4.0 INSTREAM FLOW STUDIES

This study has received much attention from PacifiCorp and the relicensing stakeholders. Many meetings have been conducted by the Aquatic Working Group and the Working Group's Instream Flow Subgroup. The Subgroup was formed to work through technical issues and towards agreed upon instream flow input, analysis, and recommendations. PacifiCorp recognizes, and requests that FERC also recognize that additional collaboration, refinement of model input variables, and analysis is needed with stakeholders to meet the company's commitment to complete the instream flow study needed to provide a good technical basis for instream flow recommendations. This includes such items as working collaboratively to develop and produce agreed upon modeling input, and consequently modeling results and recommendations.

PacifiCorp constructed its own rainbow trout envelope curves that were used for the instream flow analysis. However, these curves have not been reviewed or approved by the Instream Flow subgroup. As such, stakeholders have technical uncertainty surrounding the instream flow analysis presented in this application. PacifiCorp and the stakeholders will continue to develop Klamath River HSC curves.

In order to address the instream flow study tasks, PacifiCorp and relicensing stakeholders will continue to meet to work on the following:

- Approve rainbow trout and sucker HSC curve.
- Develop a habitat time series.
- Complete bioenergetics modeling efforts.
- Conduct peaking analysis.
- Discuss modeling results as they relate to fisheries and other interrelated studies (e.g., recreation, geomorphology, etc.).
- Develop river flow regime recommendations for aquatic resources.

It is anticipated that the above tasks will be completed by the end of May 2004. At the conclusion of these tasks, a final instream flow report will be distributed to FERC and interested stakeholders by the end of June 2004. At that time PacifiCorp will review this additional information, and revise as appropriate the Project Operations and PM&E measures included in this License Application.

4.1 DESCRIPTION AND PURPOSE

In addition to providing hydroelectric benefits, flows released below hydroelectric projects should protect or enhance the aquatic ecosystem, and, more specifically, those resources that are considered important from a commercial fishery, sport fishery, or threatened/endangered species perspective. Instream flows are almost universally specified in a FERC license and should be based on relevant site-specific information from the project area. Stakeholders participating in FERC relicensing processes commonly rely on information generated from instream flow studies to develop recommended instream flow regimes. The FERC uses these types of studies during its resource balancing deliberations before issuing long-term licenses.

Instream flow requirements, especially in the powerhouse bypass reaches, have significant consequences for power production as well as fish resources and, therefore, must be based on sound evaluation. Analysis of site-specific information, coupled with the results of the fisheries assessment, was used in discussions with the stakeholders to determine further courses of action regarding instream flow requirements in each bypass reach. The results of these discussions determined (1) whether minimum flows needed to be maintained or modified to offer adequate fisheries (and other resources) protection, and (2) additional field studies that were required. Alternatives for minimum flow modifications have been made with consideration for biological needs of the fishery, wildlife, recreation activities, and the economic consequences of power generation.

Instream Flow Incremental Methodology (IFIM) was agreed upon as the approach to instream flow analysis in the Project area. The IFIM is a structured habitat evaluation process initially developed by the Instream Flow Group of the USFWS in the late 1970s to allow evaluation of alternative flow regimes for water development projects (Bovee and Milhous, 1978; Bovee et al. 1998). Techniques used in the IFIM process have continued to evolve since its introduction (Bovee and Zuboy, 1988; Bremm, 1988; Payne, 1987, 1988a, 1988b, 1992). Improvements have been made in the process of scoping and results interpretation (Bovee, 1982), in the approaches to defining study reaches (Morhardt et al. 1984), in transect selection (Payne, 1992), and in the techniques of data collection, computer modeling, and analysis (Milhous et al. 1984, 1989; Milhous and Schneider, 1985). The IFIM involves multiple scientific disciplines and stakeholders, in the context of which physical habitat simulation studies usually are designed and implemented.

Critical stakeholder concurrence on study scope, design elements, and overall adequacy for decisionmaking is one of the principal objectives of IFIM scoping, one of the first identified steps of the methodology (Bovee et al. 1998). Depending on the desires of the participants, the IFIM can be completely comprehensive for all aquatic aspects of flow regulation or tightly focused on topics of specific concern. The study and evaluation of instream flow needs as it relates to aquatic habitat is based primarily on the PHABSIM option within the IFIM. The IFIM, for example, also can be designed to address channel stability, patterns of hydrologic alteration, species interaction, and water quality. This study is based on extended discussions and agreements forged during multiple stakeholder/resource agency meetings, instream flow workshops, and Project area site visits. Documentation of the this process is detailed in the 1.8 Instream Flow Scoping Plan and 1.12 Instream Flow Analysis Study Plan reports, which are included as part of the FERC license application.

The purpose of this instream flow study is to provide biologists, resource managers, and others in the instream flow decisionmaking process with a technical basis for systematically evaluating flow alternatives on the basis of the effects that those flows have on important fish habitats and other flow-related resources. The study results and rationale have provided the framework for including biological considerations in the process of deciding future flows for Project operation. If consensus on instream flows cannot be reached, this study fully documents and supports the rationale for instream flow recommendations so that the FERC and other agency staffs can fairly evaluate and balance the benefits and costs associated with the recommendations.

4.2 OBJECTIVES

The PHABSIM study was used to determine the incremental relationship between stream flow and WUA for various life stages of selected fish in the Project area. PHABSIM relies on hydraulic data collection for calibration of computer simulation models, plus fish species/life stage suitability criteria (also called habitat suitability criteria [HSC]) for the major habitat component variables of velocity, depth, and substrate/cover. The WUA index can be interpreted in the context of stream hydrology and species life history to evaluate project impacts, and serves as a partial basis for determining project alternatives and mitigation, along with the results of other studies. The PHABSIM study has the following objectives:

- Verify and/or develop habitat index-flow relationships (WUA) for the fry, juvenile, and adult life stages of target fish (or other) species.
- Provide calibrated hydraulic data file for potential application to habitat suitability indices for subsequently identified fish species, habitat guilds, or fish passage needs.
- Provide additional physical habitat information for application to other study plans (e.g., riparian vegetation, water quality, or substrate particle incipient motion analyses).

4.3 RELICENSING RELEVANCE AND USE IN DECISIONMAKING

The results of the PHABSIM study are intended to provide baseline information that, together with environmental data and results of other past and ongoing studies, can be used to assess effects of Project operations on fish habitat and to help formulate recommendations for PM&E measures consistent with agency and tribal management goals. Ultimately the WUA values from the PHABSIM study will be used in conjunction with the results of other studies (such as water quality, recreation, terrestrial, cultural, and power generation) to prescribe instream flows that best meet the multiple objectives determined during the stakeholder scoping process.

4.4 METHODS AND GEOGRAPHIC SCOPE

4.4.1 Geographic Scope

The geographic scope of the Upper Klamath River instream flow studies begins at Link River dam (the lake level control dam on Upper Klamath Lake and extends downstream to Iron Gate dam (Figure 4.4-1) Even though PacifiCorp recognizes the importance of maintaining minimum flows to meet certain fisheries needs in all river reaches, it now has little or no control of flow in many segments of the river. Recent federal listings of Klamath Lake suckers and coho salmon in the Klamath River under the ESA has constrained overall system operation by the USBR to the dictates of formal BOs written by the USFWS and NOAA Fisheries (USFWS, 2002; NOAA Fisheries, 2002).

- Instream flow evaluations were conducted in the following reaches of the Klamath River or its tributaries where PacifiCorp has some significant measure of flow control: J.C. Boyle bypass reach
- J.C. Boyle peaking reach

- Copco No. 2 bypass reach
- Fall Creek bypass reach

Instream flow evaluations were not conducted in the following river reaches for the indicated reasons:

- Downstream of the Link River dam (although fieldwork was completed, an evaluation was not done as PacifiCorp is proposing to decommission the East Side and West Side developments).
- Downstream of Copco No. 1 dam (discharges directly to reservoir)
- Fall Creek downstream from the powerhouse (run-of-river below powerhouse)
- Downstream of Iron Gate dam (under current operations, meeting minimum flows beyond Iron Gate dam is a USBR obligation; also, a detailed instream flow study already has been conducted)

4.4.2 Methods

4.4.2.1 Habitat Mapping

Habitat mapping provides an overall instream mesohabitat (e.g., pools, riffles, runs, etc.) representation of each stream reach in the Project area. In addition, results of habitat mapping aids transect selection and habitat weighting in reaches where fish habitat modeling was proposed. The U.S. Forest Service (USFS) (McCain et al. 1990, Overton et al. 1997) and CDFG (Flosi et al. 1998) have developed widely accepted stream habitat classification systems. The CDFG habitat classification and typing definitions are derived wholly from the USFS systems. These classification schemes are based on hierarchical gradation ranging from two to three basic habitat types (riffle-pool, riffle-flatwater-pool) up to 24 types. The most diverse grouping is pool habitat, with up to 15 different types, falling into three basic categories: main channel, lateral scour, and backwater. ODFW also has developed a habitat mapping procedure for stream inventory investigations (Moore et al. 1998), which had been applied previously to the J.C. Boyle bypass and peaking reaches.

The above habitat type classification regimes were evaluated for the Klamath Project studies. The standard USFS habitat unit types and descriptions were selected with the exception that all main channel and scour pool types were lumped into a single type. Keeping the number of habitat types to a manageable level allows for more accurate and consistent visual classification (Roper and Scarnecchia, 1995; Poole et al. 1997) and, if the need arises, allows for repeatability.

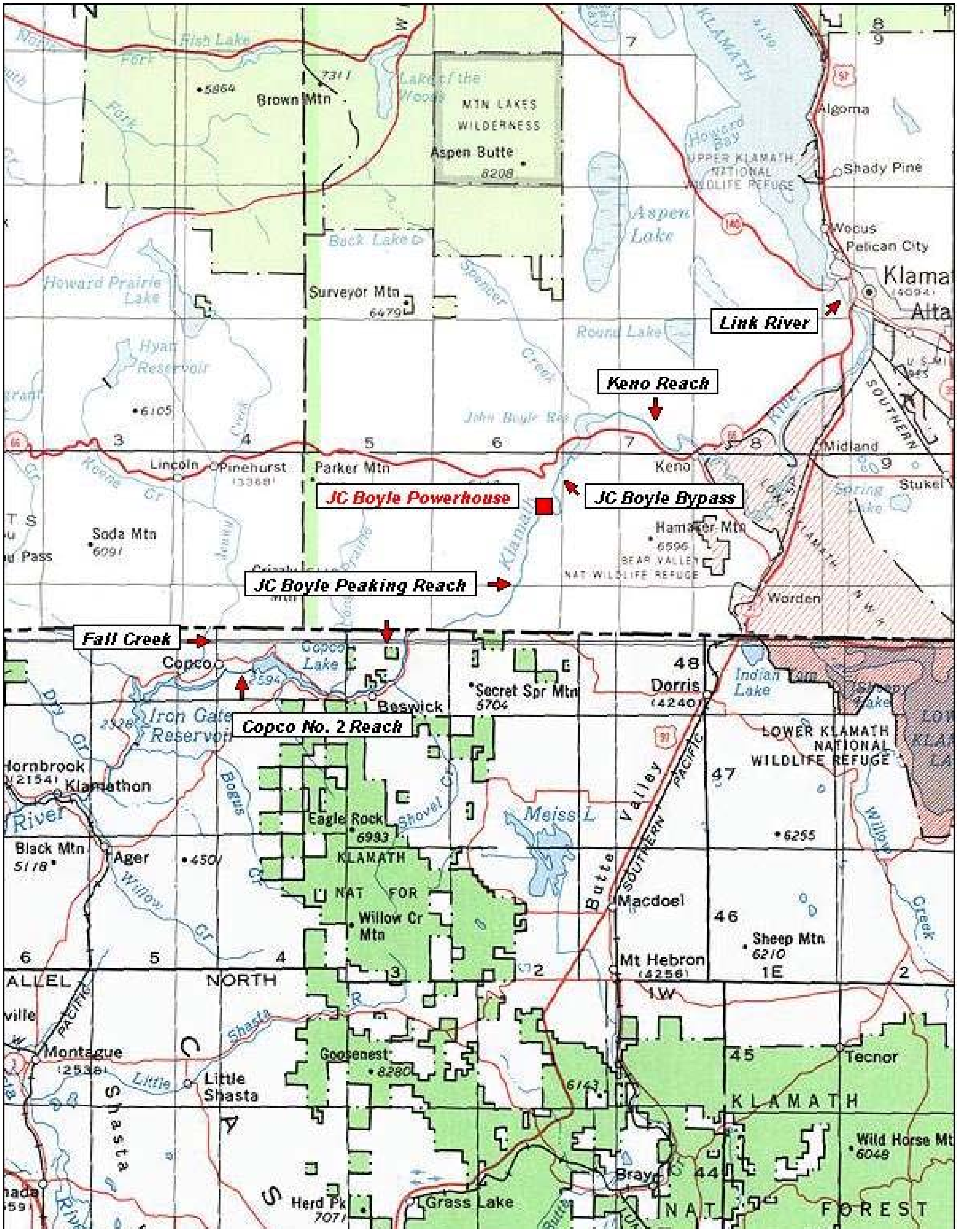


Figure 4.4-1. PacifiCorp Klamath Project area study reaches.

The following habitat types and definitions were used for mapping in the Project area:

- **Pool**—Areas of scour in the stream channel with column velocities usually less than 1 foot per second (fps) (0.3 m/s). Pools also generally lack surface agitation and commonly contain eddies or other slow water areas along one or both banks. This macrohabitat category includes main channel pools and scour pools. Other pool types that are generally noted include corner, plunge, and trench. Backwater pools are noted during mapping, but are not considered as individual habitat units.

- **Run**—Areas of swift flow with little surface agitation and no major flow obstructions. May occur at heads or tails of pools. Between hydraulic controls, may appear as flooded riffles and might contain some waves. Mean column velocities are generally in excess of 1 fps (0.3 m/s).

- **Glide**—Generally wide uniform channels with no flow obstructions, no surface agitation and low velocities. May occur at tails of pools. Substrate usually consists of cobble, gravel, and sand.

- **Pocket Water**—A section of swift flowing stream containing numerous boulders or other large obstructions, which create eddies or scour pockets. Velocities and depths are similar to run habitats. Pocket water habitat may contain small hydraulic breaks, counter currents, and velocity shear zones.

- **Low Gradient Riffle**—Shallow areas with swiftly flowing, turbulent water often with some partially exposed substrate. Gradient less than 4 percent, usually dominated by cobble substrate.

- **High Gradient Riffle**—Areas of steep, moderately swift and turbulent water. Exposed substrate is relatively great and dominated by boulders. Gradient generally more than 4 percent. Usually contains steps and multiple water surface elevations.

- **Cascade**—The steepest riffle habitat, consisting of alternating small waterfalls and shallow pools. Substrate generally boulder or bedrock. Usually contains white water at higher flows. Generally contains steps and multiple water surface elevations.

Habitat mapping was conducted by walking along the stream bank or by raft (J.C. Boyle peaking reach). Individual macrohabitat types were identified along the stream course with reference points, using the global positioning system (GPS) position and/or flagging, and were established at regular intervals to assist in relocating habitat units. Mapping within a given reach was conducted under various flow conditions dependent on Project operation at the time.

Lengths were measured with a hip-chain calibrated in feet. Width measurements were obtained with a laser rangefinder. On long or irregularly shaped units, multiple width measurements were averaged. Maximum depth was estimated on most units with a stadia rod. In the J.C. Boyle bypass and Keno reaches, it was not always possible to determine the maximum depth because wading was difficult and hazardous. In such cases, the best estimate was recorded. Gradient was determined using a hand-held level and stadia rod. Because of distance limitations of a hand-held level (maximum 50 to 60 feet (15.2 to 18.3 m) gradient in long units was estimated in a ‘typical’ section of the unit.

Initial habitat mapping was conducted in Fall Creek, Copco No. 2 bypass, J.C. Boyle bypass, Keno reach, and Link River between March 19 and March 24, 2002. Mapping in the J.C. Boyle peaking reach was delayed until May 14, 2002, to allow time to determine the appropriate method and flow level for mapping. After initial mapping, a request was made by the stakeholders to provide additional information regarding width, depth, gradient, and substrate in Fall Creek, J.C. Boyle bypass, and the Keno reach. Initial mapping in the Link River and Copco No. 2 bypass reaches was deemed adequate.

Habitat type boundaries were identified by breaks in stream channel slope or hydraulic controls. The minimum size of a habitat unit was not limited to the width of the wetted stream channel as often is prescribed. This was done because: (1) a small unit, such as a cascade or riffle, is a hydraulic control and often is used as an identifier when relocating habitat units; and (2) a unit that spans the width of the channel, such as a plunge pool between cascades, is considered a separate habitat unit even though it may not be as long as the channel is wide. Some longer pool tails were identified as run and glide habitat with unit breaks identified by changes in depth and velocity patterns. Habitat units with characteristics of more than one habitat type were identified with a sub-type, although ordinarily only the primary type was used in calculating habitat type totals and percentages.

Split channels (SPC) were indicated where a large island or bar existed (usually vegetated) and generally 10 percent or more of the total flow was in the secondary channel. Side channels (S/C) generally carried a small proportion of the total flow and sometimes were separated from the main channel by an island or boulder/cobble bar.

Substrate information was collected at regular intervals and/or when a change in overall composition was noted. Dominant and subdominant size classes were noted for all units. Because of visibility problems in the J.C. Boyle bypass and the Keno reaches, overall composition was often difficult to determine.

The following categories were used for substrate characterization during habitat mapping:

- Organic debris
- Silt/mud
- Fines less than 0.08 inch (0.2 cm)
- Sand 0.08 to 0.25 inch(0.2 to 0.64 cm)
- Gravel 0.25 to 3 inches (0.64 to 7.62 cm)
- Small cobble 3 to 6 inches (7.62 cm to 15.2 cm)
- Large cobble 6 to 12 inches (15.2 cm to 30.5 cm)
- Small boulder 12 to 24 inches (30.5 cm to 61.0 cm)
- Large boulder 24+ inches (61.0 cm)
- Bedrock

General riparian composition was noted for habitat units or sections of a reach by recording dominant/subdominant types and distance from waters edge. Large woody debris (LWD) accumulations also were noted and the number of pieces per unit recorded. LWD was defined as being at least 6 inches (15.2 cm) in diameter, and 6 feet (1.8 m) long, and within the active channel.

The J.C. Boyle peaking reach was mapped by raft. Consequently, some of the previously described procedures were modified. The survey was conducted from the J.C. Boyle powerhouse to the top of Copco reservoir. A portion of the Hell's Corner area containing numerous class IV rapids (Caldera Rapid to Snag Island, 19,464 feet (5,932.6 m) or approximately 20 percent of the total reach) was only partially mapped because of a lack of pull out areas for the rafts and the need to keep electronic equipment dry. For this section of the reach, a combination of two data sources was used to complete the mapping: (1) data as collected for this study, and (2) data previously collected by the ODFW (1998). This involved comparing measured data at known locations in addition to the use of aerial photos to reconcile habitat unit locations and unit lengths. Because this section of river is composed primarily of rapids (most identified as steep riffles) and pools, it is felt that these data provide a satisfactory picture of the instream habitat in this section of the reach.

Lengths were measured on the basis of GPS route coordinate lengths cross-checked with field-measured lengths. Widths were measured with a laser rangefinder while moving through units or when stopped. Maximum depths were estimated using either a hand-held depth finder or stadia rod. Depths were not measured on all riffle and run units because of a combination of high velocities (in rapids) and turbulence that did not allow for reliable estimates. Short units (primarily steps, rapids, and runs) were measured only sporadically for depth.

Because it was impractical to stop rafts and measure slope in every habitat unit, it was necessary to apply some sort of slope rating based on visual observations (see section below, Additional Habitat Mapping Considerations). Because the initial habitat categories for riffle included low gradient (less than 4 percent) and high gradient (more than 4 percent), it was decided to divide the riffles into low slope (zero to 2 percent), moderate slope (2 to 4 percent) and steep slope (more than 4 percent) categories. Run and pocket water, typically not steep slope habitat, were separated into low slope (zero to 1 percent), moderate slope (1 to 2 percent) and steep slope (more than 2 percent). Cascade habitat was not included in steep slope riffles because it is generally much steeper, contains vertical drops, and usually is not considered for modeling. Before habitat mapping the J.C. Boyle peaking reach, several riffles and runs were measured for slope to provide a basis for visual estimates in the field based on the slope categories described previously. During habitat mapping, additional slope measurements were obtained on a variety of runs (18) and riffles (45) to assist in visual determination during mapping and provide a good sample of actual slopes.

Some aspects of habitat mapping and habitat types changed during the scoping process. Splitting of non-pool habitat types—riffles, runs and pocket waters—into slope categories was done to accommodate agency requests to (1) attempt to duplicate habitat typing efforts in the Lower Klamath River below Iron Gate dam, and (2) provide estimates of habitat variability for sample size selection. It was determined that slope categories used below Iron Gate dam were not applicable to the Upper Klamath River. The categories were too narrow in breadth and did not apply to the generally steeper gradient character of the Upper Klamath River. The sample size selection process based on habitat variability was not pursued as a viable procedure.

During initial habitat mapping the tail-outs of many pools (and to a small extent runs at the heads of pools) were separated from the main pool body and identified as runs and/or glides. A request by stakeholders to lump these units back into pools was completed before transect selection. However, during the July 24, 2002, field trip to view selected transects in the J.C. Boyle bypass reach with stakeholders it was noted that this process had flaws. As a result, before subsequent transect selection in other reaches, combined habitat units were reexamined and adjustments made where appropriate.

4.4.2.2 Study Site and Transect Selection

Habitat mapping formed the basis for study site and mesohabitat type selection. The percent contribution of individual habitat types to total habitat is derived from the total length of a given reach. The PHABSIM habitat analysis relies on hydraulic conditions measured along stream cross sections, or transects, placed in a variety of different mesohabitats.

High gradient riffle (steep slope more than 4 percent gradient) and cascade habitats were not used in study site or mesohabitat type selection. Generally, these habitats are too dangerous to negotiate by wading or boat and usually are not suitable for adequate simulations using existing hydraulic models. Other units that could not be modeled during habitat mapping (examples include transverse flow, multiple water surfaces across the channel, units immediately upstream of cascades or rapids) also were excluded from the selection procedure. In addition, major mesohabitat types or subcategories, which account for less than 5 percent of the total reach, were not included in the study site and habitat unit selection procedure.

Actual habitat unit selection was accomplished with a combination of random selection and professional judgment through the following procedure:

1. To encourage spatial separation of study sites, the study reach may have been separated into multiple segments (two or more) by either gradient breaks, tributary location, length, or other criteria.

2. Within the predetermined study reaches, the mesohabitat type (e.g., riffle, pool, pocketwater, run) with the <u>lowest percentage</u> of abundance (but more than 5 percent of the total by length) was used as the basis for selection of a random starting habitat unit. All habitat units in this category sequentially were numbered and the first randomly selected unit was chosen.

3. In the field, the first randomly selected unit was relocated and, if it was able to be modeled, was reasonably typical (not atypical or unique), and safe to collect hydraulic data, the unit was selected and flagged. If the unit was rejected for any reason, then the next randomly selected unit was chosen.

4. At least one example of each remaining more-abundant mesohabitat type then was located in the immediate vicinity of the random unit (the closest unit upstream or downstream). This creates a “cluster” of habitat units to reduce data collection and travel time.

5. The same procedure was followed for the next randomly selected least-available unit until the total target number of mesohabitats was achieved in multiple clusters.

6. Additional habitat units may have been selected non-randomly by professional judgment to represent unique, rare, or otherwise important habitat units (e.g., spawning, passage).

The process has the advantage of using randomization for selection without precluding the use of professional judgment for sites that are unrepresentative or unworkable. It also establishes a systematic approach and minimizes the time required for travel between study sites in the field. With the exception of low and high gradient riffles (habitat types used in the initial habitat mapping effort), slope subcategories for runs and pocket waters never were intended to represent or be sampled as separate habitat types. However, these subcategories were used to assist in transect selection, and transects were placed in these habitat units in proportion to the basic mesohabitat type under which they occur. Before study site and transect selection, it was agreed that at least three examples of each major mesohabitat type would be selected in each river reach (referred to as the "guideline of three"). In addition, three transects would be placed in each mesohabitat type. Exceptions to the "guideline of three" number of transects is discussed under the basic approach to transect selection and described in individual reach summaries.

In most cases, transects were placed near the top, middle, and bottom of each mesohabitat type selected. Actual transect placement was to be agreed upon in the field with stakeholder representatives.

The "guideline of three" was followed for transect placement in mesohabitat types selected, with few exceptions. These exceptions are explained under individual reach descriptions that follow, and included agreement with stakeholders during transect selection that fewer than three transects would be adequate.

4.4.2.3 Data Collection

The flows targeted for calibrating the PHABSIM hydraulic models have been identified considering water availability, project flow control capacity, physical safety, and desired flow range for habitat analysis, incorporating unimpaired hydrology ranges where possible (Table 4.1-1). Velocity data acquisition target flows (bold) are primarily limited by physical safety for wading. Velocity data acquisition in the J.C. Boyle peaking reach and some sections of the bypass reach were by Acoustic Doppler Current Profiler (ADCP), operated from a boat, which is not as limited by concern for wading safety, which would be on the river margins only.

Table 4.4-1. Target measurement flows and proposed simulation flow range by reach, Klamath River instream flow studies (***bold italic*** is velocity data acquisition flow).

Reach	**Target Measurement Flow (cfs)**				**Simulation Flow Range (cfs)**
J.C. Boyle Bypass[1]	100 to 325	***475 to 700***	***1,500***[2]		100 to 3,750
J.C. Boyle Peaking	325	***700***	***1,500***	3000[3]	250 to 7,500
Copco 2 Bypass	***200***	***600***	1,500		100 to 3,750
Fall Creek	2	5	***10***		1 to 25

[1] Because of approximately 225 cfs of spring flow accretion in this reach, the lower end of range is target flow at upstream end of the bypass reach and upper end of range is target flow at downstream end of the bypass reach.

[2] Where possible in this reach velocities will be obtained at 1,500 cfs. However, because of safety concerns, only acquisition of velocities along one or both side margins of the transects is expected in this reach.

[3] Where possible in this reach, velocities will be obtained along one or both side margins of the transects at 3,000 cfs.

PacifiCorp provided flow levels in the respective study reaches through stable controlled releases from various Project facilities for the duration of time required. All the calibration flow released were made so that they occur at the transect sites and were stable during daylight hours.

Complete sets of depths and velocities were collected approximately at the target velocity flows at those areas that could be safely negotiated, or at the next lowest flow that could be safely accessed. Some additional velocity measurements were collected at other target flows in the J.C. Boyle bypass and peaking reaches. Additional measurements of water surface elevation for each transect and a single discharge measurement (per transect cluster) were made at the remaining flow levels. Pool transects, which cannot be safely waded, will be measured with the ADCP where feasible (depending mostly on access). See Section 4.7, Results and Discussion, for actual flows measured.

4.4.2.4 Field Techniques

Field data collection and the form of data recording follow the guidelines established in the Instream Flow Group (IFG) field techniques manuals (Trihey and Wegner, 1981; Milhous et al. 1984; Bovee, 1997). Additional quality control checks that have been found valuable with previous applications of the simulation models were included. The techniques for measuring discharge generally followed the guidelines outlined by Rantz (1982). A minimum of 20 wetted stations per stream transect was established, with a goal of no less than 15 wetted stations at the lowest measured flow. Generally, 2- to 3-foot (0.6 to 0.9 m) stations are used for large channels (more than 75 feet (22.9 m) wetted width) and 1- to 2-foot (0.6 to 0.9) stations for medium channels and 0.5 to 1 foot (0.2 to 0.3 m) stations in small channels (less than 20 feet (6.1 m) wetted width). The boundaries of each station along each transect normally were at even increments, but significant changes in velocity, substrate, depth, or other important stream habitat features may dictate additional stationing.

<u>Quality Control</u>

Considerable effort was applied to maintaining strict quality control throughout all aspects of field data collection. To ensure quality control in the collection of field data for the Klamath River instream flow studies, the following procedures and protocols were used:

- Staff gauges were established and continually monitored throughout the course of collecting data on each transect. If significant changes occurred, water surface elevations were re-measured following collection of transect water velocity measurements.

- Only high-quality current velocity meters were used in the collection of velocity data. Price AA meters were used in fast, deep waters; Pygmy-meters were used in shallow, slower waters as recommended in the USGS techniques manual (Rantz, 1982), and Marsh-McBirney electromagnetic meters, as needed, in deep, slow waters.

- Each day, before water velocity measurements, all mechanical meters were inspected. Pivot pins were replaced if significant wear was noted, pin clearances adjusted, and the meters spin tested. Magnetic meters were calibrated on a regular basis, either by following the manufacturers procedures or comparing velocity output to mechanical measurements. Meters were monitored continually during the daily course of data collection to ensure that they were functioning properly.

- An independent benchmark was established for each set of transects. The benchmark was an immovable tree, boulder, or other naturally occurring object that would not be subject to tampering, vandalism, or movement. Upon establishment of headpin and tailpin elevations, a level loop was shot to check the auto-level for measurement accuracy. Allowable error tolerances on level loops were set at 0.02 feet (0.6 cm). This tolerance also is applicable to both headpin and tailpin measurements, except where extenuating circumstances (pins under sloped banks, shots through dense foliage, etc.) explained discrepancies and the accompanying headpin or tailpin was free of excessive error.

- Water surface elevations were measured on both banks on each transect except under extenuating circumstances, such as impractical or unsafe access to the far bank at a given flow level. If possible, on more complex and uneven transects, such as riffles or pocket waters, water surface elevations were measured at a number of locations across a transect. An attempt was made to measure water surface elevations at each calibration flow at the same location (station on tape) across each transect.

- Pin elevations and water surface elevations were calculated during field measurement and compared to previous measurements. Changes in stage since the previous flow measurement were calculated. Patterns of stage change were compared between transects and determined, if reasonable. If any discrepancies were discovered, potential sources of error were explored and noted.

- All calculations were completed in the field (given adequate time and daylight). Calculated discharges were compared between transects at the same flow. If an excessive amount of discharge (more than 10 percent of the streamflow) was noted for an individual transect cell, additional adjacent stations were established to more precisely define the velocity distribution patterns at that portion of the transect.

- The ADCP output was examined in real-time as the unit was deployed. Multiple passes were made to ensure discharge calculations were reasonable and good bottom profile and velocity patterns were obtained.

- Photographs were taken of all transects from downstream, across, and upstream of the calibration flows. An attempt was made to shoot each photograph from the same location at each of the three levels of flow. These photographs provided a valuable record of the streamflow conditions (including velocity and depth), water surface levels, and channel configurations that could be used for confirmation during the hydraulic model calibration.

<u>Velocity Measurements</u>

For those transects that could be waded, either a mechanical or magnetic meters attached to top-set rods were used. Mechanical velocity meters were vertical-axis, rotating-cup Scientific Instruments Price AA and pygmy-type meters. These meters are accurate where flow is turbulent or shifts direction and where air is entrained in the water column. Magnetic Marsh-McBirney Model 2000 meters were used in more laminar flow areas and along stream margins where vegetation prohibited the use of mechanical meters. Mean column velocity was determined by a single measurement at six-tenths of the water depth in depths less than 2.5 feet (0.8 m), and a two-tenths and eight-tenths measurement for depths between 2.5 and 4.0 feet (0.8 and 1.2 m). All three points were measured where depths exceeded 4.0 feet (1.2 m), or the velocity distribution in the water column was abnormal and one or two points were not adequate to derive an accurate mean column water velocity.

For those areas that could not be safely waded, velocity acquisition was made with a ADCP. The ADCP gathers depth and velocity information at small steps, laterally and vertically, across a transect. The ADCP unit was operated either from shore with the unit encased in an Ocean Sciences trimaran riverboat, or towed by a Zodiac inflatable with a jet outboard. When operated from shore, the trimaran was secured to an overhead line and hauled back and forth across the channel with a rope and pulley system. The operator viewed data in real-time through a radio modem connection between the ADCP and a laptop computer. Because the ADCP can accurately measure only to a depth of approximately 1 foot (0.3 m), edge cell measurements were obtained by wading to complete the velocity patterns in shallow areas for each transect.

Complete sets of depths and velocity measurements were collected at most transects at the target velocity acquisition flows indicated in Table 4.1-1. For those areas that could not be sampled safely at the target flow, velocities were measured at the next lowest flow. In some cases, it was not feasible to obtain reliable velocities across an entire transect, by any means, because of excessive turbulence or unsafe conditions at certain flow levels. This occurred primarily in riffles in the J.C. Boyle peaking reach and the heads of pools in the J.C. Boyle bypass reach. In such instances, all available velocity information collected will be supplemented with modeled velocities as described in the hydraulic modeling section.

4.4.2.5 Sub-Mesohabitat and Transect Substrate and Cover Coding

Each sample point on the one-dimensional transects (and nodes of the two-dimensional sites) were described using the CDFG Klamath River Sub-Mesohabitat Components (see Appendix 4A). In addition, standard Bovee substrate codes (see Appendix 4B) were described for each sample point because there are currently no habitat suitability criteria available that incorporate the CDFG coding. All substrate and cover coding was completed at the lowest target flow when visibility was optimum.

Hydraulic Simulation Software

Originally, PHABSIM was developed and maintained by the USFWS Instream Flow Group (IFG, now USGS, Aquatic Systems and Technology Application Group, Fort Collins Science Center). PHABSIM calculates a habitat index (WUA) in part based on simulation of river depths and velocities from one-dimensional (1-D) hydraulic models that represent the river by cross-sections.

For 1-D applications in this study, the hydraulic and habitat index simulations were derived from the computer program RHABSIM (Riverine Habitat Simulation). RHABSIM is software developed by TRPA that implements the equivalent algorithms of PHABSIM and is in use throughout the world as the new generation of instream flow analysis software. RHABSIM is an enhancement of many of the original PHABSIM model’s component programs with greatly expanded input, output, graphic, error-checking, calibration, and interpretation capabilities.

For two-dimensional (2-D) application in this study, the River2D model was used (Steffler and Blackburn, 2001). River2D is a 2-D, depth-averaged hydrodynamic and fish habitat model developed for use in natural streams and rivers. The fish habitat module is based on the

PHABSIM WUA approach, adapted for a triangular irregular spatial grid network. Habitat analysis uses habitat suitability inputs like those used by PHABSIM or RHABSIM.

The ADCP uses its own proprietary software (WinRiver, RD Instruments) for data acquisition and playback. Because the ADCP collects water velocities throughout the water column at relatively short intervals it was necessary to synthesize and condense the output into a form usable by RHABSIM or PHABSIM software. For this task, TRPA developed an ADCP conversion program that allows a user to interactively view bottom profiles and velocity patterns and establish stationing that can be directly entered into the hydraulic programs.

Stage-Discharge Calibration

Stage-discharge relationships for 1-D transects were developed from measured discharge and water surface elevations using either an empirical log/log formula (IFG-4) or a channel conveyance method (MANSQ). Under these methods each transect was treated independently. The IFG-4 method required a minimum of three sets of stage-discharge measurements and an estimate of stage-at-zero-flow (SZF) for each transect. The quality of the stage-discharge relationships was evaluated by examination of mean error and slope output from the model.

MANSQ only requires a single stage-discharge pair and uses Manning's equation to determine a stage-discharge relationship (Bovee and Milhous, 1978). However, it is generally validated by additional stage-discharge measurements. In situations where irregular channel features occur on a cross section, for instance bars or terraces, MANSQ is often better at predicting higher stages than log/log. MANSQ is most often used on riffle or run transects and is not suitable for transects that have backwater effects from downstream controls, such as pools. It also can be used as a test and verification of log/log relationships.

Velocity Calibration

A 1-D model represents a stream by means of vertical slices (transects) across the channel. Depths are simulated with the rise and fall of a single, level (in most cases) water surface. For simulating water velocities, the "one-flow" option was used. This technique used a single set of measured velocities to predict individual cell velocities for a range of flows. Simulated velocities were based on measured data and a relationship between a fixed roughness coefficient (Manning's n) and depth. In some cases, roughness was modified for individual cells if substantial velocity errors are noted at simulation flows. Velocity adjustment factors (VAFs) were examined to detect any significant deviations and determine if velocities remained consistent with stage and total discharge. For those transects that velocities could not be safely or accurately measured by any reasonable means, a combination of depth-calibration and roughness coefficient adjustment was used to fill in missing data.

Calibration of 2-D hydraulic models required only detailed channel geometry data and a downstream rating curve. Two-dimensional models start at a downstream transect with a known stage-discharge relationship, and depths and velocities are propagated upstream through a defined grid of x, y, and z coordinate points. Fluid dynamic equations are solved sequentially to balance depth and velocity patterns in the cells of the grid, and can be modified by variable roughness at each grid point. Multiple iterations of the model are required before an equilibrium state is reached for any given discharge, and the process is repeated for other simulated discharges. No other measured depth or velocity calibration data are entered into the model, although results can be modified by changing grid roughness values to roughly match known data.

Habitat Suitability Criteria

An important component of an instream flow study is the HSC that typically describes the relative suitability of water depth, water velocity, stream substrate, and cover types to the fish species and life stages of interest in the Project area. Scoping determined that all existing species and those potentially to be reintroduced through fish passage alternatives were of interest. The preferred method of developing HSC was by site-specific observations of a sufficient number of each species and life stage within a rigorous study plan designed to minimize observer or habitat availability bias. This option, however, was limited in most reaches the Klamath River because of high streamflows (more than 1,000 cfs (28.3 cms**)**, large flow fluctuations, relatively high gradient, and typically poor water visibility.

Target species and life-stages for HSC data collection included fry, juvenile, and adult rainbow trout (*Oncorhynchus mykiss*), Klamath smallscale suckers (*Catostomus rimiculus*), Klamath largescale suckers (*C. snyderi*), speckled dace (*Rhinichthys osculus*), tui and blue chubs (*Gila bicolor* and *G. coerulea*, respectively), and marbled sculpins (*Cottus klamathensis*). Although the federally listed shortnose sucker (*Chasmistes brevirostris*) and Lost River sucker (*Catostomus luxatus*) are known to occur in the Project area, they are primarily lacustrine species and were not expected to be encountered during the surveys. Other species of interest that potentially may be reintroduced into the Project area include Chinook salmon (*O. tshawytscha*), coho salmon (*O. kisutch*), and steelhead (*O. mykiss*).

Initial HSC data for rainbow trout were collected in the J.C. Boyle bypass reach in 2002. This reach is unique among the Upper Klamath River study reaches because of relatively low, stable flow (300to 400 cfs (8.5 to 11.3 cms) at its bottom end) and greater water visibility. Although only 100 cfs (2.8 cms) typically is released from J.C. Boyle dam, large spring inflows occur near the midpoint of the 4.5-mile (7.2 km) reach. Between 200 and 300 cfs (5.7 and 8.5 cms) of cold (8 to 10ºC), crystal-clear water seasonally enters the bypass reach and significantly reduces summer water temperatures and increases water visibility.

Existing HSC curves were used for most target species and life stages. This section includes figures for site-specific HSC curves along with developed in other locations, that are proposed for use in instream flow modeling of the Upper Klamath River. The characteristics of the source streams, sampling designs, and other pertinent factors for these proposed curves will be listed in tables in this section.

Suitability Simulation (WUA)

After the hydraulic data were calibrated through standard methods, the probable suitability index (WUA) by discharge was generated using the approved species criteria curves. The range of flows included in the simulations was determined by the calibration flows actually obtained in the field and by the suitability of the hydraulic data for extrapolation. All the satisfactorily calibrated hydraulic transects were weighted according to the percentage of each of the major habitat types present in the study reach. The hydraulic and HSC data were used to generate WUA relationships for each of the species/life stages in the various reaches of the Klamath River and it tributaries. The standard option of multiplying the individual variable suitability's (depth, velocity, and substrate/cover) for cell centroids was selected.

4.5 RELATIONSHIP TO REGULATORY REQUIREMENTS AND PLANS

These investigations are intended to provide baseline information that, together with environmental data and results of other past and ongoing studies, can be used to assess effects of Project operations on fish resources and to help formulate recommendations for protection, mitigation, and enhancement measures consistent with agency and tribal management goals. The following contain references to objectives for fisheries in the study area:

- CDFG Upper Klamath Wild Trout Management Plan
- ODFW Klamath River Basin Fish Management Plan
- USFWS and NMFS Endangered Species Act requirements
- Klamath River Wild and Scenic River Plan
- Tribal natural resource goals and objectives and cultural values
- Klamath River Basin Task Force (KRBFTF) Long Range Plan

The results will be used to help determine whether and where current Project operations are allowing healthy fish populations to be maintained at levels consistent with management objectives, and, if not, what changes to Project operations or facilities might be needed to achieve these objectives.

4.6 TECHNICAL WORK GROUP COLLABORATION

PacifiCorp worked with stakeholders to establish a collaborative process for planning and conducting studies needed to support Project relicensing documentation. Beginning in early 2001 the stakeholders and PacifiCorp developed a Process Protocol to guide the collaborative effort. The structure is comprised of a Plenary group (all interested stakeholders) and a number of technical working groups. As part of this structure, an Aquatics Work Group (AWG) was established to address most of the fisheries studies, except those related to fish passage, which had its own working group. The AWG has met approximately monthly. Additional meetings (often via phone conference) of AWG participants have been held to address specific study topics. In late 2003 several of the monthly AWG meetings were combined with the Fish Passage Work Group meetings to address some of the study topics that cross over both work groups.

Because of the technical nature of this specific instream flow study, a subgroup of the AWG, called the Instream Flow Subgroup, was formed in the spring of 2003 to focus on study issues. The group continues to meet to complete the instream flow study tasks.

4.7 RESULTS AND DISCUSSION

A summary of the total numbers of transects by study reach/segment is presented in Table 4.7-1. The number of transects was determined on the basis of habitat mapping results, discussions with the stakeholders, and sampling requirements established during scoping. Because habitat mapping, study site selection, and transect selection are linked, results are presented by individual reach to facilitate discussion. Specific details concerning habitat mapping and transect selection timelines can be found in report 1.12 Instream Flow Analysis Study Plan, which is included as part of the FERC license. Complete habitat mapping data for all reaches is presented in Appendix 4C.

Table 4.7-1. Number of transects established in the J.C. Boyle bypass, J.C. Boyle peaking reach (two segments), Fall Creek, and Copco No. 2 bypass reach..

Study Reach or Segment	Number of Transects
J.C. Boyle Bypass	32
Upper J.C. Boyle Peaking – (Powerhouse to Caldera)	45
Lower J.C. Boyle Peaking – (Oregon-California border to Copco)	26
Fall Creek	28
Copco No. 2 Bypass	28
Total	**159**

4.7.1 J.C. Boyle Bypass Reach

Habitat mapping initially conducted at the present licensed flow regime (100 cfs (2.8 cms) release from J.C. Boyle reservoir) was used as the basis for study site, habitat unit type and transect selection. Run habitat, the least available habitat type able to be modeled, was used as the random selector. One low slope run and one moderate slope run were used as a selector above and below the canal spillway. This procedure ensured that (1) sites would be located above and below the major spring influence and (2) at least one of each sub-type of run would be encountered at each study site for possible transect placement. Transects were pre-selected by PacifiCorp consultants on July 17, 2002. The selected study sites and transects were reviewed by agency personnel during a site visit on July 23-24, 2002. With the exception of one study site, where three run and three pool transects were relocated, the selected habitat units and transects were agreed upon. Study site and habitat units selected for study are shown in Figure 4.7-1.

Because of stakeholders concerns about habitat mapping at a low flow and resulting habitat type percentages, it was agreed that habitat mapping in this reach would be reassessed at a higher flow during a scheduled powerplant outage. Flows ranged between 475 cfs (13.5 cms) in the upper section to 800 cfs (22.7 cms) at the lower end of the reach during this time. At this higher flow level, only one habitat unit that was selected for study (Pool Unit # 282) was reclassified, in this case to run habitat. No change in number of transects or locations occurred as a result of this remapping. The major difference between the low and high flow habitat mapping results was a shift in the percentage of pool and run habitat (Table 4.7-2).

The final number of transects and habitat units selected to represent this river segment are shown in Table 4.7-2. Even though riffle habitat accounts for more than 15 percent of the reach, the majority was steep slope (more than 4 percent slope) and not able to be modeled**.** The final transect weighting used for modeling this reach was based on the high flow mapping.

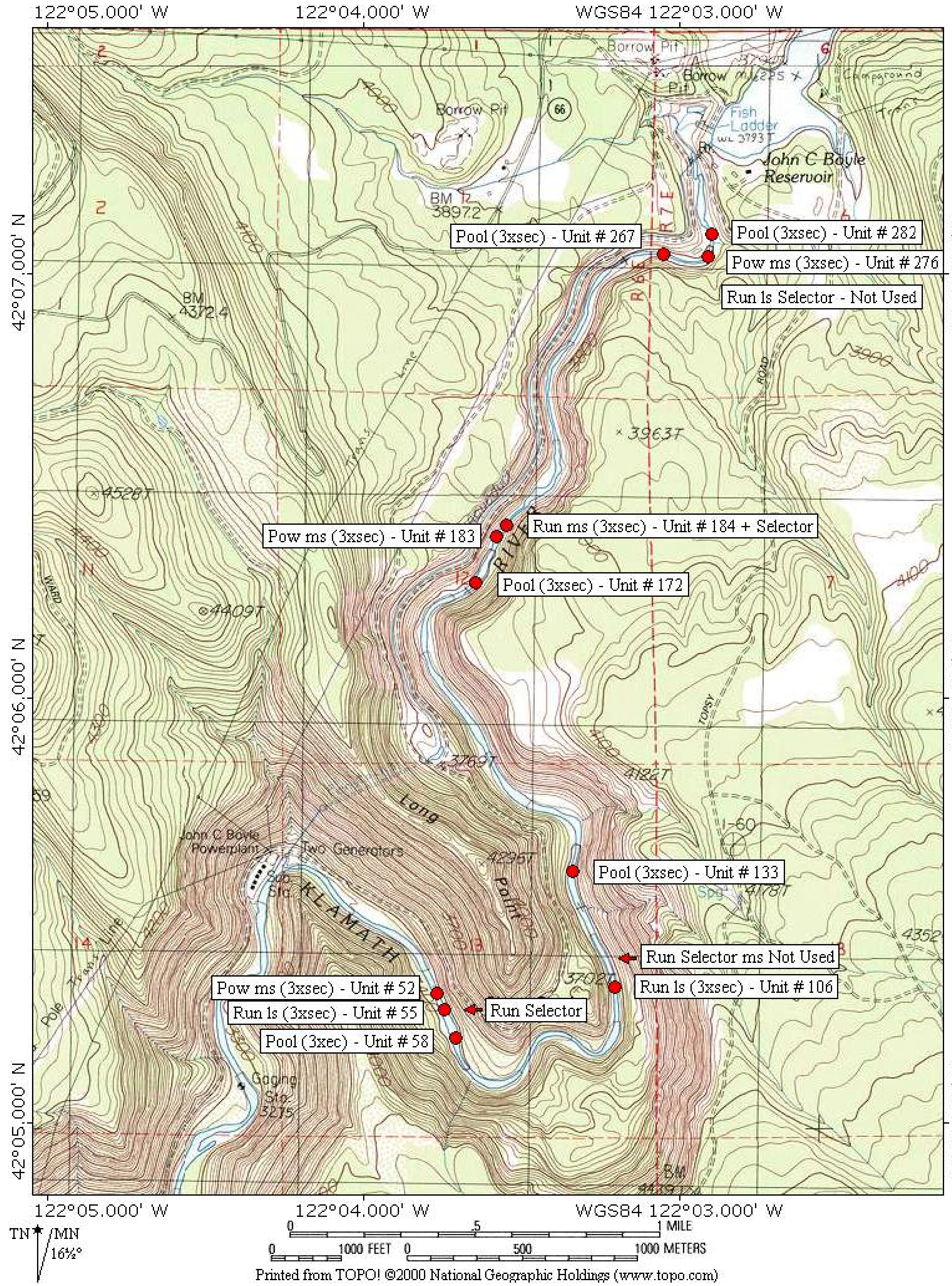


Figure 4.7-1. Study site, habitat unit, and transect locations in the J.C. Boyle bypass reach.

Table 4.7-2. Summary of low flow and high flow habitat mapping of the J.C. Boyle bypass reach. Number of transects per habitat type and resulting transect weighting estimates are included.

Habitat Type	Number Units	Total Length (ft)	Percent of Total	Percent Normalized*	Number of Transects	Number of Sample Units	Percent Weight/ Transect
J.C. Boyle Bypass – 100 cfs Release				**Transects and Weighting**			
Pool	66	11,771	50.2	63.3	15	5	4.2
Glide	0	0	0.0	----	----	----	----
Run	38	3,136	13.4	16.9	9	3	1.9
Pocket Water	57	3,684	15.7	19.8	8	3	2.5
Riffle (low gradient)	18	690	3.0	----	----	----	----
Riffle (high gradient)	56	3,093	13.2	----	----	----	----
Cascade	23	1,081	4.6	----	----	----	----
Totals	253	23,455	100.0	100.0	32	11	
J.C. Boyle Bypass – 475 cfs Release				**Transects and Weighting**			
Pool	25	5,906	25.1	35.1	12	4	2.9
Glide	1	71	0.3	----	----	----	----
Run	56	7,246	30.8	43.1	12	4	3.6
Pocket Water	36	3,675	15.6	21.8	8	3	2.7
Riffle (low gradient)	9	687	2.9	----	----	----	----
Riffle (high gradient)	38	3,911	16.6	----	----	----	----
Cascade	20	2,003	8.5	----	----	----	----
Totals	185	23,499	100.0	100.0	32	11	

* Does not include "high gradient" habitats (cascade and high gradient riffles) or habitat categories not sampled.

4.7.2 J.C. Boyle Peaking Reach

The J.C. Boyle peaking reach was divided into three segments: (1) J.C. Boyle powerhouse to Caldera (includes Frain Ranch), (2) Hell's Corner, and (3) Oregon-California border to Copco reservoir. No study sites were placed in the Hell's Corner segment because of limited access and generally unworkable conditions. In addition to standard 1-D transects, one site for 2-D sampling and modeling was selected in the lower segment of this reach, and additional main channel-side channel flow relationships were assessed at various locations in the reach.

4.7.2.1 Upper J.C. Boyle Peaking Reach (Powerhouse to Caldera)

This river segment, approximately 6.0 miles (9.7 km) long, was divided into an upper (powerhouse to Frain Ranch) and lower section (Frain Ranch) for study site and transect selection (Figures 4.7-2and 4.7-3). The first 1 mile (1.6 km) of this segment is steep, with a series of rapids, before transitioning over the next 1.5 miles (2.4 km) into the lower gradient Frain Ranch area. Pool and run were the dominant habitat types in this segment. The primary habitat type difference between the upper and lower sections of this reach segment was the riffle types. High gradient riffles/rapids dominated the powerhouse to Frain Ranch section, while low gradient riffles were more prevalent in the Frain Ranch area. The final number of transects sampled in the Powerhouse to Caldera segment of the J.C. Boyle peaking reach is shown in Table 4.7-3.

Table 4.7-3. Summary of habitat mapping of the Upper J.C. Boyle Peaking Reach (J.C. Boyle Powerhouse to Caldera). Number of habitat units and transects selected for study and resulting transect weighting estimates included.

Habitat Type	Number of Units	Total Length (ft)	Percent of Total	Percent Normalized[1]	Number of Units	Number of Transects	Percent per Transect
J.C. Boyle Peaking Reach—Powerhouse to Caldera				**Transects and Weighting**			
Pool	22	14,664	46.7	51.0	6	18	2.8
Glide	2	2,482	7.9	8.6	1	3	2.9
Run	17	6,713	21.4	2.34	4	12	2.0
Low Gradient Riffle	19	4,871	15.5	17.0	5	12	1.4
High Gradient Riffle	11	2,664	8.5	----	----	----	----
Cascade	0	0	0.0	----	----	----	----
Totals	71	31,394	100.0	100.0	16	45	

[1] Does not include "high gradient" habitats (cascade and high gradient riffles) or habitat categories not sampled.

The least-abundant sub-habitat type (more than 5 percent) for the entire segment was moderate slope run. However, because moderate slope runs were not identified in the lower portion of the segment, low slope run was used as the selector to ensure that transects would be placed in at least one such habitat category in both sections of the reach. Initially, two study sites were chosen, one in each section, and a total of 33 transects was selected. Because only two glides were identified in this river segment (both in the low gradient area), only one was selected for transect placement (this is the only instance where the "3 mesohabitat guideline" was not applied in this reach).

At the AWG meeting of August 6, 2002, it was agreed that an additional 12 transects (in four additional sample units) would be added to this river segment, to account for stakeholders concerns that neither section was being adequately sampled. At a subsequent site visit on September 9, 2002, by representatives of the AWG, the four new habitat units were selected: one (three transects) run unit at the USGS gauging site, one (three transects) pool unit above Osprey Island, one (three transects) pool unit about 0.5 mile (0.8 km)below Osprey Island, and one (three transects) riffle unit just upstream of the double bend above Caldera. Two pools were chosen because of the high percentage of pool in the segment, and the run and riffle were chosen to expand the range of variability in previously selected units. All participants indicated approval and acceptance of transect locations in these additional units. Also, previously placed main channel transect locations generally were approved, with some modifications, mainly to account for migrating mesohabitat transition areas. Several transects were moved slightly upstream or downstream. Two riffle units with three transects were reduced to two transects each and the two deleted transects were placed in a new riffle to represent a broader range of riffle types.

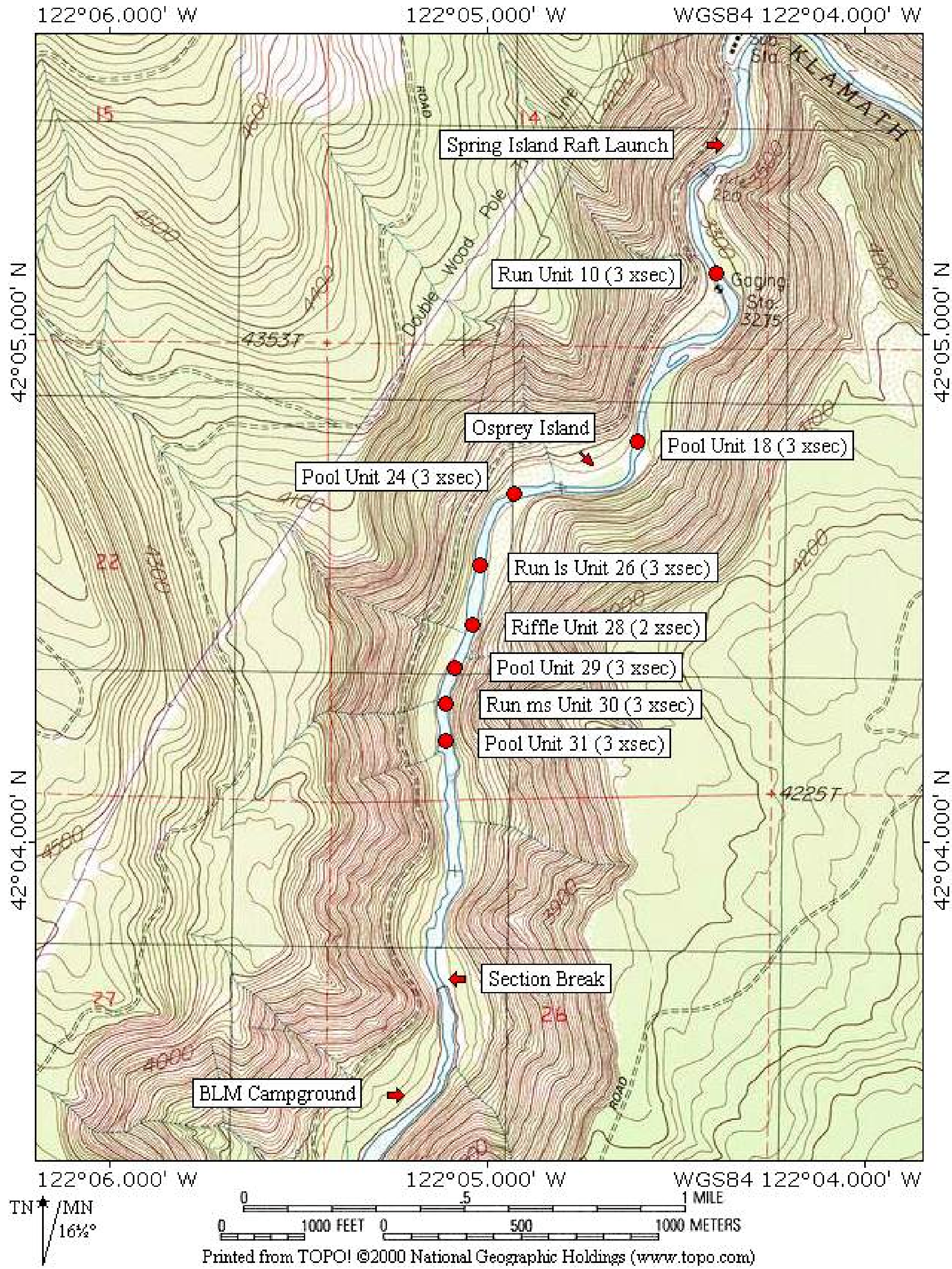


Figure 4.7-2. Study site, habitat unit, and transect locations in the upper section of the J.C. Boyle peaking reach (powerhouse to Caldera segment).

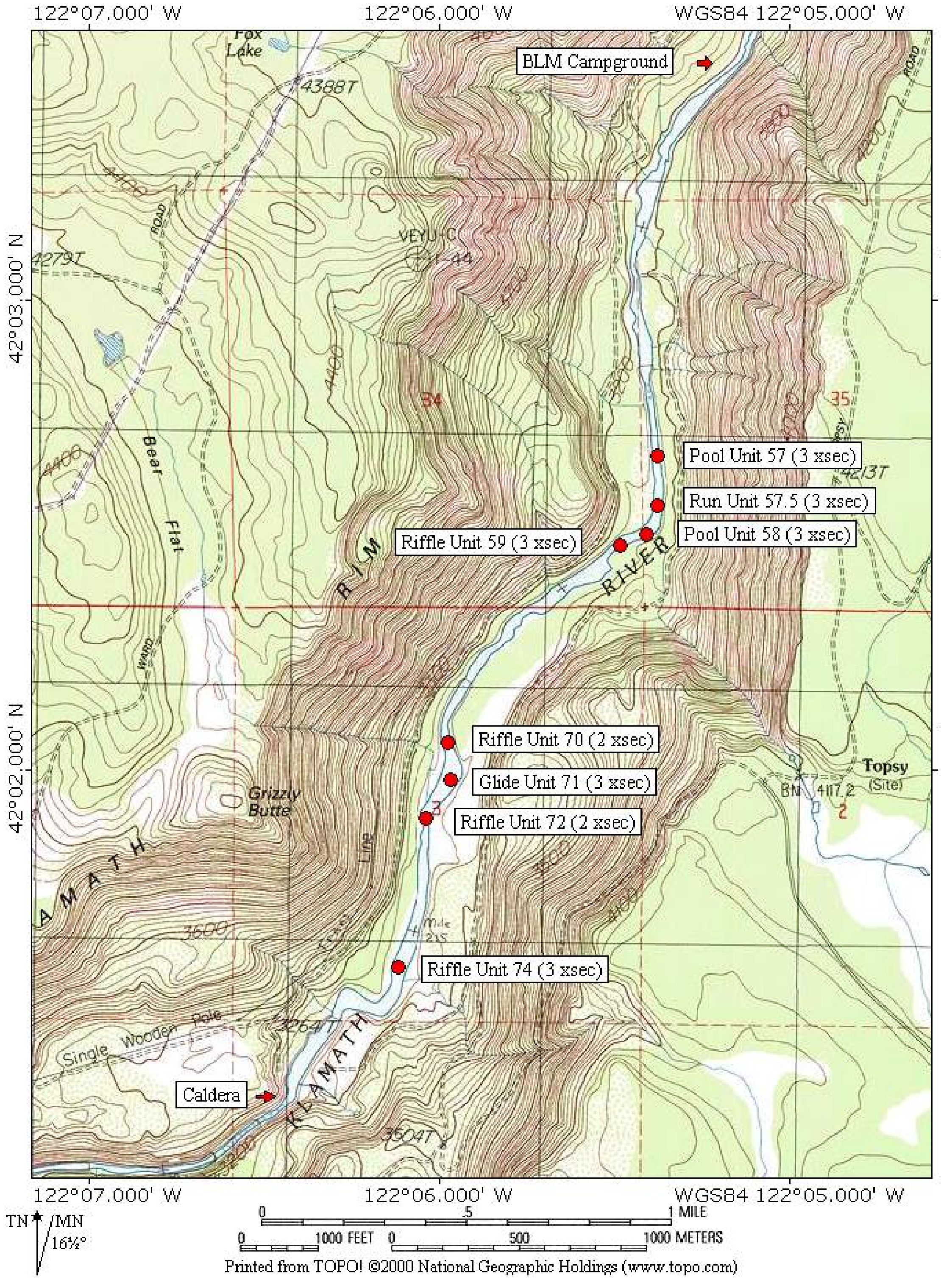


Figure 4.7-3. Study site, habitat unit, and transect locations in the Frain Ranch section of the J.C. Boyle peaking reach (powerhouse to Caldera segment).

4.7.2.2 Lower J.C. Boyle Peaking Reach (Oregon-California border to Copco reservoir)

This river segment is approximately 5.5 miles (8.9 km) long and begins at the Oregon/California border. The reach is fairly uniform in gradient. Runs and pools dominate this segment. The sub-habitat type moderate slope run was used as the selector. Because the river segment and habitat units are relatively long, the first three random selectors were used to establish different study locations. This allowed for a better longitudinal distribution of sites. The number of transects selected for study in this river segment is shown in Table 4.7-4.

Table 4.7-4. Summary of habitat mapping of the J.C. Boyle peaking reach – Oregon-California border to Copco reservoir. Number of transects per habitat type and resulting transect weighting estimates included.

Habitat Type	Number Units	Total Length (ft)	Percent of Total	Percent Normalized*	Number of Transects	Number of Sample Units	Percent Weight/ Transect
J.C. Boyle Peking Reach – Stateline to Copco				Transects and Weighting			
Pool	15	10,226	35.8	37.5	9	3	4.2
Glide	0	0	0.0	----	----	----	----
Run	21	12,780	44.8	46.8	9	3	5.2
Riffle (low gradient)	19	4,283	15.0	15.7	8	4	2.0
Riffle (high gradient)	5	1,182	4.2	----	----	----	----
Cascade	3	83	0.29	----	----		----
Totals	63	28,554	100.0	100.0	26	10	

* Does not include “high gradient” habitats (cascade and high gradient riffles) which cannot be adequately modeled under existing hydraulic simulation models or habitat categories which are less than 5% of reach.

A total of 27 transects were originally selected by PacifiCorp in this lower section of the J.C. Boyle peaking reach, consisting of three transects in each of three units of pool, run, and riffle habitat types. At a subsequent site visit on September 12, 2002, by representatives of the AWG to review and agree on transect locations, adjustments were made that reduced the total to 26 transects. This was primarily a result of trying to balance the main channel habitat that would be modeled by 2-D versus 1-D. Two new transects were placed in a short riffle upstream of the 2-D site to replace three transects in a riffle unit adjacent to a side channel that does not contain water until flows are quite high. For safety reasons, one riffle at the Oregon-California border raft takeout was reduced to one transect, and two transects placed in a riffle downstream. Finally, two 1-D habitat units, a pool and run, which were found not desirable because of the hydraulic influence of Miller’s bridge (pilings and abutments), were moved to near the 2-D site from randomly selected units just below Miller’s bridge. The final study unit and 2-D study site locations are presented in Figure 4.7-4.

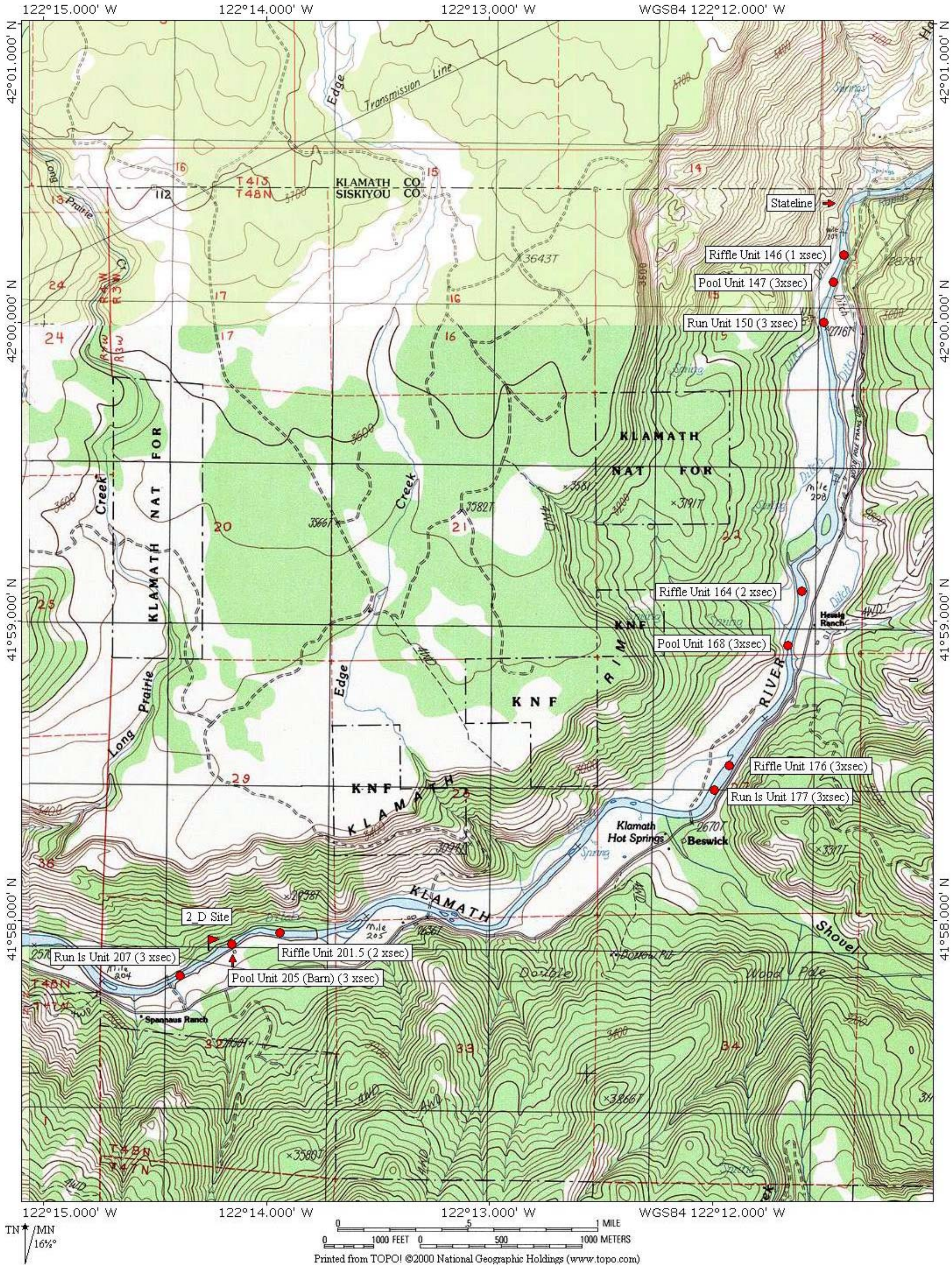


Figure 4.7-4. Study site, habitat unit, and transect locations in the lower section of the J.C. Boyle peaking reach (Oregon-California border to Copco).

4.7.2.3 J.C. Boyle Peaking Reach (Powerhouse to Copco Reservoir)

The previous sections described study site and transect selection in segments of the J.C. Boyle peaking reach. Results of habitat mapping and subsequent habitat representation is presented here for the entire peaking reach (Table 4.7-5). In addition, a summary excluding the Hell's Corner section of the reach is presented in Table 4.7-6. This represents only the portions of the reach that was considered for habitat modeling.

Table 4.7-5. Summary of habitat mapping of the J.C. Boyle Peaking Reach—Powerhouse to Copco Reservoir. Number of habitat units and transects selected for study and resulting transect weighting estimates included.

Habitat Type	Number of Units	Total Length (ft)	Percent of Total	Percent Normalized[1]	Number of Units	Number of Transects	Percent per Transect
J.C. Boyle Peaking Reach – Powerhouse to Copco				**Transects and Weighting**			
Pool	57	35622	41.1	50.1	9	27	1.85
Glide	2	2482	2.9	3.5	1	3	1.16
Run	47	22861	26.4	32.2	7	21	1.53
Low Gradient Riffle	40	10104	11.7	14.2	9	20	0.71
High Gradient Riffle	38	15293	17.6	----	----	----	----
Cascade	7	277	0.3	----	----	----	----
Totals	191	86639	100.0	100.0	26	71	

[1] Does not include "high gradient" habitats (cascade and high gradient riffles) or habitat categories not sampled.

Table 4.7-6. Summary of habitat mapping of the J.C. Boyle Peaking Reach – Powerhouse to Copco Reservoir (excluding the 5.0 mile Hell's Corner section). Number of habitat units and transects selected for study and resulting transect weighting estimates included.

Habitat Type	Number of Units	Total Length (ft)	Percent of Total	Percent Normalized[1]	Number of Units	Number of Transects	Percent per Transect
J.C. Boyle Peaking Reach—Powerhouse to Copco (excluding Hell's Corner Segment)				**Transects and Weighting**			
Pool	37	24890	41.5	44.4	9	27	1.65
Glide	2	2482	4.1	4.4	1	3	1.47
Run	38	19493	32.5	34.8	7	21	1.66
Low Gradient Riffle	38	9154	15.3	16.3	9	20	0.82
High Gradient Riffle	16	3846	6.4	----	----	----	----
Cascade	3	83	0.15	----	----	----	----
Totals	134	59948	100.0	100.0	26	71	

[1] Does not include "high gradient" habitats (cascade and high gradient riffles) or habitat categories not sampled.

4.7.2.4 Two-Dimensional Study Site

A site visit was conducted on September 9-11, 2002, by representatives of the AWG with the objectives of selecting 2-D modeling sites (one each proposed in the Oregon and California sides of the peaking reach), reviewing 1-D transects (as previously described), and discussing approaches to evaluating side channels in the peaking reach (described below). A key objective in selecting 2-D modeling sites was to capture a main channel-side channel complex. The major side/split channel in the upper portion of the J.C. Boyle peaking reach (known as Osprey Rapid/ Island) originally was proposed as one of the 2-D study sites (see Figure 4.4-1; site does not show on topographic map as an island). Based on reconnoiter of the Oregon portion of the peaking reach during the site visit, starting with Osprey Island and ending at the dual bend just above Caldera, it was determined that none of the available complexes appeared suitable for 2-D modeling. This was because the complexes contained dangerous rapids in the main channel side, complex boulder/cobble split controls, short channel length, or habitat value not dissimilar from main channel areas. The consensus of those present was to not use 2-D, but to collect data on the side channels to determine their habitat quality/quantity and flow relationship to the main channel (as described below).

There are numerous side/split channels in the California portion of the peaking reach, most occurring downstream of Shovel Creek. Based on reconnoiter of such possible complexes in the California portion of the peaking reach, a main channel-side channel complex not far above Copco reservoir was selected for 2-D modeling (see Figure 4.7-5--). The site includes a riffle-run-riffle complex in the main channel, and a long, meandering side channel that can be modeled.

4.7.2.5 Additional Analysis of Main Channel - Side Channel Flow Relationships

A number of side channels in the 16-mile J.C. Boyle peaking reach of the Klamath River are of interest for their potential fish habitat value. Some of these have no water flow at the common base flow of 350 cfs in the main river. Therefore, an effort was made to determine the flow relationship between the main Klamath River and the corresponding flows in nine side channels. These side channels were selected for evaluation following a review of aerial photographs and a site reconnaissance to confirm that they could support fish habitat. Cumulatively, they represent a total length of 5,400 feet. Two side channels were located within 2 miles downstream of the J.C. Boyle powerhouse in Oregon (Figure 4.7-5). Seven additional side channels were located along the lower portion of the peaking reach below the mouth of Shovel Creek in California (Figure 4.7-6). This lower section of river is more alluvial in nature and thus contains more side channels than the Oregon section, which is mostly confined in a canyon.

To estimate the main river streamflow at which each side channel begins to flow, we first surveyed (with differential leveling) the bottom elevation at the hydraulic control “lip” at the upper entrance to the side channel. Using the same bench mark, we then surveyed the water surface elevation of the main channel near the side channel entrance at a known river flow. The elevation difference was then used in conjunction with a stage-discharge rating curve appropriate for the main channel to estimate the change in total river flow needed to initiate side channel flow.

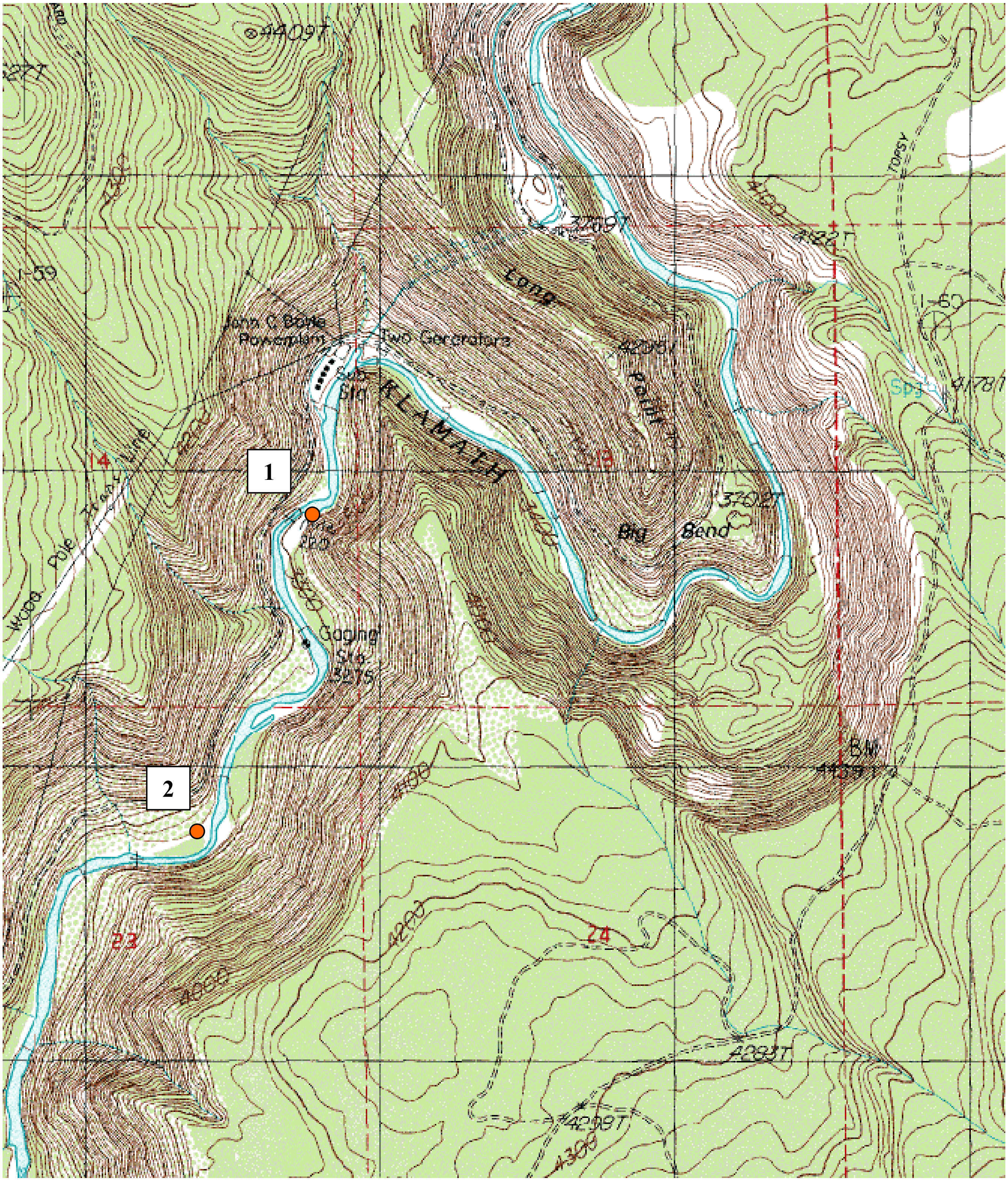


Figure 4.7-5. Two side channels located within 2 miles downstream of the J.C. Boyle powerhouse in Oregon.

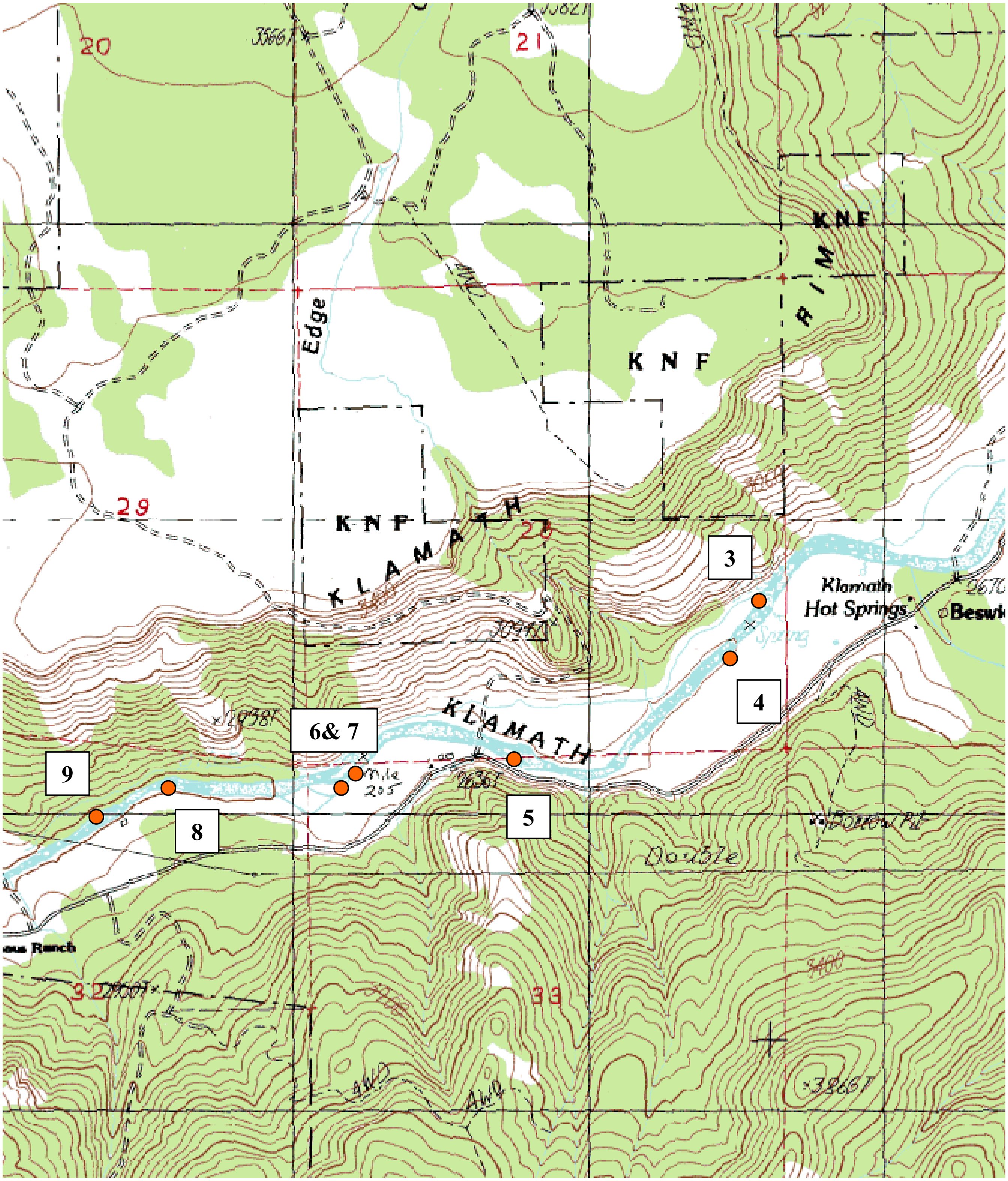


Figure 4.7-6: Seven side channels located along the lower portion of the peaking reach below the mouth of Shovel Creek in California.

Each side channel was gaged at least once when flowing. The corresponding total river flow was obtained from the USGS gage below the J.C. Boyle powerhouse. Flow travel time between the gage site an each side channel site was taken into consideration.

The measured side channel flows and corresponding main Klamath River flows are presented in Table 4.7-7. Of the nine side channels, only two flow when the main river is at its base flow of 350 cfs, although two more side channels begin to flow when the river just begins to exceed 350 cfs. Although flow into side channel 4 does not begin until river flow exceeds 1,390 cfs, interstitial flow starts emerging about 200 feet down the side channel even when the main river flow is 350 cfs. All nine side channels experience flow when the main river is flowing at 1,500 cfs.

Relationships between side channel flow and main river flow for each side channel are shown graphically in Figures 4.7-7-8 – 4.7-9.

4.7.3 Fall Creek Reach

At the AWG meeting on July 10, 2002, it was agreed that PacifiCorp consultants would pre-select study sites and transects in Fall Creek. The AWG decided that a visit to Fall Creek to review the transects was not necessary. A verbal agreement was reached that data collection could proceed on this reach without agency review of the transects.

During the week of July 15-19, 2002, PacifiCorp consultants selected study sites and transects in the reach. The Fall Creek reach is 4,605 feet (1.4 km) long from the upper falls to the diversion. A slight gradient break occurs approximately half way up the reach. To ensure dispersal of transects, random selectors (sub-habitat type moderate slope riffle was used as the selector) were picked both above and below this gradient break. Fall Creek is the only reach where high gradient riffles were modeled. This was a result of a combination of the relatively high percentage of this habitat type in the reach and the fact that this habitat could be modeled adequately in the small stream channel. A total of 28 transects was selected to represent the habitat types found in Fall Creek (Table 4.7-8). The number of transects established resulted in one transect per 164 feet (50.0 m) of stream.

Table 4.7-7. Side channel flow and corresponding main channel Klamath River flow.

No.	Location	State	River Mile (RM)	Side Channel Length (ft)	Estimated MC Flow to Start SC Flow	Flow					
						Side Channel Flow (cfs)	Main Channel Flow (cfs)	Side Channel Flow (cfs)	Main Channel Flow (cfs)	Side Channel Flow (cfs)	Main Channel Flow (cfs)
1	Boat Launch	OR	220	500	**700**	-	-	-	-	13.2	1,680
2	Osprey Island	OR	219.1	1,000	**350**	0.1*	350	-	-	180.5	1,680
3	Right bank	CA	206	500	**720**	Dry	350	-	-	12.9	1500
4	Left bank	CA	205.9	700	**1390**	Dry	350	Dry	900	9.0	1500
5	Above Miller Bridge	CA	205.4	600	**<350**	1.9	350	58.6	900	207.2	1500
6	Island Complex—left	CA	205	550	**<350**	19.4	350	79.8	900	146.4	1500
7	Island Complex—mid	CA	204.9	200	**350**	0.1*	350	25.1	900	59.8	1500
8	Above Miller Barn	CA	204.6	600	**770**	Dry	350	0.7	900	12.8	1500
9	2-D Site	CA	204.4	750	**700**	Dry	350	1.4	844	18.0	1500

* Just begins flow.
Side Channel = SC
Main Channel = MC

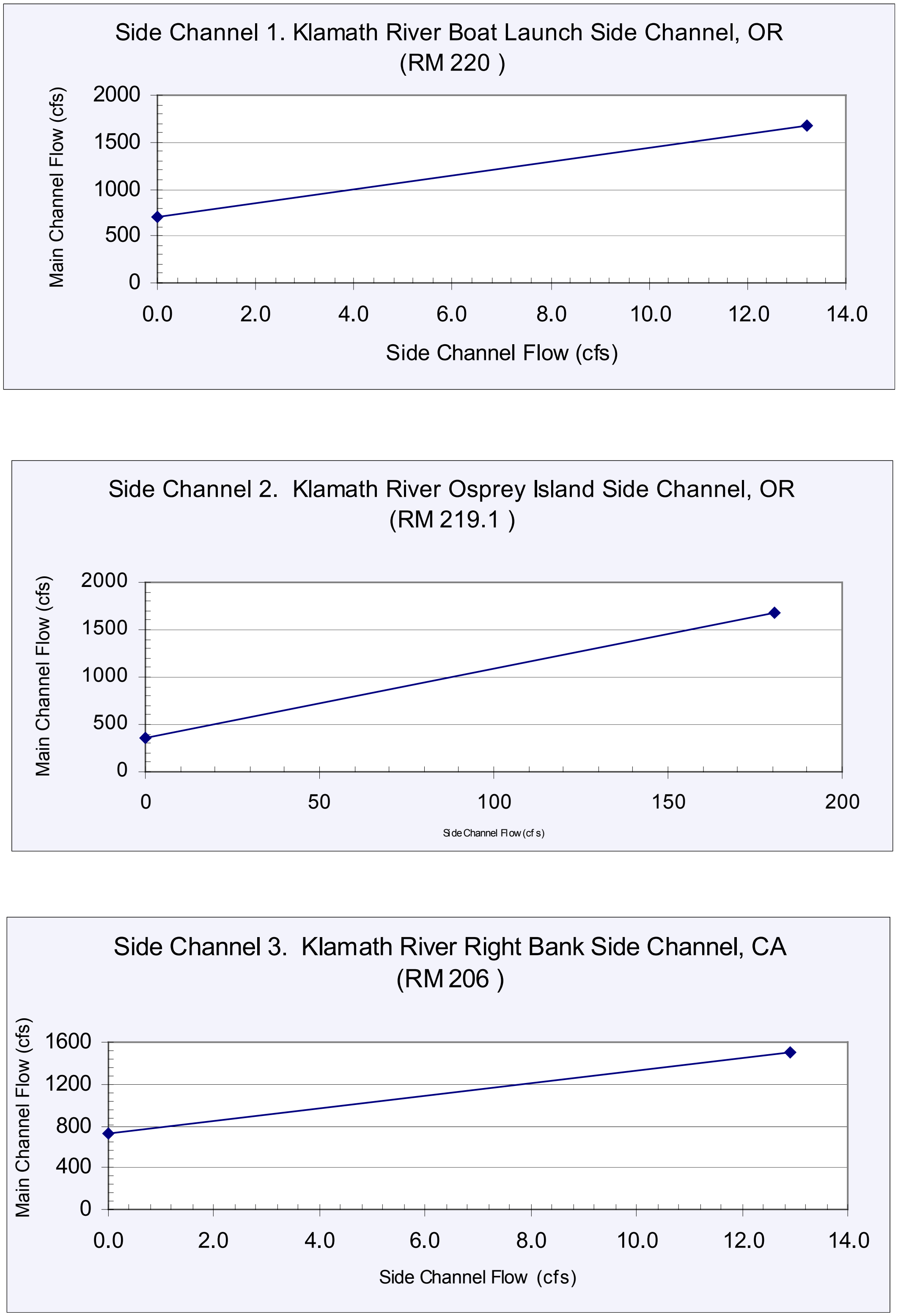
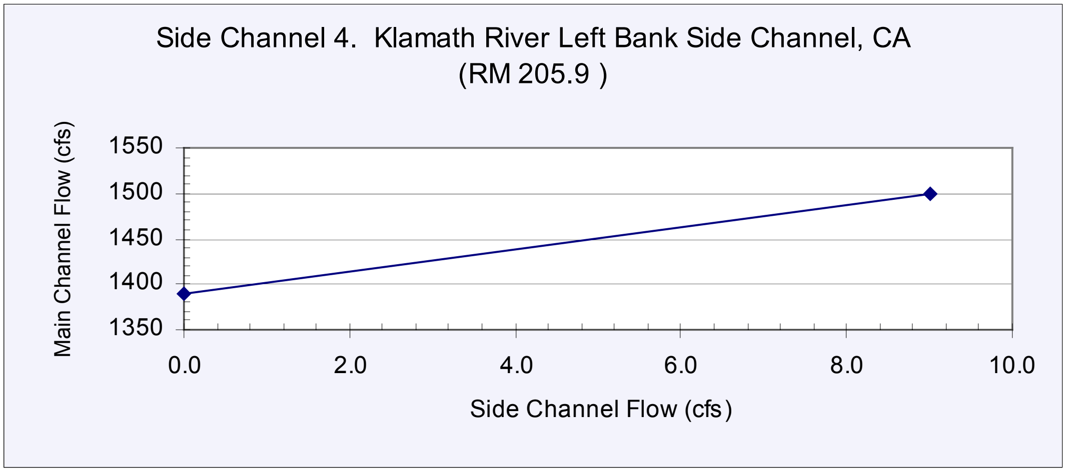
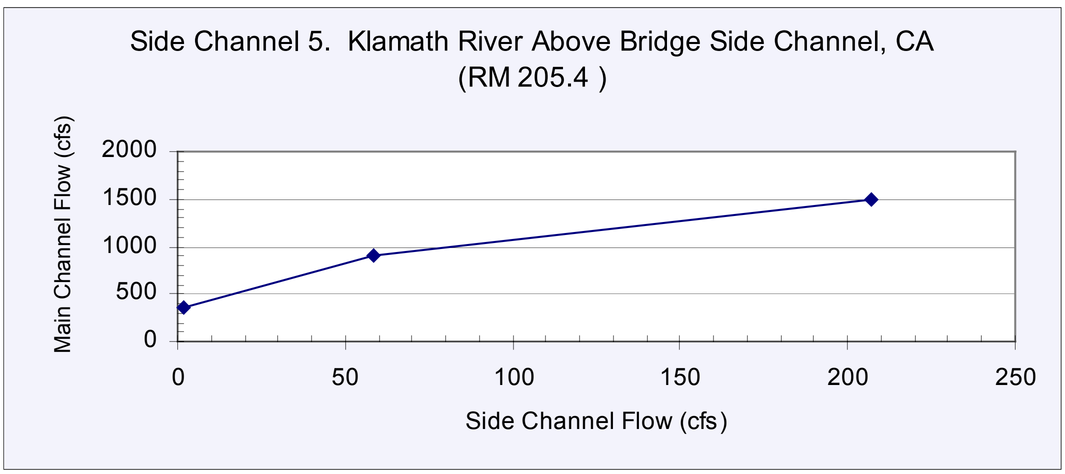


Figure 4.7-7. Relationship between side channel flow and main river flow for side channels 1 through 3.





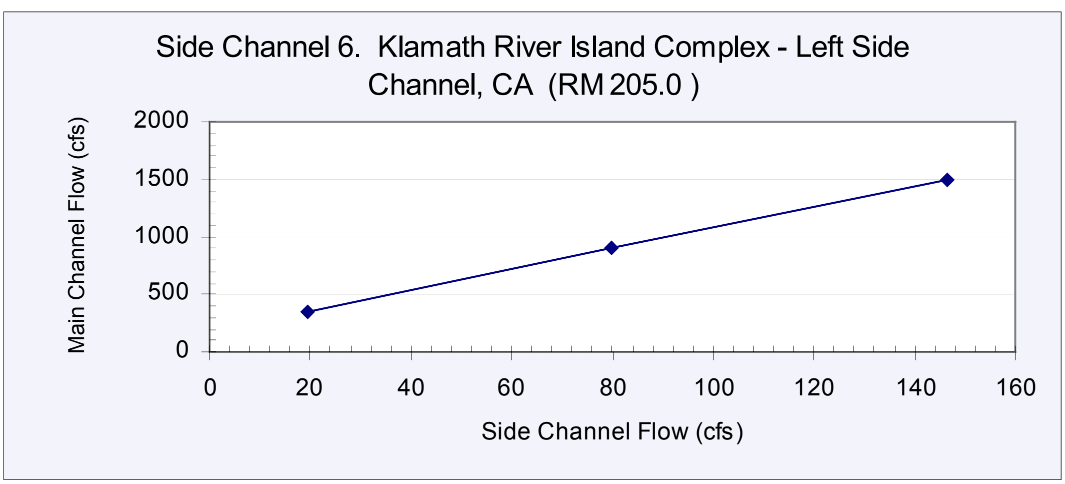
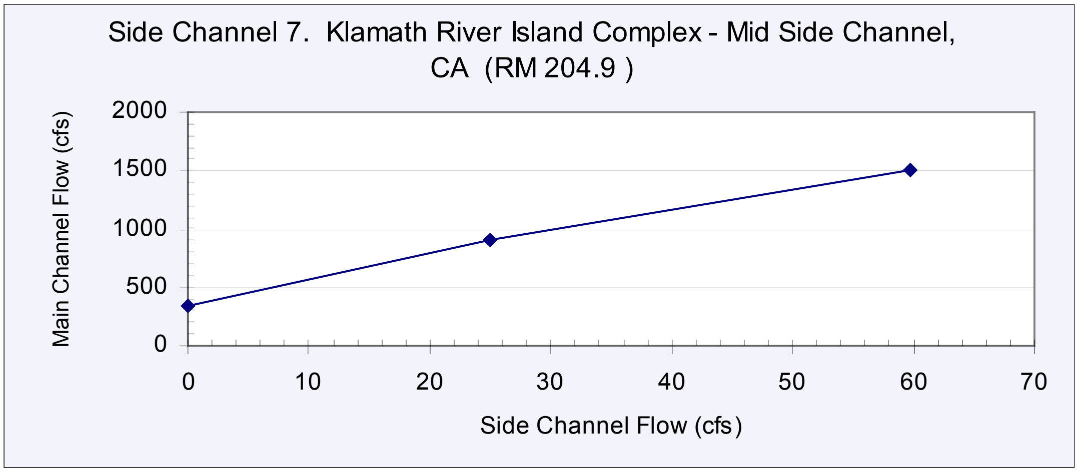
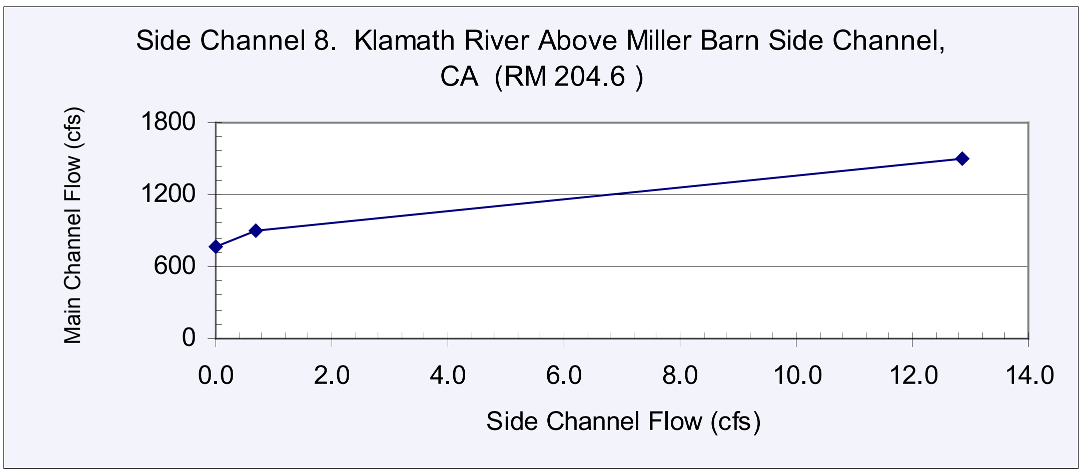


Figure 4.7-8. Relationship between side channel flow and main river flow for side channels 4 through 6.





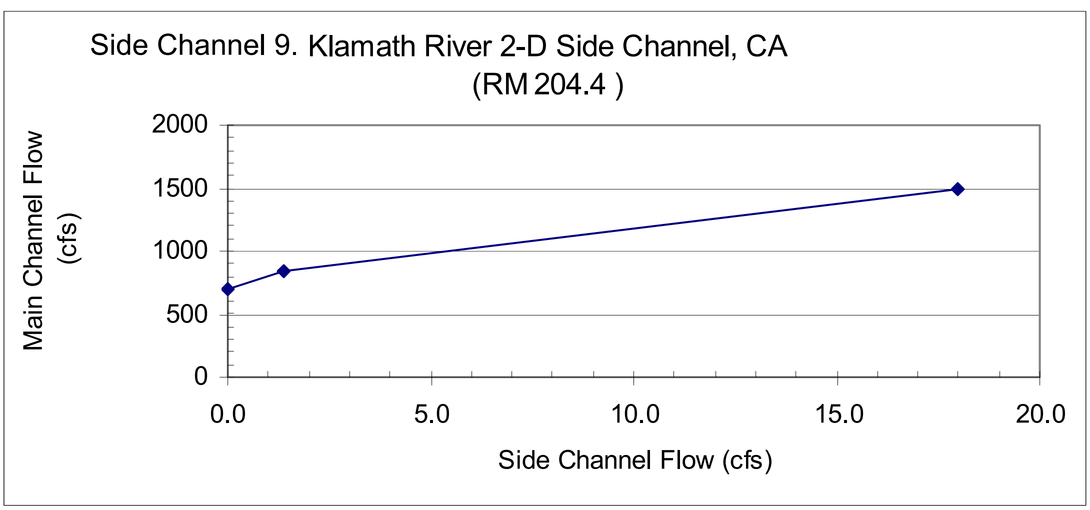


Figure 4.7-9. Relationship between side channel flow and main river flow for side channels 7 through 9

Table 4.7-8. Summary of habitat mapping of Fall Creek. Then umber of transects per habitat type and resulting transect weighting estimates included.

Habitat Type	Number Units	Total Length (ft)	Percent of Total	Percent Normalized*	Number of Transects	Number of Sample Units	Percent Weight/ Transect
Fall Creek				Transects and Weighting			
Pool	59	2,463	53.5	55.0	12	4	4.6
Glide	0	0	0.0	----	----	----	----
Run	38	851	18.5	19.0	7	3	2.7
Pocket Water	7	117	2.5	----	----	----	----
Riffle (low gradient)	45	632	13.7	14.1	5	2	2.8
Riffle (high gradient)	45	532	11.5	11.9	4	2	3.0
Cascade	2	10	0.2	----	----	----	----
Totals	196	4,605	100.0	100.0	28	11	

* Does not include "cascade" or habitat categories not sampled.

4.7.4 Copco No.2 Bypass Reach

Habitat mapping was conducted in March 2003 at 200 cfs (Table 4.7- 9). The reach is 1.4 miles in length and composed primarily of bedrock and large boulders. Riparian encroachment, mainly large alders, is also characteristic of the reach. The Copco No. 2 bypass reach was divided into three sections based on the degree of confinement and gradient. The upper 1,500 feet of the reach is relatively steep and confined to a narrow channel (40-50 feet wide) with banks composed of very large substrate. The middle 4,000 feet is generally wider, lower gradient and contains two large, unique pools. The lower 2,000 feet is similar to the upper section and also contains a 400-foot section with a bedrock spine down the center of the channel.

Prior to study site selection it was agreed that the upper portion of the reach was not suitable for PHABSIM transects. Most of the middle section and the lower 1,000 feet (downstream of the bedrock spine) of the bottom of the reach was considered suitable for study. Selection of habitat units and transects were completed by PacifiCorp consultants prior to a site visit by agency personnel. The goal was to select one study site in the lower portion of the reach and two in the middle portion. Pocket water, the lowest available modelable habitat type by percent (greater than five percent), was used for study site selection. Within the accessible portion of the lower part of the reach, only one pocket water area was identified. Only two pocket water areas were identified in the middle section of the reach. One pool and one run unit were also chosen near each of the selected habitat units. During the subsequent agency site visit it was decided to add two riffle transects, even though overall low gradient riffle habitat was less than five percent of the reach. In addition, one selected pool was moved from the middle to lower section of the reach. Because the selected pocket water areas in the middle section were short in length, and fairly uniform in nature, it was agreed that each could be represented by just two transects. In addition, four transects were placed in one run unit in the middle section partly because of the length of the unit and also to represent more run habitat. The final number of habitat units and transects selected are shown in Table 4.7-9.

Table 4.7- 9. Summary of habitat mapping of Copco No. 2 bypass. Number of habitat units and transects selected for study and resulting transect weighting estimates included.

Habitat Type	Number of Units	Total Length (ft)	Percent of Total	Percent Normalized[1]	Number of Units	Number of Transects	Percent per Transect
Copco No. 2 Bypass – 200 cfs Mapping				**Transects and Weighting**			
Pool	18	1984	26.4	32.7	3	9	3.6
Run	24	2435	32.4	40.1	3	10	4.0
Pocket Water	17	1352	18.0	22.3	3	7	3.2
Low Gradient Riffle	6	295	3.9	4.9	2	2	2.4
High Gradient Riffle	12	678	9.0	----	----	----	----
Cascade	22	761	10.1	----	----	----	----
Totals	99	7505	100.0	100.0	11	28	

[1] Does not include “high gradient” habitats (cascade and high gradient riffles) or habitat categories not sampled.

4.7.5 Copco Fish Passage

Because of stakeholder concern for fish passage within the reach at the present release flow, it was proposed that a passage evaluation be included in the flow evaluation. However, it was agreed to postpone this study pending outcome of flow recommendations.

4.8 HYDRAULIC SIMULATION

4.8.1 Calibration Flows

Calibration flow information in each of the study reaches was collected during scheduled flow releases or under normal operations of PacifiCorp Klamath River Project facilities.

4.8.1.1 J.C. Boyle Bypass Reach

Three sets of calibration flows were measured in the J.C. Boyle bypass reach (Table 4.8-1). Accretion from springs, which begin approximately 1 mile downstream from the dam, account for differences in calibration flows between groups of transects.

Depths and velocities were collected at middle and low flow. The original study design was to obtain velocities at middle and high flow. However, after collecting data at the middle flow it was decided that the high flow would be too dangerous to work in. Low flow stage measurements were initially completed in the summer and fall of 2002 during periods of the normal minimum flow release of 100 cfs. Additional low flow stage and velocity data were collected during June 2003 in order to obtain a second set of velocities on all transects. This was done to compensate for the inability to collect velocity data at high flow (1,500 cfs release) and to supplement incomplete velocity sets on some transects at middle flow.

Only edge cell velocities were collected on four transects at middle flow. These transects could not be sampled by either wading or with an ADCP. Wading was too hazardous and the ADCP could not collect data because of turbulence or suspended organics. Partial velocity profiles were collected on three transects, all pools, with the ADCP at middle flow. The middle sections of these transects were too turbulent to acquire velocities.

Table 4.8-1. Summary of calibration stage and discharge measurements in the J.C. Boyle bypass reach. Habitat type and cross section identification, date, best estimate of calibration flow and velocity data collected.

	Low Flow			Middle Flow			High Flow		
Habitat Type XSEC	**Date**	**Q cfs**	**Vels**	**Date**	**Q cfs**	**Vels**	**Date**	**Q cfs**	**Vels**
Pocket Water 52A	11/15/02	350	Yes	9/26/02	800	Yes	4/2/03	1,750	No
Pocket Water 52B	"	"	"	"	"	Edge[1]	"	"	"
Pocket Water 52C	"	"	"	"	"	Edge[1]	"	"	"
Run 55A	6/9/03	"	"	"	"	Yes	"	"	"
Run 55B	8/21/02	"	"	"	"	Yes	"	"	"
Run 55C	6/9/03	"	"	"	"	Yes	"	"	"
Pool 58A	"	"	"	"	"	Yes	"	"	"
Pool 58B	"	"	"	"	"	Part[2]	"	"	"
Pool 58C	"	"	"	"	"	Edge[1]	"	"	"
Run 108A	8/20/02	"	"	"	"	Yes	"	"	"
Run 108B	6/9/03	"	"	"	"	Yes	"	"	"
Run 108C	"	"	"	"	"	Yes	"	"	"
Pool 133A	6/10/03	"	"	9/25/02	800	Yes	"	"	"
Pool 133B	"	"	"	"	"	Part[2]	"	"	"
Pool 133C	"	"	"	"	"	Edge[1]	"	"	"
Pool 172A	"	333	Yes	"	"	Yes	"	"	"
Pool 172B	"	"	"	"	"	Yes	"	"	"
Pool 172C	"	"	"	"	"	Part[2]	"	"	"
Pocket Water 183A	6/11/03	"	"	"	"	Yes	"	"	"
Pocket Water 183B	"	"	"	"	"	Yes	"	"	"
Pocket Water 183C	"	"	"	"	"	Yes	"	"	"
Run 184A	"	"	"	"	"	Yes	"	"	"
Run 184B	"	"	"	"	"	Yes	"	"	"
Run 184C	8/8/02	"	"	"	"	Part[2]	"	"	"
Pool 267A	6/11/03	100	Yes	9/24/02	607	Yes	4/2/03	1,500	No
Pool 267B	"	"	"	"	"	Yes	"	"	"
Pool 267C	"	"	"	"	"	Yes	"	"	"
Pocket Water 276B	"	"	"	"	"	Part[2]	"	"	"
Pocket Water 276C	"	"	"	"	"	Yes	"	"	"
Run 282A	"	"	"	"	"	Yes	"	"	"
Run 282B	"	"	"	"	"	Yes	"	"	"
Run 282C	"	"	"	"	"	Yes	"	"	"

Table 4.8-1. Summary of calibration stage and discharge measurements in the J.C. Boyle bypass reach. Habitat type and cross section identification, date, best estimate of calibration flow and velocity data collected.

	Low Flow			Middle Flow			High Flow		
Habitat Type XSEC	**Date**	**Q cfs**	**Vels**	**Date**	**Q cfs**	**Vels**	**Date**	**Q cfs**	**Vels**

[1] Velocity measurements at middle flow: Edge= edge cell measurements only.

[2] Velocity measurements at middle flow: Part= some cells missing velocities.

4.8.1.2 J.C. Boyle Peaking Reach

Four sets of calibration flows were measured in the J.C. Boyle peaking reach (Table 4.8-2. The highest calibration flow (3,000 cfs) was measured for stage only and is not included in the table. Low flow ranged from 350 to 358 cfs. Middle flow ranged between 712 and 914 cfs during a planned powerhouse maintenance shutdown. Fluctuations in stage during the middle resulted from maintenance operations. High flow data were collected during normal peaking operations between 1,594 and 1,644 cfs. The only exception was for riffle 70A-C when the stage dropped during high flow measurements.

Depth and velocities were collected at the middle and high flow for most transects. No velocities were collected on five riffles and four pool transects at high flow as a result of unworkable conditions, too much turbulence, or standing waves. In addition, only low flow velocities were collected at riffle 28A.

Table 4.8-2. Summary of calibration flow measurements in the J.C. Boyle peaking reach. Habitat type and cross section identification, date, best estimate of calibration flow and velocity data collected. Note: Additional stage measurement at 3,000 cfs not included in table.

	Low Flow			Middle Flow			High Flow		
Habitat Type XSEC	**Date**	**Q cfs**	**Vels**	**Date**	**Q cfs**	**Vels**	**Date**	**Q cfs**	**Vels**
California									
Run 207A	12/4/02	358	No	9/30/02	844	Yes	10/28/02	1,594	Yes
Run 207B	“	“	“	“	“	“	“	“	“
Run 207C	“	“	“	“	“	“	“	“	“
Barn Pool A	“	“	“	“	“	“	“	“	“
Barn Pool B	“	“	“	“	“	“	“	“	“
Barn Pool C	“	“	“	“	“	“	“	“	“
Riffle 201.5A	“	“	Yes	10/9/02	900	“	“	“	“
Riffle 201.5B	“	“	No	“	“	“	10/27/02	1,592	“
Run 177A	12/3/02	350	“	10/1/02	850	“	“	“	“
Run 177B	“	“	“	“	“	“	“	“	“
Run 177C	“	“	“	“	“	“	“	“	No
Riffle 176A	“	“	“	10/9/02	900	Part[2]	“	“	“
Riffle 176B	“	“	“	“	“	Yes	“	“	“
Riffle 176C	“	“	“	“	“	“	“	“	“
Pool 168A	“	“	“	10/1/02	850	“	“	“	Yes

Table 4.8-2. Summary of calibration flow measurements in the J.C. Boyle peaking reach. Habitat type and cross section identification, date, best estimate of calibration flow and velocity data collected. Note: Additional stage measurement at 3,000 cfs not included in table.

	Low Flow			Middle Flow			High Flow		
Habitat Type XSEC	**Date**	**Q cfs**	**Vels**	**Date**	**Q cfs**	**Vels**	**Date**	**Q cfs**	**Vels**
Pool 168B	"	"	"	"	"	"	"	"	"
Pool 168C	"	"	"	"	"	"	"	"	"
Riffle 164A	"	"	"	10/10/02	914	Part[2]	"	"	"
Riffle 164B	"	"	"	"	"	Yes	"	"	"
Run 150A	12/2/02	"	Yes	10/2/02	850	"	10/26/02	1,601	"
Run 150B	"	"	No	"	"	"	"	"	"
Run 150C	"	"	"	"	"	"	"	"	No
Pool 147A	"	"	"	"	"	"	"	"	Yes
Pool 147B	"	"	"	"	"	"	"	"	"
Pool 147C	"	"	"	"	"	"	"	"	No
Riffle 146A	"	"	"	10/10/02	914	"	"	"	Yes
Oregon									
Riffle 74A	11/14/02	358	No	9/26/02	800	Yes	10/25/02	1,044	Yes
Riffle 74B	"	"	"	"	"	"	"	1,204	"
Riffle 74C	"	"	"	"	"	"	"	1,392	"
Riffle 72A	"	"	"	"	"	"	"	1,595	"
Riffle 72B	"	"	"	"	"	"	"	"	"
Glide 71A	"	"	"	9/27/02	817	"	"	"	"
Glide 71A	"	"	"	"	"	"	"	"	"
Glide 71B	"	"	"	"	"	"	"	"	"
Riffle 70A	"	"	"	"	"	Part[2]	"	"	"
Riffle 70B	"	"	Yes	"	"	Yes	"	"	"
Riffle 59A	10/31/02	"	No	"	"	Part[2]	10/24/02	1,604	"
Riffle 59B	"	"	"	"	"	Yes	"	"	"
Riffle 59C	"	"	"	"	"	"	"	"	"
Pool 58A	"	"	"	9/20/02	804	"	"	"	"
Pool 58B	"	"	"	"	"	"	"	"	"
Pool 58C	"	"	"	"	"	"	"	"	"
Run 57.5A	"	"	"	9/28/02	806	"	"	"	"
Run 57.5B	"	"	"	"	"	"	"	"	"
Run 57.5C	"	"	"	"	"	"	"	"	"
Pool 57A	"	"	"	9/21/02	712	"	"	"	"
Pool 57B	"	"	"	"	744	"	"	"	"
Pool 57C	"	"	"	"	810	"	"	"	"
Pool 31A	10/30/02	355	"	9/29/03	837	"	10/23/02	1,595	"
Pool 31B	"	"	"	"	"	"	"	"	"

Table 4.8-2. Summary of calibration flow measurements in the J.C. Boyle peaking reach. Habitat type and cross section identification, date, best estimate of calibration flow and velocity data collected. Note: Additional stage measurement at 3,000 cfs not included in table.

	Low Flow			Middle Flow			High Flow		
Habitat Type XSEC	**Date**	**Q cfs**	**Vels**	**Date**	**Q cfs**	**Vels**	**Date**	**Q cfs**	**Vels**
Pool 31C	"	"	"	"	"	"	"	"	"
Run 30A	"	"	"	9/28/02	806	"	"	"	"
Run 30B	10/30/02	355	No	9/28/03	806	Yes	10/23/02	1,595	Yes
Run 30C	"	"	"	"	"	"	"	"	"
Pool 29A	"	"	"	"	"	"	"	"	"
Pool 29B	"	"	"	"	"	"	"	"	"
Pool 29C	"	"	"	"	"	"	"	"	No
Riffle 28A	"	"	Yes	"	"	No	"	"	"
Riffle 28B	"	"	No	"	"	Yes	"	"	"
Run 26A	"	"	"	9/27/02	817	"	"	"	Yes
Run 26B	"	"	"	"	"	"	"	"	"
Run 26C	"	"	"	"	"	"	"	"	"
Pool 24A	10/29/03	355	"	"	"	"	10/22/02	1,595	"
Pool 24B	"	"	"	"	"	"	"	"	"
Pool 24C	"	"	"	"	"	"	"	"	"
Pool 18A	"	"	"	"	"	"	"	1,644	"
Pool 18B	"	"	"	"	"	"	"	"	"
Pool 18C	"	"	"	"	"	"	"	"	"
Run 10A	"	"	Yes	9/19/02	731	"	"	"	"
Run 10B	"	"	No	"	"	"	"	"	"
Run 10C	"	"	"	"	"	"	"	"	"

[1] Additional stage measurement at 3,000 cfs 3/31/03 and 4/1/03, no velocities.

[2] Velocity measurements at middle flow: Part= some cells missing velocities.

4.8.1.3 Copco No. 2 Bypass Reach

Three sets of calibration flows were measured in the Copco No. 2 bypass reach (Table 4.8-3). A lower flow stage (10 cfs minimum release) was also measured but was not incorporated into the model because of stage fluctuations during normal project operation.

Low flow was slightly less than the target of 200 cfs. Release flow adjustments on September 9, 2003 and leakage from the penstock account for different calibration flows for groups of transects at low flow. Velocity measurements were obtained on all transects at low flow.

Complete velocity sets were obtained for only nine transects at middle flow because of a combination of unworkable conditions in riffle and pocket water habitat and turbulence and entrained air on other transects. Edge cell velocities were measured at all transects where complete velocity sets could not be obtained.

Table 4.8-3. Summary of calibration stage and discharge measurements in the Copco No. 2 bypass reach. Habitat type and cross section identification, date, best estimate of calibration flow and velocity data collected.

	Low Flow			Middle Flow			High Flow		
Habitat Type XSEC	**Date**	**Q cfs**	**Vels**	**Date**	**Q cfs**	**Vels**	**Date**	**Q cfs**	**Vels**
Pool 2A	9/10/03	178	Yes	9/12/03	629	Edge[1]	9/13/03	1,200	No
Pool 2B	"	"	"	"	"	Edge[1]	"	"	"
Pool 2C	"	"	"	"	"	Edge[1]	"	"	"
Pocket Water 6A	"	"	"	"	"	Edge[1]	"	"	"
Pocket Water 6B	"	"	"	"	"	Edge[1]	"	"	"
Pocket Water 6C	"	"	"	"	"	Edge[1]	"	"	"
Run 7A	"	"	"	"	"	Yes	"	"	"
Run 7B	"	"	"	"	"	Yes	"	"	"
Run 7C	"	"	"	"	"	Yes	"	"	"
Pool 11A	"	"	"	"	"	Part[2]	"	"	"
Pool 11B	"	"	"	"	"	Edge[1]	"	"	"
Pool 11C	"	"	"	"	"	Edge[1]	"	"	"
Run 51A	9/9/03	168	"	9/11/03	610	Yes	"	"	"
Run 51B	"	"	"	"	"	Yes	"	"	"
Run 51C	"	"	"	"	"	Yes	"	"	"
Riffle 52	"	"	"	"	"	Edge[1]	"	"	"
Riffle 54	"	"	"	"	"	Edge[1]	"	"	"
Pocket Water 55A	"	"	"	"	"	Edge[1]	"	"	"
Pocket Water 55B	"	"	"	"	"	Edge[1]	"	"	"
Pocket Water 58A	"	"	"	"	"	Edge[1]	"	"	"
Pocket Water 58B	"	"	"	"	"	Edge[1]	"	"	"
Pool 60A	"	"	"	"	"	Yes	"	"	"
Pool 60B	"	"	"	"	"	Part[2]	"	"	"
Pool 60C	"	"	"	"	"	Edge[1]	"	"	"
Run 63A	"	151	"	"	"	Edge[1]	"	"	"
Run 63B	"	"	"	"	"	Part[2]	"	"	"
Run 63C	"	"	"	"	"	Yes	"	"	"
Run 63D	"	"	"	"	"	Yes	"	"	"

[1] Velocity measurements at middle flow: Edge= edge cell measurements only.

[2] Velocity measurements at middle flow: Part= some cells missing velocities.

4.8.1.4 Fall Creek

Three sets of calibration flows were measured in the Fall Creek bypass reach (Table 4.8-4). The low flow stage was measured at the minimum release from the diversion. Increase in calibration discharge from the top (unit 184) to bottom of the reach (unit 31) at all three flows resulted because of leakage from the canal, which is parallel to the stream channel. Velocities were collected at high flow only.

Table 4.8-4. Summary of calibration stage and discharge measurements in the Fall Creek bypass reach. Habitat type and cross section identification, date, best estimate of calibration flow and velocity data collected.

	Low Flow			Middle Flow			High Flow		
Habitat Type XSEC	**Date**	**Q cfs**	**Vels**	**Date**	**Q cfs**	**Vels**	**Date**	**Q cfs**	**Vels**
Riffle 31A	8/5/02	2.13	No	8/28/02	5.27	No	8/27/02	11.76	Yes
Riffle 31B	“	“	“	“	“	“	“	“	“
Run 33A	“	“	“	“	“	“	“	“	“
Run 33B	“	“	“	“	“	“	“	“	“
Pool 39A	“	“	“	“	“	“	“	“	“
Pool 39B	“	“	“	“	“	“	“	“	“
Pool 39C	“	“	“	“	“	“	“	“	“
Riffle 86A	“	“	“	“	4.21	“	“	10.75	“
Riffle 86B	“	“	“	“	“	“	“	“	“
Pool 90A	8/6/02	1.70	“	“	“	“	“	“	“
Pool 90B	“	“	“	“	“	“	“	“	“
Pool 90C	“	“	“	“	“	“	“	“	“
Riffle 165A	“	0.97	“	“	3.77	“	“	10.51	“
Riffle 165B	“	“	“	“	“	“	“	“	“
Riffle 165C	“	“	“	“	“	“	“	“	“
Pool 168A	“	“	“	“	“	“	8/28/02	“	“
Pool 168B	“	“	“	“	“	“	“	“	“
Pool 168C	“	“	“	“	“	“	“	“	“
Run 172A	“	“	“	“	“	“	“	“	“
Run 172B	“	“	“	“	“	“	“	“	“
Run 172C	“	“	“	“	“	“	“	“	“
Riffle 175A	“	“	“	“	“	“	“	“	“
Riffle 175B	“	“	“	“	“	“	“	“	“
Pool 179A	“	“	“	“	“	“	“	“	“
Pool 179B	“	“	“	“	“	“	“	“	“
Pool 179C	“	“	“	“	“	“	“	“	“
Run 184A	“	“	“	“	“	“	“	9.14	“
Run 184B	“	“	“	“	“	“	“	“	“

4.8.2 Stage-Discharge and Velocity Calibration

Complete stage-discharge calibration equations and statistics are presented in Appendix 4D. The recommended maximum mean error (less than10 percent) and slope range (2.0 to 4.5) for log/log stage-discharge regressions (Millhouse et al 1984) were used to determine the adequacy of individual transect rating curves.

Velocity simulation was evaluated based on examination of velocity adjustment factors (VAFs) and reasonableness of individual cell velocities over the range of flows being simulated. VAFs in the range of 0.8 to 1.2 at the calibration flow are considered acceptable. Generally upward extrapolation of velocity simulations are limited to 2.5 times the level at which velocities were measured. Hydraulic simulations can exceed the 250 percent criterion if simulated velocities and water surfaces appear reasonable. Bottom profiles for all transects with simulated water surface elevations (WSEL) and velocities are contained in Appendix 4E.

4.8.2.1 J.C. Boyle Bypass Reach

Three point log/log regression was used to simulate WSEL on all transects (Table 4.8-5). Twenty four of the thirty two transects in the J.C. Boyle bypass had mean errors less than three percent, and all mean errors were less than six percent.

The one -velocity method was used for simulation of velocities on all transects except Pool 58B. Depth calibration was chosen for this transect because of extreme and unrealistic velocities at higher flow levels. Even though low flow velocities were used on nine of the 32 transects, simulation appeared reasonable from 100 cfs up to the 3,000 cfs flow level for most transects. Few individual cell roughness adjustments (Manning’s n) were made during velocity calibration. After hydraulic calibration, VAFs for most transects transitioned between 0.9 and 1.1 at the calibration flow (Figure 4.8-1), and all fell within acceptable limits.

Table 4.8-5. Stage-discharge calibration summary for the J.C. Boyle bypass reach. Habitat type and cross section identification, transect weight, technique used for water surface elevation (WSEL) and velocity simulation and velocity data set used.

Habitat Type XSEC	Transect Weighting %	WSEL Method	Velocity Method	Velocity Data Set Used
Pocket Water 52A	2.73	Log/log Regression	One-velocity	Low
Pocket Water 52B	2.73	Log/log Regression	One-velocity	Low
Pocket Water 52C	2.73	Log/log Regression	One-velocity	Low
Run 55A	3.59	Log/log Regression	One-velocity	Mid
Run 55B	3.59	Log/log Regression	One-velocity	Mid
Run 55C	3.59	Log/log Regression	One-velocity	Mid
Pool 58A	2.63	Log/log Regression	One-velocity	Mid
Pool 58B	4.39	Log/log Regression	Depth	N/A
Pool 58C	1.75	Log/log Regression	One-velocity	Low
Run 108A	3.59	Log/log Regression	One-velocity	Mid
Run 108B	3.59	Log/log Regression	One-velocity	Mid
Run 108C	3.59	Log/log Regression	One-velocity	Mid
Pool 133A	3.07	Log/log Regression	One-velocity	Mid
Pool 133B	3.51	Log/log Regression	One-velocity	Low
Pool 133C	2.19	Log/log Regression	One-velocity	Low
Pool 172A	1.32	Log/log Regression	One-velocity	Mid
Pool 172B	6.14	Log/log Regression	One-velocity	Low

Table 4.8-5. Stage-discharge calibration summary for the J.C. Boyle bypass reach. Habitat type and cross section identification, transect weight, technique used for water surface elevation (WSEL) and velocity simulation and velocity data set used.

Habitat Type XSEC	Transect Weighting %	WSEL Method	Velocity Method	Velocity Data Set Used
Pool 172C	1.36	Log/log Regression	One-velocity	Low
Pocket Water 183A	2.73	Log/log Regression	One-velocity	Mid
Pocket Water 183B	2.73	Log/log Regression	One-velocity	Mid
Pocket Water 183C	2.73	Log/log Regression	One-velocity	Mid
Run 184A	3.59	Log/log Regression	One-velocity	Mid
Run 184B	3.59	Log/log Regression	One-velocity	Mid
Run 184C	3.59	Log/log Regression	One-velocity	Low
Pool 267A	1.32	Log/log Regression	One-velocity	Mid
Pool 267B	6.14	Log/log Regression	One-velocity	Mid
Pool 267C	1.36	Log/log Regression	One-velocity	Mid
Pocket Water 276B	2.73	Log/log Regression	One-velocity	Mid
Pocket Water 276C	2.73	Log/log Regression	One-velocity	Mid
Run 282A	3.59	Log/log Regression	One-velocity	Mid
Run 282B	3.59	Log/log Regression	One-velocity	Mid
Run 282C	3.59	Log/log Regression	One-velocity	Mid

4.8.2.2 J.C. Boyle Peaking Reach

Four point log/log regression was used to simulate WSEL on all but three transects (Table 4.8-6). Fifty four of the seventy one transects in the J.C. Boyle peaking reach had mean errors less than five percent and had mean errors less than ten percent. WSEL on three transects were modeled with the channel conveyance method to provide more suitable rating curves. Two of these transects had high mean errors (8.4-8.5 percent) using the log/log method, while one had a high slope (4.94), indications of uncertainty using the log/log method.

The one-velocity method was used for simulation of velocities on all transects in the peaking reach. High flow velocity data sets were used for most transects. Velocities measured at lower flow levels were used in instances where high flow data was not available. Few individual cell roughness adjustments (Manning's n) were made during velocity calibration. Simulation appeared reasonable from 100 cfs up to the 3,750 cfs flow level for all transects. However, the high flow simulation was limited to 3,000 cfs in part because of preliminary habitat modeling runs which showed a decrease in the habitat index at higher flow levels. After hydraulic calibration, VAFs for all but five transects transitioned between 0.9 and 1.1 at the calibration flow (Figure 4.8-2), and all fell within acceptable limits.

Table 4.8-6. Stage-discharge calibration summary for the J.C. Boyle peaking reach. Habitat type and cross section identification, transect weight, technique used for water surface elevation (WSEL) and velocity simulation and velocity data set used.

Habitat Type XSEC	Transect Weighting %	WSEL Method	Velocity Method	Velocity Data Set Used
California				
Run 207A	1.66	Log/log Regression	One-velocity	High
Run 207B	1.66	Log/log Regression	One-velocity	High
Run 207C	1.66	Log/log Regression	One-velocity	High
Barn Pool A	1.23	Log/log Regression	One-velocity	High
Barn Pool B	2.71	Log/log Regression	One-velocity	High
Barn Pool C	0.99	Log/log Regression	One-velocity	High
Riffle 201.5A	0.82	Log/log Regression	One-velocity	High
Riffle 201.5B	0.82	Channel Conveyance	One-velocity	High
Run 177A	1.66	Log/log Regression	One-velocity	High
Run 177B	1.66	Log/log Regression	One-velocity	High
Run 177C	1.66	Log/log Regression	One-velocity	Mid
Riffle 176A	0.82	Log/log Regression	One-velocity	Mid
Riffle 176B	0.82	Log/log Regression	One-velocity	Mid
Riffle 176C	0.82	Log/log Regression	One-velocity	Mid
Pool 168A	0.99	Log/log Regression	One-velocity	High
Pool 168B	2.96	Log/log Regression	One-velocity	High
Pool 168C	0.99	Log/log Regression	One-velocity	High
Riffle 164A	0.82	Log/log Regression	One-velocity	High
Riffle 164B	0.82	Log/log Regression	One-velocity	High
Run 150A	1.66	Log/log Regression	One-velocity	High
Run 150B	1.66	Log/log Regression	One-velocity	High
Run 150C	1.66	Log/log Regression	One-velocity	Mid
Pool 147A	0.99	Log/log Regression	One-velocity	High
Pool 147B	2.47	Log/log Regression	One-velocity	High
Pool 147C	1.48	Log/log Regression	One-velocity	Mid
Riffle 146A	0.82	Channel Conveyance	One-velocity	High
Oregon				
Riffle 74A	0.82	Log/log Regression	One-velocity	High
Riffle 74B	0.82	Channel Conveyance	One-velocity	High
Riffle 74C	0.82	Log/log Regression	One-velocity	High
Riffle 72A	0.82	Log/log Regression	One-velocity	High
Riffle 72B	0.82	Log/log Regression	One-velocity	High
Glide 71A	1.48	Log/log Regression	One-velocity	High
Glide 71A	1.48	Log/log Regression	One-velocity	High
Glide 71B	1.48	Log/log Regression	One-velocity	High
Riffle 70A	0.82	Log/log Regression	One-velocity	High
Riffle 70B	0.82	Log/log Regression	One-velocity	High

Table 4.8-6. Stage-discharge calibration summary for the J.C. Boyle peaking reach. Habitat type and cross section identification, transect weight, technique used for water surface elevation (WSEL) and velocity simulation and velocity data set used.

Habitat Type XSEC	Transect Weighting %	WSEL Method	Velocity Method	Velocity Data Set Used
Riffle 59A	0.82	Log/log Regression	One-velocity	High
Riffle 59B	0.82	Log/log Regression	One-velocity	High
Riffle 59C	0.82	Log/log Regression	One-velocity	High
Pool 58A	0.99	Log/log Regression	One-velocity	High
Pool 58B	2.96	Log/log Regression	One-velocity	High
Pool 58C	0.99	Log/log Regression	One-velocity	High
Run 57.5A	1.66	Log/log Regression	One-velocity	High
Run 57.5B	1.66	Log/log Regression	One-velocity	High
Run 57.5C	1.66	Log/log Regression	One-velocity	High
Pool 57A	2.96	Log/log Regression	One-velocity	High
Pool 57B	0.99	Log/log Regression	One-velocity	High
Pool 57C	0.99	Log/log Regression	One-velocity	High
Pool 31A	0.49	Log/log Regression	One-velocity	Mid
Pool 31B	3.46	Log/log Regression	One-velocity	High
Pool 31C	0.99	Log/log Regression	One-velocity	High
Run 30A	1.66	Log/log Regression	One-velocity	High
Run 30B	1.66	Log/log Regression	One-velocity	High
Run 30C	1.66	Log/log Regression	One-velocity	High
Pool 29A	1.48	Log/log Regression	One-velocity	High
Pool 29B	1.98	Log/log Regression	One-velocity	High
Pool 29C	1.48	Log/log Regression	One-velocity	Mid
Riffle 28A	0.82	Log/log Regression	One-velocity	Low
Riffle 28B	0.82	Log/log Regression	One-velocity	Mid
Run 26A	1.66	Log/log Regression	One-velocity	High
Run 26B	1.66	Log/log Regression	One-velocity	High
Run 26C	1.66	Log/log Regression	One-velocity	High
Pool 24A	1.48	Log/log Regression	One-velocity	High
Pool 24B	2.47	Log/log Regression	One-velocity	High
Pool 24C	0.99	Log/log Regression	One-velocity	High
Pool 18A	1.48	Log/log Regression	One-velocity	High
Pool 18B	2.47	Log/log Regression	One-velocity	High
Pool 18C	0.99	Log/log Regression	One-velocity	High
Run 10A	1.66	Log/log Regression	One-velocity	High
Run 10B	1.66	Log/log Regression	One-velocity	High
Run 10C	1.66	Log/log Regression	One-velocity	High

4.8.2.3 Copco No. 2 Bypass Reach

Three point log/log regression was used to simulate WSEL on all transects (Table 4.8-7). Twenty three of the twenty eight transects in the Copco No. 2 bypass had mean errors less than four percent and all had mean errors less than ten percent. A fourth WSEL data point was collected at the present base release flow of 10 cfs. However, because of water level fluctuations during normal project operation, it was not incorporated into the model.

The one-velocity method was used for simulation of velocities on all transects in the reach. The highest measured velocity data set was used for all transects. For those transects where the low flow velocity set was used, Manning's n adjustments were made to edge cells based on edge velocities measured at 600 cfs. This allowed for more realistic velocity predictions at higher simulation flow levels when using the low flow velocity data. Simulation appeared reasonable from 50 cfs up to 2,000 cfs for all transects. After hydraulic calibration, VAFs for twenty of the twenty eight transects transitioned between 0.9 and 1.1 at the calibration flow (Figure 4.8-3). One transect, Pool 11C, had a VAF of 1.25, which fell just outside the acceptable limits.

Table 4.8-7. Stage-discharge calibration summary for the Copco No. 2 bypass reach. Habitat type and cross section identification, transect weight, technique used for water surface elevation (WSEL) and velocity simulation and velocity data set used.

Habitat Type XSEC	Transect Weighting %	WSEL Method	Velocity Method	Velocity Data Set Used
Pool 2A	1.09	Log/log Regression	One-velocity	Low
Pool 2B	4.36	Log/log Regression	One-velocity	Low
Pool 2C	5.45	Log/log Regression	One-velocity	Low
Pocket Water 6A	3.18	Log/log Regression	One-velocity	Low
Pocket Water 6B	3.18	Log/log Regression	One-velocity	Low
Pocket Water 6C	3.18	Log/log Regression	One-velocity	Low
Run 7A	4.01	Log/log Regression	One-velocity	Mid
Run 7B	4.01	Log/log Regression	One-velocity	Mid
Run 7C	4.01	Log/log Regression	One-velocity	Mid
Pool 11A	2.18	Log/log Regression	One-velocity	Mid
Pool 11B	6.54	Log/log Regression	One-velocity	Low
Pool 11C	2.18	Log/log Regression	One-velocity	Low
Run 51A	4.01	Log/log Regression	One-velocity	Mid
Run 51B	4.01	Log/log Regression	One-velocity	Mid
Run 51C	4.01	Log/log Regression	One-velocity	Mid
Riffle 52	2.43	Log/log Regression	One-velocity	Low
Riffle 54	2.43	Log/log Regression	One-velocity	Low
Pocket Water 55A	3.18	Log/log Regression	One-velocity	Low
Pocket Water 55B	3.18	Log/log Regression	One-velocity	Low
Pocket Water 58A	3.18	Log/log Regression	One-velocity	Low
Pocket Water 58B	3.18	Log/log Regression	One-velocity	Low
Pool 60A	2.18	Log/log Regression	One-velocity	Mid

Table 4.8-7. Stage-discharge calibration summary for the Copco No. 2 bypass reach. Habitat type and cross section identification, transect weight, technique used for water surface elevation (WSEL) and velocity simulation and velocity data set used.

Habitat Type XSEC	Transect Weighting %	WSEL Method	Velocity Method	Velocity Data Set Used
Pool 60B	6.54	Log/log Regression	One-velocity	Low
Pool 60C	2.18	Log/log Regression	One-velocity	Low
Run 63A	4.01	Log/log Regression	One-velocity	Low
Run 63B	4.01	Log/log Regression	One-velocity	Low
Run 63C	4.01	Log/log Regression	One-velocity	Mid
Run 63D	4.01	Log/log Regression	One-velocity	Mid

4.8.2.4 Fall Creek

Log/log regression was used to simulate WSEL on all but two transects, channel conveyance being applied to the remaining two (Table 4.8-8). Twenty five of the twenty eight transects in Fall Creek had mean errors less than five percent and all had mean errors less than ten percent. Channel conveyance was applied to one transect because of a slope value (1.74) below the optimum range and the other to improve subsequent VAF values.

The one-velocity method was used for simulation of velocities using the high flow data for all transects in the reach. Very few Manning's n adjustments were made to individual cells. Simulation appeared reasonable up to the 30 cfs flow level for all transects. After hydraulic calibration, VAFs for twenty five of the twenty eight transects transitioned between 0.9 and 1.1 at the calibration flow (Figure 4.8-4). All VAF's fell within acceptable limits. Some transects showed increasing, instead of decreasing, VAFs at low flows. This can be an indication of either poor rating curves or large differences in measured versus simulated velocity. However, in this case it is a result of trying to predict velocities at very low stage, often with a few deep cells transporting the majority of flow.

Table 4.8-8. Stage-discharge calibration summary for the Fall Creek bypass reach. Habitat type and cross section identification, transect weight, technique used for water surface elevation (WSEL) and velocity simulation and velocity data set used.

Habitat Type XSEC	Transect Weighting %	WSEL Method	Velocity Method	Velocity Data Set Used
Riffle 31A	2.97	Log/log Regression	One-velocity	High
Riffle 31B	2.97	Log/log Regression	One-velocity	High
Run 33A	2.72	Log/log Regression	One-velocity	High
Run 33B	2.72	Log/log Regression	One-velocity	High
Pool 39A	4.58	Log/log Regression	One-velocity	High
Pool 39B	4.58	Log/log Regression	One-velocity	High
Pool 39C	4.58	Log/log Regression	One-velocity	High
Riffle 86A	2.97	Log/log Regression	One-velocity	High

Table 4.8-8. Stage-discharge calibration summary for the Fall Creek bypass reach. Habitat type and cross section identification, transect weight, technique used for water surface elevation (WSEL) and velocity simulation and velocity data set used.

Habitat Type XSEC	Transect Weighting %	WSEL Method	Velocity Method	Velocity Data Set Used
Riffle 86B	2.97	Channel Conveyance	One-velocity	High
Pool 90A	4.58	Log/log Regression	One-velocity	High
Pool 90B	4.58	Log/log Regression	One-velocity	High
Pool 90C	4.58	Log/log Regression	One-velocity	High
Riffle 165A	2.82	Channel Conveyance	One-velocity	High
Riffle 165B	2.82	Log/log Regression	One-velocity	High
Riffle 165C	2.82	Log/log Regression	One-velocity	High
Pool 168A	4.58	Log/log Regression	One-velocity	High
Pool 168B	4.58	Log/log Regression	One-velocity	High
Pool 168C	4.58	Log/log Regression	One-velocity	High
Run 172A	2.72	Log/log Regression	One-velocity	High
Run 172B	2.72	Log/log Regression	One-velocity	High
Run 172C	2.72	Log/log Regression	One-velocity	High
Riffle 175A	2.82	Log/log Regression	One-velocity	High
Riffle 175B	2.82	Log/log Regression	One-velocity	High
Pool 179A	4.58	Log/log Regression	One-velocity	High
Pool 179B	4.58	Log/log Regression	One-velocity	High
Pool 179C	4.58	Log/log Regression	One-velocity	High
Run 184A	2.72	Log/log Regression	One-velocity	High
Run 184B	2.72	Log/log Regression	One-velocity	High

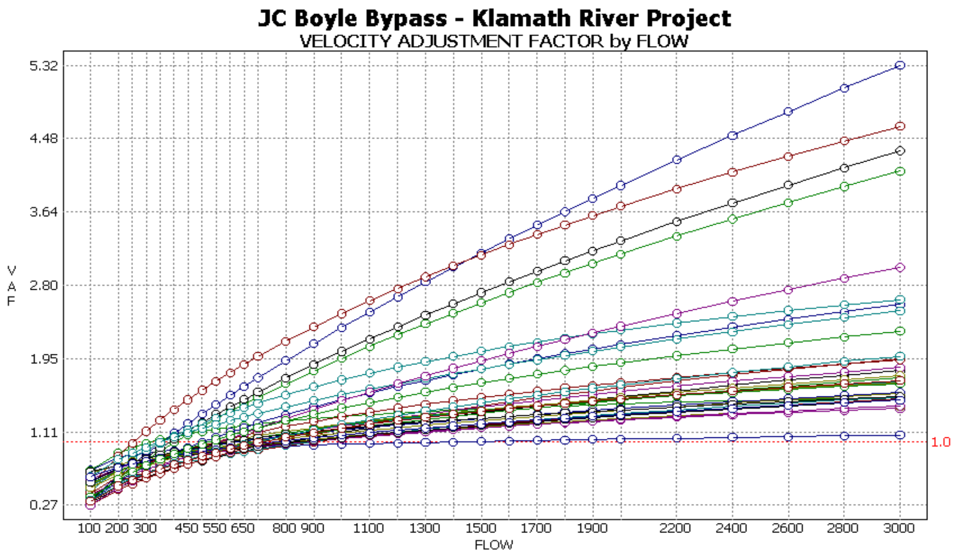


Figure 4.8-1. Velocity adjustment factors (VAF) for the 32 transects in the J.C. Boyle bypass reach over the range of simulated discharge.

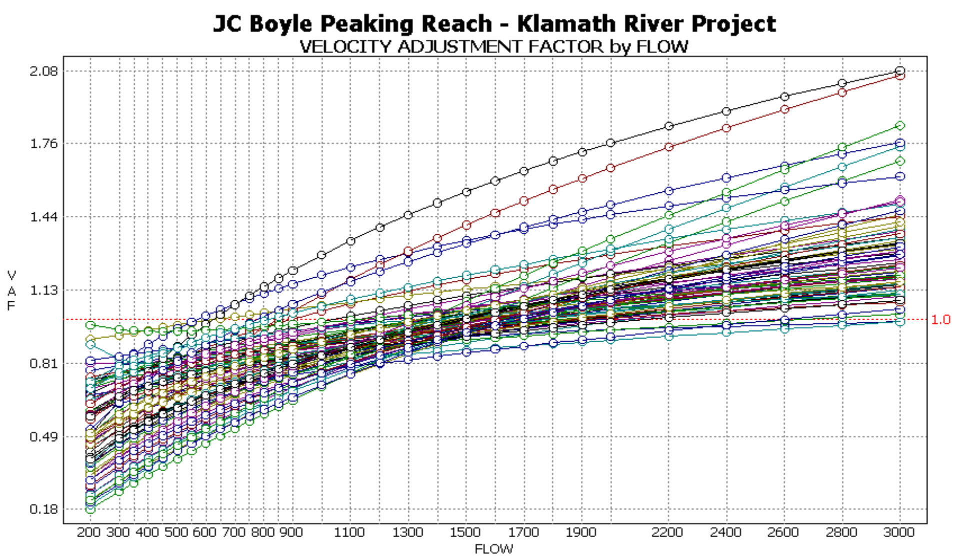


Figure 4.8-2. Velocity adjustment factors (VAF) for the 71 transects in the J.C. Boyle peaking reach over the range of simulated discharge.

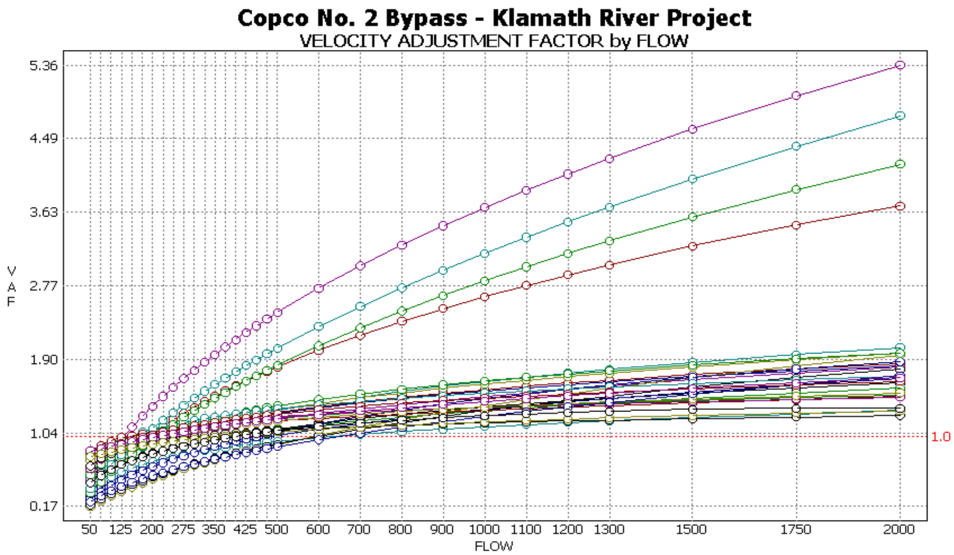


Figure 4.8-3. Velocity adjustment factors (VAF) for the 28 transects in the Copco No. 2 bypass reach over the range of simulated discharge.

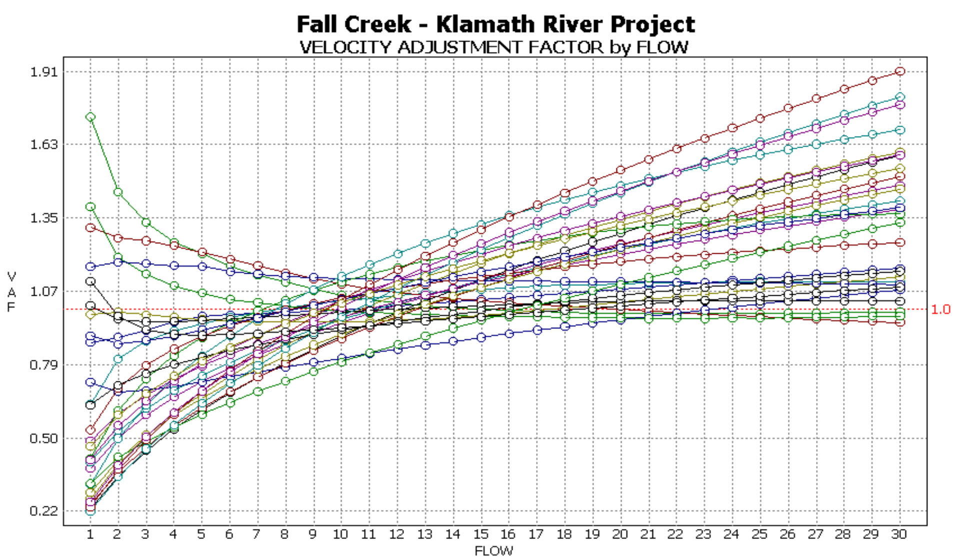


Figure 4.8-4. Velocity adjustment factors (VAF) for the 28 transects in Fall Creek over the range of simulated discharge.

4.8.3 Transect Weighting

Each of the transects is given a weighting to ensure its contribution to the habitat index simulation is indicative of its relative proportional representation to the total habitat of the study area being modeled. Individual transect weights are presented in Tables 4.8-5 to 4.8-8. Transects were weighted as a proportion of the normalized (without “high gradient” habitat types and/or non-modeled habitat types) percent they represent within a reach. For example, if the normalized percent of a given habitat type was 20 percent and that particular habitat was represented by five transects, each individual transect would be weighted as 4.0 percent of the reach. Pool transects were further weighted by the proportion of the unit (head, body, tail) each transect represented.

The J.C. Boyle bypass transects were weighted based on the habitat mapping at the 475 cfs release flow (Table 4.7-2). Transect weighting in the Copco No. 2 bypass was based on habitat mapping at 200 cfs while Fall Creek weights were from base flow mapping. All transects in the J.C. Boyle peaking reach were combined into a single data set and weighted based on habitat mapping without the segment known as Hell's Corner (Table 4.7-6). This was done for two reasons:

1. Habitat simulation should include all transects in the reach.
2. The Hell's Corner segment was not included in the study sites or transect selection process.

4.8.4 Habitat Suitability Criteria

As part of the collaborative re-licensing process, an Instream Flow Subgroup was formed to address specific technical issues relating to instream flow analysis. One of the primary elements was the development of habitat suitability criteria (HSC) (See Appendix 4F). At this time no agreement has been reached on the HSC to be used in the final instream flow analysis. However, in order to make initial instream flow recommendations it was necessary to develop modeling results.

For rainbow trout PacifiCorp relied upon the use of broad-based envelope curves in all reaches (Table 4.8-9), except Fall Creek. In addition, site specific rainbow trout curves developed from data collected in the J.C. Boyle bypass (refer to HSC Report[Appendix 4F) were applied to the J.C. Boyle bypass reach (Table 4.8-10). Envelope curves were developed from a database of rainbow trout curves. The selection process for curves to include consisted of the following criteria: HSC were developed under accepted sampling design accounting for habitat availability; sample size greater than 150; flows greater than 100 cfs to represent larger rivers (initial criterion of greater than300 cfs did not include enough curves); size of adults 30+cm; water temperatures above 60*C (initial criterion of greater than 65*C did not include enough curves); source streams within natural range of redband/rainbow trout. This process resulted in composite (envelope) HSC based on five fry and juvenile curve sets and six adult curve sets.

Table 4.8-9. Envelope habitat suitability criteria (HSC) for rainbow trout. Used for preliminary instream flow habitat analysis in the J.C. Boyle bypass, J.C. Boyle peaking reach and Copco No.2 bypass.

Envelope RBT HSC											
MCVel	**Fry**	**Depth**	**Fry**	**MCVel**	**Juvenile**	**Depth**	**Juvenile**	**MCVel**	**Adult**	**Depth**	**Adult**
0.00	0.70	0.00	0.00	0.00	0.50	0.30	0.00	0.00	0.25	0.50	0.00
0.16	1.00	.033	1.00	0.30	1.00	1.15	1.00	0.45	1.00	2.45	1.00
0.50	1.00	1.30	1.00	1.15	1.00	2.50	1.00	1.50	1.00	20.0	1.00
1.10	0.13	2.00	0.50	1.65	0.40	3.30	0.45	2.25	0.40		
2.30	0.00	3.60	0.00	3.55	0.00	5.70	0.00	4.45	0.00		

Table 4.8-10. Habitat suitability criteria (HSC) for rainbow trout based on observations in the J.C. Boyle bypass reach. (Source: Klamath River HSC Report).

Running Means Use/Availability HSC							
MCVel	Fry	Juvenile	Adult	**Depth**	Fry	Juvenile	Adult
0.00	0.35	0.15	0.05	0.0	0.00	0.00	0.00
0.05	0.53	0.32	0.08	0.1	0.39	0.13	0.02
0.15	0.89	0.63	0.16	0.3	0.64	0.29	0.04
0.25	1.00	0.91	0.23	0.5	0.96	0.50	0.06
0.35	0.90	1.00	0.32	0.7	1.00	0.68	0.08
0.45	0.68	0.97	0.41	0.9	0.83	0.84	0.11
0.55	0.46	0.83	0.52	1.1	0.61	0.97	0.14
0.65	0.29	0.67	0.63	1.3	0.43	1.00	0.18
0.75	0.18	0.52	0.74	1.5	0.39	0.86	0.22
0.85	0.12	0.41	0.84	1.7	0.25	0.68	0.29
0.95	0.08	0.35	0.92	1.9	0.18	0.65	0.38
1.05	0.06	0.34	0.97	2.1	0.10	0.60	0.50
1.15	0.06	0.31	1.00	2.3	0.09	0.53	0.63
1.25	0.06	0.25	1.00	2.5	0.07	0.30	0.73
1.35	0.06	0.20	0.97	2.7	0.05	0.26	0.77
1.45	0.06	0.19	0.94	2.9	0.03	0.22	0.77
1.55	0.05	0.19	0.90	3.1	0.02	0.24	0.78
1.65	0.03	0.20	0.86	3.3	0.00	0.25	0.82
1.75	0.02	0.17	0.82	3.5	0.00	0.20	0.89
1.85	0.01	0.13	0.77	3.7	0.00	0.15	0.95
1.95	0.00	0.09	0.69	3.9	0.00	0.09	1.00
2.05		0.06	0.59	4.1	0.00	0.10	1.00
2.15		0.06	0.49	4.3	0.00	0.10	1.00
2.25		0.05	0.40	4.5	0.00	0.09	1.00
2.35		0.06	0.32	4.7	0.00	0.05	1.00
2.45		0.05	0.25	4.9	0.00	0.04	1.00
2.55		0.07	0.22	5.1	0.03	0.04	1.00
2.65		0.05	0.20	5.3	0.04	0.05	1.00
2.75		0.03	0.19	5.5	0.05	0.03	1.00
2.85		0.01	0.18	5.7	0.00	0.00	1.00
2.95		0.01	0.17				
3.05		0.02	0.16				
3.15		0.04	0.15				
3.25		0.05	0.14				
3.35		0.03	0.13				
3.45		0.01	0.12				
3.55		0.00	0.11				
3.65			0.09				
3.75			0.08				
3.85			0.07				
3.95			0.06				
4.05			0.05				
4.15			0.04				
4.25			0.03				
4.35			0.02				
4.45			0.00				

Because of the small size of Fall Creek (channel width of 10 to15 feet and depths rarely exceeding 2 feet) it was thought that the use of HSC developed in larger channels would not be appropriate. This included the envelope curves, which were based on larger streams and rivers. In addition, adult trout in Fall Creek are relatively small in size (they range from 6 to 8 inches) compared to adults found in the J.C. Boyle bypass (site-specific curves) and streams included in the envelope curves. It was decided to apply rainbow trout juvenile and adult curves developed for small streams --Bucks Creek and Grizzly Creek in the northern Sierra -- (Thomas R. Payne & Associates 1991), to the Fall Creek reach (Table 4.8-11).

Table 4.8-11. Habitat suitability criteria (HSC) for rainbow trout (juvenile and adult) used for instream flow habitat analysis in Fall Creek. (Source: Thomas R. Payne & Associates 1991, Bucks and Grizzly Creeks).

Bucks/Grizzly RBT HSC							
MCVel	**Adult**	**Depth**	**Adult**	**MCVel**	**Juvenile**	**Depth**	**Juvenile**
0.0	0.83	0.85	0.00	0.00	0.00	0.00	0.00
0.1	0.93	1.05	0.09	0.02	0.09	0.30	0.00
0.2	0.98	1.25	0.20	0.12	0.56	0.45	0.16
0.3	1.00	1.45	0.34	0.22	0.84	0.65	0.35
0.4	0.99	1.65	0.48	0.32	0.97	0.85	0.51
0.5	0.96	1.85	0.63	0.42	1.00	1.05	0.65
0.6	0.91	2.05	0.76	0.52	0.94	1.25	0.76
0.7	0.84	2.25	0.86	0.62	0.84	1.45	0.85
0.8	0.76	2.45	0.94	0.72	0.70	1.65	0.92
0.9	0.68	2.65	0.98	0.82	0.55	1.85	0.96
1.0	0.58	2.85	1.00	0.92	0.41	2.05	0.99
1.1	0.49	3.05	0.98	1.02	0.29	2.25	1.00
1.2	0.40	3.25	0.94	1.12	0.20	2.45	0.99
1.3	0.31	3.45	0.86	1.22	0.13	2.65	0.98
1.4	0.23	3.65	0.77	1.32	0.11	2.85	0.94
1.5	0.16	3.85	0.67	1.97	0.11	3.05	0.90
1.6	0.11	4.05	0.56	2.02	0	3.25	0.85
1.7	0.08	4.25	0.44			3.45	0.79
1.8	0.07	4.45	0.33			3.65	0.72
3.3	0.07	4.65	0.22			3.85	0.65
3.35	0	4.85	0.16			4.05	0.57
		5.05	0.13			4.25	0.50
		5.25	0.11			4.45	0.42
		7.15	0.11			4.65	0.34
		7.25	0			4.85	0.27
						5.05	0.20
						5.35	0.14
						5.55	0.13
						5.75	0.13
						5.85	0

Klamath smallscale sucker (Catostomus rimiculus) and Klamath largescale sucker (C. snyderi) are species of concern in the project area. Poor water visibility and low numbers of observations precluded developing site specific information. Previously published curves from the Pit River (PIT), and North Fork Feather River (UNFFR, LNFFR) were selected for initial habitat modeling (Table 4.8-12).

Table 4.8-12. Habitat suitability criteria (HSC) for suckers used for instream flow habitat analysis in the J.C. Boyle bypass, J.C. Boyle peaking reach, and Copco No.2 bypass. Pit River (PIT), upper North Fork Feather River (UNFFR), lower North Fork Feather River (LNFFR).

Juvenile Suckers				Adult Suckers				Adult Suckers			
MCVel	**PIT**	**Depth**	**PIT**	**MC Vel**	**PIT**	**Depth**	**PIT**	**MC Vel**	**UNFFR**	**Depth**	**UNFFR**
0.00	0.72	0.16	0.00	0.00	0.04	0.00	0.00	0.00	0.20	0.50	0.00
0.19	0.78	0.49	0.03	0.19	0.18	0.49	0.02	0.05	0.23	0.70	0.01
0.49	1.00	0.82	0.05	0.49	0.36	0.98	0.07	0.15	0.32	0.90	0.02
0.82	0.47	1.15	0.20	0.82	0.60	1.64	0.08	0.25	0.43	1.10	0.04
1.15	0.42	1.48	0.39	1.15	0.60	2.30	0.19	0.35	0.54	1.30	0.07
1.48	0.38	1.80	0.55	1.48	1.00	2.95	0.45	0.45	0.64	1.50	0.10
1.80	0.33	2.13	1.00	1.80	0.43	3.61	0.83	0.55	0.74	1.70	0.14
2.13	0.28	2.46	0.87	2.13	0.43	4.27	1.00	0.65	0.83	1.90	0.18
2.46	0.00	2.79	0.82	2.46	0.24	16.00	1.00	0.75	0.90	2.10	0.24
		3.12	0.53	2.79	0.24			0.85	0.95	2.30	0.32
		3.44	0.37	3.12	0.23			0.95	0.98	2.50	0.46
		3.77	0.34	3.44	0.23			1.05	0.99	2.70	0.61
		4.10	0.30	3.77	0.23			1.15	1.00	2.90	0.73
		4.43	0.28	4.10	0.00			1.25	0.99	3.10	0.81
		4.76	0.21					1.35	0.96	3.30	0.87
		5.09	0.18					1.45	0.92	3.50	0.94
		5.41	0.17					1.55	0.88	3.70	1.00
		5.74	0.08					1.65	0.83	3.90	0.97
		6.07	0.05					1.75	0.77	4.10	0.92
		6.40	0.00					1.85	0.71	4.30	0.85
								1.95	0.64	4.50	0.82
MCVel	**LNFFR**	**Depth**	**LNFFR**	**MCVel**	**LNFFR**	**Depth**	**LNFFR**	2.05	0.58	4.70	0.76
0.00	1.00	0.00	0.00	0.00	0.26	0.00	0.00	2.15	0.52	4.90	0.75
0.25	0.73	0.66	1.00	0.25	0.43	0.67	0.16	2.25	0.47	100.00	0.75
0.42	0.59	1.33	0.63	0.42	0.55	1.33	0.26	2.35	0.43		
0.58	0.47	2.00	0.05	0.58	0.68	2.00	0.39	2.45	0.40		
0.75	0.37	2.67	0.00	0.75	0.79	2.67	0.53	2.85	0.32		
0.92	0.29			0.92	0.89	3.33	0.67	2.95	0.31		
1.08	0.22			1.08	0.96	4.00	0.80	3.25	0.26		
1.25	0.17			1.25	0.99	4.67	0.90	3.35	0.26		
1.42	0.13			1.42	1.00	5.33	0.96	3.45	0.25		
1.58	0.10			1.58	0.97	6.00	1.00	3.55	0.24		
1.75	0.08			1.75	0.91	6.67	1.00	3.65	0.24		
1.92	0.06			1.92	0.82	7.33	0.98	3.75	0.23		
2.08	0.05			2.08	0.71	8.00	0.93	3.85	0.22		
2.25	0.04			2.25	0.59	8.67	0.86	3.95	0.21		

Table 4.8-12. Habitat suitability criteria (HSC) for suckers used for instream flow habitat analysis in the J.C. Boyle bypass, J.C. Boyle peaking reach, and Copco No.2 bypass. Pit River (PIT), upper North Fork Feather River (UNFFR), lower North Fork Feather River (LNFFR).

Juvenile Suckers				**Adult Suckers**				**Adult Suckers**			
MCVel	**PIT**	**Depth**	**PIT**	**MC Vel**	**PIT**	**Depth**	**PIT**	**MC Vel**	**UNFFR**	**Depth**	**UNFFR**
2.42	0.03			2.42	0.47	9.33	0.79	4.05	0.19		
2.58	0.02			2.58	0.35	10.00	0.71	4.15	0.17		
2.75	0.02			2.75	0.24	10.67	0.63	4.25	0.15		
2.92	0.01			2.92	0.16	11.33	0.55	4.35	0.13		
3.58	0.00			3.08	0.10	12.00	0.48	4.45	0.10		
				3.25	0.06	12.67	0.42	4.55	0.08		
				3.42	0.03	13.33	0.37	4.65	0.06		
				3.58	0.02	14.00	0.33	4.75	0.04		
				3.75	0.01	14.67	0.30	4.85	0.03		
				3.92	0.00	15.33	0.27	4.95	0.02		
						16.00	0.26	5.05	0.02		
						100.00	0.26	5.15	0.00		

4.8.5 Cover and Substrate

Cover and substrate information was collected for the site-specific rainbow trout curves and at each individual cell for all transects. The Instream Flow Subgroup has not yet agreed upon how this data will be applied to both the HSC and habitat modeling. Therefore, in the initial habitat modeling, cover was not included as a variable.

4.8.6 Habitat Index Simulation

Combining the hydraulic modeling results with the habitat suitability criteria curves for the species and life stages of concern in the various study reaches generated weighted usable area (WUA) relationships. Habitat simulations with site-specific HSC were run with and without functional cover types. The standard straight multiplication option using the cell centroid was used for WUA calculations. Substrate was not used in any calculations and this variable was turned off during processing. Tabular values of WUA output are provided in Appendix 4G.

4.8.6.1 J.C. Boyle Bypass Reach

Release flows at the dam are amplified by 225 to 250 cfs at the bottom of the reach because of accretion from springs. This estimate was determined through the instream flow analysis and is slightly greater than the previous estimate of spring flow of approximately 220 cfs. WUA output in the bypass reach was adjusted to account for this accretion through the following process:

1. The percentage of reach with a given flow was estimated based on the distance to known discharge sample points. The percentages used were 21.4 percent no accretion, 13.6 percent 100 cfs accretion, and 65.0 percent 250 cfs accretion.

2. WUA values were calculated using all transects weighted for the entire reach.

3. For each release flow, the WUA at the corresponding accretion flow level was then weighted by the percent of the reach represented. For example, the WUA for a release flow of 200 cfs at the dam would equal WUA at 200 cfs * .214 + WUA at 300 cfs (100 cfs accretion) * .136 + WUA at 450 cfs (250 cfs accretion) * .65.

Habitat index simulation for rainbow trout fry, juvenile and adult life stages in the J.C. Boyle bypass are presented in Figure 4.8-5. WUA curves based on envelope or site specific HSC follow similar patterns, varying only in amplitude, a function of the range in depth and velocity suitability. Both fry and juvenile WUA decline over the range of flows simulated and flatten out at higher flows. The adult WUA curves increase slightly in the lower flow ranges before tapering off over the range of flows. The relatively flat WUA values with increasing flow is the result of suitability being maintained in margin areas while the majority of the channel becomes unsuitable as a result of increasing velocities.

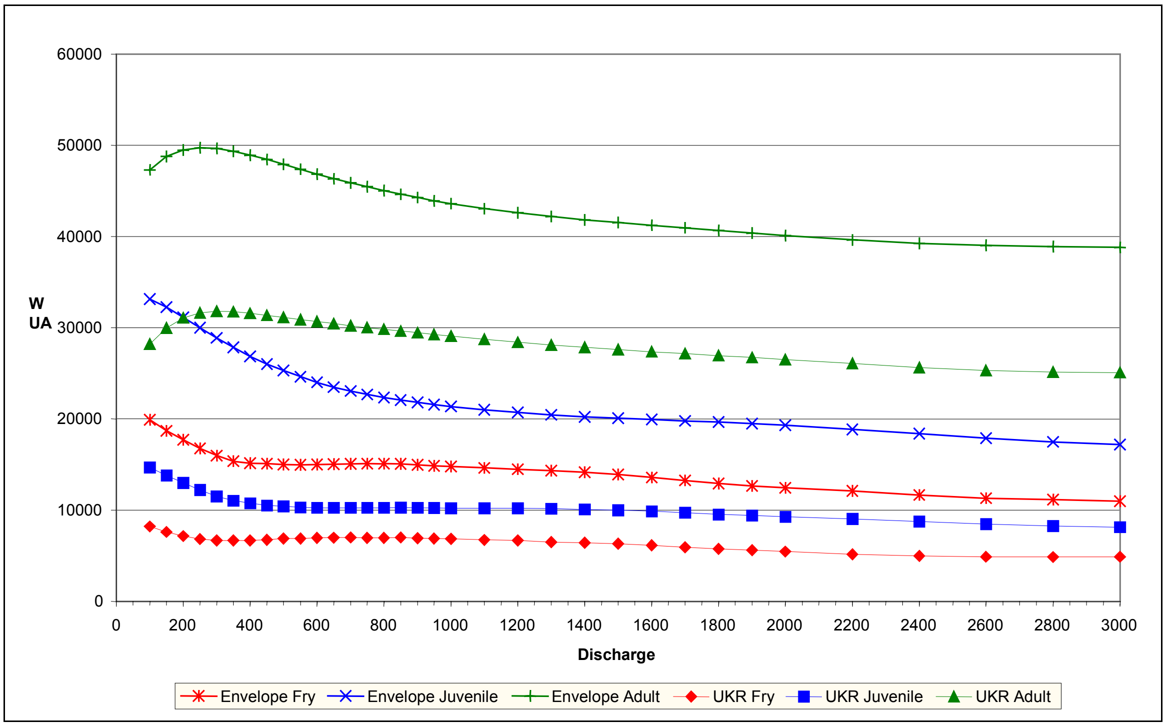


Figure 4.8-5. Habitat index simulation for rainbow trout fry, juvenile and adult in the J.C. Boyle bypass reach using upper Klamath River site-specific curves and envelope curves.

Sucker WUA curves in the J.C. Boyle bypass generally follow the same trends as rainbow trout (Figure 4.8-6). Juvenile suckers curves decline gradually before leveling off at higher flows. Both PIT and UNFFR adult sucker curves increase up to about 400 cfs then flatten out before and declining slightly over the range of flows.

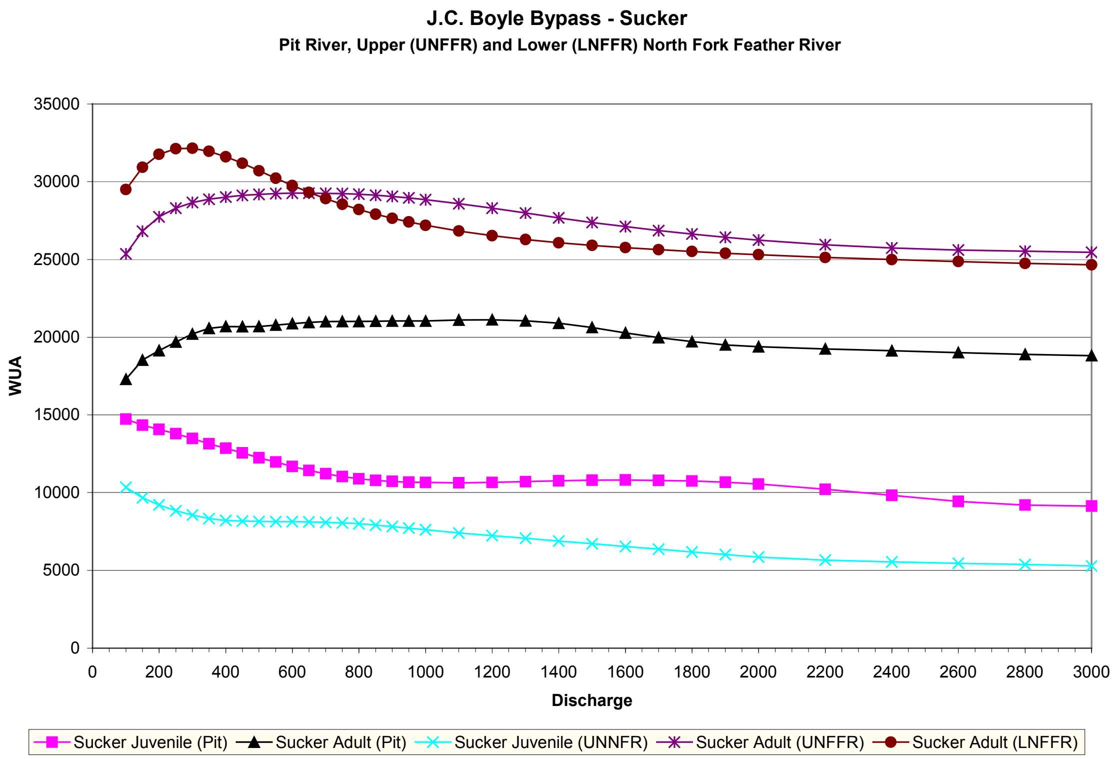


Figure 4.8-6. Habitat index simulation for juvenile and adult suckers in the J.C. Boyle bypass.

4.8.6.2 J.C. Boyle Peaking Reach

Habitat index simulation for rainbow trout fry, juvenile and adult life stages in the J.C. Boyle peaking reach are presented in Figure 4.8-7. Curves for fry and juvenile trout flatten out at higher discharge as a function of loss of suitable cells in the middle of the channel while still maintained suitability in stream margins.

Juvenile sucker WUA curves in the J.C. Boyle peaking reach decline from low flow before flattening out over the higher simulation flow range (Figure 4.8-8). Adult sucker WUA based on PIT and UNFFR curves increase sharply, level off between 500 and 900 cfs, then decrease over the higher flow range. The LNFFR adult curve shows a more abrupt increase, a narrow high arch, and steeper decline in WUA.

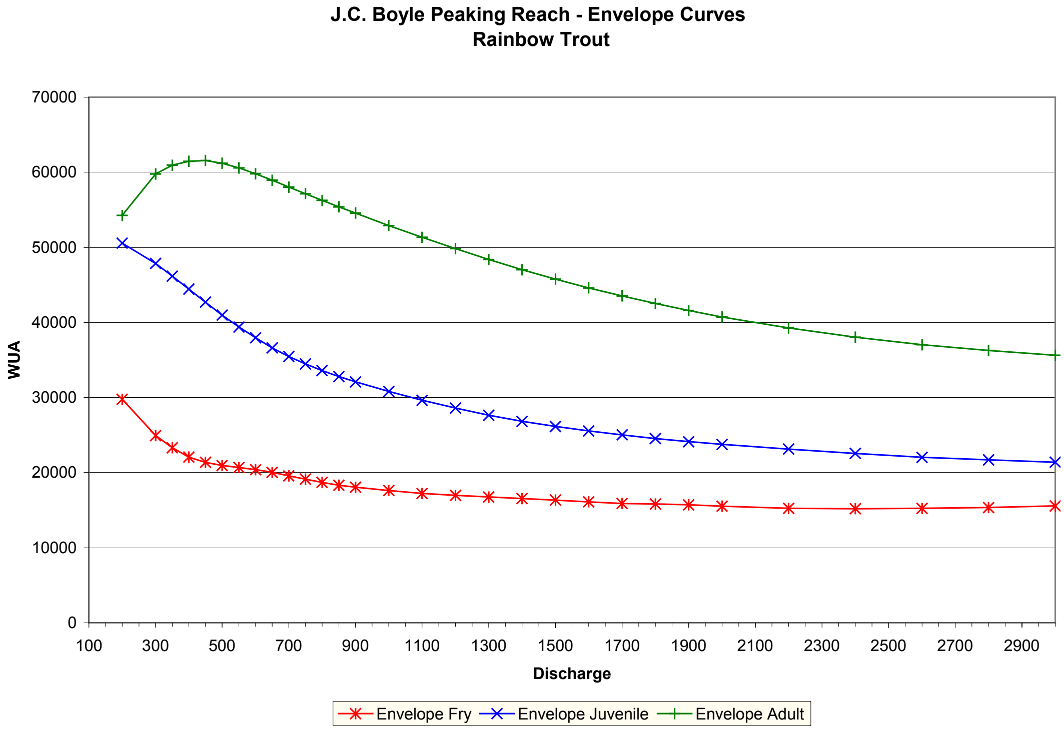


Figure 4.8-7. Habitat index simulation for rainbow trout fry, juvenile and adult in the J.C. Boyle peaking reach based on envelope HSC.

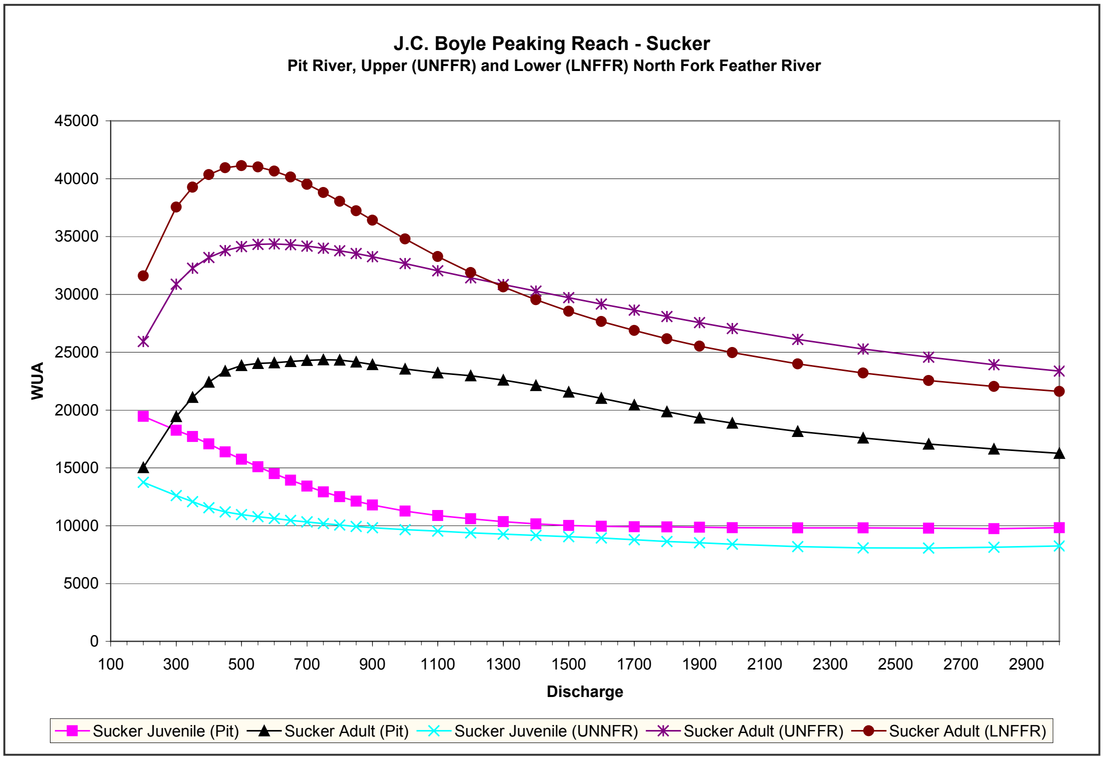


Figure 4.8-8. Habitat index simulation for juvenile and adult suckers in the J.C. Boyle peaking reach.

4.8.6.3 Copco No. 2 Bypass

Habitat index simulation for rainbow trout fry, juvenile and adult life stages in the Copco No. 2 bypass reach are presented in Figure 4.8-9. Index values are reflective of the channel shape in the reach. As a result of riparian encroachment the main channel has narrowed, leaving large, relatively flat cobble/boulder bars over portions of the reach. As water is added to the channel, velocities quickly become unsuitable for rainbow trout fry and juveniles up to 200 cfs. As flows continue to increase water spills onto the large cobble/boulder bars producing the increase in WUA. Rainbow trout adults on the other hand show an increase in WUA as flows increase up to 200 cfs, due in part to suitability for higher velocities and deeper water. Sucker WUA in the Copco bypass shows similar patterns to rainbow trout (Figure 4.8-10). It should be noted that though edge velocity data was collected for the hydraulic model at 600 cfs, the reliability of velocity simulations across large boulder bars may be suspect at higher simulation flows.

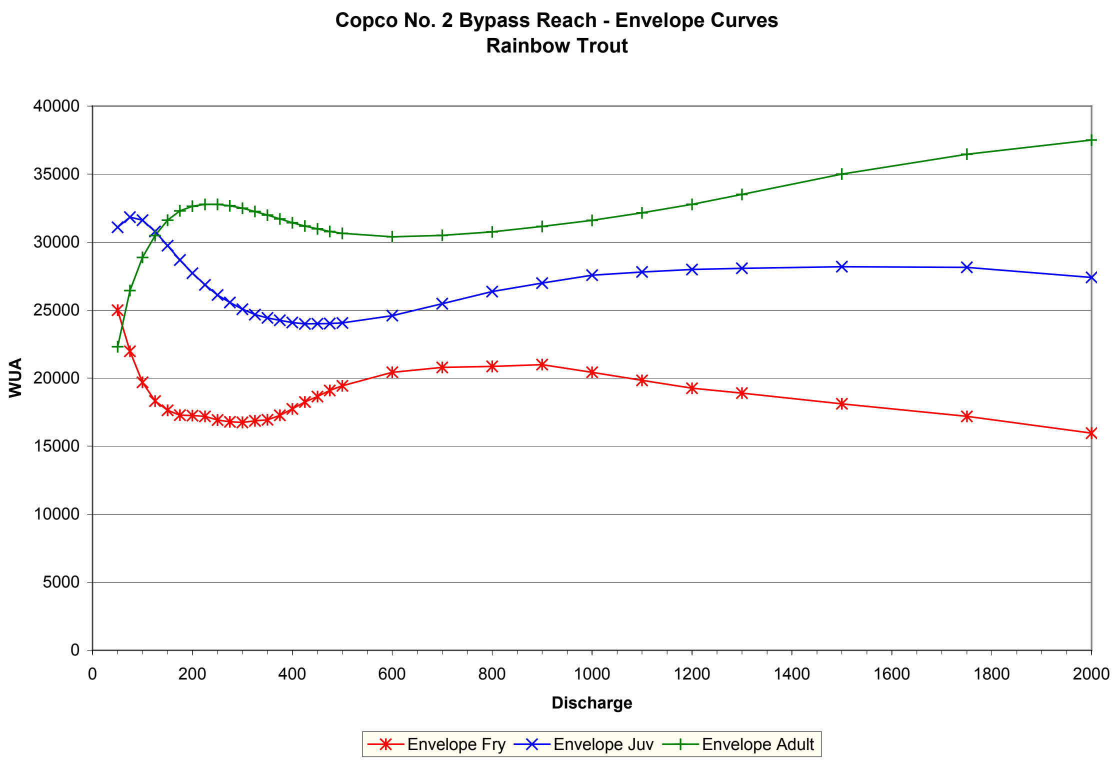


Figure 4.9-9. Habitat index simulations for rainbow trout fry, juvenile and adult in the Copco No. 2 bypass reach using envelope HSC curves.

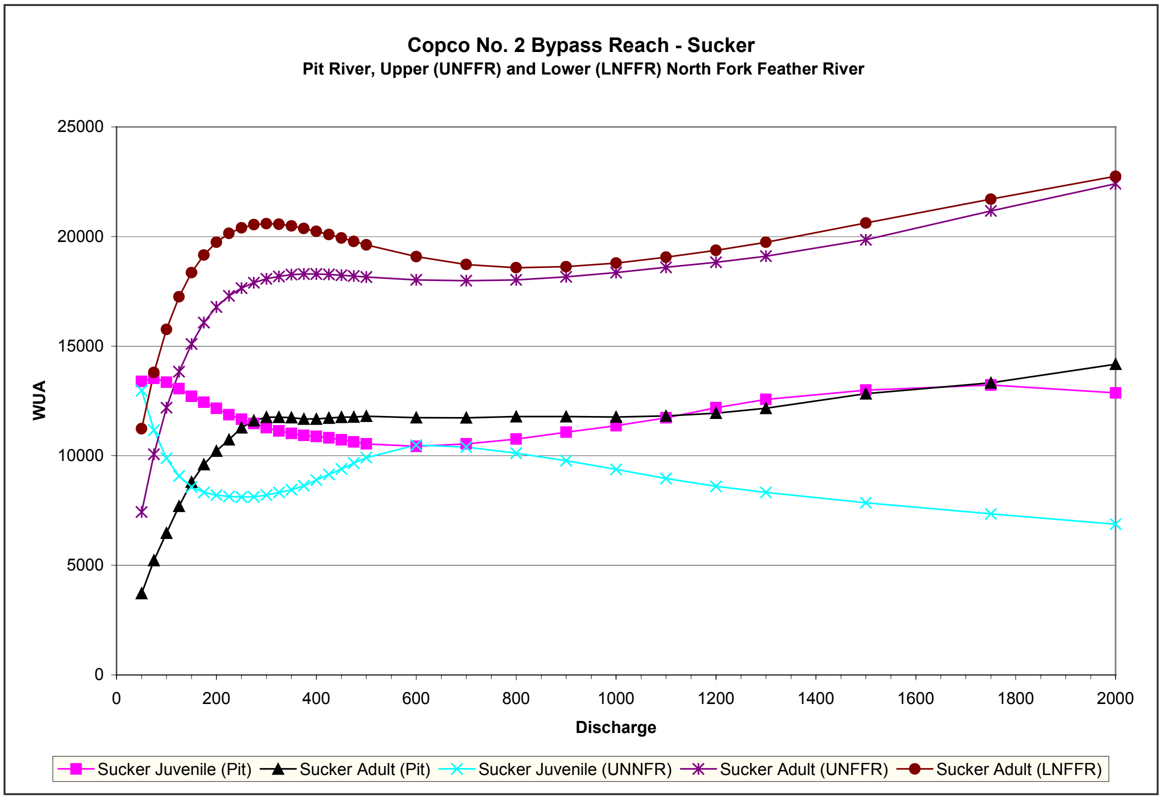


Figure 4.8-10. Habitat index simulation for juvenile and adult suckers in the Copco No. 2 bypass reach.

4.8.6.4 Fall Creek

Habitat index simulation for rainbow trout juvenile and adult life stages in the Fall Creek are presented in Figure 4.8-11. As stated previously, it was decided to use small stream HSC instead of envelope curves in Fall Creek due to the size of the channel. Juvenile WUA shows an abrupt increase up to 5 cfs followed by a relatively flat curve. Adults on the other hand show a continuous increase over the range of simulation flows.

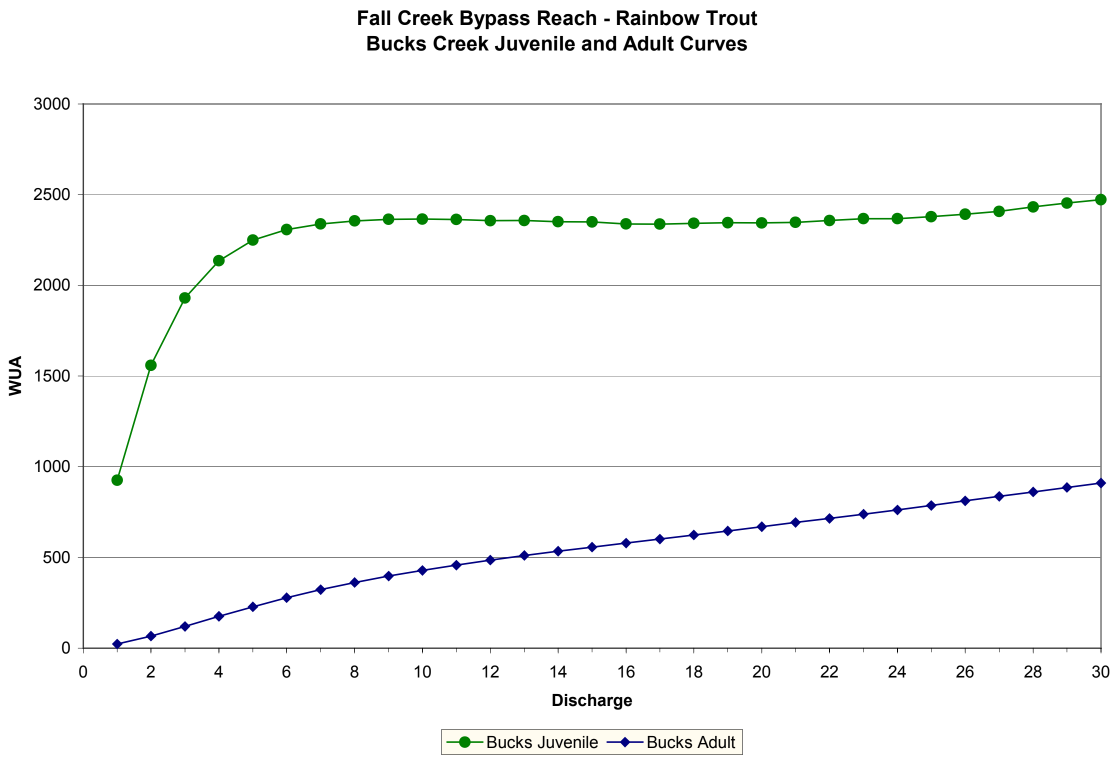


Figure 4.8-11. Habitat index simulation for rainbow trout juvenile and adult in the Fall Creek bypass. Juvenile and adult curves from Bucks Creek (Thomas R. Payne & Associates 1991).

4.8.7 Discussion

As stated at the beginning of the instream flow section, the habitat analysis presented here is PacifiCorp's own analysis. Additional or modified HSC curves or modeling variables may be implemented by the Instream Flow Subgroup which could change the instream flow study results.

While WUA indices can be examined and interpreted alone, they are most useful when linked to background hydrology and project operations over time. This temporal linkage, referred to as habitat time series, shows how WUA will vary under unimpaired or regulated hydrology, or under project spill, varied release, or non-operation conditions. WUA viewed under varied flow conditions over extended periods of time can give a more accurate picture of how the WUA habitat index (and subsequent biological responses) will actually vary.

Linkage to other studies, including water quality, recreation, bioenergetics and peaking will allow for a more complete analysis for determining appropriate project operations.