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PEND OREILLE RIVER PRIMARY PRODUCTIVITY AND WATER QUALITY OF SELECTED TRIBUTARIES

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ABSTRACT

Ecology studied primary productivity in the Box Canyon reach of Washington's Pend Oreille River during the summer of 1990. Primary productivity was in the middle to upper range reported in literature for larger rivers. Highest productivity was measured at River Mile (RM) 66.5 and attributed to extensive macrophyte beds. The productivity/respiration ratio indicates an autotrophic classification. Skookum, Bracket, and South Fork Lost Creek fecal coliform densities exceeded Class A water quality criteria. Recommendations are included to address nonpoint pollution problems from agricultural practices on specific tributaries.

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INTRODUCTION

The Clark Fork/Pend Oreille River system flows from Montana as the Clark Fork River into Lake Pend Oreille in Idaho. The Pend Oreille River, originating as the outflow from Lake Pend Oreille, enters Washington flowing north through the northeast corner of the state (Figure 1) into Canada, where it drains to the Columbia River just above the international border. Concerns over cultural eutrophication of Lake Pend Oreille from nutrient pollution in the lower reaches of the Clark Fork River and past indiscriminate disposal of copper mining and smelting wastes in the headwaters (Ingman, 1990) resulted in amendments to the Clean Water Act. In 1987 Congress authorized funding, through Section 525 of the Clean Water Act, to address water quality problems of the Clark Fork/Pend Oreille River system. Because this 26,000 square mile drainage flows from Montana into Idaho and Washington, as well as Canada, federal funds allowed for the creation of a multi-state cooperative consisting of universities, counties, state, and federal agencies. Participants in the cooperative studied problems specific to their respective portion of the drainage. In Washington State, the Department of Ecology (Ecology) has concentrated efforts on Eurasian water milfoil (*Myriophyllum spicatum*), an introduced nuisance aquatic weed, in the Box Canyon reach of the Pend Oreille River.

This is Ecology's third study year of a four-year project. In 1988, Ecology assessed the river's trophic status, determined a nutrient and water budget, characterized loading sources and evaluated internal loading by macrophytes and sediments. In 1989, Ecology studied fish communities and water quality within weedbeds. The 1990 study results presented in this report focus on primary productivity in the river mainstem (Figure 2), and nutrient sources and water quality of selected tributaries (Figures 1,3,4,5) identified as problematic in the 1988 water quality assessment. Because no previous published reports are available on primary productivity of the Pend Oreille River, this report provides a baseline for future productivity work.

OBJECTIVES

- Assess primary productivity in the river mainstem by measuring diurnal dissolved oxygen at selected sites within the Box Canyon Reach.
- Evaluate water quality and pollution sources of selected tributaries identified in the 1988 water quality assessment (Pelletier and Coots, 1990).

METHODS

Primary Productivity

The biotic community continually lowers dissolved oxygen (D.O.) in the water through respiration. Photosynthesis by green plants contributes oxygen during periods of daylight. Such

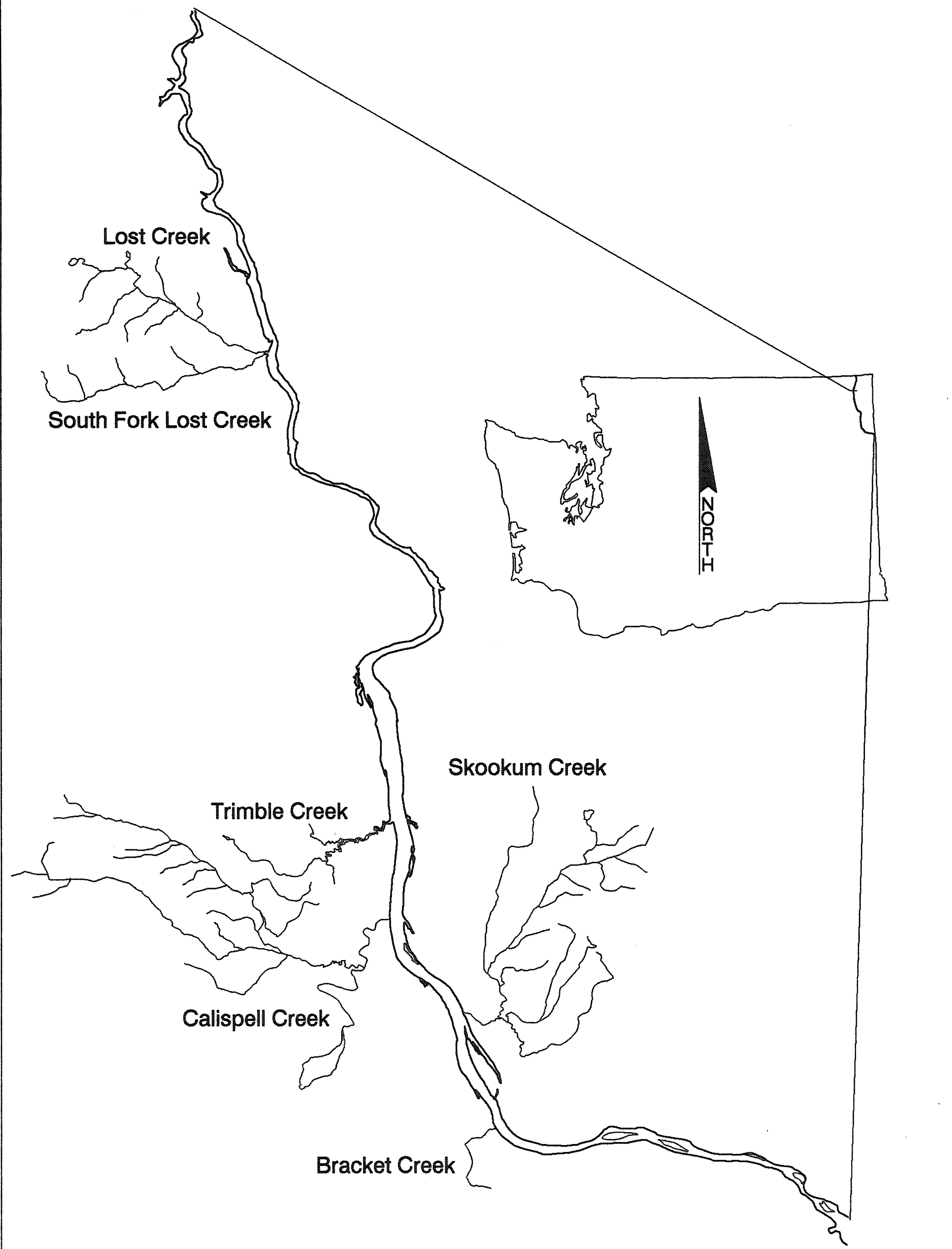

Figure 1. Pend Oreille River and tributary locations

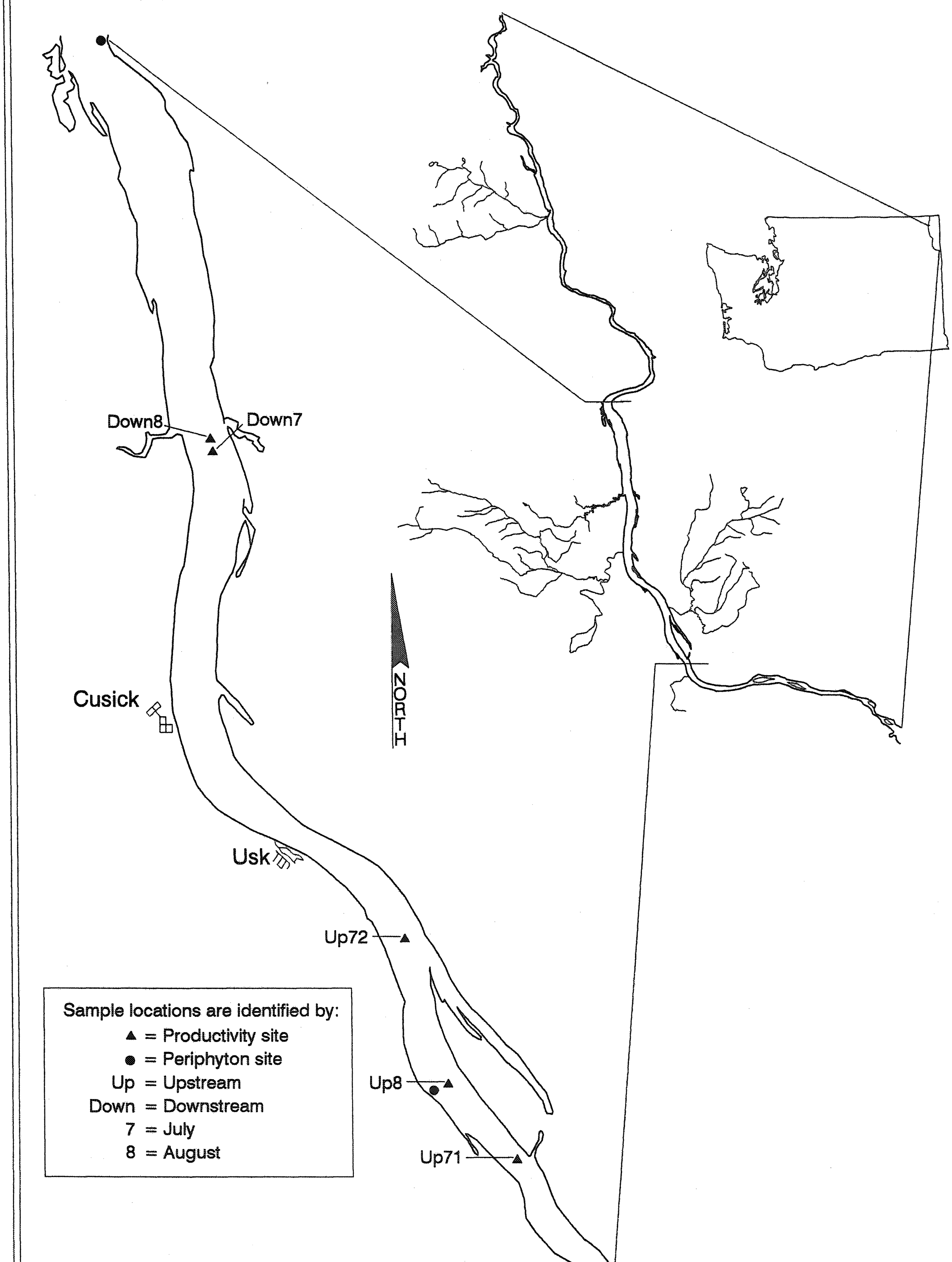

Figure 2. Primary productivity survey locations on the Pend Oreille River

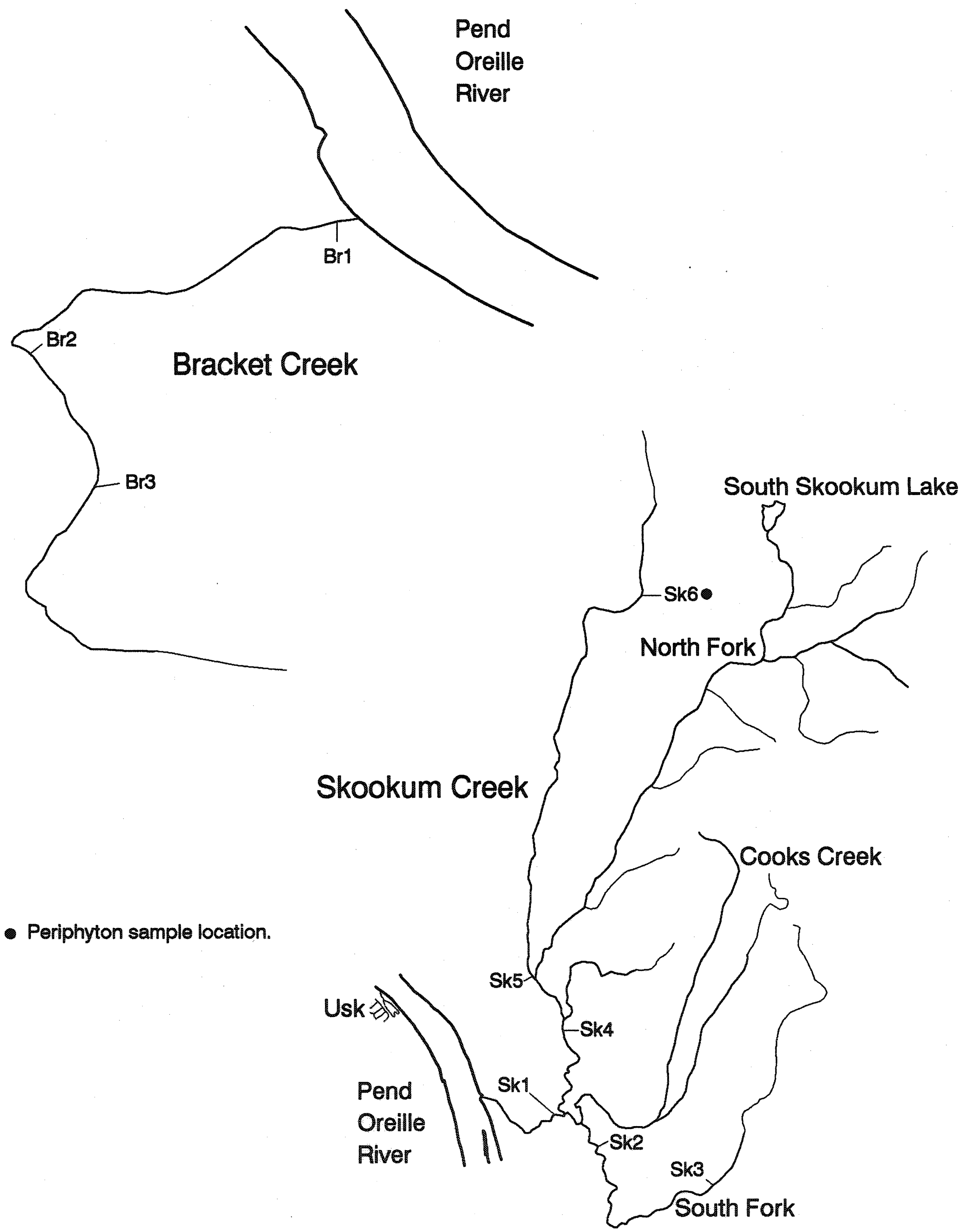

Figure 3. Bracket and Skookum Creek sampling locations for the July-August surveys of 1990.

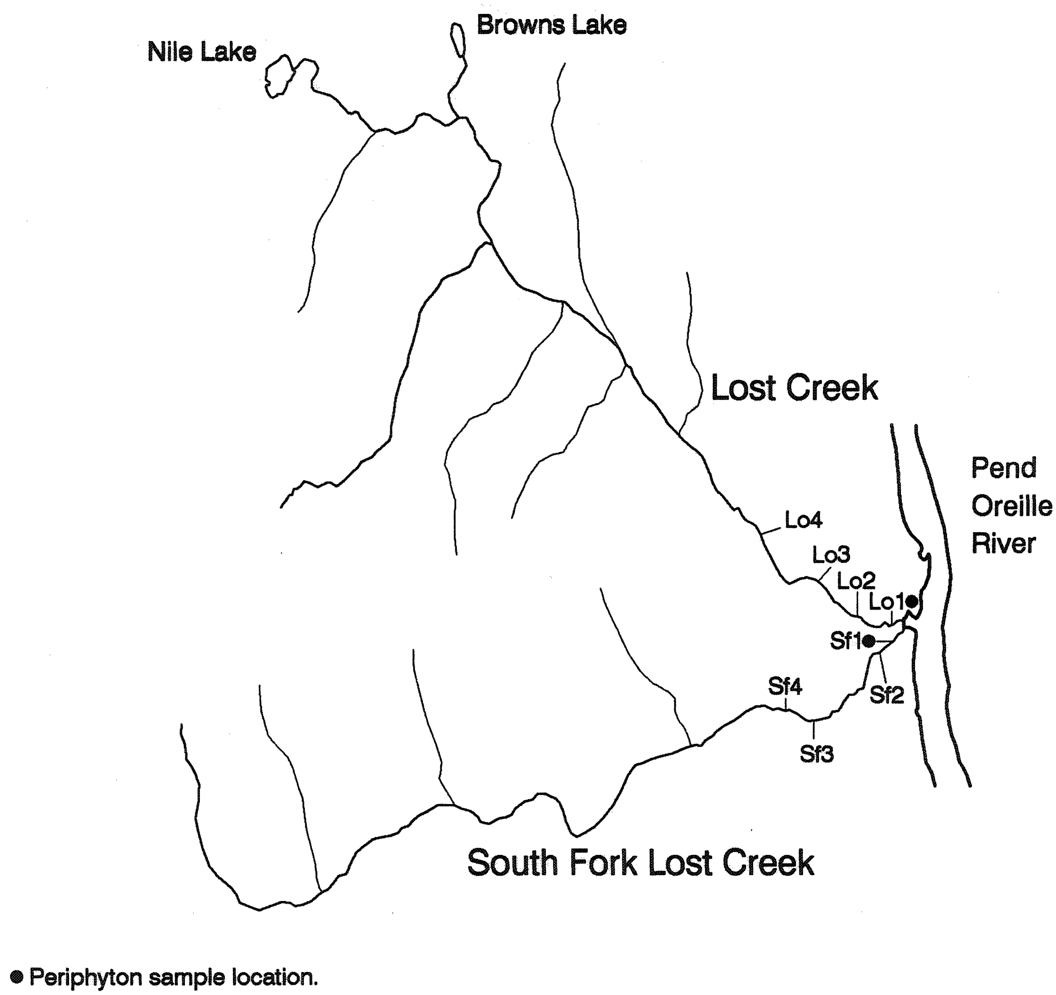

Figure 4. Lost and South Fork Lost Creek sample locations for the July-August surveys of 1990.

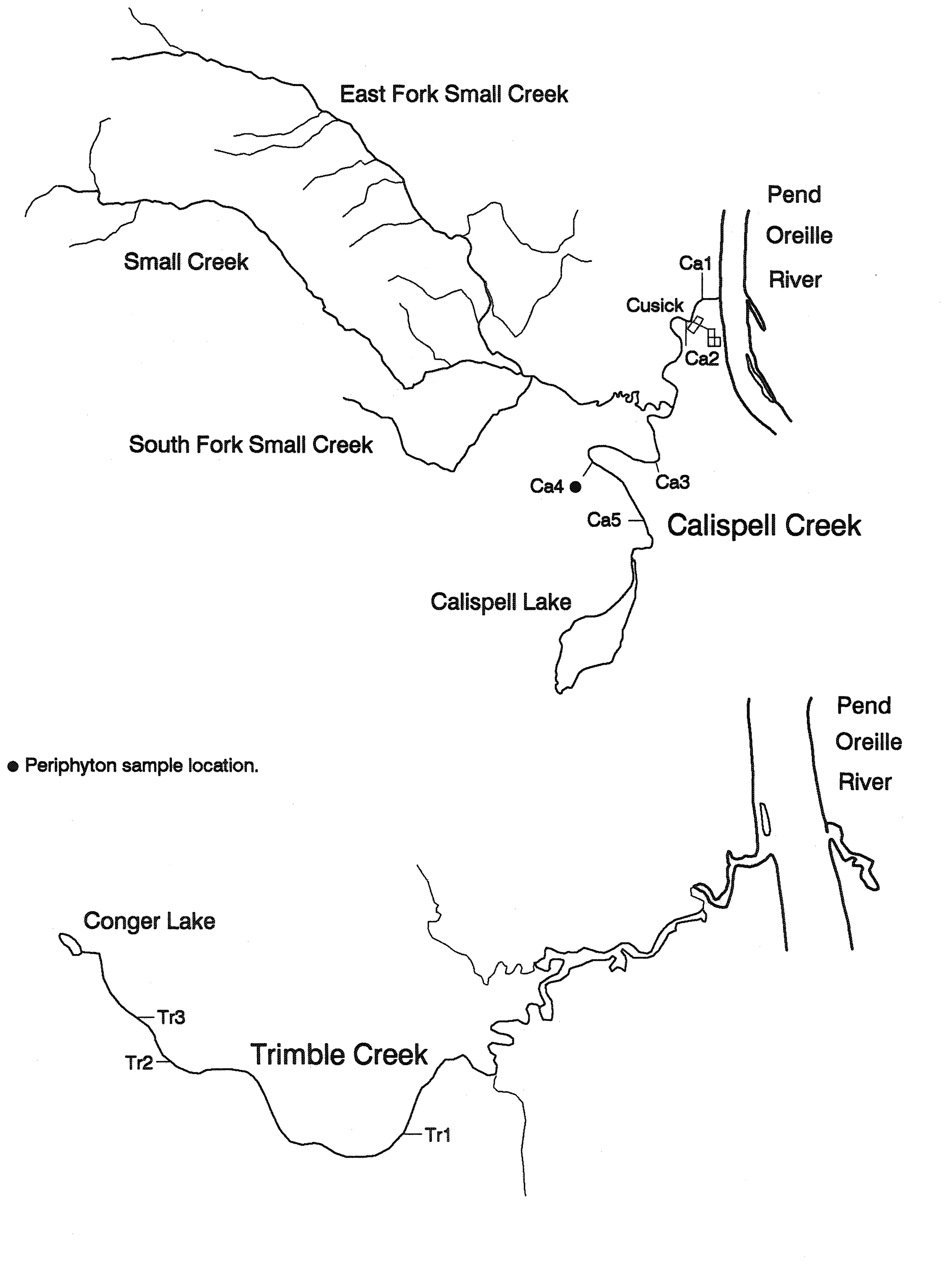

Figure 5. Calispell and Trimble Creek sample locations for the July-August surveys of 1990.

processes can produce wide diurnal swings in D.O., changing with the hour of the day, particularly in productive systems. Typically D.O. curves are parabolic with minimum concentrations occurring just prior to sunrise, increasing steadily to mid-afternoon. As the sun lowers in the sky, oxygen levels respond accordingly, lowering throughout the evening to morning, to repeat the cycle. If biotic or chemical activity is not affecting D.O. concentrations in the river, one would expect to see very little diurnal change, due only to temperature effects on saturation. Numerous investigators have used this diurnal rise and fall of D.O. as a means to estimate productivity of the biological communities in flowing waters (Odum 1956; McIntire *et al.* 1964; Thomas and O'Connell 1966; Hall and Moll 1975). This method is based on the premise that interactions between photosynthetic production, respiration, diffusion, and inflowing surface and ground water result in daily oxygen changes in a segment of flowing water. Observed daily rates of oxygen change corrected for diffusion and drainage accrual can be used to estimate rates of productivity and respiration. To simplify this process, sites were selected that were assumed to have negligible surface and ground water flux.

Two approaches are commonly used for the diurnal curve method in flowing water. The single-station method measures the rate of D.O. change at a single point and assumes stream homogeneity above the measurement point. The two-station analysis measures change in D.O. for a parcel of water as it moves from one region of the stream to another. While both approaches are acceptable, the two-station technique is considered more reliable. Both techniques were attempted in this study, although the two-station method was dropped due to exceedance of recommended travel time between stations. Hall and Moll (1975) indicate that the two-station analysis is best suited for travel time of two hours or less. Travel time between sites Up71 and Up72 was estimated at over five hours.

Methods outlined by Hall and Moll (1975) and Slack *et al.* (1973) were used for productivity determination. Instream D.O. and temperature were measured at three sites on the Pend Oreille River during July 23-26 and two sites during August 14-17, 1990 (Figure 2). Onsite measurements were made with Martek Mark XVI submersible water quality dataloggers. Each unit was positioned in the main channel of the river approximately one meter below the water surface using an anchor and float. Dataloggers were calibrated using azide-modified Winkler titration for D.O. and mercury thermometer for temperature. Dataloggers were programmed to measure D.O. and temperature each hour for 24 hours. *In situ* grabs were taken twice daily near each datalogger with a Kemmerer bottle and post-calibrations were recorded at the end of each survey to verify data quality. A considerable amount of D.O. drift was observed on two occasions. D.O. curves were corrected for drift using field and post-calibration Winkler measurements.

Productivity and respiration were estimated graphically using the rate of oxygen change corrected for the diffusion of oxygen between water and atmosphere. The temperature and D.O. data were tabulated and the hourly rate of D.O. change, percent saturation, and concentration at saturation values determined. D.O. saturation deficits were calculated by subtracting 100 from each mean hourly change in D.O. saturation. The diffusion of oxygen into or out of the water was calculated by multiplying the oxygen saturation deficit for each hour, times a gas transfer coefficient determined for the Pend Oreille River, and then dividing by 100. The gas transfer coefficient was determined by multiplying the reaeration rate times the D.O. concentration at saturation and then dividing by 24 hours. The reaeration rate was calculated for each site using the equation derived by O'Connor and Dobbins (EPA 1985). This equation uses hydraulic data and is best suited for moderately deep rivers like the Pend Oreille. Reaeration rates were corrected to ambient temperatures before being used to calculate the gas transfer coefficients.

The rates of D.O. change were corrected for diffusion to allow determination of productivity and respiration. For example, when D.O. saturation was less than 100 percent, atmospheric oxygen would diffuse into the water, and instream D.O. would increase. To accurately measure productivity levels, this increase would have to be subtracted from the instream D.O. change. Conversely, when instream DO saturation exceeded 100 percent, oxygen would diffuse from water to atmosphere. Thus, the D.O. lost would be added to the instream rate of D.O. change.

The corrected hourly rate of D.O. change curves were then plotted as step graphs. The graphs in Appendix B were used to calculate productivity and respiration. On each graph the night time respiration line is the part of the graph that occurs during darkness, and usually falls beneath the zero rate of change line, while the daytime rate of change line occurs between the sunrise and sunset points. An estimate of daytime respiration is obtained by connecting a line between the sunrise and sunset rate of change points. This is called the daytime respiration line. Gross productivity (mg/L/day) is the area of the graph above the daytime respiration line and below the daytime rate of change line. Community respiration (mg/L/day) is the area above the night time respiration line and the daytime respiration line, but below the zero rate of change line. Net productivity is defined as gross productivity minus community respiration. Areas for each graph were determined using computerized planimetry.

A typical D.O. rate of change line influenced by productivity and respiration would start below the zero rate of change line prior to sunrise, rise above the zero line during the day, decline and drop below the zero line at sunset, and remain below throughout the night until sunrise (Appendix B Example). Curves on the Pend Oreille River did not show a typical trend. In fact, highest D.O. was recorded near midnight and lowest around noon (Figures 6 and 7; Appendix A). In flowing waters, daily patterns can be influenced by upstream activity. In the Pend Oreille River, upstream areas with greater productivity likely influenced oxygen curves at the sampling sites so that the corresponding travel time created a lag in the curves. In order to use the diurnal curve technique, sunrise and sunset points were adjusted to accommodate the lag at each location.

Water Quality Sampling

Pend Oreille River tributary surveys were conducted on July 24-25 and August 13-15, 1990. Tributary selection was based on findings from an Ecology water quality investigation in 1988 (Pelletier and Coots, 1990). Fecal coliform, fecal streptococcus, and conventional water quality grab samples were collected at several points along Bracket, Skookum, Lost, and South Fork

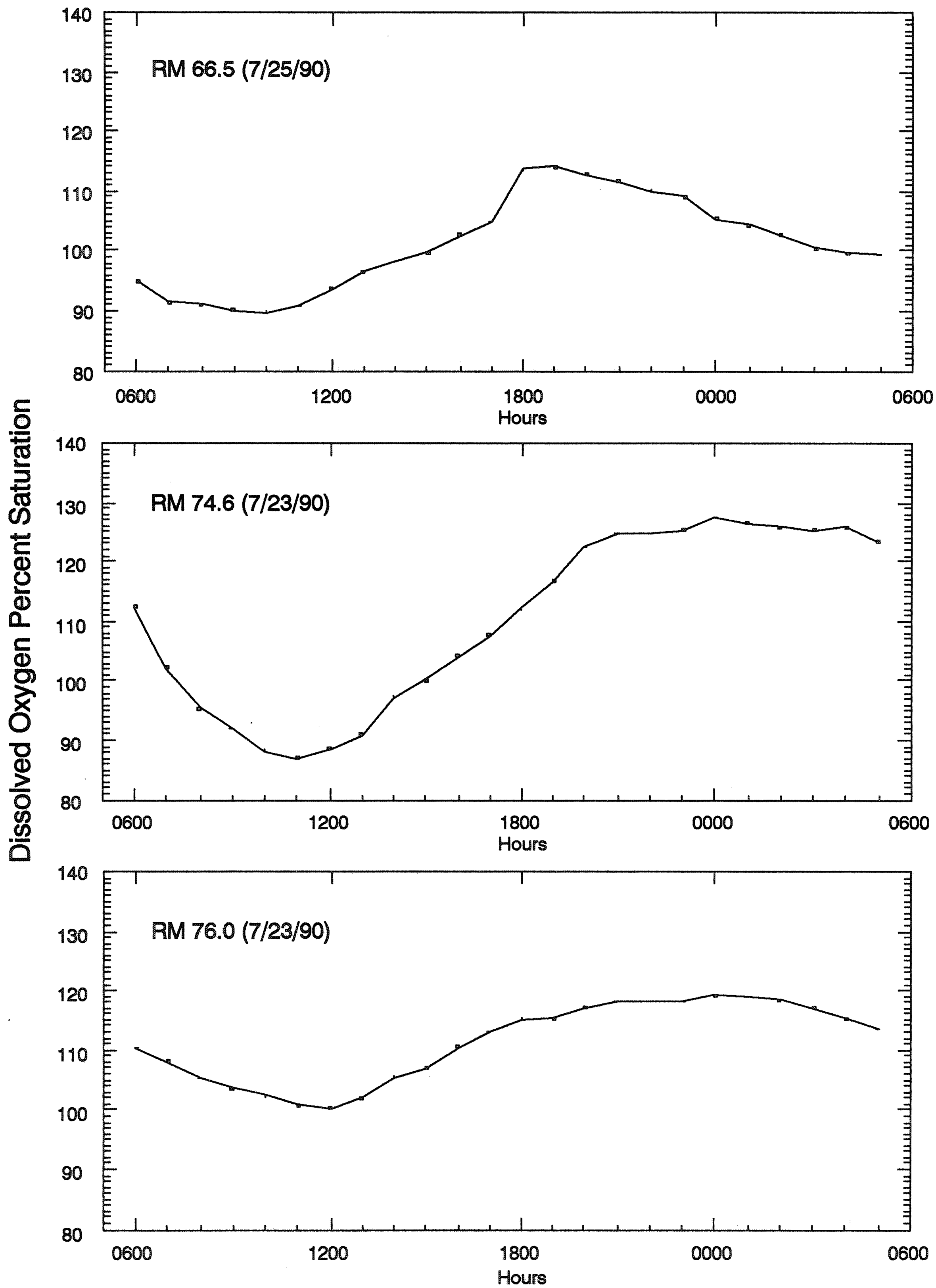

Figure 6. Diurnal dissolved oxygen in the Pend Oreille River, July 1990

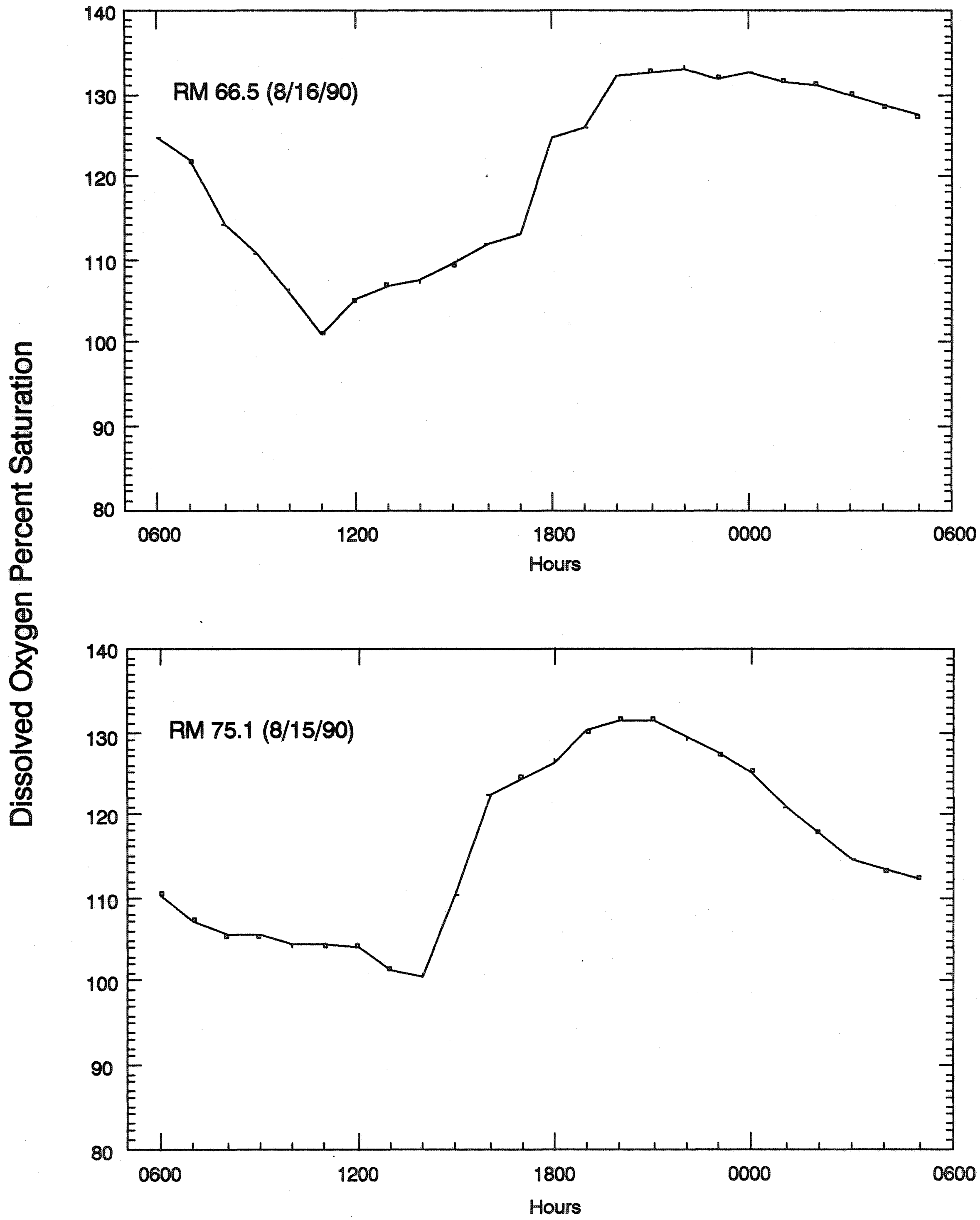

Figure 7. Diurnal dissolved oxygen in the Pend Oreille River, August 1990

Lost Creek to assess potential sources (Figures 3 and 4). Land-use was noted at each site. Additionally, nutrient and conventional samples were collected at several locations along Trimble and Calispell Creek (Figure 5). Table 1 summarizes the sampling design and schedule for both surveys.

Field measurements included temperature (mercury thermometer), pH and conductivity (Beckman meters), and dissolved oxygen (azide-modified Winkler titration). Grab samples were taken from mid-channel at all sites. Stream flow was measured by taking multiple cross-channel velocity and depth measurements with a Swoffer current meter.

Periphyton samples were collected at a single location on Skookum, Lost, South Fork Lost, Calispell, and Trimble Creek (Figure 3,4,5) and 2 near-shore areas along the mainstem Pend Oreille River (Figure 2) between August 13-15, 1990. Five rocks were selected at each site for sampling. Periphyton inside a 12.6 cm^2 plexiglass circular sampler was scrubbed from each rock with a stiff bristled brush and composited into a one liter sample bottle. De-ionized water was added to the periphyton slurry to bring the volume to one liter. The composite was homogenized by vigorous shaking and then separated into appropriate sample containers. A second composite sample was taken at each site. Depth and velocity were measured at each tributary location and depth at the mainstem sites. Periphyton samples were analyzed for total volatile solids (TVS), chlorophyll *a*, and pheophytin. Results were converted from volumetric to areal measurements by dividing volumetric results by the sampling area.

Samples for laboratory analysis were stored on ice and shipped to arrive at the Ecology/Environmental Protection Agency (EPA) Laboratory in Manchester, Washington, within 24 hours of sample collection. Laboratory analyses were performed as per EPA (1983), APHA *et al.* (1989), and Huntamer and Smith (1986).

QUALITY ASSURANCE

Standard reference materials (SRM's), field replicates, lab duplicates, lab check standards, matrix spikes and blanks (field and lab) were analyzed to assess sampling and analytical variability. Quality control results are contained in Appendix C.

SRMs and lab check standards are samples with known concentrations with which results can be compared, and are used to assess lab variability. SRMs have a certified nutrient concentration and were analyzed within the sample shipment. Lab results compared well with SRM certified concentrations, with all reported values within a relative percent difference (RPD) of seven. RPD is defined as the difference between two numbers divided by their mean expressed as a percent. Lab check standards are internal lab standards used to verify calibration of the analysis. Lab check standards were also in agreement with known concentrations, reporting no standard deviation greater than ± 1.4 with the critical point being ± 2.0.

Table 1. Sampling design and schedule for Pend Oreille River tributary surveys, 1990. Values in columns indicate the number of measurements or samples taken at each creek.

Sampling Site	Date	Flow	TEMP	COND	pH	DO	FC	FS	NUTS-5	PERI
Bracket Creek	7/24	4	3	4	4	4	4	4	–	–
	8/14	4	4	4	4	4	4	4	–	–
Skookum Creek	7/24	2	3	3	3	3	3	3	–	–
	8/14	3	4	4	4	4	4	4	–	2
S.F. Skookum Creek	7/24	–	2	2	2	2	2	2	–	–
	8/14	1	2	2	2	2	2	2	–	–
Lost Creek	7/24	1	1	1	1	1	1	1	–	–
	8/13	2	4	4	4	4	4	4	–	2
S.F. Lost Creek	7/25	2	2	2	2	2	2	2	–	–
	8/13	4	5	5	5	5	5	5	–	2
Trimble Creek	7/25	3	3	3	3	3	–	–	3	–
	8/15	4	4	4	4	4	–	–	4	2
Calispell Creek	7/25	–	4	4	4	4	–	–	5	–
	8/15	1	4	4	4	4	–	–	4	2
Pend Oreille River	8/13	–	–	–	–	–	–	–	–	2
	8/15	–	–	–	–	–	–	–	–	2

– = No sample
TEMP = Temperature
COND = Conductivity
DO = Dissolved oxygen
FC = Fecal coliform
FS = Fecal streptococcus

NUTS-5 = Nutrients: ammonia, nitrate+nitrite, total persulfate nitrogen, total phosphorus, soluble reactive phosphorus
PERI = Periphyton: total volatile solids, chlorophyll a, pheophytin

Thirteen percent of all nutrient samples and fifteen percent of all fecal coliform and fecal streptococcus samples were replicated to assess field and sampling variability. Replicate pairs were compared by determining the RPD. Results are expressed in Figure 8 using box plots. Box plots are used to illustrate the distribution of a series of data points from a ranked set of data. The example at the top of Figure 8 provides a key to box plot interpretation.

RPD's for water quality parameters, in general, were acceptable. Biological and physical (i.e., TVS) parameters exhibited higher variability. This would be expected due to patchier distributions in bacteria and periphyton biomass compared to more homogeneous water column chemistry. Some nutrient RPD's (i.e., ammonia-N, TPN, and TP) were higher than one might expect, which was at least in part due to low sample concentrations (i.e., replicate pair concentrations of 1 and 2 equal a RPD of 67%) and low number of replicates.

Quality control data were considered acceptable. Two total persulfate nitrogen lab duplicates were flagged in Appendix C as occurring outside the accepted difference of <0.01. This is not unusual however, for this digestion method.

RESULTS AND DISCUSSION

Primary Productivity

Productivity and respiration estimates are summarized in Table 2 and calculations are contained in Appendix A. To enable direct comparison of primary productivity between sites and to other studies, volumetric estimates ($g/m^3/day$) were converted to areal estimates ($g/m^2/day$) by multiplying by mean depth in meters. Most comparable literature is similarly corrected, the rational being that shallow water tends to be more responsive to D.O. change due to lesser volume.

Overall, highest gross productivity and community respiration rates occurred at RM 66.5 and lowest at RM 76.4. The most extensive weedbed development is reported between RM 60 and RM 72 (Falter *et al.*, 1991) and likely influenced productivity at RM 66.5. This portion of the reach is broad and shallow with low current velocities, which are favorable conditions for supporting dense stands of macrophytes. Net productivity ranged from -0.60 $g/m^2/day$ at RM 66.5 to 4.11 $g/m^2/day$ at RM 74.6 (Table 2).

During the July 23-26 sampling period at RM 66.5, 74.6, and 76.4, the weather was overcast and cool, and nearly an inch of rain fell during this period. Three weeks later (August 15-17), sampling at RM 66.5 and 75.1 occurred when weather was clear and warm. A comparison of July and August data collected from RM 66.5 indicate a greater than 25% increase in gross productivity. This increase in gross productivity at RM 66.5 is probably a result of greater sunlight intensity and lower stream flow, although increases in plant biomass (i.e., chlorophyll concentration) and water temperature may be involved as well.

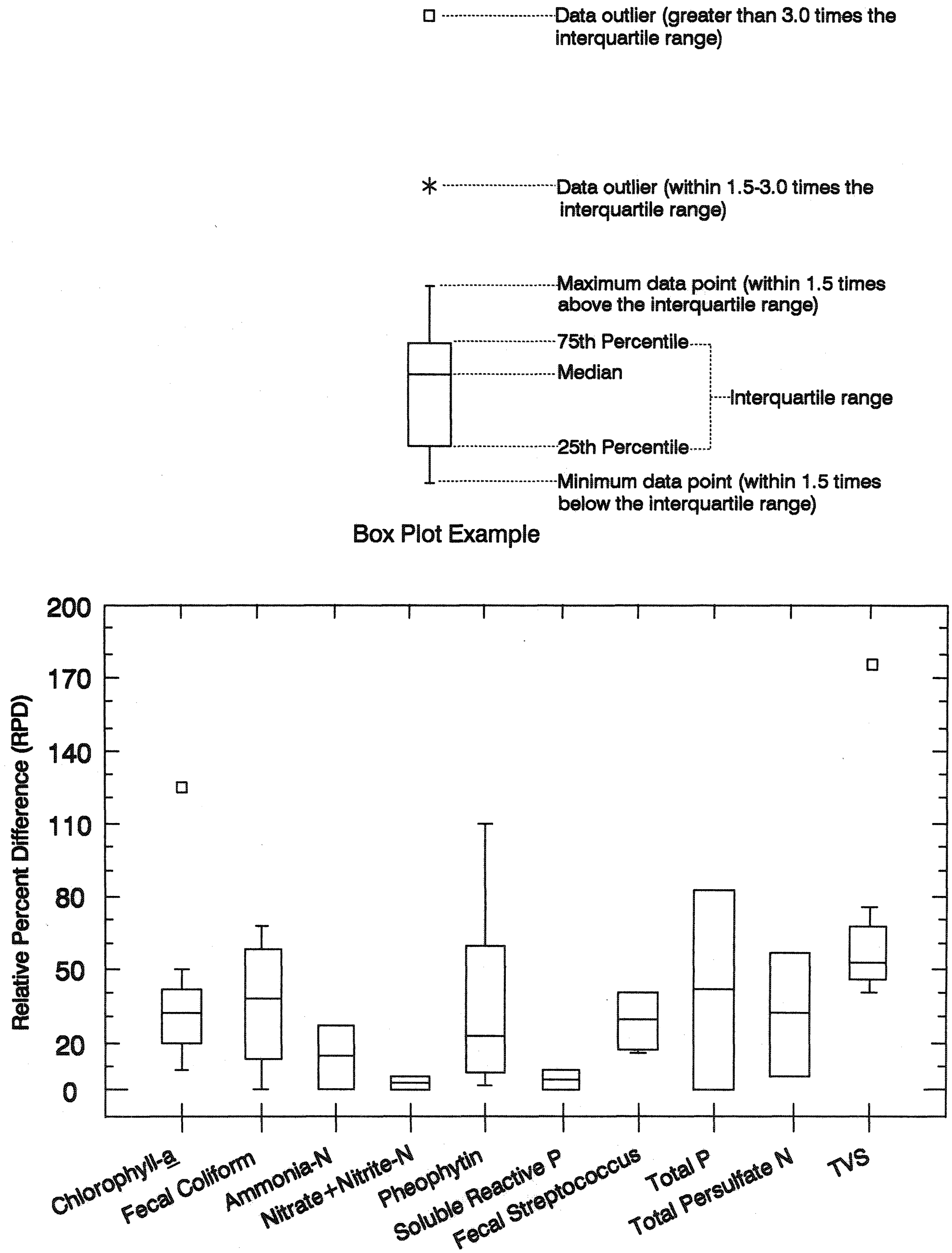

Figure 8. Comparison of field replicate samples from the Pend Oreille River and selected tributaries in July and August, 1990.

Table 2. Diurnal oxygen curve results of gross productivity and community respiration for mid–channel sites along the Pend Oreille River July 23 thru August 17, 1990.

Sampling Site	River Mile	Date	Mean Depth (m)	Mean Velocity (fps)	K Gas Transfer Coefficient (g/m²/hr)	P Gross Productivity (g/m²/day)	R Community Respiration (g/m²/day)	Net Productivity (g/m²/day)	P/R
Up71 At Red Norse Slough	76.4	7/23/90	3.0	0.42	0.30	8.5	7.5	1.1	1.1
Up8 At Davis Estates Launch	75.1	8/15/90	3.0	0.42	0.31	15.57	14.58	0.99	1.1
Up72 At Skookum Creek	74.6	7/23/90	3.0	0.42	0.30	14.85	10.74	4.11	1.4
Down7 At Cee Cee Ah Creek	66.5	7/25/90	4.6	0.35	0.35	19.50	20.01	–0.60	1.0
Down8 At Cee Cee Ah Creek	66.5	8/16/90	4.0	0.35	0.25	25.00	24.32	0.68	1.0

Each sample site was influenced differently by upstream productivity and respiration, and as a result, biotic productivity was not homogeneous throughout the study reach. Therefore, future productivity work on the Pend Oreille should attempt to apply the two-station analysis. This can be done by establishing sites with longitudinal separation of 0.5 mile or less, due to low current velocities.

Primary productivity in the Pend Oreille River is mainly attributed to the macrophyte community. Periphyton samples collected at two sites along the river mainstem had a mean chlorophyll *a* concentration of 2.2 mg/m^2. Suitable substrate was difficult to locate for sample collection. Phytoplankton in the water column, also measured as chlorophyll *a*, was collected at two mainstem sites and averaged 0.5 $\mu g/L$. Additionally, phytoplankton analysis from July through November of 1988 (Pelletier and Coots, 1990) showed low concentrations of chlorophyll *a* in the water column, averaging 1.8 $\mu g/L$. These data are consistent with the generally low nutrient concentrations found in the Pend Oreille River (Pelletier and Coots, 1990; Unpublished Ecology Ambient Monitoring data).

Productivity estimates for the Pend Oreille River were in the middle to upper range reported by other investigators for larger rivers (Odum, 1956; Thomas and O'Connell, 1966; Deb and Bowers, 1983; Joy *et al*, 1991). Highest reported gross productivity rates are typically found in recovery zones of streams polluted with organic wastes (Odum, 1956). In the case of the Pend Oreille River, high productivity is caused by proliferation of aquatic macrophytes, particularly Eurasian water milfoil, which derive nitrogen and phosphorus mostly from sediments.

To broadly classify the trophic state of the biological community, the ratio of gross productivity to community respiration (P/R) was determined. Organisms which have the ability to convert light energy to chemical energy via photosynthesis are considered autotrophs. Those which do not have photosynthetic abilities rely on the autotrophic community and are termed heterotrophs. Communities are considered autotrophic when the P/R ratio is greater than one and heterotrophic when the P/R ratio is less than one (Odum, 1956). P/R ratios from this survey range from 1.0 to 1.4, indicating a tendency toward autotrophy. This was expected given the high plant biomass densities found in the Pend Oreille.

<u>Water Quality Sampling</u>

Pend Oreille River discharge for the July-August 1990 period averaged 21,300 cubic feet per second (cfs) at Newport, which is roughly 10 percent below normal. The low river flow for 7 consecutive days with a recurrence of once in 10 years (i.e. 7Q10) is 4500 cfs. The highest flows for the Pend Oreille River normally occur during peak snowmelt in May and June. Precipitation for July and August was 3.7 inches, which is 1.5 inches above normal.

Nutrient concentrations from Calispell and Trimble Creek are summarized in Table 3 and illustrated in Figures 9 and 10. Based on flow measured at site Ca5 in August, inputs of TN and TP from Calispell Creek would account for approximately 1.1 and 1.3 percent of the total

Table 3. Pend Oreille River tributary nutrient concentrations and loads found in the survey of July and August, 1990.

Sampling Site	Date	NH3-N (mg/L)	NO3 + NO2-N (mg/L)	TPN (mg/L)	TP (mg/L)	SRP (mg/L)	TN:TP Ratio	Flow (cfs)	TPN Load lbs./day	TP Load lbs./day
Trimble Creek	7/25	0.020	<0.01	0.314	0.070	0.030	4.5	0.1	0.17	0.04
Tr1	8/15	0.028	0.014	0.241	0.048	0.036	5.0	0.2	0.26	0.05
Trimble Creek	7/25	<0.01	<0.01	0.163	0.040	0.010	4.1	0.9	0.79	0.19
Tr2	8/15	0.019	0.031	0.189	0.025	0.015	7.6	0.6	0.61	0.08
Trimble Creek	7/25	<0.01	0.010	0.114	0.030	0.010	3.8	1.1	0.68	0.18
Tr3	8/15	0.021	0.034	0.154	0.010	0.012	7.1	0.7	0.45	0.06
	Replicate	0.016	0.032	0.086	0.024	0.013		0.7		
Calispel Creek	7/25	0.010	<0.01	0.423	0.080	0.020	5.3	--	--	--
Ca1	8/15	0.025	<0.01	0.497	0.058	0.012	8.6	--	--	--
Calispel Creek	7/25	0.030	<0.01	0.406	0.070	0.020	5.8	--	--	--
Ca2	8/15	0.034	<0.01	0.821	0.134	0.009	6.1	--	--	--
Calispel Creek	7/25	0.010	<0.01	0.506	0.050	<0.01	10.4	--	--	--
Ca4	Replicate	0.010	<0.01	0.537	0.050	<0.01				
Ca3	8/15	0.024	<0.01	0.602	0.046	0.007	13.1	--	--	--
Calispel Creek	7/25	<0.01	<0.01	0.500	0.040	<0.01	12.5	--	--	--
Ca5	8/15	0.031	<0.01	0.700	0.047	0.005	14.9	41.7	157.44	10.57

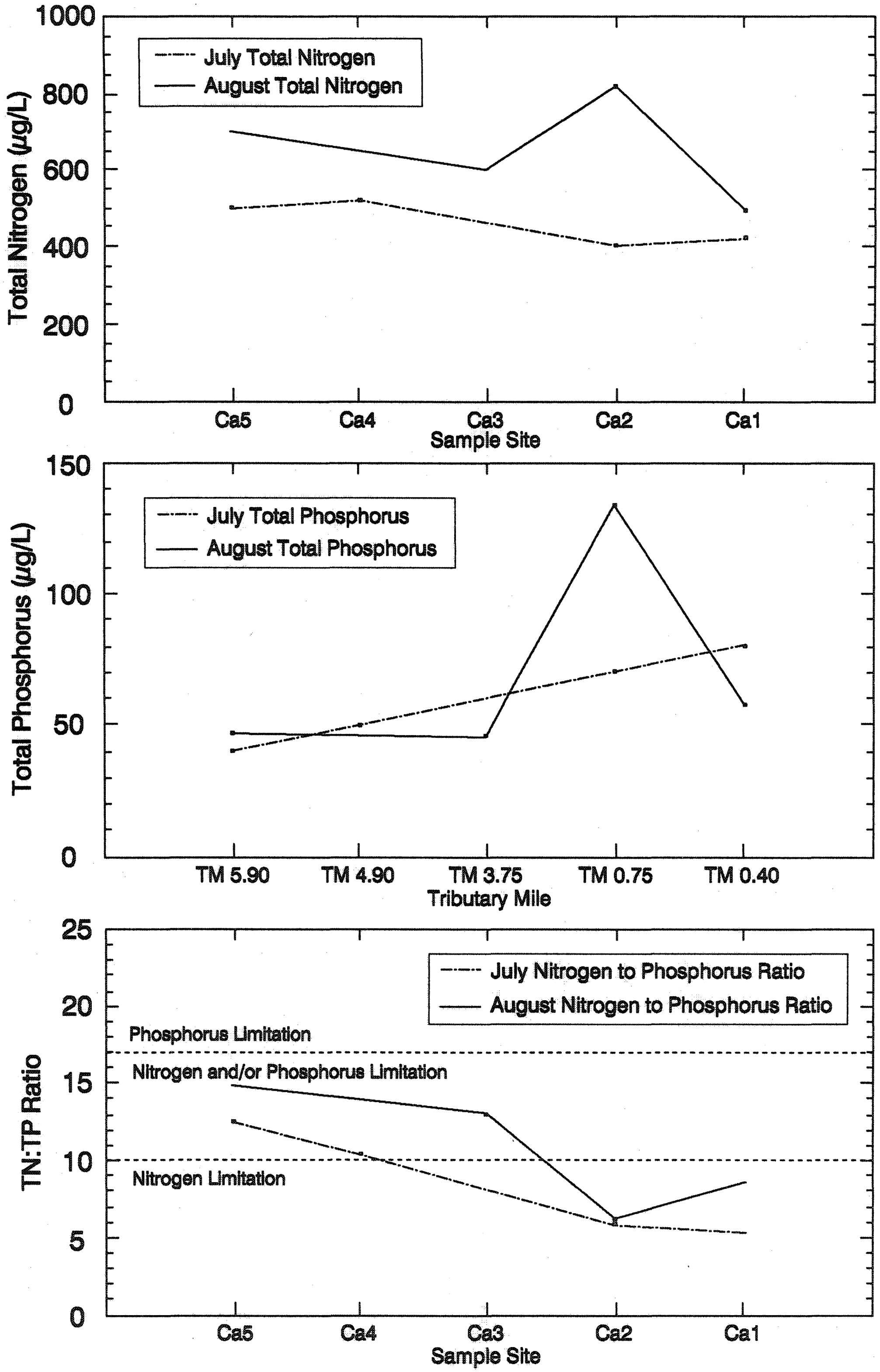

Figure 9. Calispell Creek total N, total P and total N to P ratios found during the July-August survey of 1990.

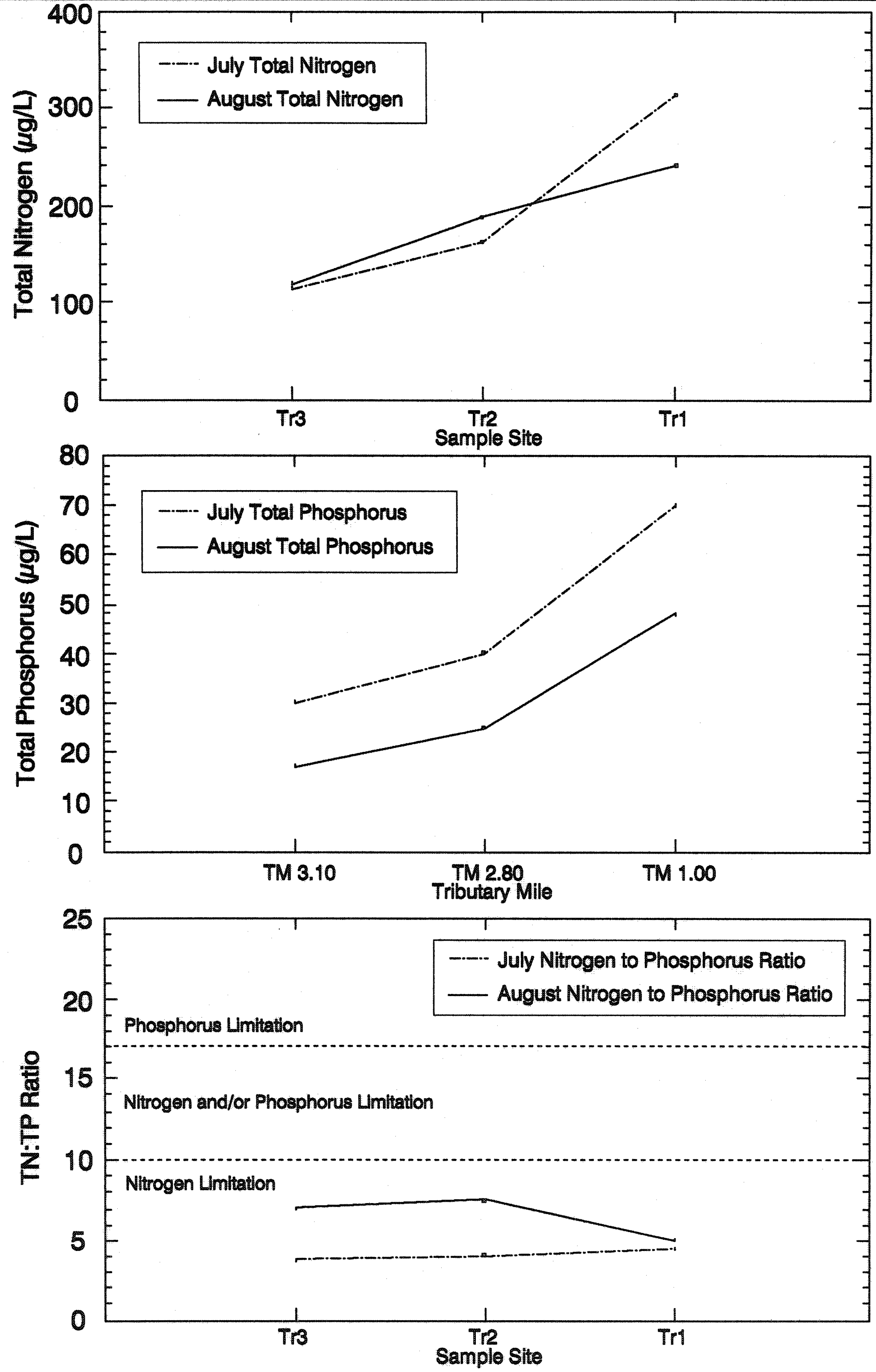

Figure 10. Trimble Creek total N, total P and total N to P ratios found during the July-August survey of 1990.

river load, respectively. At the 7Q10 low river flow, inputs of TN and TP from Calispell Creek would account for 5.3 and 6.4 per cent of the total river load, respectively. Load estimates are based on 42 samples collected from the Pend Oreille River at Newport and upstream of the Usk bridge July through November 1988 (Pelletier and Coots, 1990) and flow from the U.S. Geological Survey (USGS) gaging station at Newport. In general, nutrient concentrations varied considerably from site to site, probably due to agricultural practices, livestock handling, and grazing habits.

Calispell Creek was the largest of the tributaries sampled, and site Ca5 was the only sample location accessible to measure flow. August flow at Ca5 was 41.7 cfs. At Ca1 TN and TP concentrations were high, averaging 460 and 69 μg/L, respectively. TP increased from Ca5 to Ca1 in July. In August, both TN and TP increased significantly between Ca3 and Ca2. At Ca1, TN was within the range of concentrations found during the 1988 survey, with higher loads due to higher flow. The TP was more than twice the mean concentration found during 1988. Again, loads were higher than in 1988.

A TP criterion to control nuisance aquatic growths is not available. However, EPA recommends that to protect any lake or reservoir from cultural eutrophication, TP concentration from any stream, where it enters, should not exceed 50 μg P/L (EPA, 1986). At Ca1 in both July and August, TP exceeded the EPA's recommended guideline. Macrophytes were abundant in the lower reaches of Calispell Creek.

Trimble Creek was the smallest tributary sampled, with flow measuring 0.2 cfs at Tr1. There was a loss of flow at each of the two downstream sites in both July and August. At Tr1, TN and TP concentrations were high, averaging 277 and 59 μg/L, respectively. Both TN and TP concentration increased from upstream to downstream in July and August. TN and TP in Trimble Creek were 10 and 30 percent the concentration found in 1988. Loads were considerably lower in the present study as a result of lower concentrations and flow. At Tr1 in July, TP exceeded the EPA (1986) recommended guideline of 50 μg P/L for protection of reservoirs from cultural eutrophication. In August, TP was just under EPA's recommended guideline.

Nitrogen and phosphorus are nutrients that are needed for growth of algae. Algae can have many effects, both direct and indirect, on surface water quality. In water quality management, nitrogen and phosphorus are of primary interest because they are considered the most important growth limiting nutrients to plants (i.e., they are in the smallest supply compared to demand). Within the tables and figures reporting nutrient data are references to the TN:TP ratio. This number is an indicator of the nutrient which is most likely limiting algal growth. Freshwater habitats are generally thought to be nitrogen limited when the TN:TP ratio is less than 10:1 and phosphorus limited when the TN:TP ratio is greater than 17:1. When the TN:TP ratio is between 10:1 and 17:1, nitrogen and/or phosphorus may be limiting growth (Forsberg, 1980). There is some debate as to where to set limits, but these are generally accepted by most investigators. However, the limits are based on the assumption that nutrients are not available in excess. When nutrients are available in excess, regardless of the nutrient ratio, other factors besides nutrient concentrations limit algal growth. The TN:TP ratio for Calispell Creek indicates a tendency toward nitrogen limitation particularly in the lower reaches, although either could potentially be limiting. Trimble Creek also appears to be nitrogen limited.

Fecal coliform densities and loads are summarized in Table 4. Inputs of fecal coliform from Bracket, Skookum, Lost and South Fork Lost Creek averaged a combined total of 101 billion colony forming units (CFU) per day in July and August. Of this total, Skookum Creek accounted for 87% of the load.

Bracket Creek fecal coliform densities and loads are summarized in Table 4, and illustrated in Figure 11. Bracket Creek's discharge is relatively small, averaging 0.4 cfs for the survey. In July flows were highest upstream and declined at each of the two downstream sites. Flows in August remained fairly constant at all sites.

Tributaries to the Pend Oreille River are Class A surface waters. Water quality criteria for fecal coliform state that organisms shall not exceed a geometric mean value of 100 organisms/100 mL, with not more than 10% of samples exceeding 200 organisms/100 mL. In July and August, fecal coliform densities from sites Br1 and Br2 exceeded water quality standards. Flows were higher and discharge loads averaged an order of magnitude greater than results of the 1988 survey.

Fecal coliform to fecal streptococcus (FC:FS) ratios have been used, in the past, to determine sources of pollution. Ratios greater than four were considered indicative of human wastes and ratios less than 0.7 suggest a nonhuman source (APHA *et al.*, 1985). However, more recently the uncertainty that exists with the FC:FS ratio due to different die-off rates of certain species of streptococci bacteria (APHA *et al.*, 1989) raises serious concern and has led to the recommendation that the FC:FS ratio not be used as a direct indicator of pollution sources. Long travel time from the source of bacteria or disinfection of wastewater can lead to erroneous results. The FC:FS ratio does, however, possess value as a screening tool by indicating areas that may require further investigation. The high FC:FS ratio from site Br2 in August suggests human sources may be contributing to the observed elevations.

Site Br2 averaged fecal coliform densities nearly four times higher than at Br1. The area near the mouth is marshy and probably provides some wetland treatment. Fecal coliform sensitivity to light and travel time from the source may also contribute to load reductions. Site Br2 is located 1.25 miles upstream of the mouth and was sampled approximately 50 meters below an area where there is a livestock watering pond adjacent to the creek. Cattle had direct access to the stream and were present at the time of sampling. The FC:FS ratio and evidence of cattle accessing the stream at this site suggests both domestic and livestock contributions may be elevating fecal coliform levels. Site Br3 was located 1.75 miles upstream of the mouth and had no evidence of livestock above the sample point; it carried roughly one-tenth the load of Br2. Above Br3 fecal coliform densities averaged roughly half the water quality criteria for both sample dates.

Table 4. Results of fecal coliform and fecal streptococcus from selected tributaries of the Pend Oreille River, July and August, 1990.

Sampling Site	Date	Time	Fecal Coliform (#/100 mL)	Fecal Strep. (#/100 mL)	Flow (cfs)	Billion CFU/Day	FC:FS Ratio
Bracket Creek	7/24	0728	180*	450	0.3	1.3	0.4
Br1	8/14	1535	230*	280	0.5	2.8	0.8
Bracket Creek	7/24	0815	870*	1000	0.6	12.8	0.9
Br2	8/14	1555	670*	160	0.5	8.2	4.2
Bracket Creek	7/24	0828	27	37	0.9	0.9	1.0
Br3	Replicate	0830	44	31	1.1		
	8/14	1615	56	29	0.5	0.7	1.4
	Replicate	1625	43	43	0.6		
Skookum Creek	7/24	1410	160*	240	--	--	0.7
Sk1	8/14	0850	140*	140	23.9	81.9	1.0
S.F. Skookum Creek	7/24	1425	59	27	--	--	2.2
Sk2	8/14	0920	45	23	--	--	2.0
S.F. Skookum Creek	7/24	1445	75	16	--	--	4.7
Sk3	8/14	0930	60	16	8.7	12.8	3.7
Skookum Creek	7/24	1515	210*	110	20.6	117.9	1.9
Sk4	Replicate	1530	--	--	25.3		
	8/14	1005	220*	310	16.7	89.9	0.7
Skookum Creek	7/24	1540	410*	220	--	--	1.9
Sk5	8/14	1030	1200*	86	--	--	13.9
Skookum Creek	8/14	1045	2	1	9.9	0.5	2.0
Sk6							

Table 4. Results of fecal coliform and fecal streptococcus from selected tributaries of the Pend Oreille River, July and August, 1990 (continued).

Sampling Site	Date	Time	Fecal Coliform (#/100 mL)	Fecal Strep. (#/100 mL)	Flow (cfs)	Billion CFU/Day	FC:FS Ratio
Lost Creek Lo1	7/24	1255	22	14	6.1	3.3	1.7
	Replicate	1255	22	12	--		
	8/13	1235	45	16	4.7	5.2	2.8
Lost Creek Lo2	8/13	1345	51	100	--	--	0.5
Lost Creek Lo3	8/13	1355	53	66	--	--	0.8
Lost Creek Lo4	8/13	1410	83	49	4.5	9.1	1.7
S.F. Lost Creek Sf1	7/24	1154	240*	87	2.0	11.7	2.8
	8/13	0935	92	29	1.3	2.9	3.2
S.F. Lost Creek Sf2	7/24	1220	250*	280	2.2	13.5	0.9
	8/13	1100	9	20	1.6	0.4	0.5
S.F. Lost Creek Sf3	8/13	1120	14	6	--	--	2.3
S.F. Lost Creek Sf4	8/13	1130	6	6	1.9	0.2	1.0
	Replicate	1140	<3	9	2.0		

* Indicates value exceeds state water quality standards (WAC 173-201).

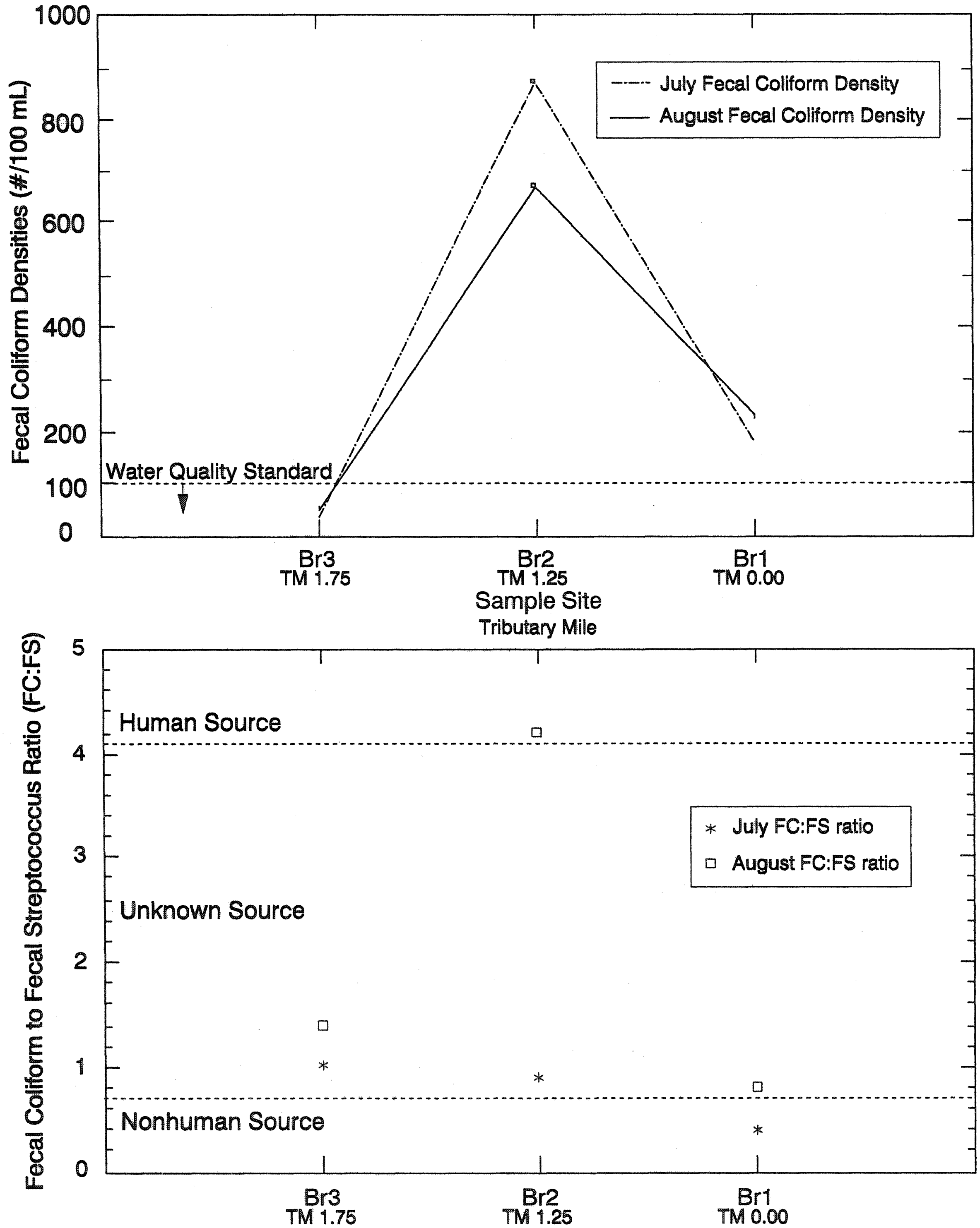

Figure 11. Bracket Creek fecal coliform densities and ratios found during the July-August survey of 1990.

Skookum Creek fecal coliform densities and loads are summarized in Table 4 and illustrated in Figure 12. Skookum Creek's mainstem and South Fork were the only portions of the basin sampled. August flow from Skookum Creek was 23.9 cfs. Fecal coliform densities from sites Sk1, Sk4 and Sk5 (Figure 3) exceeded Class A water quality criteria in both July and August (Figure 12). Flows were greater and loads were roughly three-fold higher than the 1988 survey. The FC:FS ratio from Sk3 in July and August and Sk5 in August suggest human sources may be contributing to fecal coliform impacts. As discussed earlier, further study would be needed to confirm this.

Site Sk5 had fecal coliform densities averaging over 5 times the level of Sk1. Sk6, which is located roughly 8 miles upstream of Sk1, had a fecal coliform density near the detection limit and appears to be unimpacted, although only an August sample was taken. Sites Sk2 and Sk3 had fecal coliform densities below the Class A criteria both months. However, the FC:FS ratio at Sk3 was high in June and suggests further investigation may be in order. Site Sk2 was located in an area that was marshy and evidence of cattle was not obvious. Site Sk3 was located on state land with cattle in the area with direct access to the stream. Macrophytes were abundant in the lower reaches of Skookum Creek.

Lost Creek fecal coliform densities and loads are summarized in Table 4 and illustrated in Figure 13. Flow from Lost Creek averaged roughly 5 cfs. In July the site located at the mouth of the creek was the only location sampled. Fecal coliform densities were relatively low, with no values above established water quality criteria. Fecal coliform counts were not significantly different than those found in the 1988 survey. Lands surrounding the sample locations were generally pasture areas with numerous cattlesign, but no livestock were seen during either sampling event. In August, the highest fecal coliform densities were found at the most upstream site, Lo4.

South Fork Lost Creek fecal coliform densities and loads are summarized in Table 4 and illustrated in Figure 13. Flows from South Fork Lost Creek averaged roughly 1.5 cfs. South Fork Lost Creek exhibited high variability for fecal coliform densities. In July Sf1 and Sf2 were the only sites sampled. Both sites had densities which were twice as high as water quality criteria. In August, upstream sites had low fecal coliform densities. Adjacent land-use at the three downstream sites were pasture. The area around Sf4 was brushy with no evidence of cattle. Densities encountered in the present survey were within the range found in 1988.

Periphyton biomass concentrations are summarized in Table 5 and illustrated in Figure 14. Periphyton biomass has been used by numerous investigators as a direct indicator of water quality. Research by Horner *et al.*, (1983) and Welch *et al.*, (1988) have indicated nuisance growth levels of periphyton to be above a critical range of 100-150 mg chlorophyll a/m^2. Biomass levels above this concentration are associated with a dense luxuriant growth, resulting in aesthetic impairment. In general, substrates encountered at sample locations were not conducive to growth of periphyton. Periphyton prefer a firm substrate such as rocks. Finer substrate materials (i.e., sands, silts, and clays) were more often found. Periphyton samples were collected at sites where appropriate substrate could be located. Periphyton biomass

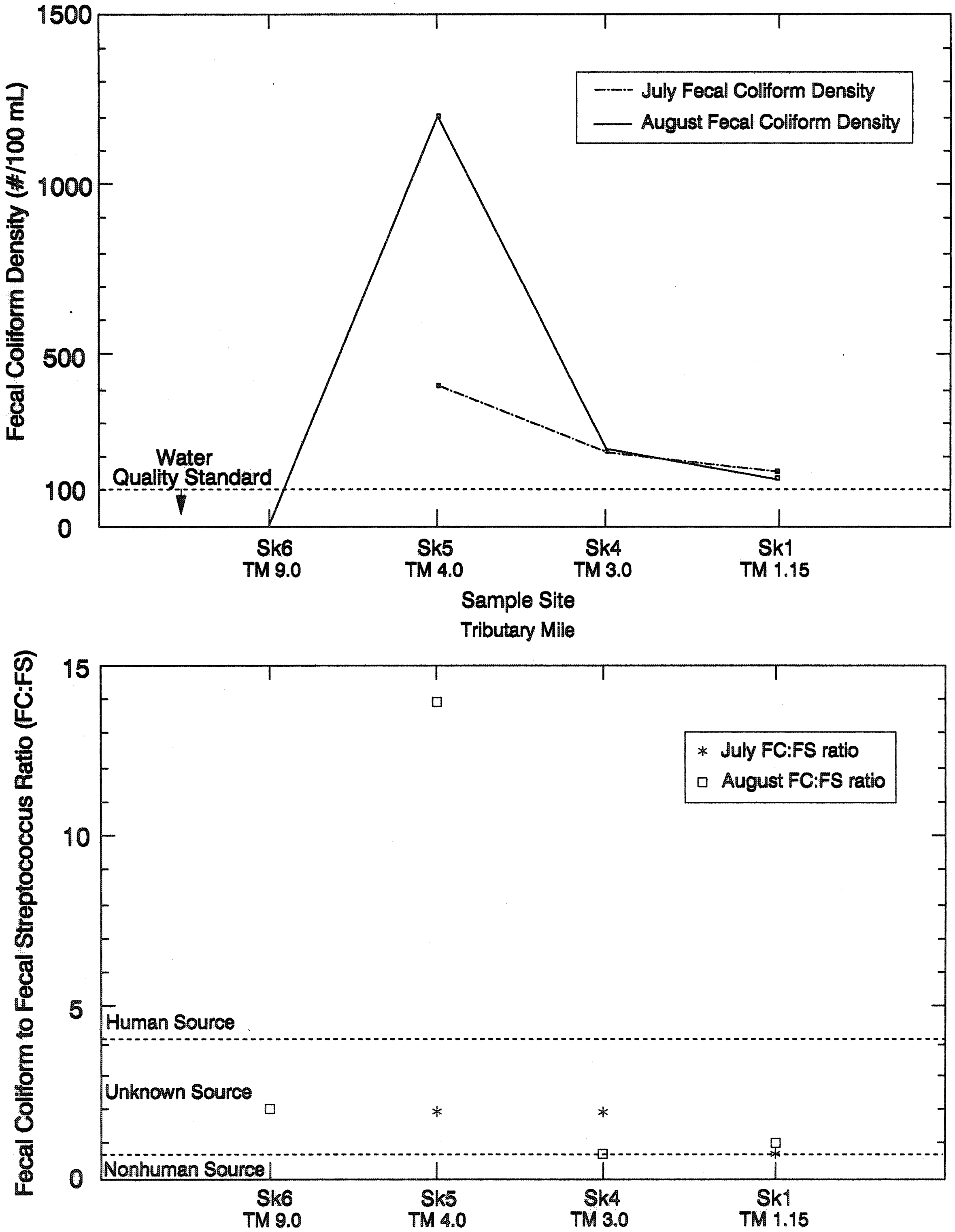

Figure 12. Skookum Creek fecal coliform densities and ratios found during the July-August survey of 1990.

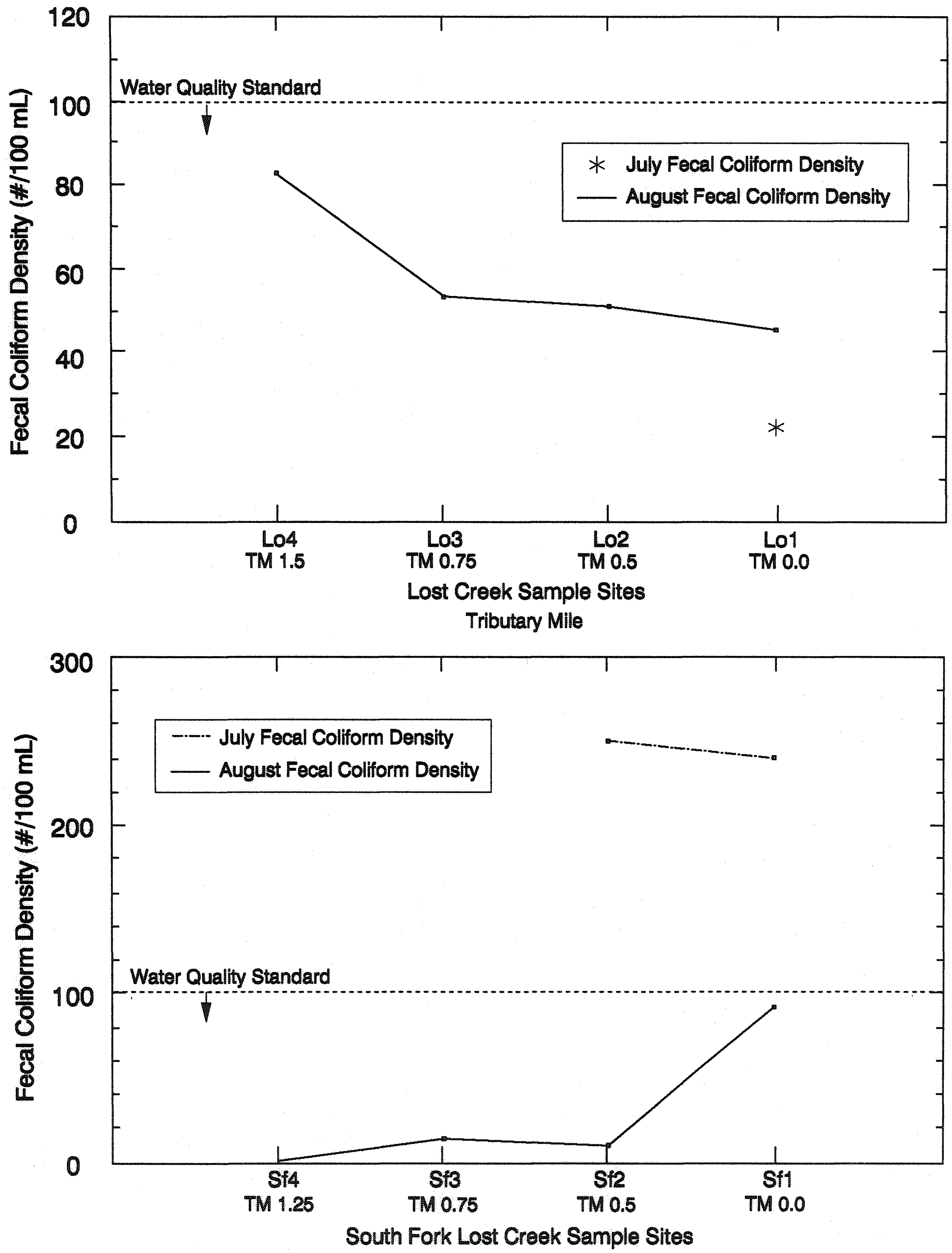

Figure 13. Lost and South Fork Lost Creek fecal coliform densities found during the July-August survey of 1990.

Table 5. Results of chlorophyll–a from periphyton and the water column of the Pend Oreille River and selected tributaries, August 1990.

Sampling Site	Date	Time	Depth (ft)	Velocity (fps)	Periphyton TVS (mg/L)	Periphyton Chl-a. ($\mu g/L$)	Periphyton Chl-a. (mg/m^2)	Periphyton Pheo. ($\mu g/L$)	Water Column Chl-a. ($\mu g/L$)	Water Column Pheo. ($\mu g/L$)
Skookum Creek	8/14	1100	1.00	0.50	117	97.5	18.69	--	--	--
Sk6	Replicate	1120	1.20	0.70	214	138.0		--	--	--
Lost Creek	8/13	1250	0.60	0.90	26	11.5	1.75	11.6	--	--
Lo1	Replicate	1310	0.40	0.65	16	10.5		12.6	--	--
S.F. Lost Creek	8/13	0950	0.45	0.70	15	13.3	1.82	12.1	--	--
Sf1	Replicate	1015	0.35	0.80	<1	9.6		8.3	--	--
Calispell Creek Ca1	8/15	1035	--	--	--	--	--	--	3.8	4.8
Calispell Creek	8/15	1155	1.65	0.10	31	53.3	7.58	51.8	3.8	6.0
Ca4	Replicate	1205	2.20	0.10	48	42.2		55.6	--	--
Trimble Creek	8/15	0920	0.60	0.40	12	7.6	0.97	8.1	0.1	0.2
Tr3	Replicate	0930	0.60	0.50	7	4.6		4.4	--	--
Pend Oreille River	8/15	1250	--	--	22	8.1	1.39	8.5	--	--
Up81	Replicate	1300	--	--	10	9.4		8.7	--	--
Pend Oreille River	8/13	1600	--	--	15	29.9	2.92	23.2	--	--
River Bend launch	Replicate	1610	--	--	20	6.9		6.7	--	--
Pend Oreille River At Skookum Creek	8/14	1415	--	--	--	--	--	--	0.6	--
Pend Oreille River At Davis Estates	8/14	1450	--	--	--	--	--	--	0.3	--

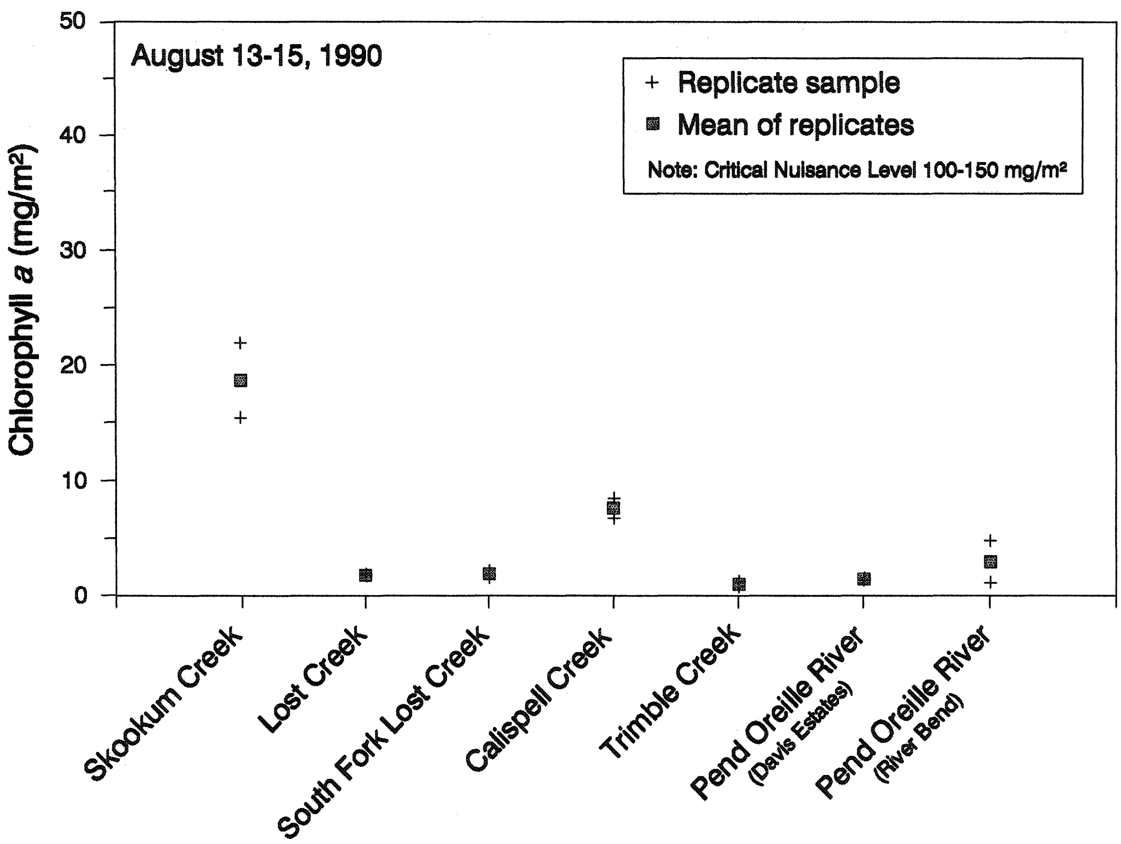

Figure 14. Periphyton biomass as chlorophyll *a* concentrations from the Pend Oreille River and tributary locations.

concentrations found during this survey were low ranging from 0.97 to 18.69 mg/m^2 with a mean of 5.02 mg/m^2.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

- Skookum, Bracket, and South Fork Lost Creek fecal coliform densities exceeded Class A water quality criteria during both July and August. Highest densities occurred at site Br2 on Bracket Creek and site Sk5 on Skookum Creek. Of the studied tributaries Skookum Creek accounted for 87 percent of the fecal coliform loading to the mainstem Pend Oreille River. Sources of water quality criteria exceedance appear to be related to animal keeping practices. The FC:FS ratio at sites Br2 and Sk5 suggest the possibility of human contributions to nonpoint source pollution.

- TP in Calispell and Trimble Creek exceeded EPA's (1986) recommended guideline of 50 μg P/L for the protection of reservoirs from cultural eutrophication.

- Primary productivity by the biotic community within the Box Canyon Reach was in the middle to upper range reported by other investigators for larger rivers. Macrophytes are the primary source of productivity for the reach. Highest productivity was measured at RM 66.5 due to extensive weedbed development immediately upstream. Diurnal variation in dissolved oxygen was up to 41 percent.

- The P/R ratio indicates an autotrophic classification for the biological community of the Pend Oreille River.

RECOMMENDATIONS

- Ecology's Eastern Regional Office should refer the nonpoint source pollution problems from agricultural practices on Skookum, Bracket, and South Fork Lost Creek to the Pend Oreille County Conservation District for corrective action under the Compliance Memorandum of Agreement relative to agricultural water quality management. Under this agreement, the Conservation District and land holders adjacent to problem streams develop management plans containing best management practices (BMP's) to correct and prevent nonpoint source pollution.

- Future work in estimating primary productivity for the Pend Oreille River by use of the diurnal dissolved oxygen curve method should utilize the two-station technique. Sites should be selected with less than 0.5 mile separation, due to the low current velocities in the Box Canyon reach during low flow.

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APPENDICES

Appendix A1. Summary of dissolved oxygen rate of change for the Pend Oreille River at Cee Cee Ah (RM 66.5) 7/25–7/26/1990.

Time (hrs)	Temp (°C)	DO* (mg/L)	Rate of change (mg/L/hr)	Conc. at saturation (mg/L)	Observed saturation (%)	Average saturation deficit, S (%)	Diffusion S x k/100 (g/m3/hr)	Corrected rate of change (g/m3/hr)
0500	20.8	8.90		8.95	99.4			
0600	20.8	8.50	-0.40	8.95	95.0	-2.79	-0.001	-0.40
0700	20.7	8.20	-0.30	8.97	91.4	-6.79	-0.003	-0.30
0800	21.7	8.00	-0.20	8.79	91.0	-8.80	-0.004	-0.20
0900	21.6	7.95	-0.05	8.81	90.2	-9.41	-0.005	-0.05
1000	21.6	7.90	-0.05	8.81	89.7	-10.06	-0.005	-0.05
1100	21.6	8.00	0.10	8.81	90.8	-9.78	-0.005	0.10
1200	21.6	8.25	0.25	8.81	93.6	-7.79	-0.004	0.25
1300	21.6	8.50	0.25	8.81	96.5	-4.95	-0.002	0.25
1400	21.6	8.65	0.15	8.81	98.2	-2.68	-0.001	0.15
1500	21.5	8.80	0.15	8.83	99.7	-1.08	-0.001	0.15
1600	21.5	9.05	0.25	8.83	102.5	1.09	0.001	0.25
1700	21.5	9.25	0.20	8.83	104.8	3.64	0.002	0.20
1800	21.4	10.05	0.80	8.85	113.6	9.19	0.005	0.80
1900	21.3	10.10	0.05	8.86	114.0	13.79	0.007	0.06
2000	21.3	10.00	-0.10	8.86	112.8	13.39	0.007	-0.09
2100	21.2	9.90	-0.10	8.88	111.5	12.16	0.006	-0.09
2200	21.1	9.80	-0.10	8.90	110.1	10.81	0.005	-0.09
2300	21.1	9.70	-0.10	8.90	109.0	9.58	0.005	-0.10
0000	21.0	9.40	-0.30	8.92	105.4	7.23	0.004	-0.30
0100	21.0	9.30	-0.10	8.92	104.3	4.88	0.002	-0.10
0200	21.0	9.15	-0.15	8.92	102.6	3.48	0.002	-0.15
0300	21.0	8.95	-0.20	8.92	100.4	1.51	0.001	-0.20
0400	20.9	8.90	-0.05	8.93	99.6	0.01	0.000	-0.05
0500	20.8	8.90	0.00	8.95	99.4	-0.46	0.000	0.00

* DO corrected using a factor of 1.14.

k = Gas transfer coefficient.

Appendix A2. Summary of dissolved oxygen rate of change for the Pend Oreille River at Red Norse Slough (RM 76.4) 7/23–7/24/1990.

Time (hrs)	Temp (°C)	DO (mg/L)	Rate of change (mg/L/hr)	Conc. at saturation (mg/L)	Observed saturation (%)	Average saturation deficit, S (%)	Diffusion S x k/100 (g/m3/hr)	Corrected rate of change (g/m3/hr)
0525	21.8	9.95		8.78	113.4			
0625	21.7	9.70	−0.25	8.79	110.3	11.84	0.012	−0.24
0725	21.7	9.50	−0.20	8.79	108.0	9.17	0.009	−0.19
0825	21.7	9.25	−0.25	8.79	105.2	6.60	0.007	−0.24
0925	21.7	9.10	−0.15	8.79	103.5	4.33	0.004	−0.15
1025	21.7	9.00	−0.10	8.79	102.3	2.91	0.003	−0.10
1125	21.8	8.85	−0.15	8.78	100.8	1.57	0.002	−0.15
1225	21.8	8.80	−0.05	8.78	100.3	0.53	0.001	−0.05
1325	21.8	8.95	0.15	8.78	102.0	1.11	0.001	0.15
1425	21.8	9.25	0.30	8.78	105.4	3.67	0.004	0.30
1525	21.7	9.40	0.15	8.79	106.9	6.13	0.006	0.16
1625	21.8	9.70	0.30	8.78	110.5	8.70	0.009	0.31
1725	21.9	9.90	0.20	8.76	113.0	11.76	0.012	0.21
1825	21.8	10.10	0.20	8.78	115.1	14.04	0.014	0.21
1925	21.9	10.10	0.00	8.76	115.3	15.18	0.015	0.02
2025	21.9	10.25	0.15	8.76	117.0	16.15	0.016	0.17
2125	21.9	10.35	0.10	8.76	118.1	17.57	0.018	0.12
2225	21.9	10.35	0.00	8.76	118.1	18.14	0.018	0.02
2325	21.9	10.35	0.00	8.76	118.1	18.14	0.018	0.02
0025	22.1	10.40	0.05	8.73	119.2	18.66	0.019	0.07
0125	22.0	10.40	0.00	8.74	118.9	19.06	0.019	0.02
0225	22.0	10.35	−0.05	8.74	118.4	18.66	0.019	−0.03
0325	21.9	10.25	−0.10	8.76	117.0	17.69	0.018	−0.08
0425	21.9	10.10	−0.15	8.76	115.3	16.15	0.016	−0.13
0525	21.8	9.95	−0.15	8.78	113.4	14.34	0.014	−0.13

k = Gas transfer coefficient.

Appendix A3. Summary of dissolved oxygen rate of change for the Pend Oreille River at Skookum Creek (RM 74.6) 7/23–7/24/1990.

Time (hrs)	Temp (°C)	DO (mg/L)	Rate of Change (mg/L/hr)	Conc. at saturation (mg/L)	Observed saturation (%)	Average saturation deficit, S (%)	Diffusion S x k/100 (g/m3/hr)	Corrected rate of change (g/m3/hr)
0525	22.0	10.30		8.74	117.8			
0625	21.9	9.85	–0.45	8.76	112.4	15.12	0.015	–0.43
0725	21.9	8.95	–0.90	8.76	102.2	7.30	0.007	–0.89
0825	21.9	8.35	–0.60	8.76	95.3	–1.26	–0.001	–0.60
0925	21.9	8.05	–0.30	8.76	91.9	–6.40	–0.006	–0.31
1025	22.0	7.70	–0.35	8.74	88.1	–10.02	–0.010	–0.36
1125	22.0	7.60	–0.10	8.74	86.9	–12.51	–0.013	–0.11
1225	22.0	7.75	0.15	8.74	88.6	–12.22	–0.012	0.14
1325	22.0	7.95	0.20	8.74	90.9	–10.22	–0.010	0.19
1425	22.0	8.50	0.55	8.74	97.2	–5.93	–0.006	0.54
1525	22.0	8.75	0.25	8.74	100.1	–1.36	–0.001	0.25
1625	22.0	9.10	0.35	8.74	104.1	2.07	0.002	0.35
1725	22.1	9.40	0.30	8.73	107.7	5.89	0.006	0.31
1825	22.0	9.80	0.40	8.74	112.1	9.90	0.010	0.41
1925	22.0	10.20	0.40	8.74	116.7	14.37	0.015	0.41
2025	22.0	10.70	0.50	8.74	122.4	19.51	0.020	0.52
2125	22.0	10.90	0.20	8.74	124.7	23.52	0.024	0.22
2225	22.0	10.90	0.00	8.74	124.7	24.66	0.025	0.02
2325	22.0	10.95	0.05	8.74	125.2	24.95	0.025	0.08
0025	22.0	11.15	0.20	8.74	127.5	26.38	0.027	0.23
0125	22.0	11.05	–0.10	8.74	126.4	26.95	0.027	–0.07
0225	22.0	11.00	–0.05	8.74	125.8	26.09	0.026	–0.02
0325	22.0	10.95	–0.05	8.74	125.2	25.52	0.026	–0.02
0425	22.0	11.00	0.05	8.74	125.8	25.52	0.026	0.08
0525	21.9	10.80	–0.20	8.76	123.3	24.54	0.025	–0.18

k = Gas transfer coefficient.

Appendix A4. Summary of dissolved oxygen rate of change for the Pend Oreille River at Cee Cee Ah (RM 66.5) 8/16–8/17/1990.

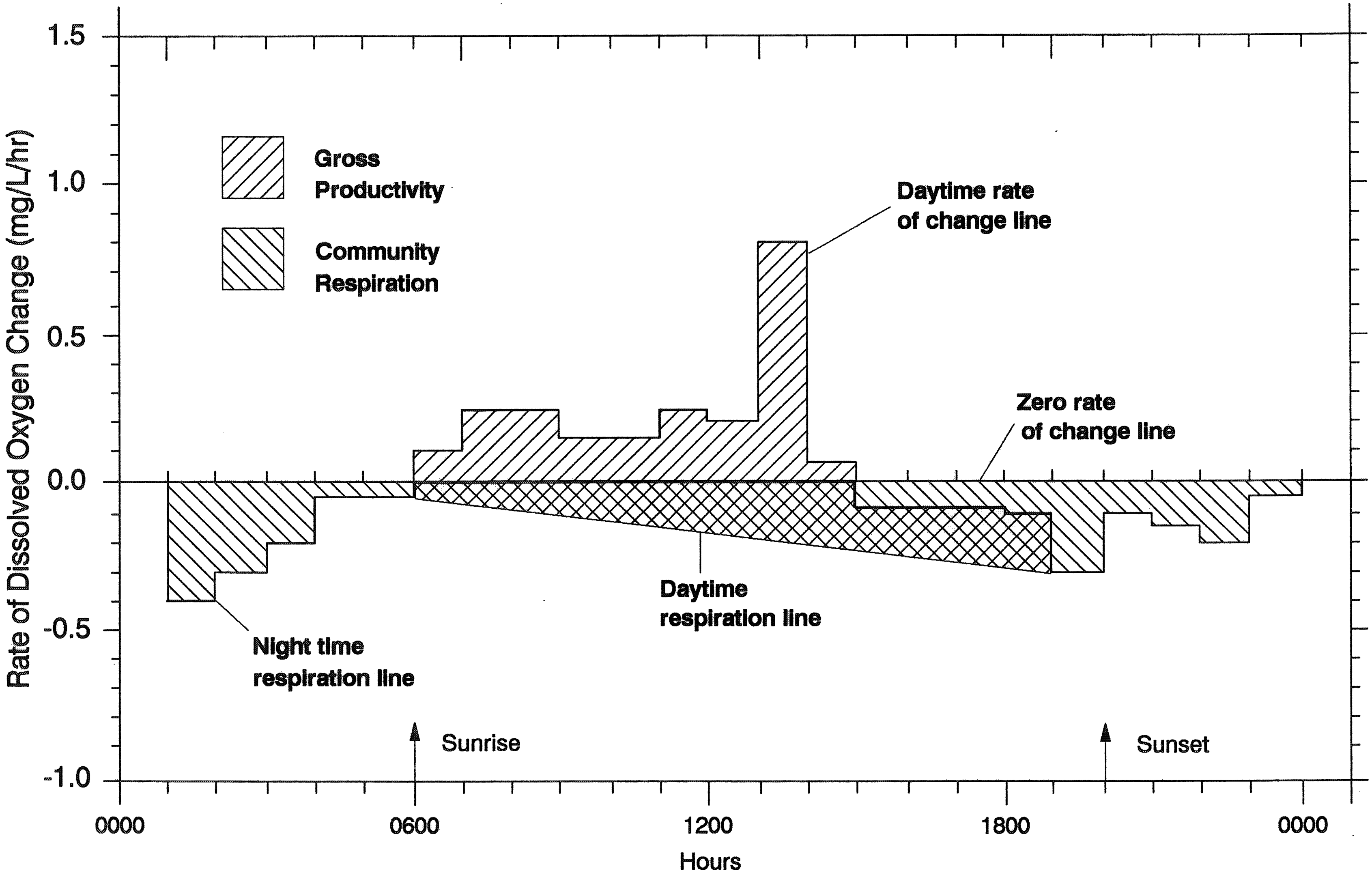
Time (hrs)	Temp (°C)	DO* (mg/L)	Rate of change (mg/L/hr)	Conc. at saturation (mg/L)	Observed saturation (%)	Average saturation deficit, S (%)	Diffusion S x k/100 (g/m3/hr)	Corrected rate of change (g/m3/hr)
0500	23.0	10.85		8.58	126.5			
0600	23.0	10.70	−0.15	8.58	124.7	25.61	0.016	−0.13
0700	23.0	10.45	−0.25	8.58	121.8	23.28	0.015	−0.24
0800	23.0	9.80	−0.65	8.58	114.2	18.03	0.011	−0.64
0900	23.0	9.50	−0.30	8.58	110.7	12.49	0.008	−0.29
1000	23.0	9.10	−0.40	8.58	106.1	8.41	0.005	−0.39
1100	23.1	8.65	−0.45	8.56	101.0	3.56	0.002	−0.45
1200	23.4	8.95	0.30	8.51	105.1	3.08	0.002	0.30
1300	23.4	9.10	0.15	8.51	106.9	6.01	0.004	0.15
1400	23.4	9.15	0.05	8.51	107.5	7.18	0.004	0.05
1500	23.5	9.30	0.15	8.50	109.4	8.46	0.005	0.16
1600	23.5	9.50	0.20	8.50	111.8	10.62	0.007	0.21
1700	23.5	9.60	0.10	8.50	113.0	12.39	0.008	0.11
1800	23.5	10.60	1.00	8.50	124.7	18.86	0.012	1.01
1900	23.5	10.70	0.10	8.50	125.9	25.33	0.016	0.12
2000	23.4	11.25	0.55	8.51	132.1	29.03	0.018	0.57
2100	23.4	11.30	0.05	8.51	132.7	32.44	0.020	0.07
2200	23.3	11.35	0.05	8.53	133.1	32.90	0.021	0.07
2300	23.3	11.25	−0.10	8.53	131.9	32.48	0.020	−0.08
0000	23.3	11.30	0.05	8.53	132.5	32.19	0.020	0.07
0100	23.2	11.25	−0.05	8.55	131.6	32.06	0.020	−0.03
0200	23.2	11.20	−0.05	8.55	131.1	31.35	0.020	−0.03
0300	23.2	11.10	−0.10	8.55	129.9	30.47	0.019	−0.08
0400	23.1	11.00	−0.10	8.56	128.5	29.18	0.018	−0.08
0500	23.1	10.90	−0.10	8.56	127.3	27.89	0.017	−0.08

* DO data corrected using a factor of 1.27.
k = Gas transfer coefficient.

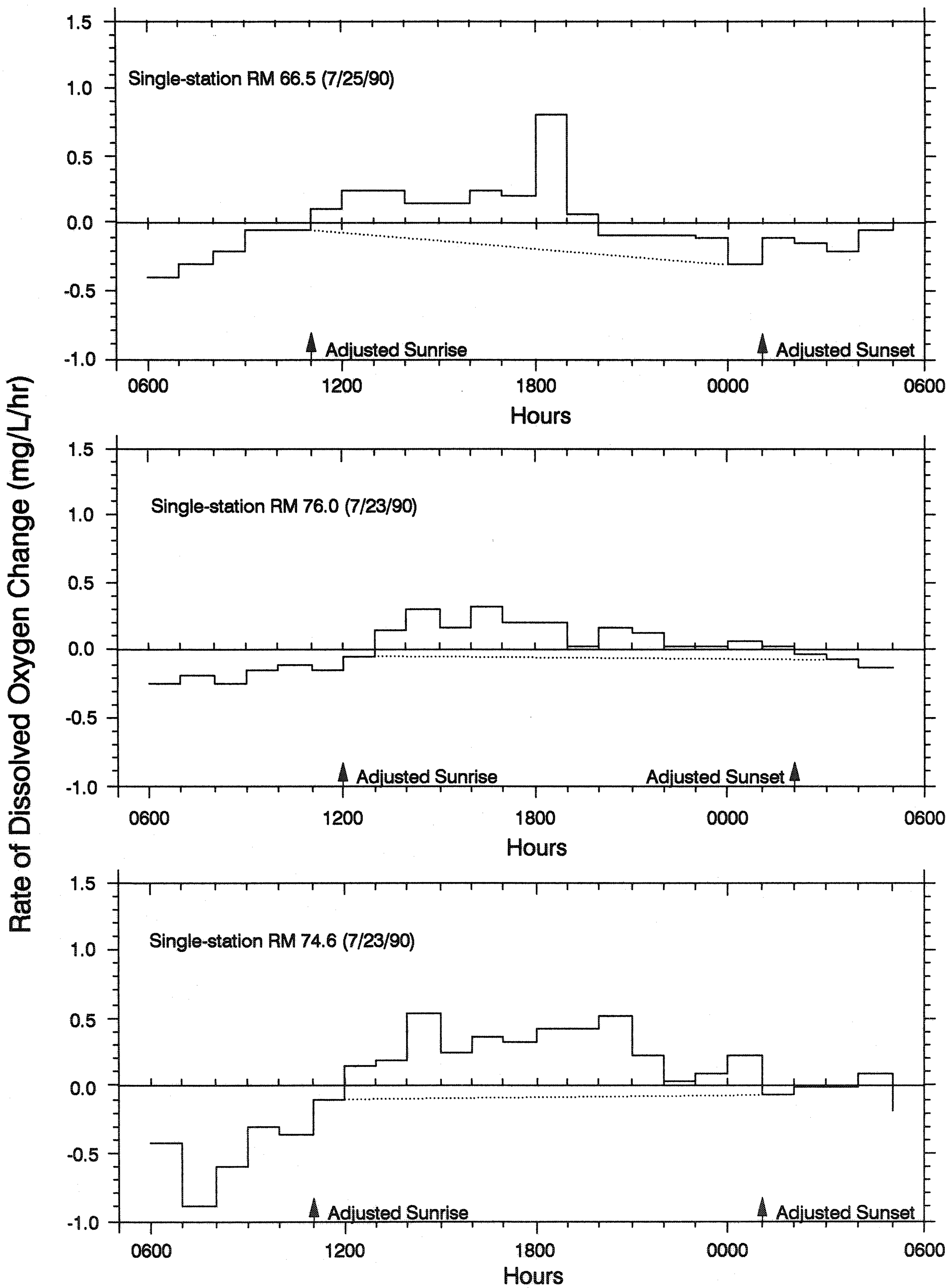
Appendix A5. Summary of dissolved oxygen rate of change for the Pend Oreille River at Davis Estates boat launch (RM 75.1) 8/14–8/15/1990.

Time (hrs)	Temp (°C)	DO (mg/L)	Rate of change (mg/L/hr)	Conc. at saturation (mg/L)	Observed saturation (%)	Average saturation deficit, S (%)	Diffusion S x k/100 (g/m3/hr)	Corrected rate of change (g/m3/hr)
0500	23.5	9.55		8.50	112.4			
0600	23.4	9.40	−0.15	8.51	110.4	11.40	0.012	−0.14
0700	23.3	9.15	−0.25	8.53	107.3	8.84	0.009	−0.24
0800	23.3	9.00	−0.15	8.53	105.5	6.39	0.007	−0.14
0900	23.3	9.00	0.00	8.53	105.5	5.51	0.006	0.01
1000	23.3	8.90	−0.10	8.53	104.3	4.93	0.005	−0.09
1100	23.3	8.90	0.00	8.53	104.3	4.34	0.004	0.00
1200	23.5	8.85	−0.05	8.50	104.1	4.24	0.004	−0.05
1300	23.6	8.60	−0.25	8.48	101.4	2.77	0.003	−0.25
1400	23.8	8.50	−0.10	8.45	100.6	1.00	0.001	−0.10
1500	23.9	9.30	0.80	8.43	110.3	5.43	0.006	0.81
1600	24.3	10.25	0.95	8.37	122.4	16.36	0.017	0.97
1700	24.4	10.40	0.15	8.36	124.5	23.45	0.024	0.17
1800	24.5	10.55	0.15	8.34	126.5	25.48	0.026	0.18
1900	24.5	10.85	0.30	8.34	130.1	28.29	0.028	0.33
2000	24.4	11.00	0.15	8.36	131.6	30.87	0.031	0.18
2100	24.4	11.00	0.00	8.36	131.6	31.65	0.032	0.03
2200	24.2	10.85	−0.15	8.39	129.4	30.51	0.031	−0.12
2300	24.1	10.70	−0.15	8.40	127.3	28.36	0.029	−0.12
0000	24.0	10.55	−0.15	8.42	125.3	26.33	0.027	−0.12
0100	23.9	10.20	−0.35	8.43	120.9	23.13	0.024	−0.33
0200	23.8	9.95	−0.25	8.45	117.8	19.35	0.020	−0.23
0300	23.7	9.70	−0.25	8.47	114.6	16.17	0.016	−0.23
0400	23.6	9.60	−0.10	8.48	113.2	13.88	0.014	−0.09
0500	23.5	9.55	−0.05	8.50	112.4	12.79	0.013	−0.04

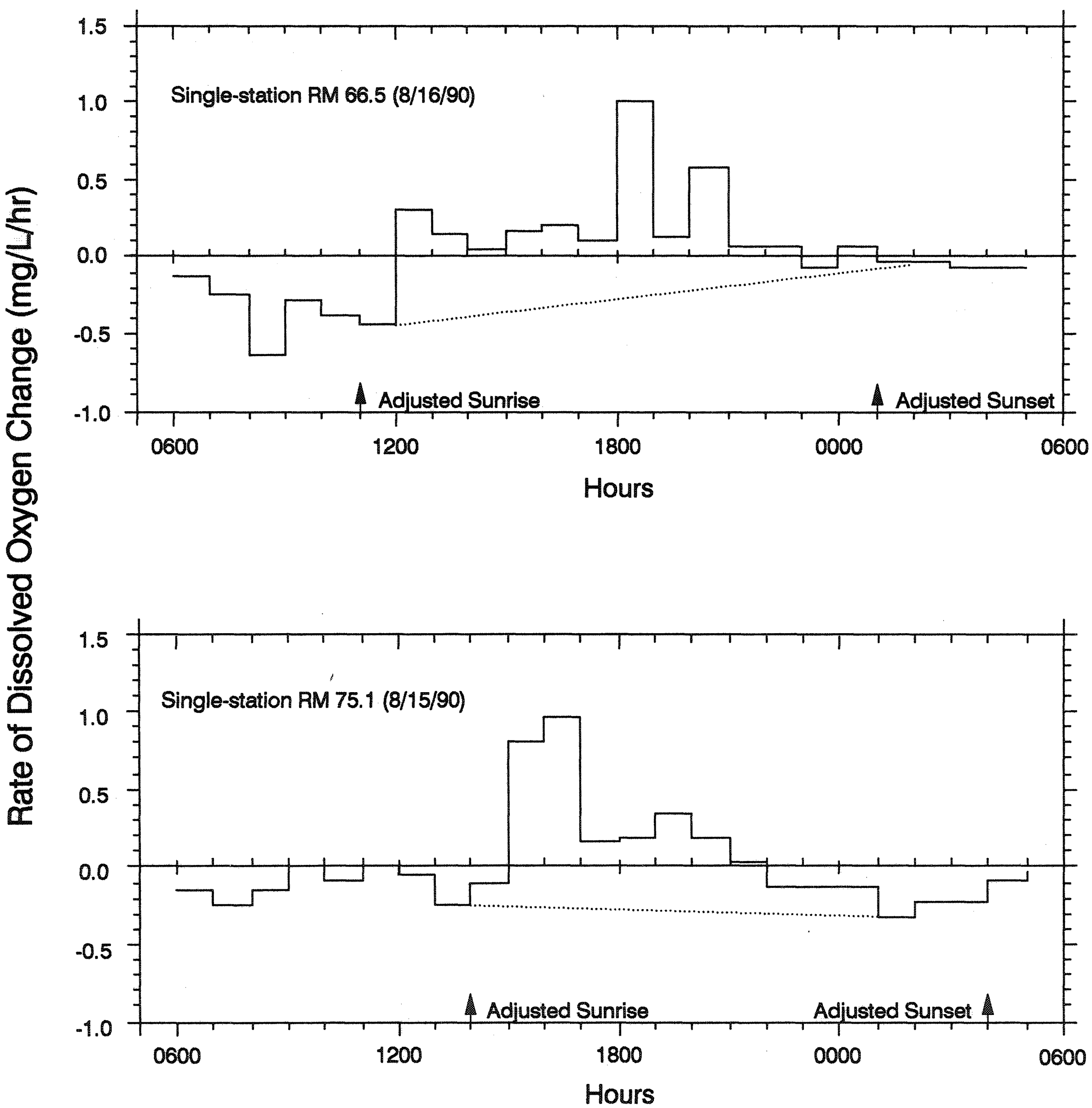
k = Gas transfer coefficient.



Appendix B Example. Diurnal rate of dissolved oxygen change for estimation of primary productivity and respiration.



Appendix B. Diurnal (24-hr) rate of dissolved oxygen change for selected sites on the Pend Oreille River in July, 1990.



Appendix B. Diurnal (24-hr) rate of dissolved oxygen change for selected sites on the Pend Oreille River in August, 1990.

Appendix C1. Nutrient quality control results for standard reference materials, lab check standards, field replicates, lab duplicates, matrix spikes, and blanks.

Parameter (mg/L)	Standard Reference Material measured	Standard Reference Material actual	RPD*	Lab# Check Standards	Field Replicates	RPD	Lab° Duplicates	Matrix@ Spikes	Lab# Blanks	Field Blanks
Ammonia	0.312	0.303	3	0.03	0.021	27	-0.004	116%	0.5	0.01U
NH3-N				0.9	0.016		0.004	103%		
					0.010	0				
					0.010					
Nitrate +	0.887	0.861	3	1.2	0.034	6	0.001	95%	-0.7	0.01U
Nitrite				0.6	0.032		0.000	83%		0.01U
NO2+NO3-N					0.010	0				
					0.010					
Total	0.641	0.661	3	0.5	0.154	57	-0.04»	86%	-0.8	0.01
Persulfate	0.233	0.238	2	1.1	0.086		-0.30»	91%	0.4	
Nitrogen				-0.7	0.506	6	0.005	90%		
TPN				0.7	0.537					
Total	0.297	0.303	2	1.0	0.010	82	0.000	104%	-0.5	0.01U
Phosphorus				0.5	0.024		-0.005	110%		
TP					0.050	0				
					0.050					
Soluable	0.014	0.015	7	-1.4	0.012	8	-0.001	100%	0.8	0.01U
Reactive				-1.0	0.013		0.000	88%		0.01U
Phosphorus					0.010	0				
SRP					0.010					

* Relative percent difference.
\# Value is the amount of one standard deviation.
° Reported value is the difference between the two samples.
@ Matrix spikes are field samples that have been spiked with the analyte at a known concentration; value reported is the percent of the spike recovered.
U Analyte not detected at the detection limit shown.
» Outside acceptable range.

Appendix C2. Biological and physical parameter quality control results for field replicates.

Fecal Coliform (#/100 mL)	RPD*	Fecal Streptococcus (#/100 mL)	RPD	PERIPHYTON Chlorophyll-a (µg/L)	RPD	Pheophytin (µg/L)	RPD	TVS^ (mg/L)	RPD
27	48	37	18	97.5	34	–	–	117	59
44		31		138.0		–		214	
56	26	29	39	11.5	9	11.6	8	26	48
43		43		10.5		12.6		16	
22	0	14	15	13.3	32	12.1	37	15	175
22		12		9.6		8.3		1	
6	67	6	40	53.3	23	51.8	7	31	43
3U		9		42.2		55.6		48	
				7.6	49	8.1	59	12	53
				4.6		4.4		7	
				8.1	15	8.5	2	22	75
				9.4		8.7		10	
				29.9	125	23.2	110	15	40
				6.9		6.7		10	

* Relative percent difference.
^ Total volatile solids.
– No data.
U Analyte not detected at the detection limit shown.