7.0 MONITORING AND ANALYSIS OF WATER QUALITY DURING PROJECT MAINTENANCE OPERATIONS

7.1 DESCRIPTION AND PURPOSE

Routine maintenance activities are a controllable aspect of Project operations that could affect water quality in the Project area. Depending on the type of maintenance required, Project operations can be disrupted to accommodate the necessary activity. Maintenance on Project waterways (e.g., canals) and powerhouses usually requires rerouting water at the diversion dams back to the river channel, typically resulting in spill at the dam. PacifiCorp conducted water quality sampling during maintenance events to determine the specific effects that these maintenance activities may have on water quality in the Project area. The information from this sampling and analysis will allow PacifiCorp to identify whether, where, and when maintenance activities affect water quality, and to further identify appropriate measures to protect water quality.

Additional components of this report include a discussion of the J.C. Boyle emergency spillway and Project-related roadways and culverts, specifically their contribution to sediment loading in the Klamath River and tributaries. Roadway and culvert information is provided in section 7.7.7, while a discussion of the emergency spillway is included in sections 7.7.3 and 7.9.1.

7.2 OBJECTIVES

The objectives and key questions to be addressed in this study are as follows:

- What are the characteristics of water quality conditions during routine Project maintenance activities?
- Monitor total dissolved gas during surface water spill from Project reservoirs.
- Document protocols used to avoid and minimize emergency spillway events, and identify potential practices to protect water quality if and when such events occur.
- What are the specific effects that maintenance activities may have on water quality in the Project area?
- Inspect and maintain Project roads and culverts to address potential erosion conditions as they relate to water quality.
- Support subsequent assessment (together with other studies and during license application preparation) of the Project's potential effects on water quality and of possible PM&E measures where necessary.

7.3 RELICENSING RELEVANCE AND USE IN DECISIONMAKING

The results of this task will be used to determine the magnitude and duration of potential water quality effects stemming from Project maintenance activities. The information will also be used to characterize potential effects from maintenance activities and develop any needed PM&E

measures. These data will also be included in PacifiCorp's 401 Application in Oregon and California.

7.4 METHODS AND GEOGRAPHIC SCOPE

In 2002, PacifiCorp monitored water quality during annual maintenance events. Additional monitoring occurred in June 2003, for a maintenance event at the J.C. Boyle canal. Water quality parameters evaluated during these activities included DO, temperature, pH, turbidity, conductivity, and total dissolved gas (TDG). Maintenance studies have been performed on the Link River, Copco No. 2 bypass reach, the J.C. Boyle bypass and peaking reaches, and mainstem Klamath River below Iron Gate dam.

Monitoring consisted of deployment of multiparameter probes (either YSI 6920© or Hydrolab©) prior to maintenance activities to establish baseline conditions. Following the initiation of the maintenance activity, data collection continued to capture any change in the selected parameters. Additional spot checks with a multiparameter water quality probe were taken to cross-check the data from the deployed instruments and to provide data if equipment malfunctions occurred. The logging equipment was set to record data at intervals of 1 hour or less, depending on the scope of the maintenance event. Spot TDG measurements were taken at J.C. Boyle, Iron Gate, Link River, and Copco No. 2 dams. All graphical data provided in this report are presented in hourly increments, with the corresponding dates of the monitoring described in the text.

All water quality testing equipment was calibrated to manufacturers' specifications prior to deployment. In-situ calibration for DO was performed to correct for local barometric pressure. Following data collection and download, postcalibration was done to determine the reliability of the data and to identify if "drift" in parameter values occurred. Failure to calibrate or post-calibrate, or data "drift" occurrences, reduces the ability to perform data analysis. Drift can be caused by gradual buildup of organic materials on the probe sensors, causing a steady increase/ decrease in parameter values. In some cases, these failures preclude any statistical interpretation and result in data that can only be used to identify trends. Even with these QA/QC procedures, equipment failure, calibration issues (pre and post), and field conditions can result in data that are lacking in comparative value.

PacifiCorp inventoried and assessed road and culvert conditions extending from Link River dam to Iron Gate dam within the FERC Project boundary. Additional road condition data have been supplied by BLM for the J.C. Boyle peaking reach, although culverts are not included in the data set. The area of effect used in assessing potential sedimentation impacts of Project roads and culverts on water quality contained in this report is defined geographically as ¼ mile from Project waterways, including canals, riverine habitat, and reservoir habitat.

7.5 RELATIONSHIP TO REGULATION REQUIREMENTS AND PLANS

This study provides information relevant to assessing potential changes in water quality resulting from Project maintenance activities. The study will assist PacifiCorp in addressing state and federal management goals and objectives as they relate to water quality. This document will also provide partial elements necessary to assess the Project's compliance under the Clean Water Act. Ultimately, PMEs will be developed based on this report to minimize impacts that may result from Project maintenance events.

7.6 TECHNICAL WORK GROUP COLLABORATION

A Water Quality Work Group, developed as part of PacifiCorp's relicensing process, convened monthly to develop the study plan. This group consisted of state agencies from Oregon and California, federal agencies and tribes, and nongovernmental organizations. Revisions to the study plan were the result of the collaborative process within the work group that lead to an approved final study plan.

7.7 BACKGROUND AND FACILITY REVIEW

Maintenance activities may require dewatering of the water conveyance system and rerouting the flows through the adjacent bypass reaches. The magnitude and frequency of these events and their potential impacts to aquatic habitat vary by individual project, by specific bypass reach geomorphology, and by hydrological conditions at the time of maintenance. Potential effects on water quality may affect biota inhabiting these reaches. Abrupt changes in flows associated with maintenance activities potentially may alter physical and chemical properties of the water in these bypass reaches. Fish salvage occurs at the diversion canals during dewatering events because of potential stranding.

Flow scenarios during maintenance events are directly related to the configuration of the intake structures and powerhouses. In some cases, these activities directly affect lotic habitat in the Klamath River; in other cases, no impacts to riverine habitat occur. The facilities and maintenance scenarios that occur with each facility are described in the following subsections. Facilities described in this study are presented in a downstream progression starting at Link River.

Water quality entering the Project area is dominated by the hypereutrophic conditions found in Upper Klamath Lake and Lake Ewauna (including Keno reservoir). Algal blooms, warm ambient summer temperatures, and shallow water depths contribute to pronounced diel fluctuations in water quality, including pH, temperature, and DO. Turbidity levels are naturally elevated as a result of these conditions, with the highest quality water found in areas of substantial spring accretions.

7.7.1 Link River (East Side and West Side Facilities)

The East Side and West Side power facilities represent PacifiCorp's upstream extent of the Project. Water from Upper Klamath Lake is diverted at USBR's Link River dam and bypassed through two separate canals. The East Side and West Side canal capacities are 1,200 and 250 cfs, respectively. The affected Link River reach measures 6,340 feet, which includes the distance of both channels around the island downstream of the diversion to the powerhouses.

The minimum flow at the Link River dam for much of the year is 90 cfs (per ODFW and FERC license), but it increases to 250 cfs in the summer (per 2001 Biological Opinion). Dates for this increased instream flow are from July 27 to October 17, corresponding to the time of year when, typically, water quality exiting Upper Klamath Lake is of poor quality (USFWS, 2001). Ramp rates at Link River dam were established in consultation with ODFW in 1987 and were subsequently adopted in the 1996 Biological Opinion. The ramp rates are:

- 50 cfs per 30 minutes at flows of 300 to 500 cfs
- 100 cfs per 30 minutes at flows of 500 to 1,500 cfs
- 20 cfs per 5 minutes at flows of zero to 300 cfs (minimum flow is 250 cfs in summer)

These rates of flow change per hour equate to approximately 2 inches per hour at the Link River USGS gauge (No. 11507500).

7.7.2 Keno

Keno dam was built to maintain the reservoir elevation in Keno reservoir, and there are no power generation facilities associated with this structure. Therefore, routine maintenance that would cause flow fluctuation is not required.

7.7.3 J.C. Boyle

Annual maintenance at this facility typically occurs in the fall following the whitewater recreation season. Outages of each of the two turbines are done separately to allow for power generation to continue at one unit while the other is being serviced. PacifiCorp typically dewaters and conducts maintenance on the canal every year. The canal is just over 2 miles long and was built alongside a high cliff wall. The annual maintenance event enables the company to inspect and repair equipment associated with the canal operations and to remove debris that has fallen off the cliff and accumulated on the floor of the canal. To bring machinery into the canal, the canal must be dewatered and the canal headgates secured. Fish salvage is performed when the canal is dewatered. During maintenance, the FERC-mandated ramp rate of 9 inches per hour is followed.

An emergency spillway is located at the end of the J.C. Boyle power canal at the entrance to the powerhouse forebay. Spillway use is initiated during forced outages when diversion flows exceed single turbine capacity. Flows less than 1,700 cfs can be interrupted without the use of the spillway, thus not affecting water quality in the J.C. Boyle bypass reach. Spillway use results in a temporary release of water from the J.C. Boyle forebay into the corresponding bypass reach. A spillway sluice transports water down an eroded bank entering on the north bank of the J.C. Boyle bypass reach.

7.7.4 Copco No. 1

The Copco No. 1 dam and powerhouse at (RM 198) are located approximately 1 mile upstream of the Copco No. 2 diversion. Water from Copco reservoir is diverted into the Copco No.1 powerhouse and is discharged immediately below the dam into the Copco No. 2 forebay. No bypass reach is associated with this facility. Maintenance at this powerhouse may affect areas immediately below the dam in the Copco No. 2 forebay, but no direct impacts to riverine habitat occur.

7.7.5 Copco No. 2

Water from the Copco No. 2 forebay is diverted to the Copco No. 2 powerhouse, which discharges directly into Iron Gate reservoir. This facility has an associated bypass reach length of

1.4 miles. Maintenance at this facility requires spilling into the bypass reach at the Copco No. 2 dam spillway, potentially affecting water quality in the 1.4-mile bypass reach that terminates at Iron Gate reservoir.

Maintenance activities at the Copco No. 2 facility may require canal headgate closure and spill into the associated bypass reach. Copco No. 2 forebay drawdown occurs as needed, depending on the maintenance activity that is required. Flows supplied to the bypass reach under normal operations at the Copco No. 2 diversion are derived from leakage of the spill gates. Flows may fluctuate rapidly during maintenance activities. The area affected during maintenance at Copco No. 2 includes the Copco No. 2 bypass reach and the associated forebay.

7.7.6 Iron Gate Dam

Maintenance at this facility usually consists of one annual outage, generally lasting 2 weeks. This work is performed in late spring when river levels are 2,000 cfs or less. Spill is passed over the dam since this structure has no spill gates. The timing of this event occurs prior to the formation of a thermocline in Iron Gate reservoir and prevents increasing water temperature below the dam from thermally heated surface waters typical of summer months.

The retention time estimate for water conveyance through Iron Gate reservoir is 3 to16 days (dependent on inflow/outflow). At the Iron Gate powerhouse, maintenance that requires the shut-down of the turbines causes water normally diverted from the reservoir to the powerhouse to be spilled directly at the Iron Gate dam spillway. There is no bypass reach associated with this powerhouse; water diverted from the reservoir is immediately discharged downstream of the stilling basin.

FERC-stipulated minimum flow requirements below Iron Gate dam are 1,300 cfs from September through April, 1,000 cfs in May and August, and 710 cfs in June and July. Since 1996, however, PacifiCorp has operated to provide instream flow releases dictated by USBR's annual Project Operations Plans. USBR's consultation with USFWS and NOAA Fisheries on the plans resulted in Biological Opinions that specifically defined Upper Klamath Lake elevations and Klamath River flows downstream of Iron Gate dam needed to protect ESA-listed species.

Ramp rates for Iron Gate dam are stipulated in the current license. However, the ramp rates outlined in recent NOAA Fisheries Biological Opinions are more restrictive. These ramp rates are:

- 50 cfs per 2-hour period when the facility is not spilling (< 1,750 cfs). In addition, flows cannot be reduced more than 150 cfs per 24 hours.

- 125 cfs per 4-hour period when the facility is spilling (> 1,750 cfs). In addition, flows cannot be reduced more than 300 cfs per 24 hours.

These ramp rates equate to a stage decrease of approximately 0.4 inch per hour at the Iron Gate USGS gauge (No. 11516530).

7.7.7 Project Roads and Culverts

To effectively operate and maintain Project facilities and lands, PacifiCorp maintains a system of access roads and associated culverts. The public uses much of this road system for access to reservoirs and other lands dedicated by PacifiCorp for public use. A small amount of unauthorized off-road vehicle use has resulted in rutted 4x4 roads and trails. These roads, as well as general sedimentation potential from culverts, are a source of potential land management and water quality concern.

The access or road system associated with the Project and the corresponding operational and public use have the potential to affect water quality to the detriment of fish and wildlife resources. The purpose of evaluating this information is to identify areas that pose potential risks to water quality, thus providing a basis for PM&E measures to alleviate potential impacts. Resources used for this assessment include the Land Use, Visual, and Aesthetic Resources Final Technical Report, which includes the road inventory of the Project area (PacifiCorp, 2003a), the Wildlife and Botanical Resources Document (Exhibit E) of the Draft License Application (PacifiCorp, 2003a), and additional road inventory data supplied by BLM.

7.8 RESULTS

In 2002, PacifiCorp monitored water quality during maintenance work at the Link River, J.C. Boyle, and Iron Gate facilities. Additional water quality monitoring was performed in 2003 during a maintenance event at the J.C. Boyle facility. The results of this monitoring are presented separately for each facility. An attempt was made to monitor maintenance at Copco No. 2, but equipment failures resulted in unreliable data.

7.8.1 Link River (East Side Maintenance)

Maintenance at the East Side facility, requiring spill in the Link River bypass reach, was initiated at 6:00 a.m. on May 9 and continued through May 22, 2002. Two YSI 6920 multiparameter sondes were deployed: one located approximately 200 feet below the Link River dam in the bypass reach (LINKT), and one below the East Side powerhouse in the peaking reach (LINKB). Probe deployment and subsequent data collection were initiated at 11:00 a.m. on May 8 to capture water quality conditions prior to maintenance.

Diel fluctuations in water quality parameters are a common occurrence in the Klamath River. These fluctuations are apparent in the DO, pH, and temperature background data collected during this event. Maintenance at this facility caused variations in the typical diel pattern, although an increase in turbidity unrelated to diel fluctuations occurred. Biofouling on the upstream probe (LINKT) caused the pH and DO measurements to drift. The temperature values recorded at this site may have also been affected. A total of 126 hourly measurements were recorded at the upper site (LINKT), and 334 measurements were recorded at the lower site (LINKB). The lower probe remained deployed below the East Side powerhouse in an attempt to capture water quality data during unit startup and operation following the termination of the maintenance event. Unfortunately, startup of the unit was delayed until May 23, 2002, after the lower probe had been removed.

Prior to the maintenance event, the upper probe (LINKT) had a range of 11.9 to 13.3°C, with a mean of 12.8°C. The probe deployed below the East Side powerhouse (LINKB) had a background range of 11.4 to 12.7°C, with a mean value of 12.3°C (Table 7.8-1). Following the initiation of spill at 6:00 a.m. on May 9, 2002, the range of temperature at both sites increased slightly (Figure 7.8-1). During the first day of the spill event at this location, daily maximum temperatures were not affected at either sampling location. However, approximately 24 hours after the project started to spill, temperatures began to increase rapidly, with a maximum temperature of 21.8°C (Figure 7.8-1). The reasons for this occurrence are not clear, but it was probably caused by biofouling since the lower probe did not display a similar increasing temperature trend from Klamath Lake outflow.

pH remained relatively stable at both sites at the beginning of the maintenance event. Average pH measured at the upper probe was 8.5 for background levels and 8.2 following maintenance (Table 7.8-1). Although the upper probe displayed a slight decrease in pH from background levels, the lower probe showed a minor increase in average pH measurements from 8.3 to 8.5. Parameter drift appears to have occurred to the upper probe, causing a steady decline in pH starting at 11:00 a.m. on May 11 (Figure 7.8-2).

Turbidity values indicated an increase in NTUs following the spill release at Link River dam (Figure 7.8-3). Prior to spill initiation, background turbidity levels ranged from 9 to 20 NTUs, with 9 and 13 NTUs for the upper (LINKT) and lower (LINKB) probes, respectively (Table 7.8-1). Maintenance caused an increase in the range of values at both sites, with the upper probe increasing in range from 2 to 280 NTUs , and the lower probe increasing from 10 to 122 NTUs. The upper probe displayed the most apparent increase in turbidity levels. Turbidity increased beyond the background mean at this site (12 NTUs) for a period of 27 hours before the recorded probe values began to drift. Turbidity peaked at 280 NTUs at this site although the average turbidity value during this 27-hour increase was 54 NTUs. Turbidity recorded at the lower site showed an apparent increase in turbidity directly related to the spill event that occurred at 6:00 a.m. on May 9. Average turbidity increased at the lower probe site, although the average increase was minor, changing from 10 to 15 NTUs (Table 7.8-1). Most increases were single spike readings that might have been caused by biofouling (Figure 7.8-3).

At the start of maintenance, there was an immediate decrease in DO at the lower probe (LINKB) and an increase at the upper probe (LINKT). Again, as with the other parameters measured at the upper location, a decreasing trend in values (drift) was apparent, starting on May 11, 2002, at 11:00 a.m. (Figure 7.8-4).

TDG measurements were taken below Link River dam before and during the planned spill event. Percent saturation differed by only 3 percent between minimal (90 cfs) and maintenance spill. Readings were 99 and 102 percent for the minimal and full spill releases, respectively.

Postcalibration of the lower probe deployed below the East Side powerhouse showed a DO level that was out of acceptable range. Although the DO concentrations appear to be acceptable based on the data collected, biofouling may have occurred prior to probe retrieval, thereby affecting the postcalibration readings. Data collected from the upper probe displayed parameter drift, particularly after May 11, 2002.

Table 7.8-1. Summary of water quality monitoring at Link River on May 8-22, 2002, during canal maintenance.

		Temperature (°C)		DO (mg/L)		pH		Turbidity (NTU)	
		Back-ground	Main-tenance[1]	Back-ground	Main-tenance[1]	Back-ground	Main-tenance[1]	Back-ground	Main-tenance
LINKT	Min.	11.9	7.7	12.2	8.7	8.3	7.6	9	2.
	Max.	13.4	21.9	12.3	13.1	8.5	8.6	20	280
	Mean	12.9	14.3	12.2	11.5	8.5	8.2	12	18
LINKB	Min.	11.4	10.8	11.6	11.2	8.3	8.1	9	11
	Max.	12.7	15.7	12.4	12.9	8.4	8.8	13	122
	Mean	12.3	12.9	12.2	11.9	8.3	8.5	10	15

[1]For site LINKT, only the first 24 hours of data after maintenance was used since the probe experienced parameter drift

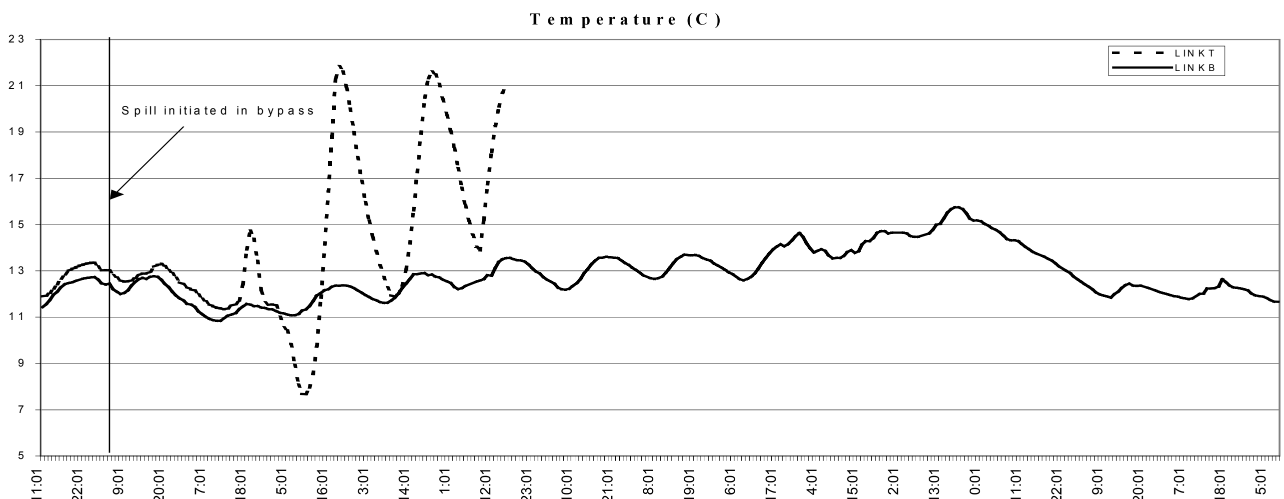

Figure 7.8-1. Temperature monitoring at Link River, May 8-22, 2002, during canal maintenance.

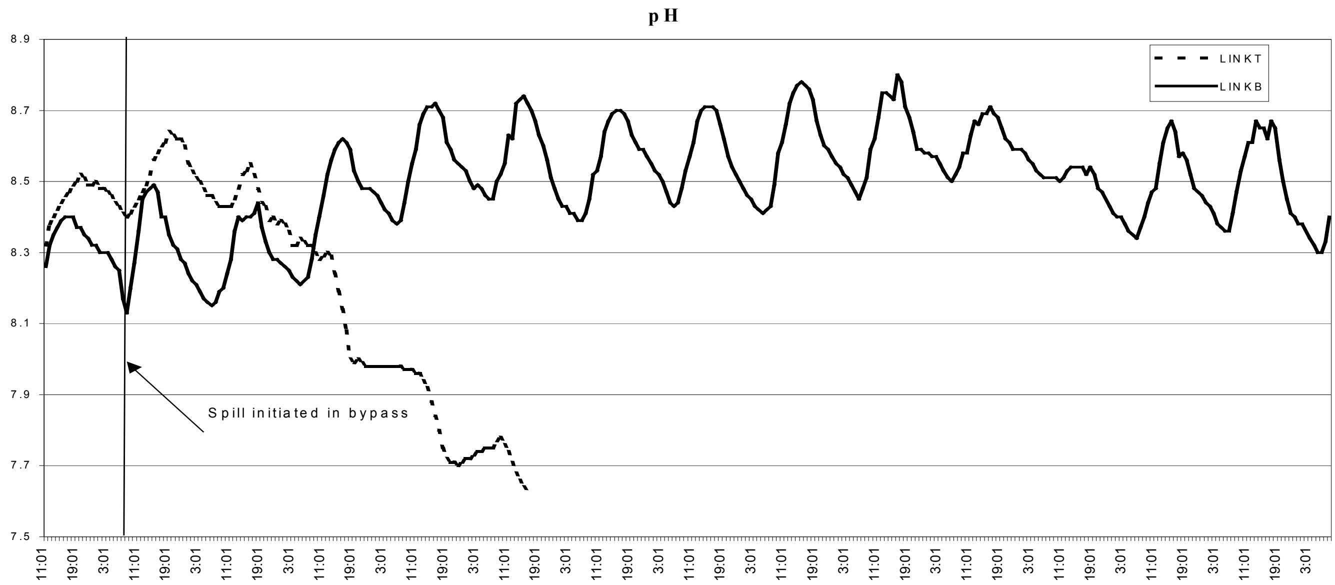

Figure 7.8-2. pH monitoring at Link River, May 8-22, 2002, during canal maintenance.

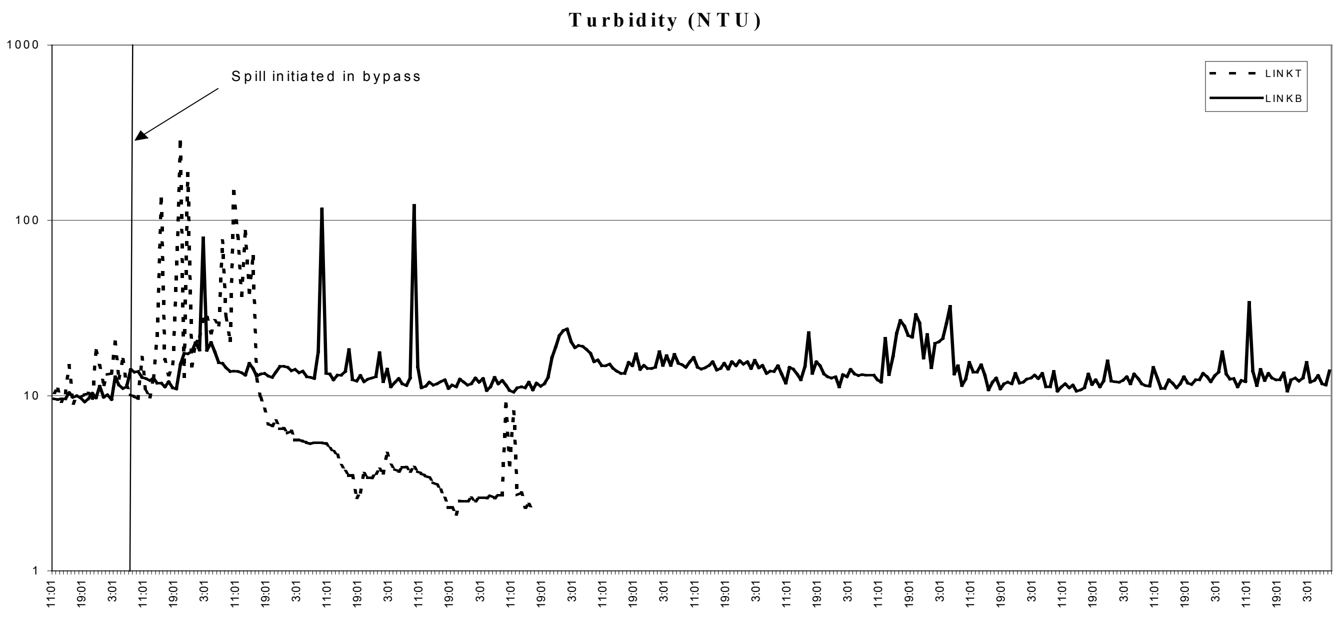

Figure 7.8-3. Turbidity monitoring at Link River, May 8-22, 2002, during canal maintenance.

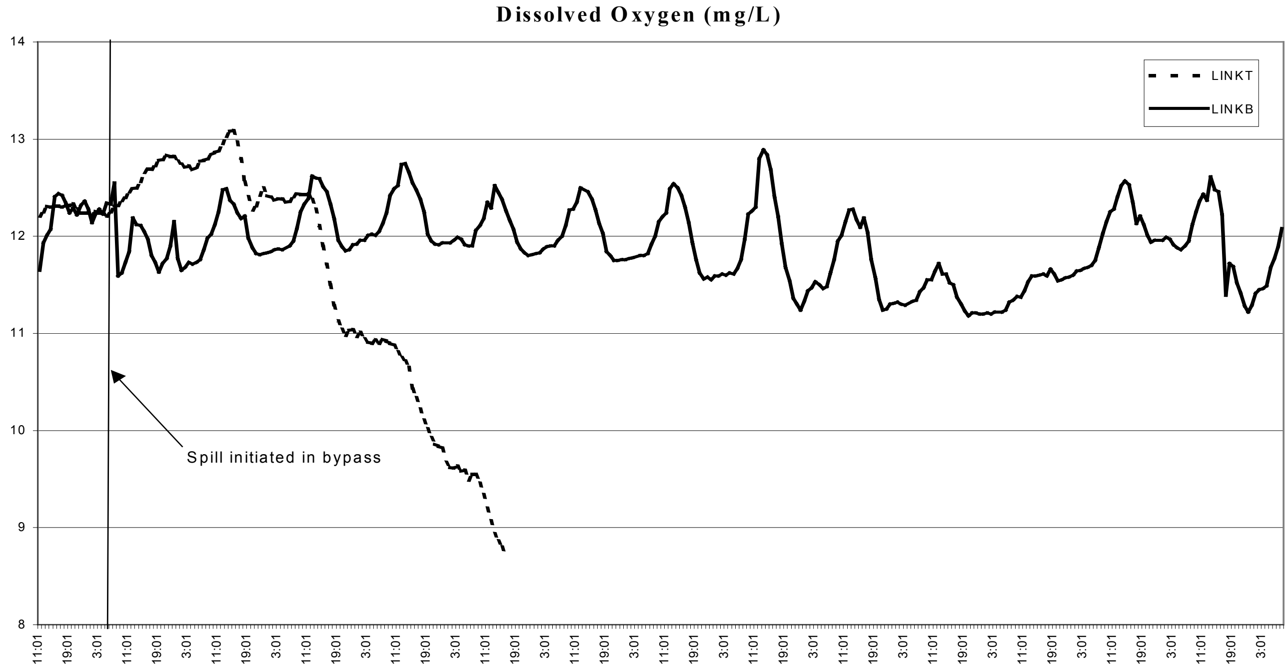

Figure 7.8-4. DO monitoring at Link River, May 8-22, 2002, during canal maintenance.

7.8.2 J.C. Boyle 2002 Maintenance

On September 11, 2002, four data sondes were deployed in locations in the J.C. Boyle bypass reach and the peaking reach to capture changes in water quality that occurred as the result of scheduled canal maintenance. These locations were as follows:

- Upper section of J.C. Boyle bypass reach (UJCB)
- Bottom of the J.C. Boyle bypass reach above the powerhouse (BJCB)
- J.C. Boyle peaking reach at the BLM boat launch (JCBP@BLM)
- J.C. Boyle peaking reach above Shovel Creek (JCBP@shovel).

The probe deployed at the BLM boat launch below the J.C. Boyle powerhouse (JCBP@BLM) incurred biofouling, preventing the use of this site for data analysis. A total of 188, 190, and 217 hourly measurements were recorded at UJCB, BJCB, and JCBP@shovel, respectively.

Data were recorded September 12-20, 2002. A total of 93 hours of background data were collected prior to the maintenance event. Additional QA/QC checks were performed that included winkler titrations (for DO) and equipment cleaning to prevent biofouling. Although equipment maintenance was done, biofouling occurred on some of the units, resulting in unreliable data for some parameters at some sites (e.g., the BLM boat launch site). During the J.C. Boyle maintenance, only temperature, DO (percent saturation), pH, and turbidity were evaluated. A calibration error for specific conductance occurred and was not identified until after data collection was completed. Because specific conductance calibration is a key component in the measurement of mg/L of DO in a YSI 6920 sonde, abnormal readings of DO in mg/L occurred, and only percent saturation was used for analysis.

Canal maintenance activities were used in PacifiCorp's recreational studies to provide various flows in the J.C. Boyle bypass reach. Flow remained stable in the bypass reach from September 12 through September 15. At 9:00 a.m. on September 16, spill into the J.C. Boyle bypass reach was increased, reaching a peak of 975 cfs at 1:00 p.m. for a period of 5 hours. Following the peak, flows were brought down to nonspill releases, increasing again the following day to 1,250 cfs at 11:00 a.m. for a period of 3 hours. Spill was reduced to 400 cfs at 2:00 p.m. that same day and remained constant for the remainder of the study (see Figure 7.8-9). Table 7.8-2 summarizes the water quality data collected during the canal maintenance on September 12-15, 2002.

Table 7.8-2. Summary of water quality monitoring in the J.C. Boyle bypass and peaking reaches on September 12-15, 2002, during canal maintenance.

		Temperature (°C)		DO (% Saturation)		pH		Turbidity (NTU)	
		Back-ground	Main-tenance	Back-ground	Main-tenance*	Back-ground	Main-tenance	Back-ground	Main-tenance
UJCB	Min.	17.1	16.6	92.9	NA	8.3	8.3	4	5
	Max.	18.8	17.8	101.5	NA	9.0	8.8	35	22
	Mean	17.6	17.3	96.6	NA	8.6	8.5	7	12
BJCB	Min.	12.2	12.4	88.9	90.9	7.9	8.0	1	2
	Max.	14.1	16.2	100.0	98.2	8.4	8.3	7	27
	Mean	13.0	14.7	92.3	93.4	8.1	8.1	2	6
JCBP@ shovel	Min.	14.0	14.0	86.5	85.5	7.6	7.7	1	2
	Max.	18.5	17.0	104.4	100.1	9.0	8.0	7	8
	Mean	16.2	15.4	92.1	89.6	7.9	7.9	4	4

*The UJCB probe experienced parameter drift in DO readings during the collection of maintenance data.

Maintenance caused a minor decrease in average temperature at both the UJCB and the JCBP@ shovel site, while an increase in average temperature occurred at the BJCB site (Table 7.8-2). At the JCBP@shovel site, located in the peaking reach, maintenance activities decreased the range, mean, and maximum water temperatures.The greatest difference in average temperature resulting from flow changes related to maintenance was seen at the lower end of the J.C. Boyle bypass reach, where an increase of 1.7°C occurred. This is most likely due to the dilution of the estimated 250 cfs of spring water found in this reach by the release of surface water from the J.C. Boyle dam. Increased flows in the J.C. Boyle bypass reach from the maintenance event decreased the range of diel temperature fluctuations; however, temperatures remained within the range of the background values (Figure 7.8-5).

pH remained relatively stable during the collection of background data except for the probe deployed at the site just upstream of Shovel Creek in the J.C. Boyle peaking reach (JCBP@shovel). Data from this site show a decreasing trend in values, with no apparent diel fluctuations occurring until after the maintenance event started (Figure 7.8-6). Overall pH values ranged from 7.6 to 9.0 for all sites, with the highest value occurring at the UJCB site prior to maintenance. Overall, maintenance had a relatively minor influence on the pH values.

DO levels (percent saturation) remained fairly stable throughout the sampling period (Figure 7.8-7). Prior to initiation of spill in the bypass reach, the probe deployed at the upper J.C. Boyle bypass reach encountered biofouling, with readings following a steadily decreasing trend for the remainder of deployment. DO data at this site (UJCB) should be considered invalid, with only the background levels prior to parameter drift used for comparison.

Increases in turbidity occurred at both of the sites monitored in the J.C. Boyle bypass reach (Table 7.8-2). Background data collected at the UJCB and BJCB sites averaged 7 and 2 NTUs, respectively. Average turbidity values increased at both sites during maintenance, to 12.44 (UJCB) and 6 (BJCB) NTUs. The highest NTU values recorded at both the bypass reach sites occurred prior to the maintenance event (Figure 7.8-8). Turbidity levels increased at the upper bypass site (UJCB) following spill for a period of 8 hours until receding to background values. The lower bypass site (BJCB) showed an increase above the average background values for a total of 15 hours, although the actual values are lower than those recorded in the upper section of the reach for the same period. No effect from the maintenance actively on turbidity at the site above Shovel Creek in the J.C. Boyle peaking reach could be identified.

Stream flows are presented in Figure 7.8-9 and show the spill at J.C. Boyle dam and the recorded flows from the USGS gauge below the J.C. Boyle powerhouse. Flows in the upper portion of the bypass reach were approximately 100 cfs before the maintenance event and were limited to leakage at the spill gates, fish ladder flows and fish bypass flows. The flows in the J.C. Boyle bypass reach increased because of spring accretions to approximately 350 cfs at the bottom of the reach. Flows in the J.C. Boyle peaking reach prior to maintenance averaged 668 cfs, with a maximum flow of 1,781 cfs and a minimum of 350 cfs, as recorded at the USGS gauge below the J.C. Boyle powerhouse (Figure 7.8-9). The powerhouse was operating on a single unit peaking regime, using only one of the two available turbines.

TDG measurements were taken during the spill event in two locations within the bypass reach. TDG measured 99 percent at the upper end of the bypass reach at the condemned bridge crossing. A value of 100 percent was measured at the lower end of the bypass reach, just upstream of the powerhouse.

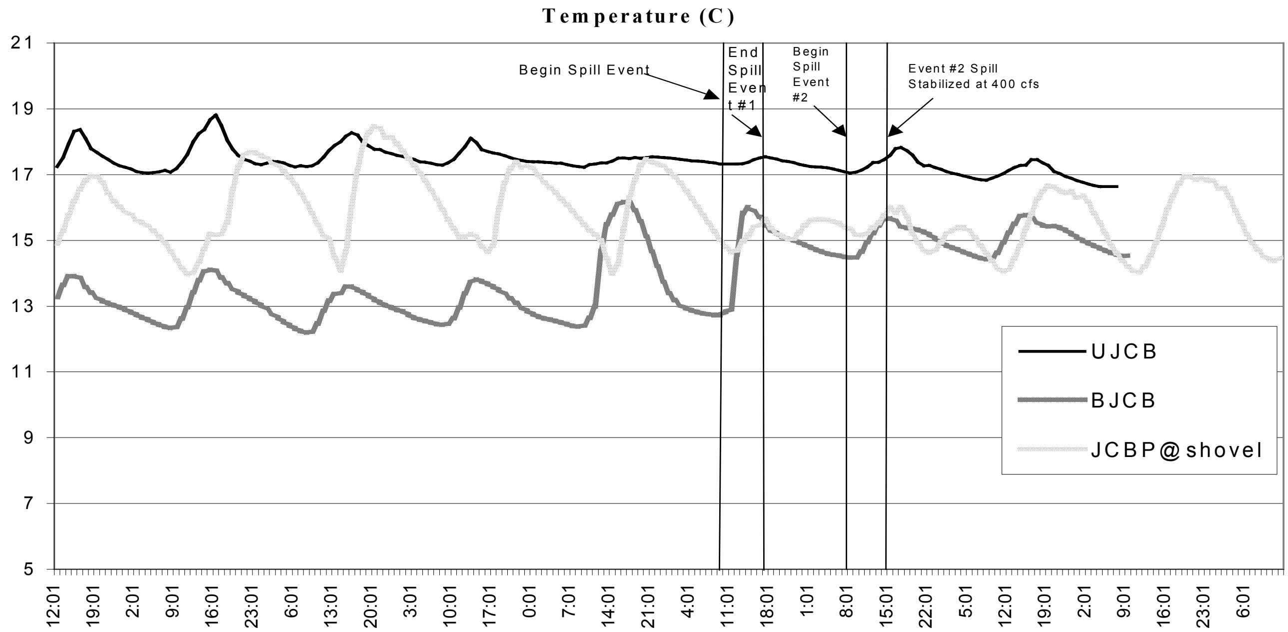

Figure 7.8-5. Temperature monitoring in the J.C. Boyle bypass and peaking reaches, September 12-15, 2002, during canal maintenance.

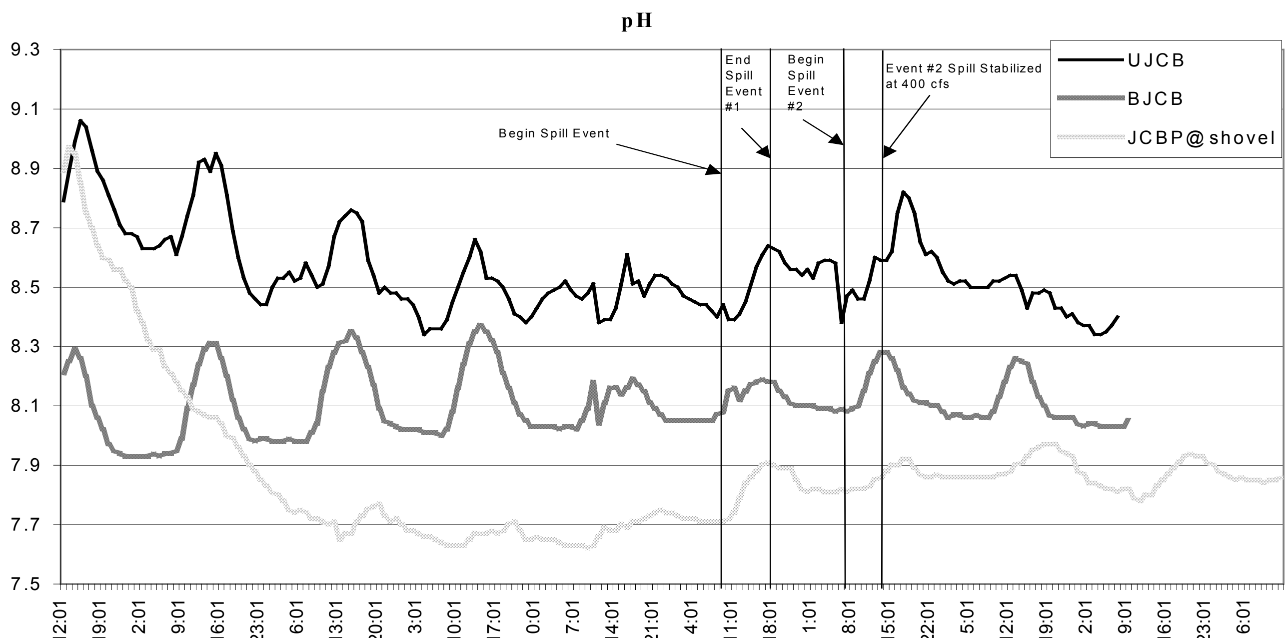

Figure 7.8-6. pH monitoring in the J.C. Boyle bypass and peaking reaches, September 12-15, 2002, during canal maintenance.

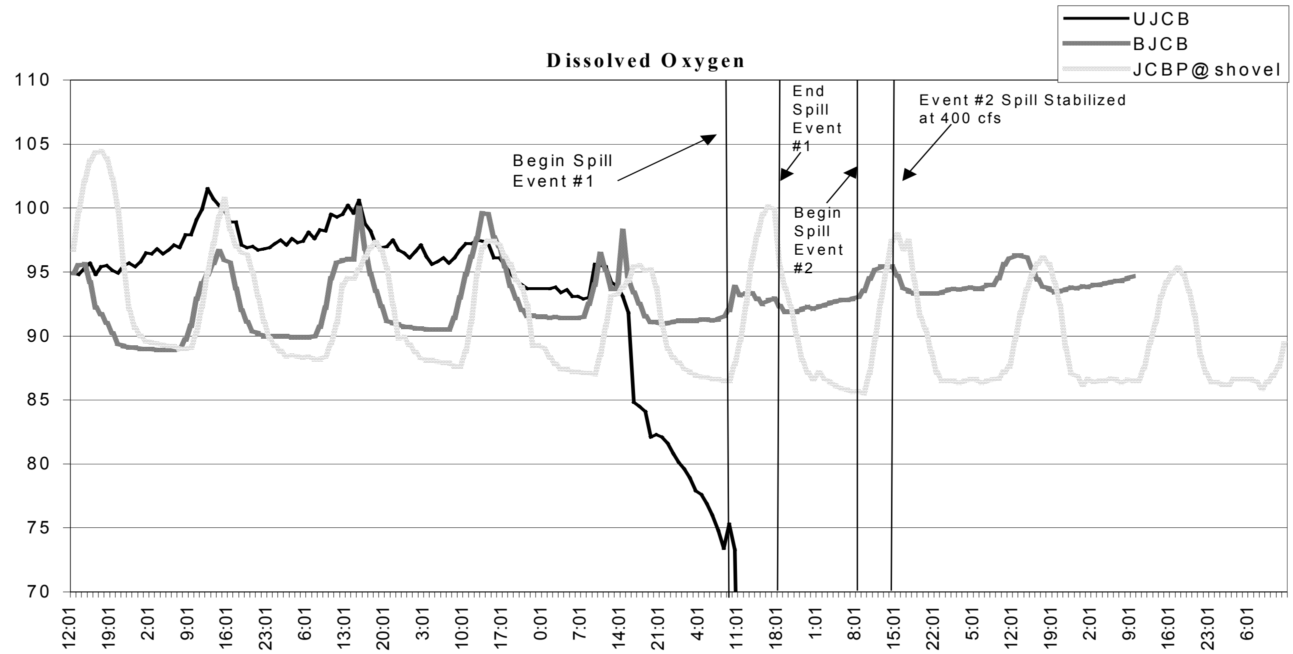

Figure 7.8-7. DO monitoring in the J.C. Boyle bypass and peaking reaches, September 12-15, 2002, during canal maintenance.

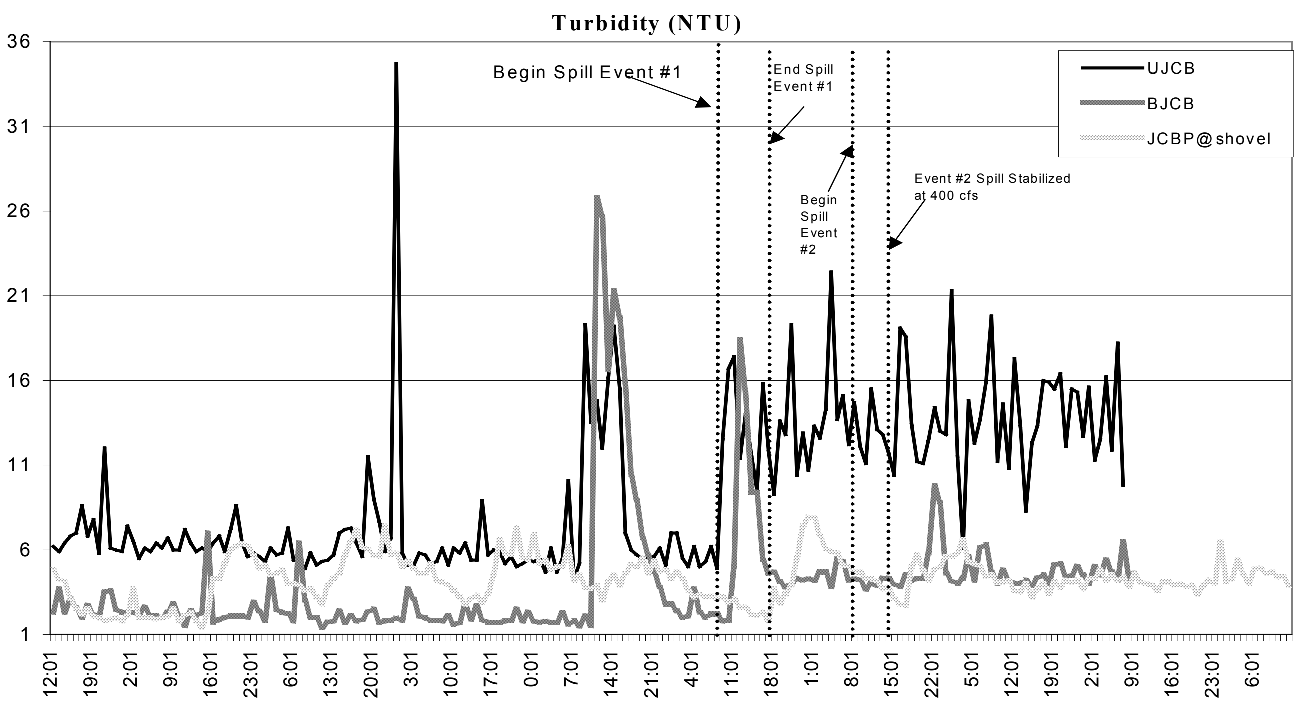

Figure 7.8-8. Turbidity monitoring in the J.C. Boyle bypass and peaking reaches, September 12-15, 2002, during canal maintenance.

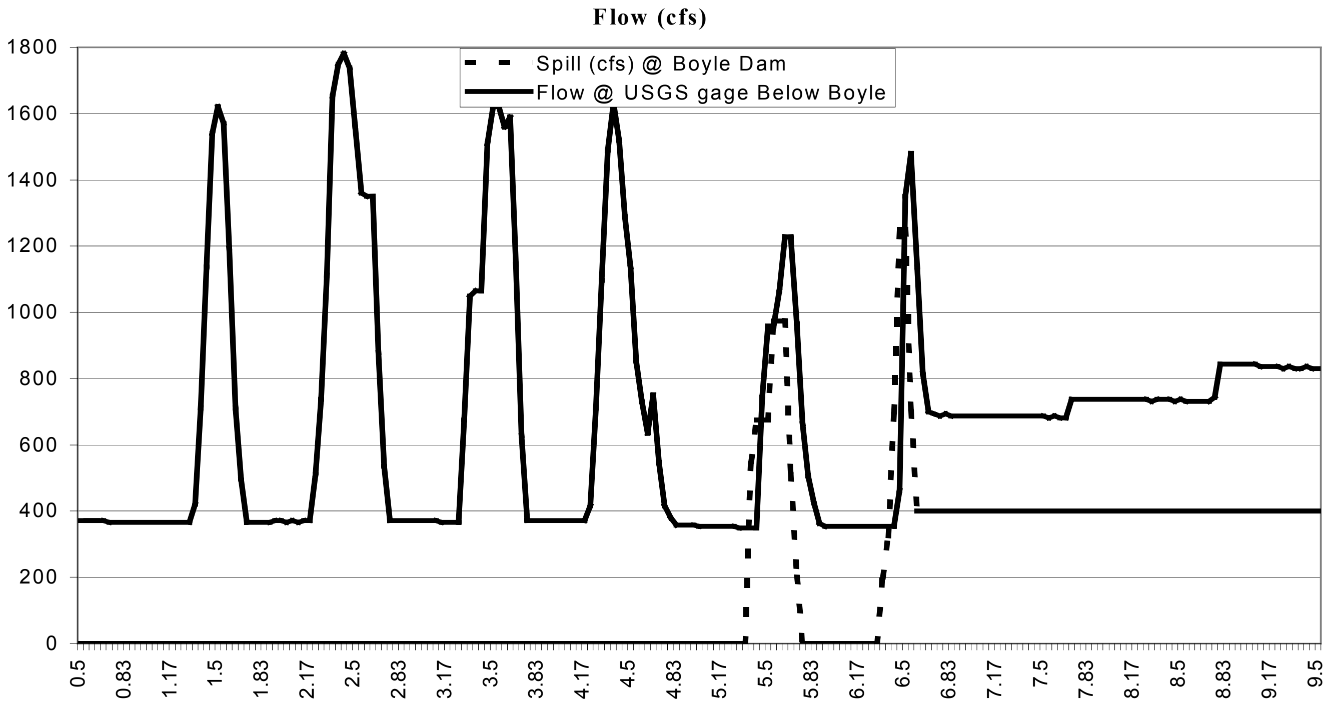

Figure 7.8-9. Spill flows at J.C. Boyle dam and recorded flows from USGS gauge below the J.C. Boyle powerhouse.

7.8.3 J.C. Boyle 2003 Maintenance

On June 13, 2003, construction work was performed on the J.C. Boyle canal headgate, requiring a shutdown of the J.C. Boyle powerhouse. This action required surface spill starting at 3:00 p.m. on June 14 from the J.C. Boyle reservoir into the bypass reach to meet flow needs below Iron Gate dam (the flow in the bypass reach equaled the flow in the peaking reach). PacifiCorp monitored the effects of this event on water quality at five locations:

- Upper J.C. Boyle bypass reach (UJCB)
- Lower J.C. Boyle bypass reach near the powerhouse (BJCB)
- J.C. Boyle peaking reach at the BLM boat launch
- J.C. Boyle peaking reach at the angler bridge upstream from Shovel Creek (JCBP@shovel)
- USGS Iron Gate gauge located below the Iron Gate fish hatchery (Klamath River@Iron Gate)

Instrument theft resulted in a complete loss of data from the site at the BLM boat launch.

Monitoring resulted in a total of 139 hourly readings for each of the deployment sites ending on June 19, 2003. A total of 22 hours of background data was collected for analysis. Analysis also included the spill occurring at the J.C. Boyle dam and corresponding flows measured at the USGS gauge below the J.C. Boyle powerhouse. Because of the multiple flow releases at J.C. Boyle dam and the limited duration of background data collection, data are presented as overall minimums, maximums, and average values (Table 7.8-3).

Table 7.8-3. Summary of water quality monitoring in the J.C. Boyle bypass and peaking reaches, on June 13-19, 2003, during canal maintenance.

		Temperature (°C)	DO (mg/L)	pH	Turbidity (NTU)
UJCB	Min.	20.4	7.6	8.1	6
	Max.	22.4	8.0	8.5	37
	Mean	21.3	7.8	8.3	9
BJCB	Min.	13.3	7.4	8.2	7
	Max.	18.4	8.4	8.7	10
	Mean	16.3	7.8	8.4	7
JCBP@ shovel	Min.	15.3	7.4	6.2	1
	Max.	21.7	10.2	9.3	9
	Mean	19.2	8.6	8.6	4
Klamath River @ Iron Gate	Min.	18.8	7.3	8.1	2
	Max.	21.3	9.0	8.8	14
	Mean	19.2	8.1	8.4	3

Temperature readings throughout the monitoring period for all sites had a minimum value of 13.3°C (BJCB) and a maximum of 22.4°C (UJCB). The maximum temperature occurred following the second spill event and was associated with an increase in the amount of surface spill from J.C. Boyle reservoir. Temperatures in the upper bypass reach remained elevated throughout the first spill event, remained elevated at the beginning of the second event, but gradually decreased when spill stabilized at 185 cfs (Figure 7.8-10). Spill at J.C. Boyle dam increased temperatures in the lower bypass reach throughout the duration of monitoring. This was caused by the dilution of spring accretions found in this reach by increased surface water spill. Maximum temperatures increased by 2°C in the lower bypass as a result of the surface spill influence. The site upstream of Shovel Creek in the peaking reach exhibited a minor decrease in the duration of the maximum daily temperature for the day of the first release, with no other discernible effects after that event. No effect on temperature was apparent in the data collected below Iron Gate dam, probably because of the lag in water travel time and the reservoir influence on inflow. The effects of the spill event were relatively minor at the UJCB, JCBP@shovel, and Klamath River@Iron Gate sites. Spill had the most influence on the lower bypass reach (BJCB) as a result of the dilution of the spring water accretions in this reach.

DO concentrations for all sites ranged from 7.3 mg/L to 10.2 mg/L (Table 7.8-3). The lowest reading occurred below Iron Gate dam, and the highest reading occurred in the J.C. Boyle peaking reach above Shovel Creek. Maintenance had only minor impacts on DO levels throughout the study (Figure 7.8-11). A general, but slight, decreasing trend in DO values occurred at the UJCB, BJCB, and Klamath River@Iron Gate sites. DO levels increased at the site in the J.C. Boyle peaking reach above Shovel Creek. It appears that this maintenance event had an overall indiscernible effect on DO concentrations.

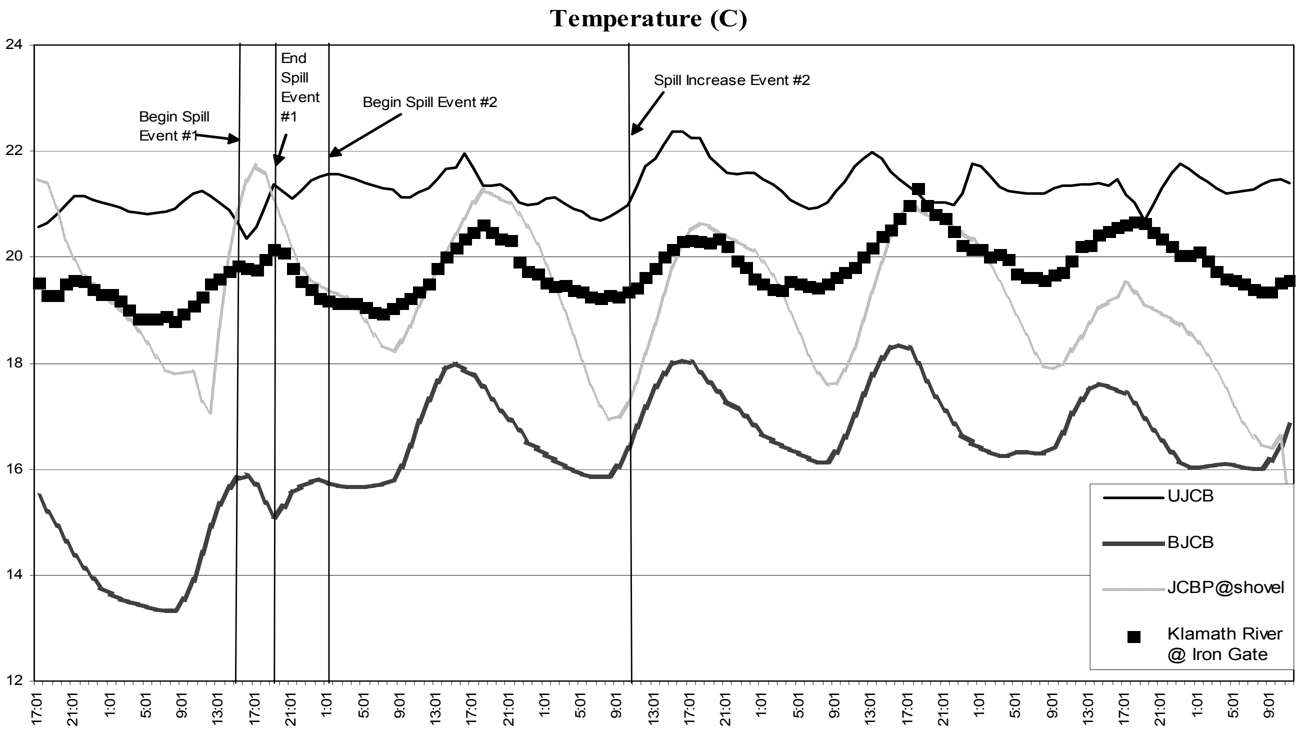

Figure 7.8-10. Temperature monitoring in the J.C. Boyle bypass and peaking reaches, June 13-19, 2003, during canal maintenance.

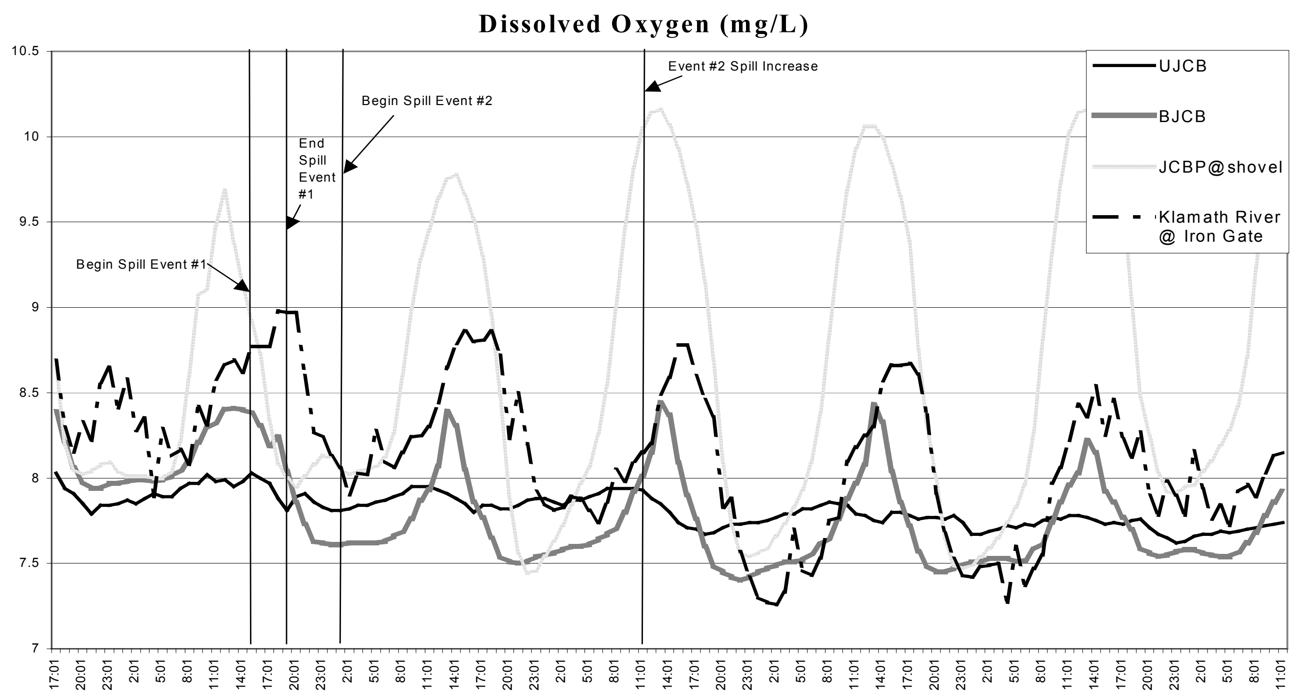

Figure 7.8-11. DO monitoring in the J.C. Boyle bypass and peaking reaches, June 13-19, 2003, during canal maintenance.

pH remained stable at most sites with the exception of the J.C. Boyle peaking reach, which ranged in values from 6.2 to 9.3 during the maintenance event (Figure 7.8-12). All other pH data collected during maintenance remained within the ranges of the background data except for the lowest site (Klamath River@Iron Gate). This location showed a decrease of less than .5 NTUs in the lower limits of the diel range following the maintenance event. No other effects were identified.

Turbidity increased at the upper end of the bypass reach in response to spill at the J.C. Boyle dam (Figure 7.8-13). Minor elevated readings occurred at both the lower bypass reach site (BJCB) and peaking reach above Shovel Creek (JCBP@shovel). Turbidity values ranged from 1 to 37 NTUs for all sites. Although an obvious increase in turbidity occurred at UJCB, the highest reading occurred 7 hours after the second release event and might be related to biofouling. Turbidity levels decreased at this site when spill was increased during the second spill event (Figure 7.8-13). No turbidity effects due to maintenance were detected at the Iron Gate site (Klamath River@Iron Gate).

Spill at J.C. Boyle dam varied between zero and 185 cfs throughout the course of monitoring (Figure 7.8-14). Two separate releases were made prior to flows stabilizing at 185 cfs for the final 73 hours of sampling. The flows in the bypass reach are a combination of the spill at the dam, fish ladder and attraction flow, fish bypass flows, and spring accretions. Actual flow in the bypass reach is 250 to 300 cfs more than the values shown as a result of these other sources (Figure 7.8-14). Flows recorded below the J.C. Boyle powerhouse ranged between 358 cfs and 3,000 cfs during the study. Flows in the J.C. Boyle peaking reach remained stable at approximately 520 cfs for the final 94 hours of monitoring.

TDG was measured during the maintenance event. This measurement, taken at the condemned bridge located below the fish bypass release, resulted in a value of 103 percent and coincided with a flow of 280 cfs. An additional TDG measurement was taken at the J.C. Boyle powerhouse tailrace on July 3, 2003, following the maintenance event. Only one of the two turbines was generating at the time of the measurement. TDG was measured at 102 percent for the tailrace release of 1,750 cfs.

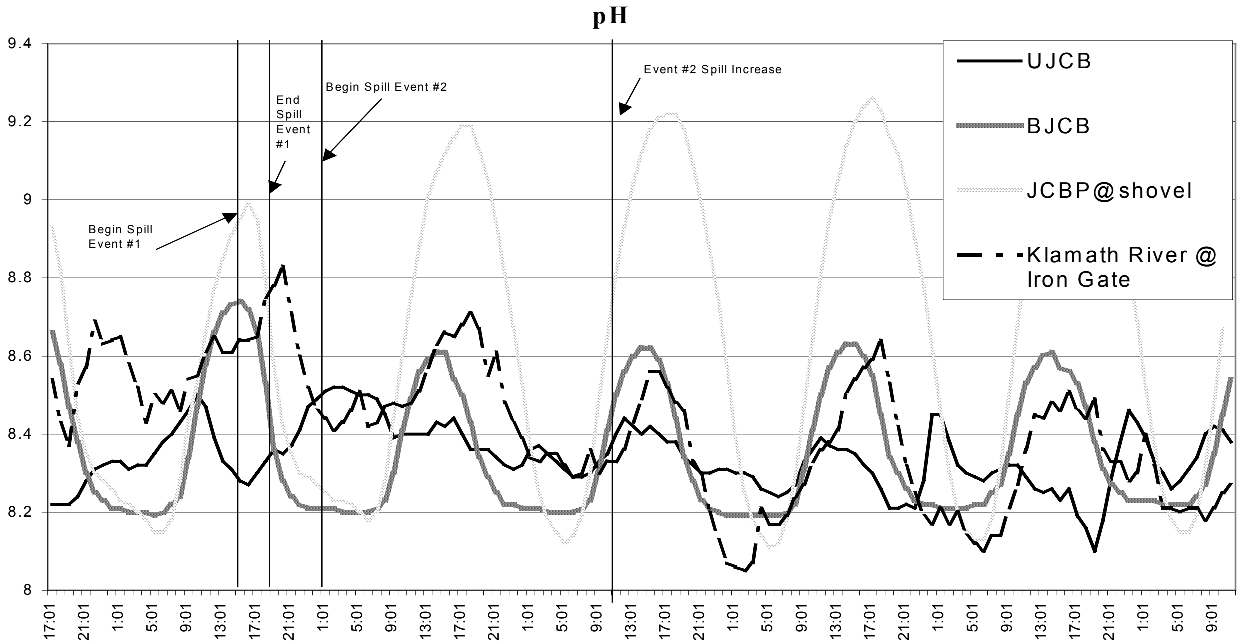

Figure 7.8-12. pH monitoring in the J.C. Boyle bypass and peaking reaches, June 13-19, 2003, during canal maintenance.

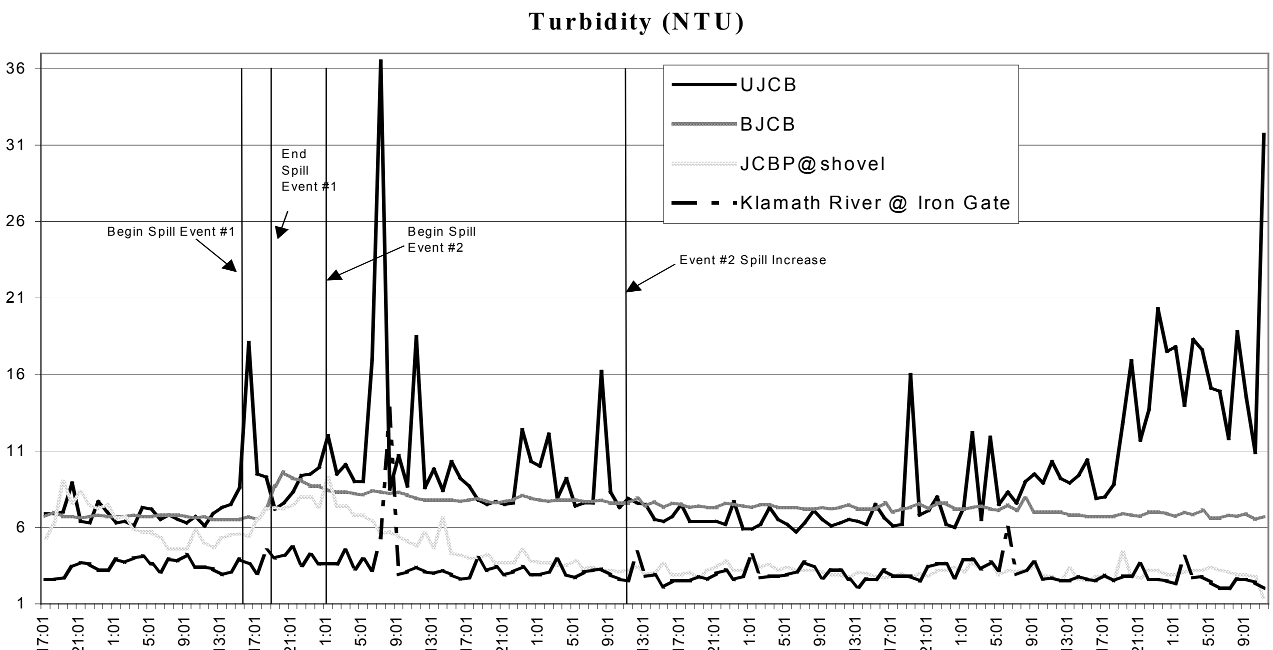

Figure 7.8-13. Turbidity monitoring in the J.C. Boyle bypass and peaking reaches, June 13-19, 2003, during canal maintenance.

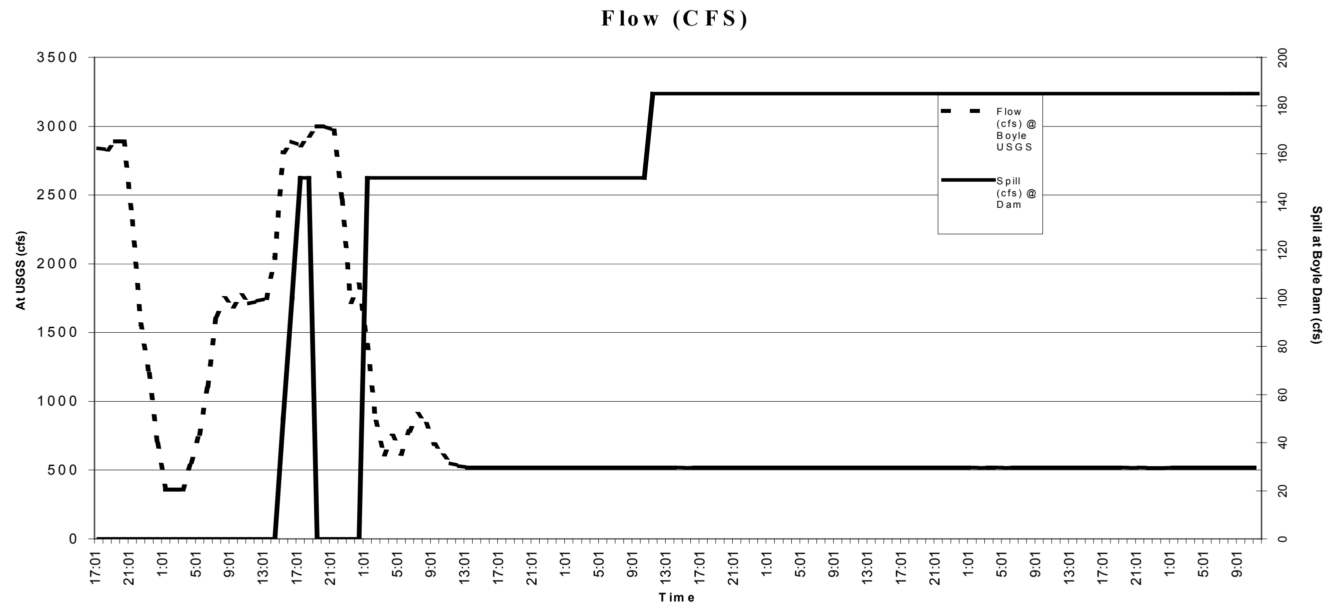

Figure 7.8-14. Spill flows in the J.C. Boyle bypass and peaking reaches, June 13-19, 2003, during canal maintenance.

7.8.4 Iron Gate Dam Maintenance

Iron Gate dam maintenance took place from May 16 through May 26, 2002. All water leaving the Iron Gate project during maintenance was passed through the spillway. Monitoring equipment was deployed at the USGS Iron Gate gauge, approximately ¼ mile below the dam. Data were collected approximately 12 hours after the project began spilling and continued until the project was back on line (Figure 7.8-15). PacifiCorp was unable to attain prespill (baseline) data for this maintenance event.

River flows below Iron Gate dam during maintenance ranged from 1,719 to 1,490 cfs. Temperatures were slightly higher at the beginning of maintenance but remained fairly stable (ranging from 12.2°C to 16.3°C) (Table 7.8-4). DO measurements were above 8.5 mg/L throughout the maintenance period, and pH remained fairly stable (ranging from 8 to 9, as outlined in Table 7.8-4). Turbidity only changed by a total of 2 NTUs for the duration of the event. TDG measurements were recorded during spill mode and again at the time of unit startup. Because of high flows, the Project continued to spill after coming back on-line. Total percent saturation only differed by 1 percent between nonspill (104 percent) and maintenance spill (103 percent) operations.

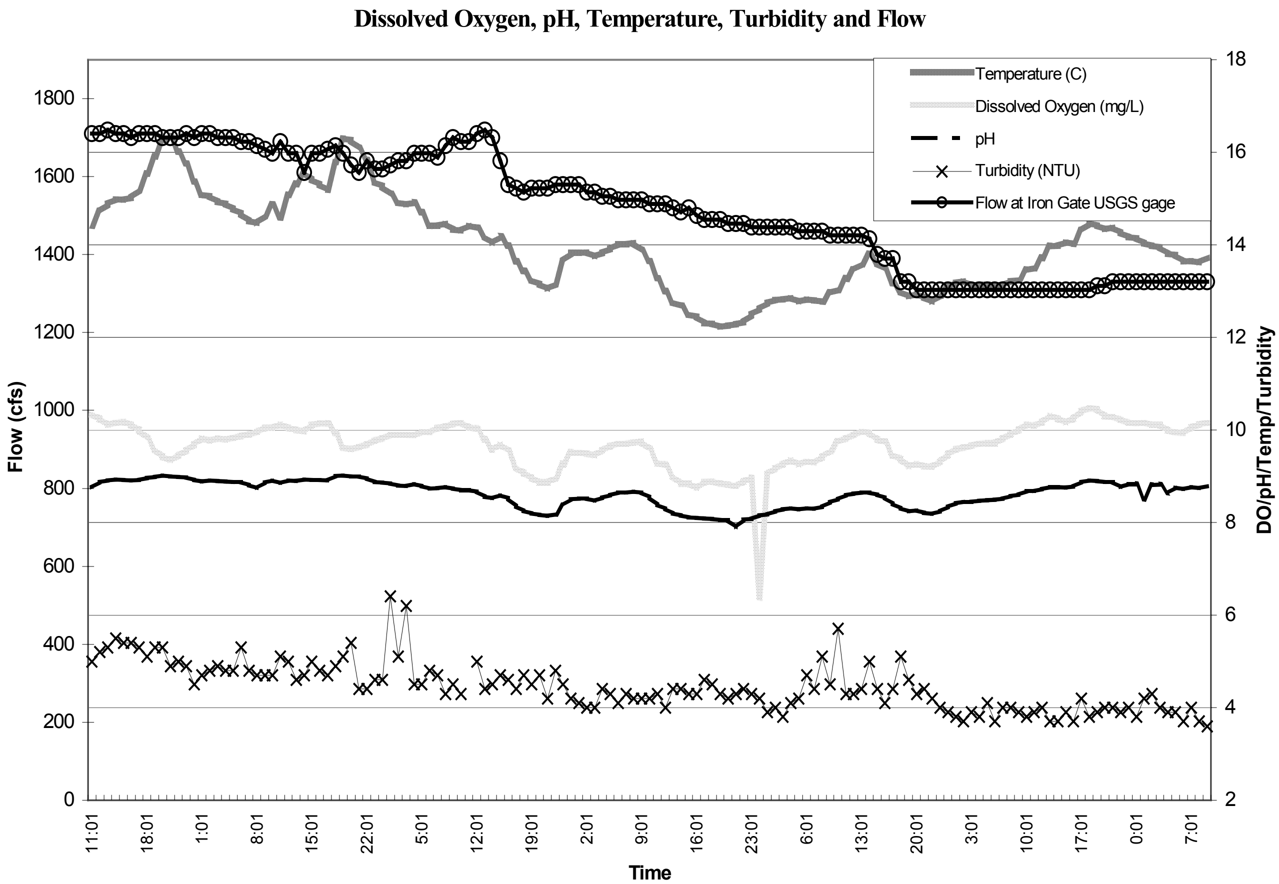

Figure 7.8-15. Temperature, DO, Turbidity, and Flow at Iron Gate.

Table 7.8-4. Summary of water quality monitoring in the Klamath River below Iron Gate dam during turbine maintenance on May 16-26, 2002.

		Temperature (°C)	Dissolved Oxygen (mg/L)	pH
Iron Gate	Range	12.2-16.3	6.4-10.5	7.9-9.0
	Minimum	12.2	6.4	7.9
	Maximum	16.3	10.5	9.0
	Mean	14.0	9.7	8.6

7.8.5 Project Roads and Culverts

The road/culvert assessments provided were performed using road inventory data collected by PacifiCorp and BLM. Additional considerations, such as proximity of roadway to a water body, condition of roadway, and ownership, are also discussed. Information pertaining to road and culvert conditions, including erosion potential, is derived from the inventory. In instances where roadway access was not available on private property, orthophotos were used to digititize linear road length. Road condition was not assessed on nonaccessible roads.

Table 7.8-5 summarizes the miles of roads, off-highway vehicle (OHV) trails, and hiking trails inventoried by PacifiCorp and represent all roads within ¼ mile of the FERC boundary. They are totaled for the study area for crossings of public and private land and for PacifiCorp property within the road inventory study area. Table 7.8-6 summarizes the miles of road surface materials inventoried within the study area. Pavement, crushed rock, cinder, native soil, herbaceous vegetation, brush, and small trees (less than 4 feet tall) were the surface types mapped for roads on public, private, and PacifiCorp land.

Table 7.8-5. Mileage of roads and trails.

Road Type	Study Area	Public Land	Private Land	PacifiCorp Land	Unknown Land
Roads	233	39.2	116.6	71.5	5.7
OHV	14.3	3.8	5.7	4.8	0
Trails	5.7	1.2	2.9	1.6	0
Total	253	44.2	125.2	77.9	5.7

Table 7.8-6. Mileage of road surfaces.

Road Surface	Study Area	Public Land	Private Land	PacifiCorp	Unknown
Paved	51.2	4.8	34.2	10.6	1.6
Crushed rock	86.8	19.9	37	27.3	2.6
Cinder	4.6	.9	1.2	2.5	0
Native soil	71	11.9	29.7	28.2	1.2
Herbaceous Vegetation	7.1	2.4	1.8	2.9	0
Brush	.8	0	.8	0	0
Trees (less than 4 feet tall)	0	0	0	0	0
Unknown	31.5	4.3	20.5	6.4	.3
Total	253	44.2	125.2	77.9	5.7

Of the 253 miles (407 km) of road systems identified within the road inventory study area, approximately 20 percent (95 km) are on PacifiCorp property. The FERC Project boundary contains 48 miles (77 km) of roadway, of which only 55 percent (42.5 km, or 26.4 miles) is on PacifiCorp land. Only unpaved roads were assessed for potential water quality impacts in the discussion below.

Roads and culverts may act to increase sediment load entering the Klamath River. Sediments can directly and indirectly affect aquatic species and their habitat. Sediment can decrease available oxygen by exacerbating BOD, can potentially harm incubating eggs by clogging interstitial pores in gravels, and can reduce macroinvertebrate productivity. Sedimentation can also affect wetlands directly through deposition that reduces wetland size and ultimately function. Long-term sediment deposition from roads and culverts into riverine habitats may affect habitat-forming processes by altering sediment budgets and, ultimately, impacting essential habitat components.

PacifiCorp identified 268 culverts within the area of concern (¼ mile from Project waterways). Culverts were generally found to be in good condition (80.5 percent). Common issues associated with these culverts were often the product of the structural condition of the pipe. Partially crushed culverts were identified at 14.5 percent of the sites, culverts with significant rusting made up 3.3 percent of the culverts inventoried, while totally crushed culverts were found 1.1 percent of the time (three sites). Only one culvert was found to be completely nonfunctional, with water flowing around the compromised structure.

Although partially crushed culverts were scattered throughout the Project area, more occurrences were found on the main roads on the north side of Copco and Iron Gate reservoirs. One culvert, in the southern portion of Sportsman's Park near J.C. Boyle reservoir was partially crushed, and another was identified on the access road to the J.C. Boyle fish ladder. One totally crushed culvert was located on the Aeger Beswick Road, approximately 1,110 feet northeast of the Mallard Cove Recreational Area. Two other completely crushed culverts were found on the west side of Iron Gate reservoir. A culvert located at the Wanaka Springs Recreation Site was found to be completely inoperable, with runoff flowing around the pipe. Significantly rusted culverts were located at the east side of Link River, below J.C. Boyle dam, and on the north side of Copco reservoir. This assessment did not include culverts found between the Oregon/California stateline to the J.C. Boyle powerhouse. Data were unavailable for this section of the Project area.

Roadways identified in the area of concern totaled 1,212,982 linear feet. Unpaved roads contributed to 79.9 percent of the total or 969,352 linear feet. Fifty-six percent of the roads were considered to be in good condition, while 12.3 percent were rutted, 5.3 percent had washboad conditions, and 3 percent were eroded. Roads exhibiting erosion were mainly found on the west side of Link River and at the south end of Keno reservoir, a road commonly used by the public for fishing access. Further erosion concerns and rutted roads were documented on the west and north banks of J.C. Boyle reservoir and were primarily associated with OHV use. Roads exhibiting washboard conditions were scattered throughout the Project area.

7.9 DISCUSSION

7.9.1 Project Maintenance and Water Quality

Increases in turbidity occurred during all events, with the highest values recorded at the locations nearest the spill release sites. Changes in other water quality parameters appear to have occurred as a result of the release of stored water in Project reservoirs and Upper Klamath Lake. In all cases, maintenance was performed in the spring and fall and resulted in the release of surface spill. Reservoir water quality at those times was more representative of riverine conditions, resulting in less of an overall change to in-river water quality parameters during spill. PacifiCorp will refine maintenance times in consultation with the appropriate agencies to minimize impacts.

Use of the J.C. Boyle power canal emergency spillway will be eliminated under future Project operations. During current use, the spillway delivers sediment, including gravel, to the lower portion of the bypass reach. These inputs will not be provided by this source following the addition of a continuous flow device at the powerhouse, eliminating the need for the emergency spillway.

7.9.2 Project Roads and Culverts

This report identified areas of concern associated with PacifiCorp roadways and culverts. PacifiCorp will continue to use Best Management Practices for the maintenance of these roads and culverts, thereby reducing the potential for impacts to aquatic habitats. Further refinement of these practices, including site-specific planning, will result from this analysis.

8.0 FALL 2002 MACROINVERTEBRATE MONITORING

8.1 DESCRIPTION AND PURPOSE

The Klamath River, from source to mouth, is listed as water quality limited by both Oregon and California under Section 303(d) of the federal Clean Water Act. Warm water temperatures and enriched nutrient conditions, particularly during summer, are the primary focus of water quality management planning in the basin by Oregon and California water quality agencies. One or more sections of the Klamath River in Oregon is Section 303(d)-listed for water temperature (summer), pH (summer), chlorophyll *a* (summer), DO (April 1-November 30), and ammonia toxicity (summer and winter). The Klamath River in California is Section 303(d)-listed for water temperature, nutrients, organic enrichment, and DO.

In response to PacifiCorp's First Stage Consultation Document and proposed aquatic studies, SWRCB, ODEQ, and other commenters recommended study of macroinvertebrates as a means of assessing water quality impacts. SWRCB indicated that benthic macroinvertebrates have become a standardized tool to evaluate impacts of water quality. ODEQ indicated that benthic macroinvertebrates are important indicators of stream water quality and ecological integrity, and that assessment of benthic macroinvertebrates at key locations can provide an indication of how Project facilities and operations affect resident biological communities.[1]

The purpose of this study was to conduct a bioassessment of macroinvertebrates in the Project area during the fall of 2002.[2] The bioassessment was used to determine the presence and composition of macroinvertebrate taxa. This information is used to (1) assess the potential relationship of macroinvertebrate community composition to water quality conditions; (2) assess the presence of designated Species of Concern;[3] (3) determine the quality of the macroinvertebrate assemblage as a food source for fish and wildlife; and (4) identify susceptibility of macroinvertebrate taxa to flow changes. In addition, macroinvertebrates were sampled throughout the Project area during spring 2003. Those results are reported in Section 12 of this document, along with a comparison to these fall 2002 results.

8.2 OBJECTIVES

The objectives and key questions addressed by this study are as follows:

1. Characterize macroinvertebrate presence and community composition in waters affected by the Project.
2. Do waters affected by the Project support healthy and diverse residential macroinvertebrate communities?

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[1] The state of Oregon has a narrative Biological Criteria water quality standard that stipulates that waters "…shall be of sufficient quality to support aquatic species without detrimental changes to resident biological communities."

[2] Consideration of additional sampling was based on further discussion with the Water Quality Work Group. Upon such discussion, it was agreed to conduct additional macroinvertebrate study in the spring of 2003. That study is described in Section 12.0 of this FTR.

[3] The U.S. Fish and Wildlife Service has designated the following macroinvertebrate Species of Concern that could occur in the Project area: *Apatania (=Radema) tavala* (Cascades apatanian caddisfly), *Homoplectra schuhi*i (Schuh's homoplectran caddisfly), and *Rhyacophila mosana* (Bilobed rhyacophilan caddisfly).

3. Develop a baseline of existing macroinvertebrate community conditions in the event monitoring of macroinvertebrates becomes a postlicensing monitoring requirement.
4. Is macroinvertebrate community composition related to water quality conditions? If so, how is it related?
5. Are designated Species of Concern present?
6. How does macroinvertebrate community composition vary between the fully wetted and varial zones of the J.C. Boyle peaking reach?
7. How do J.C. Boyle peaking operations affect macroinvertebrate drift in the peaking reach?
8. Support subsequent assessment (together with other resources studies) of the quality of the macroinvertebrate assemblage as a food source for fish and wildlife, and to identify susceptibility of macroinvertebrate taxa to flow changes.
9. Support subsequent assessment (together with other studies and during license application preparation) of the Project's potential effects on water quality and fish and wildlife resources, and identify possible PM&E measures where necessary.

8.3 RELICENSING RELEVANCE AND USE IN DECISIONMAKING

The results of this study assist the assessment of current water quality conditions in waters affected by Project facilities and operations. Relicensing of the Project requires Section 401 certifications from relevant agencies that the Project complies with requirements of the federal Clean Water Act. Information from this study helps to document water quality conditions and potential Project effects as they relate to water quality objectives and standards promulgated by these agencies for maintenance and protection of biological integrity.[4]

Relicensing of the Project also requires PacifiCorp to assess water quality effects as they relate to other resources issues. For example, water quality is important to supporting healthy and diverse macroinvertebrate communities, which in turn are important as a food resource for fish and wildlife species. Therefore, the tasks described in this section contribute information (together with other resources studies) for the assessment of fish and wildlife resources as well as water quality conditions.

8.4 METHODS AND GEOGRAPHIC SCOPE

8.4.1 Macroinvertebrate Sampling Protocol

PacifiCorp used the California Stream Bioassessment Procedure (CSBP) and the California Lentic Bioassessment Procedure (CLBP) to evaluate macroinvertebrates as appropriate throughout the study area. SWRCB stipulated that the CSBP and CLBP be used to evaluate macroinvertebrate water quality impacts from the Project.[5] The CSBP and CLBP protocols have been adapted from the EPA Rapid Bioassessment Protocols by the California Department of Fish

[4] For example, the State of Oregon water quality standards include a Biological Criteria standard that stipulates that "waters…shall be of sufficient quality to support aquatic species without detrimental changes to resident biological communities."

[5] Use of CSBP was recommended in a letter dated March 23, 2001, by Russ Kanz (SWRCB) to Todd Olson (PacifiCorp). Use of CSBP for lotic waters and CLBP for lentic waters was further stipulated by Russ Kanz (SWRCB) in follow-up phone conversations with Ken Carlson (CH2M HILL) during September 2001.

and Game (CDFG) Aquatic Bioassessment Laboratory (CDFG, 1999a and 1999b). The CSBP is a standardized protocol for assessing biological and physical/habitat conditions of wadeable streams in California (CDFG, 1999a). The CLBP is a standardized protocol for assessing biological conditions of still water environments, such as reservoirs and lakes (CDFG, 1999b). ODEQ indicated that use of either of the California bioassessment protocols would be acceptable.[6]

PacifiCorp employed CSBP and CLBP protocol guidance on various facets of sample collection and analysis, including the following (see CDFG, 1999a and 1999b, for details):

- Field and laboratory procedures
- Procedures for selecting sampling locations
- Concurrent water quality measurements
- Concurrent physical/habitat quality measurements
- Methodology for developing and analyzing data

8.4.1.1 Lotic Macroinvertebrate Sampling Procedure (River)

The CSBP was used to assess macroinvertebrate communities in riverine segments of the study area (i.e., lotic reaches, lotic sampling transects). The sampling units were riffles within each reach. For purposes of this study, a reach was defined as a distinct river segment between key Project features that contained at least five riffles within the same stream order and relative gradient. Three of the five riffles were randomly selected for sample collection. Starting with the downstream riffle, a measuring tape was placed along the bank of the entire riffle. From all meter increments along the tape in the upper third of the riffle, a single meter mark was randomly chosen. Sampling occurred along a transect across the channel at the chosen meter mark.

Collection of macroinvertebrates was obtained at three locations along the transect using a D-shaped kicknet (0.5-mm mesh), sampling a 1- by 2-foot portion of substrate upstream of the kicknet to a depth of approximately 4 to 6 inches. In locations dominated by boulder or bedrock and where sampling of substrate to a depth of approximately 4 to 6 inches was not possible, an alternative technique was used. The alternative technique entailed sampling a 1- by 2-foot area of boulder or bedrock surface by gently brushing or scraping surface material into the kicknet until the surface was “cleansed.” The three locations were selected to represent, as much as possible, the substrate and structural composition along the transect.

A consistent sampling effort of approximately 1 to 3 minutes occurred at each of the three locations. The three collections at each location along the transect were combined to form a single composite sample. The contents of the kicknet were placed in a 0.5-mm mesh sieve to remove large twigs, leaves, and rocks. The remaining sample was then placed in a plastic jar and preserved with 95 percent ethanol. The above steps were repeated for the next two randomly chosen transects within the riffle.

The CSBP protocol (CDFG, 1999a) also was used by PacifiCorp to obtain concurrent physical/ habitat measurements and field measurements of water quality parameters (temperature, pH, conductivity, and DO). EPA’s physical/habitat scoring criteria were used to measure the physical

[6] Use of either CSBP or Oregon’s protocol was indicated as acceptable in a letter dated March 19, 2002, from Paul DeVito (ODEQ) to Todd Olson (PacifiCorp).

habitat quality of the sampling sites. Physical habitat characteristics that were measured included riffle length and width, water depth and velocity, percent canopy cover, substrate composition and embeddedness, and percent gradient. A CSBP Physical/Habitat Quality Form was filled out for each sample site.

In accordance with CSBP and CLBP methods, sampling was focused in riffle habitats. Some stakeholders recommended that additional sampling also be conducted in other habitat types, including the varial zone that occurs in the J.C. Boyle peaking reach. The proposed sampling followed CSBP methods, and the riffle habitats sampled were considered to contain the most diverse and productive macroinvertebrate assemblages, representing the most sensitive areas for assessing potential effects. Regarding varial zone sampling, four of the transects selected for sampling in the J.C. Boyle peaking reach included an additional sample in the varial zone during high flow for comparison with samples in the permanently wetted channel. Each additional sample was a composite of three kicknet collections in the varial zone at each of the four transects. Varial zone locations are identified on the site location maps (Figure 8.4-1).

Some stakeholders recommended that additional sampling also be conducted for macro-invertebrate drift. In an e-mail to the Water Quality Work Group dated August 15, 2002, Paul DeVito (ODEQ) recommended a specific procedure for drift sampling. The matter was discussed at the Water Quality Work Group meeting on September 5, 2002. PacifiCorp expressed concern that macroinvertebrate drift is highly variable and difficult to sample accurately and that drift issues can be adequately addressed by other information sources. Rather than conduct a full-scale drift study, PacifiCorp agreed to conduct limited sampling for drift to test drift sampling procedures.

Test drift samples were collected within the J.C. Boyle peaking reach at three zones in the channel: (1) constantly wetted margins during low flow, (2) wetted margins during peaking operations, and (3) mid-channel or as close as possible to mid-channel. Drift invertebrates were captured on a 2.5-foot by 4-foot frame of fine-mesh window screening (approximately 1- by 2-mm mesh) held on poles, perpendicular to the current. Drift samples were taken at steady-state low and high flow operations, as well as during the upramping and downramping transitional periods. The low flow sampling occurred in the morning prior to upramping as opposed to the evening following downramping. Flows and water depths were estimated during each sampling episode to relate drift captures to changes in flow and velocity. Drift samples were identified and counted similarly to all macroinvertebrate samples, with an additional category added for terrestrial species.

8.4.1.2 Lentic Macroinvertebrate Sampling Procedure (Reservoirs)

The CLBP protocol (CDFG, 1999b) was used to assess macroinvertebrate communities in reservoir segments of the study area (i.e., lentic areas, lentic sampling transects). The sampling units were perpendicular littoral transects from the shoreline of each reservoir. Five such transects were randomly selected for sample collection. The distance of each transect was measured running perpendicular to the shoreline into the lake littoral area to a depth of 1.5 m.

A slacknet (0.5-mm mesh) was placed on the substrate at the outer edge of the transect. The net then was moved toward shore along the transect, disturbing the substrate gently. The contents of the net were sieved through a standard size 35 (0.5-mm) sieve and any large organic material removed. The contents of the sieve were placed in a plastic jar filled with 95 percent ethanol. The slacknet sampling was repeated for each of the five transects. The collections from each transect were combined to produce one composite sample of littoral macroinvertebrates for each reservoir segment.

Separate collections of littoral benthos macroinvertebrates were collected just beyond the outer edge of the five transects using a 9-inch Eckman dredge. Water column depth and volume of material in dredge were recorded at each site. Dredged material was sieved through a 0.5-mm screen to remove most of the sediment. Contents of the sieve were placed in a plastic jar and preserved with 95 percent ethanol. The dredge collections for each of the five transects were combined to produce one composite sample of littoral benthos macroinvertebrates for each reservoir segment.

8.4.2 Sampling Locations

The number of fall 2002 lotic and lentic sites and sampling transects is summarized in Table 8.4-1.

8.4.3 Sampling Schedule

Per CSBP and CLBP methods, sampling occurred during September 6-14, 2002. This sampling period coincides with annual modes in macroinvertebrate diversity and flow conditions that are safe for sampling. Some stakeholders recommended that additional sampling also be conducted during other seasons or be repeated in subsequent years. Consequently, additional macro-invertebrate sampling was conducted during May 2003.

Installation and testing of a new head gate in the J.C. Boyle canal occurred from September 16 until about October 20, 2002. During this period, typical flow diversion and peaking operations at the J.C. Boyle facilities ceased and were replaced by steady, run-of-river operation with no flow diversion to the J.C. Boyle powerhouse. In discussions with the Water Quality Work Group, it was agreed that macroinvertebrate sampling of mainstem riverine reaches would be completed before September 16, 2002, to avoid potential bias from atypical operation and flow conditions that might occur from sampling during subsequent weeks.

Table 8.4-1. Fall 2002 lotic and lentic macroinvertebrate sampling transects by reach or area.

Area	Reaches[1]	Transects[2]	Samples[3]	State	
				OR	CA
Link River				√	
East Side/West Side Bypass Reach	1	3	3	√	
East Side/West Side Full-Flow Reach	1	3	3	√	
Lake Ewauna/Keno Reservoir		5	2	√	
Keno Dam to J.C. Boyle Reservoir	2	6	6	√	
J.C. Boyle Reservoir		5	2	√	
J.C. Boyle Bypass Reach	3	9	9[4]	√	
J.C. Boyle Peaking Reach	6	18	18	√	√
Copco No. 1 Reservoir		5	2		√
Copco No. 2 Reservoir[5]		0	0		√
Copco No. 2 Bypass Reach	2	6	6		√
Copco No. 2 Full-Flow Reach[6]	0	0	0		√
Fall Creek Above Diversion	1	3	3		√
Fall Creek Bypass Reach	3	9	9		√
Fall Creek Full-Flow Reach	2	6	6		√
Iron Gate Reservoir		5	2		√
Klamath River Between Iron Gate Dam and the Shasta River	6	18	18		√
Total	**27**	**101**	**89**		

1 Reaches are defined as a stretch of stream that contains at least five riffles within the same stream order and relative gradient. Reach estimates for each area were derived from review of topographic maps and aerial photographs and initial field reconnaissance.

2 For lotic areas, a sampling transect is placed in each of three randomly chosen riffles in each reach (in the upper third of the riffle). For lentic areas, five sampling transects are randomly chosen from assigned marks around the shoreline perimeter.

3 For lotic areas, one sample is obtained at each sampling transect. The sample is a composite of kicknet collections from three areas along each transect. For lentic areas, slacknet collections from the five sampling transects are composited to produce one sample of littoral macroinvertebrates, and Ekman dredge collections from the five sampling transects are composited to produce one sample of benthic macroinvertebrates.

4 Four additional composite samples are obtained in the varial zone at four of the transects in the J.C. Boyle peaking reach.

5 Copco No. 2 reservoir is a small, steep-sided reregulating reservoir that will not be sampled.

6 The Copco No. 2 peaking reach will not be sampled because it is very short and most times is inundated by the upper end of Iron Gate reservoir.

8.4.4 Laboratory Analysis

Macroinvertebrate samples were sent to a qualified laboratory for professional sample processing and identification of organisms to a standard level of taxonomy, usually to genus and/or species level. Each sample was processed in the laboratory to obtain a subsample of 300 organisms, which were then identified to the standardized level recommended by the California Bioassessment Laboratories Network (CAMLnet)[7] using appropriate taxonomic keys and QA/QC procedures. For each sample, the laboratory reported the taxonomic list of organisms and the number of organisms within each taxon. Sample QA/QC and validation procedures followed CSBP and CLBP protocols (see CDFG, 1999a and 1999b, for details), including 20 percent taxonomic subsampling.

8.4.5 Data Development and Analysis

The CSBP and 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 were 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 following consultation with appropriate agencies (e.g., SWRCB, ODEQ).

The chosen metrics were related directly to water quality, habitat conditions, and geographic location to determine potential causal relationships and/or project impacts. The taxonomic list and metrics provided information by which other study objectives were addressed. For example, the taxonomic list and numbers of organisms were used to assess the presence of designated Species of Concern, and to determine the presence and quantity of taxa that are known food sources for fish and wildlife species. The taxonomic list and metrics were used as needed with literature-based information to identify susceptibility of macroinvertebrate taxa to flow changes. In addition to metric scores, the relative rankings of selected metrics were calculated for mainstem Klamath River sites to facilitate comparisons among sites.

River reaches were grouped by physical habitat and macroinvertebrate metrics using statistical clustering techniques (SAS, 2002). Cluster dendrograms showed the groupings of sampling sites combined by similarity of results. The diagrams show sites linked by lines of most similar sites at the left moving to least similar groups toward the right. The similarities among sites are estimated using a hierarchical clustering technique with distances between clusters as the analysis of variants (ANOVA) sum of squares between clusters, added for all variables ("Ward's Method," SAS, 2002). The cluster diagrams are provided to demonstrate relative similarities among sites, rather than precisely defined similarities.

Physical habitat characteristics and macroinvertebrate metrics were compared among sites using ANOVA, pairwise comparisons (SAS, 2002) for data grouped by reach.

8.4.6 Geographic Scope

Macroinvertebrate samples were collected in 21 lotic riverine reaches along the Klamath River from Link River dam (RM 254.3) to the mouth of the Shasta River (RM 176.7) (Table 8.4-1). Six additional stream reaches were sampled in Fall Creek. Four reservoirs on the mainstem Klamath River were sampled within this study reach. Sampling locations and reach designations are shown in Figure 8.4-1.

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[7] CAMLnet is an organization that provides technical assistance to, and ensures consistent efforts from, analytical laboratories in California.

8.5 RELATIONSHIP TO REGULATORY REQUIREMENTS AND PLANS

This study helps PacifiCorp address regulatory requirements and planning objectives related to water quality effects on macroinvertebrates. The information derived from this study helps address FERC requirements (18 CFR 4.51 and 16.8) for information on water quality and fish and wildlife in the Project area and potential effects of Project operations on water quality and fish and wildlife.

Relicensing of the Project requires certifications from relevant agencies that the Project complies with requirements of Section 401 of the federal Clean Water Act. This study provides information to assess potential Project effects as they relate to water quality objectives and standards promulgated by these agencies.

Together with other hydrology and water quality studies conducted by PacifiCorp, this study provides information to address compliance with management objectives from various resource agencies, tribes, and other stakeholders that relate to water quality and fish and wildlife, including:

- Federal Clean Water Act regulations
- State of California Water Quality Control Plan for the North Coast Region (Basin Plan)
- State of Oregon Water Quality Basin Plan for the Klamath basin
- Tribal natural resources goals and objectives and cultural values, including tribal water quality standards as promulgated
- USFS and BLM Aquatic Conservation Strategy objectives under the Northwest Forest Plan
- BLM Resource Management Plans
- USFS Land and Resource Management Plans
- ODFW Fish and Wildlife Habitat Mitigation Policy
- ODFW Klamath Basin Fish Management Plan
- CDFG management goals

This study's information also helps PacifiCorp and stakeholders develop PM&E measures to meet the intention of the regulations and management objectives related to water quality and fish and wildlife.

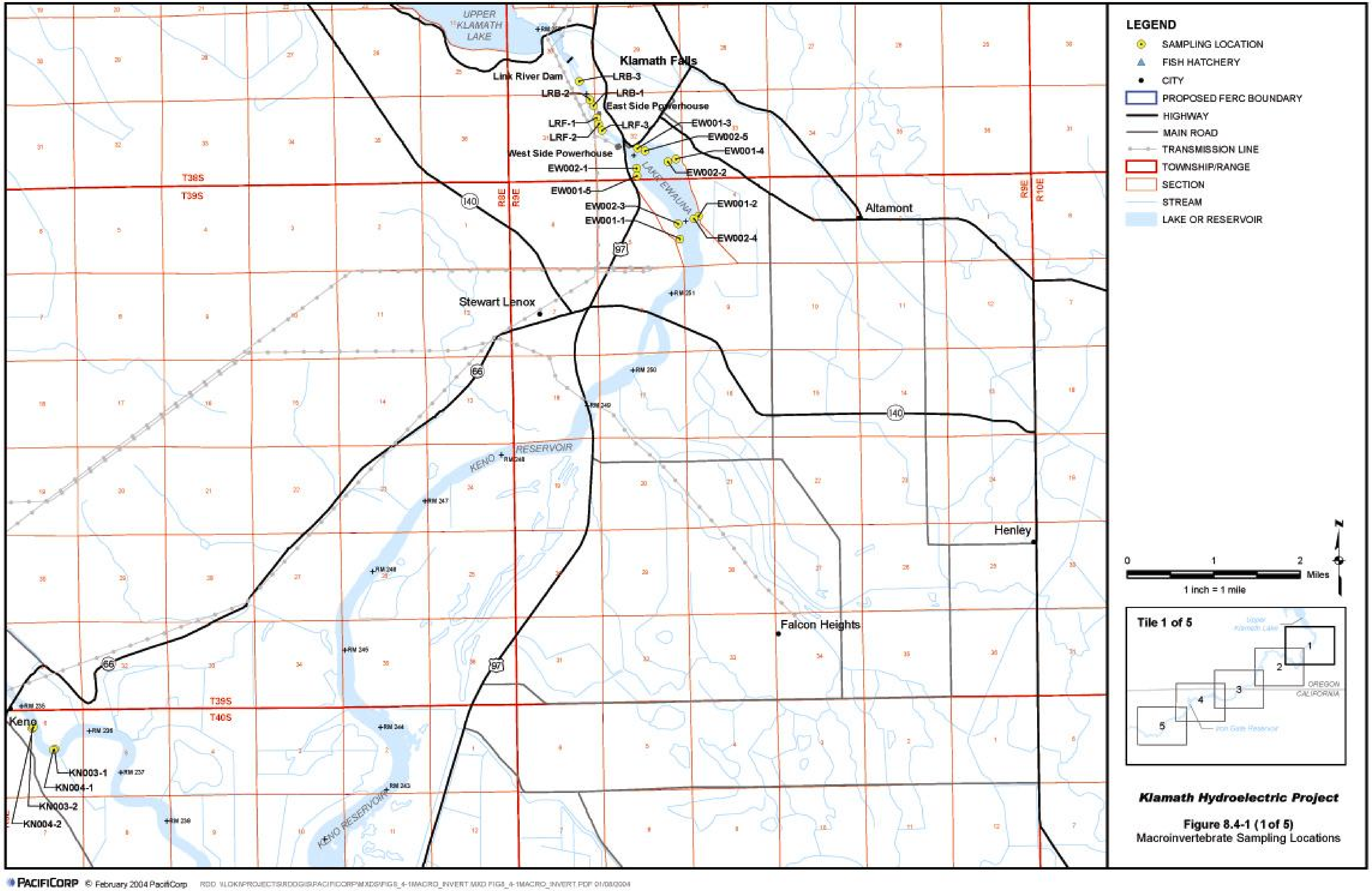
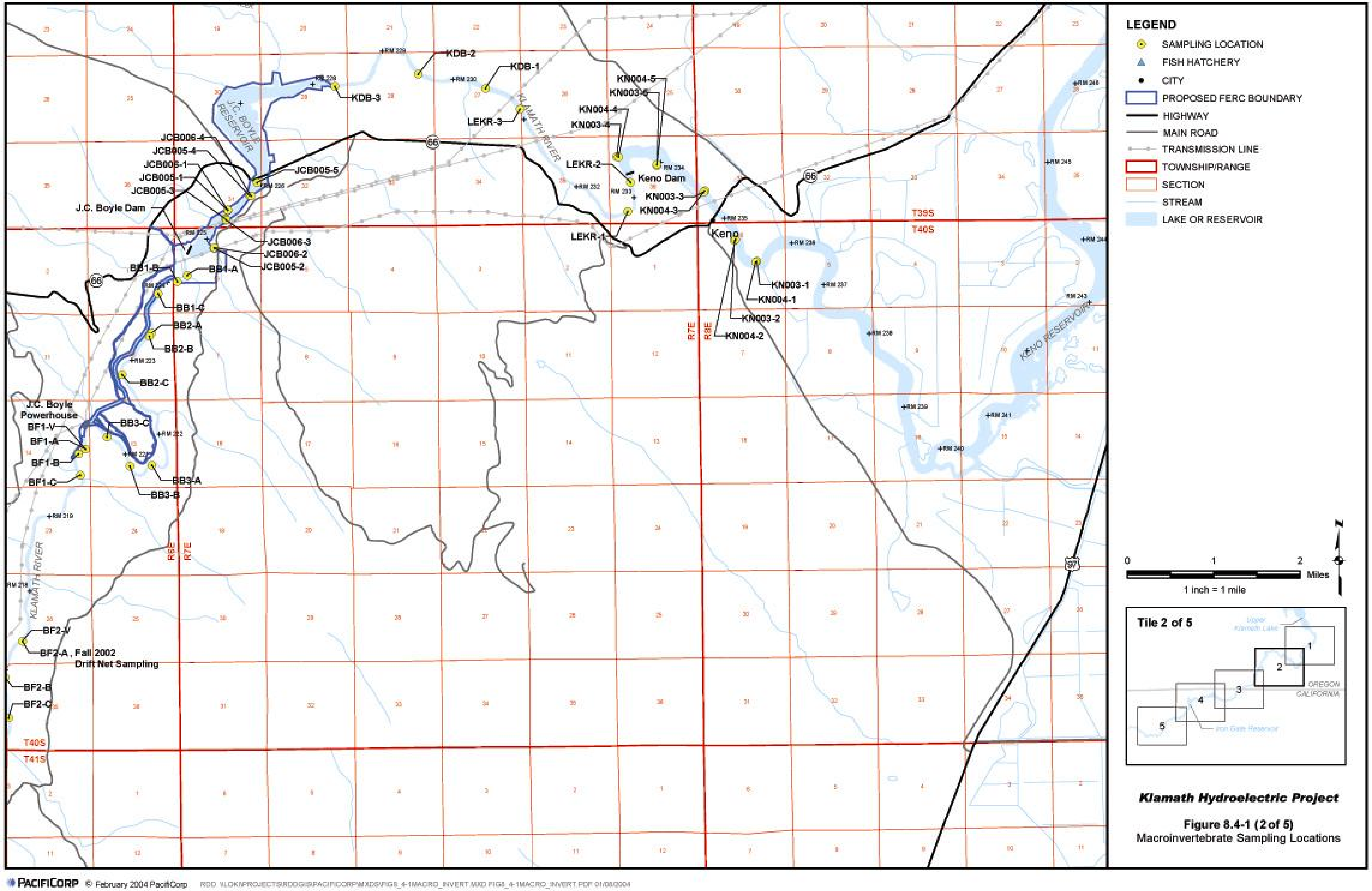
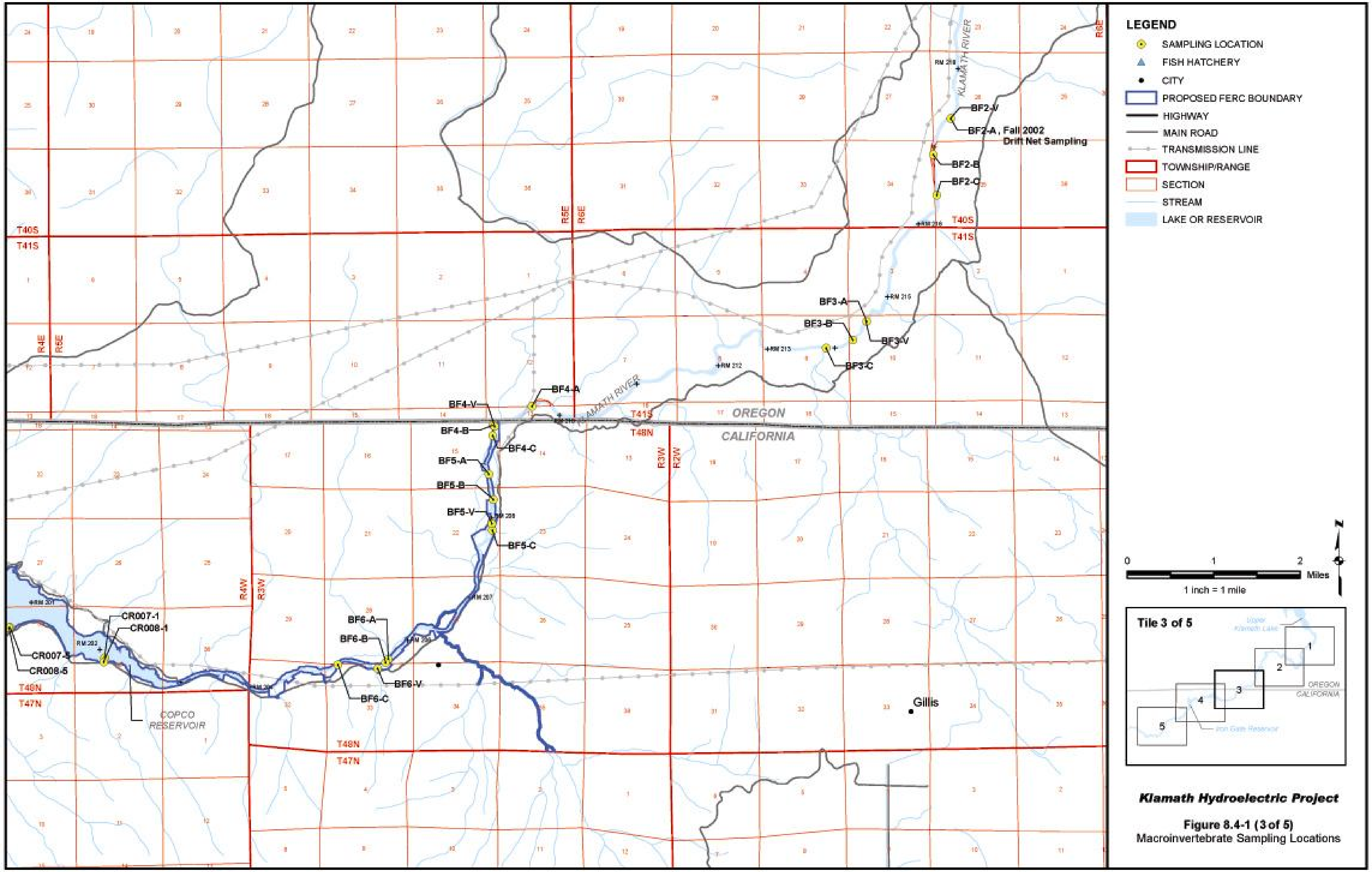


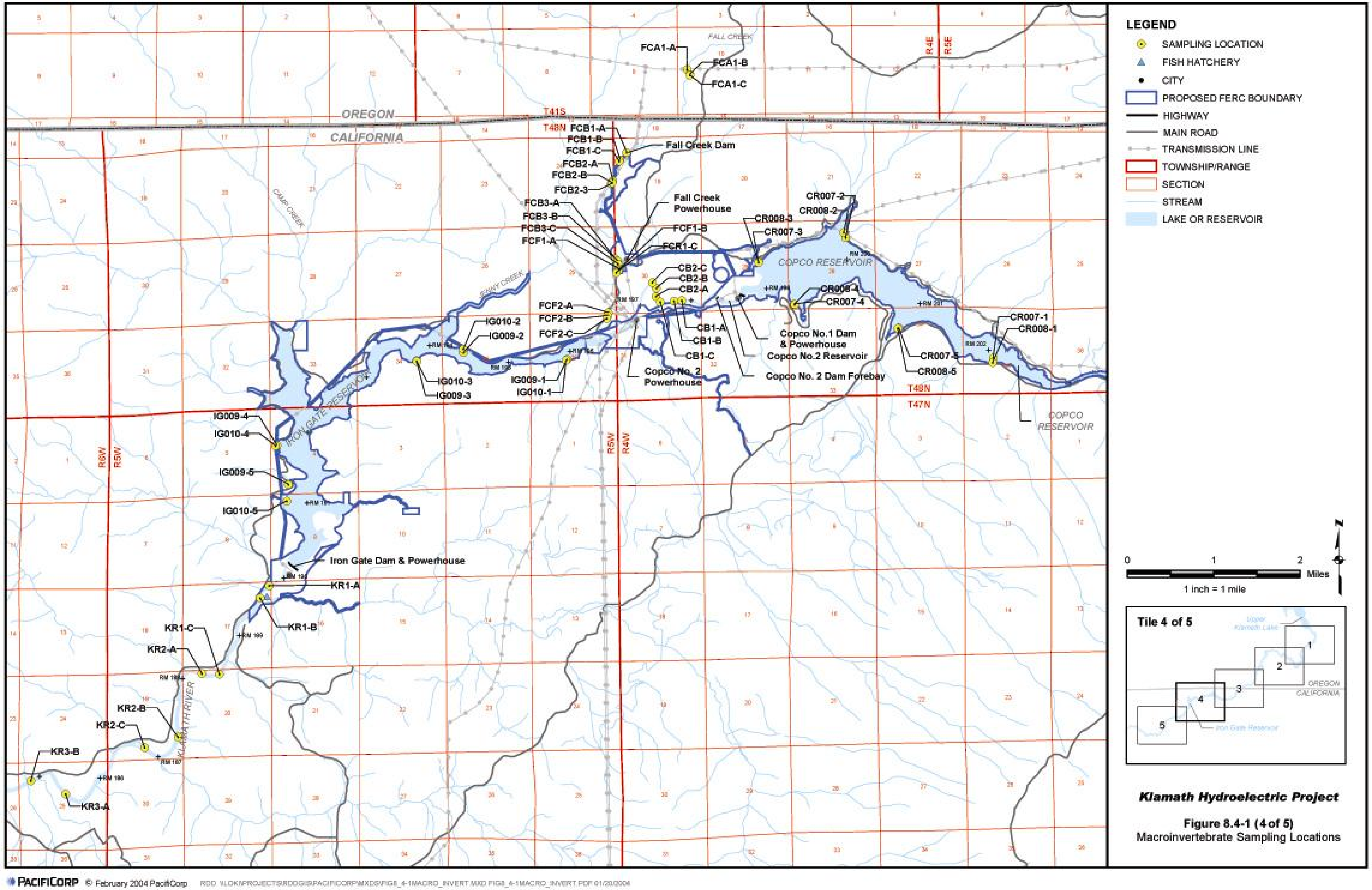
Figure 8.4-1 (1 of 5)
Macroinvertebrate Sampling Locations

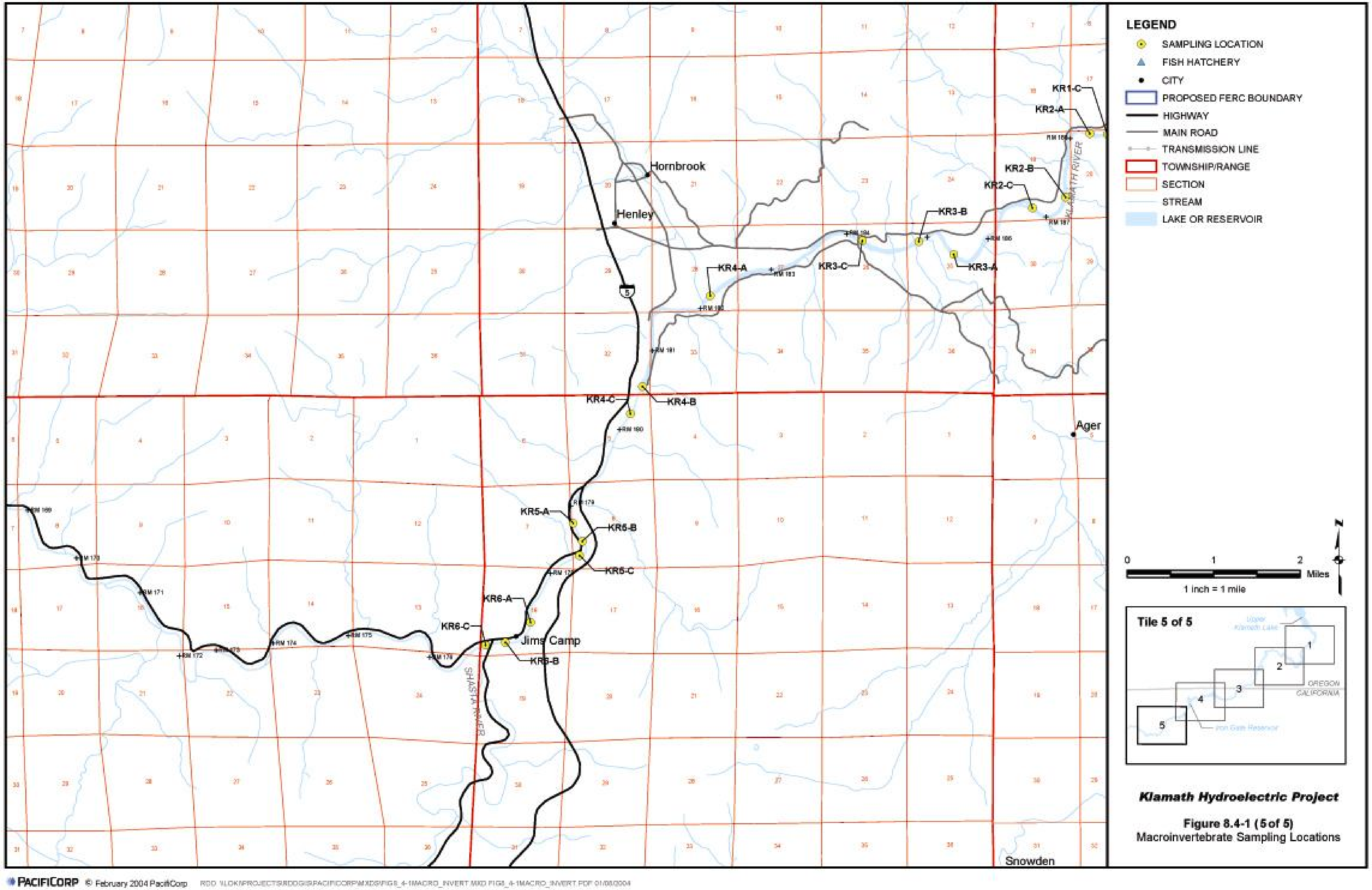

LEGEND
SAMPLING LOCATION
FISH HATCHERY
CITY
PROPOSED FERC BOUNDARY
HIGHWAY
MAIN ROAD
TRANSMISSION LINE
TOWNSHIP/RANGE
SECTION
STREAM
LAKE OR RESERVOIR
KDB-1
KDB-2
KDB-3
LEKR-1
LEKR-2
LEKR-3
KN004-5
KN003-5
KN004-4
KN003-4
KN003-3
KN004-3
KN003-1
KN004-1
KN003-2
KN004-2
Keno Dam
Keno
JCB006-4
JCB005-4
JCB006-1
JCB005-1
JCB005-3
JCB005-5
JCB006-3
JCB006-2
JCB005-2
J.C. Boyle Dam
J.C. BOYLE RESERVOIR
KLAMATH RIVER
KENO RESERVOIR
BB1-B
BB1-A
BB1-C
BB2-A
BB2-B
BB2-C
BB3-C
BB3-A
BB3-B
J.C. Boyle Powerhouse
BF1-V
BF1-A
BF1-B
BF1-C
BF2-V
BF2-A, Fall 2002 Drift Net Sampling
BF2-B
BF2-C
T39S
T40S
T41S
R6E
R7E
R8E
0 1 2 Miles
1 inch = 1 mile
Tile 2 of 5
OREGON
CALIFORNIA
Klamath Hydroelectric Project
Figure 8.4-1 (2 of 5)
Macroinvertebrate Sampling Locations
PACIFICORP © February 2004 PacifiCorp



Klamath Hydroelectric Project

Figure 8.4-1 (3 of 5)
Macroinvertebrate Sampling Locations


LEGEND
SAMPLING LOCATION
FISH HATCHERY
CITY
PROPOSED FERC BOUNDARY
HIGHWAY
MAIN ROAD
TRANSMISSION LINE
TOWNSHIP/RANGE
SECTION
STREAM
LAKE OR RESERVOIR
0
1
2
Miles
1 inch = 1 mile
Tile 4 of 5
1
2
3
4
5
OREGON
CALIFORNIA
OREGON
CALIFORNIA
T41S
T48N
T47N
R4E
R5E
R6W
R5W
R4W
FALL CREEK
CAMP CREEK
JENNY CREEK
KLAMATH RIVER
IRON GATE RESERVOIR
COPCO RESERVOIR
FCA1-A
FCA1-B
FCA1-C
FCB1-A
FCB1-B
FCB1-C
FCB2-A
FCB2-B
FCB2-3
Fall Creek Dam
Fall Creek Powerhouse
FCB3-A
FCB3-B
FCB3-C
FCF1-A
FCF1-B
FCF1-C
FCF2-A
FCF2-B
FCF2-C
CB2-C
CB2-B
CB2-A
CB1-A
CB1-B
CB1-C
Copco No. 2 Powerhouse
Copco No.1 Dam & Powerhouse
Copco No.2 Reservoir
Copco No. 2 Dam Forebay
CR007-2
CR008-2
CR008-3
CR007-3
CR008-4
CR007-4
CR007-1
CR008-1
CR007-5
CR008-5
IG010-2
IG009-2
IG010-3
IG009-3
IG009-1
IG010-1
IG009-4
IG010-4
IG009-5
IG010-5
Iron Gate Dam & Powerhouse
KR1-A
KR1-B
KR1-C
KR2-A
KR2-B
KR2-C
KR3-B
KR3-A
Klamath Hydroelectric Project
Figure 8.4-1 (4 of 5)
Macroinvertebrate Sampling Locations
PACIFICORP © February 2004 PacifiCorp



Klamath Hydroelectric Project

Figure 8.4-1 (5 of 5)
Macroinvertebrate Sampling Locations

8.6 TECHNICAL WORK GROUP COLLABORATION

PacifiCorp has worked with stakeholders to establish a more collaborative process for planning and conducting studies needed to support Project relicensing documentation. As part of this collaborative process, a Water Quality Work Group was formed and meets approximately monthly to plan and discuss water quality studies and results, including this macroinvertebrate study.

8.7 RESULTS

8.7.1 Lotic Stations (Klamath River Reaches and Fall Creek)

The overall longitudinal extent of the study reaches, extending from southern Oregon into northern California (see Figure 8.4-1), is associated with differences in physical habitat and associated water chemistry. As rivers flow through changing physical habitats and elevation gradients, they are host to changing macroinvertebrate communities. The principle of such longitudinal change is a central tenet of stream ecology, known as the “river continuum” concept (e.g., Vannote et al. 1980).

8.7.1.1 Physical Habitats

The mainstem of the Klamath River changes significantly in substrate character as it flows throughout the study reaches. Substrate character is an important physical habitat parameter in determining macroinvertebrate community structure. Changes in percentages of substrate types at Klamath River mainstem macroinvertebrate sampling sites are shown in Figure 8.7-1. Water chemistry changes observed at Klamath River mainstem macroinvertebrate sampling sites are shown in Figure 8.7-2. Groupings of stations by statistical similarity in physical habitat are shown in Figure 8.7-3. Upper, middle, and lower river reaches (as well as Fall Creek) all appear as distinct groups on the basis of substrate composition and embeddedness (Figure 8.7-3). It is apparent that substrate conditions demonstrate a longitudinal series of changes with elevation. This is not surprising, given the large boulder habitat and high velocities of the J.C. Boyle reaches compared with the cobble-dominated, slower-moving reaches of the river downstream of Iron Gate dam. In contrast, measures of channel erosion, bank stability, and riparian condition do not demonstrate the same geographic clusters (Figure 8.7-3). These factors are more variable by geographic location than by substrate characteristics (Figure 8.7-3).

Water quality conditions were variable throughout the study area during fall 2002 sampling. Some factors, such as pH and DO, are expected to be dynamic on a daily basis, and the individual, one-time measurements shown in Figure 8.7-2 are not particularly indicative of the station. Alternatively, conservative measures, such as specific conductance, are more indicative of cumulative water chemistry conditions and are relatively stable over the short term. The data appear to show the effects of the reservoirs on downstream water quality, although the results must be interpreted with caution as they represent different times of the day. Nevertheless, despite possible reservoir influences, neither pH nor DO appeared to exceed limits of concern for aquatic invertebrates or fish (Figure 8.7-2). Values for pH ranged from 7.5 to 9.3,

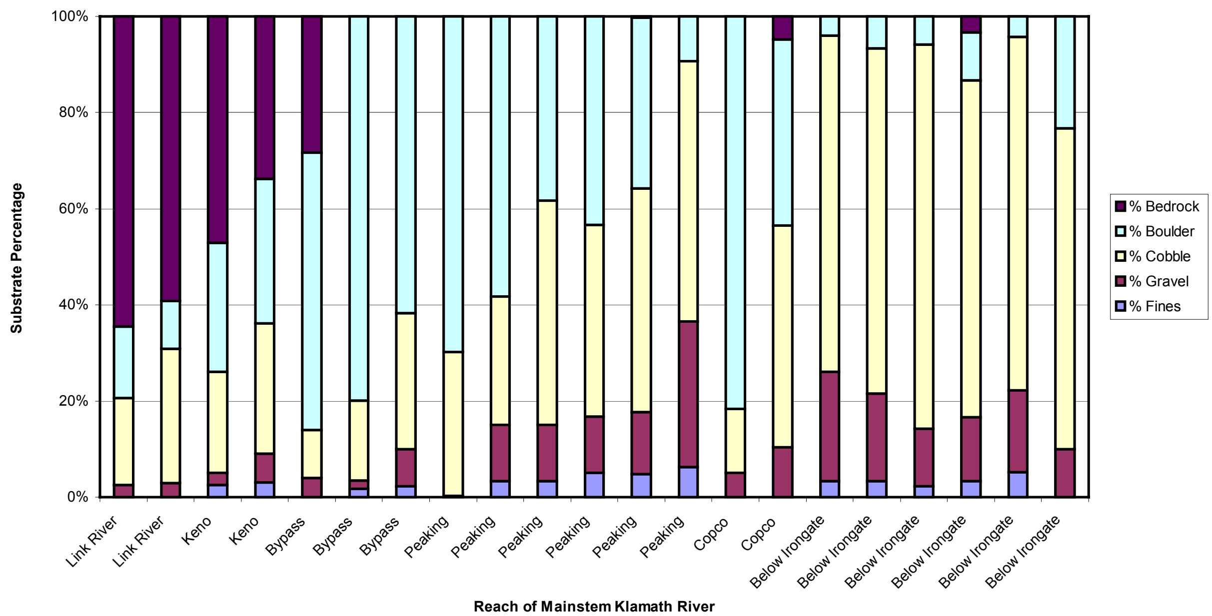


Figure 8.7-1. Substrate percentages at Klamath River mainstem macroinvertebrate sampling sites.

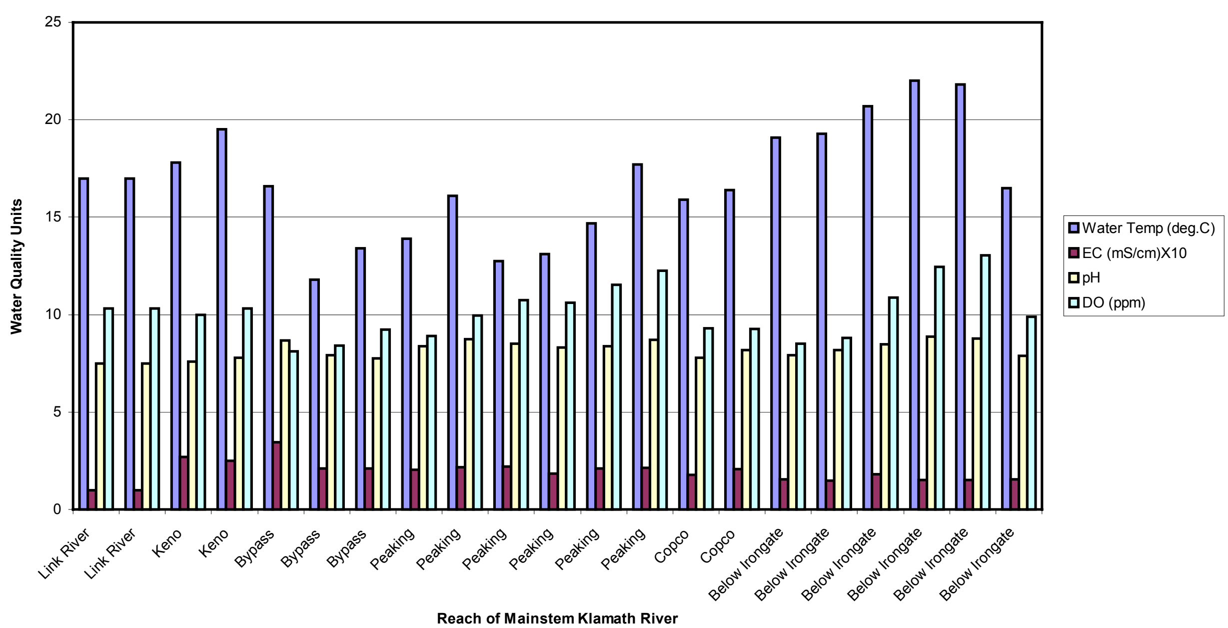


Figure 8.7-2. Water quality measurements during sampling at Klamath River mainstem macroinvertebrate sample sites.

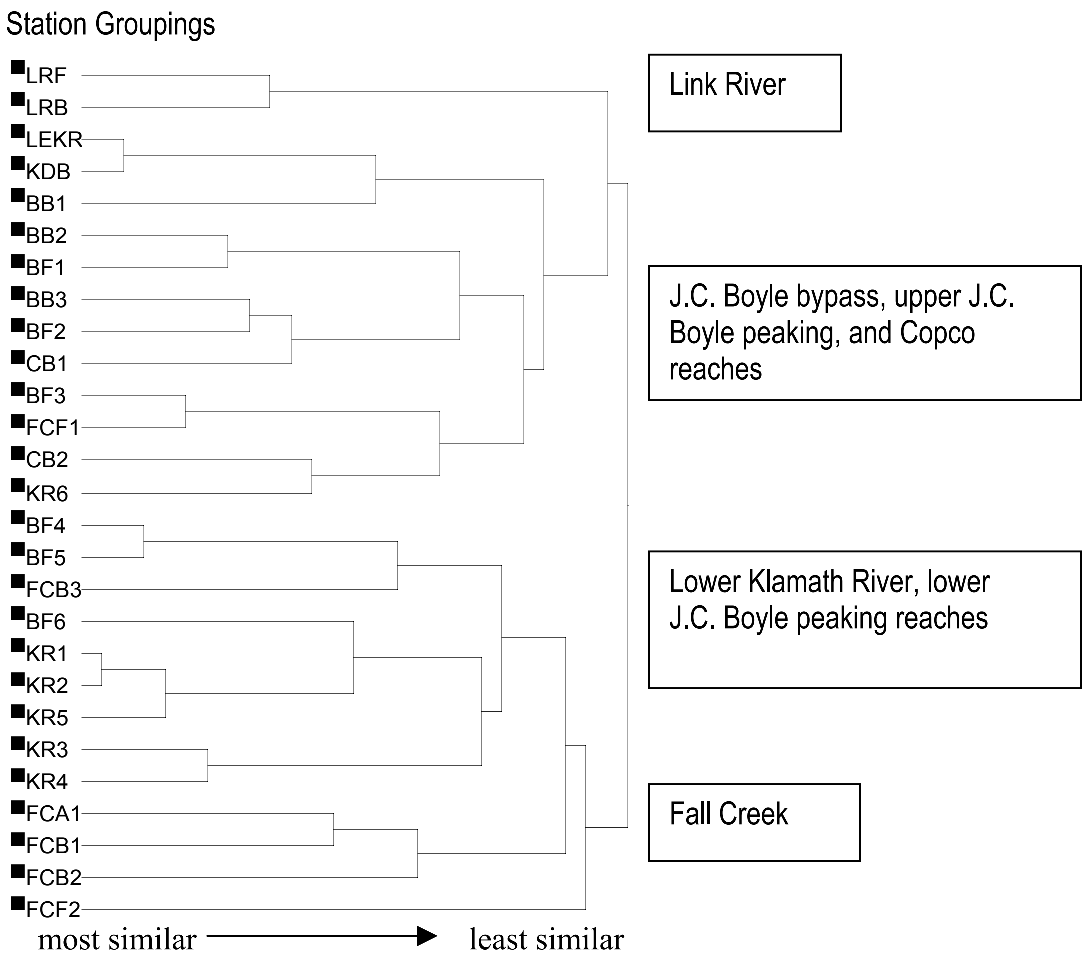


Figure 8.7-3. Hierarchical clustering of reaches based on substrate composition and embeddedness.

DO from 8.1 to 14 mg/L, and specific conductance from 0.1 to 0.345 µS/cm, all indicative of productive alkaline waters. Like DO and pH, water temperature is highly variable and dependent upon time of day and season. For this study, stream water temperatures ranged from 8.5° to 22°C. These single values cannot capture the important range of daily, monthly, or seasonal variation. For example, the high value of 22°C taken in the afternoon of a single day does not represent a seasonal average or even a daily average condition.

Several important pairwise comparisons of stations were tested for statistical similarities related to physical habitat as a means of relating patterns to those of macroinvertebrate community structure. Comparisons of adjacent sections of river (e.g., Upper Klamath River stations to J.C. Boyle bypass) indicated generally similar physical conditions in geographically adjacent areas. In fact, bank stability, riparian vegetative cover, sediment deposition, and embeddedness were statistically similar among all reaches. The few significant differences did not indicate any strong trends (Table 8.7-1). For example, J.C. Boyle peaking reach sections were not noticeably or consistently different from bypass sections with respect to physical habitat. The major changes in physical habitat are longitudinal and elevation-related (e.g., substrate percentages at sites, depicted in Figure 8.7-1). Potential project-related impacts (such as lack of sediment deposition or increased embeddedness [armoring], as might be expected in the peaking reach) were not revealed from the statistical comparisons of habitat by reach. Cobble-boulder substrates were dominant throughout the study reach of the main river, and riffle habitats were found for macroinvertebrate sampling in all reaches.

Table 8.7-1. Significant differences in physical habitat characteristics by reach comparison.

J.C. Boyle Peaking Reach to J.C. Boyle Bypass	Fall Creek Full-Flow Reach to Fall Creek Bypass	Upper Klamath to J.C. Boyle Bypass	J.C. Boyle Peaking Reach to Lower Klamath
Channel flow (BB)	Cover (FF)	Riffle frequency (BB)	Channel alteration (BF)
			Riparian vegetative zone (BF)

Note: Abbreviations for stations with higher habitat quality values are indicated. All relationships are significantly different, $P < 0.05$, ANOVA.

8.7.1.2 Macroinvertebrate Communities

A complete listing of macroinvertebrate counts, species lists, and metrics is provided in Appendix 8A (Tables 8A-1, 8A-2, and 8A-3). A listing of long-lived taxa, tolerant taxa, and intolerant taxa is also provided in Appendix 8A (Tables 8A-4, 8A-5, and 8A-6). Summary information and statistical comparisons are presented here.

The macroinvertebrate counts were presented as density of each species by sampling site (Appendix 8A, Table 8A-1) and grouped as a series of standard metrics, following discussion with CDFG and ODEQ staff (Table 8.7-2). Summary information is presented here in the form of cluster analysis results, showing similarities among river reaches based on groups of metrics, and by ANOVA test results, showing which selected stations are statistically similar or different.

Table 8.7-2. Standard list of benthic macroinvertebrate metrics used in this analysis.

Metrics	Metrics
Total abundance, H	Total taxa richness, H
EPT taxa richness, H	EPT index, H
Sensitive EPT index, H	Shannon diversity (log e), H
Total ephemeroptera taxa, H	Total plecoptera taxa, H
Total trichoptera taxa, H	Tolerant taxa richness, L
Long-lived taxa %, H	Long-lived taxa richness, H
Tolerant taxa %, L	Intolerant taxa %, H
Hydropsychidae %, L	Baetidae %, L
Dominant taxa %, L	Collectors %, L
Filterers %, L	Scrapers (grazers) %, variable
Predators %, variable	Shredders %, H
Collector-filterer abundance, L	Collector-gatherer abundance, L
Predator taxa richness, H	Scraper abundance, variable
Scraper taxa richness, variable	Hilsenhoff Biotic Index (HBI score), L

Note: H or L = Better conditions that are represented by either Higher (H) or Lower (L) score (varying among metrics); H or L indicates the direction of the better, less impaired conditions. Variable = uncertain relationship between metric score and environmental conditions (CDFG, 1999a).

Figures 8.7-4 through 8.7-7 show the cluster analysis groupings of similar sampling locations based on the similarity among sites for the values of various important metrics. In general, the cluster results showed that Link River, Fall Creek, and the J.C. Boyle varial zone samples tended to fall into separate groupings than the other stations. When examining the percentages in various functional feeding groups, Fall Creek was the most distinct outlier (Figure 8.7-5). When comparing sites on the basis of diversity and tolerance indices, the Fall Creek and J.C. Boyle varial zones appeared as distinct groups (Figure 8.7-6). Taxa richness metrics generally confirm these results; Fall Creek, the Link River sites, and the J.C. Boyle varial zones all clustered distinctively from the other mainstem Klamath River sites (Figure 8.7-7).

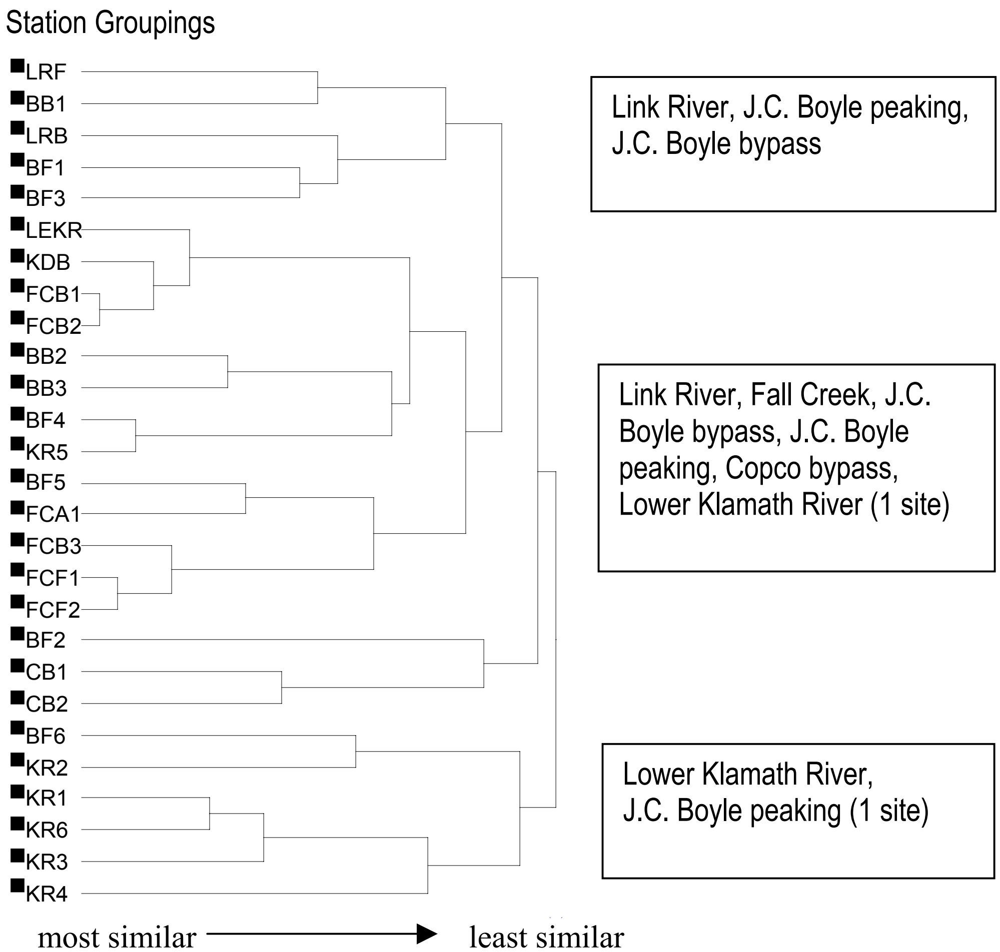


Figure 8.7-4. Hierarchical clustering of sampled reaches based on riparian and channel condition measures.

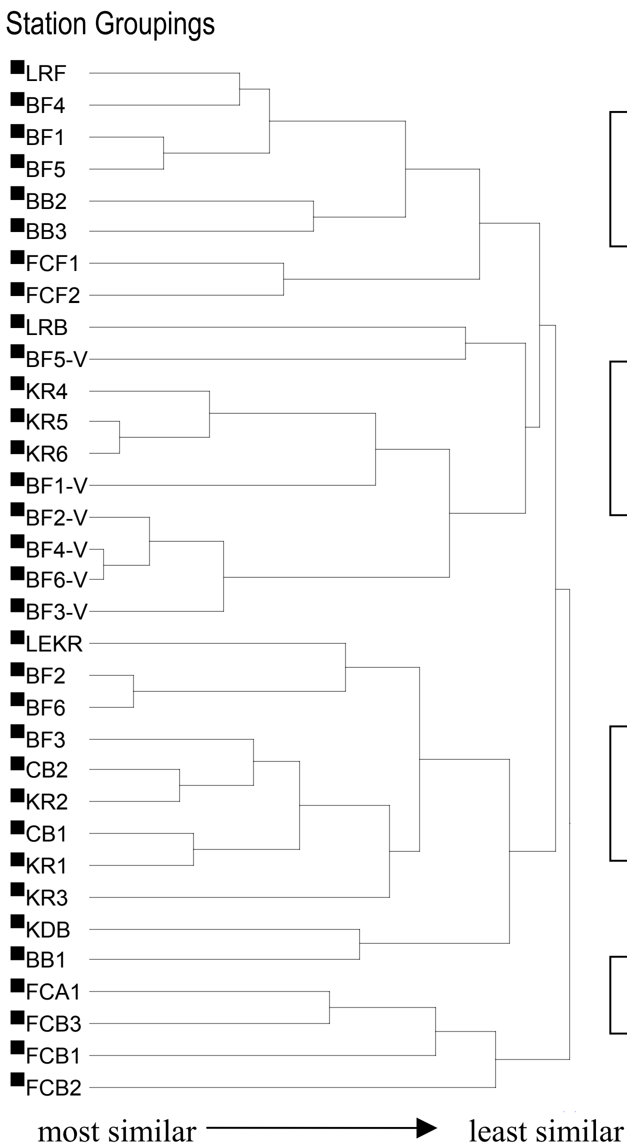


Figure 8.7-5. Hierarchical clustering of reaches based on functional feeding groups.

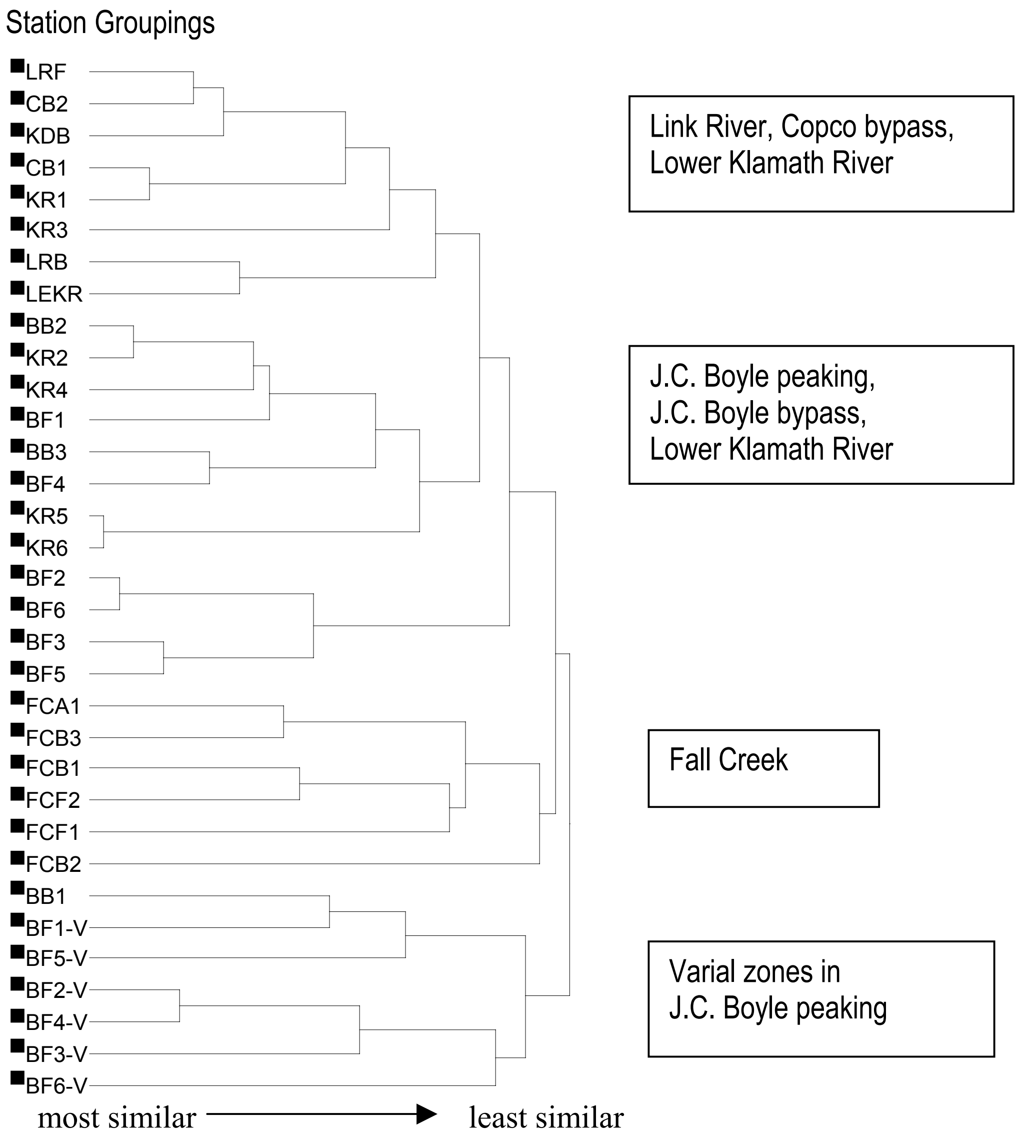


Figure 8.7-6. Hierarchical clustering of reaches based on combined biotic indices (diversity, HBI, sensitive EPT, tolerant, intolerant, dominant taxa).

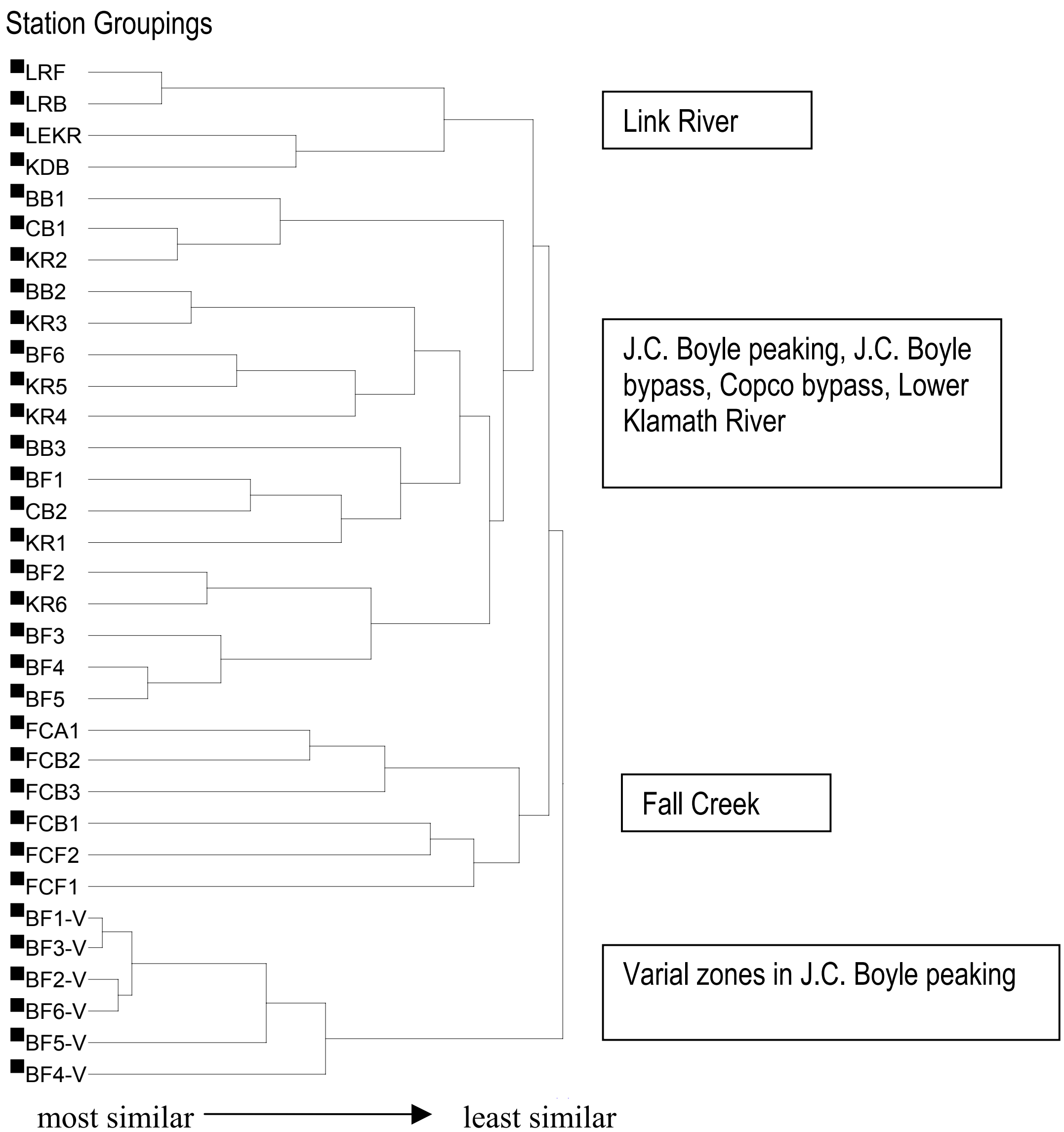


Figure 8.7-7. Hierarchical clustering of reaches based on combined taxa richness metrics.

The analysis of statistically different metrics by station helps to confirm the cluster analysis results. Table 8.7-3 presents selected comparisons among reaches and, of those, identifies which reach ranks are "less impaired" (i.e., better than average conditions) as a result of the comparison. From this analysis, it appears that a comparison of the J.C. Boyle peaking and bypass reaches shows varied results. The peaking reach scores higher for ephemeroptera, plecoptera, trichoptera (EPT) taxa and Hilsenoff Biotic Index (HBI) (lower score), but the bypass has higher scores for intolerant taxa richness (Table 8.7-2). The Fall Creek full-flow reach was generally similar to the Fall Creek bypass, except for two taxa groups that favored the full-flow reach. Macroinvertebrate metrics did not reveal a consistent effect of peaking operations as revealed by these comparisons.

Adjacent sites were generally similar with respect to the macroinvertebrate communities. When comparing longitudinally adjacent reaches, there appeared to be no distinct or consistent patterns.

From the Upper Klamath River through the J.C. Boyle bypass or from the J.C. Boyle peaking reach to the Lower Klamath River, there are few statistical differences (Table 8.7-3).

Table 8.7-3. Significant differences in macroinvertebrate metrics by reach.

J.C. Boyle: Peaking to Bypass	J.C. Boyle Peaking to Varial	Fall Creek: Full-Flow to Bypass Reaches	Upper Klamath River to J.C. Boyle Bypass	J.C. Boyle Peaking to Lower Klamath River
Ephemeroptera taxa (BF)	Abundance (BF)	Plecoptera taxa (FCF)	Abundance (UKR)	% Hydropsychidae (LKR)
% Hydropsychidae (BF)	Ephemeroptera taxa (BF)	% Baetidae (FCB)	% Hydropsychidae (BB)	% Baetidae (LKR)
EPT Index (BF)	Plecoptera taxa (BF)		EPT taxa richness (BB)	EPT Index (BF)
EPT taxa richness (BF)	Trichoptera taxa (BF)			
Intolerant taxa richness (BB)	% Hydropsychidae (BV)			
HBI (BF)	% Baetidae (BV)			
	% Dominant taxa (BF)			
	% Collectors (BV)			
	% Filterers (BF)			
	% Scrapers (BF)			
	EPT Index (BF)			
	Shannon diversity (BF)			
	EPT taxa richness (BF)			
	Tolerant taxa richness (BV)			

Note: Abbreviations for stations with less impaired condition are shown. All relationships are significantly different, $P< 0.05$, ANOVA.

The varial zone analysis showed a more clear cut response. With the exception of metrics associated with tolerant taxa and one group of caddisflies, the J.C. Boyle peaking reach showed much better condition (less impairment) than the varial zone samples. The statistical difference between the J.C. Boyle peaking stations and the associated varial zones provided the most distinct difference among groups of stations.

Molluscs were separately assessed for this study (in addition to their contribution as “non-insects” to the metrics discussed above). Detailed data are provided for mollusc species by sampling location in Appendix 8A (Table 8A-7). A comparison among river reaches on the basis of density by major molluscan taxonomic groups showed that Fall Creek had statistically higher numbers of both pelecypod (snail) and gastropod (clam) species than all other riverine sites ($P< 0.05$, ANOVA). This is another measure of the distinctness of this tributary from the mainstem sites. Other stations were statistically similar with respect to the general abundance of molluscs. Note that a number of poorly described and new species of molluscs were found during this study (Table 8A-2).

A separate set of macroinvertebrate samples was collected as riverine drift samples from nets set in the J.C. Boyle peaking reach. Three nets were sampled from sites at the margin and mid-channel at various times throughout a single day. Results are presented in Appendix 8A (Table 8A-8). When standardized by the volume of water passing the net over the sampling interval, some patterns emerged. As the peaking flows gained and lost more than 2 feet in stage height at the mid-channel net, the aquatic insects experienced an initial increase in drift, followed by a gradual (but highly variable) decline throughout the rest of the day. The peak in aquatic insect drift appeared near 10:00 a.m., while the peak in flows was at least 2 hours later. Terrestrial insect drift followed the same general pattern, but it was too low in density to allow for meaningful interpretation (Figure 8.7-8).

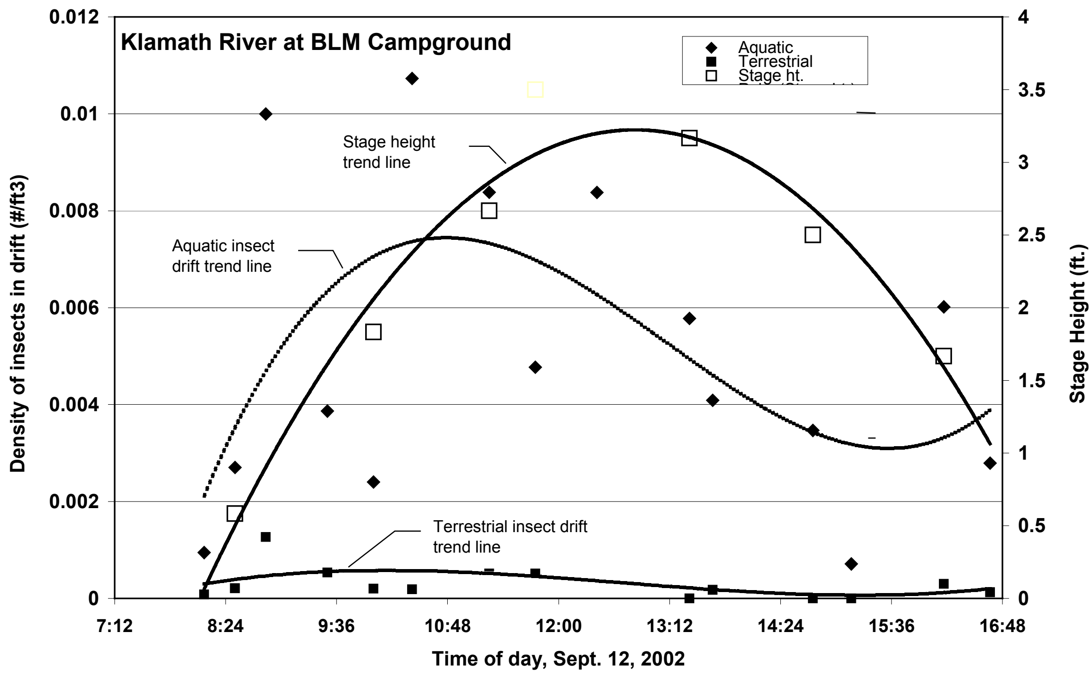


Figure 8.7-8. Macroinvertebrate drift in the J.C. Boyle peaking reach of the Klamath River during a peaking cycle on September 12, 2002. Combined results are from three channel sampling zones. Trend lines fitted to the data are based on third-order polynomials.

It is uncertain from this analysis whether aquatic insect drift was causally linked to the pulsed increase in flow or whether it followed a daily pattern related to invertebrate behavioral changes. Only one day was sampled, and flow-adjusted drift numbers were not statistically related to flow during this single day ($P > 0.05$, t-test). In general, drift varied by a factor of at least five over the course of the day (much more variable than flow) and was only roughly related to the pattern of changes in flow (Figure 8.7-8). It is generally known that drift invertebrates are a selective subset of the benthic macroinvertebrate community and that drift is enhanced by increased velocity of flows (e.g., Hynes, 2001). The Klamath samples followed this general trend but did not yield a quantifiable positive relationship between drift and flow.

The small polychaete worm, *Manayunkia speciosa*, was found in low abundance in the drift samples (Appendix 8A, Table 8A-8), but not observed in the kicknet samples. This worm is the intermediate host for the parasite *Ceratomyxa shasta*, a microscopic myxosporean protozoan causing disease in salmon and trout. This polychaete is presumed to be required for the spread of the parasitic disease in salmonids and previously has been documented throughout the Klamath River drainage (Bartholomew, 2001).

Longitudinal changes in key invertebrate metrics show trends moving downstream along the mainstem Klamath River. There appears to be a gradual increase in total taxa richness and tolerant taxa richness moving downstream (Figures 8.7-9 and 8.7-10, respectively), with an opposite trend for the percent dominant taxa (Figure 8.7-11). All riverine reaches are dominated by collector and filterer feeding groups, although some localized differences are found in the upper J.C. Boyle bypass reaches (Figure 8.7-12). The EPT index peaks in the J.C. Boyle peaking reaches and gradually declines moving downriver (Figure 8.7-13), whereas other indices (Shannon diversity, HBI) do not show consistent trends (Figures 8.7-14 and 8.7-15, respectively).

Many individual species spanned the entire longitudinal study reach and did not show clear Project-related effects. For examples, the mayfly (*Baetis tircaudatus*) and caddisfly (*Leucotrichia* sp.) were found throughout the study area, with peak abundances in the J.C. Boyle bypass reach, J.C. Boyle peaking reach, and main river below Iron Gate reservoir (Appendix 8A, Table 8A-1). Some species were dominant in discontinuous reaches, such as blackflies (*Simulium* sp.) in the J.C. Boyle bypass and lowermost river sections. Some, like the large stonefly (*Pteronarcys californica*), were found throughout the study area, but were most abundant in the reaches downstream of Iron Gate reservoir. Dominant beetle species traded abundance patterns, with *Opitioservus* sp. being abundant in the upper, peaking reach and *Zaitsevia* sp. becoming dominant in the reaches below Iron Gate reservoir.

The sum total of the tolerance scores of these individual species is used in calculating the HBI, as depicted in Figure 8.7-15. As such, the HBI represents some of the community implications of the changes in individual species discussed above. As lower HBI scores represent higher quality conditions, Figure 8.7-15 appears to indicate improved conditions within the peaking reach as compared to the bypass (shown in the Table 8.7-3 statistical summary as well), and in the peaking reach and lower river as compared to all other sites. Similarly, Karr and Chu (1999) propose a relative ranking among stations based on the ranks of combined metrics. However, the individual metrics discussed above provide more detail that might reveal important differences among reaches.

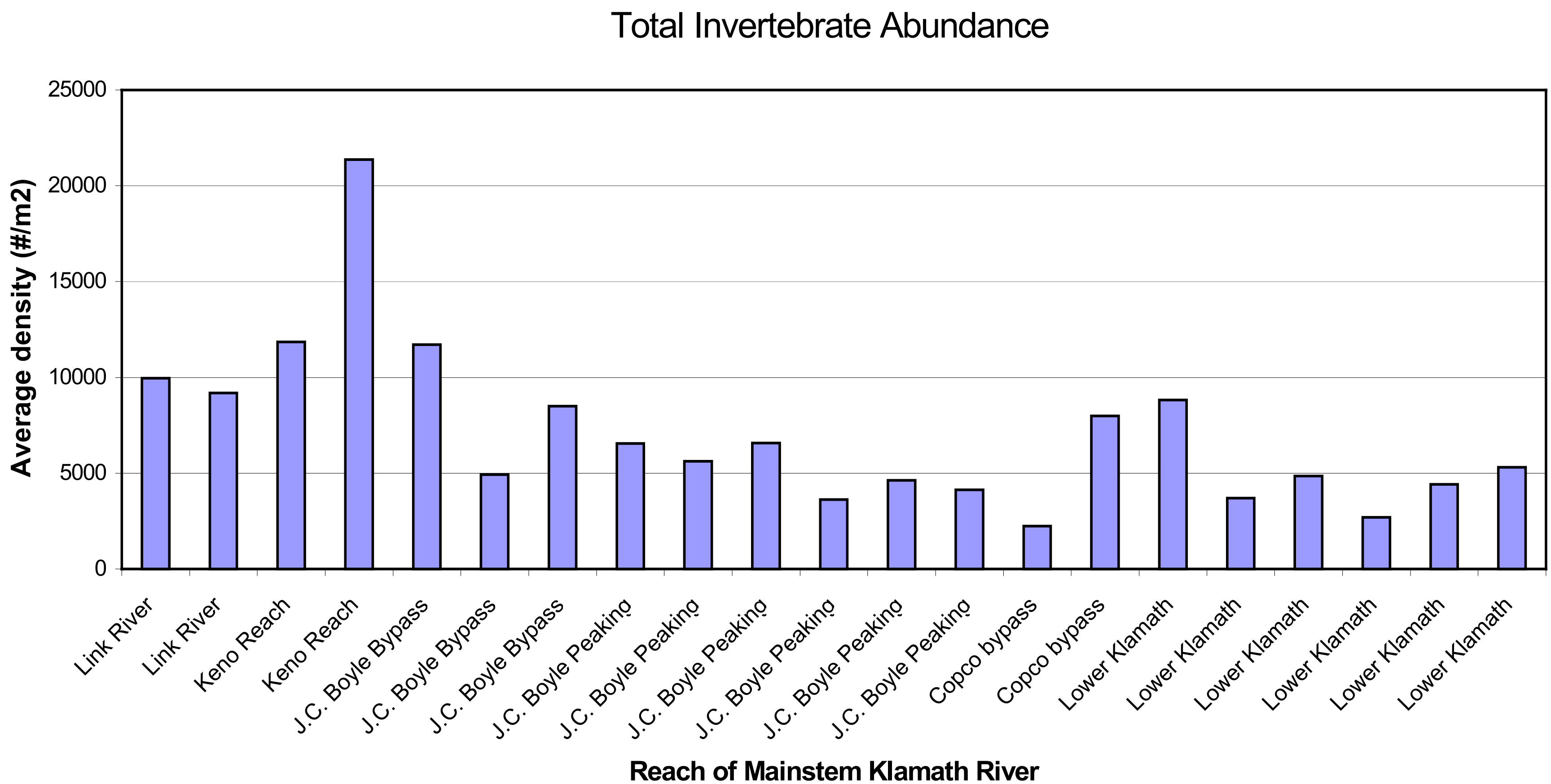


Figure 8.7-9. Macroinvertebrate abundance versus sampling reach on the Klamath River mainstem.

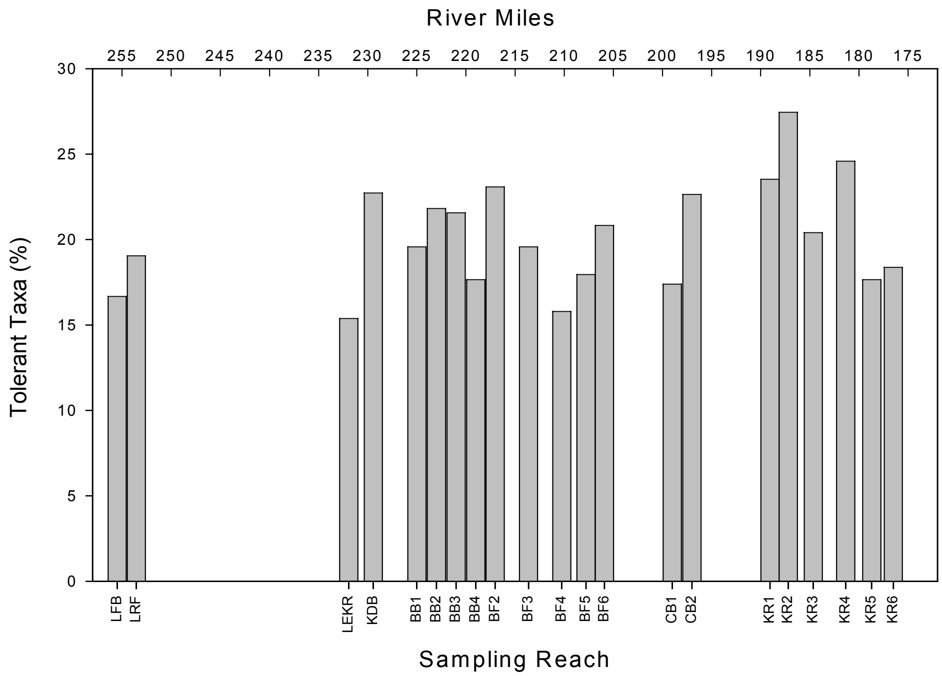


Figure 8.7-10. Macroinvertebrate tolerant taxa versus sampling reach on the Klamath River mainstem. Reaches are plotted sequentially by river miles from the most upstream reach sampled (Link River bypass).

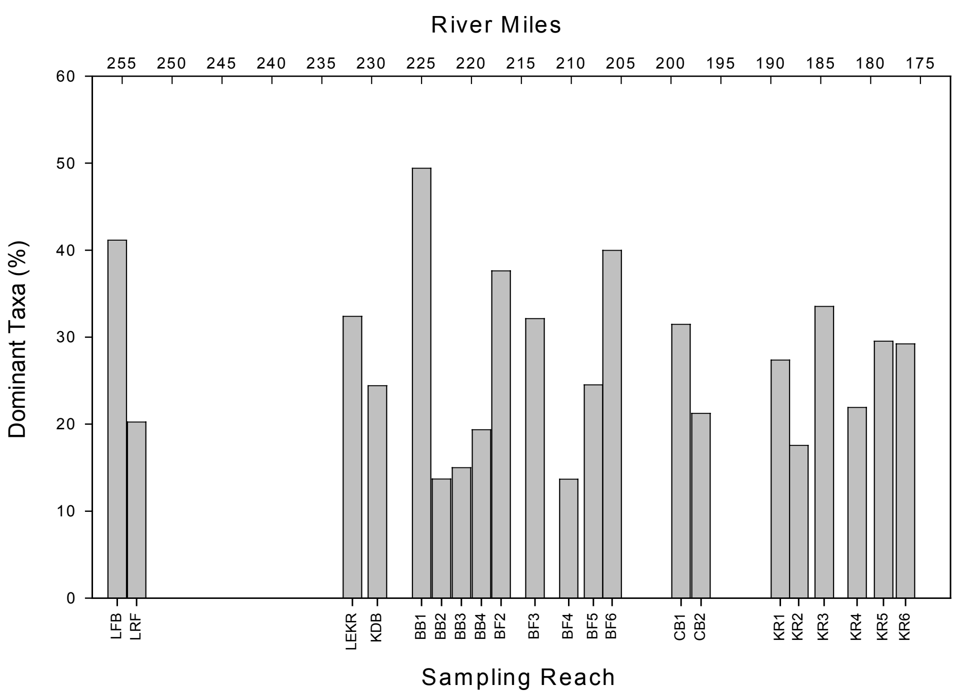


Figure 8.7-11. Macroinvertebrate dominant taxa versus sampling reach on the Klamath River mainstem. Reaches are plotted sequentially by river miles from the most upstream reach sampled (Link River Bypass).

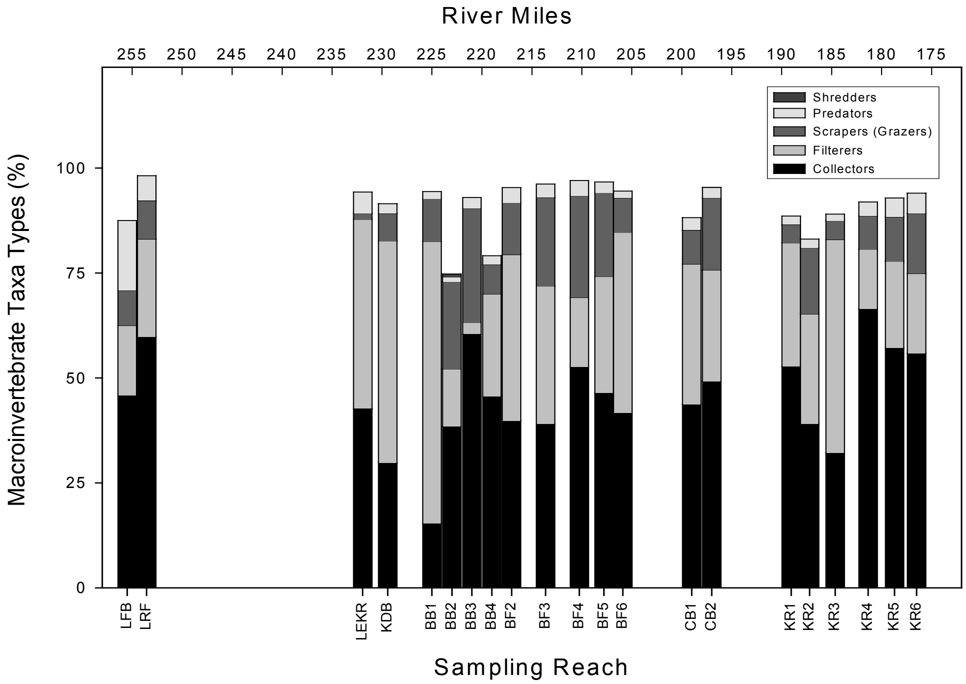


Figure 8.7-12**.** Percent of macroinvertebrate taxa types versus sampling reach on the Klamath River mainstem. Reaches are plotted sequentially by river miles from the most upstream reach sampled (Link River bypass).

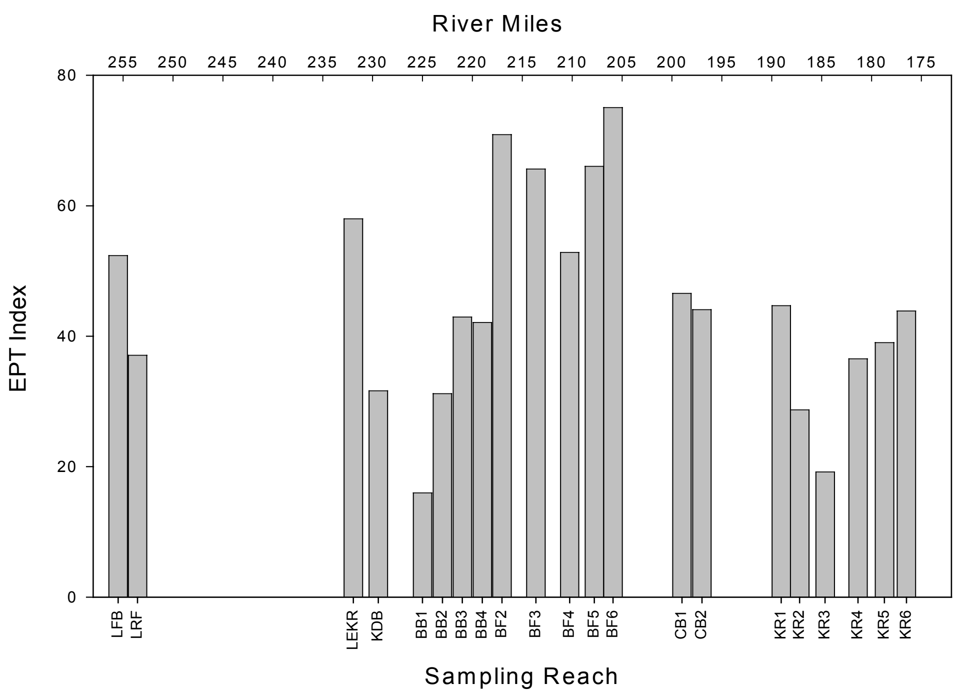


Figure 8.7-13. Macroinvertebrate EPT index versus sampling reach on the Klamath River mainstem. Reaches are plotted sequentially by river miles from the most upstream reach sampled (Link River bypass).

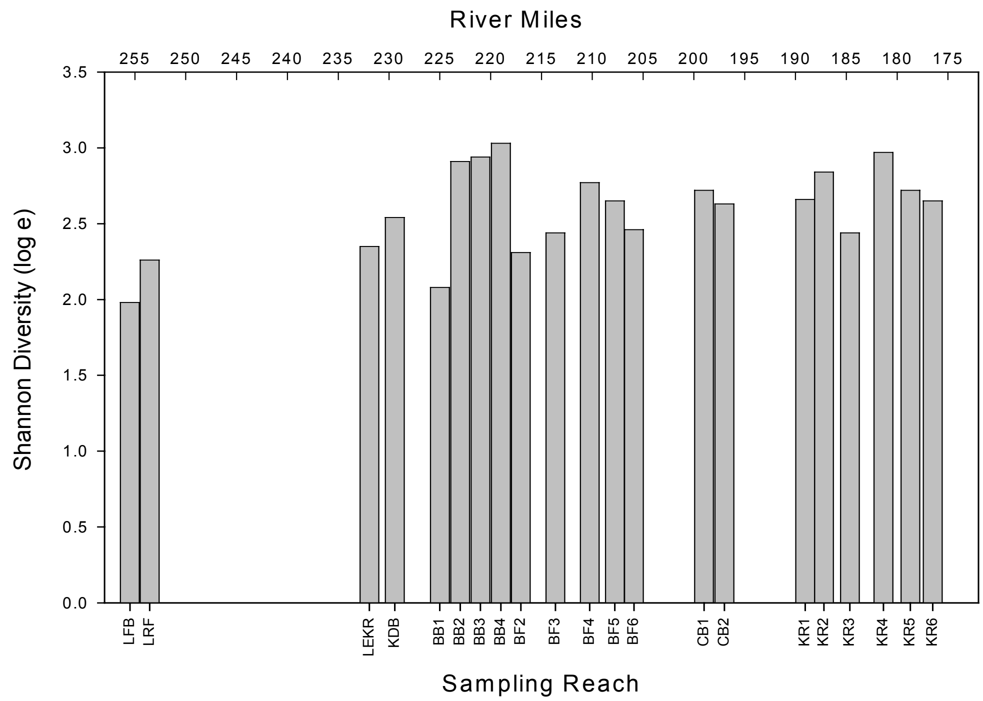


Figure 8.7-14. Shannon diversity versus sampling reach on the Klamath River mainstem. Reaches are plotted sequentially by river miles from the most upstream reach sampled (Link River bypass).

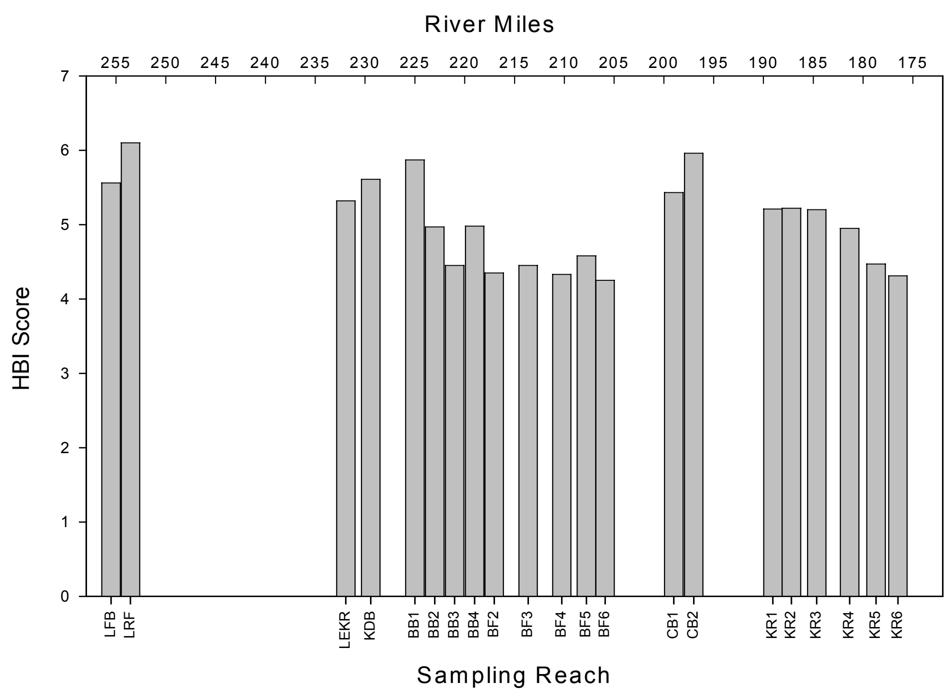


Figure 8.7-15. Macroinvertebrate Hilsenoff biotic index (HBI) score versus sampling reach on the Klamath River mainstem. Reaches are plotted sequentially by river miles from the most upstream reach sampled (Link River bypass).

8.7.2 Lentic Stations (Reservoirs)

The results for macroinvertebrate abundance and diversity from reservoirs are not strictly comparable to riverine data. Standard lentic CDFG protocols were followed and invertebrates were collected at all sites. Molluscs were enumerated separately, in detail. However, much less is known about the ecological meaning of differences in community structure as observed among groups of lake sediment invertebrates. Count and metric results are presented in Appendix 8A (Table 8A-9).

Some limited patterns are evident in the reservoir results. A lack of replicate samples by sampling type per reservoir (as would be similar to the replication within river reaches) limited the ability to statistically separate reservoirs on the basis of metric values. The two samples taken at each reservoir were collected using two independent methods and are meant to be complementary rather than to provide duplicate samples. Nevertheless, when grouped by reservoir, limited patterns were observable. The invertebrate fauna of Lake Ewauna showed evidence of impairment compared to the communities of the other lakes. Results are summarized in Table 8.7-4.

The invertebrate community of Lake Ewauna displayed a number of distinct characteristics 0that are indicative of more stressed conditions than the other reservoirs. Although possessing greater invertebrate abundance (but not of molluscs), diversity was low and the community was dominated by only a few species (Table 8.7-4). Other metrics were statistically similar among the reservoirs. Some taxa, such as plecoptera, were not expected and were not found in the lakes. In general, the fauna from all lakes was dominated by “tolerant” taxa—i.e., those taxa judged most tolerant of impaired conditions. The tolerant taxa group was dominated by Chironomid midges in all reservoirs (Appendix 8A, Table 8A-9).

Table 8.7-4. Distinct macroinvertebrate metrics indicating impaired conditions at Lake Ewauna ($P < 0.05$, ANOVA).

Metric	Statistically Distinct Reservoir from Lake Ewauna	Community Condition of Lake Ewauna Relative to the Other Reservoirs
Total Invertebrate Density	All others	Greater abundance
Species Diversity (Shannon)	All others	Lower diversity
Dominant Taxa, %	Copco, Iron Gate	Greater %
Tolerant Taxa, %	All others	Lower %
Pelecypod Mollusc Density	Keno	Lower density
Gastropod Mollusc Density*	J.C. Boyle	Lower density

*Iron Gate and Keno are also statistically lower density than J.C. Boyle.

8.8 DISCUSSION

The macroinvertebrate communities of the study riverine reaches and reservoirs revealed some basic differences among sites, most of which are attributable to expected differences associated with geographic variation and the longitudinal or elevation changes in riverine communities. The physical habitats along the river were variable in predictable ways, with fast water and boulder substrates predominating in the steep J.C. Boyle canyon reaches and a wider, even-flowing, cobble-bottomed river in the lower reaches below Iron Gate reservoir.

The existing conditions are indicative of gradual, longitudinal change along the nearly 80 miles of river from southern Oregon through northern California that were considered in the scope of this study, punctuated by the influence of reservoirs on downstream stations. Physical habitats and flows all reflect these general, large-scale changes. Figures 8.7-1 and 8.7-2 illustrate these physical habitat and water quality changes throughout the various study reaches.

The stream macroinvertebrate communities do not strongly reflect these longitudinal changes in physical habitat (e.g., Figures 8.7-9 to 8.7-15). However, some differences were observed between full-flow and bypass reaches and between geographically separate locations. Metrics showing elevation trends included taxa and EPT taxa richness, the percent dominant taxa, and the EPT index. Except for the declining EPT index, the trends are indicative of improved downstream conditions.

Full-flow and bypass comparisons were not distinctive. For both the J.C. Boyle peaking/bypass and the Fall Creek full-flow/bypass reach comparisons, most metrics did not vary significantly. For those that did, results were divided, which would indicate improved ecological conditions in either one type of reach or the other (Table 8.7-3). Similarly, geographically adjacent mainstem reaches were mostly similar with respect to metrics. The Upper Klamath/J.C. Boyle bypass and Lower Klamath/J.C. Boyle peaking comparisons did not indicate any consistent differences between paired reaches based on the tested metrics (Table 8.7-3).

The most distinct site, where conditions may reflect Project operations, was BB1, the uppermost J.C. Boyle bypass section site. At that location, evidence for slightly degraded conditions included increased dominant taxa percentage, altered feeding guilds, decreased EPT index and taxa, and lowered Shannon diversity index (Figures 8.7-11 to 8.7-14). However, not all metrics indicated degraded conditions at that location (see Figures 8.7-10 and 8.7-15). In addition, these degraded conditions were limited to that one site and did not persist in moving downstream through the rest of the reach. It is therefore doubtful that Project operations (decreased flows in the bypass reach) were the cause of unique macroinvertebrate community conditions at the single site. Rather, it is likely that local physical habitat conditions were most important in determining the macroinvertebrate metrics observed at site BB1.

The most consistent difference between pairs of tested reaches was between the wetted, central channel of the J.C. Boyle peaking reach and the reach's associated varial zones. This is not surprising because the varial zones were dry for a portion of each day. As expected, abundance and taxa richness measures all favored the wetted, central channel samples (Table 8.7-3). However, a few metrics favored varial zone results (percent baetidae, hydropsychidae, and collectors, and tolerant taxa richness). The varial and mainstem zones were so close, spatially, that it is not surprising they share the same underlying faunal base. Thus, comparisons based on percent composition cannot be expected to be as distinct as those based on abundance. The decreased abundance and lowered total taxa richness of the varial zones was expected and was found conclusively.

Comparisons between the peaking and bypass reaches demonstrated generally improved metrics scores for the peaking sites. Many of the dominant species of invertebrates in the peaking reach were found throughout the length of the river. There is no evidence for impairment of the macroinvertebrate community within the peaking reach, with the exception of the limited community available in the varial zone.

The drift sample results were generally supportive of the concept that drift is enhanced by increased flows because both drift and flows showed midday peaks. However, the relationship was statistically weak and the implications for river operations are unclear. For example, if drift is enhanced as a result of peaking flows, it is not clear that this is in any way detrimental or significant to either the macroinvertebrate or fish communities. The small numbers of the polychaete host for *Ceratomyxa shasta* found in drift samples indicate the potential presence of the salmonid disease in the study reach.

The reservoirs were dominated by tolerant fauna (compared to the streams) and were basically similar to each other in terms of community structure, with the exception of Lake Ewauna. The macroinvertebrate community of Lake Ewauna was dominated by a few tolerant species, with overall lowered species diversity but high abundance. It is not known what specific factors are responsible for generally degraded macroinvertebrate community conditions at this reservoir. Detailed and long-term water chemistry sampling at the reservoirs provides some supportive evidence for water quality impairment at Lake Ewauna compared with the other reservoirs. Lake Ewauna has highly enriched conditions, excessive algae growth, and summertime depletion of DO (see Section 3.0 of this document). High algal densities occurred at the time of the fall 2002 macroinvertebrate sampling, which also may have impaired adequate sample collection (Raymond, pers. comm., 2002).

In addition to developing baseline data on macroinvertebrates of the study area, it is possible to address some of the objectives and key questions raised in this study. Also, comparisons between the fall 2002 and spring 2003 results are available as part of Section 12, the spring 2003 results. The major project objectives and questions are:

1. Characterize macroinvertebrate presence and community composition in waters affected by the Project.

The macroinvertebrates have been characterized throughout the study area as part of both this fall 2002 report and the spring 2003 sampling and report. The diversity of sites provided an ability to characterize current conditions and to evaluate altered conditions as affected by the Project.

2. Do waters affected by the Project support healthy and diverse residential macroinvertebrate communities?

The variability in community macroinvertebrate communities is discussed above, including potential Project impacts. The communities appear comparable in overall taxa richness and abundance to those of other similar-sized river systems in the region (e.g., Clackamas and Willamette). The Klamath River’s taxa richness is relatively higher for midges, non-insects, and other Diptera, while EPT richness is generally lower. There is no dramatic evidence of impairment to macroinvertebrate communities related to Project operations. The peaking reach is not degraded with respect to other reaches.

3. Develop a baseline of existing macroinvertebrate community conditions in the event monitoring of macroinvertebrates becomes a post-licensing monitoring requirement.

The fall 2002 and spring 2003 sampling provide an excellent base of knowledge for the beginning of long-term monitoring. The design of such a program can be facilitated by the analysis of results above. The results presented here provide a characterization throughout the study area, in bypass and peaking reaches, and in areas of more constant, regulated flows (below Iron Gate reservoir).

4. Is macroinvertebrate community composition related to water quality conditions? If so, how is it related?

Both the macroinvertebrate community and water quality demonstrate gradual, longitudinal changes along the full, Project-investigated extent of the river. However, stream macro-invertebrate communities do not appear to be strongly water-quality-related. In contrast, the invertebrate communities of the reservoirs apparently vary with substrate quality and the degree of eutrophication. The eutrophic conditions of Lake Ewauna likely are related to the degraded macroinvertebrate communities at that reservoir.

The Oregon and California impaired water bodies lists show that the Klamath River is impaired for a variety of standard water quality conditions associated with nutrient enrichment and temperature. However, detrimental effects associated with nutrient enrichment (e.g., excessive algae growths, DO depletion) or high temperatures were not obvious during this study.

5. Are designated Species of Concern present?

The three caddisfly Species of Concern were not found as part of these samples. However, several new or little-described mollusc species were found, as well as the polychaete host species for an important salmonid disease.

6. How does macroinvertebrate community composition vary between the fully wetted and varial zones of the J.C. Boyle peaking reach?

The varial zone community was degraded significantly compared to the fully wetted areas of the peaking reach. The varial zone showed evidence of impairment for most measures of diversity and abundance (Table 8.7-3).

7. How do J.C. Boyle peaking operations affect macroinvertebrate drift in the peaking reach?

Drift appeared to peak as flows ramped up, then leveled off during the course of the peaking cycle (Figure 8.7-8). This provides some evidence that increased flows stimulate drift. However, only one peaking cycle's effects at one location were investigated during this study, and broad generalizations are not warranted.

8. Support subsequent assessment (together with other resources studies) of the quality of the macroinvertebrate assemblage as a food source for fish and wildlife, and to identify susceptibility of macroinvertebrate taxa to flow changes.

The overall abundance of macroinvertebrates gradually increased moving downstream through the Project study reaches (Figure 8.7-9). However, the indices of diversity and other metrics did not indicate dramatic effects of Project operations on the macroinvertebrate community. J.C. Boyle peaking area communities, compared to those of the J.C. Boyle bypass, indicate somewhat better conditions in the peaking reach (Table 8.7-3). The station showing the most consistent evidence of degradation (e.g., higher percent dominant taxa, shifted feeding groups, low EPT index, lower diversity) was the most upstream J.C. Boyle bypass site (BB1) (see Figures 8.7-10 to 8.7-14).

9. Support subsequent assessment (together with other studies and during license application preparation) of the Project's potential effects on water quality and fish and wildlife resources, and possible PM&E measures where necessary.

The macroinvertebrate fauna are susceptible to drawdown and drying of habitats in varial zones. However, the general richness and abundance of the fauna throughout the system suggest adequate to good availability of macroinvertebrates as a food source for fish and wildlife. The sampling and analysis effort provides baseline information for the design of mitigation.

9.0 DETERMINATION OF SEDIMENT OXYGEN DEMAND IN SELECTED PROJECT RESERVOIRS

9.1 DESCRIPTION AND PURPOSE

Water quality modeling of aquatic systems has proven to be a useful tool in assessing various options for managing and restoring rivers and lakes. However, the value of modeling depends on the quality of the physical and chemical characterization of the systems under consideration. Where the sediments are particularly enriched and where oxygen demand is substantial, it is important to simulate the uptake rates of oxygen and the release rates of nutrients from the sediment to the overlying water. This is particularly an issue in the Klamath River near PacifiCorp's Klamath Hydroelectric Project because of the high productivity of the source water coming from Upper Klamath Lake and other sources. In addition, high SOD is assumed to occur in Keno reservoir as a result of the settling of organic material from past and current log storage and handling, and agricultural and wetland runoff from the Klamath Straits Drain (P. DeVito, pers. comm., 2002). Efforts to simulate water quality in the Project reservoirs on the Klamath River (Keno, J.C. Boyle, Copco, and Iron Gate) require knowledge of both the water quality and the sediment properties. The specific purpose of this study was to determine SOD rates for the four reservoirs for use in water quality modeling (as described in Section 4.0 of this document).

9.2 OBJECTIVES

The objective of this study was to collect undisturbed sediment cores from sites in the Project reservoirs and to measure, in the laboratory, the rate of consumption of oxygen from the overlying water and the rate of release of nutrients from the sediment to the overlying water. The information gathered through this work was used to specify the SOD and sediment nutrient release rates used in the water quality models (see Section 4.0 of this document).

9.3 RELICENSING RELEVANCE AND USE IN DECISIONMAKING

Mathematical models of water temperature and water quality are important tools used to assess water quality conditions and determine the effects of Project operations on water quality. Water quality models are also used to determine the ability of proposed PM&E measures to meet the requirements of the Clean Water Act and influence water quality conditions as they relate to objectives of other agencies that support other aquatic resources, such as fish, wildlife, and recreation. Sediment/water interactions play a potentially important role in influencing the water quality in the Klamath River. The work proposed in this study plan provides information necessary to develop adequate, representative water quality models.

9.4 METHODS AND GEOGRAPHIC SCOPE

9.4.1 Geographic Scope

Sediment samples were collected from two locations in each of the following reservoirs:

- Lake Ewauna/Keno reservoir
- J.C. Boyle reservoir in the deepest area near the dam

- Copco No. 1 reservoir in the deepest area near the dam
- Iron Gate reservoir in the deepest area near the dam

During the Water Quality Work Group meeting on September 5, 2002, ODEQ requested that additional sampling sites be added in Lake Ewauna/Keno reservoir. After further discussion, ODEQ and PacifiCorp representatives agreed to the four sites in Lake Ewauna/Keno reservoir as listed below, and further agreed that the need for additional SOD sampling may be revisited on the basis of the results of the proposed sampling and sensitivity of subsequent modeling to SOD values.

The specific sites in each of the reservoirs were selected in consultation with the water quality modeling contractor, Dr. Michael Deas, guided by the results from the bathymetry and sediment classification work conducted by JC Headwaters, Inc. (Eilers and Gubala, 2003). The four sediment sampling sites for Lake Ewauna/Keno reservoir included Site 7 from the sediment classification work in Lake Ewauna (Figure 9.4-1), and three other sites farther downstream in Keno reservoir: (1) about 1 mile below Miller Island (RM 244), (2) about 1 mile below the Klamath Straits Drain (RM 238), and about 0.5 mile above Keno dam (RM 232). Samples from J.C. Boyle reservoir were collected in proximity to Sites 7 and 8 (Figure 9.4-2). Samples from Copco No. 1 reservoir were collected in proximity to Sites 1 and 7 (Figure 9.4-3). Samples from Iron Gate reservoir were collected in proximity to Sites 6 and 7 (Figure 9.4-4).

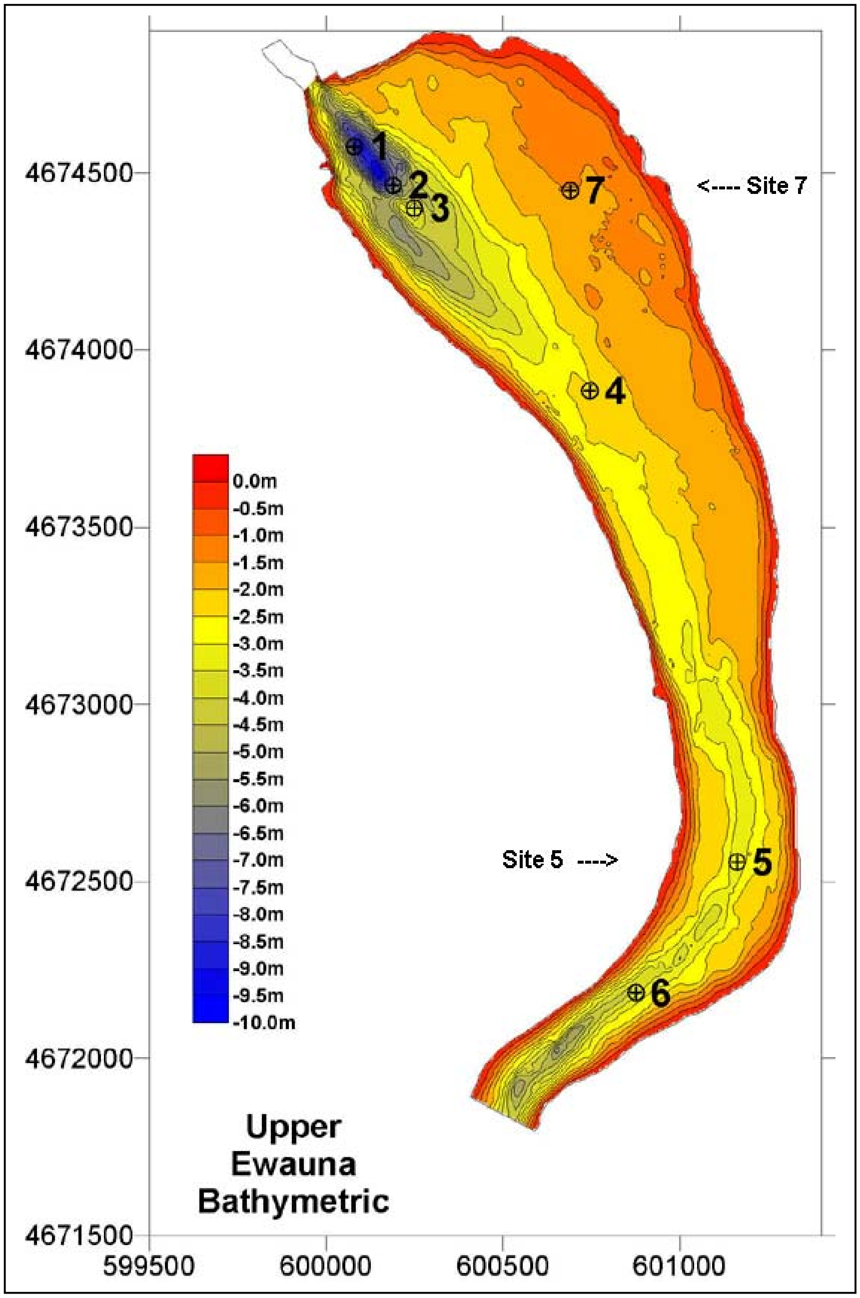


Figure 9.4-1. Bathymetry map of Lake Ewauna showing sediment sampling sites 5 and 7.

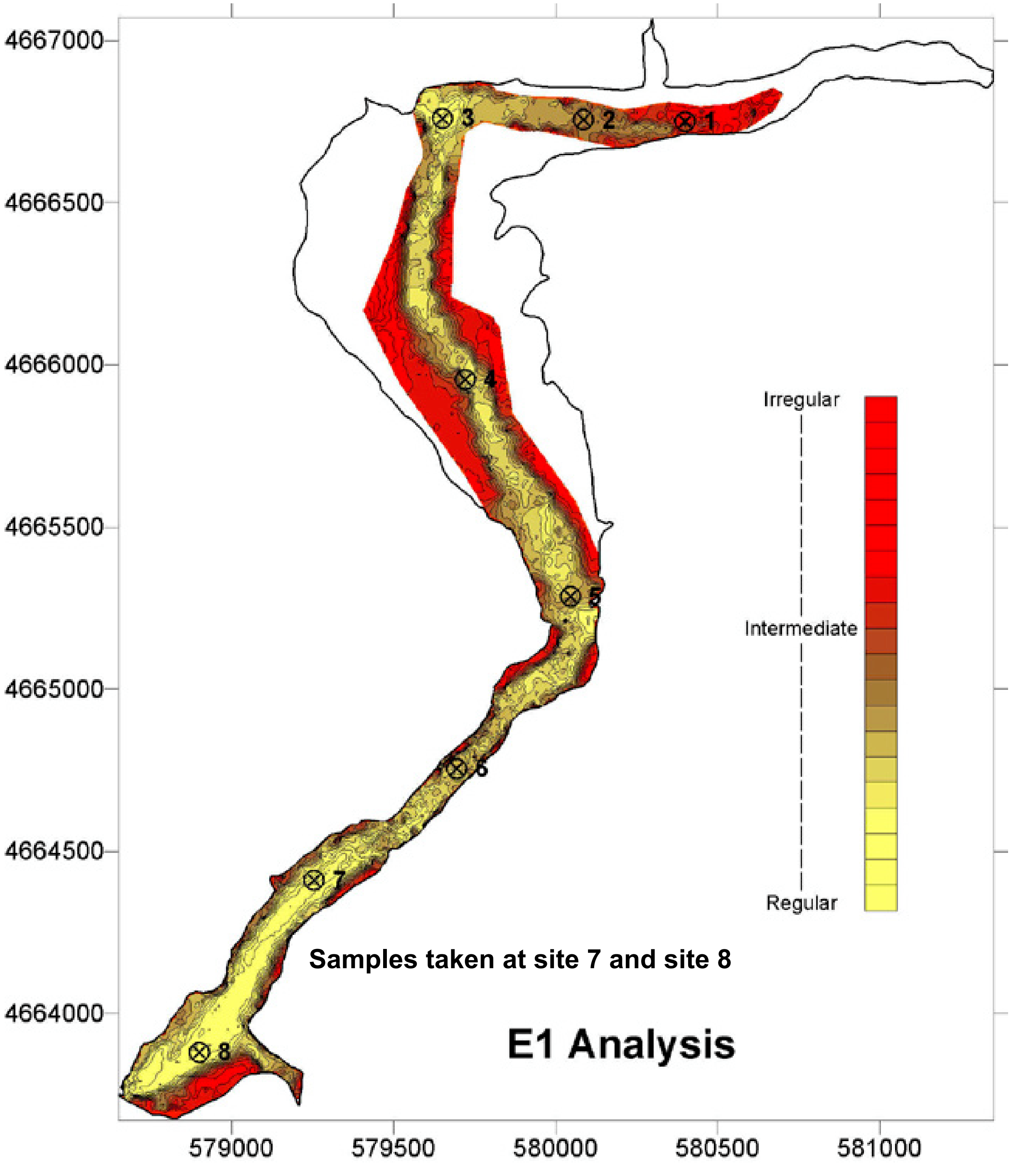


Figure 9.4-2. Bathymetry map of J.C. Boyle reservoir showing sediment sampling sites 7 and 8.

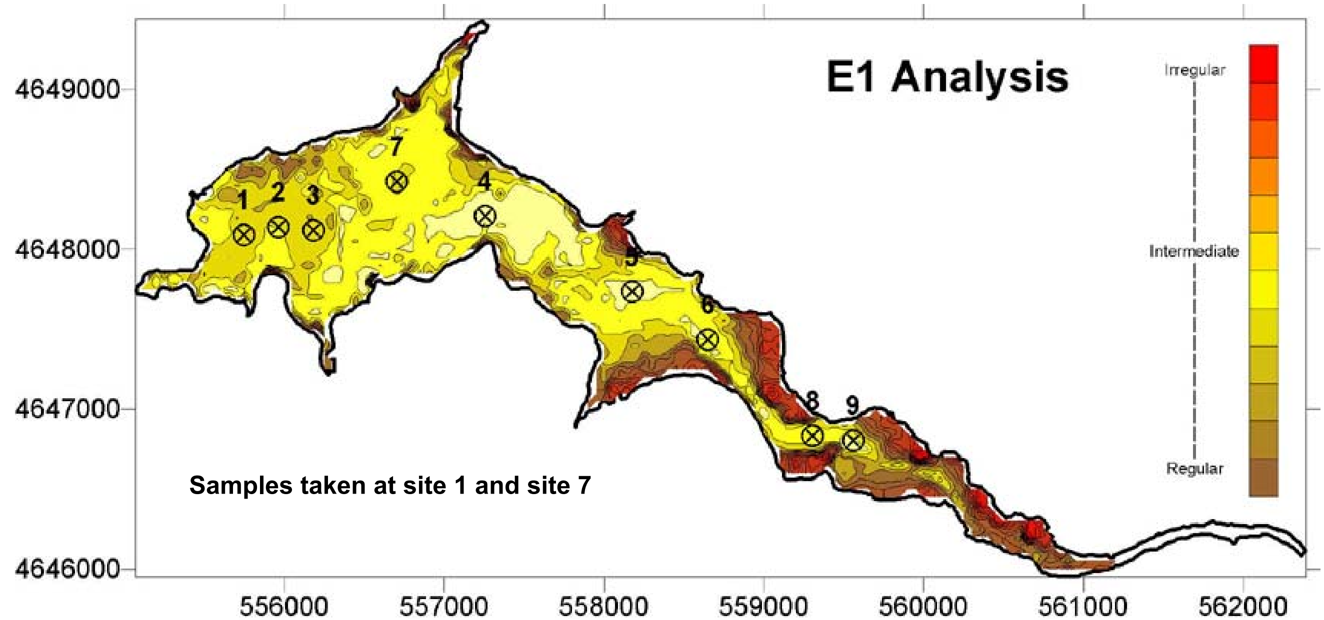


Figure 9.4-3. Bathymetry map of Copco No. 1 reservoir showing sediment sampling sites 1 and 7.

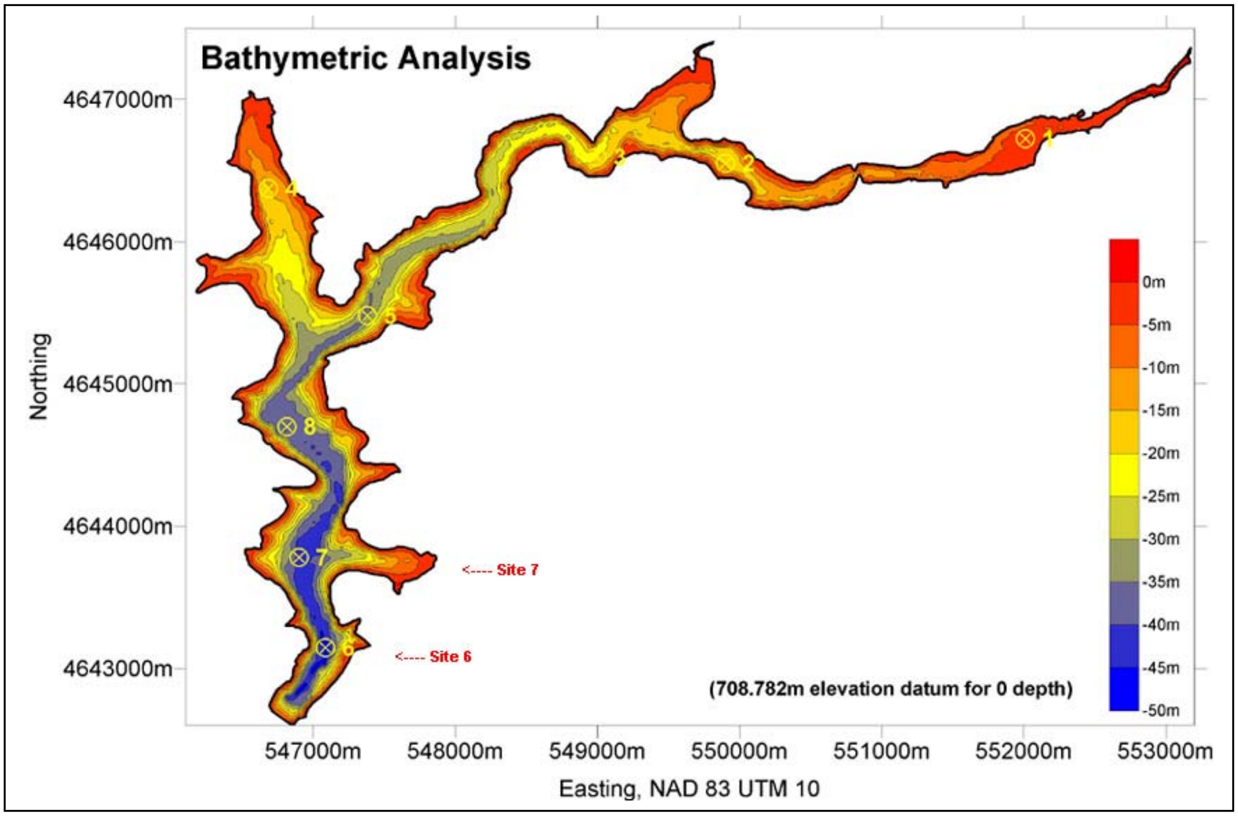


Figure 9.4-4. Bathymetry map of Iron Gate reservoir showing sediment sampling sites 6 and 7.

9.4.2 Methods

The sediment samples were collected as intact sediment cores (between 20 and 30 cm sediment depth) that were transported to the laboratory for incubation and water quality sampling. At each site, sediment cores were collected using a 10-cm-diameter, sphincter-coring device developed by JC Headwaters, Inc., for collecting undisturbed cores from unconsolidated sediments. The objective of the coring was to collect duplicate cores at each site, if possible. The sediment cores were wrapped in insulating material to prevent excess warming, and placed in upright stands for transport to the laboratory in Corvallis, Oregon. After the cores reached the laboratory, the core bungs were replaced with seals that allowed sampling of the overlying water without exposure to the air.

SOD and nutrient flux rates were determined by using the core collection tubes as core flux incubation chambers. Multiple water samples were collected from the water above the sediment over a period of several days to develop estimates of rates for oxygen uptake and sediment release rates from the sediments.

Gentle circulation was maintained to prevent overlying water stratification. All cores were oxygenated to 100 percent saturation (approximately 9.8 mg/L) at the beginning of the incubation to provide sufficient oxygen to measure the uptake rate. Incubation was started simultaneously for all cores.

The incubation chambers were fitted with a sampling top that included ports for sample withdrawal and introduction of replacement water. Incubating water was stirred via a recirculating peristaltic pump. Samples were collected twice during the first day, once each day for 4 subsequent days, and once after 2 weeks, and were analyzed immediately for specific conductance, DO, redox potential (E_H), and pH. Inorganic nutrient samples—ammonia (NH_3), nitrate (NO_3), and orthophosphate (PO_4) were collected throughout the incubation period. All water removed from the chambers for analysis was replaced with water collected from the study site. In addition, water from the study site was collected immediately above the sediment and analyzed for biochemical oxygen demand to determine the contribution of the water in the sediment incubation chambers to the gross SOD rate. Nutrient samples were filtered and analyzed with an automated ion analyzer. At the end of the incubations, water volume and visible benthic macrofauna content were recorded for each core.

Water samples were analyzed for constituents of particular importance to the needs of the water quality models (Table 9.4-1).

Table 9.4-1. Water analyses, methods, and reporting limits.

Analysis	Method	Reporting Limit
Temperature	YSI probe	NA
pH	YSI probe	NA
Redox Potential	YSI probe	NA
Specific Conductance	YSI probe	2 µS/cm
Dissolved Oxygen	YSI probe	NA (0.1 mg/L)
Orthophosphate	SM 4500-P	10 µg/L
Nitrate	SM 4500-NO3	20 µg/L
Ammonia	SM 4500-NH3	100 µg/L
Iron	E200.7	100 µg/L
Manganese	E200.7	10 µg/L
Sulfur	SM 4500-SO4	50 µg/L

NA = not applicable; µS/cm = microSiemens per centimer; µg/L = micrograms per liter.

9.5 RELATIONSHIP TO REGULATORY REQUIREMENTS AND PLANS

This study helps PacifiCorp address regulatory requirements and planning objectives related to Project effects on water quality. The information derived from this study helps address FERC requirements (18 CFR 4.51 and 16.8) for information on water quality in the Project area and potential effects of Project operations on water quality.

Relicensing of the Project requires certifications from relevant agencies that the Project complies with requirements of Section 401 of the federal Clean Water Act. This study provides information to help assess potential Project effects as they relate to water quality objectives and standards promulgated by these agencies.

Together with other hydrology and water quality studies conducted by PacifiCorp, this study provides information to address compliance with management objectives from various resource agencies, tribes, and other stakeholders that relate to water quality, including the following:

- Federal Clean Water Act regulations
- State of Oregon Water Quality Management Plan for the Klamath Basin (Basin Plan)
- State of California Water Quality Control Plan for the North Coast Region (Basin Plan)
- Federal ESA regulations
- Tribal natural resources goals and objectives and cultural values
- Tribal water quality standards as promulgated

- USFS and BLM Aquatic Conservation Strategy objectives under the Northwest Forest Plan
- BLM Klamath Falls and Redding Resource Management Plans
- USFS Land and Resource Management Plans
- ODFW Fish and Wildlife Habitat Mitigation Policy
- ODFW Klamath Basin Fish Management Plan
- CDFG management goals

This study's information also helps PacifiCorp and stakeholders to develop PM&E measures to meet the intention of the regulations and management objectives related to water quality.

9.6 TECHNICAL WORK GROUP COLLABORATION

PacifiCorp has worked with stakeholders to establish a more collaborative process for planning and conducting studies needed to support Project relicensing documentation. As part of this collaborative process, a Water Quality Work Group was formed and has met approximately monthly to plan and discuss water quality studies and results, including this study.

9.7 RESULTS AND DISCUSSION

Twelve sediment cores and substrate samples were collected from the Project reservoir sites from September 30 to October 2, 2002. The cores were transferred to the laboratory on October 3 and 4. In the laboratory, the water above the sediment was saturated with air and incubated at about 20°C for 17 days. In situ measurements were taken of temperature, specific conductance, DO, pH, and E_H. Water samples were collected for analysis of iron (Fe), managanese (Mn), ammonia nitrogen (NH_3), nitrate (NO_3), nitrogen dioxide (NO_2), orthophosphate (PO_4), and sulfur (S).

DO decreased linearly for the first 72 hours of the study, at which point it appeared that the system became anaerobic (Figure 9.7-1). DO probes can be unreliable at low concentration. The YSI probe overestimated DO concentration at values below 1 mg/L. Independent verification that the tubes became anaerobic near 72 hours is that the E_H (redox potential) continued to decline through this period, eventually reaching negative values, even though measured DO values remained greater than zero (Figure 9.7-2). Oxygen reduction is completed well before E_H becomes negative (Stumm and Morgan, 1981). Oxygen demand during the first 48 hours of incubation, as a function of sediment surface area, varied from 1.5 to 4.7 grams per square meter per day ($g/m^2/day$), as shown in Figure 9.7-3.

The rapid rate of oxygen depletion in Lake Ewauna, Keno reservoir, and J.C. Boyle reservoir can be attributed largely to the BOD of the water. Water from Upper Klamath Lake enters the Project area with a substantial oxygen demand present, presumably derived from decomposition of the entrained cyanobacteria. The oxygen demand in the upper portion of the Project area appears to overshadow the effects of the sediment to a considerable degree. This is evident when the BOD demand in the overlying water is plotted as a percentage of the available oxygen in the aerated cores (Figure 9.7-4). The results indicate that there is sufficient BOD in the overlying water to consume most or all of the oxygen in the core tubes without invoking uptake from SOD. Clearly, these sediments exert an oxygen demand, but the primary effect is from the water, not the sediments. In Copco and Iron Gate reservoirs, BOD is low and sediment effects become a more important influence on the quality of the overlying water.

The in situ results for all samples were plotted as a function of time versus concentrations or constituent value (detailed results for each of the cores are presented in Eilers and Raymond, 2003). The results show that most of the short-term oxygen demand in the system can be accounted for on the basis of the decaying organic matter in the water column. Denitrification proceeded during and following O_2 reduction. Following the loss of O_2 and nitrate from the overlying water, changes in the other measured constituents were governed by redox conditions. This included release of Fe^{+2}, Mn^{+2}, PO_4^{2-}, and NH_4^+ and loss of S to SO_4^{2-} reduction.

pH values showed a steady decrease through the study period. This decrease in pH reflects the accumulation of carbon dioxide as the system becomes anaerobic and fermentation reactions become increasingly significant (Figure 9.7-5).

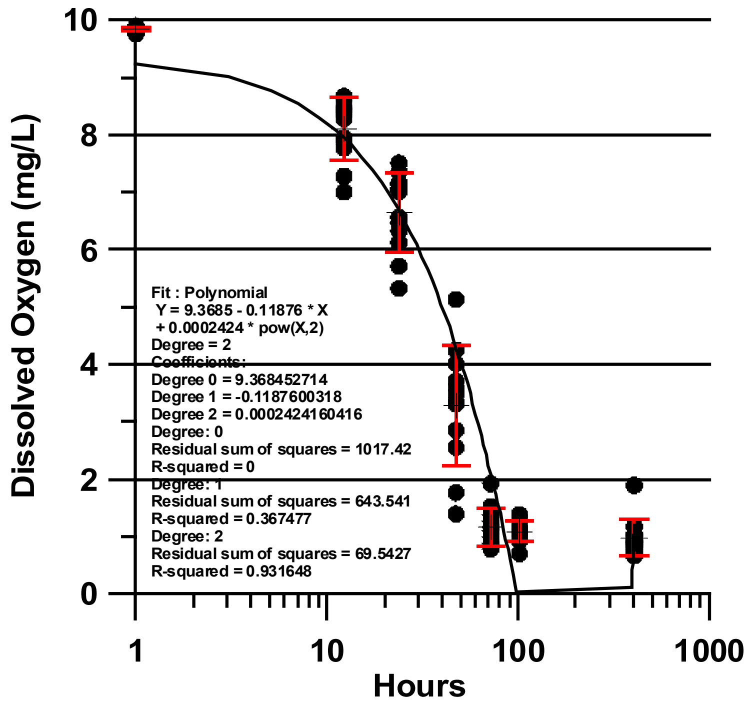


Figure 9.7-1. Dissolved oxygen concentrations measured in the incubation chambers. Actual dissolved oxygen concentrations after 72 hours are likely zero, based on the Winkler verification data.

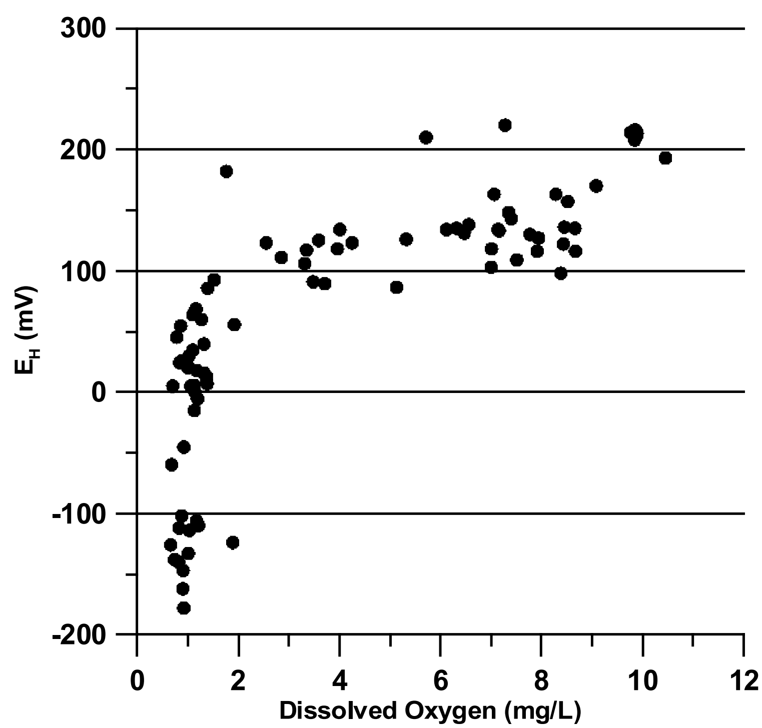


Figure 9.7-2. Redox potential versus measured dissolved oxygen concentrations in the incubation chambers.

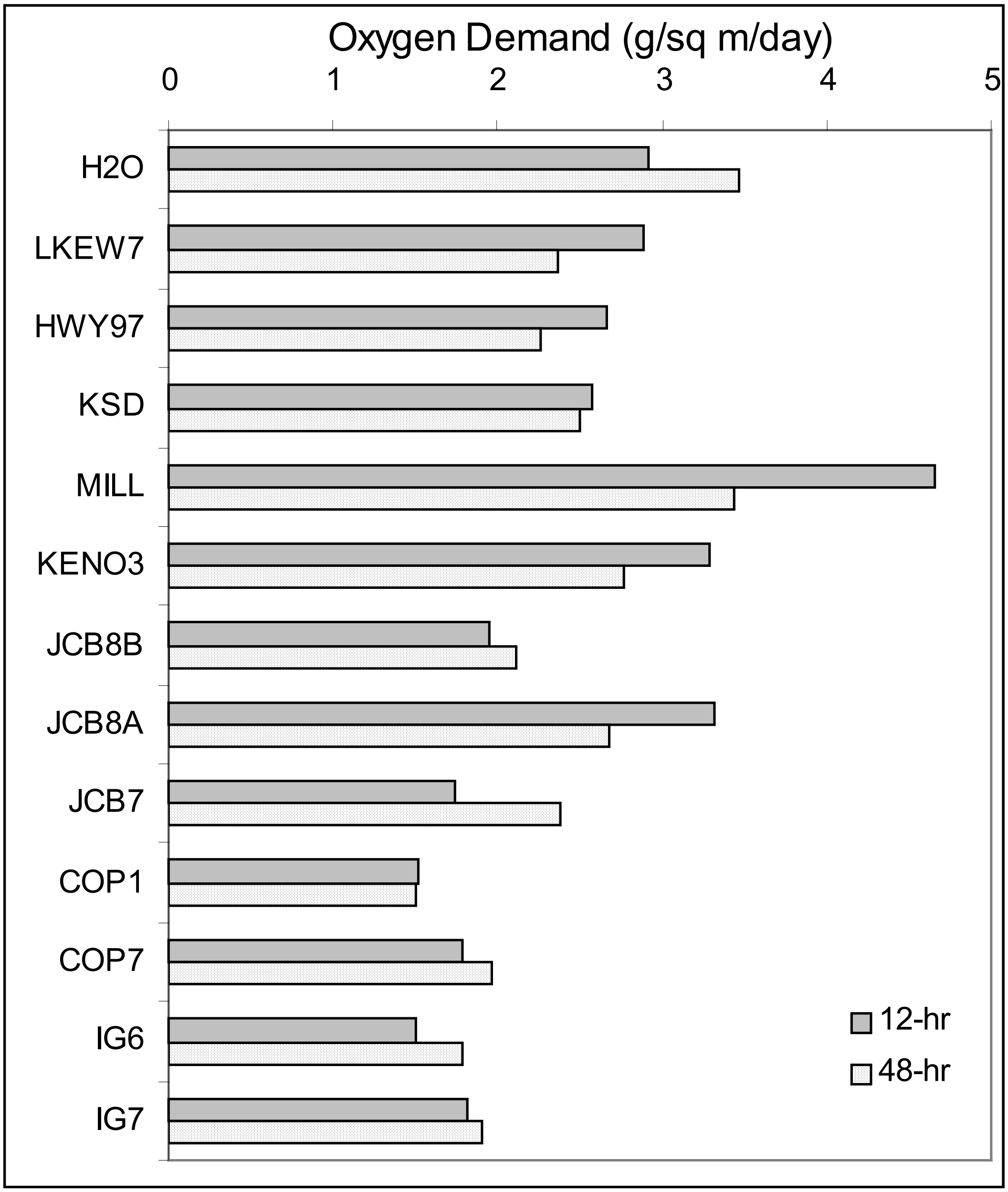


Figure 9.7-3. Oxygen demand measured in incubating sediment cores from Project reservoirs.

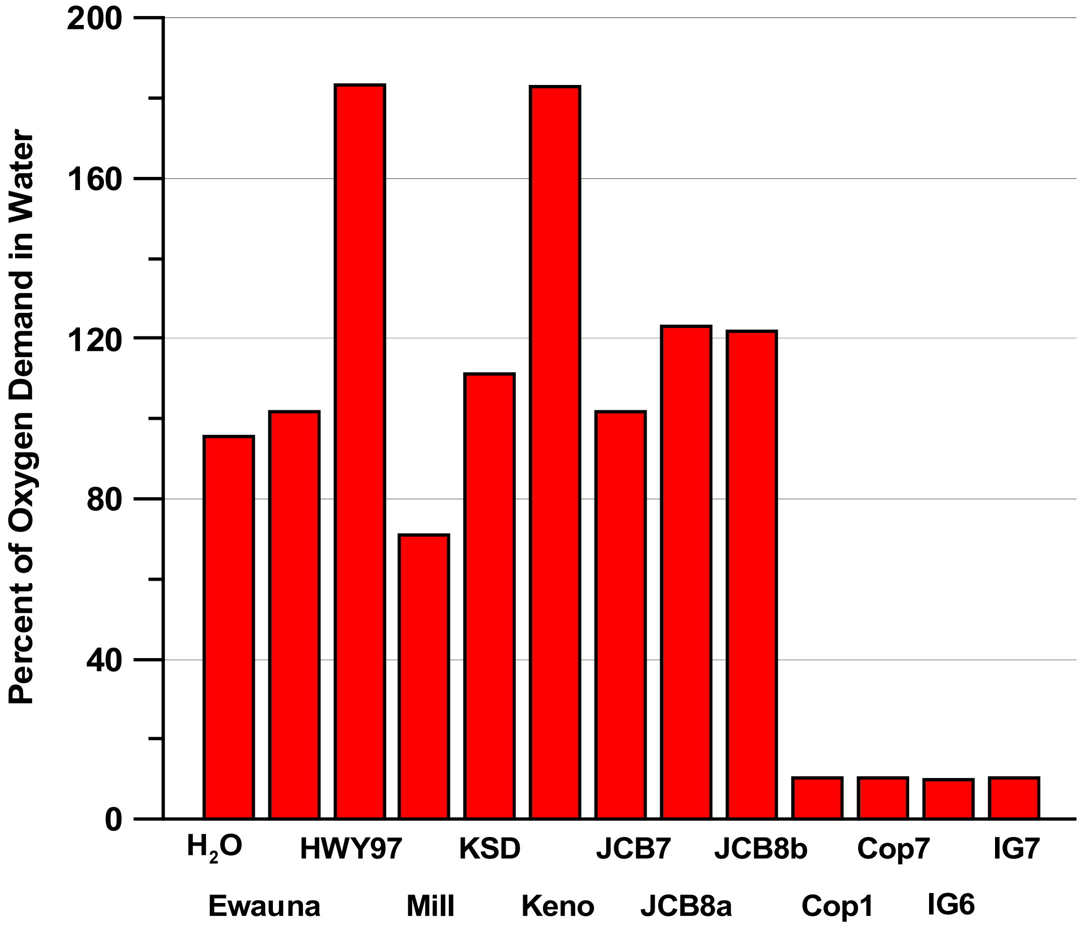


Figure 9.7-4. Percent of oxygen demand in each incubation chamber calculated as the product of the BOD in each core (BOD times water volume) divided by the oxygen content of the core water (DO [mg/L] times volume of water) multiplied by 100.

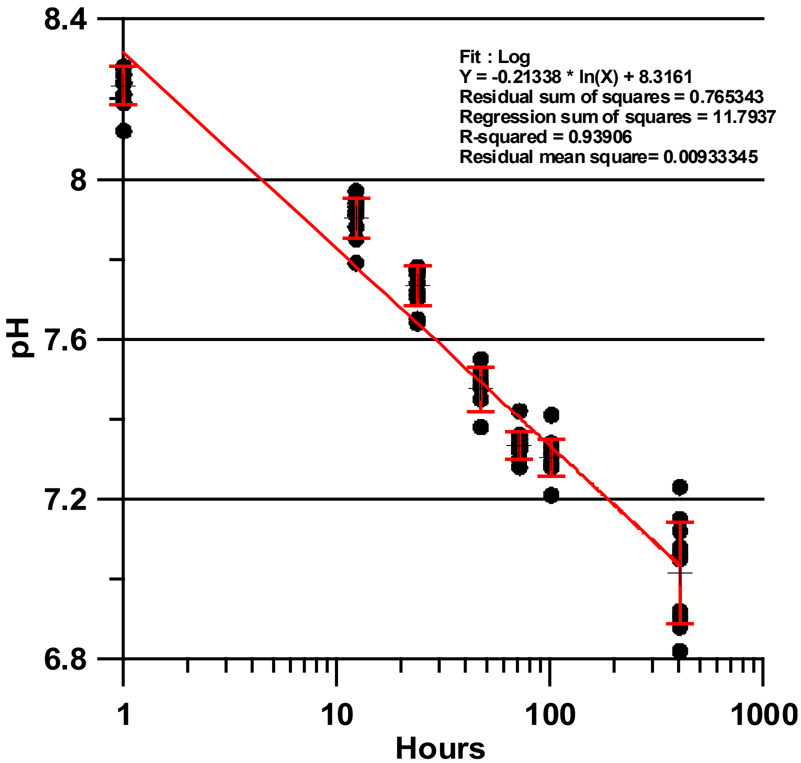


Figure 9.7-5. pH values measured in the incubation chambers.

The overlying waters in all cores showed similar responses for DO, pH, and E_H, indicating that constituents in the water column dominated the reactions affecting these parameters. Nitrate, phosphorus, and iron exhibited greater variability among the cores, but the directions of reactions appeared to be closely coupled with DO, pH, and E_H. Other analytes, such as nitrite, ammonia, manganese, and sulfur, were highly variable among cores, both in terms of direction and magnitude of responses. This suggests that the composition of the sediments was the key determinant affecting these variables.

Although variations in sediment composition lead to different levels of response, the overall processes are well described by reduction reactions presented by Stumm and Morgan (1981). Figure 9.7-6 shows how these reactions are expected to proceed given the changes in E_H. Substantial changes in the soluble concentrations of iron and sulfur are not expected to occur until the system becomes negative with respect to redox conditions. The overlapping nature of the reactions indicates that multiple reactions can be occurring at the same time and that the actual dominant reaction at any given time will change as substrate availability is altered. Furthermore, although Figure 9.7-6 provides useful insight into the expected order of various reduction reactions, it is only a guide because natural systems are seldom in equilibrium, and therefore the direction and magnitude of any set of these reactions can be quickly altered.

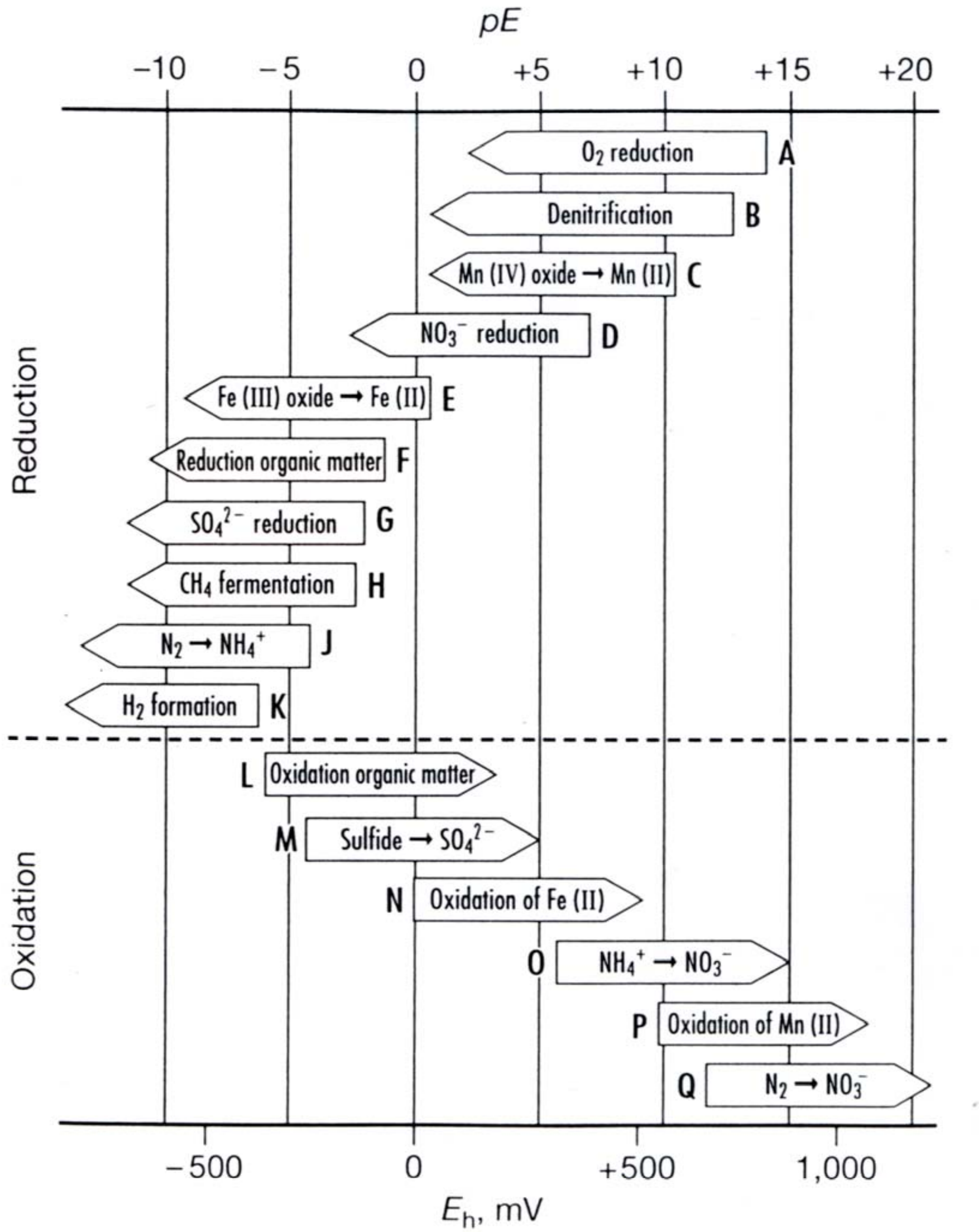


Figure 9.7-6. Sequence of microbially mediated redox processes (at pH = 7), after Stumm and Morgan (1981).

9.8 ADDITIONAL WORK

The SOD work was repeated in 2003 with a smaller set of cores. The methods were modified from those used in 2002 in order to obtain a better estimate of SOD without interference from the high BOD in the ambient water. In 2003, the ambient lake water overlying the cores was removed and replaced with distilled water. This removed the effect of the high BOD in the ambient lake water. Cores were collected from Lake Ewauna at Site 7 and from near Miller Island, as in 2002. The core at Miller Island was replicated. Three cores were incubated as in 2002. In addition three core tubes containing only water were incubated containing, respectively, ambient lake water, supernatant water from above the core samples, and a distilled water blank.

The results of the 2003 SOD test are listed in Table 9.9-1 and illustrated in Figure 9.9-1. Oxygen demand attributable to the sediment averaged 1.51 g/m^2/day in the three cores over the first 72 hours of incubation. Oxygen demand was 3.38 g/m^2/day in the ambient lake water, and 4.11 g/m^2/day in the core supernatant water. These results are comparable to the results obtained in the 2002 core incubation study for Copco and Iron Gate reservoirs and by the USGS using in situ methods in Lake Ewauna in 2003.

The results of studies to determine the oxygen demand of sediment in Lake Ewauna indicate that a major factor leading to the periodic anoxia in Lake Ewauna during the summer months is the high load of organic material entering the lake from Upper Klamath Lake.

Table 9.9-1 Results of 2003 Lake Ewauna sediment core incubation study.

Core	Sediment Oxygen Demand (g/m^2/day)		
	0-24 hours	**24-72 hours**	**Average**
Site 7	1.49	1.45	1.47
Miller Island A	1.76	1.45	1.60
Miller Island B	1.96	0.97	1.46
Core Supernatant	7.35	0.87	4.11
Ambient Lake Water	4.62	2.14	3.38

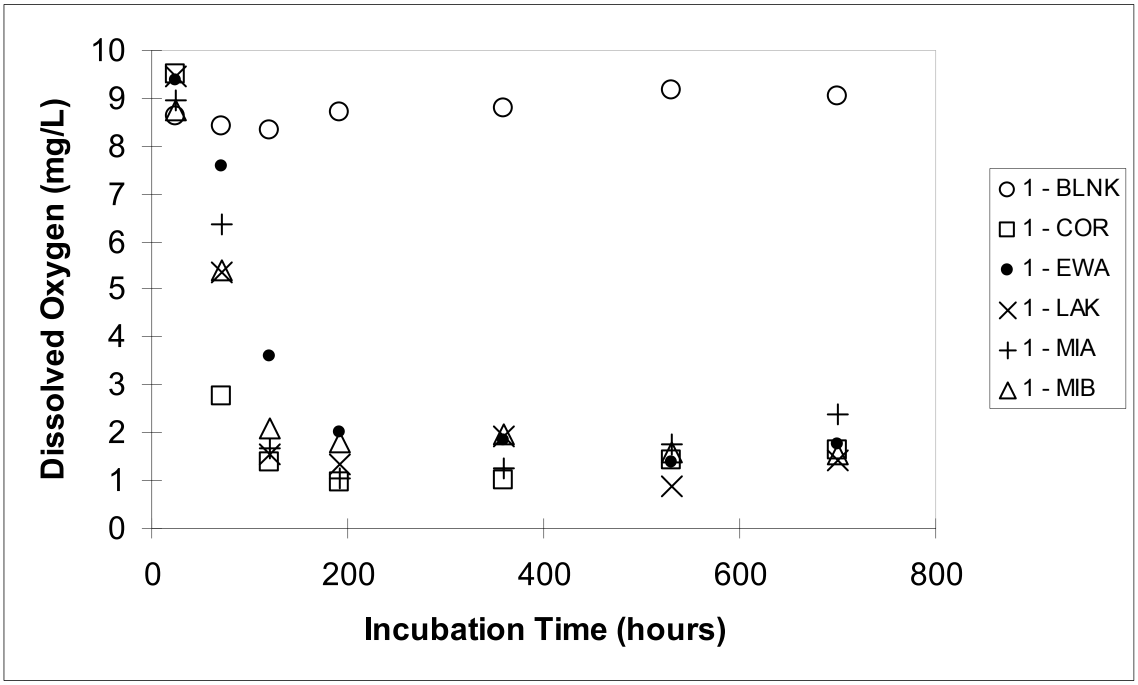


Figure 9.9-1. Results of 2003 Lake Ewauna sediment core incubation study. BLNK = distilled water blank, COR = core supernatant water, EWA = Lake Ewauna at Site 7, LAK = ambient lake water, MIA = Miller Island core A, MIB = Miller Island core B.

9.9 CONCLUSIONS

The purpose of this study was to determine the oxygen demand exerted by sediment on the overlying water in the Project reservoirs to assist in deriving sediment calibration information for the water quality modeling of the Klamath Hydroelectric Project. Measured oxygen demand ranged from 1.5 to 4.7 g/m^2/day. The results indicate, however, that the oxygen dynamics of the upper study area, especially Lake Ewauna and Keno reservoir, are controlled to a large extent by the nature of the water entering the system rather than sediment/water interactions in the impounded areas. Where anaerobic conditions exist for extended periods, nutrients and other constituents can be released from the sediment. Such effects may play a larger role in water quality dynamics in the hypolimnion in Copco and Iron Gate reservoirs. These results demonstrate the importance of E_H as a routine parameter in future monitoring programs. The DO data are important, but these results demonstrate that the redox condition of the waters affects the release of phosphorus and ammonia into the overlying waters.