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<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tr>
<td>ABA</td>
<td>Aquatic Biology Associates</td>
</tr>
<tr>
<td>AFS</td>
<td>American Fisheries Society</td>
</tr>
<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
</tr>
<tr>
<td>cfs</td>
<td>cubic feet per second</td>
</tr>
<tr>
<td>COUGM</td>
<td>Cougar mouth</td>
</tr>
<tr>
<td>CPOM</td>
<td>coarse particulate organic material</td>
</tr>
<tr>
<td>CPUE</td>
<td>catch per unit effort</td>
</tr>
<tr>
<td>DAT</td>
<td>digital audio tape</td>
</tr>
<tr>
<td>DO</td>
<td>dissolved oxygen</td>
</tr>
<tr>
<td>DPS</td>
<td>distinct population segment</td>
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<tr>
<td>EPA</td>
<td>U.S. Environmental Protection Agency</td>
</tr>
<tr>
<td>EPT</td>
<td>Ephemeroptera Plecoptera Trichoptera</td>
</tr>
<tr>
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<td>Endangered Species Act</td>
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<td>Federal Energy Regulatory Commission</td>
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<td>Merwin tailrace</td>
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<td>most probable number</td>
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<tr>
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<td>megawatt</td>
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<tr>
<td>NSO</td>
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<td>NTU</td>
<td>nephelometric turbidity unit</td>
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<td>Ortho-phosphorus</td>
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<td>PC</td>
<td>personal computer</td>
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<tr>
<td>PGE</td>
<td>Portland General Electric</td>
</tr>
<tr>
<td>PUD</td>
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</tr>
<tr>
<td>QA/QC</td>
<td>quality assurance/quality control</td>
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ACRONYMS AND ABBREVIATIONS (continued)

RM  river mile
RSD  relative standard deviation
SIOUX  Siouxon Creek
SPELL  Speelyai Lower Creek (near mouth)
SPELU  Speelyai Upper Creek (upstream of diversion)
SW2BP  Downstream end of Swift No. 2 bypass
SW2BU  Upstream end of Swift No. 2 bypass
SW2TR  Swift No. 2 powerhouse tailrace
SWRES  North Fork Lewis River inflow to Swift Reservoir
T&E  threatened and endangered
TDG  total dissolved gas
TKN  total Kjedahl nitrogen
TP  total phosphorus
TPN  total persulfate nitrogen
TS  Target Strength
USFS  U.S. Forest Service
USFWS  U.S. Fish and Wildlife Service
USGS  U.S. Geological Survey
WAC  Washington Administrative Code
WDFW  Washington Department of Fish and Wildlife
WDOE  Washington State Department of Ecology
YALTR  Yale tailrace
1.0 INTRODUCTION

The Yale Hydroelectric Project is owned and operated by PacifiCorp under a license issued by the Federal Energy Regulatory Commission (FERC; Project No. 2071). The project is 1 of 4 hydroelectric facilities located on the North Fork of the Lewis River in southwestern Washington. Three of the projects--Yale, Merwin, and Swift No. 1--are owned and operated by PacifiCorp (Figure 1.0-1). The fourth project, Swift No. 2, is owned by Public Utility District (PUD) No. 1 of Cowlitz County, and is operated and maintained by PacifiCorp for the PUD. The Yale Project is located in Cowlitz and Clark counties, approximately 23 miles east of Woodland, Washington, and 45 miles northeast of Portland, Oregon.

1.1 SCOPE OF REPORT

The Yale Project currently operates under a license from the FERC that expires on April 30, 2001. PacifiCorp is seeking a new license to continue to operate the project and (as required by the FERC) issued a Notice of Intent on February 7, 1996 to apply for a new license. FERC regulations establish a 3-stage process of consultation between the applicant, state and federal resource agencies, and tribes. The regulations also establish a process for obtaining public comment during relicensing. PacifiCorp began the first stage of consultation by issuing a First Stage Consultation Document (FSCD) (PacifiCorp 1996a) that described the facilities, operation, and environmental setting of the existing Yale Project. This document also described studies that PacifiCorp planned to conduct in the areas of aquatic (water quality and fisheries), terrestrial, land use, aesthetics, recreation, and cultural resources in accordance with Title 18, Part 4, Section 51 of the Code of Federal Regulations (18 CFR 4.51): Application for Major Project-Existing Dam.

Study results for 1996 were described in the Interim Technical Report (ITR) (PacifiCorp 1997), which covered all resource disciplines. Results of studies conducted in 1997 are combined with those for 1996 and presented in final technical reports (FTRs) that are resource specific. This draft FTR for Aquatic Resources describes environmental studies conducted during 1996 and 1997 for the Yale Project. This report focuses only on aquatic resources (water quality and fisheries). Three other reports have been issued separately, 1 each to describe terrestrial, recreation, and cultural resources.

The draft FTR for Aquatic Resources describes the area of each study, detailed methods and procedures used to conduct each study, results, and anticipated future activities (e.g., continued water temperature monitoring) in 1998. The report has been distributed for agency review. Comments on the draft FTR were received from 2 agencies. The Washington Department of Fish and Wildlife (WDFW) provided comments on both the Aquatics and Terrestrial FTRs on March 12, 1998. Similarly, the U.S. Fish and Wildlife Service (USFWS) commented on both FTRs on March 31, 1998. These and other comments were reviewed with the agencies at a meeting on January 13, 1999. The text of this FTR has been revised to reflect a number of the comments, as has the text of Exhibit.
E of the final Application for FERC License (in preparation). Copies of the referenced correspondence are presented in the final FERC Application.

1.2 OVERVIEW OF AQUATIC RESOURCE STUDIES

In compliance with FERC regulation for relicensing, PacifiCorp conducted the following studies to describe existing resources in the project vicinity, and to make informed decisions regarding the environmental effects of continued operation and maintenance of the Yale Project.

1.2.1 Water Quality Studies

- Continuous water temperature monitoring at selected sites to allow characterization of the thermal regime in the project vicinity;
- Periodic monitoring of water quality in streams and project tailraces;
- Reservoir monitoring for physical, chemical, and biological measurements;
- Continuous monitoring of total dissolved gas (TDG) at selected sites;
- Diel studies of key *in situ* parameters; and
- Benthic invertebrate community assessment.

1.2.2 Fisheries Studies

- Creel survey in Yale Lake;
- Tributary stream habitat surveys;
- Resident fish population surveys in project tributaries;
- Bull trout enumeration and population study in Cougar Creek;
- Yale dam entrainment study;
- Yale Lake hydroacoustic fish population survey; and
- Genetic analysis of bull trout.

Results of these studies are summarized in the License Application. This FTR describes the results of each aquatic resource study conducted in 1996 and 1997, as well as supplemental activities conducted in 1998.
2.0 WATER QUALITY AND WATER TEMPERATURE MONITORING

In support of relicensing, PacifiCorp conducted several studies to evaluate and describe water quality in the Yale Project vicinity. These studies are based on requirements mandated by the FERC, as well as Section 401 Water Quality Certification requirements. Study plans were presented in the FSCD (PacifiCorp 1996a). The primary objectives of these studies were to collect data necessary to adequately describe water quality and temperatures in the project vicinity, to describe seasonal trends, and to document project-related effects on water quality.

PacifiCorp’s ITR (PacifiCorp 1997) described the study area, methods, and results obtained for the period March through September or October 1996, depending on the study. The ITR included results of the following studies:

- Water temperature monitoring in the project vicinity;
- Water quality monitoring at stream and tailrace sites (in situ plus laboratory measurements);
- Limnological monitoring at Yale Lake (profiles, water chemistry, and plankton); and
- Evaluation of the influence of Yale Project operations on total dissolved gas (TDG) levels.

This report updates the ITR with study results through February 1998 for water quality and for continuous water temperature records. In addition to the studies listed above, this section includes results of benthic invertebrate sampling, the diel study, and the 1998 Yale temperature study.

2.1 WATER TEMPERATURE MONITORING

In consultation with agency staff, PacifiCorp developed a program to monitor water temperatures in streams and reservoirs associated with the Yale Project. The objective of the monitoring program is to describe the thermal regime of streams in the vicinity of the Yale Project and to assess the effects of project operations on water temperature. To accomplish this, PacifiCorp has continuously monitored water temperature at several sites since 1996.

2.1.1 Study Area

The FERC requires that the license applicant describe thermal conditions in streams affected by the project and its primary tributaries. During 1994, PacifiCorp used thermographs to monitor the thermal conditions of 11 sites in the North Fork Lewis River basin, including the North Fork Lewis River and several tributaries. PacifiCorp evaluated the data collected and consulted with agency staff to determine appropriate monitoring locations for the relicensing studies for the Yale Project. As a result, 9 continuous water temperature monitoring sites were selected (Table 2.1-1). Six of these sites were located in the North Fork Lewis River; 3 other sites were located in tributaries. Due to loss of the
thermograph just downstream of the confluence of Ole and Rain (OLECM) creeks, this
site was moved farther downstream in August 1996. Two additional sites were
monitored in Speelyai Creek beginning in mid-December 1996. The locations of the
monitoring stations are displayed in Figure 2.1-1, except for the North Fork Lewis River
inflow to Swift Reservoir (SWRES) site. This site was located approximately 200 meters
upstream of the Eagle Cliff bridge (USFS 90 Road).

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<td>SW2BP</td>
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<td>May 6, 1996</td>
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<td>Yale powerhouse tailrace</td>
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<td>MERTR</td>
<td>Merwin powerhouse tailrace</td>
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<td>Ole Creek near mouth</td>
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<td>COUGM</td>
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<td>SIOUX</td>
<td>Siouxon Creek near mouth</td>
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<td>SPLYU</td>
<td>Speelyai Creek upstream diversion</td>
<td>December 18, 1996</td>
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<td>SPLYL</td>
<td>Speelyai Creek near mouth</td>
<td>December 18, 1996</td>
</tr>
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</table>

2.1.2 Methods

PacifiCorp used Onset Optic StowAways® to continuously monitor water temperatures at
the 11 stations described above. Ten of the 11 thermographs were set to record
temperatures at hourly intervals and deployed in the field. Due to stable, relatively
constant water temperatures, the thermograph deployed at Cougar Creek was set to
record temperatures once every 2 hours. The temperature data were downloaded in the
field with an Onset Optic Shuttle®, which was used to transfer the stored data to a
personal computer (PC). All data were transferred into Excel spreadsheets and were
managed following a set protocol to ensure quality assurance/quality control (QA/QC).
Results of the water temperature monitoring program from April 1996 through February
1998 are reported in this FTR.

PacifiCorp used several methods to analyze the water temperature database, each
focusing on a particular element of the existing thermal regime. Methods were used to
assess seasonal trends in the data, site-to-site differences, warming within specific
reaches, and diel fluctuation.
Percent exceedence analyses were conducted to evaluate the recorded temperatures and diel fluctuations at each of the monitoring stations. This type of analysis is particularly useful in evaluating site-to-site differences. The minimum, maximum, median, and values exceeding 10, 25, 75, and 90 percent of the time were determined for each site and each month of the monitored period (April 1996 through February 1998). In some cases, results of this analysis are affected by data gaps, and by less than full-month periods of record at the beginning and end of the monitoring period. Continuity of the data is discussed in Section 2.1.3.

Seasonal trends in the data were assessed using average daily maximum temperatures for a moving 7-day period. This was done by first determining the daily maximum temperatures, and then averaging the values for each consecutive 7-day period. The maximum of these values and their timing were determined for each of the monitoring sites.

Differences between temperatures recorded at both ends of the Swift No. 2 bypass reach were evaluated to determine changes occurring within the bypass. Temperature changes within the bypass reach were determined by subtracting the upstream temperature (SW2BU) from the downstream temperature (SW2BP). This procedure resulted in upstream to downstream temperature changes, computed for both daily minimum and maximum temperatures. The differences were then evaluated to determine general temporal trends. Similarly, temperatures for the site near the mouth of Speelyai Creek (SPLYL) were subtracted from temperatures for Speelyai Creek upstream of the diversion (SPLYU), and the differences evaluated for both daily maximum and daily minimum temperatures. The Speelyai Creek analyses were conducted at the request of the Washington Department of Ecology (WDOE) to assess effects of the diversion of Speelyai Creek to Yale Lake.

2.1.3 Results and Discussion

2.1.3.1 Recorded Temperatures

A summary of daily values and comments on observations are presented in Appendix 2.1-1. This summary contains the minimum, maximum, and mean temperatures; difference between the maximum and minimum temperature; standard error of recorded temperatures; and number of recorded temperatures for each day at each monitored site. Data gaps occurring due to lost or stolen thermographs or instrument failure are also indicated in Appendix 2.1-1. PacifiCorp conducted a monthly percent exceedence analysis for all data recorded from April 1996 through February 1998. Results of the analysis are displayed in Appendix 2.1-2.

Temperatures recorded at Lewis River monitoring sites including the inflow to Swift Reservoir, 3 powerhouse tailraces, and the upstream and downstream ends of the Swift No. 2 bypass reach ranged from a low of 0.2°C recorded at the inflow to Swift Reservoir to a high of 21.7°C recorded in the Yale powerhouse tailrace (Appendix 2.1-2). Minimum temperatures recorded at the 5 Lewis River monitoring sites downstream of Swift Reservoir ranged between 1.2 and 4.1°C, whereas temperatures of near freezing were recorded at the reservoir’s inflow. The maximum temperatures recorded at the
uppermost and lowermost Lewis River sites (SWRES and MERTR) were cooler than at the other 4 Lewis River sites. Their maximum temperatures were between 15 and 17°C, whereas the maximum recorded temperatures were 19 to 20°C at the 2 sites in the Swift No. 2 bypass reach and 21 to 22°C in the Swift No. 2 and Yale powerhouse tailraces.

To assess the relationship of project operations on water temperatures in the powerhouse tailraces, water temperatures recorded during July 1996 and information on discharges from the powerhouses were compiled (Figure 2.1-2) and evaluated. Operations of the Swift No. 2 and Yale powerhouses had differing effects on tailrace temperatures.

At the Swift No. 2 project, relatively warmer water in the canal is discharged immediately following the start-up of the Swift No. 2 powerhouse. This effect increases tailrace temperature, but is diminished as the warmer water that was in the canal was replaced by cold water flowing through the Swift Reservoir turbines. Conversely, summer temperatures in the Yale powerhouse tailrace typically increase after discharges from the powerhouse are stopped. The temperature in the Yale powerhouse tailrace rapidly decreased when the powerhouse began discharging water (i.e., was put back on-line). These temperature fluctuations at the Yale powerhouse tailrace are a result of the backwater effect of Lake Merwin. When the Yale powerhouse is not discharging water (off-line), Lake Merwin surface water backs up into the tailrace, whereas discharged water is forced down into Lake Merwin when the powerhouse is on-line. The Merwin Project is operated as a re-regulation facility; therefore, load factoring does not occur at the powerhouse, and the temperature of water discharged from the powerhouse remains stable.

Review of data collected during the summer of 1997 indicated that conditions at the Swift No. 2 tailrace were similar to conditions observed in 1996, but that much cooler (about 7°C) daily maximum temperatures were recorded in 1997 at the Yale tailrace in June and July. Warmer temperatures at Yale in 1996 can be attributed to maintenance activities associated with runner replacement.

The differences in daily maximum and minimum temperatures between the upstream and downstream ends of the Swift No. 2 bypass reach are displayed in Figure 2.1-3. Daily minimum temperatures at the 2 ends of the bypass reach were generally within 1.0°C of one another. In April through July, daily minimum temperatures were between 1 and 2°C cooler at the downstream end of the bypass than the upper end. Daily maximum temperatures were generally cooler at the downstream end of the bypass reach.

Temperatures recorded at tributary sites ranged from a low of −0.2°C to a high of 20.6°C. Both of these temperatures were recorded in Siouxon Creek (Appendix 2.1-1). Temperatures recorded upstream of the diversion in Speelyai Creek ranged from 0°C to 19.0°C. Cougar Creek temperatures exhibited a narrow range (4.5 to 9.6°C). Temperatures recorded in Ole Creek during April, May, August, and September of 1996 ranged from 5.2 to 16.9°C.
Figure 2.1-2. Recorded water temperatures (bold) in the Swift No. 2, Yale, and Merwin powerhouse tailraces and corresponding discharges, July 15 through July 28, 1996.
Figure 2.1-3. Differences between daily maximum and daily minimum temperatures at the downstream (SW2BP) and upstream (SW2BU) ends of the Swift No. 2 bypass reach, May 1996 through February 1998. Note: Graph shows lower site temperatures minus the upper site temperatures.
A comparison of the differences between daily minimum and daily maximum temperatures was conducted for Speelyai Creek (Figure 2.1-4). Both daily minimum and daily maximum temperatures were warmer at the site near the hatchery intake than temperatures upstream of the diversion during December 1996 through mid-March 1997, and from September through February 1998. Maximum summer temperatures were substantially cooler at the lower site in 1998.

The monthly median temperatures were compiled for the May 1996 through February 1998 period to facilitate evaluation of seasonal trends in water temperatures (Tables 2.1-2 and 2.1-3). Since little data were recorded at most sites during April 1996 and in Ole Creek during most of the monitoring period, these data were not included in the compilation.

Monthly median temperatures at stations on the North Fork Lewis mainstem (Table 2.1-2) and tributaries (Table 2.1-3) were generally lowest during January and February 1997 although the minimum occurred during December 1996 at SWRES and SPLYU. Median temperatures were highest at most stream sites during July and August.

The monthly median temperatures of Cougar Creek (COUGM) varied little (5.3°C to 7.5°C) from May 1996 through February 1998 (Table 2.1-3). Both Cougar and Speelyai creeks receive substantial groundwater inflow. Evidence of this at Speelyai Creek is the relatively stable median temperatures near the mouth, in contrast to temperatures upstream of the diversion (7.8 to 12.1°C at SPLYL versus 4.8 to 15.3°C at SPLYU).

2.1.3.2 Diel Temperature Fluctuations

Diel temperature fluctuations ranged from 0.0°C to 11.2°C at the 11 sites monitored (Appendix 2.1-3). The ranges of diel fluctuations in the Merwin powerhouse tailrace and Cougar Creek were considerably smaller than at the other sites monitored. Both of these sites had maximum diel fluctuations of less than 3°C (Appendix 2.1-3). The maximum diel fluctuations for Cougar Creek were between 1.0 and 1.6°C on 14 of the 22 months when temperatures were recorded for most of the month. Maximum diel fluctuations at the other tributary sites were between 3.6 and 6.9°C. The largest diel fluctuations were measured in the Swift No. 2 and Yale powerhouse tailraces; these are the only sites where diel fluctuations were larger than 10°C.

Monthly median diel temperature fluctuations were compiled in a similar manner as monthly median temperatures (Tables 2.1-4 and 2.1-5). Most of the median values for the Lewis River sites were less than 4.0°C; however, median values for the tributary sites were considerably higher (up to 15°C at SPLYU in August 1997). Based on monthly median values, the largest diel fluctuations occurred in the Yale tailrace (YALTR) and the downstream end of the Swift No. 2 bypass reach (SW2BP). The Merwin powerhouse tailrace (MERTR) experienced small diel fluctuations in temperature throughout the entire 22-month period. Median diel fluctuations were typically smaller in Cougar Creek than the other tributary sites, particularly during the summer (Table 2.1-5).
Figure 2.1-4. Differences between daily maximum and daily minimum temperatures in Speelya Creek near the hatchery intake (SPLYL) and upstream of the diversion (SPLYU), December 1996 through February 1998. Note: Graph shows lower site temperatures minus the upper site temperatures.
Table 2.1-2. Monthly median temperatures (°C) of Lewis River sites.

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Table 2.1-3. Monthly median temperatures (°C) of tributary sites.

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1 Site codes translated in Table 2.1-1.
2 More than 5 days not monitored.
3 Indicates less than 5 days monitored.

Note: Ole Creek thermograph lost in flood; insufficient data to enable comparison.
Table 2.1-4. Monthly median diel temperature fluctuations (°C) of Lewis River sites.

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</tr>
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* represents more than 5 days not monitored  ** represents less than 5 days monitored
Table 2.1-5. Monthly median diel temperature fluctuations (°C) of tributaries.

<table>
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<tr>
<th>Month</th>
<th>OLECM</th>
<th>COUGM</th>
<th>SIOUX</th>
<th>SPLYU</th>
<th>SPLYL</th>
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<tr>
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<tr>
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<td>15.3</td>
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<td>12.0</td>
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<tr>
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<td>4.9</td>
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<tr>
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<td>12.8</td>
<td>13.0</td>
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<tr>
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<tr>
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<td>5.5</td>
<td>7.9</td>
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<td>**</td>
<td>5.9*</td>
<td>5.5</td>
<td>5.5</td>
<td>8.5*</td>
</tr>
</tbody>
</table>

* represents more than 5 days not monitored
** represents less than 5 days monitored

2.1.3.3 7-Day Average Maximum Temperatures

The daily maximum temperatures were averaged for each period with 7 consecutive days of data to enable evaluation of average maximum temperatures (Appendix 2.1-4). Following computation of the average 7-day maximum temperatures, the highest value reported for each year at each site was determined. These temperatures are listed along with the dates that they occurred for each of the monitored sites in Table 2.1-6. The dates in the table specify the first 7-day period that the maximum value was reached if the maximum value occurred on more than one 7-day period within the year.

With few exceptions, the highest 7-day average maximum temperatures occurred during July in 1996 and during August and September in 1997. Exceptions to this general trend are described below.

The highest 7-day average maximum temperature at the Merwin tailrace occurred in early October of both 1996 and 1997. Similarly, maximum temperatures occurred during October 1994 (PacifiCorp 1995a).
Table 2.1-6. Highest 7-day average maximum temperatures (°C) recorded between May 1996 and late August 1997.

<table>
<thead>
<tr>
<th>Site Code</th>
<th>Temp. (°C)</th>
<th>Dates</th>
<th>Temp. (°C)</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWRES</td>
<td>16.2</td>
<td>Jul 21 - Jul 27</td>
<td>14.7</td>
<td>Jul 31 - Aug 05</td>
</tr>
<tr>
<td>SW2BU</td>
<td>18.5</td>
<td>Jul 09 - Jul 15</td>
<td>18.4</td>
<td>Aug 01 - Aug 07</td>
</tr>
<tr>
<td>SW2BP</td>
<td>17.7</td>
<td>Jul 09 - Jul 15</td>
<td>17.6</td>
<td>Aug 01 - Aug 07</td>
</tr>
<tr>
<td>SW2TR</td>
<td>15.8</td>
<td>Jul 11 - Jul 17</td>
<td>16.9</td>
<td>Aug 30 - Sep 05</td>
</tr>
<tr>
<td>YALTR</td>
<td>19.3</td>
<td>Jul 14 - Jul 20</td>
<td>15.1</td>
<td>Sep 19 - Sep 25</td>
</tr>
<tr>
<td>MERTR</td>
<td>15.2</td>
<td>Oct 09 - Oct 15</td>
<td>15.8¹</td>
<td>Oct 01 - Oct 07</td>
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<td>n/a</td>
</tr>
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<td>COUGM</td>
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<td>Jul 09 - Jul 15</td>
<td>8.6</td>
<td>Sep 16 - Sep 22</td>
</tr>
<tr>
<td>SIOUX</td>
<td>19.9</td>
<td>Jul 23 - Jul 29</td>
<td>18.7</td>
<td>Aug 01 - Aug 07</td>
</tr>
<tr>
<td>SPLYU</td>
<td>6.2²</td>
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<td>18.3</td>
<td>Aug 11 - Aug 17</td>
</tr>
<tr>
<td>SPLYL</td>
<td>8.5²</td>
<td>Dec 29 - Dec 04</td>
<td>14.1³</td>
<td>Jul 31 - Aug 05</td>
</tr>
</tbody>
</table>

¹ Data not collected during most of July and August.
² Thermograph was deployed on December 8.
³ Thermograph stolen during period of March 20 through May 20.
⁴ Thermograph broke and partial data recovered during period of August 29 through October 27.

Table 2.1-6. Highest 7-day average maximum temperatures (°C) recorded between May 1996 and late August 1997.

The 1996 highest 7-day average maximum temperature for Ole Creek occurred in late August to early-September, where a stolen thermograph resulted in a data gap during most of July and August. It is unlikely that the value reported for Ole Creek was the highest 7-day average maximum temperature during the year, supported by the fact that it occurred immediately following the data gap.

The highest 7-day average maximum temperatures in the Yale tailrace occurred in July 1996. Turbine runner replacement was occurring at this time, resulting in extended off-line periods and warming of the tailrace area by Lake Merwin surface waters.

The highest 7-day average maximum temperatures for the monitored sites extended over a wide range of temperatures (6.2 to 19.9°C). Both the lowest and highest values were reported for tributary sites. The highest 7-day average maximum temperatures for Cougar Creek were similar (within 0.5°C) for both 1996 and 1997, and were considerably lower than values for all of the other sites monitored during both years. These characteristics are presumably due to the influence of subsurface water inflow. Siouxon Creek (SIOUX) had the highest 7-day average maximum temperature during both years. The Yale powerhouse tailrace (YALTR) had the second highest 7-day average maximum temperature; as discussed above, this is probably a result of the backwater effect from Lake Merwin when the Yale powerhouse is not operating (i.e., discharging water).

2.2 WATER QUALITY MONITORING AT STREAM AND TAILRACE SITES

Results of the water quality monitoring program for the period March 1996 through February 1998 are discussed in this section of the report. Monitoring was conducted on a monthly basis. Data collected at stream and tailrace sites included in situ measurement of temperature, dissolved oxygen (DO), pH, specific conductance, and TDG. In addition, samples were collected for analysis of the following parameters:
An expanded suite of analytes was measured on a quarterly basis at the Yale tailrace. These included pesticides/polychlorinated biphenyls (PCBs), herbicides, metals, and major cations and anions.

The study area, methods, and results for the water quality monitoring program conducted in stream and tailrace sites are described in the following sections.

2.2.1 Study Area

Stream and tailrace sites monitored in 1996 included:

- Inflow to Swift Reservoir (SWRES)
- Swift No. 2 tailrace (SW2TR)
- Swift No. 2 bypass (SW2BP)
- Siouxon Creek mouth (SIOUX)
- Cougar Creek mouth (COUGM)
- Yale tailrace (YALTR)
- Merwin tailrace (MERTR)

Two Speelyai Creek stations were added at the request of WDOE in December 1996. The upper site is located 100 m upstream of the diversion headgate on Speelyai Creek, and the lower site is just above the Speelyai Hatchery intake.

2.2.2 Methods

Study methods for water quality sampling and in situ measurements are summarized below.

2.2.2.1 Laboratory Samples

At stream sites, samples for laboratory analysis were collected as grab samples in flowing water near the center of the channel. Tailrace samples were collected with a Van Dorn sampler, which was lowered into the tailrace area to a depth of approximately 1 meter (m). A blank sample (deionized water) and a field duplicate sample were collected at 1 of the sample locations (possibly a reservoir site - see below) during each monthly visit. The blank sample was used to assess potential contamination due to field and/or laboratory methods. The field duplicate was a second sample used to assess natural variability and laboratory precision. These QA/QC samples were over and above the routine quality assurance program maintained by the analytical laboratory (Oregon Analytical Laboratory in Beaverton, Oregon).
2.2.2.2 In Situ Measurements

*In situ* water quality data (with the exception of TDG) were collected with a Hydrolab® Surveyor 2 or 3 multiparameter probe. The Hydrolab was calibrated immediately prior to field data collection, using commercial buffers (pH 7 and 10) and a low ionic strength specific conductance standard (typically less than 100 µS/cm). Dissolved oxygen was calibrated in water-saturated air following manufacturer’s recommendations. Post calibration checks for Hydrolab parameters were conducted as soon as possible following each day in the field.

TDG was measured *in situ* with a Common Sensing® Total Dissolved Gas meter. The instruments were allowed to stabilize prior to recording data. At stream sites, the Hydrolab and TDG measurements were taken in flowing water near the center of the channel. The instruments were lowered to an approximate 1-m depth at tailrace sites.

Field and calibration data were recorded on standardized data sheets for the Yale Project. The field data sheets included the instrument serial number to allow verification of calibration for a particular day’s use.

2.2.3 Results and Discussion

2.2.3.1 Laboratory Data

Turbidity at Cougar and Siouxon creeks was consistently below 5 nephelometric turbidity units (NTUs). Levels at Swift Reservoir inflow were typically higher, increasing to over 30 NTUs in April of both 1996 and 1997 and to 76 NTUs in March 1997 (Figure 2.2-1). With the exception of high runoff periods during the spring, turbidity at tailrace sites was typically higher than at stream sites. These higher levels occur because turbine inflow is withdrawn from reservoir depths where sediment is more concentrated. In addition, agitation in the tailrace causes localized turbidity. Summer turbidity levels were low at all sites, typically 2 to 3 NTUs.

Alkalinity at tailrace sites was between 10 and 29 mg/l; alkalinity levels at bypass and tributary sites were slightly higher and more variable (Figure 2.2-2). The inlet to Swift Reservoir (SWRES) was typically higher in alkalinity than other sites, and Cougar Creek typically lowest.

With few exceptions, total phosphorus (TP) levels at sites in the Swift project area, particularly the inflow to Swift Reservoir, were higher than other sites (Figure 2.2-3), possibly a result of the pumice and volcanic ash content of soils in the Swift watershed following the Mount St. Helens eruption. TP in excess of 0.05 mg/l is considered high relative to other data collected during this study. The maximum TP value was 0.26 mg/l at Swift Reservoir in November 1997 (Appendix 2.2-1). TP values were usually lower at Siouxon Creek than other stream sites. Values at the Swift No. 2 tailrace were typically higher than other tailrace sites, again reflective of the volcanic influence in the Swift Creek watershed.
Figure 2.2-1a. Turbidity at tributary sites, March 1996 through February 1998.
Figure 2.2-1b. Turbidity at tailrace sites, March 1996 through February 1998.
Figure 2.2.2a. Alkalinity at tributary sites, March 1996 through February 1998.

Alkalinity at Tributary Sites, March 1996 - February 1998

mg/l as CaCO₃

- SWRES
- SW2BP
- COUGM
- SIOUX

Alkalinity at Tributary Sites, March 1996 - February 1998

Figure 2.2.2a. Alkalinity at tributary sites, March 1996 through February 1998.
Figure 2.2-2b. Alkalinity at tailrace sites, March 1996 through February 1998.
Figure 2.2-3a. Total phosphorus at tributary sites, March 1996 through February 1998.
Figure 2.2-3b. Total phosphorus at tailrace sites, March 1996 through February 1998.
Ortho-phosphorus (OP) levels at tributary sites were variable, typically less than 0.05 mg/l (Figure 2.2-4). A pattern of lower OP values during the growing season and higher values during the winter months was seen at tailrace sites. During periods of low biological demand (i.e., December 1996 through March 1997), ortho-phosphorus levels were highest at the inflow to Swift Reservoir, intermediate at the Yale tailrace, and lowest at the Merwin tailrace. Ortho-phosphorus levels reached 0.07 mg/l at the Swift No. 2 tailrace in January and February 1997. This pattern reflects deposition of adsorbed phosphorus on fine sediment as suspended material moves through the Lewis River projects.

Data collected during the summer of 1997 suggest that less phosphorus was available for primary production during the summer of 1997 than in 1996. Chlorophyll $a$ and phytoplankton data (see below) support this assertion. These differences may be a result of the high flow event in February 1996, which probably increased the amount of fines and associated phosphorus in runoff throughout the 1996 field season. Turbidity during the spring of 1996 was 2 to 3 times higher than the same period in 1997.

Nitrate levels ($\text{NO}_2 + \text{NO}_3$, mg/l as N) ranged from less than detection (0.01 mg/l) to 0.27 mg/l in October 1996 at COUGM. All sites had relatively high levels in April 1996, possibly due to mobilization of nitrogen from scoured sediments during the previous month’s flooding (Figure 2.2-5). However, the April 1996 blank sample result for nitrate was 0.06 mg/l, which suggests potential contamination of the April 1996 samples with the exception of SW2BP in 1997.

In contrast to the pattern seen for ortho-phosphorus at tailrace sites (i.e., decreasing concentrations from Swift to Merwin), an opposite pattern occurred for $\text{NO}_2 + \text{NO}_3$. However, the pattern was not apparent during the growing season (June through August). The downstream increases in nitrogen levels are likely due to allochthonous inputs from the watershed. The pattern breaks down during the growing season as nitrate is utilized by phytoplankton.

Ammonia levels (mg/l as N) ranged from less than detection (0.01 mg/l) to 0.11 mg/l at Yale Lake in December 1997, the Swift No. 2 tailrace in January 1997 (Appendix 2.2-1). In general, higher levels occurred during the summer of both 1996 and 1997. The primary source of ammonia is decomposition of organic material; higher levels in the summer are expected with breakdown of algae, zooplankton, and allochthonous organic material.

Total persulfate nitrogen (TPN) is a digestion method which, unlike total Kjeldahl nitrogen (TKN), accounts for inorganic nitrogen as well as organic nitrogen and ammonia. Thus, TPN is a measure of total available nitrogen. TPN values were seldom above the 0.2 mg/l detection limit. The 2 highest TPN concentrations, 1 mg/l and 0.49 mg/l, were recorded at the Swift Reservoir inlet in March 1997 and April 1996, respectively (Appendix 2.2-1). Both of these values were much higher than corresponding nitrate ($\text{NO}_3 + \text{NO}_2$) or ammonia levels. Despite the predominance of less than detectable values, the TPN results suggest that organic nitrogen, probably of allochthonous origin, can be an important component of the nitrogen pool entering the project area during the spring.
Figure 2.2-4a. Ortho-phosphorus at tributary sites, March 1996 through February 1998.
Figure 2.2-4b. Ortho-phosphorus at tailrace sites, March 1996 through February 1998.
Nitrogen (NO₂+NO₃) at Tributary Sites, March 1996 - February 1998

Figure 2.2-5a. Nitrate plus nitrite nitrogen at tributary sites, March 1996 through February 1998.
Figure 2.2-5b. Nitrate plus nitrite nitrogen at tailrace sites, March 1996 through February 1998.
Fecal coliform levels were less than two colonies per 100 ml in most cases. The highest fecal coliform count was 170 colonies per 100 ml at the Swift Reservoir inlet in October 1996 (Appendix 2.2-1).

Quarterly sampling at YALTR showed low levels of all analytes measured, including cations and anions, metals, and organics (pesticides, herbicides, and PCBs) (Table 2.2-1). No detectable levels of pesticides, herbicides, or PCBs were found in any of the quarterly samples. With the exception of a detectable level of mercury in July 1996 and January 1998, metals were all non-detectable. The mercury level in the July sample was 0.00031 mg/l (0.31 µg/l) and was 0.41 µg/l in the January sample. Both values are below the State of Washington acute criteria of 2.4 µg/l (0.0024 mg/l), but above the chronic criteria of 0.012 µg/l (WAC 173-201A-040). Note that the criteria for chronic mercury levels are based on 4-day averages, while the sample in reference is a single measurement. Mercury was undetectable in all of the other samples collected.

With the exception of silica, cations and anions measured in the quarterly samples were below average levels in drinking water (National Environmental Testing 1995). Silica levels (approximately 13 to 16 mg/l) were approximately twice the average levels in drinking water.

2.2.3.2 In Situ Data

Results of pH, DO, specific conductance, and TDG are summarized below for stream and tailrace sites. Results for Speelyai Creek are discussed separately at the end of this section.

The minimum DO concentration observed during the monitoring period was 7.3 mg/l at the SW2TR in August 1997. A value of 8 mg/l was recorded at the Merwin tailrace in September 1996. All other DO values were greater than 9 mg/l (Appendix 2.2-2). Values were generally higher in the spring, and decreased slightly with increasing water temperature through the summer (Figure 2.2-6).

Overall, monthly pH values ranged from 5.9 to 7.8 (Appendix 2.2-2). The minimum value was observed at the Swift No. 2 tailrace, and although this was the only measurement less than 6.0, several relatively low values were observed throughout the monitoring program (Figure 2.2-7). Decomposition of organic material may be occurring at a relatively high rate in the Lewis River watershed, at times causing slightly lower pH due to high rates of CO₂ evolution.

Specific conductance was typically higher at the uppermost station monitored (SWRES) inflow, with a maximum of 73 µS/cm in August 1997. There was less variation in specific conductance at tailrace sites, with values typically between 30 and 40 µS/cm (Figure 2.2-8).
### Table 2.2-1. Results of quarterly lab analyses at Yale powerhouse tailrace.

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<td>mg/L</td>
<td>mg/L</td>
<td>mg/L</td>
<td>mg/L</td>
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TDG levels were close to 100 percent (equilibrium) saturation for the majority of sampling events (Figure 2.2-9). Higher values were observed at the Swift No. 2 tailrace and Yale tailrace sites; measurements in June and July 1997 at these sites exceeded 110 percent saturation. Gas saturation at the Yale tailrace was the subject of separate studies reported in Section 2.4 of this report.

Speelyai Creek Monitoring

Monitoring at Speelyai Creek began in December 1996 at 2 locations: upstream of the diversion near the Highway 503 bridge, and at the Speelyai Fish Hatchery. Speelyai Creek (upstream of the springs) was diverted at the headgate diversion to Yale Lake in the 1950s due to the dominance of cold spring inflows in the reach between the hatchery and diversion site. The purpose of the diversion is to divert warm surface flows away from the hatchery inflow. In situ monitoring by PacifiCorp documented temperature at upper and lower sites (SPLYU and SPLYL, respectively), as well as DO, pH, and specific conductance. Temperature differences were described in Section 2.1; results of other in situ parameters are discussed below.

Differences in DO at the 2 locations were within a milligram per liter on most visits, and never differed by more than 2 mg/l. Minimum DO occurred in May 1997, with readings near 9 mg/l at both sites. Values were generally above 10 mg/l (Figure 2.2-10).
Figure 2.2-6a. Dissolved oxygen concentrations at tributary sites, March 1996 through February 1998.
Figure 2.2-6b. Dissolved oxygen concentrations at tailrace sites, March 1996 through February 1998.
Figure 2.2-7a. pH at tributary sites, March 1996 through February 1998.
Figure 2.2-7b. pH at tributary sites tailrace sites, March 1996 through February 1998.
Figure 2.2-8a. Specific conductance at tributary sites, March 1996 through February 1998.
Specific Conductance at Tailrace Sites, March 1996 - February 1998

Figure 2.2-8b. Specific conductance at tailrace sites, March 1996 through February 1998.
Figure 2.2-9. Total dissolved gas levels at tailrace sites, March 1996 through February 1998.
Figure 2.2-10. Dissolved oxygen concentrations at Speelyai Creek monitoring sites, November 1996 – February 1998.
pH values were also similar between upper and lower Speelyai sites. Values were slightly higher at the lower site during the winter months, and similar or slightly higher at the upper site during the summer months. This weak pattern in the data is probably due to precipitation effects on surface water flows prior to the diversion, which tends to depress pH at the upper site relative to groundwater (Figure 2.2-11).

Specific conductance was consistently higher at the downstream site, reflecting greater ionic strength of groundwater than the undiverted surface water of Speelyai Creek. Values at SPLYL were from 17 µS/cm to 28 µS/cm greater, or 50 percent to nearly 100 percent higher than upstream values (Figure 2.2-12).

2.2.4 Quality Assurance/Quality Control

Results of duplicate and blank sample analyses are shown in Appendix 2.2-3. Field duplicates, which were blind to the analytical laboratory, were generally in close agreement to the routine samples. Percent relative standard deviation (RSD) was lowest for alkalinity (typically zero, maximum of 16.4 percent RSD). RSD values for nutrients were usually low, but there were several sample pairs between 20 and 50 percent RSD. Precision could not be quantified for total persulfate nitrogen, or for other parameters in which one or both measurements were less than the detection limit. RSD for turbidity was high in some cases (maximum 115 percent); however, all but 3 values were under 20 percent. Most of the fecal coliform sample pairs were less than detection (2 most probable number [MPN]/100 ml), but precision was poor when both samples had detectable coliform numbers (50 to 80 percent RSD).

With few exceptions, blank samples had undetectable levels of analytes normally measured in routine samples. Nitrate + nitrite was detectable at a relatively high level in April 1996 (0.06 mg/l). April 1996 nitrate values were higher than other months; sample contamination may have contributed to the relatively high values. Total phosphorus was also detectable on several samples, but at levels near the detection limit (maximum of 0.03 mg/l).

2.3 RESERVOIR MONITORING

The reservoir monitoring program consisted of monthly visits for physical, chemical, and biological measurements. The objective of this study element is to characterize the limnology of the reservoir and to assess the influence of project operations on reservoir water quality.

2.3.1 Study Area

The study area for activities specific to Yale Lake monitoring was the same as described for water quality monitoring in Section 2.2.1. Data were collected at 2 locations in Yale Lake: the upstream end of the reservoir near the Cougar Creek mouth, and near the dam. The sites were located over the old river channel and are shown in Figure 2.1-1. The monitored sites were consistent with those identified in the Yale FSCD.
Figure 2.2-11. pH at Speelyai Creek monitoring sites, November 1996 – February 1998.
Figure 2.2-12. Specific conductance at Speelyai Creek monitoring sites, November 1996 – February 1998.
2.3.2 Methods

At each reservoir monitoring station, profiles of *in situ* parameters were conducted, secchi disk transparency was measured, and samples were collected for analysis of water quality and biological constituents. The *Hydrolab*® Surveyor 2 or 3 previously described for streams and tailraces was used for reservoir profiling. Data were collected at 1-m intervals from the surface to a depth of 15 m, and at 5-m intervals from 15 m to the reservoir bottom.

The same laboratory analyses for samples collected at stream and tailrace sites were also conducted on the Yale Lake samples. Samples for water chemistry were collected at a depth of 1.5 m at both stations (YRESU-S and YRESL-S), and near the intake depth at the lower station, approximately 20 m deep at full pool (YRESL-B). A Van Dorn sampler was used for reservoir sampling.

Chlorophyll *a* and phytoplankton samples were collected as separate aliquots poured from the sampler used for the surface water sample collection (1.5-m depth). Chlorophyll samples were stored in opaque bottles pre-preserved with MgCO₃. Chlorophyll analyses in March, April, and May 1996 were conducted spectrophotometrically by Oregon Analytical Laboratory. Subsequent samples were sent to Aquatic Analysts, Inc. and measured fluorometrically. The latter is a more sensitive technique better suited to unproductive water bodies. Phytoplankton samples were preserved in the field with Lugol’s solution.

Zooplankton samples were collected monthly at each station with vertical tows (bottom to surface) at each of the 2 stations previously described. An 80μ mesh plankton net was used for the plankton tows; samples were preserved in the field using 5 percent buffered formalin. Preserved samples were shipped to the University of Washington Fisheries Research Institute and analyzed by Mr. Jeff Cordell.

2.3.3 Results and Discussion

The results of monthly temperature, DO, and pH profile monitoring studies conducted in Yale Lake are summarized below. The following sections also describe the results of water chemistry, chlorophyll *a*, phytoplankton, and zooplankton studies completed over the monitoring period.

2.3.3.1 Reservoir Profiles

Monthly profile data collected at the upstream and downstream reservoir stations are shown in Appendix 2.3-1. Summaries of profile data for temperature, DO, and pH at the downstream station are contained in Figures 2.3-1 through 2.3-3. No profile data were collected in March 1996 or August 1997 due to equipment failure. Inclement weather prevented access in January and February 1997. A weak thermocline was evident by April of both years; maximum thermal stratification was seen in July of each year. Surface temperatures were 23°C and 21°C at the upstream and downstream stations, respectively, in July 1996, and 21°C at the downstream site in July 1997. Surface to
Figure 2.3-1a. Yale Lake temperature profiles; April through December 1996.
Figure 2.3-1b. Yale Lake temperature profiles; March 1997 through February 1998.
Figure 2.3-2a. Yale Lake dissolved oxygen profiles; April through December 1996.
Figure 2.3-2a. Yale Lake dissolved oxygen profiles; March 1997 through February 1998.
Figure 2.3-3a. Yale Lake pH profiles; April through December 1996.
Figure 2.3-3b. Yale Lake pH profiles; March 1997 through February 1998.
bottom temperature differences of 10°C at the upstream site, and 17°C at the downstream site were observed in July 1996. The same difference (17°C) between surface and bottom temperatures was also seen in July 1997. During mid-summer, the thermocline resided between 10 and 15 m at both locations.

Effects of algal photosynthesis were most evident in the June 1996 pH profiles. Epilimnetic pH was above 8 at both stations, with a maximum of 8.4 at the downstream station at 2 m. These results correspond with chlorophyll a and phytoplankton data; maximum chlorophyll a values and phytoplankton biovolumes were recorded at this time (see below). In 1997, sampling either missed the maximum bloom conditions, or there was reduced effect of phytoplankton on pH. Epilimnetic pH was consistently less than 8.0 at both stations in 1997 (see Appendix 2.3-1 for profiles at Upper Yale Lake Station).

The reservoir bottom did not approach anoxic conditions during either field season (1996 or 1997). Minimum DO was observed in November and December 1996, when values were near 7 mg/l at a depth of 60 to 65 meters. The minimum DO observed in 1997 was 8.6 mg/l at a depth of 75 m in July (Figure 2.3-2).

A spring algae bloom is evident from the DO profile at the downstream station in April 1996. Gradually increasing DO levels were seen from the surface to a depth of 30 m, where DO reached 17.5 mg/l. A much smaller bloom occurred in April of 1997, causing slight increases in DO within the upper 5 m at the downstream station. The dominant algae during both of these periods were diatoms- Cryptomonas erosa in April 1996, and Rhodomonas minuta in 1997. Diatom blooms are common during early spring when light levels and water temperatures are still relatively low.

Specific conductance was typically between 30 µS/cm and 50 µS/cm at both stations. Values were somewhat higher and more variable later in the summer, with slightly higher readings at the downstream station.

Secchi depth, a measure of water transparency, was less than 2 m in April and May of both years at upper and lower stations (Figure 2.3-4). Values steadily increased during the summer, reaching 8 m in August 1996 and over 10 m in July 1997 at the downstream station. Greater transparency at the downstream station is likely due to loss of suspended sediment as water traveled down-lake.

2.3.3.2 Yale Lake Water Chemistry

Alkalinity at Yale Lake stations averaged 16 mg/l CaCO3 over the monitoring period (March 1996 through August 1997). Alkalinity at the intake depth was similar to surface values during most months. However, surface levels were higher at both stations in October and November of 1996 (Figure 2.3-5).

Total phosphorus was typically less than 0.03 mg/l, with values ranging from less than detection (0.01 mg/l) to 0.09 mg/l in March 1997. A similarly high value (0.08 mg/l) occurred in March 1996. With the exception of higher TP concentrations in March of both years, there were no apparent patterns in the data with respect to upper and lower station differences, or between surface and intake depth measurements (Figure 2.3-6).
Figure 2.3-4. Secchi depth (meters) at upper and lower Yale Lake stations.
Figure 2.3-5. Alkalinity at Yale Lake monitoring stations, March 1996 through August 1997.
Figure 2.3-6. Total phosphorus monitoring stations, March 1996 through August 1997. YRESU-S = Upper station, surface; YRESL-S = lower station, surface; YRESL-B = lower station, intake depth.
Ortho-phosphorus (OP), which is biologically available, declined to non-detectable levels in May 1996 at all 3 locations (both surface sites and the intake depth), and at the 2 surface sites from June through August 1996. Values near the intake (approximately 20 m) were detectable during this period. OP levels in 1997 were generally higher, suggesting reduced phytoplankton activity over that seen in 1996. OP concentrations were a large fraction of total phosphorus during both years (Figure 2.3-7).

As seen in tributary and tailrace samples, nitrogen (nitrate + nitrite) was markedly higher at Yale Lake sites in April 1996 than in all other months (Figure 2.3-8). Levels at this time were 0.14 mg/l at the upstream site, 0.19 mg/l at the lower surface site, and 0.15 mg/l at the intake depth. Nitrogen values during other months were typically half or less of the April 1996 concentrations. As noted previously, the April 1996 field blank had a measurable (0.06 mg/l) nitrate + nitrite concentration (Appendix 2.2-3). This suggests that the April nitrate results were biased high. Nitrogen levels from May through October 1996 were at or near detection at all 3 stations (0.01 mg/l). Levels increased again during fall turnover (November and December). A similar but reduced pattern of Nitrogen concentration was seen in 1997. Values at the 2 surface stations declined from 0.04 mg/l in March to less than detection from May through August. In contrast to 1996, values near the intake depth were above detection from March through June of 1997.

Turbidity at Yale Lake stations was markedly higher in the spring of 1996 than at any other time. Maximum turbidity was 30 NTUs at the upper surface station. Spring 1997 turbidity levels were approximately one-third of the values seen at the same time in 1996. Summer levels were less than 5 NTUs in both years (Figure 2.3-9).

### 2.3.3.3 Chlorophyll a and Phytoplankton

Chlorophyll *a* is an indicator of algal biomass; values mirrored those of phytoplankton biovolume throughout the monitoring period (Figure 2.3-10). Chlorophyll *a* levels were less than 5 mg/m³ in most months, but substantially higher in June 1996 than all other months (34 mg/m³ and 12 mg/m³ at the upstream and downstream stations, respectively).

The number of phytoplankton species identified in monthly samples ranged from 6 in March 1996 near Yale Dam, to 27 species in May and November 1996 at the upstream station. The spring samples (March through May) of both years were dominated by diatoms, primarily *Diatoma hiemale mesodon*, *Melosira italica*, and *Cryptomonas erosa*. Blue-green algae, which are often used as indicators of eutrophic conditions, were dominant each year at Yale Lake during early summer. The shift from diatoms to blue-greens was most dramatic in June 1996, when the blue-green alga *Anabaena flos-aquae* was dominant at both stations (85 percent of the biovolume at the upstream station, and 94 percent at the lower station). Algal biovolume during most months was less than 100,000 cubic µM/ml; however, the June 1996 biovolume was approximately 8 times higher than this at the upstream station, and approximately 4 times higher at the downstream station.
Figure 2.3-7. Ortho-phosphorus at Yale Lake monitoring stations, March 1996 through August 1997.
Figure 2.3-8. Nitrogen (nitrate + nitrite) at Yale Lake monitoring stations, March 1996 through August 1997.
Figure 2.3-9. Turbidity at Yale Lake monitoring stations, March 1996 through August 1997.
Figure 2.3-10a. Yale Lake chlorophyll $a$, March 1996 through February 1998.
Figure 2.3-10b. Yale Lake phytoplankton biovolume, March 1996 through February 1998.
Blue-green algae were also observed later in the summer during both field seasons. In August 1996, the blue green alga *Aphanizomenon flos-aquae*, a species often associated with eutrophic conditions, was present at both stations (37 percent of biovolume at the upstream station, and 8 percent at the downstream station). *Aphanizomenon flos-aquae* was also seen in July 1997 at both stations, and in August 1997 at the lower station. Species observed during each of the monthly sampling periods are listed Appendix 2.3-2.

2.3.3.4 Zooplankton

Results of zooplankton sample analyses are contained in Appendix 2.3-3 for 1996 and 1997. Summaries of results for each field season are presented below.

### 1996 Results

Species of *Daphnia*, a cladoceran, were the most abundant zooplankton in the Yale Lake samples. In April and May of 1996 at both stations and in June 1996 at the downstream station, when *Daphnia* densities were relatively very low, *Daphnia rosea* was the most abundant *Daphnia* species. However, during periods of peak *Daphnia* density in July and August, *D. galeata* was the dominant *Daphnia* species at both stations. *D. galeata* was always more abundant at the upstream station than at the downstream station. *D. rosea* was either more abundant or occurred at similar densities at the upstream station compared to the downstream station. *Daphnia* in the *pulicaria/schodleri* complex were the least abundant *Daphnia* group (Appendix 2.3-3, Figure 1).

Densities of other cladoceran species (*Bosmina longirostris*, *Holopedium gibberum*, and *Leptodora kindtii*) were also more abundant at the upstream station, with the exception of July when *Holopedium gibberum* was more abundant at the downstream station. (Appendix 2.3-3, Figure 2).

The copepod fauna was completely dominated by 2 calanoid species, *Hesperodiaptomus franciscanus* and *Epischura nevadensis*. Cyclopoid copepods, represented by *Macrocyclops albidus*, occurred only rarely. *E. nevadensis* was the dominant copepod at both stations April through June but decreased greatly thereafter, disappearing from the samples in August (upstream station) and September (downstream station). *H. franciscanus* was the most abundant copepod in July through September, occurring at peak or near-peak densities throughout this period. Both dominant copepod species and copepod nauplii were more abundant at the upstream station, with 2 exceptions—densities of copepod nauplii were approximately the same in July, and *E. nevadensis* was more abundant in August at the downstream station (Appendix 2.3-3, Figure 3). Similarly, total rotifer densities were higher at the upstream station on 4 of 6 sampling dates. Rotifer densities peaked in June at the upstream station and in August at the downstream station (Appendix 2.3-3, Figure 4).

### 1997 Results

As in the 1996 samples, the early spring 1997 samples had the lowest densities of *Daphnia* spp. at both sites, represented mainly by *D. rosea*. Also as in 1996, during periods of peak *Daphnia* density June through August, *D. galeata* was usually the
dominant *Daphnia* species at both sites. In contrast to 1996, when *Daphnia* spp. were usually more abundant at the upper reservoir site, higher numbers of *Daphnia* spp. were seen at the lower reservoir site on several occasions in 1997 (Appendix 2.3-3, Figure 1). However, overall *Daphnia* densities were higher in 1996 than in 1997; in the 1997 samples *Daphnia* numbers never exceeded 300 m$^{-3}$. In contrast, *Daphnia* numbers in 1996 exceeded this number 5 times between the 2 sites, and on several occasions exceeded 1,000 m$^{-3}$.

In 1997 there were no months in which *Daphnia* in the *pulicaria/schodleri* complex dominated the total *Daphnia* numbers. *Daphnia* was dominant in 1996 in November and December. However, during these months, overall *Daphnia* numbers were low, about one-fifth of peak spring-summer densities.

As in 1996 samples, densities of other cladoceran species (*Bosmina longirostris*, *Holopedium gibberum*, and *Leptodora kindtii*; Appendix 2.3-3, Figure 2) peaked in June and July. These cladocerans were scarce or nonexistent in samples from November through May. In June, when densities began to rise, these species were more abundant at the upper reservoir site. Highest densities of these other cladocerans peaked in the July lower reservoir samples due to high numbers of *Holopedium gibberum*.

The copepod fauna was completely dominated by the calanoid copeods *Hesperodiaptomus franciscanus* and *Epischura nevadensis* (Appendix 2.3-3, Figure 3). In 1997 samples, *E. nevadensis* first appeared in zooplankton samples in May and peaked in June, decreasing thereafter. In contrast to data from 1996, *H. franciscanus* was always the most abundant copepod. In 1997 this species occurred in peak densities during the June-August sampling period. *E. nevadensis* was always more abundant at the upper reservoir site, but in contrast to 1996 samples, *H. franciscanus* was more abundant at the lower site in April and May. Similar to results from the 1996 samples, total rotifer densities were higher at the upper reservoir site during periods of peak density. Rotifer densities were highest in June at both sites (Appendix 2.3-3, Figure 5). As with *Daphnia* spp., rotifer numbers were higher in 1996 than in 1997. Rotifer abundance exceeded 1,000 m$^{-3}$ six times in 1996 samples but only three times in 1997 samples. Also, while 1997 rotifer densities never exceeded 2,000 m$^{-3}$, those in 1996 samples did so three times, reaching peak densities in excess of 9,000 m$^{-3}$. Copepod nauplii were also most abundant at the lower site on several occasions but were more abundant at the upper site during periods of peak density (Appendix 2.3-3, Figure 5).

### 2.4 TOTAL DISSOLVED GAS STUDY

*In situ* data collected by PacifiCorp in 1994 indicated a potential influence of Yale Project operations on total dissolved gas (TDG) levels in the Yale tailrace. At times, TDG levels exceeded the 110 percent WDOE limit. To determine the extent of elevated dissolved gas levels in the tailrace and, if possible, to confirm the source of elevated TDG, PacifiCorp initiated 4 separate evaluations of the Yale tailrace beginning in 1995.

The first study was an initial evaluation of how dissolved gases responded to fluctuating discharge levels. A second study was conducted to determine if dissolved gas levels improved with the installation of new turbine runners. The third study evaluated the
effects of the turbine air admission system on tailrace TDG levels. Studies revealed that elevated TDG levels were attributed principally to the air admission system, which improves operating efficiencies at low generation levels. After reviewing these studies, PacifiCorp modified both the air admission system and turbine operation. These modifications were evaluated in a fourth study to determine whether modifications adequately reduced dissolved gases during turbine operation.

2.4.1 Study Area

PacifiCorp’s TDG study was conducted in the North Fork Lewis River in the Yale Project tailrace.

2.4.2 Methods

Evaluation periods (date and time) were selected when surface water temperatures in the tailrace were the warmest of the year (July and August) and thus, the potential of elevated gas supersaturation is highest. The duration of evaluation periods was based on the ability of the powerhouse operators to regulate turbine operation. Predetermined operating schedules, based on data and generation needs, were incorporated into each evaluation period to ensure that data were collected over a broad range of discharges (Table 2.4-1).

Common Sensing® Total Dissolved Gas meters in conjunction with Licor® data loggers collected and continuously logged TDG data. Adjustments and calibration of TDG meters, if necessary, were made according to the manufacturer’s specifications prior to deployment.

Data loggers were programmed to record TDG data at various time intervals. Logging intervals were selected based on the time required for tailrace TDG readings to stabilize between changing powerhouse discharges. A 30-minute logging interval was selected during the initial evaluation to ensure that TDG had stabilized prior to being recorded. It was later learned that a 15-minute logging interval was adequate. During the air vent evaluation, 1-minute intervals were used because the purpose was to identify trends, rather than a statistical relationship.

TDG probes were always placed adjacent to discharge flow. A 2-pound lead weight was fastened to the probe to restrict movement and prevent it from surfacing during turbulent flows. Probes were submerged to a depth of at least 2 m to prevent the formation of air bubbles on the probe membrane.

The evaluation of the air admission system required the manipulation of the turbine air vent. At the time of the evaluation, the valve regulating air flow leaked even when fully closed. Complete closure of the air vent was accomplished by capping the vent on the outside, which effectively prevented air from entering the turbine. The turbine was operated at 2 generation levels: 40 megawatts (MW) and 1 MW. For both generation levels, the air vent was moved to both a closed and open position.
During the operational evaluation it was necessary to isolate the operation of each unit for comparability to previous studies. Therefore, 2 test periods were used: Unit No. 1 was evaluated on July 21, and Unit No. 2 on August 28, 1997.

2.4.3 Results and Discussion

Results obtained from the 4 evaluation periods at the Yale tailrace are described below. The initial evaluation identified the severity of TDG in the tailrace; the second period evaluated the effect of new turbine runner on tailrace TDG levels with respect to 1995 results; the third period identified the source of elevated TDG after it was learned that the new turbine runners did not effectively reduce tailrace TDG; and the fourth evaluation showed the effect modifications to the air admission system have on tailwater gas saturation.

2.4.3.1 Initial Evaluation

The relationship of percent saturation and discharge at the Yale powerhouse shows a strong negative linear correlation ($r^2 = 0.93$; see Figure 2.4-1). At discharge levels below
Figure 2.4-1. Percent saturation (n = 132) in relation to Unit No. 1 turbine operation at Yale powerhouse (old runner) from July 17 through July 20, 1995.
500 cfs, dissolved gas approaches 125 percent gas saturation. However, as discharge levels increase, percent saturation decreases. During typical daytime operations (2,800 to 3,200 cfs per unit), percent saturation is normally below 105 percent. At approximately 2,200 cfs, percent saturation in the tailrace would be expected to be, on average, 110 percent (±4.8 percent at the 95 percent confidence level). Therefore, to meet state dissolved gas standards, the turbine must discharge at least 2,200 cfs of water based on conditions (e.g., water temperature) at the time of the study.

The inefficiency of the turbine at discharge levels below 1,000 cfs is illustrated by the wide dispersion of data points at these levels compared to data points at discharge levels above 2,800 cfs. For example, the variance in percent saturation at a discharge of 1,000 cfs is 10.9, compared to a variance of 0.4 at discharges above 2,800 cfs. Therefore, at discharges below 2,800 cfs it becomes difficult to predict dissolved gas levels with confidence.

Based on the slope (-0.0069) of the regression line depicted in Figure 2.4-1, percent saturation does not seem to be particularly sensitive to discharge. For example, an increase of 500 cfs results in a reduction of only about 3.5 percent saturation. This relationship, however, can be highly variable, especially at low discharge levels.

2.4.3.2 Evaluation After Runner Replacement

Despite improved operating efficiencies as a result of turbine upgrades, a similar relationship between percent saturation and discharge was observed before and after runner replacement (Figure 2.4-2). Tailrace TDG was again strongly correlated with discharge ($r^2 = 0.84$). Also, at low discharge levels (e.g., 700 cfs), dissolved gas approaches 120 to 125 percent saturation, and the dispersion of data once again becomes unpredictable. At full generation, the data are consistent and remain below state limits.

Some visible differences after runner replacements include reduced sensitivity of percent saturation to discharge, less variation in data at full generation, and the point at which percent saturation exceeds state limits. The difference in the discharge at which percent saturation exceeds WDOE limits (2,800 cfs after runner upgrade compared to 2,300 cfs before runner upgrade) is a reflection of the expanded discharge range of the upgraded turbine. The new runner enables the turbine to discharge more water, thus causing the discharge at which percent saturation exceeds the state limit to also increase relative to the previous study. The relationship and dispersion trends of TDG data to discharge, however, remain the same compared to the previous study despite the difference in discharge rates. The invariability of the data at full generation illustrates improved efficiency of the turbine as a result of the new runner installation.

The inability of the new runner(s) to effectively reduce dissolved gas levels led to the evaluation of alternative sources of dissolved gases. The air admission system was evaluated as a primary source of elevated dissolved gas levels.
Figure 2.4-2. Percent saturation (n = 259) in relation to Unit No. 2 turbine operation at Yale powerhouse (with new runner) from July 21 through July 26, 1996.

\[ y = -0.0035x + 119.66 \]

\[ R^2 = 0.84 \]
2.4.3.3  Evaluation of Turbine Air Vent Influence

The Yale Project turbines incorporate an air admission system that draws air directly into the turbine via an outside vent. When air enters the turbine, it is subject to increased pressure and mixing within the turbine, which helps dissolve the entrained air into solution. The air admission system is necessary to equalize pressure within the turbine, which reduces cavitation and improves operating efficiency.

Trends were observed for both the 40 and 1 MW generation levels (Figure 2.4-3). At the 40 MW level, dissolved gases were allowed to stabilize for approximately 35 minutes before any manipulation of the air vent. Within minutes after the air vent was closed, tailrace TDG began to decline at a rate of about 0.5 percent per minute. The decline continued until the air vent was opened after about 15 minutes. Time constraints prevented further evaluation of the decline. At the 1 MW level, dissolved gases were again allowed to stabilize with the air vent open. After a stabilization period of about 45 minutes, the air vent was again closed. Within minutes after capping the air vent, TDG began to decline. In about 1 hour, TDG had declined from 128 to 110 percent saturation -- the state limit. These trends support the conclusion that the air vent(s) is the primary influence on tailrace TDG levels.

Air Vent and Load Modifications

The data show that at discharges below approximately 3,000 cfs (~50 MW), TDG may exceed the WDOE limit (Figure 2.4-2). However, by closing the air vent at discharges below 3,000, it has been demonstrated that TDG remains within acceptable state standards (Figure 2.4-3).

As a result of these data, PacifiCorp initiated load restrictions at the Yale Project to prevent TDG in the tailrace from exceeding state limits. Sustained generation is currently limited to at or below 20 MW and above 50 MW per unit. At levels below 20 MW, the air vent will always be closed via an isolation valve within the vent piping. The isolation valve is controlled electronically by a wicket gate position signal from a cam inside the governor cabinet. The valve is currently set to be closed at wicket gate positions below 30 percent, which corresponds to a load of 20 MW or less. No regulation of the air vent is necessary above loads of 50 MW, as TDG remains within WDOE standards above this level. At mid-operational ranges (20 to 50 MW), destructively high levels of cavitation occur if the air vent is closed. Because the air vent must be closed in this operating range to limit dissolved gases, PacifiCorp has proposed to only ramp and not generate in this range.
Figure 2.4-3. The effect of capping the turbine Unit No. 2 air vent on Yale tailrace gas saturation levels at 40 and 1 MW loads.
Figure 2.4-3. The effect of capping the turbine Unit No. 2 air vent on Yale tailrace gas saturation levels at 40 and 1 MW loads (continued).
2.4.3.4 Operational Evaluation

The intent of this study was to determine if the modifications to the air admission system are adequate in reducing dissolved gases in the tailrace during turbine operation. The air vent modifications were specifically designed to reduce dissolved gases at generation levels below 20 MW (~1,500 cfs). Therefore, predetermined discharge schedules for this evaluation are weighted toward the lower end of the turbine operating range (Table 2.4-1).

Data from the operational evaluation show that TDG levels remain within state standards at or below 1,500 cfs (20 MW) generation (Figure 2.4-4). This contrasts with previous studies that show gas saturation levels approaching 125 percent at these levels (Figures 2.4-1 and 2.4-2). This decrease is attributed to the air vent modifications and is significant (p < 0.001 at 400 cfs discharge).

At loads above 20 MW, the air admission system must be activated to compensate internal pressures during operation. This activation of the air admission system appears to affect the dispersion of data in mid-operational ranges (20-50 MW). Observations in this range display different patterns than observations in the lower and upper generation levels (Figure 2.4-4). For example, the mid-operational variance of observations at 1,650 and 2,000 cfs is 3.66 and 2.28, respectively. Conversely, at lower (400 cfs) and upper (3,500 cfs) operation levels, variance estimates are 0.13 and 0.20, respectively. Thus, as in previous studies, the ability to predict percent saturation in the mid-range is difficult. However, after the air vent modification, observations in the low range (< 20 MW) are less variable and more predictable than in previous studies. That is, less air entrainment appears to reduce variability or uncertainty of the data. Therefore, by closing the air vent at lower generation levels, predictions of dissolved gas levels are more reliable.

Surprisingly, in the upper operating range (>3,000 cfs), dissolved gas readings were higher than expected. In prior studies, dissolved gas levels were shown to meet state TDG criteria in this range. PacifiCorp believes that these readings are atypical, possibly related to ambient conditions in Yale (or Merwin) Lake, or a result of seasonal variations.

2.4.4 Compensation Depth

Compensation depth is an important component in addressing the biological effects of gas supersaturation. Simply put, the compensation depth is the depth at which no air bubbles can form. That is, the hydrostatic pressure equals atmospheric pressure. Therefore, below this depth the effects of supersaturation cannot occur. Assuming a constant atmospheric pressure, the compensation depth exhibits a linear relationship with percent saturation (Figure 2.4-5).

At the most severe saturation levels recorded in the Yale tailrace (~125 percent), the compensation depth approaches 2.6 m (at 1 atmosphere). The average depth of the tailrace area is 9 m. Therefore, fish have the opportunity to avoid the effects of supersaturation at this extreme level of saturation, assuming the ability to detect supersaturated conditions.
Figure 2.4-4. Percent saturation (n = 191) in relation to turbine No. 1 and No. 2 discharge at Yale powerhouse (with air regulation valve operating) on July 21 and August 28, 1997.
Figure 2.4-5. Compensation depths (in freshwater) for gas saturation levels ranging from 100 to 126 percent of 1 atmosphere (760 mm Hg).
The highest saturation level recorded in the restricted operating range (< 20 and > 50 MW per unit) at Yale during the 1997 evaluation was about 113 percent. This corresponds to a compensation depth of 1.3 m. The compensation depth at 110 percent, the WDOE standard, is 1 m. Whether this is biologically significant given the depth of the tailrace is unknown.

2.5 DIEL STUDIES

*In situ* data collected by PacifiCorp during monthly water quality visits are primarily used to characterize seasonal trends and differences between sites. However, diel changes cannot be inferred from these data. Daily minimum and maximum values of pH and DO are potential stressors to aquatic communities; thus, knowledge of diel fluctuations is important in an overall assessment of aquatic habitat. PacifiCorp conducted diel studies in 1997. These studies involved hourly monitoring of pH, DO, specific conductance, and temperature at 4 locations. The study area, methods, and results of these studies are presented below.

2.5.1 Study Area

Diel studies were conducted in August 1997 at 4 locations: Cougar Creek, the Swift No. 2 bypass reach, Siouxon Creek, and the Yale tailrace (Figure 2.5-1). Cougar Creek monitoring was conducted approximately 0.5 mile upstream of the Highway 503 bridge. Siouxon Creek was monitored approximately 300 m upstream of the farthest point accessible by boat at full pool conditions. This location was well above the influence of Yale Lake. The site at the Swift No. 2 bypass reach was approximately 50 m upstream of the mouth of Ole Creek. At the Yale tailrace, monitoring was conducted near the existing thermograph location.

In addition to documenting the extent of diel changes at these sites, data from this study were used to assess the relative importance of temperature versus primary production (i.e., benthic algae) in causing diel changes in pH and DO. Changes in generation levels (discharge) at the Yale tailrace were also evaluated to assess project-related influences on water quality within the Yale tailrace.

2.5.2 Methods

Hydrolab® Datasonde 3 multiparameter probes were used for diel studies at Cougar, Siouxon, and the Swift No. 2 bypass reach. A Hydrolab® Surveyor 4 unit was used at the Yale tailrace. All of the instruments were calibrated on the day of deployment following manufacturer’s recommendations, and given post-calibration checks immediately following the study. The Hydrolabs were programmed to record pH, DO, specific conductance, and temperature at all 4 sites; TDG was also recorded at the Yale tailrace. All data were collected at hourly intervals.

The 4 instruments were deployed on August 15, 1997 and retrieved 1 week later on August 22. Duration of monitoring was slightly less than 7 days at each site (162 hours at Yale tailrace, and 163 hours at the other 3 sites).
2.5.3 Results and Discussion

Post-calibration checks on the 4 Hydrolabs used during the study showed that very little drift occurred in the instruments. All parameters were close to their original calibration levels (less than 0.1 pH units, 1 percent DO saturation, and 3 µS/cm specific conductance). No adjustments to the data were made to correct for instrument drift.

Monitoring results showed a range of diel variation, from relatively constant conditions at Cougar Creek, intermediate diel changes at Siouxon Creek, to quite variable conditions at the Yale tailrace and Swift No. 2 bypass reach (Figures 2.5-2 through 2.5-5). Maximum, minimum, and median values for the monitored parameters are shown in Table 2.5-1.

Maximum temperatures during the 7-day study were recorded on August 17 at all 4 sites, and ranged from 7.8°C at Cougar Creek, to 24.2°C at the Yale tailrace. Cougar Creek is predominantly spring-fed; temperatures remain cold year-round and there is little diel variation. Daily temperatures at the Yale tailrace are strongly influenced by the Merwin pool. As generation at Yale is reduced, warmer water from Merwin enters the Yale tailrace area and increases ambient tailrace temperatures (Figure 2.5-6). Note, however, that data collected in 1998 contradict this trend (see Section 2.6).

Diel changes in temperature (i.e., the difference between daily minimum and maximum temperatures) were less than 1°C at Cougar Creek, 2-5°C at Swift No. 2 and Siouxon Creeks, and 5-12°C at the Yale tailrace (Figure 2.5-7). As noted above, the large diel fluctuations at the Yale tailrace reflect the influence of the Merwin pool during periods of reduced power generation at Yale.

Maximum pH during the study ranged from 7.2 at the Swift No. 2 bypass reach, to 7.8 at Siouxon Creek. With the exception of the Yale tailrace, little diel change in pH was observed among the 4 sites (Figure 2.5-8). Variation at the Swift No. 2 bypass, Siouxon, and Cougar Creek was less than 0.5 pH units. Diel changes at the Yale tailrace were similar to the other sites on days when generation was reduced for extended periods. However, on days when normal cycles of generation occurred, greater diel change in pH was observed. This can be attributed to alternating periods of dominance by more productive Merwin surface waters, with periods in which the tailrace volume was primarily water from the intake depth of Yale Lake (approximately 20 m at full pool). The relationship of pH to discharge levels during the study period is shown in Figure 2.5-9. Note that pH measurements were instantaneous, and discharge is averaged over the preceding hourly period.

Maximum DO concentrations ranged from 9.5 mg/l at Siouxon Creek, to 12.4 mg/l at Cougar Creek (Table 2.5-1). Minimum values ranged from 8.2 at Siouxon and the Swift No. 2 bypass reach, to 11.8 at Cougar Creek. The 8.2 mg/l value at Siouxon Creek was 87 percent of saturation. Maximum oxygen saturation at the 4 sites ranged from 107 percent at the Yale tailrace, to 99 percent at Siouxon Creek. Median percent saturation was less than 90 percent at both Siouxon Creek and the Swift No. 2 Bypass reach. Minimum percent saturation ranged from 79 percent at the Swift No. 2 Bypass, to 97 percent at Cougar Creek.
Yale Hydroelectric Project

Figure 2.5-1
Diel Study Site Locations

Legend
- Diel Study Site Locations
- Study Area
- FERC Project Boundary
- Recreation
- Residential
- Transmission Line
- Public Land Survey
- County Line
- Topography
- Water
- Stream
- Primary Road
- Secondary Road

Scale 1:90000

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February 09, 1999
Figure 2.5-2. Hourly monitoring of pH, dissolved oxygen, and temperature at Cougar Creek mouth, August 15-22, 1997.
Figure 2.5-3. Hourly monitoring of pH, dissolved oxygen, and temperature at Yale powerhouse tailrace, August 15-22, 1997.
Figure 2.5-4. Hourly monitoring of pH, dissolved oxygen, and temperature at Swift No. 2 bypass reach, August 15-22, 1997.
Figure 2.5-5. Hourly monitoring of pH, dissolved oxygen, and temperature at Siouxon Creek, August 15-22, 1997.
Table 2.5-1. Summary of diel study results, August 15-22, 1997.

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<td>8.5</td>
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<tr>
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<td>7.1</td>
<td>36.0</td>
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<td>162</td>
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<td>162</td>
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</tr>
<tr>
<td><strong>Siouxon Creek</strong></td>
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<td>Max</td>
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<tr>
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<tr>
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<td></td>
</tr>
<tr>
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<tr>
<td>N (Hrs.)</td>
<td>163</td>
<td>163</td>
<td>163</td>
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</table>

Diel changes in DO were lowest at Cougar Creek (less than 0.5 mg/l), approximately 1 mg/l at Siouxon Creek, and between 2.2 mg/l and 2.6 mg/l at the Swift No. 2 bypass and Yale tailrace sites, respectively (Figure 2.5-10).

Distinct diel changes in oxygen saturation occurred at the Swift No. 2 bypass reach. Values increased in late afternoon to between 100 percent and 104 percent, and fell to near 80 percent between midnight and 06:00. A similar pattern was seen at Siouxon Creek, but with lower maximum and higher minimum values. Diel patterns in oxygen saturation were apparent at the Yale tailrace, although there was greater variability and values remained above or near 100 percent (Figure 2.5-3). At Cougar Creek, oxygen saturation remained at or slightly above 100 percent throughout the study (Figure 2.5-2).

Little change in specific conductance was seen on a diel basis at any of the 4 sites. The maximum daily change was 3 µS/cm per day at the Yale tailrace (Figure 2.5-11). Median specific conductance was highest at the Swift No. 2 bypass reach (56 µS/cm) and between 36 and 47 µS/cm at the other 3 sites.
Figure 2.5-6. Hourly monitoring of temperature and average hourly flow at Yale powerhouse tailrace, August 15-22, 1997
Figure 2.5-7. Diel changes in temperature at Swift No. 2 Bypass Reach, Cougar Creek, Siouxon Creek, and Yale powerhouse tailrace, August 16-22, 1997.
Figure 2.5-8. Diel changes in pH at Cougar Creek, Siouxon Creek, Swift No. 2 bypass reach, and the Yale tailrace; August 15 - 22, 1997.
Discharge and pH at Yale Powerhouse Tailrace
August 15 - 22, 1997

Figure 2.5-9. Average hourly discharge levels and instantaneous hourly pH measurements at the Yale tailrace, August 15 through 22, 1997.
Figure 2.5-10a. Diel changes in dissolved oxygen at Swift No. 2 bypass reach, Cougar Creek, Siouxon Creek, and Yale powerhouse tailrace; August 16-22, 1997.
FIGURE 2.5-10b. Diel changes in percent saturation at Swift No. 2 bypass reach, Cougar Creek, Siouxon Creek, and Yale powerhouse tailrace; August 16-22, 1997.
Figure 2.5-11. Diel changes in specific conductance at Swift No. 2 bypass reach, Cougar Creek, Siouxon Creek, and Yale powerhouse tailrace; August 16-22, 1997.
As noted above, assessing the relative importance of primary production in influencing diel changes in pH and DO was an objective of the diel studies. Results of regression and correlation analyses suggest that primary production is a factor at the Swift No. 2 bypass reach (SW2BP), but that water temperature is the controlling factor at the 3 other sites. This observation is based on: (1) a slight increase in DO as temperature increased at SW2BP (in contrast to the expected pattern seen at the other sites), and (2) a positive correlation ($r^2 = 0.75$) between DO and pH at this site (Figure 2.5-12). No correlation was seen between pH and DO at Siouxon or Cougar creeks. At the Yale tailrace, an opposite effect was seen to that at SW2BP (i.e., decreasing pH with increasing DO) ($r^2 = 0.82$). This is an indirect effect of project operations on temperature, which bring cold, lower productivity water from the intake depth of Yale Lake to the tailrace area, with corresponding higher DO and lower pH.

Summary of Diel Studies

Results of the diel studies suggest that, in addition to temperature, primary production contributes to diel fluctuation of pH and DO at the Swift No. 2 bypass reach (SW2BP). Release of oxygen by attached algae at this site appears sufficient to counteract the effect of rising temperatures in lowering DO levels. Night-time minimums in DO concentration and percent saturation were lower, and the magnitude of diel changes in percent saturation were higher at SW2BP than at the other 3 sites.

The influence of project operations was evident at the Yale tailrace (YALTR). Diel changes in temperature, pH, and specific conductance were much higher at YALTR than at the other 3 sites. These results are due to varying levels of power generation. At reduced generation, the tailrace area is strongly influenced by warmer surface waters of the Merwin pool. Normal generation brings relatively deep, colder water from Yale Lake to the tailrace area.

The results of the diel studies indicate that substantial diel variability occurs at the Swift No. 2 bypass reach, Siouxon Creek, and at the Yale tailrace. Note that this type of variation is expected in surface water dominated systems. Results of instantaneous measurements of temperature, DO, and pH at these sites are influenced by time of day, and, at the Yale tailrace, by project operations. At groundwater-fed Cougar Creek, instantaneous measurements are representative of conditions that are relatively constant over the course of a day.

2.6 1998 YALE TAILRACE TEMPERATURE STUDY

To further evaluate thermal impacts of project operations at the Yale Project, PacifiCorp conducted an additional study during the summer of 1998. As discussed earlier in this section, temperatures at the Yale tailrace are largely determined by release temperatures from Yale Dam. Thus, when the project is at full generation, tailrace temperatures are near hypolimnetic temperatures of Yale Lake, and Lake Merwin surface waters are displaced. Despite the understanding of this general trend, the longitudinal extent of operational effects was unknown. To further address this issue and to look more closely at potential biological impacts of Yale operations on water temperature, an additional study was conducted from August 7-13, 1998.
Figure 2.5-12. Relationship between dissolved oxygen and pH at Swift No. 2 bypass reach, August 15-22, 1997 (hourly measurements, \( n = 163 \)).
2.6.1 Study Area

The Yale tailrace temperature study was conducted at the following 3 locations:

- Yale tailrace;
- Buoy line downstream of the tailrace, approximately 150 m from Yale Dam; and
- Upper Lake Merwin at U.S. Geological Survey (USGS) monitoring cable, approximately 350 m downstream of Yale Dam.

2.6.2 Methods

PacifiCorp utilized the same instrumentation for temperature data collection during this study as was described earlier for routine temperature monitoring. At the Yale tailrace, thermographs were deployed near the surface (3 m) and near the bottom (20 m). Surface and bottom data were also collected at the buoy line, at a bottom depth of 6.4 m, and at the USGS location. At the latter site, temperature data were collected at the surface and at 6.2 m. All temperature data were collected at 15-minute intervals and converted to hourly averages for analysis.

During the study, PacifiCorp modified the normal generation schedule to provide a range of test flows separated by off-line periods. Discharge ranged from 0-7,600 cfs.

2.6.3 Results

In contrast to the pattern observed to date at the Yale tailrace, temperatures at both depths (3 and 20 m) remained relatively cool during off-line periods (approximately 10°C), and, surprisingly, increased slightly with increasing discharge (Figure 2.6-1). This pattern has not been previously observed during PacifiCorp’s monitoring program. The same instrument that had been used in previous tailrace monitoring was active during the study. Results from that unit compared closely to those obtained with the 2 thermographs deployed specifically for this study. Groundwater seepage and spring activity may provide an explanation for these data.

At downstream locations, the pattern historically seen at the tailrace was observed at both the buoy and USGS locations (Figure 2.6-2). Temperatures were substantially higher during off-line periods at both sites, most notably at the surface buoy site. Flows as low as approximately 300 cfs caused marked drops in temperature near the bottom at both downstream locations. Substantially higher flows (approximately 3,000 cfs) were necessary to reduce surface temperatures at the buoy site by about 2°C (24 to 22°C). However, flows of approximately 2,000 cfs reduced surface temperatures at the USGS site by 10°C. These results suggest that, although a thermal gradient is obvious from surface to bottom at the USGS site, the stability of thermal stratification is more easily disrupted here than at the buoy location. The channel is narrower in this area and flow is more confined; thus, colder flows occupy a greater percentage of the water column and surface temperatures respond more quickly.
Figure 2.6-1. Discharge and temperature at Yale tailrace, August 7-13, 1998.
Figure 2.6-2. Discharge and temperature at sites downstream of Yale tailrace, August 7-13, 1998.
Maximum temperatures during the study ranged from 24.2°C at the buoy surface site, to 11.9°C at the USGS bottom site. Off-line temperatures were near 24°C at the surface locations, and between 12°C and 14°C at all 4 downstream sites during full generation (approximately 7,000 cfs).

The results of this study indicate that project operations have a direct influence on temperatures in the upper portion of Lake Merwin. This effect is measurable but less pronounced near the USGS site, where the channel is more constricted and thermal layering is easily disrupted at flows of approximately 3,000 cfs. Surface temperatures during off-line periods were warm (approximately 20°C), typical of surface waters in Yale Lake and Lake Merwin during mid-summer. In contrast, temperatures during full generation were between 12°C and 14°C.

2.7 BENTHIC MACROINVERTEBRATES

As part of the relicensing process, PacifiCorp assessed benthic macroinvertebrate communities in the Yale project vicinity. The health and diversity (biotic integrity) of macroinvertebrate populations was evaluated as an indirect measure of water quality and aquatic habitat condition.

2.7.1 Study Area

Benthic macroinvertebrate samples were collected at 3 sites in the project area: Cougar Creek, the Swift No. 2 bypass reach, and Siouxon Creek (Figure 2.7-1). Cougar Creek was sampled approximately 200 m upstream of the Highway 503 bridge, just upstream of the location of the bull trout trap established in 1996. The site in the Swift bypass reach was 200 to 300 m upstream of the bridge crossing, in the first riffle upstream of the large pool in this area. Siouxon Creek was sampled at the farthest upstream point that could be accessed by boat. Samples were collected in a riffle area, but the site was still within the zone of influence of Yale Lake.

2.7.2 Methods

Benthic macroinvertebrate samples were collected in erosional (riffle) areas using a methodology recommended by Aquatic Biology Associates (ABA) of Corvallis, Oregon (pers. comm., R. Wisseman, ABA, Corvallis, Oregon, October 1996). The samples were processed and the data analyzed using the ABA Rapid Bioassessment Methodology (ABA 1996).

The ABA methodology is designed to detect impacts and trends of biotic/habitat integrity in watersheds where monitoring objectives seek to document cumulative impacts from land management activities. Advantages of using the ABA bioassessment approach to monitor water/habitat quality include:
Figure 2.7-1. Benthic invertebrate sampling locations.
Vestra map – 8.5 x 11 – has to start on odd page - needs 2 pages
• Benthic invertebrate assessment is a direct or definitive measure of biotic integrity, not an indirect (or predictive) measure (as are physical/chemical parameters).

• Benthic invertebrates can be used as a measure of the overall biodiversity of aquatic/riparian ecosystems.

• Invertebrate communities respond to changes in water/habitat quality and integrate impacts over time because of their extended residence in the stream.

• The presence or absence of specific taxa can be indicative of specific environmental factors.

• Benthic organisms are abundant and diverse in most streams and rivers, and are relatively easy to sample and analyze.

• Invertebrates are relatively immobile and cannot avoid "events" or "pulses" of pollutants or other forms of stress often missed by conventional water or habitat quality sampling.

• Aquatic invertebrates serve as the primary food source for stream fishes and thus reflect habitat quality for resident fish.

2.7.2.1 Sampling Methods

Benthic macroinvertebrate samples were collected by Bob Wiseman of ABA on October 20, 1996. Three samples were collected at each site using a traveling kick-net method (500µ mesh) which covered a distance of approximately 5 m. This is a semi-quantitative, non-random technique because the objective was to assess biotic and habitat integrity, not to provide a standing crop estimate for a single point in time, or estimates of spatial variation in individual or aggregate population densities. All samples were collected in erosional (riffle) habitats, and analyzed by ABA using their standard laboratory and taxonomic protocols for montane stream and riverine communities (ABA 1996).

All macroinvertebrate samples were processed in the ABA lab. Either the entire sample was sorted under 6X magnification with a dissecting microscope, or a fraction that contained a minimum of 400 organisms.

Organisms were identified by qualified specialists and professionals. The level of taxonomic effort applied to each group of invertebrates was standardized. Genus was utilized for most insects, although some of the better known and more distinct taxa were identified to species.

2.7.2.2 The ABA Bioassessment

In the ABA bioassessment, a total of 43 metrics are used to rate the riffle macroinvertebrate samples (Table 2.7-1). All of the individual metrics are described in detail in Appendix 2.7-1.
Table 2.7-1. Metrics and scoring criteria used in the ABA benthic invertebrate bioassessment protocol. (Adapted from ABA 1996).

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<th>METRIC</th>
<th>SCORING CRITERIA</th>
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<tr>
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<tr>
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<tr>
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<tr>
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<td>2.0-3.9</td>
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<tr>
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<td>&gt;10 5.0-9.9</td>
<td>2.0-4.9</td>
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<td>8 Percent Intolerant dipterans</td>
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</tr>
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<td>10 Intolerant stonefly richness</td>
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</tr>
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<td>2</td>
</tr>
<tr>
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<tr>
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</tr>
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<td>&gt;3</td>
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</tr>
<tr>
<td>4 Percent Leech</td>
<td>&lt;1</td>
<td>&gt;1</td>
</tr>
<tr>
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<td>A &lt;1 1.0-4.9</td>
<td>5.0-9.9</td>
</tr>
<tr>
<td>6 Percent Tolerant crustacea</td>
<td>A</td>
<td>P</td>
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Table 2.7-1. Metrics and scoring criteria used in the ABA benthic invertebrate bioassessment protocol. (Adapted from ABA 1996) (continued).

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<tr>
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<tr>
<td>Percent Tolerant mayflies</td>
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<td>Percent Tolerant caddisflies</td>
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<tr>
<td>Percent Tolerant beetles</td>
<td>A</td>
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<tr>
<td>Percent Tolerant dipterans</td>
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<td>A</td>
<td>1</td>
</tr>
<tr>
<td>Tolerant dipteran richness</td>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>Percent Simuliidae</td>
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<td>&gt;10</td>
</tr>
<tr>
<td>Percent Chironomidae</td>
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<td>10-19</td>
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</table>

Subtotal Negative Indicators 49

MAXIMUM POSSIBLE SCORE
A = Absent  P = Present

124

Scoring Criteria

Each of the metrics (e.g., total taxa richness) received a score based on the value calculated for the site. For most of the metrics, values are assigned 4, 3, 2, 1, or 0 points, depending on site-specific results. Higher individual metric scores indicate more positive or healthy conditions. Metrics may also be scored on a 3, 2, 1, 0; 2, 1, 0; 2, 0; or 1, 0 basis, depending on metric sensitivity and/or how much that individual metric is weighted in the overall analysis.

For the scoring criteria, a fixed value approach was used instead of attempting comparisons with a reference value as used in the U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocol. That is, actual site values were scored directly and not first expressed as a percentage of a reference value. Thus, if a site has more than 60 taxa it receives a 4 for total taxa richness; 50 to 59 taxa receives a 3; 40 to 49 taxa scores a 2; etc.

Tiered Assessment

The ABA bioassessment protocol provides a tiered approach to assessing the integrity of benthic invertebrate communities at a site. First, there is a single "bottom line" value that is a cumulative score of all the metrics, which is expressed as a percentage of the maximum possible score. These single cumulative values can be viewed as a final grade for the site. Second, metrics have been grouped into the following 3 categories:

- **Primary Metrics** - There are 6 primary metrics used that evaluate community composition in general terms.
• **Positive Indicators** - These are particular taxa, taxa assemblages, or feeding groups whose presence or increased abundance is a positive sign.

• **Negative Indicators** - Converse of the positive indicators.

Third, individual metrics or collections of metrics can be used as indicators of specific habitat parameters such as coarse particulate organic matter (CPOM) retention capability, winter scour, excessive summer water temperatures, crevice space limitation, etc.

**Bioassessment Model**

It is important to note that the ABA Bioassessment (as do most other bioassessments) evaluates a benthic invertebrate community based on what is considered to be "ideal." Thus, a high taxa richness, or a predominance of taxa adapted to high water quality and diverse aquatic habitat, is considered to be a positive sign. The "ideal" that the ABA Bioassessment is based on is a mid-order mountain stream with:

• A dense riparian overstory providing heavy shading to the channel.

• A moderate to high gradient.

• Cobble and boulder substrates dominant (i.e., high roughness).

• A strong, perennial flow of cool or cold water.

• A relatively narrow and deep channel with high habitat complexity.

• A moderate to high amount of bole wood present to increase habitat complexity and aid retention of CPOM.

• High diatom production to support scrapers, and low filamentous algae production.

• High inputs of deciduous leaves and conifer needles.

• Low inputs of fine sediment.

• Limited scouring and resorting of substrates, but with an intermediate level of disturbance to increase habitat complexity.

• A hyporheic zone open to invertebrate colonization.

• A high amount of "crevice space" around and under surface rocks.

Possession of the entire suite of ideal habitat/water quality conditions is probably only met by a limited number of streams in old-growth forests in western North America. Most forested watersheds display more limited or impaired habitat conditions even in the absence of human management activities. Sites that are more open, lower gradient, or larger streams will naturally score lower.
Potential total scores for least impacted streams are expected to vary from region to region, and within a region. For example, western Cascade streams may tend to score higher than streams in interior mountain ranges. Or, a north-facing watershed may have habitat conditions which more nearly approximate the "ideal" than a nearby south-facing watershed.

The scoring adopted in the ABA bioassessment protocol is intended to grade most benthic aquatic communities lower than a theoretical ideal. This increases sensitivity and allows a fuller range of final values to be obtained. General impairment categories have been assigned as follows:

- 80 to 100 percent - High habitat complexity, biotic integrity, taxa richness, percent of cold water adapted fauna, number of more specific microhabitat related taxa, etc.

- 60 to 79 percent - Moderate habitat complexity, biotic integrity, taxa richness, percent of cold water adapted fauna, number of more specific microhabitat related taxa. The scores point to some habitat limitations.

- 40 to 59 percent - Low habitat complexity, biotic integrity, taxa richness, percent of cold water adapted fauna, number of more specific microhabitat related taxa. The community reflects significant habitat and/or water quality limitations compared to the "ideal" headwater stream.

- Less than 40 percent - Severe; the community present has developed under habitat conditions that represent a severe departure from the ideal headwater conditions.

2.7.3 Results and Discussion

This section presents a summary of the scores and analysis for each of the macroinvertebrate samples collected in the Yale project area. Detailed information on scores, metric values, and total abundance is provided in Appendix 2.7-1.

Total bioassessment scores for macroinvertebrate samples ranged from 39 to 80 percent of maximum (Table 2.7-2). Samples collected at the Swift No. 2 Bypass and Siouxon Creek had low habitat complexity and the scores reflect significant habitat and/or water quality limitations. The sample collected at Cougar Creek scored within the high habitat complexity category. More detailed discussion of scores is provided below; the ABA data reports are included in Appendix 2.7-1.

<table>
<thead>
<tr>
<th>Location</th>
<th>ABA Score</th>
<th>Percent of Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cougar Creek</td>
<td>99</td>
<td>80</td>
</tr>
<tr>
<td>Swift No. 2 Bypass Reach</td>
<td>58</td>
<td>47</td>
</tr>
<tr>
<td>Siouxon Creek</td>
<td>48</td>
<td>39</td>
</tr>
</tbody>
</table>

Table 2.7-2. Cumulative scores for Yale macroinvertebrate sample sites.

Total ABA scores for the Cougar Creek samples were within the High habitat/biotic integrity category. Total and EPT (Ephemeroptera/Trichoptera/Plecoptera; or mayflies,
caddisflies, and stoneflies) taxa richness were high. Despite the high taxa richness, overall densities were low. A high percentage of the taxa were cold-water dependent.

In addition to the overall high scores in Cougar Creek, the samples there contained Hydrobiidae snails, which are potentially threatened or endangered species. The snails could only be identified to family; further analysis is underway to determine whether any listed species were collected. Also notable were caddisflies in the Rhyacophila Vagrita Group, and the stonefly *Rickera sorpta*. The caddisflies in the latter group are more typically associated with smaller streams or springs. *R. sorpta* is very uncommon in western Cascade streams (pers. comm., B. Wisseman, ABA, Corvallis, Oregon September 18, 1997).

Total scores at the Swift No. 2 bypass reach ranged from 44 to 50 percent, placing this site in the low habitat/biotic integrity category. Invertebrate densities were moderate, but total and EPT taxa richness were low. Dominance of the benthic community by a single taxa (black flies/Simulidae) was high (49 percent). Community tolerance was high, but within the range seen for most Pacific Northwest rivers (pers. comm., B. Wisseman, ABA, Corvallis, Oregon, March, 1997). Percent contribution of cold-water biota was low and there were few long-lived taxa present.

No threatened or endangered species were found in the Swift No. 2 bypass reach (SW2BP) sample. However, the SW2BP sample contained caddisflies in the Rhyacophila Rotunda group, which are more typically associated with smaller streams or springs.

Results from the Siouxon Creek sample point to the effects of periodic inundation and de-watering by Yale Lake. Total scores were low to severely low (average 39 percent). Total and EPT taxa richness were very low, as were densities in the kick samples (average 121 organisms per sample). Cold-water biota and taxa indicative of high habitat complexity were absent. Dominance of the community by a single taxa was moderate, and community tolerance was high. Note that Siouxon Creek was sampled within the zone of influence of Yale Lake, so scores are not representative of Siouxon Creek itself.

The total bioassessment scores previously presented in Table 2.7-2 are cumulative scores derived from primary metric, positive indicator, and negative indicator subtotal scores. These indicator subtotal scores are listed for each of the macroinvertebrate sample sites in Table 2.7-3.

Table 2.7-3. Primary metric, positive indicator, and negative indicator subtotal scores for Yale macroinvertebrate sample sites.

<table>
<thead>
<tr>
<th>Location</th>
<th>Primary Metric</th>
<th>Positive Indicators</th>
<th>Negative Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cougar Creek</td>
<td>82</td>
<td>71</td>
<td>89</td>
</tr>
<tr>
<td>Swift No. 2 Bypass Reach</td>
<td>26</td>
<td>25</td>
<td>81</td>
</tr>
<tr>
<td>Siouxon Creek</td>
<td>20</td>
<td>9</td>
<td>80</td>
</tr>
</tbody>
</table>

1 Note: Samples collected within Yale Lake inundation zone.
Primary metric subtotal scores, which rate standing crop, total richness, EPT taxa richness, diversity, and tolerance, are an indicator of overall habitat/water quality (stream health). Primary metric subtotal scores were high at Cougar Creek and very low at Siouxon Creek and the Swift No. 2 Bypass Reach.

Positive indicators are particular taxa, taxa assemblages, or feeding groups whose presence or increased abundance is an indication of a healthy, unimpacted mountain stream. Positive indicators include predator, scraper, and shredder richness; percent cold-water adapted biota; percent wood-eating beetles; and long-lived taxa richness. Positive indicator scores were high in Cougar Creek, and very low in the Swift No. 2 bypass reach and Siouxon Creek.

Negative indicators are taxa or feeding groups whose presence or unusually high abundance is indicative of a stressed stream system and a departure from ideal habitat/water quality conditions. Negative indicators include percent collectors, percent worms and mollusks, percent tolerant taxa, and percent blackflies and midges. These organisms can survive well in streams where there is a large amount of organic material or fines in transport, and where temperature may be above optimal. The ABA system assigns high scores for the absence of these metrics; thus, a high negative score is a positive indicator of habitat quality. As expected, Cougar Creek scored higher than the Swift bypass or Siouxon Creek in this category. However, the difference was not nearly as great as for the positive indicator scores. These results point to the lack of positive indicators, rather than dominance of negative indicators in the Swift bypass and Siouxon Creek.

As discussed above, the ABA methodology is composed of over 50 metrics used to rate habitat quality and biotic integrity. Perhaps the most indicative of these are total taxa richness (i.e., the total number of different types of organisms, and EPT taxa richness). Unimpacted streams will have as many as 70 taxa in riffle samples, depending on geographic location. Cougar Creek contained an average of 62 taxa per sample, 23 more than at the Swift No. 2 bypass reach, and 40 more taxa than were observed in Siouxon Creek.

EPT taxa richness is very sensitive to changes in water quality and is less variable than total taxa richness (Lenat and Barbour 1994). Values higher than 35 receive the maximum score in the ABA methodology. Average EPT values for the 3 sites were 39 at Cougar Creek, 19 at SW2BP, and 13 at Siouxon Creek. Again, these numbers reflect high biotic integrity at Cougar Creek, and impaired conditions at SW2BP and Siouxon Creek.
3.0 FISHERIES STUDIES

Relicensing the Yale Project requires that PacifiCorp describe aquatic resources associated with the study area (Figure 3.0-1) and develop measures to protect and/or enhance fisheries resources and associated habitat (FERC 1990). Numerous fisheries studies were proposed in the FSCD to accomplish this goal (PacifiCorp 1996a). PacifiCorp initiated 4 of these studies in the spring of 1996:

- Creel survey in Yale Lake;
- Tributary stream habitat surveys;
- Resident fish population surveys in project tributaries; and
- Bull trout enumeration and population study in Cougar Creek.

The results of these studies through September 1996 were reported in the Yale Project ITR (PacifiCorp 1997). This FTR updates these results with data collected during 1997 and presents the methods and results for 3 additional fisheries studies completed in 1997 and 1998.

- Yale dam entrainment study;
- Yale Lake hydroacoustic fish population survey; and
- Bull trout genetics study for the Yale, Swift, and Merwin projects.

3.1 CREEL SURVEY OF YALE LAKE

Fish species known to reside in Yale Lake include kokanee (*Oncorhynchus nerka*), cutthroat trout (*O. clarki*), rainbow trout (*O. mykiss*), bull trout (*Salvelinus confluentus*), northern pikeminnow (*Ptychocheilus oregonensis*), mountain whitefish (*Prosopium williamsoni*), largescale sucker (*Catostomus macrocheilus*), lamprey (*Lampetra spp.*), sculpin (*Cottus spp.*), and dace (*Rhinichthys spp.*) (Graves 1983). Three spine stickleback (*Gasterosteus aculeatus*) are also found in Yale Lake.

Kokanee were first introduced into Yale Lake in the late 1950s; a self-sustaining population currently exists. Rainbow trout fry were stocked in the lake between 1953 and 1957 and between 1960 and 1980 for recreational harvest. Rainbow trout stocked during these periods averaged approximately 80,000 fry per year (WDFW 1996). A limited number of sea-run cutthroat trout and steelhead (*O. mykiss*) yearlings were also planted during this time. No hatchery fish have been released into Yale Lake since 1980.

Approximately 1,000,000 hatchery rainbow trout fingerlings are planted into Swift Reservoir each year. It is likely that some of these fish are transported downstream into Yale Lake during spill events and contribute to the Yale Lake rainbow trout fishery.

In 1992, the WDFW adopted regulations prohibiting the harvest of bull trout in Yale Lake.

Current fishery management objectives for Yale Lake are to:
Maintain a self-sustaining kokanee population while maximizing angler recreation;

Increase the length of kokanee harvested by reducing densities by allowing a greater daily limit (16) and extending the season to year round;

Maintain maximum kokanee spawning length of 250 to 275 mm; and

Maintain viable naturally reproducing populations of bull trout (WDFW 1994).

Creel surveys documenting angling success and effort have been infrequent or limited in scope (Graves 1983; PacifiCorp 1984; PacifiCorp 1995b). To better describe the existing sport fishery in Yale Lake, and provide data to assist state fishery management, PacifiCorp initiated a comprehensive creel survey in April 1996. The objectives of the survey were to estimate angling effort, catch per unit effort (CPUE), and the number of fish harvested over a 1-year period. Additional objectives were to describe the species and size composition of the catch and harvest, and overall satisfaction of anglers. The following sections describe PacifiCorp’s creel survey performed during 1996 and 1997.

3.1.1 Study Area

The creel survey was conducted within Yale Lake and the Swift bypass reach. Creel survey viewpoints/angler contact points are shown in Figure 3.1-1.

3.1.2 Methods

Because Yale Lake is open to year-round angling, sampling was planned for a 1-year period. To accomplish the objectives of the study, PacifiCorp counted and surveyed anglers using a 3-stage stratified sampling design (Malvestuto 1983). This approach apportioned sampling effort to the periods when most angling was expected. Sampling strata consisted of time blocks, types of day (weekday or weekend), and periods of day (morning, evening, or night). Ten time blocks were surveyed:

<table>
<thead>
<tr>
<th>Block Number</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>April 1 to May 31, 1996</td>
</tr>
<tr>
<td>2</td>
<td>May 25 to May 27, 1996 (Memorial Day weekend)</td>
</tr>
<tr>
<td>3</td>
<td>June 1 to June 30, 1996</td>
</tr>
<tr>
<td>4</td>
<td>July 4 to July 7, 1996 (4th of July weekend)</td>
</tr>
<tr>
<td>5</td>
<td>July 1 to July 3, and July 8 through July 31, 1996</td>
</tr>
<tr>
<td>6</td>
<td>August 1 to August 31, 1996</td>
</tr>
<tr>
<td>7</td>
<td>August 31 to September 2, 1996 (Labor Day weekend)</td>
</tr>
<tr>
<td>8</td>
<td>September 3 to September 30, 1996</td>
</tr>
<tr>
<td>9</td>
<td>October 1 to November 30, 1996</td>
</tr>
<tr>
<td>10</td>
<td>December 1, 1996 to March 31, 1997</td>
</tr>
</tbody>
</table>
Yale Hydroelectric Project

Figure 3.1-1
Creel Survey Viewpoints/
Angler Contact Points
Holiday weekends and summer months were emphasized because they were expected to have the highest angler effort. Considering these periods separately allowed for a better description of peak effort periods. Within each time block sampled (except for the holiday weekends), sampling occurred during 6 weekday periods (3 mornings, 3 evenings) and 4 weekend periods (2 mornings, 2 evenings). During the holiday time blocks, sampling occurred during 4 periods (2 mornings, 2 evenings). Mornings were defined as 600 to 1400 hours and evenings as 1400 to 2200 hours. Logistic efficiency was improved by linking sampling periods such that evening sampling periods were randomly selected, and linked to the following morning period. PacifiCorp’s originally proposed creel survey method included sampling nighttime periods (2200 to 600 hours) (PacifiCorp 1995b). However, repeated surveys showed that very few or no anglers fished after 2200 hours. As a result, nighttime surveys were canceled.

Within each period, sampling consisted of counting the number of boats and number of anglers in boats and along the shore throughout the lake. This was accomplished using binoculars from 7 primary viewpoints, of which most are along the north and west side of the lake. These viewpoints allowed observation of 80 percent of the reservoir. Viewpoints included the IP Road at Siouxon Creek, Yale Dam, Saddle Dam, Yale Park, Cougar Creek Campground, Beaver Bay Campground, and the Yale bridge at the downstream end of the Swift No. 2 bypass reach (Figure 3.1-1). Counts occurred at approximately 3-hour intervals starting at the beginning of each survey period. The time between counts and toward the end of each survey period was used to survey anglers and their catches at boat launches, campgrounds, and along the shore. The goal was to sample at least 30 percent of the anglers present at the lake during each period.

To determine catch and harvest rates, anglers were surveyed between effort counts. Using the WDFW creel survey form (Appendix 3.1-1), PacifiCorp obtained the following information from anglers:

- The number of anglers in the boat or group;
- The number of hours spent fishing;
- The number and species of fish caught;
- The number, species, and length of fish harvested;
- The overall satisfaction of anglers with their catch;
- The number and species of fish released; and
- Any specific suggestions anglers might have to improve the facilities or experience.

Anglers were surveyed only once per sampling period, and attempts were made to sample creels at the end of the individual’s or group’s angling trip rather than near the beginning.

Fork length (mm) and weight (gm) were measured on a subsample of harvested kokanee, cutthroat trout, and rainbow trout during each time block.
The mean CPUE, or catch per unit effort, of angler group $j$ during time block $k$ was computed using:

$$\text{CPUE}_{jk} = \frac{\sum_{i=1}^{I_{jk}} \text{CPUE}_{ijk}}{I_{jk}}$$

(1)

where, $I_{jk}$ is the total number of anglers surveyed in angler group $j$ (bank or boat angler) and during the time block $k$.

A unit of fishing effort ($E$) is defined as 1 angler fishing for 1 hour (i.e., an angler-hour). The daily fishing effort on Yale Lake was computed by summing the average number of anglers ($\bar{A}_{kwhjl}$) counted at each of the viewpoints times the number of hours in the morning and evening sample periods (typically 8 hours each period). The following equations were used to estimate the total fishing effort:

$$\bar{A}_{kwhjl} = \frac{\sum_{m=1}^{M_{kwhl}} A_{kwhjlm}}{M_{kwhl}}$$

(2)

where, $A_{kwhjlm}$ is number of anglers of $m^{th}$ observation during hour block $h$ (mornings and evenings), on $n^{th}$ day, in the weekday group $w$ (weekday or weekend), from viewpoint $l$, in angler group $j$, during time block $k$. $M_{kwhl}$ is the number of observations made during hour block $h$, on $n^{th}$ given day, in the weekday group $w$, from viewpoint $l$, during the time block $k$. The average total number of anglers fishing at any given hour block $h$, of a day is:

$$\bar{A}_{kwhj} = \sum_{l=1}^{L} \bar{A}_{kwhjl}$$

(3)

where, $L$ is number of viewpoints where observations were. The average number of anglers during hour block $h$, in weekday group $w$, in angler group $j$, and during time block $k$ was estimated by:

$$\bar{A}_{kwhj} = \frac{1}{n_{kwh}} \sum_{n=1}^{n_{kwh}} \bar{A}_{kwhjn}$$

(4)

where, $n_{kwh}$ is the number of days when observations were made during the hour block $h$, in weekday group $w$, and during time block $k$. The total fishing effort of angler group $j$ and during time block $k$ was estimated by:
\[ E_{kj} = \sum_{h=1}^{H} \sum_{w=1}^{W} \overline{A}_{kwhj} \times N_{kwh} \times T_h \] (5)

where, \( T_h \) was the number of hours in the morning and evening sample periods. In this analysis it was assumed to be 8 hours (0600 hours through 1400 hours for mornings and 1400 hours through 2200 hours for evenings); \( N_{kwh} \) was the total number of days during hour block \( h \), in the weekday group \( w \), and in time block \( k \); \( H \) was the number of hour blocks, morning or evening; \( W \) was the number of weekday groups, weekday or weekend.

The mean CPUE of angler group \( j \) over the period of April 1, 1996 through March 31, 1997 was calculated as:

\[
\overline{CPUE}_j = \frac{\sum_{k=1}^{K} E_{jk} \times CPUE_{jk}}{\sum_{k=1}^{K} E_{jk}}
\] (6)

where, \( K \) is the number of time blocks surveyed. The overall mean CPUE during the 10 time blocks was estimated by:

\[
\overline{CPUE} = \frac{\sum_{j=1}^{2} E_j \times CPUE_j}{\sum_{j=1}^{2} E_j}
\] (7)

Harvest yield in Yale Lake was estimated by first calculating the total catch of each species from the mean CPUE and effort data. Then, a length-weight relationship was developed from length and weight data collected during the survey. If a limited amount of length-weight data were available for a given species (as was the case for rainbow trout), condition factors were used to estimate individual body weight at a given length. Length-frequency information for each species was then used to estimate the number of fish in each length group (2 cm bin size). Finally, by multiplying the number and weight of fish in each length group, the total yield was determined.

3.1.3 Results and Discussion

PacifiCorp’s 1996-1997 Yale Lake creel survey began on April 1, 1996 and was completed on March 31, 1997 after 1 year of sampling. The following section describes the results of this survey.

During the 1-year period (10 sample blocks), surveyors contacted a total of 326 bank and 341 boat anglers on 75 days of sampling (morning, afternoon, or both). Bank and boat anglers fished for 1,935 hours and caught 604 gamefish (kokanee, cutthroat trout, and rainbow trout). Gamefish caught included 441 kokanee (73 percent), 27 cutthroat trout (4 percent), and 136 rainbow trout (23 percent). Of the 2 groups surveyed, boat anglers
caught 96 percent of the creelred kokanee, 44 percent of the cutthroat trout, and 23 percent of the rainbow trout. A single, illegally creelred bull trout and 15 bull trout released by anglers were not included in the estimates. Northern pikeminnow were also caught during the sampling period but were not included in the catch estimates.

The mean catch rate (CPUE) of all gamefish, including fish released by anglers, was 0.30 fish per angler hour. The mean CPUE for bank anglers was 0.31 fish per hour, and the mean CPUE for boat anglers was 0.30 fish per hour (Table 3.1-1).

Table 3.1-1. Estimated angler hours, number of anglers surveyed, estimated mean catch rate, estimated mean harvest rate, estimated number of gamefish caught, and the estimated number of gamefish harvested for Yale Lake, April 1, 1996 through March 31, 1997.

<table>
<thead>
<tr>
<th>Block</th>
<th>Estimated Angler Hours</th>
<th>Number of Anglers Surveyed</th>
<th>Estimated Mean Catch Rate (fish/hour)</th>
<th>Estimated Mean Harvest Rate (fish/hour)</th>
<th>Estimated Gamefish* Caught</th>
<th>Estimated Gamefish* Harvested</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Block</td>
<td>Bank</td>
<td>Boat</td>
<td>Bank</td>
<td>Boat</td>
<td>Bank</td>
</tr>
<tr>
<td>1</td>
<td>1,472</td>
<td>445</td>
<td>58</td>
<td>6</td>
<td>0.67</td>
<td>0.35</td>
</tr>
<tr>
<td>2</td>
<td>496</td>
<td>186</td>
<td>53</td>
<td>34</td>
<td>0.26</td>
<td>0.19</td>
</tr>
<tr>
<td>3</td>
<td>1,608</td>
<td>3,728</td>
<td>51</td>
<td>102</td>
<td>0.32</td>
<td>0.26</td>
</tr>
<tr>
<td>4</td>
<td>364</td>
<td>548</td>
<td>49</td>
<td>22</td>
<td>0.06</td>
<td>0.10</td>
</tr>
<tr>
<td>5</td>
<td>1,066</td>
<td>2,159</td>
<td>51</td>
<td>58</td>
<td>0.12</td>
<td>0.31</td>
</tr>
<tr>
<td>6</td>
<td>1,118</td>
<td>3,216</td>
<td>29</td>
<td>63</td>
<td>0.16</td>
<td>0.40</td>
</tr>
<tr>
<td>7</td>
<td>136</td>
<td>397</td>
<td>16</td>
<td>25</td>
<td>0.49</td>
<td>0.29</td>
</tr>
<tr>
<td>8</td>
<td>246</td>
<td>1,635</td>
<td>14</td>
<td>30</td>
<td>0.27</td>
<td>0.23</td>
</tr>
<tr>
<td>9</td>
<td>123</td>
<td>59</td>
<td>5</td>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Totals</td>
<td>6,629</td>
<td>12,337</td>
<td>326</td>
<td>341</td>
<td>0.31</td>
<td>0.30</td>
</tr>
<tr>
<td>Combined</td>
<td>19,003</td>
<td>667</td>
<td>0.30</td>
<td>0.25</td>
<td>5,756</td>
<td>4,789</td>
</tr>
</tbody>
</table>

* Gamefish = kokanee, cutthroat trout, and rainbow trout.

Most kokanee caught ranged between 220 and 300 mm in length. Most cutthroat trout and rainbow trout ranged between 200 and 300 mm (Figure 3.1-2). The single, illegally creelred bull trout measured 320 mm.

Estimates of angler effort, catch rates, harvest rates, total catch, and total harvest are presented in Table 3.1-1. From the survey data, it was estimated that 832 bank anglers fished for 6,629 hours and caught 2,077 gamefish, and 1,566 boat anglers fished for 12,337 hours and caught 3,679 gamefish. The total estimated bank and boat catch was 5,756 fish. Based on the relative proportion of species in the creel surveys, the catch of gamefish was comprised of 4,202 kokanee, 257 cutthroat trout, and 1,296 rainbow trout. The estimated total harvest for Yale Lake was 4,789 fish. Total harvest was comprised of 3,656 kokanee, 221 cutthroat trout, and 912 rainbow trout. Estimated total yield of all gamefish harvested was 1,456 kg (3,209 pounds).
Figure 3.1-2. Length-frequency histogram for kokanee, cutthroat trout, and rainbow trout harvested by anglers in Yale Lake (April 1, 1996 to March 31, 1997).

It should be noted that a math error made in calculating the effort estimates presented in the Yale ITR (PacifiCorp 1997) resulted in an underestimation of angler effort for 8 out of the 10 sample blocks. The data have been corrected, and this FTR contains the corrected effort estimates for all 10 sample blocks.

Catch rates and harvest rates for bank anglers in Yale Lake were variable during the year (Table 3.1-1). Bank anglers had the highest catch rates and harvest rates from early April.
through June, with another slight increase over the Labor Day weekend. Catch rates and harvest rates for boat anglers were fairly consistent from April through September. During sample blocks 9 and 10 (October 1 through March 31), catch rates and harvest rates for both boat and bank anglers dropped off to zero. This reduction in angler success coincided with the annual drawdown of Yale Lake which began at the end of September. When the water surface elevation of Yale Lake is reduced to approximately 425 feet msl, the boat launch at Yale Park becomes unusable and, as a result, boat angler effort falls to near zero. This reduction in effort may also be the result of poor winter weather conditions. No anglers were observed fishing on the lake during surveys conducted in block 10.

It should be noted that in February 1996, an 86,400 cfs flow event occurred in the North Fork Lewis River (USGS 1997). This flood caused extensive erosion and streambed scouring in the upper watershed, creating high (non-typical) levels of turbidity in Yale Lake through May 1996 (Section 2.3.3.2). These high levels of turbidity most likely had a negative effect on the overall CPUE for anglers in blocks 1 through 3; however, the specific effects of this non-typical event on the 1996-97 Yale Lake fishery are unknown.

Angler satisfaction was also assessed as part of the 1996-97 creel survey. All anglers interviewed were asked if they were satisfied or unsatisfied with their fishing experience. Thirty-four percent of the anglers contacted were satisfied with their experience. Sixty-four percent were unsatisfied. Most people who were unsatisfied with their fishing experience wished they had caught more fish.

As part of this study, PacifiCorp compiled information from past creel surveys conducted on Yale Lake, Lake Merwin, Swift Reservoir, and 2 similar cold water reservoirs in the Cowlitz River basin (Riffe Lake and Mayfield Lake). These data were reviewed, summarized, and compared with the 1996-97 Yale Lake angler effort, harvest, and catch data (Table 3.1-2).

Between 1978 and 1980, the estimated mean catch rate for Yale Lake was approximately 2 to 3 times higher than the estimated mean catch rate for Yale Lake in 1996-97 (Table 3.1-2). However, from 1978 to 1980 an average of 450,000 rainbow trout fry were still being planted into the lake each year. These planted rainbow trout comprised approximately 20 to 30 percent of the total catch during the period. In 1982, just 2 years after the eruption of Mount St. Helens and the discontinuation of rainbow trout plants in Yale Lake, the mean catch rate dropped to 0.30 fish per hour (Graves 1983). This catch rate was very similar to the catch rate observed in 1996-97. As expected, estimated harvest in Yale Lake followed a similar trend.

In 1995, WDFW completed a creel survey on Lake Merwin (Tipping 1996). The estimated angler effort calculated from May through August 1995 was very similar to the estimated angler effort on Yale Lake from May through August of 1996. Both were approximately 19,000 angler hours (Table 3.1-2). Unlike Yale Lake, Lake Merwin is planted with approximately 200,000 juvenile hatchery coho (Onchorhyncus kisutch) a year. Unfortunately, comparable catch rate estimates for salmonids (gamefish) were not included in the Lake Merwin survey report.
Table 3.1-2. Past creel survey data collected at Yale Lake, Lake Merwin, Swift Reservoir, Riffe Lake, and Mayfield Lake compared with the 1996-97 Yale Lake survey data.

<table>
<thead>
<tr>
<th>Lake or Reservoir</th>
<th>Year</th>
<th>Survey Period</th>
<th>Estimated Angler Hours</th>
<th>Estimated Gamefish Harvested</th>
<th>Mean Catch Rate (fish/hr)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yale Lake</td>
<td>1996-97</td>
<td>Apr.-Mar.</td>
<td>19,003</td>
<td>4,789</td>
<td>0.30</td>
<td>PacifiCorp (1997)</td>
</tr>
<tr>
<td></td>
<td>1978</td>
<td>Apr.-Oct.</td>
<td>31,700</td>
<td>20,743</td>
<td>0.65**</td>
<td>Graves (1983)</td>
</tr>
<tr>
<td></td>
<td>1979</td>
<td>Apr.-Oct.</td>
<td>32,296</td>
<td>25,865</td>
<td>0.80**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1980</td>
<td>*Apr.-May</td>
<td>4,634</td>
<td>4,273</td>
<td>0.96**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1981</td>
<td>Apr.-Oct.</td>
<td>15,062</td>
<td>9,540</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1982</td>
<td>Apr.-Oct.</td>
<td>16,219</td>
<td>4,838</td>
<td>0.30**</td>
<td></td>
</tr>
<tr>
<td>Swift Reservoir</td>
<td>1990</td>
<td>May-Oct.***</td>
<td>NA</td>
<td>NA</td>
<td>0.97</td>
<td>PacifiCorp (1996)</td>
</tr>
<tr>
<td>****Riffe Lake</td>
<td>1990</td>
<td>May-Aug.</td>
<td>NA</td>
<td>NA</td>
<td>0.35</td>
<td>(Tipping 1991)</td>
</tr>
<tr>
<td></td>
<td>1991</td>
<td>May-Aug.</td>
<td>NA</td>
<td>NA</td>
<td>0.22</td>
<td>(Tipping 1992)</td>
</tr>
<tr>
<td></td>
<td>1992</td>
<td>May-Aug.</td>
<td>NA</td>
<td>NA</td>
<td>0.24</td>
<td>(Tipping 1993)</td>
</tr>
<tr>
<td></td>
<td>1993</td>
<td>May-Aug.</td>
<td>NA</td>
<td>NA</td>
<td>0.39</td>
<td>(Tipping 1994)</td>
</tr>
<tr>
<td></td>
<td>1994</td>
<td>May-Aug.</td>
<td>NA</td>
<td>NA</td>
<td>0.56</td>
<td>(Tipping 1995)</td>
</tr>
<tr>
<td>Mayfield Lake</td>
<td>1990</td>
<td>May-Aug.</td>
<td>4,101</td>
<td>179</td>
<td>0.04</td>
<td>(Tipping 1991)</td>
</tr>
<tr>
<td></td>
<td>1991</td>
<td>May-Aug.</td>
<td>6,262</td>
<td>47</td>
<td>0.01</td>
<td>(Tipping 1992)</td>
</tr>
<tr>
<td></td>
<td>1992</td>
<td>May-Aug.</td>
<td>9,474</td>
<td>149</td>
<td>0.02</td>
<td>(Tipping 1993)</td>
</tr>
<tr>
<td></td>
<td>1993</td>
<td>May-Aug.</td>
<td>10,495</td>
<td>770</td>
<td>0.07</td>
<td>(Tipping 1994)</td>
</tr>
<tr>
<td></td>
<td>1994</td>
<td>May-Aug.</td>
<td>15,108</td>
<td>1,026</td>
<td>0.07</td>
<td>(Tipping 1995)</td>
</tr>
</tbody>
</table>

* Survey data collected before May 1980 closure (Mount Saint Helens eruption)
** Boat CPUE only
*** Excluding July and August
**** Estimates of CPUE in Riffe Lake include gamefish other than salmonids which accounted for less than 5 percent of the total catch.
NA = information is not available

As part of the Merwin Project studies in 1990, a creel survey was also completed on Swift Reservoir (PacifiCorp 1996). Like Lake Merwin, Swift Reservoir is a put-grow-take fishery. Approximately 1,000,000 hatchery rainbow trout fingerlings are planted annually. From May through October 1990, Swift Reservoir had a catch rate over 3 times as high as those observed in Yale Lake during the 1996-97 survey (Table 3.1-2). However, survey results showed rainbow trout comprised approximately 99 percent of the fish harvested in Swift Reservoir. Thus, the high catch rate was most likely a direct result of the rainbow trout plants. Angler effort estimates for the 6-month period were not included in the report.

Between 1990 and 1994, the catch rate on Riffe Lake (a large reservoir on the Cowlitz River) was very similar to the catch rate on Yale Lake. These rates were similar despite the fact that Riffe Lake was planted with an average of 700,000 salmonid juveniles (surplus hatchery coho, cutthroat trout, rainbow trout) each year during this 5-year period. Catch rates and total harvest on Mayfield Lake (downstream of Riffe Lake) were
considerably lower than those observed on Yale Lake in 1996-97. Mayfield Lake was planted with an average of 100,000 surplus hatchery fish each year from 1991 to 1994.

The creel data suggest that Yale Lake provides a popular recreational fishery that produces adequate catch rates while maintaining its self-sustaining kokanee population. The angler effort and catch rate in Yale Lake were not substantially different from those observed in the other Lewis River reservoirs, despite the fact that both Swift Reservoir and Lake Merwin are stocked on an annual basis. The catch rate in Yale Lake was also similar to the catch rates observed in Riffe Lake and substantially higher than those observed in Mayfield Lake.

3.2 TRIBUTARY STREAM HABITAT SURVEYS

Stream habitat in the study area has been previously described for Cougar Creek (USFS 1995a) and Siouxon Creek (Conklin 1992). To augment these data and complete the description of stream habitat in the study area, PacifiCorp surveyed streams that were not previously described. The primary objective of these surveys was to describe the quality, quantity, and overall condition of aquatic habitat in the Swift No. 2 bypass reach between Yale Lake and Swift Dam (hereafter referred to as the bypass reach), and in several tributaries including Panamaker Creek, Ole Creek, Rain Creek, Dog Creek, and Speelyai Creek. The portion of Cougar Creek immediately upstream of the point at which it emerges out of its subterranean reach was also surveyed. A secondary objective of these surveys was to create a detailed database of stream habitat information to facilitate resident fish population sampling (Section 3.3).

A more detailed quantitative habitat survey was completed in the Swift No. 2 bypass reach upstream from Yale Lake to collect baseline data for the development of possible enhancement measures. Less comprehensive assessments were completed in the smaller tributaries. All surveys, with the exception of Speelyai Creek, were completed in September 1996. Speelyai Creek was surveyed in August 1997.

The following sections describe the study area and methods used in PacifiCorp’s 1996 aquatic habitat survey, and summarize the current (low or base flow) condition of stream habitat within the Yale Project study area. Additional and/or expanded Lewis River tributary surveys, not described in this report, are currently under discussion with the agencies and interested parties. Pending the results of these discussions, surveys may be scheduled for the summer or fall of 1999.

3.2.1 Study Area

Aquatic habitat surveys were completed in the Swift No. 2 bypass reach between Yale Lake and the base of Swift Dam (River Mile [RM] 44.4 to 47.1) (Figure 3.2-1), and in the lower reaches of Panamaker Creek, Ole Creek, Rain Creek, Dog Creek, and Speelyai Creek. The previously unsurveyed upper portion of Cougar Creek was also surveyed (Figure 3.2-2).
Yale
Hydroelectric Project

Figure 3.2-2 (1 of 2)
Qualitative Habitat Survey Reaches
Yale Hydroelectric Project

Figure 3.2-2 (2 of 2) Qualitative Habitat Survey Reaches

Legend
- Stream Reaches Surveyed During Qualitative Fish Habitat and Fish Population Surveys
- Study Area
- Public Land Survey
- County Lines
- Topography
- Water Body
- Class 1 Stream
- Class 2 Stream
- Class 3 Stream

Scale 1:35000
3.2.2 Methods

Aquatic habitat surveys included: (1) a quantitative assessment of fish habitat in the Swift No. 2 bypass reach; and (2) qualitative surveys in Panamaker Creek, Ole Creek, Rain Creek, Dog Creek, the upper portion of Cougar Creek, and Speelyai Creek. The methods used in each of these surveys are described below.

3.2.2.1 Quantitative Habitat Survey

The quantitative fish habitat survey in the Swift No. 2 bypass reach was conducted using a modified U.S. Forest Service (USFS) Region 6 stream survey methodology (USFS 1995b). The survey began at the downstream end of the reach (upper end of Yale Lake) and proceeded upstream. A biologist, accompanied by a field technician, walked the reach and systematically classified stream habitat into a series of habitat types (units). These habitat types included pools, riffles, glides, cascades, side channels, dry channels, and step/falls as described by the American Fisheries Society (AFS 1985). Each habitat type is defined below:

- **Pool**: Characterized by reduced current velocity, often with deeper water than surrounding habitats.
- **Riffle**: Shallow habitat where water flows swiftly over completely or partially submerged substrate to produce surface agitation.
- **Glide**: A slow moving, relatively shallow area of flowing water without surface agitation or waves.
- **Cascade**: Characterized by swift current, exposed rocks and boulders, high gradient, and considerable turbulence and surface agitation.
- **Side Channel**: Lateral channel with an axis of flow roughly parallel to the mainstem and which is fed by water from the mainstem.
- **Dry Channel**: A section of channel that contains no water or subsurface flow.
- **Step/Falls**: Discrete break in channel gradient, such as a waterfall or fish migration barrier, usually shorter in length than width.

The total length of each habitat unit (pool, riffle, etc.) encountered was measured to the nearest foot using a hip chain, and the average width of the habitat unit was estimated. Each individual habitat unit was assigned an "NSO," or natural sequence order (the first habitat unit encountered was assigned NSO 1, the second habitat unit was assigned NSO 2, etc.). Side channels entering a habitat unit were given a sub-NSO number (e.g., NSO 17.1) corresponding to the NSO of the main channel unit entered.

Habitat quality parameters, including flow, habitat type ratios, substrate composition, number of pieces and size class of large woody debris (LWD), and total cover, were
assessed for each habitat unit (USFS 1995b). Bankfull width (at ordinary high water mark) was also recorded periodically. Points of reference, such as tributary junctions and road crossings, were noted so that habitat unit locations could be better identified when the survey was completed. Photographs of representative habitat units and special features including excellent habitat, poor habitat, and fish migration barriers were taken throughout each reach.

### 3.2.2.2 Qualitative Habitat Surveys

To increase understanding of fish habitat within the study area, PacifiCorp targeted several small streams for less comprehensive qualitative habitat surveys. Qualitative habitat surveys were completed in early September 1996 (during the low flow period) in Panamaker Creek, Ole Creek, Rain Creek, Dog Creek, and in the upper portion of Cougar Creek (Figure 3.2-2). Speelyai Creek was surveyed in late August 1997.

Surveys were designed to assess fish habitat quality parameters including flow, depth, substrate composition, cover, and channel complexity. Possible resident and anadromous fish migration barriers were also examined. Surveys in Panamaker Creek, Rain Creek, and Dog Creek started at the mouth of each stream and continued upstream for a length of 0.5 mile. The survey in Ole Creek started at the mouth and continued upstream for a length of 1 mile. In Cougar Creek, the survey began at its subterranean section and continued upstream to a point where the channel became undefined (approximately 0.5 mile). Surveys in Cougar Creek were designed to determine if fish habitat existed immediately upstream of the point at which it emerges out of its subterranean reach. Two reaches totaling 3.3 miles of fish habitat were surveyed in Speelyai Creek. One reach was located downstream from the Speelyai Canal diversion (RM 0 to RM 2.2), the other reach extended upstream from the diversion (RM 4.0 to RM 5.1) (Figure 3.2-2). The survey in Speelyai Creek was designed to determine the differences in fish habitat both upstream and downstream from the diversion.

In each survey reach, an experienced biologist walked upstream, examined habitat parameters, and documented special habitat features including possible fish migration barriers in individual segments. Segments were defined as relatively homogeneous sections of stream having similar physical and geomorphological characteristics. Survey distances were recorded using a hip chain. Photographs of special habitat features were also taken throughout each reach.

### 3.2.3 Results and Discussion

The following section presents the results of PacifiCorp’s aquatic habitat survey in streams within the Yale Project study area. Comprehensive fish habitat survey data for the North Fork Lewis River are presented in Appendix 3.2-1. Photographs of representative habitat for all surveyed streams are presented in Appendix 3.2-2.
3.2.3.1  Quantitative Habitat Survey

PacifiCorp’s quantitative habitat survey in the Swift No. 2 bypass reach was completed in early September 1996, during low flow conditions. The following section includes a description of flow, habitat type ratios, LWD densities, substrate composition, effective cover, and migration barriers in the bypass reach.

Flow

The 2.7-mile-long bypass reach has no minimum instream flow requirement. Except during spill events, all water flows directly from the Swift No. 1 powerhouse into the Swift No. 2 power canal. However, as a result of seepage from the canal, water flows annually throughout most of the reach’s length. During PacifiCorp’s habitat survey, surface discharge at the downstream end of the bypass reach was estimated to be approximately 10 cubic feet per second (cfs). Discharge decreased with distance upstream and eventually became intermittent near the base of Swift dam.

The only major tributary to the Swift No. 2 bypass reach is Ole Creek (Figure 3.2-2). This small, third order stream contributed approximately 1 cfs to the total flow. Most of the remaining flow resulted from seepage from the power canal. Seepage from the canal enters the bypass reach through a series of very small side channels, seeps, ponds, and wetland complexes along the north side of the reach.

Habitat Type Ratios

The size and frequency of individual habitat units such as pools, riffles, and glides can affect the overall quality of the habitat. Using data collected during the physical habitat survey, pool:riffle:glide:cascade:side channel ratios were calculated for the bypass reach.

These area-based ratios are presented in Table 3.2-1 and discussed below. A detailed geographic information system (GIS) based habitat map of the bypass reach is presented in Figure 3.2-1.

<table>
<thead>
<tr>
<th>Habitat Type</th>
<th>Total Area (acres)</th>
<th>Ratio (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pool</td>
<td>3.5</td>
<td>18</td>
</tr>
<tr>
<td>Riffle</td>
<td>6.6</td>
<td>34</td>
</tr>
<tr>
<td>Glide</td>
<td>5.6</td>
<td>29</td>
</tr>
<tr>
<td>Cascade</td>
<td>0.5</td>
<td>2</td>
</tr>
<tr>
<td>Side channel</td>
<td>3.0</td>
<td>16</td>
</tr>
<tr>
<td>Total</td>
<td>19.2</td>
<td>100</td>
</tr>
</tbody>
</table>

The Swift No. 2 bypass reach contained 61 distinct habitat units, including 3 side channels and 2 dry channel segments (Appendix 3.2-1). Stream habitat was dominated by low-gradient riffles and glides, each of which comprised approximately one third of the total wetted habitat area (Table 3.2-1) (Appendix 3.2-2, photos 1 and 2). Seven
relatively large pools comprised approximately one-fifth of the wetted habitat area (Appendix 3.2-2, photos 3 and 4), and 3 long side channels totaling 1.1 miles in length comprised 16 percent of the total wetted habitat area (Appendix 3.2-2, photo 5). Cascades comprised only 2 percent of the habitat. The average channel gradient in the reach was 1.5 percent.

Many species and age classes of salmonids depend on pools for rearing habitat, particularly during summer low flow periods. Percent pool area in the reach was below ideal target conditions (approximately 50 percent) for streams with comparable gradient (Peterson et al. 1992). However, the 7 relatively large, deep pools in the reach did appear to provide excellent cover and thermal refuge for fish. Riffles and glides appeared to provide substantial habitat for macroinvertebrate production as well as some salmonid spawning habitat. The 3 large side channels, which contained several beaver pond complexes, provide good off-channel rearing habitat for juvenile salmonids. These side channels also provide an excellent refuge habitat for fish during high flow periods or flood-related spill events. The 2 dry channel segments in the reach are discussed in the migration barrier section.

Large Woody Debris

Large woody debris (LWD) can influence channel form, sediment transport, pool formation, and nutrient storage. LWD provides some of the most important hiding and holding cover for fish. In the bypass reach, the amount of woody debris was quantified for every habitat unit (NSO) encountered. If pieces of LWD were present within the apparent bankfull width of the habitat unit, it was counted and categorized as 1 of the following 4 sizes: small brush, brush, small tree, or large tree. PacifiCorp calculated the average number of LWD pieces per mile of main channel habitat (LWD/mile) for the entire reach by dividing the number of pieces in each size class by the total reach length. Qualifiers for each of the size classes were based on a modified USFS protocol, as presented in Appendix 3.2-1.

LWD was extremely limited in the bypass reach. Only 18 pieces of small brush (greater than 6 inches in diameter and greater than 20 feet in length) and 1 piece of brush (greater than 12 inches in diameter and greater than 25 feet in length) were counted. Most of the small brush was recently toppled alder. No larger, more stable pieces of LWD were encountered.

LWD densities averaged 6.8 pieces of small brush per mile and 0.4 piece of large brush per mile. These LWD densities are far below established ideal LWD target conditions for unmanaged streams in western Washington (Peterson et al. 1992). Future recruitment of LWD into the bypass reach appears to be limited due to a lack of large trees in the riparian zone.

Substrate Composition

An understanding of substrate composition and embeddedness is important to assess physical stream habitat quality. The composition of substrate has implications with
respect to sediment supply, stream hydrology, fish spawning and rearing opportunities, and providing cover from predation.

During the stream habitat survey, streambed substrate was assessed in each habitat unit in the bypass reach. This was a visual assessment based on USFS protocol (1995b) and consisted of recording the dominant and subdominant substrate in each habitat unit (NSO).

Results of the stream habitat survey showed that streambed substrates in the bypass reach were dominated by small boulders (10 to 40 inch) and cobble (2.5 to 10 inch). Large boulders (>40 inches) were also abundant. Some high-quality spawning gravel was present in the reach, most of which was below the mouth of Ole Creek.

Embeddedness is a measure of the degree that gravel and cobble is surrounded or covered with fine-grained sediment. This measure indicates the suitability of the substrate to provide a healthy environment for spawning and incubation of salmonids, as well as to provide areas for macroinvertebrate production. Greater than 35 percent embeddedness would be an indication that there was an excessive amount of fine sediment in the system; less than 35 percent embeddedness would be an indication of a relatively healthy stream environment. The percentage of streambed embeddedness was estimated at less than 35 percent for all habitat units in the bypass reach.

Effective Cover

Effective cover is used by fish for various activities including predation avoidance, feeding, hiding, and avoiding adverse conditions. During the stream habitat survey, 6 types of cover for salmonids were rated in each habitat unit encountered: undercut banks, substrate, depth, overhanging vegetation, woody material, and turbulence. After a dominant cover type was determined for each habitat unit, the percentage of cover that occupied the wetted surface area of each habitat unit was determined and recorded as 1 of the following categories: 0 to 5 percent, 6 to 20 percent, 21 to 40 percent, or >40 percent (Appendix 3.2-1).

The bypass reach contained a limited amount of cover (6 to 20 percent of the wetted habitat area) for salmonids. Nearly all instream cover was provided by small boulders and depth (>3 feet). Woody material was limited in the reach. Undercut banks, overhanging vegetation, and turbulence provided little or no cover in the reach.

Migration Barriers

The only total barrier to upstream or downstream migration of fish in the bypass reach at the time of the survey was a 198-foot-long dry channel segment approximately 300 feet downstream from Swift Dam (Appendix 3.2-1). This segment separated a large 150-foot-long pool at the upstream end of the reach from the rest of the wetted channel. Another 519-foot mainstem dry channel segment (NSO 48 DC 1 in Appendix 3.2-1) was passable by fish through a small wetted side channel (NSO 36.1 SC 3 in Appendix 3.2-1). There were no waterfalls or steps in the bypass reach.
3.2.3.2 Qualitative Habitat Surveys

Qualitative habitat surveys were completed between September 9 and September 11, 1996 in Dog Creek, Panamaker Creek, Ole Creek, Rain Creek, and in the upper portion of Cougar Creek. Surveys in Speelyai Creek were completed on August 27 and 28, 1997 (Figure 3.2-2). Results of these habitat surveys are described below. Information on fish populations within these streams is presented in Section 3.3.

Dog Creek

The survey in Dog Creek started at the mouth and continued upstream for 0.5 mile. Between RM 0 and RM 0.2, Dog Creek lacked surface flow and contained only 2 small, isolated pools (Appendix 3.2-2, photo 6). These gravel- and cobble-dominated pools appeared to provide little or no rearing habitat for salmonids. Bankfull width in the intermittent segment ranged from 30 to 50 feet. Instream cover and LWD were limited. This intermittent segment was a total barrier to the upstream and downstream migration of fish at the time of the survey. At higher spring and fall flows, this segment would most likely be passable by salmonids. However, a culvert located at Lewis River Road (RM 0.2), still within the dry channel segment, was believed to be an upstream migration barrier even at high flows (Appendix 3.2-2, photo 7).

Between RM 0.2 and RM 0.5, Dog Creek was more confined and higher gradient (3 to 5 percent), with a surface flow of approximately 0.5 cfs. Habitat in this segment was comprised of 4- to 6-foot-wide pools and cobble-dominated riffles (Appendix 3.2-2, photo 8). Instream cover, spawning gravel, and LWD were abundant. No additional migration barriers were observed in the segment.

Ole Creek

The survey in Ole Creek started at the mouth and continued upstream for a length of 1 mile. Habitat in the lower 200 feet of Ole Creek (RM 0 to RM 0.04) was relatively complex, dominated by shallow, 4- to 8-foot-wide cascades and pocket pools. Bankfull widths averaged 20 feet and discharge was approximately 1 cfs. Substrate in this relatively short, moderate-gradient segment (3 to 6 percent) was dominated by small boulders and cobble (Appendix 3.2-2, photo 9). Abundant boulders provided adequate instream cover.

Between RM 0.04 and RM 0.4, Ole Creek was lower-gradient (1 to 2 percent) and intermittent (Appendix 3.2-2, photo 10). Habitat in this segment was comprised of shallow gravel and sand-dominated disjunct plunge pools. Cover in the these isolated pools was abundant and bankfull widths averaged approximately 35 feet. At the time of the survey, the reach was classified as a low flow complete migration barrier to all fish. At higher spring and fall flows, this section would be easily passable by salmonids and would most likely provide excellent spawning habitat. In October 1996, several kokanee were observed actively spawning throughout this segment of Ole Creek, which was completely wetted at that time.
Between RM 0.4 and RM 0.8, Ole Creek was more confined, higher gradient (3 to 6 percent), and no longer intermittent. Surface discharge returned to approximately 1 cfs and habitat became more complex, comprised of a mixture of cobble-dominated pools, riffles, and cascades. Bankfull widths narrowed to approximately 18 feet, and LWD and boulder cover were abundant throughout the segment (Appendix 3.2-2, photo 11). A 30-foot-high debris jam was located at RM 0.8 (Appendix 3.2-2, photo 12). This debris jam is the lowermost total barrier (at all flows) to the upstream migration of fish in Ole Creek. Upstream from the debris jam, all streamflow was subsurface for approximately 250 feet.

Between RM 0.8 and RM 1.0, Ole Creek increased in gradient (6 to 10 percent) and was deeply incised. Habitat in this segment was comprised of cobble-dominated pools and bedrock-dominated cascades and waterfalls (Appendix 3.2-2, photo 13). Several of the waterfalls, 6 feet to 30 feet high, were believed to be total barriers to the upstream migration of salmonids.

Rain Creek

The survey in Rain Creek started at the mouth and continued upstream for a length of 0.5 mile. At the time of the survey, this portion of Rain Creek lacked surface flow or standing water and provided no fish habitat. However, a clearly defined, unvegetated channel with an average bankfull width (assuming water is present) of approximately 10 feet was evident throughout the entire surveyed segment (Appendix 3.2-2, photo 14). This channel indicated that Rain Creek most likely contains a significant amount of flow during certain times of the year.

Cougar Creek

Habitat in the lower 1.68 miles of Cougar Creek (downstream from its subterranean section) has been described in detail in USFS (1995a). PacifiCorp’s 1996 habitat survey began at RM 1.68, the lowermost point in the subterranean section, and continued upstream for a length of approximately 0.5 mile. The goal of the survey was to determine if fish habitat existed immediately upstream from the subterranean section.

The lower 500 feet of the surveyed reach, upstream from its subterranean section, had a clearly defined, deeply incised channel (>60 percent slope) with an average gradient of approximately 20 percent. This bedrock and boulder-dominated segment lacked surface flow or standing water during the 1996 survey (Appendix 3.2-2, photo 15).

Upstream from the lower 500-foot segment, the Cougar Creek (dry) channel decreased in gradient and became less confined (Appendix 3.2-2, photo 16). Bankfull widths averaged approximately 10 feet, and cobble and gravel were the dominant substrates. This segment also lacked surface flow or standing water. At approximately 1,500 feet upstream of the survey start point, the Cougar Creek dry channel became completely unconfined, vegetated, and indistinguishable from the surrounding landscape (Appendix 3.2-2, photo 17).
Panamaker Creek

The survey in Panamaker Creek started at the mouth and continued upstream for a length of 0.5 mile. Panamaker Creek lacked surface flow between RM 0 to RM 0.2 (Appendix 3.2-2, photo 18). A single isolated pool was located approximately 200 feet upstream from the dry channel’s mouth; however, this relatively small gravel-dominated pool provided little or no salmonid habitat. This intermittent segment was relatively unconfined, braided, and dominated by cobble and gravel substrates. Bankfull widths ranged from 40 to 60 feet. At the surveyed flow, the segment was a total upstream and downstream migration barrier to all fish. At higher spring and winter flows, this section would be passable for salmonids.

According to PacifiCorp biologists, a major slope failure occurred in the upper reaches of Panamaker Creek in February, 1996. This slope failure completely changed habitat conditions in the upper portion of Panamaker Creek, and also contributed large amounts of bedload to the lower creek, creating the 800-foot-long passage barrier described above.

Upstream from the 800-foot dry channel segment, Panamaker Creek was more confined and higher gradient (5 to 10 percent). Bankfull widths narrowed to approximately 40 feet and surface discharge increased to approximately 0.5 cfs (Appendix 3.2-2, photo 19). Fish habitat was comprised of a mixture of cobble and bedrock-dominated pools, riffles, and cascades. Cover and LWD was limited.

Between RM 0.2 and RM 0.3, Panamaker Creek was deeply incised (Appendix 3.2-2, photo 20). Habitat within this segment was comprised of bedrock-dominated pools and cascades. Instream cover in the form of boulders was abundant. A 30-foot-high waterfall located at RM 0.3 was a total barrier to the upstream migration of salmonids at all flows (Appendix 3.2-2, photo 21).

Between RM 0.3 and RM 0.5, Panamaker Creek was less confined and lower-gradient (3 to 5 percent). Cobble and gravel were the dominant substrates and cover was abundant. LWD was common throughout the segment. Immediately upstream from RM 0.5, Panamaker Creek appeared to be heavily affected by the recent slope failure and timber harvest activities. Habitat in this gravel and cobble-dominated segment was non-complex and extremely unstable. The segment lacked riparian vegetation and substantial amounts of stable LWD. Streambanks appeared to be actively eroding and contributing large amounts of sediment to the system (Appendix 3.2-2, photo 22).

Speelryai Creek

Two sections of Speelryai Creek were surveyed to assess the differences in fish habitat upstream and downstream from PacifiCorp’s diversion. The downstream portion began at the mouth (Lake Merwin) and continued upstream for approximately 2.2 miles. The stream channel in this segment was relatively low gradient (1 to 2 percent) and moderately confined with an average bankfull width of about 40 feet. Discharge was approximately 20 to 30 cfs in late August. This relatively high flow was caused by numerous springs and small tributaries entering the stream throughout the reach. Habitat
in this reach was comprised of complex 20- to 25-foot-wide gravel and cobble dominated riffles, and sand and gravel dominated glides (Appendix 3.2-2, photo 23). Plunge pools, lateral scour pools, and side channels were common but not abundant. Both LWD and aquatic vegetation provided a substantial amount of instream cover throughout the reach. The only migration barrier observed during the survey from RM 0 to RM 2.2 was the WDFW hatchery diversion located approximately 300 feet upstream from Lake Merwin.

The surveyed portion of Speelyai Creek upstream from the canal diversion began at the diversion structure (RM 4.0) and continued upstream for approximately 1.1 miles. The stream channel in this undiverted segment was confined, and was somewhat steeper (3 to 4 percent gradient) than the lower reach. Bankfull widths averaged 45 feet and discharge was approximately 15 to 25 cfs. Fish habitat in this portion of Speelyai Creek was dominated by 20- to 30-foot-wide cobble and small boulder dominated riffles. Pools and glides were common but comprised only about 20 percent of the total habitat area (Appendix 3.2-2, photo 24). Boulders and some LWD provided a limited amount of instream cover. No migration barriers were observed in the Speelyai Creek channel upstream from the canal; however, an approximately 0.2 mile-long dry channel reach located immediately downstream from the canal diversion was a low flow migration barrier.

In addition to the Speelyai Creek survey, habitat in the Speelyai Creek canal was surveyed from its confluence with Yale Lake upstream to the point of diversion, a distance of approximately 1,000 feet. On August 28, 1997 (the survey day), the lower 600 feet of the canal was influenced by a backwater effect created by Yale Lake, forming a deep 600 foot-long glide. Upstream of this point, habitat in the canal consisted of cobble and small boulder dominated riffles (Appendix 3.2-2, photo 25). Bankfull width in the canal averaged approximately 40 feet, cover was limited and little or no LWD was present.

3.3 RESIDENT FISH POPULATION SURVEYS IN PROJECT TRIBUTARIES

This section describes PacifiCorp’s resident fish population surveys in stream reaches within the Yale Project study area. Surveys included a quantitative estimate of fish populations in the Swift No. 2 bypass reach upstream of the Yale Project, as well as a qualitative survey of fish populations in several small tributaries that had not been examined previously. The objective of these studies is to provide a detailed description of existing fish populations in stream reaches within the Yale Project study area.

3.3.1 Study Area

PacifiCorp’s quantitative fish population estimate was completed in the Swift No. 2 bypass reach between the upstream end of Yale Lake (RM 44.4) and Swift Dam (RM 47.1). Qualitative fish population surveys were completed in the lower reaches of Panamaker Creek, Ole Creek, Rain Creek, Dog Creek, and in the upstream end of Cougar Creek. Speelyai Creek was surveyed both upstream and downstream of PacifiCorp’s diversion into Yale Lake. The stream reaches were the same as those assessed in the tributary stream habitat survey (Section 3.2). Surveyed reach locations are shown in Figure 3.2-2.
3.3.2 Methods

The methods used in PacifiCorp's fish population estimate and surveys are described below.

3.3.2.1 Quantitative Fish Population Estimate

PacifiCorp's quantitative fish population estimate in the Swift No. 2 bypass reach was completed using a modified version of the Hankin and Reeves (1988) methodology for systematic random sampling in streams.

All wetted habitat types (pools, riffles, glides, cascades, and side channels) identified during the tributary stream habitat survey (Section 3.2) were sampled during the tributary stream population estimate. The first unit of each habitat type to be sampled was selected randomly; subsequent units were selected systematically. The percentage of each habitat type sampled was based on the number and distribution of that habitat type in the reach. The goal was to sample a minimum of 20 percent of each habitat type (Table 3.3-1).

Table 3.3-1. Total number of units of each habitat type selected for fish population sampling in the Swift No. 2 bypass reach.

<table>
<thead>
<tr>
<th>Habitat Type</th>
<th>Total Selected</th>
<th>Total Represented</th>
<th>Percent Selected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pool</td>
<td>3</td>
<td>7</td>
<td>43</td>
</tr>
<tr>
<td>Riffle</td>
<td>5</td>
<td>21</td>
<td>24</td>
</tr>
<tr>
<td>Glide</td>
<td>5</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>Cascade</td>
<td>2</td>
<td>6</td>
<td>33</td>
</tr>
<tr>
<td>Side channel</td>
<td>2</td>
<td>3</td>
<td>67</td>
</tr>
<tr>
<td>Dry channel</td>
<td>NA</td>
<td>2</td>
<td>NA</td>
</tr>
</tbody>
</table>

A Smith-Root® electrofisher was used to sample each riffle, glide, cascade, and side channel selected using a multi-pass depletion method (Seber 1982). Voltage and pulse rate were adjusted to maximize capture efficiency while minimizing injury to fish. Each pass was designed to maintain consistent effort, and block nets were used at the upstream and downstream end of all sampled units. Block nets ensured that sampling was completed within a "closed system."

In most cases, the entire habitat unit was sampled for fish. If the selected unit exceeded 200 feet in length, a portion of that unit, typically 200 feet in length, was sub-sampled. Because the 2 selected side channels were more than 2,000 feet long, they were sub-sampled over representative reaches.

Captured fish were identified to species and measured (fork length in mm). Representative groups of fish collected in each reach were weighed to the nearest gram. After the data were collected and recorded, all fish were returned unharmed to the area in which they were captured.
Because pools in the bypass reach were generally too deep to effectively electrofish, fish numbers in these units were counted by a team of divers in snorkel gear (USFS 1983). In larger pools, 2 divers were used to count fish. In smaller pools, a single diver completed the count. In both situations divers moved upstream through the unit and identified, counted, and recorded all fish observed.

Salmonid densities in riffles, glides, cascades, and side channels (electrofished units) were calculated using either a 2-pass or 3-pass (multi-pass) depletion method. If the total catch of salmonids in the second pass was less than 30 percent of the catch in the first pass, a third pass was not completed.

Salmonid densities in this stream reach were calculated as follows:

Fish density of the sampled habitat unit was calculated as:

\[ \hat{D}_t = \frac{\hat{N}_t}{SL_{ti}} \quad (1) \]

and

\[ \text{Var}(\hat{D}_t) = \frac{\text{Var}(\hat{N}_t)}{SL_{ti}^2} \quad (2) \]

where, \( \hat{D}_t \) is the estimated salmonid density in \( i \)th unit of habitat type \( t \); and \( SL_{ti} \) is the length or area of the sampled portion of \( i \)th unit of habitat type \( t \).

Mean density of a habitat type \( t \) was computed using:

\[ \bar{D}_t = \frac{\sum \hat{D}_t}{n_t} \quad (3) \]

and

\[ \text{Var}(\bar{D}_t) = \frac{\sum \text{Var}(\hat{D}_t)}{n_t^2} + \frac{\sum (\hat{D}_t - \bar{D}_t)^2}{n_t(n_t - 1)} \quad (4) \]

where, \( n_t \) is the number of units sampled of habitat type \( t \).

The overall salmonid density of the bypass reach was calculated as a weighted mean density and was weighted by total length of a habitat type, such as a glide:

\[ \bar{D} = \frac{\sum L_t \bar{D}_t}{\sum L_t} \quad (5) \]

and
where, $L_t$ is the length or area of habitat type $t$.

### 3.3.2.2 Qualitative Fish Population Survey

PacifiCorp targeted several small streams for less comprehensive, 1-pass electrofishing surveys. The purpose of these surveys was to describe the species composition and relative abundance of fish populations within the study area, which included the lower reaches of Panamaker Creek, Ole Creek, Rain Creek, Dog Creek, and the upper portion of Cougar Creek. Speelyai Creek was surveyed upstream and downstream of PacifiCorp’s diversion. Stream reaches selected for electrofishing were the same as those assessed during PacifiCorp’s qualitative tributary stream habitat survey (Figure 3.2-2). Detailed surveys of fish populations in other Yale Project tributaries (Siouxon Creek and in the lower portion of Cougar Creek) have been completed previously (USFS 1995a and Conklin 1992).

In each surveyed stream reach, a group of representative habitat units was selected for qualitative 1-pass electrofishing. Selected habitat units were distributed throughout the lower 0.5 mile of Panamaker Creek, Rain Creek, Dog Creek, Cougar Creek (upstream from its subterranean reach), and the lower 1 mile of Ole Creek. In Speelyai Creek, selected habitat units were distributed throughout the 2.2-mile survey reach downstream from the diversion and in the 1.1-mile survey reach upstream from the diversion. In some reaches, habitat units were sampled both upstream and downstream of suspected resident fish migration barriers. All captured salmonids were counted, identified to species, measured for fork length, and released. Non-salmonids observed or captured in the reach were noted.

### 3.3.3 Results and Discussion

All fish species observed or captured during fish population sampling in the Yale Project study area were either cutthroat trout, rainbow trout, bull trout, mountain whitefish, largescale sucker, lamprey, sculpin, or dace. A pair of spawning kokanee were also observed in the Swift No. 2 bypass reach; however, these fish were outside of the selected units. Detailed results for the quantitative and qualitative surveys are summarized below.

#### 3.3.3.1 Quantitative Fish Population Estimate

Quantitative fish population sampling in the Swift No. 2 bypass reach was completed between September 17 and September 21, 1996. Seventeen habitat units were electrofished or snorkeled to produce a fish population estimate for the 2.7-mile-long bypass reach (Table 3.3-2). Detailed habitat data for each habitat unit sampled during the quantitative population estimate in the Swift No. 2 bypass reach are presented in Appendix 3.2-1. Water clarity during sampling was excellent and low flows facilitated data collection. Water temperatures in the reach ranged from 10 to 13°C.
Table 3.3-2. Habitat units sampled for quantitative fish population estimates in the Swift No. 2 bypass reach.

<table>
<thead>
<tr>
<th>NSO</th>
<th>Habitat Type</th>
<th>Habitat Unit Length (ft.)</th>
<th>Sampled Length (ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Pool</td>
<td>510</td>
<td>510</td>
</tr>
<tr>
<td>5</td>
<td>Cascade</td>
<td>73</td>
<td>73</td>
</tr>
<tr>
<td>8</td>
<td>Riffle</td>
<td>196</td>
<td>196</td>
</tr>
<tr>
<td>11</td>
<td>Glide</td>
<td>332</td>
<td>200</td>
</tr>
<tr>
<td>16</td>
<td>Riffle</td>
<td>182</td>
<td>182</td>
</tr>
<tr>
<td>17.1</td>
<td>Side channel</td>
<td>3,048</td>
<td>358</td>
</tr>
<tr>
<td>19</td>
<td>Glide</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>28</td>
<td>Glide</td>
<td>1,270</td>
<td>200</td>
</tr>
<tr>
<td>29</td>
<td>Pool</td>
<td>104</td>
<td>104</td>
</tr>
<tr>
<td>30</td>
<td>Riffle</td>
<td>131</td>
<td>131</td>
</tr>
<tr>
<td>36.1</td>
<td>Side channel</td>
<td>2,450</td>
<td>400</td>
</tr>
<tr>
<td>38</td>
<td>Glide</td>
<td>132</td>
<td>132</td>
</tr>
<tr>
<td>39</td>
<td>Riffle</td>
<td>240</td>
<td>200</td>
</tr>
<tr>
<td>44</td>
<td>Pool</td>
<td>260</td>
<td>260</td>
</tr>
<tr>
<td>51</td>
<td>Glide</td>
<td>188</td>
<td>188</td>
</tr>
<tr>
<td>52</td>
<td>Riffle</td>
<td>400</td>
<td>200</td>
</tr>
<tr>
<td>54</td>
<td>Cascade</td>
<td>124</td>
<td>124</td>
</tr>
</tbody>
</table>

NSO = Natural sequence order, which corresponds to habitat data presented in Appendix 3.2-1.

Fish captured or observed during sampling in the Swift No. 2 bypass reach included cutthroat trout, rainbow trout, kokanee, bull trout, mountain whitefish, largescale sucker, sculpin, lamprey, and dace. Cutthroat trout, sculpin, and dace were abundant throughout the reach. A total of 137 cutthroat trout were captured throughout the reach. Over 200 largescale suckers and 5 whitefish were observed in a pool immediately upstream of Yale Lake. Largescale suckers were not captured or observed in any other units. Only 1 rainbow trout, 1 bull trout, 1 lamprey, and 1 additional whitefish were captured or observed in the remainder of the reach.

Fisheries agencies are primarily concerned with management of salmonids within the project area; suckers, lamprey, sculpin, and dace were therefore not included in the population estimate. The captured rainbow trout, bull trout, and mountain whitefish were also excluded from the estimate to avoid errors associated with extrapolating small fish numbers over the entire reach. Consequently, the population estimate was completed for cutthroat trout only.

An attempt was made to estimate cutthroat trout density by size class (i.e., 65 to 120 mm, and greater than 120 mm) in the Swift No. 2 bypass reach. Results were poor, however, due to the small sample size. All size classes were therefore lumped to create a single population estimate, which is presented below.

The Swift No. 2 bypass reach contained an estimated 924 cutthroat trout greater than 65 mm in length. The density of cutthroat trout was approximately 250 fish per mile, or 75 fish per acre (Table 3.3-3). A length-frequency histogram produced from electrofishing
data appeared to show size classes (modes) for captured cutthroat trout at about 90 mm, 140 mm, 170 mm, and possibly 200 mm (Figure 3.3-1).

Table 3.3-3. Estimates of numbers and densities of cutthroat trout greater than 65 mm (fork length) in length in the Swift No. 2 bypass reach (95 percent confidence interval).

<table>
<thead>
<tr>
<th>Total No. of Cutthroat Trout</th>
<th>*Reach Length (ft)</th>
<th>*Reach Area (acres)</th>
<th>No. of Cutthroat Trout/Mile</th>
<th>No. of Cutthroat Trout/Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>SD</td>
<td>924</td>
<td>19,249</td>
<td>19.1</td>
<td>254</td>
</tr>
<tr>
<td></td>
<td>340</td>
<td></td>
<td>93</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SD</td>
<td>SD</td>
</tr>
</tbody>
</table>

* Includes side channel habitat.

These modes most likely corresponded to age 0+, 1+, and 2+ fish. Of the fish sampled, approximately 69 percent were less than 120 mm in length. Four percent were greater than 200 mm.

The relatively large number of 0+ cutthroat trout captured during sampling indicated that substantial natural reproduction occurred in the reach. The presence of a juvenile bull trout and 2 adult kokanee (observed outside of the sampled habitat units) may also indicate that the reach or tributaries are used for spawning by these species. The bull trout (<150 mm) could have also been introduced via spill from Swift Reservoir or may have move upstream from Yale Lake.
Percentages of the estimated cutthroat trout population found in each type of habitat (pools, riffles, etc.) are shown in Table 3.3-4. Cutthroat trout seemed to prefer riffle, cascade, and side channel habitat and were not observed in pool and glide habitat in the bypass reach. Most side channel habitat contained a mixture of low flow pool and riffle habitat types.

Table 3.3-4  The percentages of the estimated cutthroat trout population found in each habitat type in the Swift No. 2 bypass reach.

<table>
<thead>
<tr>
<th>Habitat Type</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pool</td>
<td>2</td>
</tr>
<tr>
<td>Riffle</td>
<td>46</td>
</tr>
<tr>
<td>Glide</td>
<td>9</td>
</tr>
<tr>
<td>Cascade</td>
<td>9</td>
</tr>
<tr>
<td>Side channel</td>
<td>33</td>
</tr>
</tbody>
</table>

3.3.3.2 Qualitative Fish Population Survey

Qualitative fish population surveys in Panamaker Creek, Ole Creek, Rain Creek, and Dog Creek, and in the upper portion of Cougar Creek were completed between September 9 and September 11, 1996. Surveys in Speelyai Creek were completed on August 27 and 28, 1997. Species captured included cutthroat trout and sculpin. No other fish species were observed or captured during sampling in these tributaries.

Results of qualitative fish population surveys in each of the surveyed stream reaches are presented below.

Panamaker Creek

Four representative reaches totaling 555 feet of stream length were sampled for fish in the lower 0.5 mile of Panamaker Creek. Flow was subsurface in the lower 800 feet of Panamaker Creek on September 10, 1996. Upstream from this dry channel segment, the stream had an estimated surface flow of approximately 0.5 cfs. Fish habitat was comprised of a mixture of cobble- and bedrock-dominated pools, riffles, and cascades. Water temperature measured 13°C during sampling. Cutthroat trout and sculpin were present but not abundant in the sampled stream reaches. Eighteen cutthroat trout were captured and less than 100 sculpin were observed. Captured cutthroat ranged from 74 to 249 mm in length. Most measured less than 140 mm. Both species were captured upstream and downstream from a 30-foot-high waterfall at RM 0.3 (Section 3.2).

Ole Creek

Six representative habitat units totaling 328 feet of stream length were sampled for fish in the lower 1 mile of Ole Creek. Flow in the surveyed section ranged from intermittent in the lower 0.5 mile of stream to approximately 1 cfs in the upper portion of the reach. Water temperatures ranged from 14 to 15°C. Habitat consisted of a mixture of cobble-
dominated pools, riffles, and cascades. LWD jams were common (Section 3.2). Cutthroat trout and sculpin were abundant in the sampled habitat units, including those in the intermittent section. Thirty-six cutthroat trout were captured and hundreds of sculpin were observed. Captured cutthroat ranged from 53 to 260 mm in length, with substantial numbers of both adult and juvenile fish. These fish were present both upstream and downstream of several waterfalls in the reach’s upper section (RM 0.8 to RM 1.0). Because of their height (6 to 30 feet), some of these waterfalls appeared to be total barriers to the upstream migration of resident fish.

On November 1, 1996, PacifiCorp biologists surveyed portions of this reach and observed approximately 175 kokanee actively spawning in the lower Ole Creek.

Rain Creek

The lower 0.5 mile of Rain Creek lacked surface flow or standing water and was not sampled during the 1996 survey (Section 3.2).

Dog Creek

Six representative habitat units totaling 135 feet of stream length were sampled for fish in the lower 0.5 mile of Dog Creek. Sampling in Dog Creek was completed on September 10, 1996. Flow in Dog Creek ranged from intermittent near the mouth to approximately 0.25 cfs at the upper end of the reach. Water temperature was 9°C during sampling. Habitat in the reach was primarily cobble-dominated riffles and pools (Section 3.2). Both cutthroat trout and sculpin were abundant throughout the sampled reach and were even captured in 2 isolated pools in the stream’s intermittent section. A total of 38 cutthroat trout were captured and between 100 and 200 sculpin were observed. Captured cutthroat trout ranged from 80 to 170 mm in length, with the majority less than 120 mm.

Cougar Creek

The 0.5-mile-long surveyed section of Cougar Creek lacked surface flow or standing water and was not sampled during the 1996 survey (Section 3.2).

Speelyai Creek

Thirty-two habitat units totaling 760 linear feet of stream were sampled for fish in Speelyai Creek. Water temperature during sampling was 15.5°C and discharge ranged from approximately 30 cfs near the mouth to approximately 15 cfs upstream from the canal diversion (RM 5.1). Habitat in the reach downstream of the canal diversion (RM 0 to RM 2.2) consisted of a mixture of riffles and glides; habitat upstream of the diversion (RM 4.0 to RM 5.1) was dominated by riffles with occasional pools (Section 3.2).

Eighty-one cutthroat trout, more than 100 sculpin, and 5 lamprey were captured in the 20 sampled habitat units downstream from the diversion. Captured cutthroat trout ranged from 50 mm to 203 mm in length; both fry and adults were abundant. Sixty cutthroat trout and more than 100 sculpin were captured in 12 habitat units upstream of the
diversion. No lamprey were observed in the upper reach. Cutthroat trout captured upstream from the diversion ranged from about 50 mm to 280 mm in length; both fry and adults were also abundant in this reach.

3.4 BULL TROUT ENUMERATION/POPULATION SURVEY IN COUGAR CREEK

Studies to evaluate fisheries resources in Yale Lake, including bull trout, date back to 1978. Creel surveys conducted between 1978 and 1982 indicated that anglers harvested between 4 and 57 bull trout annually (Graves 1983). Bull trout spawning population estimates in Cougar Creek from 1979 to 1982 ranged from a low of zero fish in 1981 and 1982, to a high of 40 fish in 1979. The Mount St. Helens eruption in 1980 caused adverse impacts to Cougar Creek (as well as the entire North Fork Lewis River basin), which may explain the lack of spawning in 1981 and 1982.

Annual bull trout spawning surveys in Cougar Creek initiated by PacifiCorp in 1988 have provided some information on timing of spawning migrations, as well as location and status of the spawning population. Spawning surveys reported that between 7 and 37 bull trout spawned annually in Cougar Creek since 1988. Spawning escapement into Cougar Creek represents only a percentage of the actual Yale Lake spawning population since not all sexually mature bull trout in a population spawn annually (Fraley and Shepard 1988).

In response to the low adult counts mentioned above, bull trout harvesting in Yale Lake and tributaries was closed by the state in 1992. In 1993, the state classified the Yale Lake bull trout population as at "moderate risk" of extinction (Mongillo 1993). The U.S. Fish and Wildlife Service (USFWS) in 1994 determined that bull trout listing under the federal Endangered Species Act (ESA) was warranted but precluded due to other higher priority listing actions. In June 1998, the USFWS listed the Columbia River distinct population segment (DPS) of bull trout as a threatened species. The Lewis River is included in this DPS.

In fall 1995, WDFW, in cooperation with PacifiCorp staff, began an annual program to net adult bull trout from the Yale tailrace and return these fish to Yale Lake, where it is thought they originated. These fish were tagged with individual numbers for identification. Fish captured in the fall of 1995 and 1996 were tagged with yellow Floy tags. Fish tagged in the fall of 1997 and 1998 received pink floy tags. A total of 46 bull trout have been captured and tagged since fall 1995, of which 38 have been transported above Yale Dam and released in or near the mouth of Cougar Creek. The remaining 8 bull trout were tagged but not released in Yale Lake due to a lack of transportation services. Of the 38 fish transported from the Yale tailrace to Cougar Creek, 1 fish was observed in 1996 and 4 were observed in 1997 at a weir installed in Cougar Creek as part of the monitoring study described below.

The objective of this study was to gather baseline information on bull trout that would allow a more accurate assessment of the current status of the population. The enumeration study, which was initiated in fall 1996 and continued through fall 1997, was designed to describe the number and timing of adult bull trout migrating into Cougar Creek to spawn, and number and timing of juvenile outmigrants.
Comments received on this section of the draft FTR indicate that agency representatives would like to see an expansion of this study to include a survey of bull trout use in the Yale tailrace, Swift No. 2 tailrace, and Swift No. 2 bypass reach. A description of the Yale tailrace, the potential for bull trout to access the tailrace, and an analysis of the level of fish impacts resulting from access into the tailrace was also requested. PacifiCorp agrees that bull trout distribution will play a critical role in the relicensing of the Lewis River projects. PacifiCorp’s response to this request for additional studies is addressed in Exhibit E (PacifiCorp 1999).

3.4.1 Study Area

The study area is Cougar Creek, a tributary of Yale Lake that originates near the base of Mount St. Helens. Cougar Creek is the primary bull trout spawning and rearing tributary of Yale Lake. During the 1996 enumeration study, a weir was installed several hundred feet upstream of the Lewis River Road bridge crossing, which is 0.25 mile upstream of Yale Lake. In 1997 the weir was moved upstream, just above the confluence of Panamaker Creek, to reduce adverse flow and turbidity effects originating from Panamaker Creek during rain events (Figure 3.4-1).

3.4.2 Methods

Methods presented below describe techniques used to assess both adult and juvenile bull trout populations in Cougar Creek.

3.4.2.1 Spawning Migration into Cougar Creek

Adult bull trout spawning migration begins in July and extends into October each year. Adult bull were enumerated by capturing upstream and downstream migrants in traps within a vertical picket weir (Figure 3.4-2). In 1996, the 20-foot-long weir spanned the width of the creek and consisted of a series of steel pickets inserted through 2 (top and bottom) horizontal angle-iron railings and driven several inches into the streambed. In 1997, the weir was relocated to a wider, shallower section of creek and was extended to span the channel at the new sampling location. This modification allowed the weir structure to accommodate increased flows by spreading the volume of water over a greater surface area.

In 1996, the picket panel was supported by 2 steel tripods placed approximately 8 feet apart on the stream bottom. Gaps between the pickets were initially 1.45 inch but were reduced to 0.85 inch after an adult bull trout was found "gilled" in the pickets. In 1997, the picket panel was supported by 7 steel tripods placed approximately 8 feet apart. Gaps between the pickets were 0.95 inch. The top of the weir was angled downstream, allowing the force of the water to be placed on the tripod legs and creating a barrier that fish could not leap over.
Figure 3.4-1. Location of Cougar Creek fish weir.
Figure 3.4-2. Plan drawing of Cougar Creek fish weir.

The weir contained both upstream and downstream traps; migrant adults encountering the weir were diverted along the picket "fence" and into the traps, 4-foot by 6-foot holding boxes with an adjustable 4-inch "V" shaped entrance. The traps were constructed of steel pickets spaced approximately 1.45 inch apart, with a hinged steel locking lid. The spacing in the pickets was sufficient to allow upstream passage of spawning kokanee, while preventing passage of adult bull trout. Both upstream and downstream traps were located near the stream bank, where flow was considered sufficient to attract fish. Depth of water in the traps was always greater than 20 inches, and was sufficient to hold fish for a prolonged period of time.

After installation, small cobble and gravel substrate was laid along the stream bed where the pickets entered the substrate to effectively seal off the bottom. The trap was periodically examined underwater using a mask and snorkel to ensure there were no gaps where fish could escape.

Daily monitoring of adult bull trout began on September 18 during the 1996 sampling season, and on July 15 in 1997. Each captured fish was measured (fork length to nearest mm), had a small part of its anal fin removed for genetic analysis, and was tagged with an
individually numbered green Floy tag (Appendix 3.4-1). The results of genetic analysis are reported in Section 3.7.

3.4.2.2 Juvenile Emigration from Cougar Creek

The downstream migration timing and abundance of juvenile bull trout was assessed during the spring of 1997. Daily sampling of outmigrants began on April 16 and continued through May 1. To facilitate the sampling of juveniles, the entire weir, including the downstream trap, was covered with 1/4-inch mesh polyethylene screen.

Two upstream fence panels located somewhat parallel to the channel were also covered with 1/4-inch screen mesh. This modification was designed to direct juvenile outmigrants toward the weir and into the downstream trap. The bottom of the screen was covered with small cobble and boulder substrate along the channel bottom to prevent any openings. All captured juvenile bull trout were counted and measured (fork length to the nearest mm).

3.4.3 Results and Discussion

The following sections describe the results of the 1996-1997 bull trout enumeration/population survey in Cougar Creek.

3.4.3.1 1996 Enumeration of Adult Spawners

Because of a delay associated with permitting, the sampling of adult bull trout didn't begin until September 18, 1996. At the start of sampling, it was assumed that many adult bull trout had already moved upstream into the upper reaches of Cougar Creek. The downstream trap was intended to capture these fish.

On the morning of September 23, 5 days after weir installation, an adult bull trout was found "gilled" between 2 pickets on the weir face. The adult fish was 581 mm long. It was retained and delivered to the Merwin hatchery for examination.

On September 28, an adult bull trout was observed in the creek just upstream of the weir. The fish remained in the area (upstream side) in front of the weir until the weir attendant entered the water and "herded" the fish downstream into the trap. The fish was netted, measured (525 mm), and tagged (green Floy #001). The fish had several puncture wounds on the dorsal side posterior of the operculum, and a wound near the pectoral fins, indicative of an avian predator.

On the evening of October 1, an adult bull trout was captured upstream of the weir, apparently on its way back downstream to Yale Lake. This fish had been previously captured at the Yale tailrace on September 10, 1996, where it was tagged (yellow Floy #083) and transported to the mouth of Cougar Creek.

On October 14 and 15, heavy rains caused the water level (stage) in Cougar Creek to rise approximately 8 inches in the vicinity of the weir. During the night of October 15, stage
increased further and water began flowing around the right bank of the weir in an area about 3 feet wide and 6 inches deep. Cobble and large gravel substrate was placed in this area to prevent fish from swimming past the weir.

Coincident with increased flow moving through the weir, the steel pickets began to vibrate, making a loud chattering noise. The noise, which continued for several days, may have frightened away fish that were approaching the weir. Heavy rains continued intermittently for the next week, and on October 17 the cobble barrier was breached. On October 18, about half of the pickets were removed from the weir panel to allow flow to pass unimpeded through the weir. When heavy rains continued, the entire weir was removed a week later on October 25.

3.4.3.2 1997 Enumeration of Juvenile Outmigrants

Sampling for juvenile outmigrants proved to be difficult in Cougar Creek. Heavy debris load during the months of April and May caused the 1/4-inch mesh on the weir surface to clog, despite daily attempts to keep it clean.

On the evening of April 20, heavy rains caused a 0.4-foot increase in the stage of Cougar Creek. Estimated flow was greater than 500 cfs. This increased flow, combined with a heavy debris that covered the mesh screening on the face of the weir, caused the water stage to rise on the upstream side, creating a large pool. The increase in stage upstream of the weir allowed water to flow around both sides of the weir and resulted in the toppling of the fence guide panels.

Because of continued high flow conditions, the weir was not fished from April 21 through April 25. On the evening of April 26, flows subsided enough to repair the weir’s guide panels and begin fishing again.

On April 30, a single juvenile bull trout, measuring 104 mm, was found captured on the main face of the weir. The fish was examined and released downstream of the trap.

Because the first fish captured was actually somewhat impinged on the weir face, it was determined that velocities were too strong for juvenile outmigrants to utilize the trap without the risk of injury. Because of this risk, the mesh screen and a majority of the pickets were removed on May 1 to allow unimpeded downstream passage of juvenile fish.

3.4.3.3 1997 Enumeration of Adult Spawners

In 1997, daily monitoring of adult bull trout in Cougar Creek began on July 15 and continued until October 17. On August 19, 35 days after the start of monitoring, 5 adult bull trout were captured on the upstream side of the weir, indicating these fish had been in Cougar Creek prior to installing the trap. All 5 fish were corralled into the downstream trap and held there until each was processed. Two of the fish had yellow Floy tags (#00080 and #00084) on the left side of their dorsal fin (Table 3.4-1), indicating they had been previously captured in the Yale tailrace. Fish #00080 was 650 mm long and had...
grown 60 mm since its initial capture in September 1996. Fish #00084 was 500-550 mm long, showing a growth range of 40-90 mm after 1 winter’s growth in the reservoir, since its initial capture in September 1996. The other 3 fish were untagged and showed no signs of having been tagged (no needle scar near dorsal fin). These fish were tagged by the weir attendant with green Floy tags (#004, #007, and #011) on the left side of their dorsal fin. Fish ranged in length from 520-620 mm. All newly tagged fish had a small sample of their anal fin clipped for genetic analysis and were released downstream of the trap.

Table 3.4-1. Adult bull trout captured and tagged at the Cougar Creek weir during the 1996-97 enumeration study.

<table>
<thead>
<tr>
<th>Tag Number</th>
<th>Tag Color/Location</th>
<th>Fork Length (mm)</th>
<th>Capture Date</th>
<th>Genetic Sample Number</th>
<th>Recapture (Y/N)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Tag</td>
<td>n/a</td>
<td>581</td>
<td>9/23/96</td>
<td>n/a</td>
<td>N</td>
<td>weir mortality</td>
</tr>
<tr>
<td>001</td>
<td>green/rd</td>
<td>525</td>
<td>9/28/96</td>
<td>1Y</td>
<td>N</td>
<td>previously captured 9/10/96 in Yale Tailrace</td>
</tr>
<tr>
<td>00083</td>
<td>yellow/ld</td>
<td>660</td>
<td>10/1/96</td>
<td>n/a</td>
<td>Y</td>
<td>previously captured 9/10/96 in Yale Tailrace</td>
</tr>
<tr>
<td>00084</td>
<td>yellow/ld</td>
<td>500-550</td>
<td>8/19/97</td>
<td>n/a</td>
<td>Y</td>
<td>previously captured 9/10/96 in Yale Tailrace</td>
</tr>
<tr>
<td>00080</td>
<td>yellow/ld</td>
<td>650</td>
<td>8/19/97</td>
<td>na</td>
<td>Y</td>
<td>previously captured 9/10/96 in Yale Tailrace</td>
</tr>
<tr>
<td>004</td>
<td>green/ld</td>
<td>520-620</td>
<td>8/19/97</td>
<td>3Y</td>
<td>N</td>
<td>estimated data</td>
</tr>
<tr>
<td>007</td>
<td>green/ld</td>
<td>520-620</td>
<td>8/19/97</td>
<td>4Y</td>
<td>N</td>
<td>estimated data</td>
</tr>
<tr>
<td>011</td>
<td>green/ld</td>
<td>520-620</td>
<td>8/19/97</td>
<td>5Y</td>
<td>N</td>
<td>estimated data</td>
</tr>
<tr>
<td>No Tag</td>
<td>n/a</td>
<td>463</td>
<td>10/6/97</td>
<td>n/a</td>
<td>N</td>
<td>weir mortality</td>
</tr>
<tr>
<td>00514</td>
<td>pink/rd</td>
<td>635</td>
<td>10/6/97</td>
<td>n/a</td>
<td>Y</td>
<td>weir mortality; previously captured in Yale Tailrace 9/24/97</td>
</tr>
<tr>
<td>012</td>
<td>green/ld</td>
<td>505</td>
<td>10/15/97</td>
<td>6Y</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>013</td>
<td>green/ld</td>
<td>575</td>
<td>10/15/97</td>
<td>8Y</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>014</td>
<td>green/ld</td>
<td>520</td>
<td>10/15/97</td>
<td>7Y</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>015</td>
<td>green/ld</td>
<td>548</td>
<td>10/15/97</td>
<td>9Y</td>
<td>N</td>
<td>white fungus around dorsal fin</td>
</tr>
<tr>
<td>00080</td>
<td>yellow/ld</td>
<td>650</td>
<td>10/17/97</td>
<td>n/a</td>
<td>Y</td>
<td>fish bypassed weir, returning upstream, after initial capture</td>
</tr>
<tr>
<td>016</td>
<td>green/ld</td>
<td>410</td>
<td>10/17/97</td>
<td>10Y</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>017</td>
<td>green/ld</td>
<td>540</td>
<td>10/17/97</td>
<td>11Y</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>00059</td>
<td>yellow/rd</td>
<td>705</td>
<td>10/17/97</td>
<td>n/a</td>
<td>Y</td>
<td>previously captured 9/26/95 in Yale tailrace</td>
</tr>
</tbody>
</table>

On September 11, while conducting an annual spawning survey in Cougar Creek, a PacifiCorp biologist located 7 adult bull trout (2 with green tags) upstream of the weir, in the upper reach of the creek. Another adult was located holding in a pool, just downstream of the weir near the confluence of Panamaker Creek. In each case, the tag
numbers were not visible from the observer’s vantage point. The 2 green-tagged bull trout observed upstream of the weir were fish that had been tagged and released downstream of the weir on August 19 (Table 3.4-1). It was apparent that these fish had migrated upstream past the weir without detection. A subsequent snorkel survey of the weir face located a 4-inch wide gap in a piece of perforated plate. This gap was not present during a survey of the weir the week before; it was sealed the next day.

On October 5, 7 adult bull trout were observed in a pool just upstream of the trap along the right hand bank. Two of the fish had green tags (left dorsal), and one had a yellow tag (left dorsal). These fish continued to hold just upstream of the trap until they were captured on October 15. Tag numbers were recorded at the time of capture (Table 3.4-1).

On the morning of October 6 an adult bull trout measuring 463 mm was found on the upstream face of the weir. The fish was exhibiting signs of stress. The weir attendant placed the fish in a pool for recovery; however, it never stabilized and was found dead shortly after. The fish was badly scarred and had several lacerations from what looked like attempted avian predation. On the same morning, an adult bull trout was captured in the upstream trap. High water velocities in the trap prevented the fish from holding; as a result, the fish was washed against the back of the trap, exhibiting signs of stress and exhaustion. Attempts by the weir attendant to stabilize the fish were not successful. This 635-mm long fish had been captured on September 24, 1997 in the Yale tailrace and released at the mouth of Cougar Creek, as evidenced by the pink Floy tag (#00514) (Table 3.4-1).

By October 11, 8 to 12 bull trout had moved downstream from the upper reaches of Cougar Creek and were holding in a pool just upstream from the trap, apparently intimidated by the weir. This weir-avoidance behavior with outmigrating adults has been documented on the Metolius River in Oregon (pers. comm., D. Ratliff, Portland General Electric [PGE] Company, 1996). On October 15, the weir attendant and a PacifiCorp biologist attempted to capture the adult bull trout upstream of the weir by drifting seine nets through pools and backwater areas. Four fish were captured. None of the fish were tagged or showed signs of prior tags. The 4 fish were tagged by the weir attendant with green Floy tags (#012, #013, #014, and #015) on the left side of their dorsal fin. Fish #012 was 505 mm long, fish #013 was 575 mm long, fish #014 was 520 mm long, and fish #015 had a length of 548 mm. All fish had a small portion of the anal fin removed for genetic analysis (Table 3.4-1).

On October 17, the same pool upstream of the weir was again seined for adult bull trout. Four more bull trout were caught, of which 2 had been previously captured in the Yale tailrace. One of the fish was tagged with a yellow Floy tag (#00059) on the right side of its dorsal fin. Fish #00059 was 705 mm long and had grown only 25 mm after 2 years of reservoir growth, since its initial capture in 1995 (Table 3.4-1). Although size ranges are variable for each system, adfluvial bull trout populations have shown an average growth rate of 90 mm a year (Willamette National Forest 1989). The other previously captured fish was yellow tag #00080, which was captured on August 19 at the weir, apparently heading downstream. This fish had been previously released on the downstream side of...
the weir and subsequently made its way back past the weir through the gap that was discovered on September 11. The other 2 fish had not been previously tagged. These fish were tagged by the weir attendant with green Floy tags (#016 and #017). Both of these fish had a small portion of their anal fin removed for genetic analysis. The 8 fish captured over the 2-day period (October 15 and 17) constituted the majority of the fish holding above the weir. Of the 3 or 4 fish left above the weir that could not be captured, 2 of them had green tags on their left dorsal. These fish had also been previously tagged by the weir attendant on August 19, and evidently made their way back upstream using the hole in the weir, as fish #00080 did.

After collecting and transferring the fish below the weir on October 17, and assuming that no other adults would be heading upstream to spawn, the weir was removed. In 1997, a total of 16 adult bull trout were trapped and tagged at the Cougar Creek weir site. Of these 16 fish, 5 had previously been captured and tagged in the Yale tailrace and transported to the mouth of Cougar Creek. Size of adult spawners ranged from 410 to 705 mm (Table 3.4-1).

Various bull trout populations throughout western Canada and the United States have been documented to have a peak of spawning activity in September and October (Willamette National Forest 1989). Bull trout populations in the Metolius/Lake Billy Chinook system showed a peak migration into tributary streams after water temperatures dropped below 9°C (pers. comm., D. Ratliff, PGE, 1996). In PacifiCorp's study, adults moving into Cougar Creek by mid-August, had probably begun staging at the mouth throughout the month of July. Adult outmigrants were located at the weir in early October. Based on the limited data collected during the 1996 and 1997 field seasons, it seems that the peak spawning period for the Cougar Creek population is mid to late-September. Average stream temperatures during this time were 7.0 to 8.0°C. Data collected from the enumeration study and by visual observations suggest an adult spawning population of 15 to 20 bull trout in the Cougar Creek system for the 1997 sampling season. In September and October 1997, PacifiCorp biologists observed 14 adult bull trout in Cougar Creek during annual snorkel surveys.

The objective of this study was to gather baseline information on bull trout migration, timing, and abundance in Cougar Creek. The picket weir proved to be an ineffective sampling tool in a system with such rapidly fluctuating flows. Frequent rain events increased flows and velocities on the face of the weir and in the traps, making upstream and downstream passage difficult. Downstream migrants had difficulty finding the downstream trap and at least 1 fish was temporarily impinged on the weir pickets by high velocities. The majority of adult fish encountering the weir tended to hold upstream, rather than enter the trap. Increased flows and the resulting high velocities through the traps appeared to stress fish. Boards placed around the traps tended to reduce velocities but diverted attraction water to other areas of the channel, away from the trap.

If additional bull trout life history/population data are collected in the future, other methodologies such as snorkeling, electroshocking, or repetitive stream surveys should be considered as sampling techniques.
3.5 HYDROACOUSTIC EVALUATION OF FISH ENTRAINMENT AT YALE DAM

In 1997 PacifiCorp conducted a hydroacoustic study to estimate turbine entrainment rates at Yale dam. Split-beam hydroacoustic data were collected at Yale dam between January 20 and April 4 to evaluate project entrainment during the late winter and early spring periods.

The primary objective of the study was to monitor entrainment rates of salmonids and other fish at Yale Dam. A secondary study objective was to evaluate fish entrainment at 1 of the spillways during a controlled 24-hour spill test to estimate fish bypass efficiency (FBE), defined as the percentage of fish passing the spillway relative to total project passage (turbine and spillway combined).

In addition, the following estimates were made from entrainment data collected during the hydroacoustic study:

- Vertical distribution of fish in the turbine intakes and in front of spillway number 3;
- Horizontal distribution of fish within the turbine intake structure and spillway number 3;
- Target strength (i.e., fish length) distribution of fish approaching the turbine intakes and spillway number 3 gate opening; and
- Weekly passage rate throughout the study period.

3.5.1 Study Area

Yale Dam is located on the Lewis River in eastern Cowlitz County, Washington, southeast of the town of Cougar. Construction of the dam was completed in 1953. The dam has a generating capacity of 134 MW. Typical total turbine outflow during the study period was 7,500 cfs. The dam impounds Yale Lake (Figure 3.0-1), and is located upstream of Merwin dam, and downstream of Swift dam.

The dam is of earthfill construction, incorporating an offshore turbine intake structure and concrete spillways. The intake tower is divided into 2 separate penstock intakes. The dam has 4 spillways and 2 turbine units.

3.5.2 Methods

A split-beam hydroacoustic system was used to monitor fish entrainment rates based on fish movement in 3 dimensions. Using the split-beam system, direction of travel, fish acoustic size, velocity, and position relative to the dam or intake were known for each fish in each monitored location.
3.5.2.1 System Description

Two HTI Model 243 Split-Beam Hydroacoustic Systems were used during the study, 1 each to monitor the turbine intake and the spillway. Each system consisted of a 200-kHz Model 243 Digital Echo Sounder, a 24-pin computer printer, a 2-channel oscilloscope, digital audio tape data recording system, Dell Pentium computer, and 1 or 2 200 kHz transducers of 6° x 10° elliptical or 15° circular nominal beam width.

The hydroacoustic system electronic components were housed in a small building on the deck of the intake structure (turbine monitoring system), and in the emergency generator building on the spillway deck (spillway monitoring system). Elliptical-beam transducers were mounted on the upstream face of the dam 18 meters (59 feet) above the floor of the turbine penstock openings. A single up-looking circular-beam width transducer was mounted below spillway number 3 to monitor entrainment during the spillway evaluation.

3.5.2.2 Transducer Placement

The transducers were mounted with adjustable aiming-angles to the upstream face of the dam by a commercial diving crew. Both uplooking and downlooking transducer sampling orientations were used. Two 6° x 10° beam width downlooking transducers were placed in the turbine intake structure, 1 in each intake bay. Each transducer was mounted on the centerline of each bay and aimed downward to sample the area immediately in front of the penstock openings.

The transducer used to monitor the spillway was mounted on the dam face at an approximate elevation of 445 feet (approximately 23 feet below the reservoir’s surface), and aimed upward to monitor the area immediately in front of the gate opening.

At the turbine intake, the 2 transducers were sampled alternately for 5-minute intervals, 6 times each per hour. Sub-sampling was necessary because of the large amount of data collected by the instruments. The spillway hydroacoustic system sampled a single transducer continuously during spillway operation.

3.5.2.3 Turbine Entrainment Monitoring

Sampling was conducted 24 hours per day at the turbine intakes during the 11-week study period (January 20 to April 4, 1997), except during occasional power interruptions or when large data volumes required downloading the computer hard disk. The hydroacoustic system was visited 1 to 2 times per week to download data.

Two consecutive days were selected randomly from each week to represent fish entrainment rates for that week. The selected days were reviewed with respect to plant operations and hydroacoustic system operation. Periods containing interruptions in turbine operations or when the hydroacoustic system was not sampling were rejected and an alternative selection made from that sampling week. With the exception of Week 1 (January 20-26), when a power interruption limited data collection to 13 hours, all weekly entrainment estimates were based on 47 to 71 hours of passage data collection.
A sampling pulse rate of 8 pings/second and a minimum on-axis detection threshold of -55 dB were used during data collection at the turbine intakes. This detection threshold corresponded to a minimum fish size of approximately 30 mm on-axis or 61 mm across the full nominal transducer beam width, applying Love’s equation (1971), an empirical formula relating target strength to mean fish size.

Plant operations were factored into all expanded entrainment estimates. Expanded estimates (both weekly and for the entire study) were based on the number of hours the turbines were operating during the referenced time period. The units were considered running if there was significant flow (>1,000 cfs) during a given hour. During the 11-week monitoring period, the units operated more than 96 percent of the time.

3.5.2.4 Spillway Entrainment Monitoring

Hydroacoustic data were collected from a single spillway during a 24-hour period from 1000 hours on February 13 to 1000 hours on February 14. The corresponding time block from the turbine intake data set was analyzed to allow an estimate of project fish bypass efficiency at the spillway.

A sampling ping rate of 20 pings/sec and a minimum on-axis detection threshold of -55 dB were used during spillway data collection. This minimum detection threshold encompassed the smallest fish of interest at the site and allowed direct comparison with the turbine entrainment estimates.

3.5.2.5 Data Analysis

Hydroacoustic data collected were stored as single-target echo data files and printed echograms. The files were analyzed using HTI’s proprietary software, and estimates were obtained for the following parameters:

- Total entrainment rates at both the turbine intake and spillway. Weekly and hourly entrainment rates were analyzed at the turbine intakes. Weekly estimates were calculated by summing total weighted fish entrainment at both turbine intakes over a representative 2-day sampling period, and dividing this total by the number of hours sampled. The hourly fish passage rate was assumed to be representative of the respective monitored week.

- Fish vertical distribution at the turbine intakes and spillway number 3. Vertical distributions were calculated based on the average range of fish passage from the transducer(s).

- Fish horizontal distribution at the turbine intakes and spillway number 3. These data were based on total weighted fish entrainment counts at each sample location.

- Mean fish acoustic target strengths (TS) (i.e., average fish size) were calculated weekly at the turbine intakes to evaluate potential changes in mean fish size distributions over time. Mean fish TS was also calculated at the spillway to compare...
the average size of fish passing the spillway relative to the turbines during the single 24-hour spillway test. Mean fish TS values were converted into estimated fish lengths using Love (1971), an empirical formula relating fish length to mean acoustic size for salmonids.

- Fish bypass efficiency (FBE) was calculated for the 24-hour spill study period by dividing total estimated fish entrainment at the spillway by total project entrainment (turbine and spillway combined).

### 3.5.2.6 Fish Weighting Factor

Because the acoustic beam width used to sample fish was only large enough to subsample part of each intake or spillway area, each acoustically detected fish was numerically expanded to provide a total estimate of fish passing through the entire monitored location. Each detected fish was grouped into 1-meter-range bins, based on its location. The number of fish detected in each bin was multiplied by the intake or spillway gate width, then divided by the acoustic beam width to determine the appropriate number of weighted fish for that bin. All weighted fish were then summed on an hourly basis to provide an estimate of total fish passage into the turbine unit or spillway. Spatial fish passage was estimated as follows:

\[
W_n = \sum_i \left( \frac{I_n * F_n}{B_n} \right) * M_n , \text{ and} \]

\[
B_n = 2 * R_i * \tan \frac{1}{2} \alpha
\]

Where: 

- \( W_n \) the weighted fish in cell \( n \),
- \( I_n \) the intake or spillway width for cell \( n \),
- \( F_n \) the number of fish in cell \( n \),
- \( B_n \) the beam width of the acoustic in cell \( n \),
- \( M_n \) the sample time expanded to full hour for cell \( n \),
- \( R_i \) the distance from the beginning of cell \( n \) to the far end, and
- \( \alpha \) the major axis of the beam angle.

This fish passage per hour was used as the basis for estimating the efficiency of entrainment rates discussed below.

### 3.5.2.7 Fish Bypass Efficiency Estimates

Fish bypass efficiency (FBE) was calculated for the 24-hour spillway evaluation by estimating the number of fish detected moving toward the spillway gate opening, dividing
by the sum of that number and the number of fish moving toward the turbine unit opening, and multiplying by 100. This technique estimated bypass efficiency as the number of weighted fish passing through the spillway as a percentage of total project fish passage (turbines and spill combined). The average bypass efficiency estimate was calculated for the 24-hour sample block as a whole. The formula used to calculate bypass efficiency is shown below:

$$B_E = \frac{S_f}{S_f + T_f}$$  \hspace{1cm} (3)

where:
- $B_E$ = the bypass efficiency expressed as a percentage of fish entrained to the spillway,
- $S_f$ = the number of fish moving toward the spillway, and
- $T_f$ = the number of fish moving toward the turbine unit.

3.5.3 Results and Discussion

This section summarizes results of the dam entrainment evaluation, with entrainment rates provided for both the turbine and spillway. Horizontal and vertical fish distribution is presented with respect to the sample location; fish target strength (i.e., length) and spillway bypass efficiency are also presented.

3.5.3.1 Turbine and Spillway Entrainment

Total entrainment was calculated using mean hourly entrainment rates to minimize potential estimation bias due to unequal weekly sampling periods. Mean hourly fish entrainment over the 11-week study period was 28.5 fish per hour. This value was multiplied by the total number of turbine operation hours (1,782 hours) in the 11-week period, resulting in a total entrainment estimate of 50,780 fish.

During the first week of the entrainment study (January 20-26), which consisted of only a single 13-hour sampling period, fish entrainment averaged 184 fish/hour. Following the first week of the study, fish entrainment rates at the dam varied between approximately 10 and 44 fish per hour, or between 1,692 and 7,321 fish per week (Table 3.5-1).

Spillway number 3 was operated for a 24-hour period from 1000 hours on February 13 to 1000-hours on February 14 at approximately 3,220 cfs. Average flow through the turbines during the sampling event was 7,939 cfs. Data collected at the spillway were expanded to the full gate opening to provide comparable entrainment estimates between the turbines and spillway.
Table 3.5-1. Weekly and study period estimated fish entrainment and descriptive parameters at Yale Dam, January 20-April 6, 1997.

<table>
<thead>
<tr>
<th>Sample Week</th>
<th>Sample Dates</th>
<th>Data Hours Analyzed</th>
<th>Mean Fish/Hr</th>
<th>Monitored Total</th>
<th>Study Week (Expanded)</th>
<th>TS (dB)</th>
<th>Depth* (m)</th>
<th>Velocity (m/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1/20-1/21</td>
<td>13</td>
<td>184.24</td>
<td>2,395</td>
<td>30,952</td>
<td>-47.9</td>
<td>4.3</td>
<td>1.1</td>
</tr>
<tr>
<td>2</td>
<td>2/2-2/3</td>
<td>48</td>
<td>10.07</td>
<td>483</td>
<td>1,692</td>
<td>-41.0</td>
<td>9.0</td>
<td>0.9</td>
</tr>
<tr>
<td>3</td>
<td>2/5-2/6</td>
<td>47</td>
<td>43.58</td>
<td>2,048</td>
<td>7,321</td>
<td>-43.1</td>
<td>4.7</td>
<td>1.0</td>
</tr>
<tr>
<td>4</td>
<td>2/12-2/15</td>
<td>71</td>
<td>17.07</td>
<td>1,212</td>
<td>2,458</td>
<td>-42.3</td>
<td>8.3</td>
<td>0.8</td>
</tr>
<tr>
<td>5</td>
<td>2/17-2/20</td>
<td>49</td>
<td>21.83</td>
<td>1,070</td>
<td>3,558</td>
<td>-42.8</td>
<td>7.9</td>
<td>1.2</td>
</tr>
<tr>
<td>6</td>
<td>2/28-3/2</td>
<td>49</td>
<td>35.66</td>
<td>1,747</td>
<td>5,706</td>
<td>-41.9</td>
<td>7.1</td>
<td>1.3</td>
</tr>
<tr>
<td>7</td>
<td>3/6-3/7</td>
<td>48</td>
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<td>957</td>
<td>3,348</td>
<td>-42.2</td>
<td>8.4</td>
<td>1.6</td>
</tr>
<tr>
<td>8</td>
<td>3/13-3/14</td>
<td>48</td>
<td>26.45</td>
<td>1,270</td>
<td>4,444</td>
<td>-43.3</td>
<td>9.1</td>
<td>1.1</td>
</tr>
<tr>
<td>9</td>
<td>3/20-3/21</td>
<td>48</td>
<td>32.01</td>
<td>1,536</td>
<td>5,378</td>
<td>-41.6</td>
<td>10.2</td>
<td>0.9</td>
</tr>
<tr>
<td>10</td>
<td>3/26-3/27</td>
<td>48</td>
<td>22.45</td>
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<td>8.9</td>
<td>1.3</td>
</tr>
<tr>
<td>11</td>
<td>3/31-4/1</td>
<td>47</td>
<td>18.97</td>
<td>892</td>
<td>2,978</td>
<td>-42.8</td>
<td>10.5</td>
<td>1.5</td>
</tr>
<tr>
<td>SUM (11 wk)</td>
<td>1/20-4/6</td>
<td>516 hr</td>
<td>--</td>
<td>14,688 (sum)</td>
<td>71,270 (sum)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>SUM (10 wk)</td>
<td>1/27-4/6</td>
<td>503 hr</td>
<td>--</td>
<td>12,293 (sum)</td>
<td>40,318 (sum)</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>TOTAL (11 wk)</td>
<td>1/20-4/6</td>
<td>516 hr</td>
<td>28.46 fish/hr</td>
<td>50,724 (sum)</td>
<td>4,781 (avg/wk)</td>
<td>-42.8dB</td>
<td>8.0</td>
<td>1.2m/sec</td>
</tr>
<tr>
<td>TOTAL (10 wk)</td>
<td>1/27-4/6</td>
<td>503 hr</td>
<td>24.44 fish/hr</td>
<td>39,446 (sum)</td>
<td>4,106 (avg/wk)</td>
<td>-42.3dB</td>
<td>8.4</td>
<td>1.2m/sec</td>
</tr>
</tbody>
</table>

* Measured as depth below transducers.

For the 24-hour evaluation period, total fish entrainment was estimated at 676 fish through spillway number 3 and 786 fish at the turbine intakes (Figure 3.5-1). This corresponded to 28.2 fish/hour and 32.7 fish/hour at the spillway and turbine intakes, respectively. With respect to discharge, 9.2 fish and 4.1 fish per 1,000 cfs were entrained at spillway number 3 and the turbines, respectively.

3.5.3.2 Fish Vertical Distribution at the Turbine Intakes and Spillway Number 3

Fish vertical distribution behind the turbine intake trash racks are shown in Table 3.5-1 and Figure 3.5-2. Total sampling range (i.e., distance) from the transducers to the intake floor was approximately 18 meters (59 feet), or approximately 13 meters (43 feet) to the top of the penstock openings. Fish typically were observed entering the intake structure higher in the water column, then diving toward the penstock. Mean weekly fish vertical distribution in the intakes varied from 4.3 (14 feet) to 10.5 meters (34 feet) below the level of transducers, with a general trend toward deeper mean passage over time, suggesting that fish entering the turbine intakes were generally surface-oriented.

Mean fish vertical distribution relative to the transducer was estimated for the 24-hour sampling period on February 13-14. The uplooking spillway transducer was located at elevation 445 feet and the spillway gate crest was located at approximately elevation 460 feet. Reservoir elevation at the time of the study was approximately 468 feet. Total sampling range from transducer to the reservoir water surface was approximately 6.2 m
Figure 3.5-1. Estimated total fish entrainment at the turbine intake structure and spillway number 3 during the 24-hour spillway test conducted February 13-14, 1997.

Figure 3.5-2. Weekly mean fish vertical distribution by range at the Yale Dam turbine intakes with logarithmic trendline, January 20-April 6, 1997.
Fish passing the spillway during the monitoring period were on average 3.3 meters (11 feet) above the transducer, indicating that fish appeared to be surface-oriented, approaching the spillway opening.

3.5.3.3 Fish Horizontal Distribution at the Turbine Intakes and Spillway 3

Figure 3.5-3 presents estimated fish entrainment by turbine intake bay for the entire study period (January 20-April 6). For reference, the 2 turbine intakes were numbered Bay 1 and Bay 2. Bay 1 is located at the northwest corner of the turbine intake structure, closest to the spillway. Bay 2 is located at the southeast corner of the intake structure, adjacent to the shoreline.

Total turbine entrainment at both intake bays was estimated at 50,724 fish (20,399 fish in Bay 1 and 30,325 fish in Bay 2) based on mean hourly entrainment rates for the entire sampling period. This corresponded to 40.2 percent of total turbine entrainment via Bay 1 and 59.8 percent via Bay 2 over the 11-week sampling period.

Expressed on an hourly basis, average fish entrainment for both turbine intake bays was 28.5 fish per hour. On an individual basis, mean entrainment was 11.4 and 17.1 fish per hour at Bay 1 and 2, respectively.

Estimated fish entrainment by turbine intake bay for the 24-hour spillway monitoring period (February 13-14) is presented in Figure 3.5-4. Total turbine entrainment (both
intakes) was estimated at 786 fish during the spillway test. Of this total, 8 fish were entrained at Bay 1, and 778 fish at Bay 2. The entrainment bias toward Bay 2 may have been due to flow patterns at the intake, or high numbers of fish approaching the turbine intake structure from the reservoir shoreline, which is where the turbine is located.

![Figure 3.5-4. Estimated total fish entrainment by turbine intake bay at Yale Dam during the 24-hour spillway monitoring period, February 13-14, 1997.](image)

Expressed on an hourly basis, average fish entrainment for both turbine intake bays was 32.7 fish per hour. On an individual turbine basis, mean hourly fish entrainment at Bay 1 was estimated at 0.4 fish per hour, and 32.4 fish per hour at Bay 2.

3.5.3.4 Fish Target Strength Distribution at the Turbine Intakes and Spillway Number 3

Fish target strength (TS) distributions at the turbine intakes are presented in Table 3.5-1 and Figure 3.5-5. For the 11-week study period, mean fish target strength was estimated at –42.8 dB, corresponding to a mean fish length of 13.0 cm. Except for the first week of sampling, weekly mean fish TS was generally similar over the study period, varying between –43.3 and –41.0 dB (12.3-16.2 cm), with a mean TS for weeks 2 to 11 of –42.3 dB (13.8 cm). Fish observed during week 1 were smaller, with mean TS of –47.9 dB (7.0 cm).

Mean TS for all entrained fish at spillway number 3 was –39.4 dB (19.8 cm), substantially larger than the corresponding –42.5 dB (13.6 cm) mean TS observed behind the turbine intake trash racks for the same 24-hour period.
### Figure 3.5-5. Mean target strength and estimated length of entrained fish at the Yale Dam turbine intakes with logarithmic trendline, January 20-April 6, 1997.

#### 3.5.3.5 Weekly Entrainment Rates at the Turbine Intakes

Weekly estimated fish passage at the turbine intakes is presented in Table 3.5-1 and Figure 3.5-6. The highest turbine intake entrainment rate occurred during the first week of monitoring. Turbine entrainment was estimated at approximately 184 fish/h during this period. Following week number 1, entrainment was generally consistent, varying between 10 and 44 fish per hour.

Hydroacoustic monitoring proved an effective method of monitoring entrainment at Yale dam. Transducer placement behind the trash racks and immediately in front of the spillway gate opening allowed sampling in areas where fish were entrained with flow, removing behavioral or other biases.

Reservoir hydroacoustic surveys discussed in Section 3.6 provide estimates of total fish population and distribution in Yale Lake. These data will assist in evaluating the fish entrainment at the dam in relation to the population in Yale Lake.
3.6 HYDROACOUSTIC FISH POPULATION STUDY

As part of the FERC relicensing process for the Yale Project, PacifiCorp conducted a mobile hydroacoustic assessment of Yale Lake to estimate the number and evaluate the distribution of the fish population in the reservoir.

A mobile hydroacoustic survey is performed by placing a hydroacoustic system in a boat, traversing predetermined transects in a body of water, and sampling fish as the acoustic beam passes over them. Sampled fish produce characteristic traces on chart recorder (echograms), and the returning acoustic signals can be processed using computer-based signal processing software to produce estimates of fish density, abundance, behavior, and size distribution.

The primary objective of the Yale Lake hydroacoustic survey was to develop a "snapshot" estimate of the abundance and distribution of fish in the reservoir. Specific objectives were to estimate:

1. Total fish abundance and surrounding confidence intervals in Yale Lake;
2. Horizontal distribution of fish in Yale Lake;
3. Vertical distribution of fish in Yale Lake; and
4. Target strength (i.e., size) distribution of fish in Yale Lake.

This report presents methods and results from the September 4-5, 1997 Yale Reservoir mobile hydroacoustic survey.

3.6.1 Study Area

Yale Lake (Figure 3.0-1) is impounded by Yale dam, constructed in 1953. The mean reservoir elevation during the September 4-5 survey period was 489 feet, corresponding to an estimated surface area of 3,759 acres (15,211,418 m²). The reservoir extends from just upstream of River Mile 44, at the inflow point of the Lewis River, downstream to Yale Dam.

3.6.2 Methods

Split beam hydroacoustic techniques were used to estimate the abundance, distribution, and size of the Yale Lake fish population. Split-beam hydroacoustic systems can precisely locate each observed fish in 3 dimensions, providing the highest level of accuracy to estimate fish size, sampling volume, and fish behavior, relative to other techniques.

Because the 3-dimensional location of each fish is known, improved spatial resolution results in improved target strength estimates, resulting in more accurate estimates of fish abundance and/or biomass. For these reasons, a split-beam system was used for the 1997 mobile hydroacoustic survey of Yale Lake.

3.6.2.1 Hydroacoustic Equipment

An HTI 200 kHz Model 241 Split-Beam Hydroacoustic System was used to hydroacoustically evaluate the Yale Lake fish population. A chart recorder and oscilloscope were used to monitor the system operation, and provide visual indicators of the amplitude, duration, and range (i.e., depth in this case) of the returning signals. The chart recorder also provided a permanent paper record of the survey for reference. Data were recorded during field collection and analyzed later at HTI’s Seattle offices using TRAKMAN and FISHPROC processing software. The complete split-beam data set was recorded on digital audio tape (DAT).

The hydroacoustic instruments were placed in an 18-foot-long open aluminum boat. The transducer was attached to a vertical aluminum pole mounted on the port side of the bow, and aimed straight down (vertically in the water column). A 1,000-watt 110 volt generator provided power to the system. All electronic equipment was securely grounded, and electrical surge suppressors were used to minimize ambient electrical noise.

A Garmin® global positioning system (GPS) receiver was interfaced with the system electronics to log the true boat track and position of each observed fish at 1-second intervals.
intervals in the computer record. It also served as a navigation aid to accurately locate and determine the length of the survey transects.

Prior to the survey, the *Model 241 Split-Beam System* was calibrated to allow only fish above a minimum acoustic size to be detected, and exclude smaller targets such as returns from noise, debris, zooplankton, etc. from being counted. A minimum detection threshold of -55 dB was used during the Yale Lake mobile survey, which corresponded to an on-axis fish detection length of approximately 30 mm, and a full nominal transducer beam detection threshold of 61 mm (Love 1977).

### 3.6.2.2 Data Collection

Since fish are typically distributed more uniformly in the water column during nighttime, the survey was conducted during the night of September 4-5, 1997, between approximately 2130-0300 hours. The survey was scheduled shortly after a new moon (September 1) to minimize the potential effects of light on vertical fish distribution. Previous studies have found biases in hydroacoustic fish population estimates due to aggregated fish distributions in response to light (Luecke and Wurtsbaugh 1993, MacLennan and Simmonds 1992).

Twenty-seven predetermined transects were surveyed within the area between Yale Dam and the buoy line at the upper end of the reservoir, near Beaver Bay Campground (Figure 3.6-1). Each transect started from either the east or west shore of the reservoir and traversed approximately perpendicular to flow across to the opposite shore. The end of 1 transect served as the beginning of the next transect, so that sampling occurred in a zig-zag pattern up the reservoir. Transect 1 was located at the southern end of the survey grid (closest to the dam) and Transect 27 was the northernmost transect in the survey area (terminating near the buoy line downstream of the inflow of the Lewis River).

Prior to the survey, the start and end point of each transect (in longitude and latitude) was determined using a Garmin® *Model 75 GPS* and a USGS 7-1/2 minute topographic map. The GPS was installed on the survey boat and used to navigate the transect series. It was also interfaced with the hydroacoustic system to log the position of each observed fish to the computer record, such that fish densities could be accurately located within the survey area. Boat position was logged to the computer record from the GPS at 1-second intervals to precisely determine total transect lengths.

To maximize detection of individual fish targets, the survey transects were traversed at a relatively low boat speed (approximately 3.5-4.0 knots). The acoustic repetition (ping) rate was 5.0-7.0 pings/sec, and was maximized dependent on total water depth in each survey area in the reservoir. This combination resulted in very good fish detectability, with multiple echo returns from individual fish targets.
Figure 3.6-1. Location of Yale Lake Transects 1-27, sampled during the Yale Lake mobile hydroacoustic survey, September 4-5, 1997.

3.6.2.3 Data Analysis

The raw data files collected in the field were processed with the HTI TRAKMAN manual tracking program. Since the split-beam system collects data in 3 dimensions, all potential fish targets were scrutinized as they passed through the acoustic beam in each of the 3 dimensions.

Once individual fish were identified using TRAKMAN software, a set of descriptive parameters for each fish included in the output data files was retained. These included fish position and distance traveled in 3 dimensions, fish acoustic size, and other descriptive parameters.
Each detected fish was weighted by the ratio of the area used to describe fish density (i.e., 1 m) to the diameter of the acoustic beam at the range of a detected target. This spatial weighting was calculated and applied to each fish detected to remove the effect of increasing transducer sampling volume with range (transducer beam spreading). Each individual fish detection was weighted by the following equation:

\[ W_f = \frac{1}{2R \tan \left( \frac{BW}{2} \right)} \]  

(1)

where;

\[ W_f = \text{weighted fish value}, \]
\[ R = \text{range of the fish from the transducer in meters}, \]
\[ BW = \text{the nominal transducer beamwidth of the transducer in degrees as measured at calibration}. \]

Weighted fish were summed by transect, then divided by the individual transect length, as determined from the GPS data record. This resulted in an estimate of mean fish/m² for each transect. The mean number of fish m² was summed for each of the 27 transects, then divided by the total length of all transects combined, providing an estimate of mean fish/m² for the entire reservoir. Multiplying this mean fish/m² value times the surface area of the reservoir (15,211,418 m²) resulted in the total population estimate for the survey.

To determine the fish density distribution within the surveyed area, the tracked fish records were merged with the concurrently collected GPS position files using time as the common denominator. These summary files were used for all subsequent analyses.

The confidence intervals around each estimate were calculated using a standard 2-tailed t-test using each survey bin as a replicate (Sokal and Rohlf 1969). This provided multiple replicates per transect to incorporate a measure of within-transect variability in the confidence intervals. The standard deviation was calculated using the mean fish density within each survey bin as a replicate and used to estimate confidence intervals at several levels of assurance for the entire reservoir.

3.6.2.4 Fish Species Composition Estimates

Midwater trawl samples were collected on the same night as the hydroacoustic survey to verify species and size composition of the acoustic targets surveyed. Trawls were conducted primarily along the longitudinal axis of the lake. The trawl had a cross-sectional mouth opening of 10.9 m² (vertical and horizontal openings of 3.3 m), with variable mesh net decreasing in mesh size from mouth to the 3 mm mesh cod end. The trawl was towed at a speed of 1.5 m/s through a series of 10-foot stepped intervals within the range of depths containing targets. Trawling time within an individual step varied from 3-1/2 minutes to more than 12 minutes. When acoustic targets occupied a narrow range of depths, greater time was spent in a specific step.
3.6.3 Results and Discussion

This section summarizes results of the fish population evaluation in Yale Lake. Total fish abundance, horizontal and vertical fish distribution with respect to location, target strength (i.e., length) by location, and midwater travel results are presented below.

3.6.3.1 Fish Abundance

The expanded total fish population estimate in Yale Lake during the September 4-5, 1997 survey period was 96,236 +/-8,729 at an 80 percent confidence interval (i.e., between 87,507 to 104,966 fish at this level of assurance). Applying a 90 percent confidence interval resulted in an estimated fish population range of between 85,016 and 107,457. The population estimate, with corresponding confidence intervals for levels of certainty of 80, 90, and 95 percent, is presented in Table 3.6-1.

<table>
<thead>
<tr>
<th>Confidence Level</th>
<th>Population Estimate</th>
<th>Confidence Interval</th>
<th>Population Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>95%</td>
<td>13,393 (13.9%)</td>
<td>82,843-109,629</td>
<td></td>
</tr>
<tr>
<td>90%</td>
<td>96,236</td>
<td>11,221 (11.7%)</td>
<td>85,016-107,457</td>
</tr>
<tr>
<td>80%</td>
<td>8,729 (9.1%)</td>
<td>87,507-104,966</td>
<td></td>
</tr>
</tbody>
</table>

3.6.3.2 Horizontal Distribution of Fish

In general, fish were consistently observed in Yale Lake along all transects downstream of approximately the town of Cougar. This may have been due to habitat preference. Water depths upstream of Cougar were generally less than 20 to 25 m (65 to 82 feet). In the reservoir downstream from Cougar, increased fish densities were generally biased away from the shoreline, again in deeper water areas.

3.6.3.3 Horizontal Distribution by Grouped Area

Fish horizontal distribution in the reservoir was also mapped by individual and grouped regions (north-south geographic areas within the reservoir) to evaluate fish distribution in the survey area.

Mean fish densities were calculated for 5 separate geographic regions within the reservoir by combining all observed fish within the transects surveyed in each respective area (Figure 3.6-2 and Table 3.6-2). Geographic regions were selected based on maximum depth strata. Region 1 near the dam had total depths between approximately 20 to 60 m (65 to 197 feet); moving upstream, Region 2 had maximum depths in excess of 60 m; Region 3 exhibited depths between 40 and 60 m (131 to 197 feet), Region 4 had depths between 20 and 40 m (65 to 131 feet), and Region 5 between 10 and 20 m (33 to 65 feet).
Figure 3.6-2. Observed horizontal fish distribution by north-south geographic region within Yale Lake, September 4-5, 1997.

Region 1 exhibited low to moderate fish densities (0.0038 fish/m²) relative to the remaining upstream areas. Moving upstream, the highest fish densities were observed in Region 2, below Siouxon Creek (0.0084 fish/m²). Fish densities decreased slightly to moderate relative levels in Region 3, from the area below Siouxon Creek upstream to approximately Speelyai Creek (0.0055 fish/m²). In Region 4, the large center section of the reservoir between Speelyai Creek and Cougar Park, fish densities increased to 0.0076 fish/m², the second highest observed mean density. Relative fish densities were lowest in Region 5, the upper reservoir area upstream of Cougar Park (0.0017 fish/m²).
Table 3.6-2. Observed horizontal distribution of fish densities between combined north-south geographic regions in Yale Lake, September 4-5, 1997.

<table>
<thead>
<tr>
<th>Region</th>
<th>Transects</th>
<th>Raw Count</th>
<th>Total Weighting Factor</th>
<th>Total Transect Distance (meters)</th>
<th>Fish/m²</th>
<th>Percent Distribution</th>
<th>Weighted Fish</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-4</td>
<td>73</td>
<td>11.97</td>
<td>3,152</td>
<td>0.0038</td>
<td>14.1%</td>
<td>13,576</td>
</tr>
<tr>
<td>2</td>
<td>5-11</td>
<td>359</td>
<td>59.20</td>
<td>7,073</td>
<td>0.0084</td>
<td>31.1%</td>
<td>29,927</td>
</tr>
<tr>
<td>3</td>
<td>12-16</td>
<td>238</td>
<td>37.98</td>
<td>6,889</td>
<td>0.0055</td>
<td>20.5%</td>
<td>19,712</td>
</tr>
<tr>
<td>4</td>
<td>17-24</td>
<td>543</td>
<td>92.78</td>
<td>12,273</td>
<td>0.0076</td>
<td>28.1%</td>
<td>27,029</td>
</tr>
<tr>
<td>5</td>
<td>25-27</td>
<td>21</td>
<td>5.76</td>
<td>3,440</td>
<td>0.0017</td>
<td>6.2%</td>
<td>5,989</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>1,234</strong></td>
<td></td>
<td><strong>32,827</strong></td>
<td></td>
<td><strong>100.0%</strong></td>
<td></td>
</tr>
</tbody>
</table>

3.6.3.4 Vertical Distribution of Fish

Fish distributions were highly stratified between a depth of 19 to 27 m (62 to 89 feet) (Figure 3.6-3 and Table 3.6-3). Approximately 83 percent of all fish were observed within this depth range. Fish may have been concentrated in this area due to a thermocline or other environmental factors. Based on the individual 2-m depth strata bins, the highest fish densities were observed between a depth of 23 to 25 m (75 to 82 feet). The percentage of all observed fish occurring in this depth stratum was 34.1 percent. The mean fish depth for the entire survey was 24 m (79 feet). Less than 5 percent of all observed fish were above a depth of 15 m (49 feet), or below a depth of 27 m (88 feet). The deepest fish observed during the hydroacoustic survey was located at a depth of approximately 65 m (213 feet).

Water depths along the survey area varied between approximately 3 to 85 m (10 to 279 feet) and were generally deepest in the downstream third of the reservoir, gradually decreasing to a maximum depth of less than 20 m (65 feet) in the uppermost third of the reservoir.

3.6.3.5 Target Strength Distributions of Fish

Target strength data were used to assess mean acoustic size of the fish population in the reservoir as a whole, as well as differences in fish size distribution by depth in Yale Lake. The fish target strength distributions for the reservoir as a whole are presented in Figures 3.6-4 and 3.6-5, and Table 3.6-4.

Mean fish target strength for all fish observed during the survey was –46.7 dB, corresponding to an estimated mean fish length of 8.2 cm applying Love (1977), an empirical formula relating target strength to mean salmonid length. Approximately 52 percent of all observed fish were within the –48 to –53 dB target strength range (approximately 4-7 cm length). Approximately 45 percent of all observed fish had target strengths between –47 and –38 dB (approximately 8-23 cm length). A few larger fish with target strengths between –30 and –26 dB were observed, but these made up only about 0.3 percent of the total population estimate.
Figure 3.6-3. Percent fish vertical distribution by 2-m range bin for Yale Lake, September 4-5, 1997.

<table>
<thead>
<tr>
<th>Range Bin (m)</th>
<th>Percent Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>0.0</td>
</tr>
<tr>
<td>3-5</td>
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<tr>
<td>5-7</td>
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</tr>
<tr>
<td>7-9</td>
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</tr>
<tr>
<td>9-11</td>
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</tr>
<tr>
<td>11-13</td>
<td>0.5</td>
</tr>
<tr>
<td>13-15</td>
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</tr>
<tr>
<td>15-17</td>
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</tr>
<tr>
<td>19-21</td>
<td>10.7</td>
</tr>
<tr>
<td>21-23</td>
<td>25.6</td>
</tr>
<tr>
<td>23-25</td>
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</tr>
<tr>
<td>25-27</td>
<td>12.5</td>
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<tr>
<td>27-29</td>
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<tr>
<td>29-31</td>
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</tr>
<tr>
<td>31-33</td>
<td>0.6</td>
</tr>
<tr>
<td>33-35</td>
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<table>
<thead>
<tr>
<th>Range Bin (m)</th>
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<td>35-37</td>
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<tr>
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<td>41-43</td>
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Figure 3.6-4. Percent fish target strength distribution by size bin for Yale Lake, September 4-5, 1997.

Figure 3.6-5. Weighted fish population by estimated length class for Yale Lake, September 4-5, 1997.
Table 3.6-4. Percent fish distribution by target strength bin and weighted fish population by estimated length class for Yale Lake, September 4-5, 1997.

<table>
<thead>
<tr>
<th>Target Strength Bin (dB)</th>
<th>Estimated Length (cm)</th>
<th>Raw Count</th>
<th>Percent Distribution</th>
<th>Weighted Fish</th>
</tr>
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<tbody>
<tr>
<td>-55</td>
<td>3.0</td>
<td>5</td>
<td>0.4</td>
<td>390</td>
</tr>
<tr>
<td>-54</td>
<td>3.4</td>
<td>20</td>
<td>1.6</td>
<td>1,560</td>
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<td>3.8</td>
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<td>5.7</td>
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<td>10,060</td>
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3.6.3.6 Target Strength Distributions by Depth

A general increase in mean fish target strength was observed with depth. Larger fish tended to be concentrated in deeper water during the survey period. However, fish below a depth of 29 m (90 feet) made up only about 2 percent of the total population estimate. In the depth strata between 17 and 29 m (56 to 90 feet), where 90 percent of all observed fish were located, mean fish target strength was generally consistent, varying between –46 and –47.4 dB (7.5-8.8 cm).

3.6.3.7 Midwater Trawl Species Composition and Size Structure

A total of 6 midwater trawls were made in Yale Lake, of which the trawl locations corresponded to acoustic target locations and depths as communicated by the hydroacoustic survey boat. The trawl was fished (depending on reservoir location) in depths ranging from 30 feet (corresponding to the upper, shallower portion of the reservoir) to 80 feet (corresponding to the reservoir forebay and the mid-body of the reservoir). Altogether, the trawl was fished for nearly 80 minutes (includes time moving trawl from 1 step to the next).

A total of 2 juvenile kokanee salmon, 40 sculpin, and 17 threespine stickleback (Gasterosteus aculeatus) were caught in the reservoir. The lengths of the kokanee were 65 and 54 mm. All other fish were less than 50 mm long. Approximately 25 percent of the acoustic targets (i.e., estimated fish lengths) were also less than 50 mm.

The low numbers of fish captured in the mid-water trawl collections can be attributed to several factors:

- Since only 2 of the 59 captured fish were greater than 50 mm (5 cm), it is assumed that larger fish were able to escape the net, thus avoiding capture.

- Overall, fish densities in the reservoir were low. Fish density by geographic area ranged from a low of 0.0017 fish/m$^2$ to a high of 0.0084 fish/m$^2$, with an average reservoir density of 0.0063 fish/m$^2$. Given these low densities, it is likely that very few fish were encountered by the trawl boat. Therefore, the low numbers captured by the trawl would be expected.

- Some of the acoustic targets counted were among or near submerged trees located in the reservoir. The trawl boat was unable to tow the net through these areas because of the potential risk of hanging the net on a submerged tree.

The hydroacoustic study provided a "snapshot" or instantaneous estimate of the Yale Lake fish population. It was intended that the trawl sampling would allow identification of species composition of the fish hydroacoustically enumerated in the lake. This proved to be relatively unsuccessful as the trawl was unable to capture any fish greater than 65 mm in length.
Netting using vertical gill nets may have provided additional information regarding species composition, except that gill nets require fishing for long time period to capture fish. In Yale Lake this was undesirable because of the risk of catching bull trout in the nets, which would not survive for more than a few hours.

The hydroacoustic fish population study presented in this section of the FTR was conducted according to the study plan outlined in PacifiCorp’s FSCD and ITR, which were modified to include agency comments (PacifiCorp 1996a). More recent comments received from WDFW on PacifiCorp’s draft Aquatics FTR (PacifiCorp 1998) suggest that PacifiCorp should conduct more than 1 hydroacoustic fish population survey to evaluate the impacts of entrainment at Yale Dam. PacifiCorp agrees that the issue of entrainment at Yale Dam is a very important component of Yale Project relicensing; however, no new hydroacoustic fish populations studies are currently planned for Yale Lake. PacifiCorp’s approach to addressing entrainment at all 3 Lewis River dams through ESA consultation is discussed in detail in PacifiCorp’s Final License Application (PacifiCorp 1999).

3.7 BULL TROUT GENETICS

Between 1996 and 1998, PacifiCorp conducted a bull trout genetics study to determine if genetic differences exist in bull trout populations collected from each of the 3 project reservoirs (Swift, Yale, and Merwin). Significant differences between groups would suggest that the groups are genetically isolated, or have unique adaptations specific to their environmental surroundings. Conversely, if no significant differences exist, then it is probable that genetic drift occurs, or has occurred within the 3-reservoir system. This information is valuable because it provides insight into the inherent risks or effects of environmental change associated with each reservoir group.

The Methods, Results, and Discussion presented in this section of PacifiCorp’s FTR were adapted directly from Spruell et al. (1998) “Genetic Analysis of Lewis River Bull Trout.” A copy of this final report was provided to the agencies and interested parties in December 1998.

3.7.1 Study Area

Three separate study areas were chosen to represent the 3 reservoir groups. Bull trout genetic samples were collected from fish captured in the upstream end of Lake Merwin (i.e. the Yale tailrace), Cougar Creek (a tributary to Yale Lake), and in the upper end of Swift Reservoir (including the mainstem North Fork Lewis River near the confluence of Rush Creek).

3.7.2 Methods

A total of 64 samples were collected from Swift, Yale, and Merwin reservoirs in the summer and early fall of 1996 and 1997. The goal was to collect 30 samples from each reservoir. However, capture efficiency was not as successful as anticipated in Lake
Merwin and Yale Lake. In Swift Reservoir, all 30 samples were collected in 1996. In Merwin and Yale, 24 and 10 samples were collected, respectively.

Bull trout from Swift and Merwin were captured with gill nets. Passive gill net sets were used in Merwin. In Swift, both passive and active (drifting) sets were employed. A weir placed in Cougar Creek was used to capture bull trout from Yale Lake. Some seining was also conducted above the weir to capture fish migrating downstream after spawning. Passive gill net sets were allowed to fish for no more than 20 minutes (usually less).

For age estimation, the length of each fish was recorded before a tissue sample was removed from the anal or caudal fin (approximately 0.5 x 0.5 cm). The samples were preserved and labeled in vials containing 95 percent ethanol until DNA was isolated for genetic analysis. DNA was extracted using the Puregene kit from Gentra following the manufacturer’s directions.

3.7.2.1 Microsatellites

Six microsatellite loci were amplified in an MJ Research PTC-100 thermocycler using the profiles and conditions of the individuals initially describing each locus (Appendix 3.7-1 Table 1). Amplified products were size fractionated on 7 percent denaturing polyacrylamide gels and visualized using a Hitachi FMBIO-100 fluorescent imager. Product sizes were determined using MapMarkerLOW size standards (BioVentures Inc.) and Hitachi FMBIO software (version 6.0). Each gel also included previously amplified individuals to ensure consistent scoring across all gels.

3.7.2.2 Data Analysis

GENEPOP (Raymond and Rousset 1995) was used to calculate allele frequencies, probability of deviations from Hardy-Weinberg expectations, exact probability of population differentiation, and F-statistics. GENEPOP also was used to calculate the average expected heterozygosity \( (H_e) \) using only the 4 loci for which extensive data are available (Spruell and Allendorf 1997) to allow comparison to other bull trout populations. Cavalli-Sforza and Edwards’ (1967) chord distance (CSE) was calculated using PHYLIP (version 3.5c; Felsenstein 1992). These distances were then used to generate a cluster diagram using UPGMA and the NEIGHBOR option of PHYLIP. The resulting diagram was visualized using the radial option of TREEVIEW PCC (Page 1996).

3.7.3 Results

3.7.3.1 Within Population Variation

Two of the 6 loci analyzed were monomorphic. Only 2 alleles were observed at each of the remaining 4 loci. Allele sizes and frequencies are given in Table 2 of Appendix 3.7-1. No statistically significant deviations from Hardy-Weinberg genotypic proportions (\( P<0.05 \)) were observed. Bull trout sampled from each of the 3 reservoirs on the Lewis River had similar amounts of genetic variation (Appendix 3.7-1, Table 2).
to other bull trout populations, Lewis River bull trout had levels of heterozygosity slightly above the mean of 60 previously analyzed populations (Spruell and Allendorf 1997).

3.7.3.2 Between Population Comparisons

Pairwise comparisons of genotypic frequencies across all loci (Fisher 1954) indicate statistically significant differentiation between bull trout in Swift Reservoir and those in both Yale Lake (P<0.05) and Lake Merwin (P<0.005). These differences are primarily the result of differences at 2 of the 6 loci analyzed (ONEµ7 and OCL12 (Appendix 3.7-1, Table 2). This differentiation is reflected in an index of genetic diversity (FST) of 0.103. In other words, approximately 10 percent of the genetic variation found in the Lewis River is due to differences between sample sites. No statistically significant differentiation was observed between bull trout in Yale and Merwin reservoirs.

Previously, 4 loci were used to infer the genetic relationships among 60 bull trout populations, including the sample from Swift Reservoir (Spruell and Allendorf 1997). The data from bull trout sampled from Lake Merwin and Yale Lake were added, and allele frequencies at these 4 loci (ONEµ7, µSAT73, SFO18, and FGT3) were used to estimate the relationship of bull trout in the Lewis River to other populations from throughout the range of the species. The 3 populations from the Lewis River are more similar to each other than to any other populations (Appendix 3.7-1, Figure 1). The 3 Lewis River populations fall into a larger group of genetically similar populations that are called "coastal" (Appendix 3.7-1, Figure 1) but are fixed for an allele (FGT3*165) that is not found in other coastal populations.

3.7.4 Discussion

Barriers to migration can result in small isolated populations that are subject to random genetic drift and loss of genetic variation. Moving fish around these barriers could restore the historic connectivity and buffer the system against this loss. However, if genetic exchange between populations was historically limited, passage of individuals around such barriers might result in the disruption of population-specific adaptations to local environments.

The differentiation between bull trout in Swift Reservoir and those in Yale and Merwin reservoirs must be addressed in this context. There are two possible explanations for this differentiation. First, recent genetic drift may have resulted in different allele frequencies in these populations after they were separated by the construction of Swift Dam. Alternatively, the observed differences may reflect historic isolation between populations that had limited genetic exchange.

It is impossible to differentiate these two hypotheses based strictly on allele frequencies. However, if the observed differences were strictly the results of genetic drift, the differentiation would be expected to be greatest in the smallest populations that have been isolated for the longest time. Swift Reservoir, on the other hand, probably contains at least as many individuals as the other sample sites, has levels of heterozygosity similar to the other populations, and is the most recently isolated. In addition, if drift were the
primary cause of population differences, differentiation would be expected between random pairs of populations at different loci rather than between the same pairs of populations at 2 loci. The differentiation between Swift Reservoir bull trout and the other two sample sites at 2 loci is inconsistent with this expectation. The data suggest that historic differentiation may be responsible for genetic variation between Lewis River populations.

Based on these data, the most conservative approach to management of bull trout in the Lewis River would be to consider the Swift Reservoir populations to be distinct from those of Merwin and Yale reservoirs. However, if demographic data indicate that these populations are at risk of extinction, transfer of individuals between reservoirs within the Lewis River basin may be an appropriate action to prevent the loss of spawning population.
4.0 LITERATURE CITED


Felsenstein, J. 1992. PHYLIP (Phlogeny Inference Package) Version 3.5C. Department of Genetics, SK-50, University of Washington, Seattle, 98195, USA.


