CALIFORNIA DEPARTMENT OF FISH AND GAME

WATER BRANCH

INSTREAM FLOW PROGRAM

STUDY PLAN:
HABITAT AND INSTREAM FLOW RELATIONSHIPS FOR
STEELHEAD IN THE BIG SUR RIVER, MONTEREY COUNTY

September 2009

Preface

This study plan document outlines the approach and methods that will be used by the California Department of Fish and Game (Department) to conduct an instream flow study on the Big Sur River, Monterey County. The Department intends to use existing staff resources from the Water Branch, Fisheries Branch, Engineering Branch, the Bay Delta Region, and the Central Region to conduct this study. In addition, the Department intends to use a grant award of $100,000.00 from the Ocean Protection Council (OPC) to fund the Pacific States Marine Fisheries Commission (PSMFC) to conduct the habitat suitability criteria development portion of this study. The Big Sur River flow study reflects part of the activities that the Department plans to begin work on in 2009 as part of its responsibility to implement Public Resources Code (PRC) sections 10000-10005 through the Department's Instream Flow Program.

The primary objective of the Department's Instream Flow Program is to develop scientific information on the relationships between flow and available stream habitats to determine what flows are needed to maintain healthy conditions for fish and wildlife. Relationships between flow and habitat will be developed on the selected streams for each species' critical lifestage need, including spawning, rearing and migration. The Department has interest in assuring that water flows within streams are maintained at levels which are adequate for long-term protection, maintenance and proper stewardship of those resources.

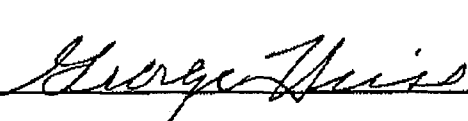For more information or questions about this study plan please contact:

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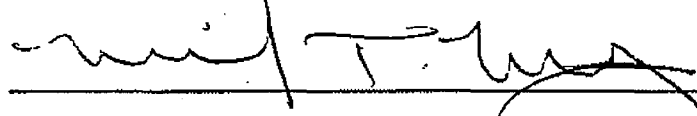> fax (916) 445-1768
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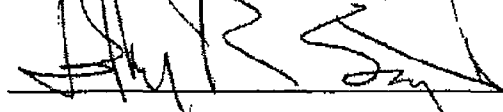
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Background

South-Central California Coast Steelhead populations have declined from annual runs totaling 25,000 spawning adults to less than 500 (NMFS, http://swr.nmfs.noaa.gov/recovery/Steelhead_SCCS.htm). Consequently, the south-central DPS (Distinct Population Segment) of California steelhead (hereinafter south-central steelhead, anadromous form of rainbow trout *Oncorhynchus mykiss*) was listed as threatened in 1997 and reaffirmed in 2006 (NMFS 1997; NMFS 2006). All of the four largest watersheds (Pajaro, Salinas, Nacimiento/Arroyo Seco, and Carmel Rivers) have experienced declines in run sizes of 90% or more. Present population trends in many other individual watersheds remains unknown.

The Big Sur River is among the larger watershed drainages south of San Francisco Bay currently supporting south-central steelhead (Titus et al., *In Prep*). The Big Sur River originates in the steep canyons of the Ventana Wilderness, and flows northwest through two state parks (Pfeiffer Big Sur and Andrew Molera), and a lagoon, before emptying into the Pacific Ocean. Coastal estuaries are an important part of the life cycle of steelhead trout (Bond, 2006). Currently, only the lower 7.5 miles of the river are accessible to south-central steelhead, with upstream fish migration blocked either by a partial or complete bedrock barrier depending on streamflow conditions.

Although the Big Sur River appears to be in a relatively pristine state containing one of the last strongholds of quality steelhead habitat on California's south coast, this habitat is at risk from pending water diversion applications requesting a large portion of available flow, existing permitted diversions, illegal unpermitted diversions, and dewatering. Such water management activities pose additional risk to south-coast steelhead populations in the Big Sur River (Monterey County, 1986). Subsequently, the Big Sur River has been identified as one of the Department's priority streams in 2008 for future instream flow assessments due to its' high resource value, presence of south-central steelhead, and increasing water rights pressure.

Project Organization

The Department intends to use existing staff resources from the Water Branch, Fisheries Branch, Engineering Branch, and the Central Region to conduct this study. Department staff from the Bay-Delta Region will be coordinating the stream survey portion of the study. Staff from the Water Branch will serve as the overall project coordinator. The Department also intends to use a grant award of $100,000.00 from the Ocean Protection Council (OPC) to fund the Pacific States Marine Fisheries Commission (PSMFC) to conduct the habitat suitability criteria development portion of this study. Table 1 outlines the responsibilities of Department staff in the Big Sur River flow study.

Table 1. Responsibilities of Department Staff in Big Sur River Flow Study.

RESPONSIBILITIES		DEPARTMENT STAFF (Branch/Region)
Project Coordinator/Study Plan		Robert Holmes (Water)
PSMFC Contract/Project Manager		Robert Holmes (Water)
Study Design and Approach		Robert Holmes (Water), Bob Hughes (Engineering), Rob Titus (Fisheries)
Surface Water/Ground Water Interface		Kit Custis (Engineering)
Field Data Collection[1]	Reconnaissance, study site and transect selection	Patricia Anderson (Central), Kit Custis (Engineering), Deborah Hillyard (Central), Robert Holmes (Water), Bob Hughes (Engineering), Rob Titus (Fisheries)
	Stream Surveys (Habitat mapping, weekly stream flows, continuous temperature Monitoring)	Jennifer Nelson (Bay Delta)
	Habitat Suitability Criteria development/ Lagoon Assessment	Robert Holmes (Water)[2]
	Hydraulic and Structural Data	Robert Holmes (Water), Bob Hughes (Engineering), Rob Titus (Fisheries)
Hydraulic Model Construction and Calibration[3]		Robert Holmes (Water) Bob Hughes (Engineering)
Quality Assurance/Quality Control		Robert Holmes (Water), Bob Hughes (Engineering), Jennifer Nelson (Bay Delta), Rob Titus (Fisheries)
Data Management and Reporting		Robert Holmes (Water), Bob Hughes (Engineering), Jennifer Nelson (Bay Delta), Rob Titus (Fisheries)

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[1] The US Fish and Wildlife Service (USFWS) will be assisting the Department in form of a two-dimensional (2D) stream flow model training, including 2D field data collection.
[2] Manage contract, provide field work assistance and project oversight to Pacific States Marine Fisheries Commission (PSMFC) staff to develop habitat suitability criteria for rearing steelhead in the Big Sur River and conduct lagoon assessment.
[3] The USFWS is responsible for construction and calibration of the 2D model component of the study.

Problem Statement

The PRC mandates the Department to develop stream flow requirements for the long-term protection, maintenance and proper stewardship of fish and wildlife resources. Pursuant to the PRC, the Department needs to conduct field studies to identify stream flow requirements for the protection of south-central steelhead in the Big Sur River.

Goals and Objectives

The overall goal of this project is to quantify or characterize south-central steelhead habitat as a function of flow in the Big Sur River using modeling, hydrologic, and empirical methods. Development of habitat and flow relationships will allow the Department to identify flow requirements needed to protect south-central steelhead in the Big Sur River.

The objectives of this project include:
1) Estimate the habitat index versus flow relationships using a one-dimensional (1D) and/or a two-dimensional (2-D) hydraulic and habitat model.
2) Use habitat index versus flow relationships to develop habitat duration or time series analysis of south-central steelhead habitat in the Big Sur River over time under alternative flow scenarios.
3) Develop habitat suitability criteria that reflect south-central steelhead behavior and habitat sensitivity in the Big Sur River.
4) Develop habitat and flow relationships for two distinct south-central steelhead life stages in the Big Sur River including: adult upstream migration passage and juvenile rearing.
5) Investigate the relationship between Big Sur River south-central juvenile steelhead data and hydraulic and habitat modeling.

General Approach

The relationship between flow and habitat availability will be developed using a 1D Physical Habitat Simulation (PHABSIM) and/or a River2D 2-D hydraulic and habitat model (Steffler and Blackburn, 2001; Gard, 2006). Data collection procedures are outlined in Bovee (1997), Bovee et al., (1998), and Milhous et al., (1984). The approach will be to collect hydraulic and physical modeling data at study sites representing steelhead mesohabitat types (e.g., pools, runs, riffles, glides) to identify habitat availability in each reach. Representative study sites will be identified by: 1) classifying habitat types within the study reach to identify dominant and critical habitat types using Flosi et al., (1998), 2) select habitat types to represent the dominant and critical types, and 3) identify and establish study site locations in each reach using a combination of targeted and randomly selected sites to collect the required hydraulic and geomorphic data.

Unimpaired annual flow time series and exceedance hydrograph information for the period of record will be developed and evaluated and used to select target flow for hydrological data collection. Hydrological data will be collected at each study site at three distinct flows. Study site data will be collected and then entered into the PHABSIM and/or the River2D model by habitat type, calibrated, and modeled to identify flow versus habitat relationships for each habitat type. The model results will then be weighted to represent the proportion of the represented habitat

type within the study reach, and then combined to identify flow and habitat relationships for the study reach. Adult south-central steelhead passage at targeted critical riffles will also be evaluated individually using a minimum depth of 0.8 to 1 ft. using the PHABSIM and/or the River2D model.

For 2-D sites, a 1-D PHABSIM transect will be placed at the upstream and downstream end of each study site. Water surface elevations at the downstream end of the site, along with bed topography and bed roughness, will be used to develop stage/discharge relationships as part of the 2-D model. The amount of physical habitat present at a site will be predicted using the substrate composition and cover at each site, along with the predicted depths and velocities predicted by the 2-D model.

Study Reaches

In 1994 the Department initiated a validation program of the 1-D PHABSIM model developed by Bovee (1982) in the Big Sur River and Juan Higuera Creek, a significant tributary (Titus, 1994). Data collected included 1-D transect placement and hydraulic variable measurements in conjunction with juvenile steelhead/rainbow trout abundance. The current project intends to reassess the study reaches that the Department identified and assessed in 1994 using a 1-D and/or a 2-D model. The Department has traditionally used the 1-D PHABSIM model for instream flow assessments in California streams and rivers throughout the 1980's and 1990's. However, the 2-D model may be able to model the depths and velocities over a range of flows more accurately than the 1-D model (Gard, 2009; Ghanem et al., 1996; Leclerc et al., 1995). The 2-D model also avoids problems of transect placement, since data are collected uniformly across the entire site. The 2-D model may therefore be particularly applicable for use on the Big Sur River, where many low gradient riffle habitats have been reported at lengths of 25 - 40 meters (Titus, 1994), and it will be necessary to evaluate contiguous depths and velocities throughout such sites to identify appropriate adult south-central steelhead passage flows and velocities.

With an objective of evaluating and comparing the physical habitat characteristics of several stream reaches, the 1994 Department reach designations would be replicated with the addition of a lagoon reach. The reaches represent homologous stream segments based upon gradient, geomorphology, hydrology, riparian zone types, flow accretion, diversion influence, and channel metrics (Figure 1). Assessment reaches would be:

- Lagoon Reach – from tail of lagoon to head of lagoon/river mouth.
- Lower Molera Reach – from tail of lagoon to upstream radius of well pumping zone of influence in lower Andrew Molera State Park.
- Molera Reach – Lower Andrew Molera State Park to upstream boundary of Park.
- Campground Reach – from upstream boundary of Andrew Molera State Park to the bottom of the gorge in the upper campground area of Pfeiffer Big Sur State Park
- Juan Higuera Creek Reach – from Big Sur confluence to upstream limit of steelhead migration

Figure 1. Map of Big Sur River showing flow study reaches.

Generally, the number of 1D transects placed within each mesohabitat of each reach will be proportional to the percentage of mesohabitat type in the reach, and will meet recently published conclusions concerning minimum PHABSIM transect needs (Payne et al., 2004; Gard, 2005).

Stream Surveys and Habitat Mapping

Stream surveys will be conducted by Department staff from the Bay Delta Region. The survey work is in response to recent wildfires and is funded through a Steelhead Report Card grant. The survey work includes habitat mapping, weekly stream flow measurements, continuous temperature monitoring, and fish population work in the anadromous zones of the Big Sur River. Department staff anticipates using the level four habitat mapping portion of the survey work as described in the *California Salmonid Stream Restoration Manual* (Flosi et al., 1998) to facilitate site selection within each reach for the flow study. The habitat classification is based on channel morphology, gradient, substrate composition, and hydraulic characteristics. Habitats will be generally classified as riffle, run, glide, or pool. Review of historical habitat classification done by Snider in 1989 (unpublished data) suggests that pools may be further classified into lateral scour pools and main channel pools in the anadromous zone of the Big Sur River. Other habitat types may be further identified and classified based upon the future habitat mapping to be conducted as planned in Summer 2009. An alternative habitat mapping approach may be used, such as outlined in Snider et al., (1992), if conditions warrant such use.

Target Fish Species and Life Stages

The species and lifestages that will be used for 1-D PHABSIM and/or River 2D modeling are based upon management importance and/or sensitivity to water withdrawal operations. Life stage periodicity and target life stages for south-central steelhead are shown in Table 2 and Table 3, respectively.

Table 2. Life stage periodicity for south-central steelhead in the Big Sur River, Monterey County.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Adult Migration[1]												▓
Spawning												▓
Egg Incubation												▓
Emergence/Fry						▓						
Juvenile Rearing												▓
Smolt Emigration												▓

[1]Dependent upon sand bar breaching.

Table 3. Target species and life stages for 1D PHABSIM model and/or River2D model.

Species	Lifestages	Location
South-central steelhead, anadromous form of rainbow trout *Oncorhynchus mykiss*	adult migration juvenile rearing	All reaches[4]

Selection and Location of Study Sites

Representative habitat types will be both targeted and selected randomly in each reach to represent the study reaches for development of flow habitat relationships at each study site. The number of study sites in a given reach will be dependent upon the number and types of dominant and critical habitat types within each reach. Generally, the number of study sites selected in each reach will proportionally reflect dominant and critical mesohabitat type in the reach.

Study sites for rearing will be randomly selected to ensure unbiased selection of the study sites. The upstream and downstream end of each rearing study site will be selected to correspond to the upstream and downstream ends of the mesohabitat units selected.

Hydraulic and Structural Data Collection

Hydraulic and structural parameters will be measured using a combination of standard techniques of the U.S. Fish and Wildlife Service (USFWS) methodology (Trihey and Wegner, 1981; Bovee, 1982; Bovee, 1997; Bovee et al., 1998). The data collected at the upstream and downstream transects at each site will include: 1) Water Surface Elevations (WSELs); 2) wetted streambed elevations; 3) dry ground elevations to points above bankfull discharge ; 4) mean water column velocities measured at the points where bed elevations were taken; and 5) substrate and cover classification at these same locations (Appendix 1 and 2) and also where dry ground elevations were surveyed. If there is a hydraulic control downstream of a given transect, the stage of zero flow in the thalweg downstream of that transect will be surveyed in using differential leveling.

Data collected between the upstream and downstream transects at a site will include: bed elevation; horizontal location; substrate composition; and cover. The bed topography data are planned to be collected with a total station. Data will be collected at least up to the location of the water's edge at the highest flow to be simulated. Bed topography data will be collected at a higher density of points in areas with rapidly varying topography and patchy substrate and cover, and lower densities of points in areas with more uniform topography, substrate and cover. Bed topography and substrate data will be collected at a low flow. Only water surface elevations at the upstream and downstream ends of the sites, flow, and edge velocities will be needed at moderate and high flows. The horizontal locations of the transect headpins and tailpins are

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[4] The PHABSIM and River2D models will not be used for Lagoon reach. Lagoon reach assessment will include: bathymetric mapping (using semi-permanent transects) to track changes in water volume, fish surveys using visual observation and seining to assess presence/absence of south-central steelhead, and monitoring of water quality conditions (temperature, dissolved oxygen, conductivity) to assess estuary habitat suitability.

planned to be determined with the total station so that the topography for the transects can be incorporated into the bed topography of the sites. Topography data will be collected at a distance of one channel-width upstream of the upstream transect to improve the accuracy of the flow distribution at the upstream end of the sites.

At least 50 velocity measurements determined by the total station will be collected (in addition to the velocities measured at the upstream and downstream transects) to validate the hydraulic predictions of the 2-D model. The locations of these velocity measurements will be distributed throughout the site. The flow present during validation velocity data collection will be determined from gage readings, if the proposed gage in Andrew Molera State Park is available. If the proposed gage is not available, the flow present during validation velocity data collection will be measured.

Target Calibration Flows

Target calibration flows will be selected to allow for development of an adequate stage/discharge relationship in the PHABSIM and/or River2D model. The flows targeted for data collection will be measured at a proposed gage to be located in lower Andrew Molera State Park and the current United States Geological Survey (USGS) stream gauge # 11143000. The proposed gage would be funded through a potential grant from the Department Fisheries Restoration Grant Program and would ideally be in place by Summer/Fall 2009. Mean daily flows and the percent exceedence flows for the Big Sur River at station 11143000 are presented in Figures 2 and 3, respectively. Preliminary target calibration flows are presented in Table 4.

**Mean Daily Flow at Station 11143000
Big Sur River 1977-2008**
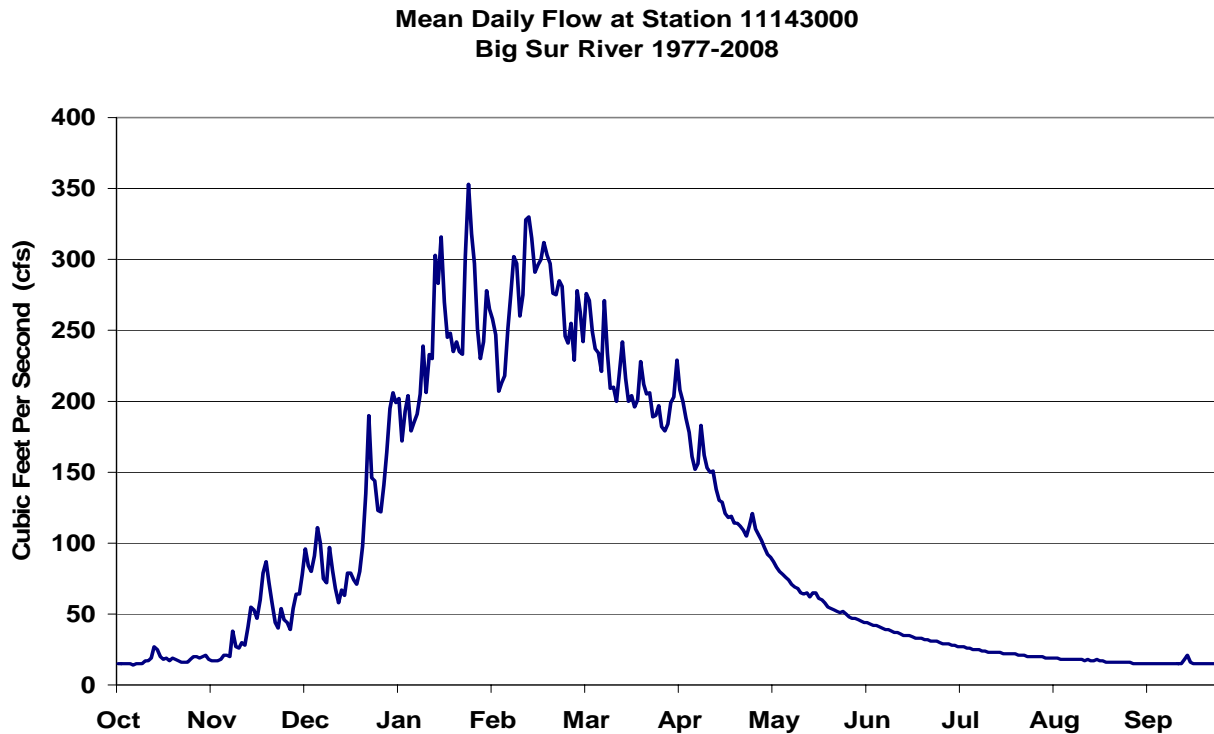
Figure 2. Mean daily flow at USGS Station 1143000, Big Sur River, 1977-2008 (n = 11,150).

Flow Exceedence Probability
Big Sur River 1977-2008

Figure 3. Flow exceedance probability, Big Sur River, 1977-2008. Data from USGS 11430000 (n = 11,150).

Table 4. Target calibration flows by PHABSIM and/or River2D reach[6].

PHABSIM or River2D Reach	20% Exceedance (cfs)	80% Exceedance (cfs)	Target Calibration Flow		
			Low (cfs)	Middle (cfs)	High (cfs)
Lower Molera Reach	80 - 100	10 - 15	5 - 10	45 - 55	80 - 100
Molera Reach					
Campground Reach					

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[6] Exceedence flows calculated using USGS station 11143000 data.

Habitat Suitability Criteria (HSC) Development

Accurate representation of habitat index-discharge results requires linking stream channel hydraulics over a range of flows with known habitat suitability criteria (HSC) for the target species and life stages. For the HSC component of this project, the target species and life stages would be south-coast steelhead fry (0+) and juveniles (1+). The spawning life stage is not proposed for HSC development. Even though appropriate HSC are a critical element of 1-D and 2-D flow studies, no HSC have been developed for coastal California steelhead rearing life stages.

Creation of suitable HSC requires a minimum sample size of fish observations (typically greater than 150 per a lifestage, mesohabitat category, and microhabitat component) made under a rigorous study plan that accounts for the influence of habitat availability on observed habitat use. Preparation of a detailed site-specific study plan incorporating these elements would be the first task of this study component by PSMFC staff. The HSC will be developed using water depth, velocity, cover, and adjacent velocity. General guidelines for HSC development are contained in Bovee, 1986; Bovee and Zuboy, 1988; and CDFG, 2006.

1-D Hydraulic Model Construction and Calibration

The current project will include habitat predictions using the 1-D PHABSIM model and/or the River2D model at study sites within the Big Sur River. For 1-D modeling the Department intends to use a commercial version of PHABSIM known as the Riverine Habitat Simulation (RHABSIM). Hydraulic modeling procedures appropriate to the study site and level of data collection will be used for modeling water surface elevations and velocities across each cross section. For water surface elevations, these procedures include: the development of stage-discharge rating curves using log-log regression (IFG4), Manning's formula (MANSQ), and/or step backwater models (WSP, HecRas); direct comparison of results; and selection of the most appropriate and accurate method. If, for example, rating curves using log-log and MANSQ are nearly identical, then log-log will be used to easily allow changes in simulated flows. But, if the two methods diverge and the transect is a riffle or run, then MANSQ will be selected for flow simulation. Water velocities will be simulated using the Manning's n method of velocity distribution across all transects, with calibrations generally consisting of correction of over- or under-simulated velocities at individual sample points (i.e. velocity adjustment factors or VAFs). Data file construction, calibration, simulation, reporting, review, and consultation will follow standard procedures and guidelines.

Habitat modeling will be conducted using an approach consistent with the Instream Flow Incremental Methodology (IFIM) approach (Bovee et al., 1998). Mesohabitat types will be weighted and combined to develop a representation of hydraulic characteristics and fish habitat suitability for the PHABSIM reach. Mesohabitat weighting will be based on the relative proportion of each of the modeled mesohabitats within the PHABSIM reach, as described above.

2-D Hydraulic Model Construction and Calibration

The topographic data described above will be combined with the bed topography from the upstream and downstream transects to create the initial bed file. See Appendix 1 and Appendix 2 for the substrate and cover codes, respectively. The bed file contains the horizontal location, bed elevation and initial bed roughness value for each point. The initial bed roughness values will be determined from the substrate and cover data using the values in Appendix 3. If the topography data collected upstream of the upstream transect does not extend at least 1 channel width upstream of the top of the site, a one-channel-width artificial extension will be added upstream of the measured topography data to enable the flow to be distributed by the model when it reaches the study area, thus minimizing boundary conditions influencing the flow distribution at the upstream transect and within the study site. A utility program, R2D_BED (Steffler 2002), will be used to define the study area boundary and to refine the raw topographical data triangulated irregular network (TIN) by defining breaklines[7] going up the channel along features such as thalwegs, tops of bars and bottoms of banks.

Breaklines will also be added along lines of constant elevation. An additional utility program, R2D_MESH (Waddle and Steffler 2002), will be used to define the inflow and outflow boundaries and create the finite element computational mesh for the River2D model. R2D_MESH uses the final bed file as an input. Mesh breaklines[8] will be defined which coincided with the final bed file breaklines. Additional mesh breaklines will then be added between the initial mesh breaklines, and then additional nodes will be added as needed to improve the fit between the mesh and the final bed file and to improve the quality of the mesh, as measured by the Quality Index (QI) value. The computational mesh will be run to steady state at the highest flow to be simulated (approximately 200 to 250 cfs), and the water surface elevations (WSELs) predicted by River2D at the upstream end of the site will be compared to the WSELs predicted by PHABSIM at the upstream transect.

In cases where the simulated WSELs at the highest simulation flow varies across the channel by more than 0.1 foot, the highest measured flow within the range of simulated flows will be

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[7] Breaklines are a feature of the R2D_Bed program which force the TIN of the bed nodes to linearly interpolate bed elevation and bed roughness values between the nodes on each breakline and force the TIN to fall on the breaklines (Steffler 2002).

[8] Mesh breaklines are a feature of the R2D_MESH program which force edges of the computation mesh elements to fall on the mesh breaklines and force the TIN of the computational mesh to linearly interpolate the bed elevation and bed roughness values of mesh nodes between the nodes at the end of each breakline segment (Waddle and Steffler 2002). A better fit between the bed and mesh TINs is achieved by having the mesh and bed breaklines coincide.

used for River2D calibration. The bed roughnesses of the computational mesh elements will then be modified by multiplying by a constant bed roughness multiplier (BR Mult) until the WSELs predicted by River2D at the upstream end of the site matched the WSELs predicted by PHABSIM at the top transect. The minimum groundwater depth will be adjusted to a value of 0.05 to increase the stability of the model. The values of all other River2D hydraulic parameters will be left at their default values (upwinding coefficient = 0.5, groundwater transmissivity = 0.1, groundwater storativity = 1, and eddy viscosity parameters ε_1 = 0.01, ε_2 = 0.5 and ε_3 = 0.1).

Velocities predicted by River2D will be compared with measured velocities to determine the accuracy of the model's predictions of mean water column velocities. After the River2D model is calibrated, the flow and downstream WSEL in the calibrated cdg file will be changed to simulate the hydraulics of the site at 30 simulation flows, ranging from approximately 3 to 4 cfs to approximately 200 to 250 cfs. The cdg file for each flow contains the WSEL predicted by PHABSIM at the downstream transect at that flow. Each cdg file will be run in River2D to steady state.

Habitat modeling will be conducted using an approach consistent with the Instream Flow Incremental Methodology (IFIM) approach (Bovee et al., 1998). Mesohabitat types will be weighted and combined to develop a representation of hydraulic characteristics and fish habitat suitability for the River2D reach. Mesohabitat weighting will be based on the relative proportion of each of the modeled mesohabitats within the River2D reach, as described above.

Quality Assurance/Quality Control (QA/QC)

Water Surface Elevations (WSELs) will be measured to the nearest 0.01 foot at a minimum of three significantly different stream discharges using standard surveying techniques (differential leveling). Wetted streambed elevations will be determined by subtracting the measured depth from the surveyed WSEL at a measured flow.   Dry ground elevations to points above bankfull discharge will be surveyed to the nearest 0.1 foot. WSELs will be measured along both banks and in the middle of each transect if conditions allow. Otherwise, the WSELs will be measured along both banks. If the WSELs measured for a transect are within 0.1 foot of each other, the WSELs at each transect will be derived by averaging the two to three values. If the WSEL differ by greater than 0.1 foot, the WSEL for the transect will be selected based on which side of the transect was considered most representative of the flow conditions. The range of flows to be simulated should go up to the mean unimpaired flow in the highest flow month. Water surface elevations will be collected at a minimum of three relatively evenly spaced calibration flows, spanning approximately an order of magnitude. The calibration flows will be selected so that the lowest simulated flow is no less than 0.4 of the lowest calibration flow and the highest simulated flow is at most 2.5 times the highest calibration flow.

For bed topography data collected with the total station, the accuracy of the bed elevations will be 0.1 foot, while the accuracy of the horizontal locations will be at least 1.0 foot. Velocities will be measured to the nearest 0.01 ft/s at 0.6 of the depth for 20 seconds using either a Price AA or a Marsh-McBirney velocity meter.

For the computational mesh, QI value of at least 0.2 is considered acceptable (Waddle and Steffler 2002). For River2D, a stable solution will generally have a solution change (Sol Δ) of

less than 0.00001 and a net flow (Net Q) of less than 1% (Steffler and Blackburn 2002). In addition, solutions for low gradient streams will usually have a maximum Froude Number (Max F) of less than one. Calibration is considered to have been achieved when the WSELs predicted by River2D at the upstream transect is within 0.1 foot of the WSEL predicted by PHABSIM. BR Mult values should lie within the range of 0.3 to 3.0. The criterion used to determine whether the model is validated will be whether the correlation between measured and simulated velocities is greater than 0.6. The model would be in question if the simulated velocities deviated from the measured velocities to the extent that the correlation between measured and simulated velocities fall below 0.6. For simulation flows, again, a stable solution will generally have a Sol Δ of less than 0.00001 and a Net Q of less than 1%. In addition, solutions should usually have a Max F of less than one.

Biovalidation

Habitat suitability criteria (HSC) curves are used to translate hydraulic and structural elements of rivers in combined suitability indices (CSI), which are calculated as the product of depth, velocity, adjacent velocity, and substrate suitability's for fry and juvenile rearing. South-central steelhead juvenile rearing CSI will be calculated using HSC developed through the current project as part of a biovalidation process. Biovalidation will be conducted at the microhabitat scale ($1ft^2$ grid) to determine if the combined suitability of occupied locations is greater than the combined suitability of unoccupied locations. These data are needed to verify the accuracy of the model's predictions regarding habitat availability and use.

Data Management and Reporting

Field data will be collected by Department staff from the Engineering, Fisheries, and Water Branches. All data generated by this project will be maintained in both field log books and electronic spreadsheet format. A final technical report will be prepared by Water Branch staff, with assistance from the Engineering and Fisheries Branches staff.

Target Audience and Management Decisions

The Department has interest in assuring that water flows within streams are maintained at levels which are adequate for long-term protection, maintenance and proper stewardship of fish and wildlife resources. Using data generated from the flow study outlined herein, the Department intends to develop stream flow recommendations for the Big Sur River. The Department also intends to transmit those stream flow recommendations to the State Water Resources Control Board (Water Board) for consideration by the Water Board as set forth in 1257.5 of the Water Code. Submission of such flow recommendations to the Water Board complies with Public Resources Code Section 10000-10005.

Coordination and Review Strategy

To the extent possible, entities or stakeholders which might have an interest in the results and interpretation of habitat index modeling will be involved in study scoping and implementation.

To promote coordination this study plan will be distributed for review and comments among interested Department staff, other interested agencies such as the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS), other interested groups and/or scientists. The project coordinator will facilitate and coordinate this review and addressing comments.

It is anticipated that the instream flow project will be coordinated and leveraged with planned survey work on the Big Sur River by the Bay Delta Region (Department of Fish and Game Region 3) staff. The survey work will likely include habitat mapping, weekly stream flow assessments, continuous temperature monitoring, and fish population studies. The Habitat Suitability Criteria (HSC) development portion of the current study will also include development of study plan that will be developed by the Pacific State Marine Fisheries Commission (PSMFC) staff.

Products

A final project report will be prepared that will include the results of the 1-D and 2-D analyses including the habitat suitability development task. Study products will include: a) a summary of field methods, data analysis, and results; b) all PHABSIM and River2D data on CD; and c) spreadsheet based interactive analytical tools. Habitat suitability criteria (HSC) study products will include a study plan, and a final south-central rearing steelhead HSC report outlining the methods, results, and discussion.

Field Methods Summary

Field methods for each reach will be summarized to include but not be limited to the following:

- Maps showing study site locations
- Photographs of study sites at calibration flows
- Date and discharge of calibration flows
- Description of any deviations from the study plan

Data Analysis Summary

Data analysis for each reach will be summarized to include but not be limited to the following:

- Hydraulic calibration report (detailed modeling procedures and model performance)
- Habitat modeling report (target species, and HSC used)
- Habitat Duration Analysis (species/life stage periodicity, hydrologic data sources, index, benchmark, and metrics applied)
- Description of any deviations from the study plan

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Results Summary

Results for each reach will be summarized to include but not be limited to the following:

- Graphic and tabular results of Weighted Useable Area vs. flow
- Habitat modeling report (target species and HSC used)
- Habitat Duration Analysis (species/life stage periodicity, hydrologic data sources, index, and metrics applied)
- Description of any deviations from the study plan

Results Summary – Passage at Targeted Critical Riffles

Results for each passage assessment at critical riffles will be summarized to include but not be limited to the following:

- Graphic and tabular results of the relationship between flow and depth, velocity, and width criteria
- The analysis will include the use of minimum depths at critical riffles
- Description of any deviations from the study plan

Project Schedule

ACTIVITY	DATE
Study Plan	September 2009
Stream Surveys	September 2009 – June 2010
Reconnaissance, Study Site and Transect Selection	June - July 2010
Habitat Suitability Criteria Development	May 2010 – April 2011
Hydraulic and Structural Data Collection	July 2010 – June 2011
Hydraulic Model Construction and Calibration	July 2011 – February 2012
Final Project Report	August 2012

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Appendix 1. Substrate codes, descriptors and particle sizes.

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

Appendix 2. Cover coding system.

Cover Category	Cover Code
No cover	0
Cobble	1
Boulder	2
Fine woody vegetation (< 1" diameter)	3
Fine woody vegetation + overhead	3.7
Branches	4
Branches + overhead	4.7
Log (> 1' diameter)	5
Log + overhead	5.7
Overhead cover (> 2' above substrate)	7
Undercut bank	8
Aquatic vegetation	9
Aquatic vegetation + overhead	9.7
Rip-rap	10

Appendix 3. Initial bed roughness values.

Substrate Code	Bed Roughness (m)	Cover Code	Bed Roughness (m)
0.1	0.05	0.1	0
1	0.1	1	0
1.2	0.2	2	0
1.3	0.25	3	0.11
2.3	0.3	3.7	0.2
2.4	0.4	4	0.62
3.4	0.45	4.7	0.96
3.5	0.5	5	1.93
4.6	0.65	5.7	2.59
6.8	0.9	7	0.28
8	1.25	8	2.97
9	0.05	9	0.29
10	1.4	9.7	0.57
		10	3.05