10.0 EVALUATION OF EFFECTS OF FLOW FLUCTUATION ON AQUATIC RESOURCES WITHIN THE J.C. BOYLE PEAKING REACH

10.1 DESCRIPTION AND PURPOSE

Peaking operations at the J.C. Boyle powerhouse create flow fluctuations that can affect aquatic biota and habitats in various ways (e.g., changes in physical habitat availability, fish movement, potential stranding) and through various processes (e.g., changes in hydrologic conditions, water quality, stream channel morphology, and riparian vegetation). PacifiCorp proposed to evaluate the effects of peaking using information from various studies. At the August 6, 2002, AWG meeting, stakeholders requested that PacifiCorp develop a study plan to coordinate and integrate the various aquatic resource study concerns and key questions associated with the peaking operations at the J.C. Boyle powerhouse. This section describes pertinent study concerns and how the coordinated analysis of information is accomplished.

10.2 OBJECTIVES

The objective of this study is to ensure coordination of pertinent study elements and questions related to effects of peaking-related flow fluctuations on aquatic resources in the J.C. Boyle peaking reach. The study elements addressed are as follows:

- Hydrology and physical changes
  - Describe the extent of existing flow fluctuations in the J.C. Boyle peaking reach as affected by Project operations and assess the physical limitations of Project facilities to control these flow fluctuations.
  - Describe the physical extent of streambed habitat affected by flow fluctuations.
- Water temperature/water quality
  - Describe how water temperatures change during flow fluctuations.
  - Describe how does water quality (e.g., DO, suspended sediments, nutrients) change during flow fluctuations.
  - Assess how these water temperature and water quality changes affect fish growth or survival.
- Channel morphology/bedload movement
  - Describe how current flow fluctuations affect bedload movement and sedimentation rates.
  - Describe how these changes in bedload movement result in changes to channel morphology.
  - Describe how these changes affect fish production or survival.

- Riparian vegetation
  - Characterize how flow fluctuations affect the riparian vegetation.
  - Assess how these effects influence channel morphology and fish habitat (e.g., cover).
- Fish habitat
  - Describe how flow fluctuations affect habitat quality and quantity.
  - Describe how flow fluctuations affect habitat use by various fish species and life stages.
- Fish movement/migration
  - Assess whether trout are free to move throughout the J.C. Boyle peaking reach and if they access available habitat.
  - Quantify any "non-natural" delays in movement associated with Project operations in the reach (e.g., false attraction to tailrace, flow/water quality barriers).
  - Assess whether trout are induced to move laterally or longitudinally during periods of flow changes. How far? If so, does this affect their growth or survival?
- Fish spawning/incubation
  - Determine whether trout spawn in the peaking reach and if so, where does spawning occur?
  - Assess whether flow fluctuations hinder the success of trout spawning and fry recruitment in the peaking reach.
- Fish stranding
  - What is the potential that down-ramping will strand juvenile fish?
  - Assess whether the current down-ramping rate (9 in/hr allowed, approximately 7 in/hr in practice) strand juvenile fish. If so, how many fish are stranded?
  - Quantify what fish/size are present to be subjected to possible stranding.
- Macroinvertebrate production
  - Characterize the impacts of Project peaking on macroinvertebrate community structure and production.
  - Describe the effects of food availability on growth and production of trout in the peaking reach.
- Other considerations
  - Although this study is focused on aquatic resources, what potential conflicts or opportunities posed by new or modified flow and ramping regimes are needed to avoid or minimize potential impacts to other resources (e.g., recreation, aesthetics, power production)?

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10.3 RELICENSING RELEVANCE AND USE IN DECISIONMAKING

PacifiCorp is evaluating potential effects of hydro-peaking operations at the J.C. Boyle powerhouse on aquatic resources, including fish. The effort is primarily an integration of information from several studies associated with peaking operation at the J.C. Boyle powerhouse. The studies are used in this integration of information are cited in the Methods discussion below.

10.4 METHODS AND GEOGRAPHIC SCOPE

10.4.1 Geographic Scope

The geographic scope of this study plan is the J.C. Boyle peaking reach from the J.C. Boyle powerhouse to Copco reservoir.

10.4.1.1 Methods

Hydrology and Physical Changes

The extent of existing flow fluctuations in the J.C. Boyle peaking reach is described in Section 5.0 of the Water Resources FTR and in Section 6.0 of the Fish Resources FTR, and is based on an analysis of streamflow data from the USGS gauge downstream of the J.C. Boyle powerhouse (USGS Gauge No. 11510700) (Study 1.7). Hourly streamflow data available since 1990 has been analyzed to depict the rate (stage change per hour) and frequency of down-ramping in the peaking reach. This time period contains a good representation of wet, average, and dry years.

The analysis consists of computing the change in river stage from one hour to the next, ranking these stage changes, and then computing the percent of time within the period that a particular stage reduction rate is being equaled or exceeded. The results are tabulated and graphed as exceedance curves so one can readily determine the rate of stage change and the percent of time in which that rate or a higher rate occurs. The exceedance percentages are computed for the total time within the period (e.g., season) and flow range is examined to accurately reflect the percent of time that a particular rate of stage change is being exceeded.

Flow fluctuations in the J.C. Boyle peaking reach also are modeled using RMA-2, a one-dimensional finite-element hydrodynamic model capable of simulating highly dynamic flow regimes in short space and time intervals (see Sections 4.0 and 5.0 of the Water Resources FTR). RMA-2 is used in water quality modeling studies (Section 4.0 of the Water Resources FTR) to examine the short-term hydrology and hydrodynamic effects of Project operations scenarios, together with examination of water quality effects using RMA-11. The RMA models are using 2000 and 2001 boundary conditions to simulate flow and water quality. The output from RMA-2 is provided on an hourly time step. RMA-2 has been used to assess four basic scenarios:

1. Existing operations conditions, which represents current facilities, operations, and general water quality conditions within the J.C. Boyle peaking reach.

2. Steady flow operations conditions, which represents conditions without peaking hydropower operations at J.C. Boyle powerhouse.

3. A hypothetical “without Project” condition, with boundary conditions that represent existing inflow conditions.

4. A second hypothetical “without Project” condition, with boundary conditions that represent existing smoothed flow management conditions at Keno dam.

The without-Project scenarios represent conditions with no J.C. Boyle hydroelectric development in place. Hourly flow exceedance curves are being derived by month to compute the percent of hours within a given month that a particular temperature is equaled or exceeded.

The physical extent of streambed habitat affected by flow fluctuations is determined by quantifying the amount of streambed, including side-channels, that is alternately watered and dewatered within the peaking cycle (see Section 6 of the Fish Resources FTR). This area is referred to as the zone-of-influence, or varial zone. Quantification of the varial zone among different increments of flow is based on the stage-discharge relationships and cross-sections surveyed as part of the instream flow study conducted using PHABSIM[1] (see Section 4.0 in the Fish Resources FTR). A total of 71 cross-sections are available for analysis in the peaking reach. Standard output of the hydraulic model used in PHABSIM includes wetted perimeter as a function of flow at each cross-section. Wetted perimeter versus discharge data: (1) are presented for each of the 71 cross-sections, (2) are combined (averaged) for cross section within a mesohabitat type, and (3) are combined (averaged) for all cross sections weighted by mesohabitat proportions within the reach.

The summarized wetted perimeter/discharge information are tabulated onto worksheets to readily quantify the varial zone between two different streamflows (see Section 6.0 of the Fish Resources FTR). The varial zone is the wetted perimeter change in feet and as percent change, from the high flow to the low flow being compared. This quantification of the varial zone between flow increments is used to compare aquatic streambed effects among various alternative pairs of starting and ending flows.

The existing physical limitations of Project facilities to control flow fluctuations are described in Exhibit B of the license application and Section 5.0 of the Water Resources FTR. Exhibit B includes descriptions of the J.C. Boyle dam spillway, gates, and turbines, and their flow control capabilities. Examples of various operations scenarios are provided, which describe specific facilities operations, settings, and flow contributions. The description includes graphs of hourly flows during the course of operation scenarios.

[1] The Physical Habitat Simulation System (PHABSIM) is part of the Instream Flow Incremental Methodology (IFIM). PHABSIM predicts physical microhabitat changes associated with flow alterations. It provides a variety of simulation tools, which characterize the physical microhabitat structure of a stream and describe the flow-dependent characteristics of physical habitat in light of selected biological responses of target species and life stages. When interpreting PHABSIM results, an assumption is normally made that flow-dependent physical microhabitats are useful in determining carrying capacity and therefore are related to the instream flow needs or impacts of flow variations on fish or other aquatic organisms in streams. The relationship of physical habitat to fish (or any other aquatic organism) production assumes the production of benefits for fish is limited by the availability of physical habitat. This assumption is not always true, because production may be limited by other factors (e.g., water quality).

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Water Temperature/Water Quality

The change in water temperatures during flow fluctuations is examined based on analysis of RMA-11 water quality model output (Section 4.0 of the Water Resources FTR). RMA-11 is an overall water quality model that simulates water temperature, among other parameters. Time series plots of water temperature model output and concomitant flow data (at an hourly time step) are generated for visual trend analysis. Water temperature exceedance curves are being derived by month to compute the percent of hours within a given month that a particular temperature or temperature rate-of-change is equaled or exceeded. Analyses are being performed, and comparisons made, for four modeled scenarios, as described above. Additional analyses will be performed for scenarios that assume that Copco No. 1, Copco No. 2, and Iron Gate dams are removed from the river system. In the scenario that assumes all three of these dams are removed, peaking at J.C. Boyle is eliminated and operates under ROR flows. In the scenario that assumes only Iron Gate dam is removed, peaking operation at J.C. Boyle is retained. These comparisons will allow the temperature effects of existing flow fluctuations to be assessed relative to non-peaking flow regimes.

For FERC licensing analysis purposes, the baseline for assessing effects is existing Project-related environmental conditions as operated under the existing FERC license. For 401 analysis purposes, compliance with water quality standards (WQS) is assessed using current conditions, Project operations, and configuration of Project facilities. In order to assign Project-related water quality impacts in instances of identified WQS non-attainment, PacifiCorp is using water quality modeling based on scenarios “with” and “without” the-Project. Comparisons of predicted water quality under both scenarios will yield an estimate of Project-related water quality impacts.

Other water quality parameters (e.g., DO, nutrients) also are being examined based on analysis of RMA-11 water quality model output (Section 4.0 of the Water Resources FTR). Output is being analyzed in similar fashion as described above for water temperature.

A bioenergetics analysis is being done for site-specific application to the J.C. Boyle peaking reach. Bioenergetics analysis is used to address the implications and interaction of temperature and food availability on trout growth. Temperature and food availability in the Klamath River is affected at least in part by the flow regime. For example, during high flows the temperature of the upstream reservoir water “dominates” the river temperature (warm in the summer); whereas, at low flow the temperature of accretion flow from large springs “dominates” the river temperature (cooler in the summer). The bioenergetics analysis, being performed by Craig Addley of Utah State University, is assessing food availability and temperature over a reasonable range of flow scenarios (existing peaking–stable flows) in the J.C. Boyle peaking reach. The analysis also uses a bioenergetics foraging model to integrate flow, food, and temperature to predict the range of growth rates over the range of peaking versus stable daily flow scenarios.

Channel Morphology/Bedload Movement

The effects of current flow fluctuations on bedload movement and sedimentation rates is assessed from bedload sampling, tracer gravel surveys, and bed mobility calculations (Section 6.0 of the Water Resources FTR). Bedload and suspended sediment transport was sampled within the J.C. Boyle peaking reach upstream of Copco reservoir (at the railroad box car bridge just upstream of the Shovel Creek confluence). The site was selected to characterize bedload transport from the river reach between J.C. Boyle dam and Copco reservoir. This site is near the lower end of the reach. Because of likely sediment trapping by J.C. Boyle dam, this site provides a characterization of bedload from sediment stored in the channel, in bars and banks, and contributed from tributaries and slope erosion over the river reaches between J.C. Boyle dam and Copco reservoir. The site was also chosen because of the availability of a bridge from which sampling is possible.

In the 2002-2003 flow season, bedload samples in the J.C. Boyle peaking reach were obtained at flows of approximately 3,000 cfs, which is the approximate flow release when both J.C. Boyle powerhouse turbines are running. The 3,000-cfs samples will provide a basis for assessing possible effects of these hydroelectric generation-induced fluctuating flows on sediment transport.

Tracer gravels were placed in the Klamath River in the J.C. Boyle peaking reach upstream of the Shovel Creek confluence, in the Frain Ranch area, and near the USGS gauge site below the J.C. Boyle powerhouse. Tracer gravels provide basic information on bed mobility at various flow levels and, with suitable assumptions, can be used to provide independent estimates of bedload transport rates (e.g., Kondolf and Matthews, 1986). These tracers consist of stones of white quartz, which is highly visible in the bed and exotic to the basin, so is easily identified even if the stones move from where they were original placed. The tracers are emplaced along surveyed cross sections so that changes in bed elevation can provide evidence of scour or burial in the event that tracer particles are not visible where emplaced. At intervals along the transect, stones are removed from the bed (marking the hole from which it was drawn); the stones are measured, recorded as to intermediate axis and general shape, and replaced with a quartzite stone of similar size and shape (recording the tracer size and shape); then the tracer is fit into the hole from which the native stone was drawn.

The tracer gravel and bedload sampling data are used, along with cross-sectional and long-profile data for the representative reaches and hydrologic records, to evaluate flows needed to mobilize various particle sizes from along the top of the river bed. The data also help with the evaluation of the frequency and duration of mobilization under Project operations conditions. The critical shear stress (shear stress that mobilizes various particles from along the top of the river bed) is determined using Shield's Equation (see Study Plan 1.5 for details). It is then used to determine the flow depth required to mobilize the various particle sizes from along the top of the bed. The discharge required to mobilize various particle sizes is calculated as the product of the cross-sectional area and the flow velocity, and is compared using frequency and duration of bed mobilization for both current and pre-Project hydrology. After calculating and calibrating the flow at the threshold of mobility for each site, the number of days the bed would have been mobile according to the calculations is determined for assumed hydrologic records (as derived according to methods described in the preceding section, Hydrology and Physical Changes).

Two caveats are noted with respect to the geomorphology analysis. One caveat is the need to distinguish the geomorphic effects caused by peaking flows versus larger peak flows (that is, flood flows in excess of peaking flows) that would occur with or without peaking. The other caveat is to recognize that smaller particle sizes, such as gravel, are currently lacking in the peaking reach. However, information obtained from the geomorphology analysis, particularly

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bedload sampling and bed mobility analysis, allows the geomorphologists to estimate the effects caused by peaking flows versus larger peak flows, and also estimate the effects of peaking if gravel was more abundant.

To assess whether systematic changes in channel morphology have occurred in the J.C. Boyle peaking reach from flow fluctuations, available historical aerial photography was compiled and examined. Several sets of aerial photos were obtained at various scales that cover the J.C. Boyle peaking reach, including those for the years 1955, 1965, 1968, 1979, 1980, 1986, 1988, 1993, 1994, and 2000. The photos were examined to determine whether large changes in channel form and/or riparian vegetation distribution were evident. Preliminary review of historical aerial photographs for the J.C. Boyle peaking reach showed minor changes in channel form over the period with available air photographs, but some localized changes to channel features are evident.

The presence and fate of suitable substrate (i.e., gravels) for trout spawning is a particularly important link between potential flow-related geomorphic effects and fish production in the J.C. Boyle peaking reach. A sediment budget for the Project area is estimated using the various field measurements and observations, along with the insights gleaned from the aerial photograph analyses, sediment sampling, tracer gravel studies, and reservoir sedimentation studies (Section 6.0 of the Water Resources FTR). This sediment budget describes sediment production and routing through reservoirs and river reaches in the Project area, and provides a framework to describe the relative importance of various sediment sources (both coarse and fine).

The sediment budget is constructed for discrete “cells” along the length of the river, with boundaries corresponding to primary sediment traps (project reservoirs) and other important changes, using the basic sediment budget equation of:

$$I +/- dS = O$$

where I is input, dS is change in storage, and O is output.

For each cell, inputs are defined as sediment carried from upstream in the river, sediment added from tributaries, and sediment directly contributed from slopes. Changes in storage are primarily reservoir sedimentation, bank erosion or deposition, and inferred aggradation/degradation. Outputs are sediment transported downstream from the cell on site. Where possible, the values are based on quantitative measurements on site. In many cases, however, values were extrapolated from measured rates in nearby basins or in similar settings elsewhere, or based on other available data and information to estimate the magnitude of the sediment budget components.

For channel morphology or sediment transport/storage changes that are evident, Project geomorphologists identify specific locations of the changes and judge the approximate time and flow conditions related to the change. The contribution to, and effect of Project operations on such flow conditions is described. Project biologists are identifying mesohabitats at specific locations of the changes to help determine likely effects of these changes on mesohabitat use by species and life stages using inference from the findings of on-site fisheries studies, review of research literature findings, or results of PHABSIM simulations (which can be examined by mesohabitat type) for the J.C. Boyle peaking reach.

Riparian Vegetation

The effects of flow fluctuations on riparian vegetation in the J.C. Boyle peaking reach are described using the results of a study relating riparian vegetation composition to flow inundation frequency and duration (see Section 3.0 of the Terrestrial Resources FTR). Sixteen cross-sectional sampling sites have been sampled in the J.C. Boyle peaking reach, stratified by geomorphic reach and, wherever possible, coordinated with PHABSIM and geomorphology study sites. Transects were positioned perpendicular to the flow of the river or reservoir shoreline and starting at a depth in the channel sufficient to capture the low elevation edge of the submerged and emergent vegetation or unvegetated shoreline habitat and spanning the full width of the riparian/wetland vegetation and draw-down zone to the upland-riparian ecotone.

During the summer of 2002, Project plant ecologists sampled vegetation along each transect in plots placed every other meter along the transect. The species plot data were subjected to two-way indicator species analysis (TWINSPAN) (Hill, 1979a). TWINSPAN was used to cluster the plots into species assemblages using plant species abundance data. Detrended Correspondence Analysis (DCA) is used to show the distribution of plots among community types developed from the TWINSPAN analysis (Hill, 1979b; Auble et al. 1994).

Stage-discharge relationships were developed for each sampling site (for example, using PHABSIM modeling analysis) to predict water surface elevations for any discharge. By establishing the stage discharge relationship, the flow required to inundate vegetation plots are predicted. Flow gauge data during the vegetation growing season (approximately April-October) are analyzed to produce plot-level estimations of inundation duration and inundation frequency. To describe the relationship between Project flow patterns and riparian/wetland vegetation patterns, an indirect gradient analysis is used to investigate the extent to which inundation duration and inundation frequency are explanatory variables for the distribution of riparian species assemblages.

The analysis provides correlations relating riparian vegetation composition to flow fluctuations in the J.C. Boyle peaking reach, including for key focal vegetation types (e.g., willow, emergent grasses) that are thought to be important as cover for juvenile trout in the Klamath River. Using these correlations, flows that are being considered for protection or enhancement of fish habitat also are being assessed as to their potential effects on riparian vegetation composition. Once the effects of flow conditions on riparian vegetation composition are described, Project biologists will relate these conditions to fish habitat suitability and use by inference from Habitat Suitability Criteria (HSC) (used as part of PHABSIM simulations) that include vegetative cover components.

Fish Habitat

The effects of flow fluctuations on fish habitat quality and quantity are being assessed based on wetted perimeter calculations and PHABSIM simulations. The physical extent of streambed habitat affected by flow fluctuations will be determined by quantifying the amount of streambed that is watered and dewatered during flow fluctuations (see Section 6.0 of the Fish Resources FTR). Quantification of this varial zone among different increments of flow will be based on the stage-discharge relationships and cross sections surveyed as part of the instream flow study (see

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Section 4.0 of the Fish Resources FTR). A total of 71 cross sections are available for analysis in the peaking reach. Standard output of the hydraulic model used in PHABSIM includes wetted perimeter as a function of flow at each cross section. Wetted perimeter versus discharge data will be derived according to methods described in the preceding section, Hydrology and Physical Changes.

EDT modeling is being performed as part of study 1.10, Fish Passage Planning and Evaluation (see Section 7.0 of the Fish Resources FTR). The EDT model evaluates 19 different habitat attributes (that encompass flow, geomorphology, water quality, physical habitat, and fish behavior categories) that are defined in terms of 45 measurable environmental attributes. EDT uses species-specific algorithms to relate the condition of environmental attributes to survival, capacity, and life history diversity of fish populations[2].

EDT estimates both “patient” and “template” conditions, which correspond respectively to existing and historic conditions. These two conditions are used to benchmark estimates of other management alternatives (fish passage options include the KlamRAS model) that are being or will be considered. For the existing (“patient”) condition, the EDT model is configured to capture peaking flow effects through two of the model’s parameters: interannual flow variation and diel flow variation. As such, the results of the EDT analyses, specifically related to the J.C. Boyle peaking reach, are being used as an additional source of information for assessing the effects of peaking. However, as a steady-state model, EDT is not considered an appropriate tool for assessing subtle, incremental variations in peaking operations.

Fish Movement/Migration

Information from radiotelemetry tagging of adult trout in the J.C. Boyle peaking reach (see Section 5.0 of the Fish Resources FTR) are used to assess adult trout movement and migration throughout the J.C. Boyle peaking reach, and the potential effects of flow changes on such movements. This tagging study describes movement under current project operations, including peaking.

The initial monitoring period was from early February to mid May 2003, the general timeframe for trout migration and spawning. Radio-tagged adult trout were monitored via three stationary receivers and mobile surveys. For the second monitoring period from June to end of August 2003, only mobile monitoring was used to track the fish. Radio-tagged fish were monitored 2-3 days/week during this period.

Test fish were collected at two locations within the peaking reach: (1) above and below the Shovel Creek confluence; and (2) near the BLM Spring Island Access Point. Test fish also were collected below J.C. Boyle dam in the bypass reach. Three separate groups of fish from the three capture locations were tagged. Each group consisted of 14 adult trout. Fish were tagged with small surgically implanted digitally-encoded transmitters.

[2] EDT is currently focused mainly on evaluation of salmon and steelhead populations. However, for purposes of this analysis, it is assumed that results from analysis of anadromous salmon and steelhead can be used as reasonable surrogates for similar life stages of resident salmonids.

Mobile surveys of the study area including Shovel Creek were conducted using a vehicle equipped with a three-element Yagi antenna. For the initial study period, these surveys occurred on a daily basis (excluding weekends). For the summer monitoring period, surveys occurred about 2 to 3 days/week. The general location of radio-tagged fish was ascertained by traveling access roads along the river. After detection, the specific locations of tagged adult trout were identified using triangulation techniques. These locations were recorded, and used to aid in the identification of areas of spawning and holding.

Radio telemetry is a tool that can document movement of tagged adult trout. In this study, tracking the fish described when, where, and how long an individual fish is at a location. The difficulty comes in interpreting definitive results from behavior characteristics like migration, delay, and in this case, what movement behavior defines spawning, and how these may be related to or affected by flow changes. The tracking data are presented in a manner that shows where fish were during the monitoring period; this data is compared with concomitant hydrograph and water temperature data for the J.C. Boyle peaking and bypass reaches. The movement of tagged fish through reaches is assessed in light of physical features (river gradient), Project operations (including flows), and biological and/or behavior causes (e.g., water temperature, flows, life history periodicity – spawning versus non-spawning periods, etc).

Information from trout fry (less than 5 cm FL) distribution and abundance studies in the J.C. Boyle peaking and bypass reaches (see Section 5.0 of the Fish Resources FTR) are used to assess fry longitudinal movement throughout the peaking reach, and to gain insights into the potential effects of flow fluctuations on fry rearing and movement. The primary objective of this proposed study was to assess the relative distribution and abundance of trout fry in the peaking and bypass reaches using a repeated series of electrofishing surveys at 26 index sites along the river.

Electrofishing surveys of fry were conducted twice per month in June (beginning the first week) and July 2003, with a single survey in mid-August. Fry surveys were not planned to occur after August because most YOY trout grow from the “fry” size-class into the “juvenile” size class, and they are expected to be more widely distributed throughout the reaches and in non-margin habitats (which are not accessible to electrofishing).

In the J.C. Boyle peaking reach, the repeated surveys were conducted under peaking flow operations in early-June, July, and August, whereas a steady flow (ca. 500 cfs) was sampled during mid-June when the J.C. Boyle powerhouse was receiving maintenance. In the J.C. Boyle bypass reach, the repeated surveys were conducted under a range in flows. Low flows (100 to 350 cfs) were sampled in early-June, July, and August, whereas higher flows (ca. 500 cfs) were sampled during the mid-June powerhouse maintenance.

Changes in the relative distribution and abundance of fry by sampling period and study site are evaluated graphically, or with a time-series or trend analysis, in order to identify obvious trends or patterns. Temporal and spatial changes in the relative distribution and abundance of fry provide insight into the timing of fry emergence and movement within the peaking reach. In particular, comparisons of changes in distribution and abundance between the peaking and bypass reaches provide insights on potential effects related specifically to flow, since the flow conditions in the two reaches differed during the study period.

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Fish Spawning/Incubation

Observations from previous studies (e.g., Beak 1993, Beyer 1984, City of Klamath Falls, 1986) have been reviewed to provide background information on the occurrence of spawning in the J.C. Boyle peaking reach (see Section 2.0 the Fish Resources FTR). There is apparently no (or a very small amount of) spawning habitat for trout in the peaking reach (City of Klamath Falls, 1986). Lack of gravel recruitment and accumulation in the reach are suspected limiting factors. Desjardins and Markle (1999) reported that use of the J.C. Boyle peaking reach (in this case to the Oregon/California state line) by the endangered Lost River and shortnose suckers likely is limited to the downstream emigration of juveniles and adults from upstream basin habitat, with no documented rearing or spawning by listed suckers in this reach. However, observations (by Beak in 1987, and USFWS and CDFG in 1989) of Lost River and Klamath smallscale suckers in the lower end of the reach near Copco reservoir during the last 2 weeks of April, suggest that sucker spawning may be occurring in the reach. Shovel Creek is known to be an important spawning tributary for redband/rainbow trout occurring in the J.C. Boyle peaking reach, especially for the California portion (Beyer, 1984).

The findings of the radiotelemetry tagging study (see Section 5.0, radiotelemetry analysis, of the Fish Resources FTR) and trout fry distribution and abundance studies (see Section 3.0 of the Fish Resources FTR) in the J.C. Boyle peaking and bypass reaches, as described above, also are being used to assess trout spawning in the J.C. Boyle peaking reach.

Fish Stranding

A general review of literature on the potential effects of the river flow fluctuations/peaking on fish was performed to provide background on the issue of ramping (see Section 6.0 of the Fish Resources FTR). Most available information is on salmonids, which are of primary concern in the J.C. Boyle peaking reach. Both anadromous salmonids and resident trout are emphasized in the review. Categories of effects include juvenile fish stranding and behavioral changes. Factors associated with stranding include channel configuration, species and life stages, timing (seasonal and diurnal), and rate of river stage reduction. Behavioral factors include spawning disruption, emigration/movement, age/size structure changes, growth, and condition factors.

Native fish species including redband/rainbow trout, suckers (all species), chubs, dace, lamprey, and sculpin are considered to the extent that information is available regarding ramping effects on these species. Each species' life stage timing and size are used to determine potential vulnerability to ramping operations in the J.C. Boyle peaking reach. Timing information was obtained from the Fish Periodicity table constructed by the AWG (see Table 2.7.3 of the Fish Resources FTR).

Observations for potential fish stranding in the J.C. Boyle peaking reach were conducted at two locations in Oregon (Frain Ranch) and three locations in California (see Section 6.0 of the Fish Resources FTR). These sites were selected for having high potential for fry stranding based on low beach gradient (less than two percent), depressions, and presence of both aquatic vegetation and submerged grasses at the high-flow end of the ramping event. These sites were selected following a review of maps, aerial photos, and a shore reconnaissance (in Oregon segment) and by raft (in California segment) under low flow conditions. The two Oregon sites include the large cobble/gravel bar immediately upstream of the Caldera Rapid (RM 214.3) and a point bar and side channel (RM 214.7). The sites in California include a side channel/island complex at RM 204.9, an island at RM 205.3, and a side bar/alcove at RM 205.6. Physical measurements (dimensions) of the varial zone were made at each site.

Observations were made in early June, July, and August, 2002 and in June, July, and August 2003 to coincide with potentially vulnerable juvenile fish life stages. Ramping on these dates typically (and generally throughout this period) consisted of up-ramping in the morning (at the powerhouse) and down-ramping in late afternoon through a flow range from approximately 1,500 cfs (one turbine unit) to 350 cfs. Ramping rates at the gauge just downstream of the powerhouse are about 0.7 feet/hour. Details of field observation methods are provided in Section 6.0 of the Fish Resources FTR.

Macroinvertebrate Production

The effects of flow fluctuations on macroinvertebrates in the J.C. Boyle peaking reach is being assessed based on:

- A review of pertinent research literature
- Wetted perimeter calculations
- Sampling of macroinvertebrate community composition (including drift)
- A comparative analysis of macroinvertebrate composition in the J.C. Boyle peaking reach with other non-peaking reaches in the Project area

Research literature on the effects of peaking and flow fluctuation on macroinvertebrates is being reviewed.

The physical extent of streambed macroinvertebrate habitat affected by flow fluctuations will be determined by quantifying the amount of streambed that is watered and dewatered during flow fluctuations (see Section 6.0 of the Fish Resources FTR). Macroinvertebrate production in the varial zone is low; therefore, the amount of dewatered area (varial zone) provides a conservative estimate of the loss of macroinvertebrate production that results from peaking. Quantification of this varial zone between different increments of flow is based on the stage-discharge relationships and cross sections surveyed as part of the instream flow study conducted in 2002 (see Section 4.0 of the Fish Resources FTR). A total of 71 cross sections is available for analysis in the peaking reach. Standard output of the hydraulic model used in PHABSIM includes wetted perimeter as a function of flow at each cross section. Wetted perimeter versus discharge data are derived according to methods described in the preceding section titled "Hydrology and Physical Changes."

The California Stream Bioassessment Procedure (CSBP) was used to evaluate macroinvertebrate community composition at 18 sampling sites in the J.C. Boyle peaking reach (see Sections 8.0 and 12.0 of the Water Resources FTR). The sampling sites were riffles within each of six subreaches. Sampling occurred along a transect across each chosen riffle. Collection of macroinvertebrates was done at three locations along the transect using a D-shaped kicknet (0.5-mm mesh), and sampling a 1- by 2-foot portion of substrate upstream of the kicknet to a depth of

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approximately 4 to 6 inches. Sampling occurred during Fall 2002 (see Section 8.0 of the Water Resources FTR) and again in Spring 2003 (see Section 12.0 of the Water Resources FTR).

Limited sampling of macroinvertebrate drift also was conducted. Drift samples were collected within the J.C. Boyle peaking reach at three zones within the channel: (1) constantly wetted margins during low flow; (2) wetted margins during high-flow operations; and (3) mid-channel or as close as possible to mid-channel. Drift samples were taken at steady-state low- and high-flow operations as well as during the up-ramping and down-ramping transitional periods. The low-flow sampling occurred in the morning prior to up-ramping as opposed to the evening following down-ramping.

The CSBP and California Lentic Bioassessment Procedure (CLBP) data analysis procedures are based on a multimetric approach to bioassessment data analysis. The taxonomic list and numbers of organisms reported for each sample was used to generate a table of sample values and means for several biological metrics in four categories: richness measures, composition measures, tolerance/intolerance measures, and functional feeding groups. The final choice of metrics and procedures used to compare sites was developed in consultation with the Water Quality Work Group. The data analysis includes cluster analysis groupings of similar sampling locations based on different types of metrics. Distinctive clustering of samples from the J.C. Boyle peaking reach will be used to assess potential flow fluctuation effects on the macroinvertebrate community.

Another aspect of varying flow fluctuations in the J.C. Boyle peaking reach is how they affect macroinvertebrates as a food source for trout. This aspect is being addressed by comparing trout length-at-age and condition factor (K) between the J.C. Boyle peaking reach and other non-peaking reaches (i.e., Keno reach, J.C. Boyle bypass reach) as an indicator of whether food availability is limiting the growth of trout in the peaking reach (see Section 3.0 of the Fish Resources FTR). Trout length-at-age and condition factor (K) also is compared between the J.C. Boyle peaking reach and literature-based values from other wild trout streams.

Scale samples have been collected from trout of various sizes from each of three reaches:

1. Keno dam to J.C. Boyle reservoir
2. J.C. Boyle bypass reach between J.C. Boyle dam and powerhouse
3. J.C. Boyle peaking reach between J.C. Boyle powerhouse and Copco reservoir

This resulted in a total of about 400 individual trout scale samples for all three reaches and sampling periods (spring, summer, and fall 2002). About 245 of these samples are being examined to determine the age of fish, and to estimate growth rates of trout in each reach using methods, including scale annulus identification and length-to-last annulus back-calculations, as outlined in Section 3.0 of the Fish Resources FTR.

Condition factor (K) and relative weight also are being calculated for each sampled trout. Condition factor is the length-weight relationship used to express relative plumpness or robustness of fish, and is assumed to be related to environmental conditions, including food and feeding. Condition factors are being calculated using the equation of Carlander (1969). Condition factor (K) information is provided in Section 3.0 of the Fish Resources FTR.

In addition to the above analysis, a bioenergetics analysis approach is being done for site-specific application to the J.C. Boyle peaking reach. Bioenergetics analysis is used to address the implications and interaction of temperature and food availability on trout growth. The analysis includes a foraging model to integrate flow, food, and temperature in order to predict the range of growth rates over the range of peaking versus stable daily flow scenarios.

Other Considerations

Although this study is focused on aquatic resources, the potential conflicts or opportunities posed by new or modified flow and ramping regimes are being identified to avoid or minimize potential impacts across all pertinent resource areas (e.g., aquatics, water quality, recreation, aesthetics), as well as power production. Using this information, PacifiCorp will propose new or modified flow regimes that integrate flow needs across resources. The general approach to this integration was presented by PacifiCorp to the Plenary Group in November 2002, and to the AWG Instream Flow Analysis Subgroup in June 2003.

10.5 RELATIONSHIP TO REGULATORY REQUIREMENTS AND PLANS

This study, which integrates the results of several other studies associated with the operation of the J.C. Boyle powerhouse, helps PacifiCorp address FERC requirements (18 CFR 4.51 and 16.8) for information on potential effects of Project operations on fish and other aquatic resources. The information is being used to assess current effects as well as to formulate recommendations for changing ramping regimes, as necessary, in the J.C. Boyle peaking reach. Such recommendations will be consistent with the various resource agency and tribal management goals for protection and enhancement of fish and other aquatic resources. As outlined in the FSCD, the following management plans contain references to objectives for fisheries:

- CDFG Upper Klamath Wild Trout Management Plan
- ODFW Klamath River Basin Fish Management Plan
- U.S. Fish and Wildlife Service (USFWS) and NMFS Endangered Species Act requirements
- Klamath River Wild and Scenic River Plan
- U.S. Forest Service Klamath River Restoration Plan

While none of these plans contains specific objectives dealing directly with hydro-peaking in the Klamath River, they do state objectives directed toward the maintenance, protection, and/or enhancement of fish resources in the river. Clearly, Project-induced flow fluctuations have the potential to affect these resources. The results of the studies are being used to determine whether and where current Project operations are consistent with these management objectives, and if they are not, what changes to Project operations are needed to meet these objectives.

10.6 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

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technical working groups. As part of this structure, an 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.

10.7 RESULTS AND DISCUSSION

This evaluation of flow fluctuation effects on aquatic resources in the J.C. Boyle peaking reach integrates the findings of various other studies, most of which have just recently been completed and documented in the final technical reports referenced in the methods above. The instream flow analysis, including a bioenergetics fish model, is ongoing. Also, the EDT fish production modeling, which may provide some valuable insight to the peaking analysis, will continue to be used as a tool to assess effects of habitat quality conditions on fish production potential. Although these ongoing modeling efforts may produce some useful information, most of the other information identified in the methods above will be integrated and summarized by end of April 2004 for distribution to FERC and the AWG.