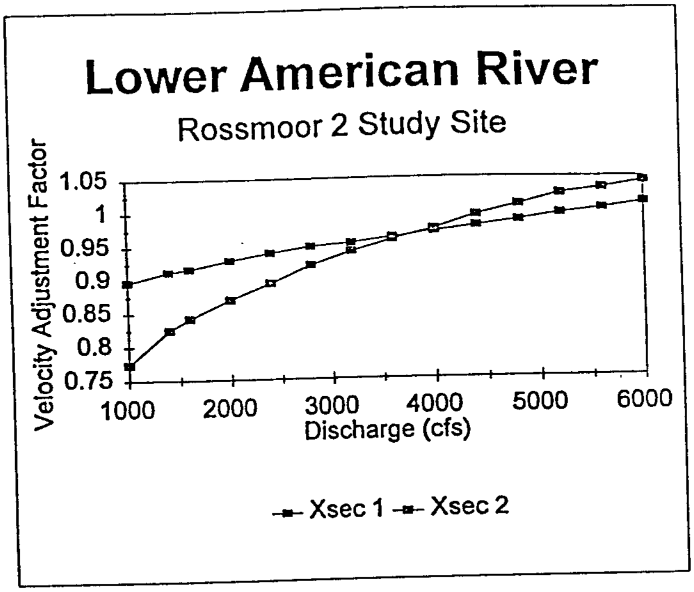
TRANSECT 2

	meas. 2750	sim. 1000	sim. 2750	sim. 6000
avg	2.9	1.44	2.84	4.26
std dev	1.28	0.78	1.26	2.19
max	4.85	2.54	4.77	7.76
avg diff			**0.06**	
+/-			**-1.74**	
max diff			**0.08**	

LOWER AMERICAN RIVER
ROSSMOOR 2 STUDY SITE

VELOCITY CALIBRATION

	Velocity Adjustment Factors	
Discharge	Xsec 1	Xsec 2
1000	0.897	0.774
1400	0.912	0.825
1600	0.916	0.842
2000	0.929	0.87
2400	0.94	0.894
2800	0.949	0.921
3200	0.954	0.941
3600	0.962	0.958
4000	0.97	0.974
4400	0.978	0.994
4800	0.986	1.009
5200	0.996	1.025
5600	1.003	1.033
6000	1.012	1.043



CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

Rossmoor 2 Study Site

2750 CFS VELOCITY SET USED

TRANSECT 1

	meas 2750	sim 1000	sim 2750	sim 6000
avg	2.92	1.85	2.75	3.89
std dev	1.38	1.05	1.31	1.81
max	5.38	3.58	5.07	6.80
avg diff			**0.17**	
+/-			**-7.71**	
max diff			**0.31**	

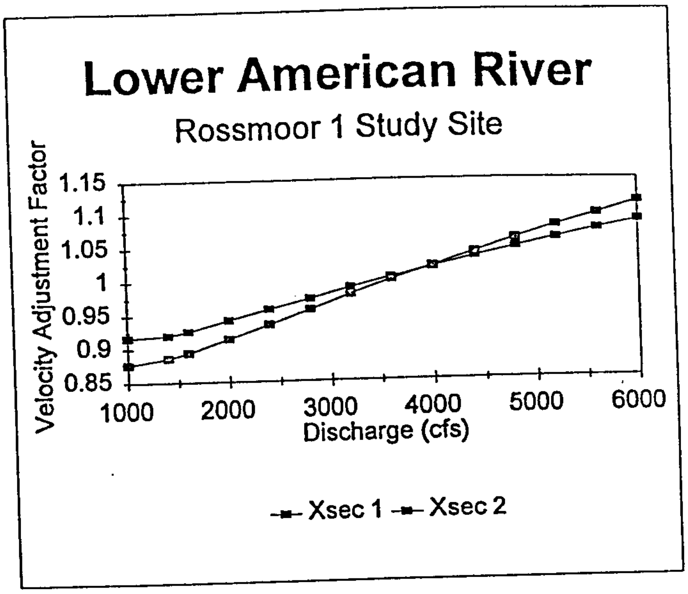
TRANSECT 2

	meas 2750	sim 1000	sim 2750	sim 6000
avg	2.76	1.52	2.54	3.83
std dev	1.34	0.97	1.23	1.70
max	5.01	2.98	4.60	6.45
avg diff			**0.22**	
+/-			**-10.25**	
max diff			**0.41**	

LOWER AMERICAN RIVER
ROSSMOOR 1 STUDY SITE

VELOCITY CALIBRATION

Discharge	Velocity Adjustment Factors Xsec 1	Xsec 2
1000	0.917	0.877
1400	0.92	0.886
1600	0.926	0.894
2000	0.942	0.914
2400	0.958	0.935
2800	0.973	0.957
3200	0.989	0.979
3600	1.004	1
4000	1.018	1.02
4400	1.033	1.04
4800	1.047	1.06
5200	1.06	1.079
5600	1.074	1.097
6000	1.087	1.115



CALIBRATION VELOCITY ANALYSIS (all values in feet per second)

Rossmoor 1 Study Site

2750 CFS VELOCITY SET USED

TRANSECT 1

	meas 2750	sim 1000	sim 2750	sim 6000
avg	2.63	1.80	2.54	3.72
std dev	1.70	1.05	1.64	2.35
max	4.76	2.94	4.59	6.65
avg diff			0.10	
+/-			-2.94	
max diff			0.17	

TRANSECT 2

	meas 2750	sim 1000	sim 2750	sim 6000
avg	2.69	1.79	2.57	3.23
std dev	1.39	0.75	1.32	2.28
max	4.35	2.71	4.16	6.16
avg diff			0.12	
+/-			-3.26	
max diff			0.19	

APPENDIX D
HSI CRITERIA

Feather River Chinook Salmon Spawning

Water Velocity (ft/s)	SI Value	Water Depth (ft)	SI Value	Substrate Composition	SI Value
0.00	0.00	0.00	0.00	0.0	0.00
0.60	0.10	0.20	0.00	1.0	0.31
0.70	0.20	0.60	0.10	1.2	0.78
1.10	0.50	0.90	0.20	2.3	0.91
1.50	1.00	1.00	0.50	2.4	0.95
2.60	1.00	1.40	1.00	3.4	1.00
3.20	0.50	100.00	1.00	4.6	1.00
3.60	0.20			6.8	0.59
3.80	0.10			8.0	0.00
4.00	0.00			100.0	0.00
100.00	0.00				

Yuba River Chinook Salmon Spawning

Water Velocity (ft/s)	SI Value	Water Depth (ft)	SI Value	Substrate Composition	SI Value
0.00	0.10	0.00	0.00	0.0	0.02
0.35	0.10	0.25	0.00	1.0	0.07
0.85	0.20	0.45	0.10	1.2	0.50
1.25	0.50	0.65	0.20	2.3	0.85
1.55	1.00	0.75	0.50	2.4	0.92
2.95	1.00	0.95	1.00	3.4	1.00
3.25	0.50	100.00	1.00	4.6	1.00
3.85	0.20			6.8	0.37
4.45	0.10			8.0	0.02
4.65	0.00			9.0	0.00
100.00	0.00			10.0	0.02
				11.0	0.02
				100.0	0.00

Sacramento River Use Chinook Salmon Spawning

Water Velocity (ft/s)	SI Value	Water Depth (ft)	SI Value	Substrate Composition	SI Value
0.00	0.00	0.00	0.00	0.0	0.00
0.01	0.06	0.25	0.00	1.2	0.00
0.12	0.09	0.30	0.01	2.3	1.00
0.22	0.11	0.42	0.02	4.6	1.00
0.33	0.15	0.54	0.03	6.8	0.18
0.38	0.16	0.66	0.07	8.0	0.00
0.48	0.21	0.78	0.12	100.0	0.00
0.64	0.28	0.83	0.16		
0.85	0.41	0.95	0.25		
0.96	0.48	1.07	0.37		
1.07	0.55	1.19	0.51		
1.17	0.63	1.31	0.66		
1.28	0.71	1.42	0.80		
1.38	0.78	1.48	0.86		
1.49	0.84	1.54	0.91		
1.59	0.90	1.60	0.95		
1.70	0.95	1.78	1.00		
1.80	0.98	100.00	1.00		
1.91	1.00				
2.02	1.00				
2.12	0.99				
2.23	0.96				
2.33	0.92				
2.44	0.86				
2.54	0.80				
2.65	0.73				
2.75	0.66				
2.91	0.54				
3.33	0.27				
3.65	0.14				
3.86	0.08				
3.97	0.06				
4.18	0.03				
4.71	0.01				
4.75	0.00				
100.00	0.00				

Trinity River Chinook Salmon Spawning

Water Velocity (ft/s)	SI Value	Water Depth (ft)	SI Value	Substrate Composition	SI Value
0.00	0.00	0.00	0.00	0.0	0.00
0.10	0.03	0.40	0.24	1.2	0.00
0.30	0.11	0.50	0.37	2.3	0.75
0.50	0.23	0.60	0.51	2.4	1.00
0.70	0.39	0.70	0.64	3.4	0.75
0.90	0.59	0.80	0.75	4.6	0.75
1.10	0.83	0.90	0.83	6.8	0.00
1.20	0.94	1.10	0.94	100.0	0.00
1.30	1.00	1.20	0.98		
1.40	1.00	1.30	1.00		
1.50	0.96	1.40	0.98		
1.80	0.78	1.50	0.94		
2.20	0.50	2.30	0.50		
2.30	0.44	2.70	0.24		
2.60	0.30	2.80	0.19		
2.90	0.20	2.90	0.16		
3.10	0.16	3.10	0.12		
3.90	0.04	3.20	0.11		
4.00	0.04	3.30	0.09		
4.10	0.03	3.50	0.07		
4.20	0.02	3.60	0.05		
4.40	0.01	3.90	0.02		
5.60	0.00	4.10	0.01		
100.00	0.00	4.60	0.00		
		100.00	0.00		

CDFG Lower American River Chinook Salmon Spawning

Water Velocity (ft/s)	SI Value	Water Depth (ft)	SI Value	Substrate Composition	SI Value
0.00	0.00	0.00	0.00	0.0	0.00
0.20	0.00	0.50	0.00	1.0	0.10
0.21	0.18	0.51	0.19	1.2	0.27
0.61	0.40	0.76	0.40	2.3	0.78
1.31	0.89	1.13	0.80	2.4	0.89
1.66	1.00	1.35	0.97	3.4	1.00
1.76	1.00	1.44	1.00	3.5	0.66
2.01	0.94	100.00	1.00	4.5	0.33
3.01	0.28			4.6	0.13
3.46	0.10			6.8	0.05
4.01	0.02			8.0	0.01
4.41	0.00			9.0	0.00
100.00	0.00			10.0	0.00
				11.0	0.00
				100.0	0.00

CDFG Lower American River Steelhead Spawning

Water Velocity (ft/s)	SI Value	Water Depth (ft)	SI Value	Substrate Composition	SI Value
0.00	0.00	0.00	0.00	0.0	0.00
0.29	0.00	0.70	0.00	1.0	0.00
0.31	0.53	0.73	0.32	1.2	0.30
0.70	0.97	1.30	0.87	2.3	1.00
0.79	1.00	1.51	1.00	2.4	0.30
0.88	1.00	100.00	1.00	3.4	0.00
1.14	0.90			100.0	0.00
1.61	0.62				
2.00	0.49				
3.39	0.49				
3.61	0.38				
4.20	0.00				
100.00	0.00				

Trinity River Steelhead Spawning

Water Velocity (ft/s)	SI Value	Water Depth (ft)	SI Value	Substrate Composition	SI Value
0.00	0.00	0.00	0.00	0.0	0.00
0.30	0.15	0.30	0.07	1.0	0.00
0.50	0.39	0.40	0.11	1.2	0.30
0.60	0.55	0.50	0.19	2.3	1.00
0.70	0.72	0.60	0.31	2.4	0.30
0.80	0.85	0.70	0.47	3.4	0.00
0.90	0.94	0.80	0.64	100.0	0.00
1.00	0.99	0.90	0.82		
1.10	1.00	1.00	0.96		
2.00	0.65	1.10	1.00		
2.10	0.59	1.20	0.90		
2.20	0.48	1.30	0.72		
2.30	0.37	1.40	0.54		
2.40	0.29	1.50	0.40		
2.50	0.25	1.60	0.31		
2.60	0.23	1.70	0.25		
2.70	0.23	1.80	0.21		
2.80	0.22	1.90	0.18		
2.90	0.20	2.00	0.16		
3.00	0.17	2.10	0.12		
3.10	0.13	2.20	0.08		
3.20	0.12	2.30	0.05		
3.70	0.11	2.40	0.03		
3.90	0.07	2.90	0.03		
4.10	0.03	3.00	0.02		
4.40	0.00	3.10	0.01		
100.00	0.00	3.20	0.01		
		3.30	0.00		
		100.00	0.00		

APPENDIX E
HABITAT MODELING RESULTS

Sailor Bar Study Site - Transect 1, Left Channel

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	80.2	46.7	102.6	28.8	46.5	18.9	24.3
1200	74.6	41.2	91.0	22.7	38.8	17.4	28.5
1400	62.1	33.7	81.9	17.8	31.1	15.1	28.8
1600	49.3	26.3	72.3	14.0	24.1	13.9	28.1
1800	41.1	21.1	64.2	11.0	18.6	10.8	24.5
2000	37.9	17.9	53.0	8.8	15.1	8.6	21.7
2200	32.1	14.9	39.9	7.1	12.3	7.2	19.8
2400	25.4	12.1	32.1	5.6	9.8	5.6	17.1
2600	20.7	10.7	25.8	4.4	8.4	4.1	15.1
2800	17.0	9.8	20.2	3.5	7.4	3.1	13.4
3000	14.0	8.9	18.0	2.7	6.4	2.7	12.5
3200	11.4	7.7	16.4	2.1	5.5	2.7	10.8
3400	11.0	6.7	15.2	1.6	5.0	2.9	9.2
3600	10.8	5.7	13.7	1.3	4.6	3.0	7.3
3800	10.0	4.9	13.3	1.0	4.8	3.2	6.0
4000	10.1	4.2	12.7	0.8	4.8	3.4	5.0
4200	10.8	3.5	12.9	0.6	4.9	3.7	4.2
4400	11.2	3.0	12.5	0.5	5.0	4.0	5.7
4600	11.3	2.4	12.6	0.4	5.1	4.5	5.8
4800	12.2	2.0	13.2	0.3	5.2	5.1	5.9
5000	14.5	1.5	14.7	0.3	6.0	5.6	6.0
5200	15.9	1.3	15.0	0.2	6.4	6.1	5.8
5400	17.0	1.0	15.2	0.1	7.0	6.4	5.6
5600	18.1	0.8	16.2	0.1	7.3	6.5	6.9
5800	19.3	0.6	17.7	0.1	7.6	6.4	6.7
6000	20.8	0.5	20.0	0.1	8.1	6.4	6.6

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs).

Sailor Bar Study Site - Transect 1, Right Channel

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	34.3	43.6	28.0	16.3	18.8	4.4	5.8
1200	43.6	50.9	35.3	18.0	21.9	6.9	8.6
1400	52.0	57.6	42.7	19.6	26.4	8.3	11.4
1600	59.9	64.0	51.0	21.2	29.9	7.8	14.2
1800	67.2	70.0	57.4	22.5	33.3	6.8	16.4
2000	73.6	75.5	64.1	23.5	36.5	5.6	17.7
2200	80.0	80.8	70.9	24.5	39.5	5.0	18.0
2400	85.7	85.4	75.4	25.2	42.3	4.4	18.0
2600	90.9	89.4	80.1	25.9	44.9	4.0	17.9
2800	95.7	93.3	85.4	26.8	48.2	3.7	17.7
3000	100.0	96.8	90.6	27.7	50.7	3.4	17.4
3200	103.3	100.1	94.7	28.6	52.8	3.2	17.2
3400	106.5	103.2	98.1	29.3	54.8	3.1	17.0
3600	109.5	105.9	100.8	29.9	56.5	2.9	16.8
3800	112.0	108.5	103.3	30.4	58.1	2.7	16.6
4000	114.5	110.9	105.8	30.6	59.5	2.4	16.4
4200	117.0	113.0	108.5	30.8	60.7	2.1	16.3
4400	118.8	114.9	111.1	31.0	61.8	1.9	16.1
4600	120.5	116.6	113.5	31.1	62.9	1.7	15.8
4800	122.4	118.2	115.4	31.1	63.9	1.5	15.7
5000	124.1	119.4	117.0	31.1	64.8	1.3	15.5
5200	125.7	120.6	118.5	31.1	65.6	1.2	15.3
5400	127.2	121.6	119.9	31.1	66.4	1.1	15.2
5600	128.3	122.4	121.1	30.9	67.0	1.0	15.0
5800	129.4	123.2	122.4	30.8	67.6	0.9	14.9
6000	130.4	123.9	123.6	30.7	68.0	0.8	14.8

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs).

Sailor Bar Study Site - Transect 2

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	224.0	210.2	200.1	169.5	220.9	78.7	104.0
1200	263.6	252.1	252.9	171.6	247.4	80.2	106.2
1400	299.2	286.5	294.4	166.0	265.0	75.9	104.5
1600	331.2	313.6	326.5	152.1	272.8	64.2	101.2
1800	355.6	332.7	350.4	133.9	269.1	50.1	98.2
2000	370.1	343.0	361.2	114.5	258.8	36.9	95.7
2200	375.7	344.6	365.2	96.4	242.0	26.0	93.9
2400	373.7	338.8	368.4	80.2	221.6	17.5	92.9
2600	363.3	325.2	367.9	66.3	198.8	12.4	91.8
2800	346.1	305.2	360.8	54.6	174.1	9.3	91.5
3000	326.6	284.4	346.9	44.9	152.0	6.8	91.5
3200	304.2	260.8	323.8	37.2	131.2	5.0	89.9
3400	281.5	236.9	301.8	31.0	112.7	3.8	87.3
3600	257.9	214.4	281.2	26.0	96.3	3.1	82.6
3800	234.2	193.7	263.0	21.8	82.5	2.6	75.9
4000	208.8	173.0	244.6	18.4	69.8	2.2	67.3
4200	184.8	154.6	226.5	15.6	58.5	1.9	58.8
4400	163.5	138.6	208.9	13.3	48.7	1.5	51.4
4600	145.6	124.5	189.9	11.4	40.7	1.2	44.5
4800	130.1	112.4	169.9	9.9	34.2	0.9	39.7
5000	117.2	101.7	152.3	8.6	28.9	0.8	36.4
5200	104.7	91.5	136.6	7.5	23.9	0.7	33.4
5400	93.9	82.8	124.7	6.6	19.7	0.6	30.7
5600	85.5	76.1	116.1	5.7	16.8	0.5	28.5
5800	77.5	69.7	107.1	5.0	14.3	0.5	25.1
6000	70.4	64.1	97.9	4.3	12.5	0.5	21.5

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs).

Above Sunrise 14 Study Site - Transect 1

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	234.9	195.1	193.9	116.2	209.8	20.1	71.3
1200	259.6	216.5	221.1	98.3	221.3	22.4	69.8
1400	281.6	231.0	238.9	84.0	225.1	25.7	68.5
1600	300.8	238.1	255.4	74.0	223.4	27.7	71.5
1800	318.4	239.1	275.7	66.4	217.7	28.2	72.3
2000	329.1	236.1	294.9	60.0	210.1	27.6	71.6
2200	327.4	230.6	310.4	54.5	201.1	25.9	71.1
2400	319.9	224.0	305.8	49.4	191.7	22.9	70.2
2600	311.0	215.9	291.7	44.6	182.8	19.7	68.7
2800	300.6	206.9	282.4	39.7	172.8	16.6	66.9
3000	289.0	199.1	274.8	34.7	163.2	13.7	63.9
3200	273.8	190.4	266.1	30.0	155.1	11.3	60.4
3400	260.0	182.2	254.7	25.9	145.8	9.2	56.9
3600	245.8	173.9	244.2	22.2	135.6	7.6	53.5
3800	234.6	165.7	233.7	19.0	125.7	6.4	50.3
4000	226.3	157.4	223.7	16.1	116.8	5.2	47.3
4200	218.2	149.6	214.4	13.6	108.0	4.3	46.3
4400	210.4	141.2	203.8	11.5	99.6	3.5	45.4
4600	203.5	132.6	194.1	9.7	91.9	2.8	44.8
4800	195.3	124.4	187.4	8.2	84.3	2.1	43.9
5000	186.1	116.0	182.3	7.1	77.3	1.7	42.9
5200	176.2	108.1	178.6	6.0	70.7	1.3	42.0
5400	165.6	100.5	173.8	5.2	64.2	1.0	40.8
5600	155.7	92.8	168.9	4.5	58.1	0.9	39.9
5800	144.4	85.3	163.0	3.9	52.6	0.8	39.0
6000	133.0	78.3	155.4	3.4	47.2	0.7	38.2

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs).

Above Sunrise 14 Study Site - Transect 2

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	220.4	214.5	174.6	104.5	179.6	12.1	53.4
1200	263.6	247.8	229.7	92.3	198.7	12.9	50.0
1400	292.1	274.4	264.4	81.5	210.6	16.8	51.6
1600	312.5	294.0	288.8	71.5	217.4	22.4	53.7
1800	328.8	306.3	310.4	62.5	217.2	26.9	55.3
2000	339.0	312.2	324.6	55.8	214.2	29.1	55.6
2200	346.3	312.6	334.3	50.5	208.8	28.3	55.5
2400	345.6	308.4	338.6	46.0	200.9	24.9	55.9
2600	341.8	300.3	342.9	41.8	191.0	20.8	55.6
2800	334.6	289.7	340.3	37.4	179.8	17.1	54.9
3000	324.9	276.8	328.2	32.9	168.5	14.0	54.3
3200	312.9	262.4	316.5	28.8	157.0	11.6	52.9
3400	297.3	247.5	307.0	25.1	145.1	9.8	50.8
3600	280.6	231.8	294.9	21.7	133.9	8.4	48.0
3800	264.0	215.7	284.2	18.9	123.0	7.3	45.3
4000	247.5	200.2	269.8	16.4	112.5	6.4	42.5
4200	232.1	184.8	255.0	14.1	102.5	5.5	39.6
4400	216.5	170.0	239.4	12.1	93.3	4.7	38.2
4600	201.5	155.6	225.6	10.3	84.5	4.1	37.3
4800	186.1	142.2	213.1	8.8	75.8	3.4	37.2
5000	171.0	129.4	202.0	7.5	68.1	2.8	37.0
5200	156.6	117.3	188.4	6.4	60.9	2.2	36.6
5400	142.9	105.6	174.2	5.5	54.6	1.8	36.0
5600	130.0	95.0	159.7	4.7	48.7	1.5	35.3
5800	118.1	85.0	145.0	4.1	43.4	1.3	34.5
6000	106.0	75.9	130.4	3.5	38.4	1.1	33.6

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs).

Above Sunrise 16 Study Site - Transect 1

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	23.8	14.9	45.6	41.3	31.0	8.0	3.2
1200	42.7	29.9	64.2	46.2	43.7	13.1	3.9
1400	58.8	43.7	75.8	49.2	52.1	17.1	6.8
1600	70.9	53.6	86.4	52.1	58.3	19.5	11.5
1800	80.9	60.3	98.6	53.2	63.8	21.0	14.0
2000	89.9	64.2	114.4	51.4	65.9	21.7	16.3
2200	94.3	66.4	123.9	48.1	66.8	20.6	18.3
2400	97.1	72.7	135.7	48.8	69.7	17.8	19.5
2600	100.0	73.1	133.4	45.9	68.1	15.8	20.9
2800	99.6	73.0	127.0	43.0	65.4	14.3	22.0
3000	97.3	72.2	120.4	40.3	62.2	13.0	22.8
3200	93.6	70.7	114.3	37.5	58.9	11.6	23.3
3400	97.0	69.0	109.3	34.7	55.0	9.8	25.7
3600	91.1	66.8	103.9	32.0	51.1	8.0	25.3
3800	84.2	64.2	98.3	29.6	47.3	6.5	24.7
4000	83.9	64.1	98.0	29.5	47.1	6.4	24.7
4200	77.4	61.4	93.1	27.3	43.6	5.2	23.9
4400	71.8	58.2	88.7	25.3	40.0	4.2	22.8
4600	66.4	55.2	83.1	23.5	36.6	3.5	21.2
4800	61.5	52.4	77.4	22.0	33.8	3.0	19.5
5000	57.3	49.6	72.6	20.6	31.4	2.6	17.6
5200	54.1	46.9	68.8	19.3	28.9	2.2	15.5
5400	51.2	44.4	66.3	18.2	26.8	1.9	13.9
5600	48.5	42.3	63.9	17.1	24.6	1.7	12.4
5800	45.8	40.3	61.5	16.3	23.0	1.5	10.9
6000	43.5	38.4	58.5	15.4	21.6	1.2	9.6

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs).

Above Sunrise 16 Study Site - Transect 2

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	15.8	10.5	28.8	59.8	29.4	12.6	3.5
1200	36.6	23.9	66.2	77.9	47.5	18.3	8.9
1400	59.2	40.3	93.6	83.2	63.4	20.0	10.5
1600	77.9	56.7	107.9	81.2	76.3	18.9	12.2
1800	90.9	70.8	119.3	75.6	81.2	17.0	13.7
2000	102.1	80.9	129.3	68.5	81.6	14.8	15.6
2200	110.7	87.2	134.3	61.9	80.1	12.7	16.4
2400	116.6	89.3	138.0	52.7	74.3	11.6	18.8
2600	119.4	88.7	138.8	47.7	69.1	11.1	19.6
2800	117.0	85.6	137.2	42.9	63.3	10.7	20.3
3000	111.8	80.3	131.4	38.7	57.6	10.0	20.9
3200	105.5	74.7	122.6	35.0	52.6	9.5	20.8
3400	101.0	69.0	117.1	31.8	48.0	8.0	20.8
3600	92.3	63.3	106.8	28.9	43.4	6.9	20.6
3800	83.4	58.4	99.1	26.4	39.2	5.8	20.2
4000	83.0	58.2	98.8	26.3	39.0	5.7	20.1
4200	74.8	53.9	92.3	24.2	35.6	4.9	19.3
4400	67.4	49.7	85.1	22.0	32.8	4.0	18.1
4600	60.9	45.9	77.9	20.1	30.1	3.3	17.0
4800	54.7	42.7	72.0	18.5	27.6	2.7	15.9
5000	49.4	39.7	66.4	17.1	25.1	2.2	14.9
5200	44.8	37.1	62.1	16.0	22.9	1.7	13.8
5400	41.4	34.7	59.0	15.0	21.0	1.3	12.9
5600	38.9	32.6	55.3	14.2	19.3	1.0	12.2
5800	36.6	30.8	51.4	13.6	17.9	0.8	11.6
6000	34.5	29.1	47.1	13.1	16.7	0.7	11.2

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs)

Above Sunrise 23 Study Site - Transect 1

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	124.8	87.5	149.1	76.9	88.3	50.3	54.9
1200	127.8	93.6	140.2	71.0	87.9	39.1	58.9
1400	126.5	96.7	135.5	67.0	85.2	32.6	60.2
1600	125.3	96.9	132.6	65.9	86.4	32.5	59.6
1800	121.3	95.7	132.3	66.3	86.7	34.9	59.3
2000	119.2	93.2	138.2	65.5	87.0	37.8	60.9
2200	121.0	92.4	146.6	63.3	88.4	39.4	60.2
2400	128.1	92.4	148.0	60.1	88.8	39.2	59.3
2600	130.8	92.8	149.8	56.4	88.6	36.9	61.1
2800	135.2	93.7	150.8	52.0	86.9	31.0	62.1
3000	138.4	94.4	149.1	47.4	84.2	24.3	63.0
3200	139.6	94.4	143.8	42.6	80.7	18.3	63.0
3400	136.3	93.4	138.1	37.9	76.7	13.7	62.8
3600	130.8	91.2	134.4	33.6	72.1	10.4	62.1
3800	124.3	88.4	130.5	29.7	67.3	8.1	60.1
4000	116.9	84.6	124.6	26.3	62.7	6.2	58.3
4200	109.9	80.5	117.2	23.2	58.2	4.8	56.2
4400	102.6	76.3	108.5	20.6	54.3	3.7	54.1
4600	95.7	71.9	100.0	18.3	50.7	2.8	51.7
4800	89.3	67.5	93.4	16.2	47.5	2.3	49.2
5000	83.1	63.5	88.6	14.4	44.3	1.9	46.9
5200	77.4	60.0	83.9	12.7	41.3	1.6	44.2
5400	71.8	56.6	79.7	11.3	38.9	1.2	41.0
5600	66.7	53.5	75.6	10.1	36.6	1.0	37.6
5800	62.6	50.6	71.7	8.9	34.5	0.7	34.0
6000	58.6	47.9	68.6	7.9	32.5	0.6	30.9

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs).

Above Sunrise 23 Study Site - Transect 2

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	108.7	86.7	139.5	49.1	78.2	21.3	19.6
1200	108.1	81.0	144.8	51.7	75.4	30.8	28.6
1400	107.0	76.6	133.2	54.2	76.4	36.6	32.2
1600	106.1	75.1	141.9	54.5	73.3	39.0	36.4
1800	103.9	73.8	144.9	53.9	73.5	37.2	41.9
2000	100.9	73.3	135.3	52.4	76.8	35.4	43.1
2200	97.6	73.3	134.5	48.9	74.7	31.7	43.7
2400	95.3	73.3	140.1	44.2	72.2	27.4	45.7
2600	93.6	73.5	145.7	39.0	68.3	23.4	44.0
2800	99.2	73.0	143.4	34.1	63.9	18.2	41.8
3000	102.0	71.9	131.8	29.8	59.8	14.0	40.1
3200	99.0	70.5	121.0	26.2	55.8	11.3	38.6
3400	94.6	68.3	108.4	23.2	52.4	8.6	36.2
3600	89.3	65.5	97.1	20.5	48.7	6.3	33.8
3800	84.0	62.9	89.1	18.1	45.4	4.3	31.4
4000	78.8	60.1	84.0	16.1	42.5	2.9	29.1
4200	74.6	57.8	80.5	14.2	39.6	2.0	26.9
4400	70.6	55.5	75.9	12.6	37.0	1.4	25.7
4600	67.3	53.2	71.4	11.4	35.0	1.1	24.7
4800	64.0	50.9	67.5	10.3	33.0	0.9	23.8
5000	61.0	48.4	65.0	9.4	31.0	0.8	23.4
5200	58.4	46.2	63.3	8.5	29.1	0.6	22.9
5400	56.0	44.0	62.0	7.8	27.3	0.5	22.3
5600	53.7	41.9	61.0	7.1	25.7	0.4	21.6
5800	51.4	39.9	59.3	6.5	24.3	0.4	20.9
6000	49.3	38.0	57.6	5.9	23.0	0.3	20.0

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs).

At Sunrise 26 Study Site - Transect 1

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	145.9	114.6	184.2	66.3	100.2	40.7	33.6
1200	158.2	124.0	217.6	65.6	109.0	45.9	44.4
1400	175.4	133.7	232.7	60.2	112.0	35.3	52.4
1600	192.5	141.0	233.1	53.1	110.6	25.0	60.3
1800	195.7	143.1	226.0	45.5	104.4	19.1	64.8
2000	187.3	139.0	214.2	38.7	95.0	13.0	66.9
2200	175.3	131.0	200.0	33.2	85.6	7.6	67.7
2400	160.0	120.6	186.5	29.0	76.3	4.7	67.2
2600	145.0	109.5	174.7	25.7	68.3	3.2	65.9
2800	130.2	99.5	165.1	23.1	61.1	2.3	63.3
3000	115.4	89.9	152.0	20.9	55.6	1.6	59.1
3200	103.5	81.3	138.9	19.0	51.0	1.3	54.9
3400	93.3	73.7	125.5	17.3	46.7	1.2	50.3
3600	83.7	66.9	113.9	15.8	43.1	1.3	46.4
3800	74.5	61.2	105.3	14.6	39.5	1.3	42.6
4000	66.0	56.5	98.7	13.8	36.3	1.3	38.3
4200	59.2	52.5	93.1	13.2	34.2	1.4	34.4
4400	53.7	48.8	88.1	13.2	33.6	2.0	30.8
4600	49.2	45.7	82.2	13.5	32.7	3.0	28.6
4800	45.8	42.7	77.0	13.9	32.6	4.5	30.5
5000	43.2	40.4	72.6	14.6	32.6	6.5	29.3
5200	40.9	38.5	69.2	15.2	32.7	8.9	29.5
5400	39.3	37.3	66.6	15.9	33.2	11.5	30.5
5600	37.9	36.4	63.8	16.7	33.8	13.6	30.6
5800	37.0	35.7	60.7	17.4	34.7	14.7	31.2
6000	36.9	35.6	56.7	18.1	35.7	14.9	32.0

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs).

At Sunrise 26 Study Site - Transect 2

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	264.8	162.4	227.0	94.4	189.1	54.1	101.1
1200	280.0	180.1	234.4	78.0	189.4	34.0	97.5
1400	284.3	186.6	239.4	63.5	179.9	23.6	96.2
1600	289.3	184.1	244.2	52.6	168.4	19.6	97.2
1800	292.6	176.5	248.6	44.6	155.8	18.7	97.0
2000	289.5	166.7	252.0	38.8	143.8	18.1	98.8
2200	279.8	155.8	255.4	34.7	131.6	17.1	99.0
2400	267.7	144.8	254.2	32.0	120.3	15.8	101.2
2600	254.5	134.1	244.7	30.1	110.1	14.6	101.3
2800	240.5	123.8	231.0	28.9	100.8	13.7	101.6
3000	224.9	114.6	217.9	28.1	93.5	13.0	101.1
3200	209.1	106.1	206.9	27.2	87.4	12.5	98.7
3400	194.4	98.2	197.7	26.1	81.5	12.1	97.3
3600	179.5	91.5	189.2	24.8	75.8	11.8	94.2
3800	165.5	85.7	180.7	23.3	71.0	11.7	89.3
4000	153.5	80.8	169.5	22.0	66.4	11.2	83.1
4200	143.3	76.2	158.3	20.8	62.3	10.1	76.3
4400	134.2	71.8	148.4	19.6	58.2	8.5	69.8
4600	125.8	68.1	139.9	18.5	54.1	7.0	64.5
4800	118.0	64.7	132.7	17.3	49.9	5.4	60.1
5000	110.6	61.4	124.3	16.0	46.1	3.9	55.8
5200	102.3	58.1	116.5	14.8	42.7	2.9	51.2
5400	93.5	54.8	109.6	13.6	39.6	2.2	47.3
5600	85.9	51.4	102.3	12.6	36.6	1.6	43.7
5800	78.8	48.0	95.5	11.5	34.0	1.3	39.9
6000	71.8	45.0	89.3	10.7	31.6	1.1	36.7

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs).

Below Sunrise 29 Study Site - Transect 1

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	281.3	255.4	278.7	144.3	236.0	43.8	66.7
1200	297.3	283.9	287.0	115.5	241.9	26.8	66.9
1400	304.2	299.4	291.8	87.7	237.4	16.0	64.5
1600	307.6	303.4	295.0	64.9	224.4	10.3	62.3
1800	310.5	298.5	297.3	48.4	207.8	6.6	61.3
2000	313.0	287.4	299.8	37.1	190.6	4.5	60.9
2200	313.6	272.3	301.6	28.6	173.3	3.4	60.7
2400	309.1	254.7	303.7	22.5	156.3	3.2	61.9
2600	296.4	235.5	305.2	17.8	139.7	3.4	62.3
2800	277.3	215.3	302.4	14.4	123.8	3.9	62.5
3000	255.6	195.5	290.8	12.0	109.1	4.1	62.7
3200	232.8	176.2	270.9	10.2	95.9	3.9	62.9
3400	210.4	158.3	244.0	8.9	84.2	3.5	63.0
3600	189.0	141.8	216.1	8.1	74.4	3.2	62.0
3800	168.5	126.8	189.3	7.4	66.0	3.1	60.9
4000	149.3	113.1	167.2	6.8	58.9	3.1	58.3
4200	131.3	101.3	150.2	6.4	52.6	3.2	55.1
4400	114.5	91.3	136.6	6.0	47.5	3.3	51.2
4600	99.7	82.4	125.7	5.6	43.5	3.4	46.8
4800	87.7	74.8	116.5	5.4	40.4	3.3	42.0
5000	77.8	68.5	108.1	5.1	37.7	3.0	37.4
5200	69.6	63.3	100.5	4.9	35.3	2.8	34.0
5400	62.4	59.0	93.9	4.6	33.1	2.4	30.9
5600	56.8	55.4	87.8	4.4	31.2	2.1	28.0
5800	53.1	52.4	82.4	4.1	29.8	1.8	25.5
6000	50.5	49.7	77.5	3.9	28.6	1.6	23.2

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs).

Below Sunrise 29 Study Site - Transect 2

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	240.6	226.8	237.7	78.1	197.0	2.3	19.3
1200	244.0	241.1	242.7	58.7	197.3	3.9	18.7
1400	247.3	245.4	246.4	44.5	189.1	5.9	17.7
1600	250.7	241.6	250.4	34.3	174.5	7.3	18.6
1800	254.6	231.2	253.7	27.0	158.2	7.5	18.8
2000	253.8	216.1	255.8	22.2	141.9	7.3	19.3
2200	245.4	198.0	257.9	19.2	125.5	7.0	19.4
2400	229.9	178.6	256.2	17.4	109.7	6.9	20.6
2600	208.6	158.7	246.5	16.0	94.4	6.9	20.7
2800	187.0	139.2	227.0	14.7	80.7	6.8	21.5
3000	165.0	121.2	199.7	13.7	68.8	6.5	21.7
3200	144.3	104.5	170.9	12.9	59.4	6.1	21.8
3400	124.6	89.8	146.9	12.0	50.7	5.5	21.9
3600	105.7	77.1	128.2	11.0	43.4	4.9	22.8
3800	88.0	66.0	114.4	10.0	37.1	4.2	23.1
4000	72.7	56.4	102.3	8.9	32.2	3.6	22.5
4200	60.1	48.4	91.1	8.0	28.2	3.5	21.8
4400	49.3	41.5	80.8	7.2	24.6	3.4	20.5
4600	40.0	35.8	72.5	6.5	21.6	3.4	19.3
4800	33.2	30.9	65.8	6.1	18.9	3.3	17.7
5000	28.3	27.0	59.9	5.8	17.3	3.1	15.9
5200	25.2	24.0	53.1	5.7	15.8	3.2	13.9
5400	23.1	21.4	47.2	5.6	14.7	3.4	11.8
5600	21.2	19.3	41.9	5.5	13.7	3.7	11.0
5800	19.6	17.7	36.9	5.4	12.8	4.1	9.9
6000	18.2	16.3	32.5	5.5	12.0	4.5	8.5

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs).

Below Sunrise 30 Study Site - Transect 1

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	136.0	119.9	137.3	59.9	59.9	17.9	22.2
1200	147.3	127.8	148.2	60.2	60.2	10.7	22.7
1400	151.8	132.3	156.0	54.8	54.8	6.9	20.7
1600	148.2	134.0	155.8	48.3	48.3	5.3	18.7
1800	142.8	132.9	151.9	42.2	42.2	5.2	17.2
2000	137.8	129.3	148.0	36.8	36.8	5.9	18.5
2200	135.6	123.6	141.9	32.2	32.2	6.9	18.8
2400	132.0	116.1	137.3	28.2	28.2	7.3	19.1
2600	126.6	107.9	135.6	25.0	25.0	6.4	19.3
2800	119.2	99.1	133.3	22.3	22.3	4.9	19.3
3000	109.5	90.7	128.4	20.0	20.0	3.9	19.1
3200	99.3	82.2	119.6	18.1	18.1	3.3	20.2
3400	89.6	74.5	107.1	16.4	16.4	3.0	20.3
3600	80.1	67.1	92.9	15.1	15.1	3.0	20.7
3800	71.2	60.7	80.9	14.1	14.1	3.2	20.9
4000	63.0	54.7	71.9	13.2	13.2	3.6	21.2
4200	55.8	49.8	65.5	12.5	12.5	4.2	21.8
4400	48.8	45.3	60.5	11.9	11.9	4.8	21.1
4600	43.1	41.5	57.2	11.6	11.6	5.5	20.3
4800	38.8	38.4	54.2	11.5	11.5	6.2	19.3
5000	35.8	35.8	51.1	11.7	11.7	7.2	18.2
5200	33.6	33.9	47.8	12.4	12.4	8.5	17.6
5400	32.4	32.2	44.5	13.2	13.2	10.3	17.0
5600	31.4	30.8	42.2	14.2	14.2	12.8	16.9
5800	30.7	29.7	40.7	15.6	15.6	16.0	24.3
6000	30.2	29.0	38.8	17.2	17.2	20.0	26.4

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs).

Below Sunrise 30 Study Site - Transect 2

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	140.0	118.5	147.3	74.2	132.6	17.5	19.5
1200	165.5	135.0	180.6	81.1	146.6	30.7	29.0
1400	176.0	150.7	198.5	76.0	154.7	35.2	33.3
1600	181.2	161.7	200.1	67.6	153.7	30.4	33.7
1800	184.3	166.7	196.9	58.5	147.5	22.9	34.2
2000	183.9	165.4	194.7	49.8	136.4	17.0	33.9
2200	182.3	158.9	195.2	42.1	123.9	14.3	33.2
2400	180.4	148.7	196.6	36.2	112.6	14.2	33.7
2600	171.7	137.3	197.1	31.7	99.6	15.1	33.9
2800	159.1	124.6	196.9	29.2	87.5	15.0	36.9
3000	145.1	112.1	191.2	29.7	77.3	15.6	38.2
3200	133.7	100.3	175.5	30.6	71.6	16.6	41.1
3400	119.5	89.3	157.4	31.4	65.5	16.7	42.2
3600	105.6	79.4	143.7	31.7	60.2	16.1	44.7
3800	94.4	71.4	133.1	31.3	56.2	16.0	45.6
4000	87.9	64.8	123.1	30.4	53.2	15.8	43.6
4200	80.8	59.9	112.7	29.2	50.8	14.6	40.6
4400	73.8	56.0	103.8	27.6	48.8	12.8	37.0
4600	68.4	52.7	96.9	25.9	46.8	10.8	33.0
4800	63.2	50.4	90.8	24.0	44.8	8.5	29.8
5000	58.7	48.5	85.0	22.0	42.7	6.8	27.0
5200	54.8	46.6	78.9	20.2	40.3	5.5	24.4
5400	49.7	44.8	73.2	18.4	37.5	4.6	23.1
5600	45.6	42.9	68.0	16.8	35.0	4.0	22.1
5800	42.4	40.8	62.7	15.4	32.9	3.5	21.0
6000	40.1	38.7	56.8	14.1	31.2	3.1	20.3

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs).

El Manto Study Site - Transect 1

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	146.6	133.8	141.2	23.1	80.1	2.3	5.7
1200	148.7	128.3	150.4	21.5	74.3	4.1	6.2
1400	144.5	117.9	148.4	21.2	67.2	4.8	6.5
1600	134.5	105.2	141.9	21.8	60.3	4.1	6.7
1800	122.3	93.4	134.2	22.0	54.3	3.8	6.5
2000	108.1	83.0	118.6	21.7	49.1	4.2	8.1
2200	96.4	74.1	109.0	21.0	44.3	5.1	8.2
2400	87.0	67.3	97.8	20.3	40.9	5.9	8.2
2600	79.2	61.4	87.9	19.6	38.2	6.1	8.3
2800	72.8	56.4	83.8	18.9	35.4	5.9	8.3
3000	67.7	52.5	79.8	18.4	33.2	5.5	9.8
3200	64.4	49.3	74.3	17.9	31.2	5.4	10.1
3400	61.3	46.6	68.7	17.4	29.4	5.6	10.5
3600	58.5	43.9	63.1	16.9	27.9	6.0	10.9
3800	56.4	41.6	59.9	16.4	26.3	6.3	10.9
4000	53.6	39.7	57.0	15.8	24.6	6.3	11.9
4200	50.4	37.8	53.5	15.2	23.4	6.2	12.0
4400	47.5	35.9	50.7	14.5	22.3	6.1	12.2
4600	44.8	34.1	49.4	13.8	21.0	5.9	12.3
4800	41.7	32.7	46.6	13.2	19.8	5.9	12.4
5000	38.9	31.3	43.5	12.6	18.9	5.8	12.4
5200	36.5	29.8	40.7	12.2	18.1	5.7	12.6
5400	34.4	28.5	38.3	11.8	17.5	5.4	12.7
5600	32.2	27.2	36.8	11.4	16.8	5.0	12.9
5800	30.3	26.1	34.5	11.1	16.2	4.6	12.9
6000	29.0	25.0	32.5	10.8	15.8	4.1	12.7

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs).

El Manto Study Site - Transect 2

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	132.9	123.2	129.7	26.1	85.3	5.1	7.3
1200	136.2	117.2	139.0	26.6	77.8	7.3	8.0
1400	129.2	107.5	142.3	27.0	69.3	8.5	10.5
1600	119.1	97.4	128.1	26.7	61.9	9.8	12.1
1800	106.7	88.5	115.9	26.0	55.7	10.9	13.2
2000	96.3	81.1	105.9	24.9	50.6	11.8	15.0
2200	86.2	75.4	98.8	24.1	46.9	12.4	15.4
2400	81.1	70.7	94.6	23.4	43.3	12.5	15.5
2600	78.1	67.2	89.4	22.9	40.5	12.3	16.3
2800	76.3	63.9	84.8	22.0	38.1	11.5	16.9
3000	74.5	61.0	81.1	21.3	35.6	10.7	17.0
3200	72.0	58.3	78.3	20.7	33.4	10.1	16.8
3400	69.1	55.5	74.6	20.3	31.8	9.5	16.5
3600	65.6	52.9	71.2	19.9	30.0	8.9	16.3
3800	62.2	50.4	67.8	19.2	28.2	8.4	16.0
4000	59.6	47.7	67.1	18.3	26.5	8.1	17.8
4200	57.3	45.5	65.6	17.3	25.0	8.0	17.8
4400	54.0	43.3	63.2	16.4	23.5	7.9	17.9
4600	51.9	41.2	59.5	15.8	22.0	7.6	18.0
4800	49.7	39.2	56.3	15.2	21.3	7.3	18.0
5000	47.3	37.3	53.7	14.7	20.2	6.9	17.9
5200	45.2	35.5	51.7	14.3	19.3	6.3	17.9
5400	43.7	33.8	50.2	14.2	18.3	5.7	17.7
5600	41.7	32.2	48.5	14.4	18.6	5.2	17.5
5800	39.7	30.7	46.6	14.8	18.9	4.9	17.1
6000	37.4	29.3	44.3	15.4	19.0	4.7	16.6

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs).

Rossmoor 2 Study Site - Transect 1

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	158.0	119.2	190.0	73.7	72.1	2.3	0.0
1200	158.0	121.9	195.1	68.9	70.6	5.4	0.0
1400	152.8	119.5	194.9	62.7	67.3	8.9	4.5
1600	150.9	118.3	194.0	58.5	66.1	12.5	5.7
1800	148.3	113.8	186.5	54.8	63.8	13.1	6.9
2000	144.3	110.5	180.0	53.0	63.6	11.9	10.1
2200	138.0	106.9	172.7	52.2	61.6	10.8	11.4
2400	131.9	102.7	163.3	51.6	60.6	9.8	12.1
2600	125.0	99.4	156.0	51.3	60.5	8.4	12.5
2800	117.5	95.9	147.3	50.6	62.5	6.7	12.4
3000	111.0	93.2	143.0	49.5	63.5	5.1	12.4
3200	108.3	91.7	147.6	46.7	63.4	3.8	12.3
3400	104.5	90.5	149.5	43.0	61.8	2.9	12.0
3600	104.0	90.1	151.0	38.8	59.9	2.3	11.2
3800	105.3	89.6	148.1	34.7	57.4	1.7	10.4
4000	104.6	88.3	143.0	30.7	54.0	1.2	9.5
4200	102.6	86.9	136.3	27.0	50.0	0.8	8.7
4400	99.4	85.1	128.0	23.6	46.3	0.6	8.0
4600	95.7	82.0	119.1	20.6	42.5	0.4	7.2
4800	92.3	79.1	112.1	17.6	39.1	0.3	6.5
5000	87.7	75.7	105.4	15.0	35.6	0.2	6.4
5200	82.4	71.4	99.2	12.8	32.9	0.2	6.4
5400	77.5	67.5	93.5	10.8	30.6	0.1	6.4
5600	72.8	63.6	88.3	9.0	28.5	0.1	6.4
5800	68.4	60.0	83.8	7.6	26.5	0.1	6.4
6000	64.4	56.3	79.5	6.4	24.7	0.1	6.4

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs).

Rossmoor 2 Study Site - Transect 2

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	172.0	137.1	210.6	79.3	109.2	18.1	18.6
1200	174.5	133.7	210.2	73.3	108.5	14.9	19.7
1400	171.0	130.0	203.2	67.6	105.9	12.1	20.5
1600	164.9	127.1	197.0	63.1	101.0	10.8	20.2
1800	156.3	122.8	185.7	60.6	96.8	10.9	22.4
2000	144.5	117.1	178.2	60.0	92.2	12.8	21.7
2200	135.7	110.6	174.1	59.9	87.6	15.0	22.2
2400	131.6	105.5	174.6	59.6	86.8	16.9	23.5
2600	126.8	101.0	170.7	58.2	85.7	17.7	24.8
2800	121.1	96.3	164.5	56.1	83.7	17.6	26.5
3000	118.1	95.0	160.1	53.5	82.4	16.8	27.5
3200	113.3	91.5	154.1	50.0	78.7	15.5	27.9
3400	113.2	90.6	149.4	46.1	75.6	13.8	28.2
3600	111.4	88.6	142.5	42.2	71.5	12.1	27.8
3800	108.7	86.6	134.9	38.5	67.1	10.3	27.5
4000	104.6	84.2	128.0	35.1	62.6	8.5	27.1
4200	98.9	80.3	121.2	31.9	57.9	7.2	26.2
4400	92.8	76.4	111.5	29.0	53.9	6.1	25.1
4600	85.6	72.2	103.8	26.5	50.3	5.0	24.0
4800	79.1	67.9	96.1	24.3	46.9	4.3	22.7
5000	72.9	64.0	89.2	22.3	44.0	3.7	21.5
5200	66.7	60.0	81.7	20.7	41.4	3.2	20.7
5400	61.8	56.6	75.2	19.1	39.3	2.9	20.1
5600	57.5	53.6	69.5	17.6	37.7	2.5	19.8
5800	53.6	50.7	64.3	16.2	36.2	2.2	19.4
6000	50.5	48.1	59.9	15.0	34.9	1.9	19.0

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs).

Rossmoor 1 Study Site - Transect 1

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	165.2	141.7	172.9	32.3	67.3	0.6	9.8
1200	150.7	123.7	171.7	21.4	57.5	0.2	9.3
1400	130.5	106.1	158.6	13.8	48.3	0.2	9.0
1600	109.7	89.9	135.4	8.8	40.5	0.2	8.8
1800	90.6	75.8	109.2	6.0	34.5	0.1	8.5
2000	74.1	64.0	88.7	4.4	29.8	0.0	8.1
2200	59.8	55.2	77.4	3.5	25.7	0.0	7.5
2400	47.8	48.0	68.5	2.7	23.0	0.0	6.8
2600	39.2	42.6	62.0	2.1	21.0	0.0	6.2
2800	33.3	38.4	56.3	1.6	19.3	0.0	5.5
3000	28.6	35.5	51.1	1.3	17.7	0.0	4.8
3200	27.1	33.3	47.1	1.0	16.7	0.0	4.2
3400	26.3	31.7	42.4	0.8	15.9	0.0	3.9
3600	26.0	30.6	38.9	0.7	15.2	0.0	3.9
3800	25.8	29.6	36.8	0.6	14.9	0.0	3.9
4000	25.4	29.0	33.6	0.5	14.8	0.0	3.9
4200	25.0	28.5	31.0	0.4	14.6	0.0	3.9
4400	24.6	27.7	30.3	0.4	14.5	0.0	3.9
4600	24.4	27.5	29.6	0.3	14.3	0.0	3.9
4800	24.1	27.3	28.3	0.3	15.0	0.0	3.9
5000	23.9	27.2	27.0	0.2	15.4	0.0	3.9
5200	23.7	27.1	26.5	0.2	15.4	0.0	3.9
5400	23.4	27.0	26.2	0.2	15.4	0.0	3.9
5600	23.4	27.0	25.9	0.1	15.3	0.0	3.9
5800	23.5	27.0	25.8	0.1	15.2	0.0	3.9
6000	23.6	27.0	26.0	0.1	15.2	0.0	3.9

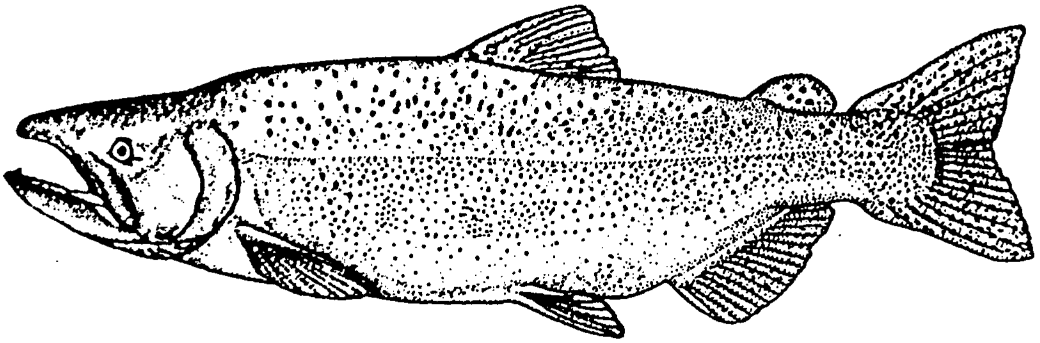
Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs).

Rossmoor 1 Study Site - Transect 2

Flow	Feather Chinook	Upper Sac Chinook	Yuba Chinook	Trinity Chinook	American Chinook	Trinity Steelhead	American Steelhead
1000	144.9	119.5	156.2	67.0	46.6	0.0	0.0
1200	157.2	127.0	172.5	57.0	46.9	0.0	0.0
1400	157.1	128.9	172.5	46.3	45.4	0.0	0.0
1600	149.1	125.1	165.3	36.9	42.3	0.0	0.0
1800	137.5	117.1	152.1	29.8	39.0	0.0	0.0
2000	126.4	107.2	138.9	24.4	35.9	0.0	0.0
2200	115.3	97.1	127.8	20.4	32.8	0.0	0.0
2400	104.7	87.6	119.3	17.5	30.2	0.0	0.0
2600	93.8	79.3	110.8	15.2	28.1	0.0	0.0
2800	84.7	71.8	104.4	13.4	26.0	0.0	0.0
3000	75.4	65.7	98.2	11.8	24.1	0.0	0.0
3200	67.9	60.2	91.6	10.4	22.5	0.0	0.0
3400	62.6	55.2	84.9	9.2	21.1	0.0	0.0
3600	57.1	51.4	78.0	8.2	19.9	0.0	0.0
3800	52.2	47.6	69.1	7.4	18.9	0.0	0.0
4000	49.0	44.4	60.6	6.5	18.2	0.0	0.0
4200	45.6	41.4	54.2	5.7	17.3	0.0	0.0
4400	42.5	38.8	51.7	5.0	16.6	0.0	0.0
4600	40.0	36.9	49.3	4.3	15.9	0.0	0.0
4800	38.1	35.2	46.4	3.7	15.3	0.0	0.0
5000	36.0	33.5	44.3	3.2	14.8	0.0	0.0
5200	34.0	32.0	42.5	2.7	14.3	0.0	0.0
5400	32.2	30.8	40.2	2.3	13.8	0.0	0.0
5600	31.0	29.8	37.7	2.0	13.3	0.0	0.0
5800	29.7	28.6	36.0	1.7	12.8	0.0	0.0
6000	28.2	27.7	35.1	1.5	12.3	0.1	0.0

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for each criteria set in Appendix C. Flow is release from Nimbus Dam (cfs).

SUPPLEMENTAL REPORT ON THE INSTREAM FLOW REQUIREMENTS FOR FALL-RUN CHINOOK SALMON SPAWNING IN THE LOWER AMERICAN RIVER



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Prepared by staff of
The Instream Flow Assessments Branch

February 1997

PREFACE

The following is a supplemental report for the U.S. Fish and Wildlife Service's investigations on the Lower American River, part of the Anadromous Doubling Plan Instream Flow Investigations, a 5-year effort which began in February, 1995. Title 34, Section 3406(b)(1)(B) of the Central Valley Project Improvement Act, P.L. 102-575, requires the Secretary of the Interior to determine instream flow needs for anadromous fish for all Central Valley Project controlled streams and rivers, based on recommendations of the U.S. Fish and Wildlife Service after consultation with the California Department of Fish and Game (CDFG). The purpose of these investigations is to provide scientific information to the U.S. Fish and Wildlife Service Central Valley Anadromous Fish Restoration Program to be used to develop such recommendations for Central Valley rivers.

To those who are interested, comments and information regarding this report are welcomed. Written comments or information can be submitted to:

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The field work for this supplemental report was conducted by Jeff Thomas, Mark Gard and Sean Gallagher. Data analysis and report preparation were performed by Mark Gard and Jeff Thomas.

ANADROMOUS DOUBLING PLAN INSTREAM FLOW INVESTIGATIONS LOWER AMERICAN RIVER FALL-RUN CHINOOK SPAWNING SUPPLEMENTAL REPORT

INTRODUCTION

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act requires the doubling of the natural production of anadromous fish stocks, including the four races of chinook salmon (fall, late-fall, winter and spring runs), steelhead, and white and green sturgeon. For the Lower American River, the Central Valley Project Improvement Act Anadromous Doubling Plan calls for October through February (during fall-run chinook salmon spawning) flows at the H Street Bridge ranging from 1,750 cfs in critically dry years to 2,500 cfs in wet years. In December 1994, the U.S. Fish and Wildlife Service prepared a study proposal to identify the instream flow requirements for anadromous fish in certain streams within the Central Valley of California, including the Lower American River. In March 1996, the U.S. Fish and Wildlife Service released a final report on physical habitat availability for spawning steelhead trout and fall-run chinook salmon (*Identification of the Instream Flow Requirements for Steelhead and Fall-Run Chinook Salmon Spawning in the Lower American River*). Five different sets of habitat suitability criteria (HSC or HSI Curves) were used to predict weighted useable area (WUA) over a range of streamflows for chinook salmon spawning. One of these sets was site-specific for the Lower American River, however, the criteria were developed from CDFG data not specifically intended for this purpose. The data base was not as large (N=118) as would have been preferred and over 20% of the data were collected in 1992 (a drought year when river flows were around 1000 cfs during the fall). The 1996 spawning season presented an opportunity to develop new site-specific HSC which better represent the physical habitat conditions selected by spawning fall-run chinook salmon in the Lower American River. This supplemental report details the procedures followed in the development of these criteria and presents habitat modeling results obtained using these HSC.

METHODS

Field Data Collection

The primary habitat variables which are used to assess physical habitat suitability for spawning chinook salmon are water depth, velocity, and substrate composition (including embeddedness). Data relative to these variables were collected from 218 fall-run chinook salmon redds on November 6 and 7, 1996 in five of the study sites previously used for habitat modeling (Above Sunrise 14, Above Sunrise 16, At Sunrise 26, Below Sunrise 29 and Below Sunrise 30). Measurements were taken with a wading rod and a Price-AA velocity meter equipped with a current meter digitizer. All recently constructed redds (redds without periphyton) within each study site which could be conclusively identified were measured. Depth and velocity data were collected two to four feet upstream of the spot which was assumed to have hydraulic conditions similar to the redd location prior to redd construction. Depth was recorded to the nearest 0.1 ft and mean water column velocity was recorded to the nearest 0.1 ft/s. Substrate (Table 1) was visually assessed in the tailspill for the dominant particle size range (e.g., range of 1-2"). Substrate embeddedness data were not collected because the substrate adjacent to all of the redds sampled was predominantly unembedded. Releases from Nimbus Dam averaged 2780 cfs during the sampling period. All data were entered into a spreadsheet for analysis and development of HSC (HSI Curves).

Table 1
Substrate Descriptors and Codes

Code	Type	Particle Size (inches)
0	Sand/Silt	< 0.1
1	Small Gravel	0.1 - 1
1.2	Medium Gravel	1 - 2
1.3	Medium Gravel	1 - 3
1.4	Medium Gravel	1 - 4
2.3	Large Gravel	2 - 3
2.4	Gravel/Cobble	2 - 4
3.4	Cobble	3 - 4
3.5	Cobble	3 - 5
3.6	Cobble	3 - 6
4.5	Cobble	4 - 5
4.6	Cobble	4 - 6
5.6	Cobble	5 - 6
6.8	Cobble	6 - 8
8	Cobble	8 - 12
9	Boulder	12 - 24
10	Boulder	> 24
11	Bedrock	

Habitat Suitability Criteria (HSC) Development

Using the data collected from the 218 redds and entered into a spreadsheet, frequency distributions were calculated for depth and velocity and input into the PHABSIM suitability index curve development program (CURVE). The HSI curves were then computed using exponential smoothing. The curves generated were exported into a spreadsheet and modified by truncating at the lower end, so that the next depth or velocity value below the lowest observed value had a SI value of zero; and eliminating points not needed to capture the basic shape of the curves.

Substrate criteria were developed by: 1) determining the number of redds with each substrate code (Table 1); 2) calculating the proportion of redds with each substrate code (number of redds with each substrate code divided by total number of redds); and 3) calculating the HSI value for each substrate code by dividing the proportion of redds in that substrate code by the proportion of redds with the most frequent substrate code.

The initial HSC showed suitability rapidly decreasing for depths greater than 2 feet. This effect was likely due to the low availability of deeper water in the Lower American River with suitable velocities and substrates rather than a selection by the salmon of only shallow depths for spawning[1]. The following method was used to correct the depth criteria for the low availability of deeper water with suitable velocities and substrates. Based on the distribution of velocity and substrate redd data, we concluded that suitable velocities were between 1.3 and 3 ft/s, while suitable substrates were 1-3 to 3-4 inches in diameter (i.e., substrate codes 1.3, 1.4, 2.3, 2.4 and 3.4). A series of HSC sets were constructed where: 1) each set held velocity and substrate HSI values at 1.0 for the velocity and substrate range noted above with all other velocities and substrates assigned a value of 0.0; and 2) each set assigned a different 0.5-foot depth increment an HSI value of 1.0 for depths between 2.0 and 6.0 feet deep, with the other 0.5 foot increments and depths less than 2.0 foot and greater than 6.0 feet given a value of 0.0 (e.g., 2.0-2.5' depth HSI value equal 1.0, <2.0' and >2.5' depths HSI value equals 0.0 for set #1, etc.). Thus, eight sets of HSC were constructed differing only in the suitabilities assigned for optimum depth ranges. Each HSC set was run through the *HABTAE* program using the output of the calibrated hydraulic decks for the five study sites at which HSC data was collected, with the resulting habitat output combined in a spreadsheet to determine the available river area with suitable velocities and substrates for the 0.5-foot depth increments from 2 to 6 feet. The redd data were used to determine the number of redds in each of the above depth increments to assess use. Relative availability and use were then computed by dividing the availability and use for each

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[1] Areas of the river with depths up to six feet were sampled with approximate equal effort as those with depths less than three feet and few redds were found. This sampling confirmed that substrate size and water velocities were generally unsuitable in deeper water.

depth increment by the largest availability or use, thus scaling both measures to have a maximum value of 1.0. Linear regressions of relative availability and use versus the midpoint of the depth increments (i.e., 2.25' for 2-2.5' depth increment) were used to remove noise from the data and produce linearized values of relative availability and use at the midpoints of the depth increments. The results of the regressions showed that availability dropped with increasing depth, but not quite as quickly as use. For the range of depths where the regression equations predicted positive relative use and availability, linearized use was divided by linearized availability, and the resulting ratios were scaled so that the maximum ratio was 1.0. A third linear regression of the scaled ratios versus the midpoint of the depth increments was used to determine the depth at which the scaled ratios reached zero. The result of this regression was that the scaled ratio reached zero at 10.8 feet; thus, the depth criteria were modified to have a linear decrease in suitability from 1.0 for the highest depth in the original criteria which had a suitability of 1.0, to a suitability of 0.0 at 10.8 feet. The resulting criteria are show in Figures 1 through 3 and Appendix A.

These HSC differ substantially from the previous Lower American River criteria presented in the March 1996 report. As mentioned above, those HSC were developed from data not collected for this purpose and appear biased toward shallow depths and slower velocities. As a result, we recommend that those criteria not be used.

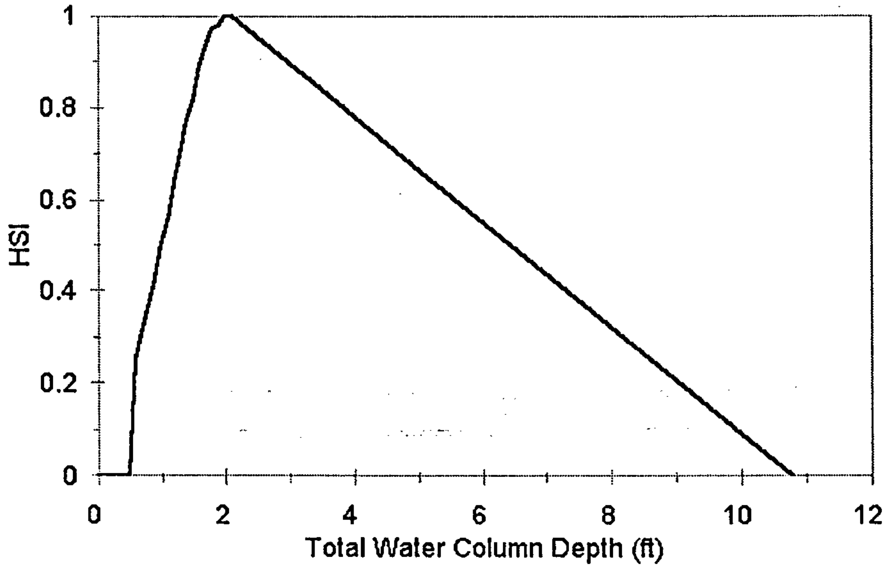

Figure 1
Fall-run Chinook Salmon HSI Curve for Depth

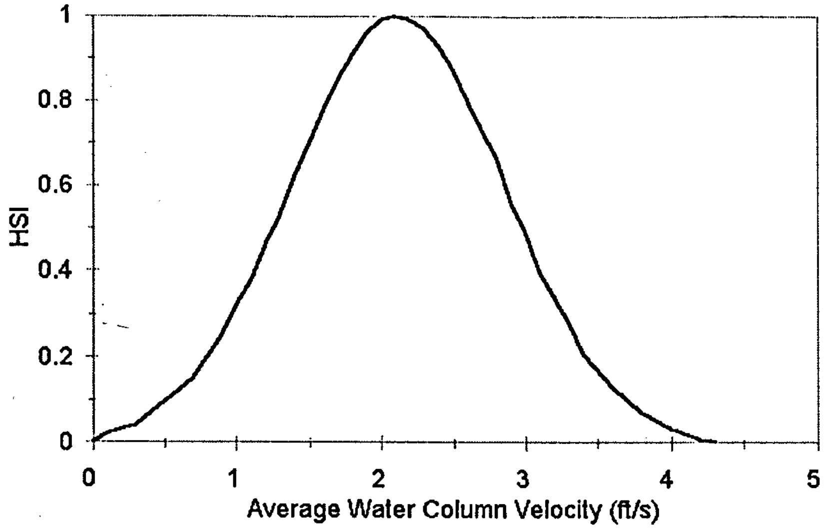

Figure 2
Fall-run Chinook Salmon HSI Curve for Velocity

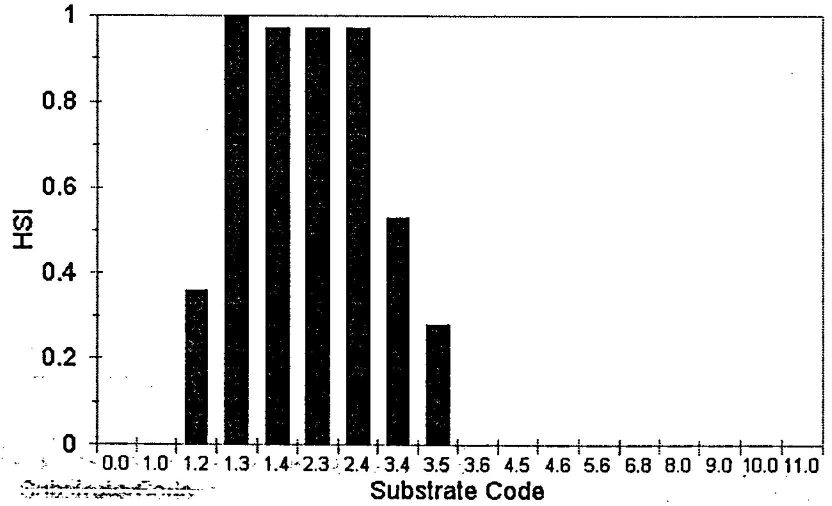

Figure 3
Fall-run Chinook Salmon HSI Curve for Substrate

Habitat Simulation

After creating an input file with the HSC set in Appendix A, habitat simulations were run using the *HABTAE* program to predict physical spawning habitat availability for chinook salmon in the Lower American River at flows between 1000 and 6000 cfs by 200 cfs increments.

RESULTS

Weighted Usable Area (WUA) was computed using the criteria set cited above and is presented in Appendix B. These results are presented by transect at the request of CDFG, the primary recipient of this report. The information contained herein will presumably be considered, along with empirical data which continues to be collected, in formulating instream flow recommendations that should benefit the fall chinook salmon population of the Lower American River.

APPENDIX A

HSI CRITERIA

Water Velocity (ft/s)	SI Value	Water Depth (ft)	SI Value	Substrate Composition	SI Value
0.00	0.00	0.00	0.00	0.0	0.00
0.10	0.02	0.50	0.00	1.0	0.00
0.30	0.04	0.60	0.25	1.2	0.36
0.40	0.07	0.70	0.31	1.3	1.00
0.70	0.15	0.90	0.43	1.4	0.97
0.90	0.25	1.00	0.50	2.4	0.97
1.00	0.32	1.10	0.56	3.4	0.53
1.10	0.38	1.20	0.64	3.5	0.28
1.20	0.46	1.30	0.70	3.6	0.00
1.30	0.53	1.40	0.77	100.0	0.00
1.40	0.62	1.50	0.82		
1.50	0.70	1.60	0.89		
1.60	0.78	1.80	0.97		
1.70	0.85	1.90	0.98		
1.80	0.91	2.00	1.00		
1.90	0.96	2.10	1.00		
2.00	0.99	10.80	0.00		
2.10	1.00	100.00	0.00		
2.20	0.99				
2.30	0.97				
2.40	0.93				
2.50	0.88				
2.60	0.80				
2.70	0.73				
2.80	0.67				
2.90	0.56				
3.00	0.49				
3.10	0.40				
3.30	0.28				
3.40	0.21				
3.60	0.13				
3.80	0.07				
4.00	0.03				
4.20	0.01				
4.30	0.00				
100.00	0.00				

APPENDIX B

HABITAT MODELING RESULTS

	Sailor Bar			Above Sunrise 14		Above Sunrise 16	
Flow	XS 1 LC	XS 1 RC	XS 2	XS 1	XS 2	XS 1	XS 2
1000	45.7	2.4	107.3	133.1	85.4	12.7	12.9
1200	42.9	3.2	140.1	158.5	107.8	21.8	24.6
1400	37.1	4.2	168.5	175.4	126.9	30.4	36.2
1600	30.2	5.3	190.8	184.1	141.7	37.4	48.6
1800	24.6	6.2	205.9	187.0	151.9	44.0	59.1
2000	20.3	7.2	213.1	185.2	158.2	47.9	65.6
2200	16.7	8.4	212.9	180.9	160.6	49.9	69.7
2400	13.4	9.5	206.5	174.8	160.5	51.5	70.6
2600	11.5	10.6	195.0	168.9	158.0	51.1	69.9
2800	10.3	11.7	179.1	163.5	154.1	49.8	67.2
3000	9.2	13.0	162.4	157.6	149.4	48.2	63.6
3200	8.0	14.1	144.3	152.6	144.2	46.1	59.4
3400	7.3	15.1	126.2	147.6	138.4	44.0	54.9
3600	6.5	16.1	109.1	142.0	132.4	41.2	50.1
3800	6.0	16.9	94.0	137.1	126.2	38.6	45.5
4000	6.0	17.8	78.8	131.3	119.4	38.5	45.3
4200	5.8	18.6	65.8	125.6	112.6	36.3	41.4
4400	5.8	19.4	54.1	119.9	105.1	33.6	37.7
4600	5.8	20.2	44.0	113.2	98.1	31.4	34.1
4800	5.9	20.9	35.9	106.8	91.1	29.1	30.8
5000	6.1	21.5	28.9	100.0	84.1	27.3	28.2
5200	6.8	22.0	22.9	93.1	77.2	25.5	25.6
5400	7.3	22.5	18.2	86.0	70.6	23.7	23.4
5600	7.8	23.0	14.4	79.1	63.9	22.1	21.3
5800	8.3	23.4	11.3	72.3	57.4	20.8	19.4
6000	8.8	23.8	8.7	65.2	51.8	19.5	17.8

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for the criteria set in Appendix A. Flow is release from Nimbus Dam (cfs).

	Above Sunrise 23		At Sunrise 26		Below Sunrise 29	
Flow	XS 1	XS 2	XS 1	XS 2	XS 1	XS 2
1000	77.3	65.7	90.8	163.7	115.3	86.1
1200	82.8	66.2	105.6	185.7	136.6	97.1
1400	86.3	69.6	114.0	196.6	151.3	102.9
1600	91.2	68.4	116.4	198.2	159.0	103.6
1800	94.4	65.9	113.5	192.0	159.3	100.8
2000	96.8	70.9	107.8	181.3	154.6	95.4
2200	98.4	70.7	99.2	168.1	146.2	88.3
2400	98.5	69.8	89.5	154.1	134.6	80.1
2600	98.2	68.3	79.1	140.1	121.9	71.9
2800	96.9	65.7	69.6	126.8	108.5	63.4
3000	94.2	62.8	60.8	115.8	95.5	55.5
3200	91.4	60.3	53.0	106.0	82.9	48.4
3400	87.9	57.2	46.4	97.0	71.7	42.3
3600	83.9	54.3	40.7	88.9	61.3	36.8
3800	79.6	51.7	35.8	81.3	52.8	31.9
4000	74.4	48.9	31.5	75.0	45.4	27.8
4200	69.6	46.0	28.1	69.0	39.2	24.2
4400	64.9	43.4	25.5	63.4	34.0	21.1
4600	60.2	40.7	23.5	58.0	29.7	18.5
4800	55.9	38.5	21.9	53.1	26.3	16.3
5000	51.7	36.4	20.5	48.5	23.5	14.5
5200	48.0	34.5	19.3	44.2	21.4	13.1
5400	44.5	32.4	18.4	40.2	19.9	12.0
5600	41.2	30.4	17.8	36.5	18.7	11.0
5800	38.2	28.6	17.3	32.7	17.7	10.2
6000	35.5	26.7	16.9	29.5	17.0	9.7

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for the criteria set in Appendix A. Flow is release from Nimbus Dam (cfs).

	Below Sunrise 30		El Manto		Rossmoor 2		Rossmoor 1	
Flow	XS 1	XS 2	XS 1	XS 2	XS 1	XS 2	XS 1	XS 2
1000	51.0	61.0	25.2	34.3	34.6	62.6	33.0	3.8
1200	58.3	72.0	26.4	34.2	34.4	65.8	30.7	4.1
1400	65.0	84.0	26.6	32.8	32.6	67.3	27.0	4.2
1600	69.8	94.6	26.2	30.8	31.9	66.6	23.2	4.3
1800	72.8	101.9	25.8	29.5	31.0	65.5	20.0	4.4
2000	73.0	105.3	25.0	28.4	31.0	63.1	17.4	4.4
2200	71.3	105.1	24.2	27.9	30.5	59.4	14.9	4.4
2400	68.2	100.3	23.2	27.6	30.5	57.4	13.2	4.4
2600	64.0	93.7	22.5	27.7	30.9	54.5	11.6	4.4
2800	58.9	85.1	21.8	27.7	31.9	52.0	10.3	4.4
3000	53.6	76.0	20.9	27.7	33.3	50.4	9.3	4.3
3200	48.3	68.2	20.2	27.7	34.3	47.9	8.4	4.2
3400	43.2	60.7	19.5	27.7	34.1	46.4	7.6	4.1
3600	38.9	54.2	19.0	27.5	34.1	44.5	6.9	4.1
3800	35.0	48.2	18.3	27.3	33.4	42.9	6.4	4.1
4000	31.6	43.4	17.8	26.7	32.1	41.1	6.0	4.0
4200	28.8	39.7	17.2	26.3	30.6	39.2	5.6	4.0
4400	26.5	36.7	16.6	25.6	28.8	37.3	5.1	3.9
4600	24.4	34.2	15.9	24.6	27.2	35.2	4.8	3.9
4800	22.6	31.9	15.1	23.8	25.3	33.6	4.5	3.9
5000	21.0	30.0	14.5	23.1	23.2	31.6	4.1	3.9
5200	20.0	28.5	13.9	22.3	21.4	29.9	3.8	3.8
5400	19.3	26.9	13.2	21.3	19.8	28.5	3.6	3.8
5600	18.5	25.7	12.6	20.5	18.3	27.2	3.5	3.7
5800	17.8	24.6	12.1	19.9	16.8	26.0	3.3	3.6
6000	17.6	23.6	11.7	19.6	15.2	25.0	3.1	3.5

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for the criteria set in Appendix A. Flow is release from Nimbus Dam (cfs).