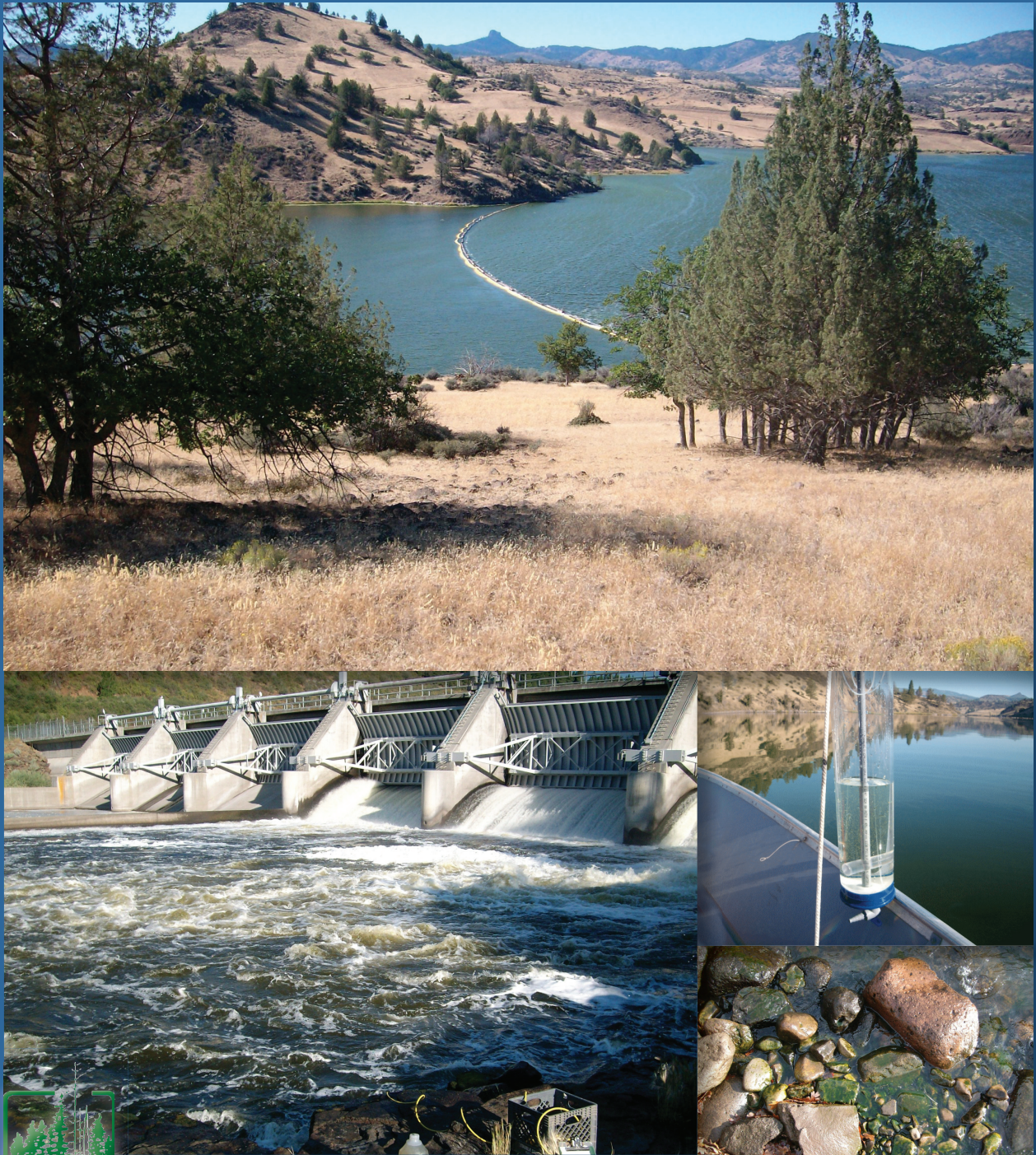


# WATER QUALITY CONDITIONS DURING 2008 IN THE VICINITY OF THE KLAMATH HYDROELECTRIC PROJECT



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# Water Quality Conditions During 2008 in the Vicinity of the Klamath Hydroelectric Project

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## INTRODUCTION

### Introduction

This report presents the results of the monitoring of water quality conditions during 2008 in the vicinity of the Klamath Hydroelectric Project (Project), located along the upper Klamath River in Klamath County, south-central Oregon, and Siskiyou County, northern California.

The water quality monitoring in 2008 was a continuation of similar monitoring conducted by PacifiCorp Energy (PacifiCorp) in 2000, 2001, 2002, 2003, 2004, 2005, and 2007<sup>1</sup> to characterize water quality conditions in the Project area. Results of water quality monitoring in these previous years are described in other documents (PacifiCorp 2004a, 2004b, 2006, 2007a, 2007b; Raymond 2008); these documents and the data are available on PacifiCorp's Project website at <http://www.pacificorp.com/Article/Article82800.html>.

The baseline water quality monitoring was one of several water quality studies conducted by PacifiCorp in the vicinity of the Project during 2008. These studies were conducted to provide information for PacifiCorp's on-going assessment of reservoir management plan (RMP) actions in support of PacifiCorp's application for water quality certification for the Project from the California State Water Quality Control Board (State Water Board) and the Oregon Department of Environmental Quality (ODEQ). The purpose and approach to the water quality monitoring conducted in 2008, as well as the other studies conducted in 2008, were described in PacifiCorp (2008a). The other 2008 studies are the subject of separate reports.

### Description of Program

The objective of the 2008 water quality monitoring program was to gather water quality information on a representative suite of physical, chemical, and biological water quality constituents to characterize water quality in the Klamath River, describe the Project's effects on water quality, and evaluate the effectiveness of Project measures to protect and enhance water quality (as described in the RMPs in PacifiCorp 2008a, 2008b). To achieve this objective selected physical, chemical and biological constituents were measured at frequencies ranging from sub-daily to monthly.

The 2008 water quality monitoring included five components, including:

- measurements of physical water quality parameters (water temperature, dissolved oxygen, pH, and specific conductance) with multi-probe instrumentation;
- grab samples for laboratory analysis of water chemistry (forms of nitrogen and phosphorus, suspended solids, and dissolved organic carbon);
- deployment of a data sonde to continuously record physical water quality parameters in the Klamath River below Iron Gate dam;
- deployment of thermographs to continuously record water temperature at seven sites upstream, within, and downstream of the Project area; and
- sampling for phytoplankton abundance and microcystin at 17 sites, including five sites in the vicinity of Upper Klamath Lake and 12 additional sites upstream, within, and downstream of the Project area.

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<sup>1</sup> Water quality sampling was not conducted in 2006.

This report presents the results of the water chemistry and physical measurements. The phytoplankton abundance and microcystin results will be the subject of another separate report. The results of the data sonde and thermograph deployments will be posted on PacifiCorp's Project website at <http://www.pacificorp.com/Article/Article82800.html>.

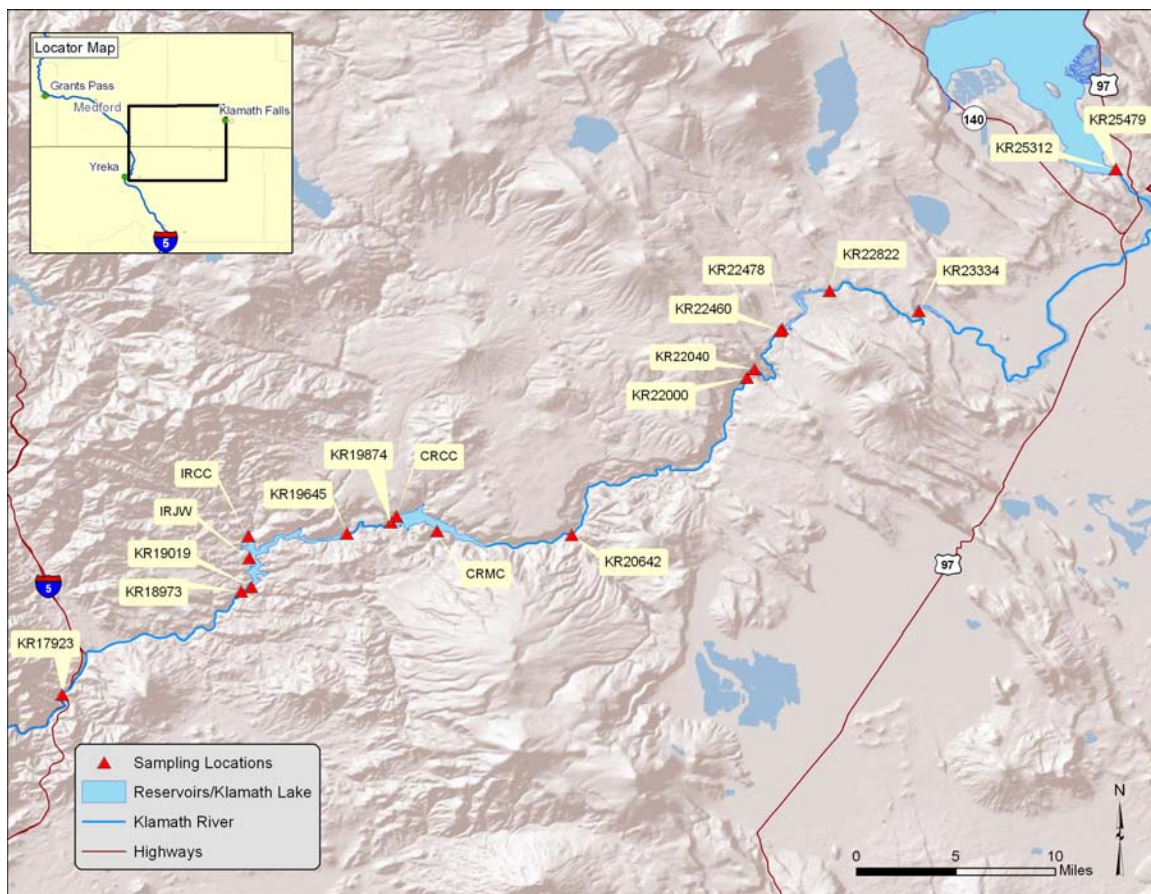
### **Sites**

Physical measurements were made and samples for analysis of water chemistry were collected at 14 river and reservoir sites between Link River and Walker Bridge Road. Table 1 identifies the site locations associated with the five components of the water quality monitoring program. River miles for the site locations refer to distance from the mouth of the Klamath River. Sample site locations on the Klamath River are shown in Figure 1.

**Table 1. Sample sites and associated water quality sub-programs.**

Location	Site ID	River Mile	Chemistry Sampling	Physical Measurements	Data sonde	Thermograph	Phytoplankton Sampling
Upper Klamath Lake near Eagle Ridge ramp	UKER	UKL					X
Upper Klamath Lake near Hagelstein Park	UKHP	UKL					X
Upper Klamath Lake at Wocus Bay	UKWB	UKL					X
Upper Klamath Lake at Pelican Bay ramp	UKPB	UKL					X
Mouth of Link River below Upper Klamath Lake	KR25312	253.1	X	X			X
Klamath R. below Keno dam	KR23334	233.4	X	X		X	X
Klamath R. above J.C. Boyle reservoir	KR22822	228.2	X	X		X	
J.C. Boyle reservoir near dam	KR22478	224.8	X	X			
Below J.C. Boyle Dam	KR22460	224.6	X	X			
Klamath R. below J.C. Boyle powerhouse	KR22000	220.0	X	X		X	
Klamath R. above Shovel Creek	KR20642	206.4	X	X		X	X
Copco reservoir at Mallard Cove ramp	CRMC	201.5					X
Copco reservoir at Copco Cove ramp	CRCC	200.0					X
Copco reservoir lower end at log boom	KR19874, CR01	198.7	X	X		X	X
Klamath R below Copco 2 powerhouse	KR19645	196.3	X	X			
Iron Gate reservoir at Camp Creek area	IRCC	192.8					X
Iron Gate reservoir at Williams boat ramp	IRJW	192.4					X
Iron Gate reservoir lower end above log boom	KR19019, IR01	190.2	X	X		X	X
Iron Gate powerhouse tailwaters	KR19000	190.0	X	X			X
Klamath R. at Iron Gate Hatchery bridge	KR18973	189.7	X	X	X		X
Klamath R. at I-5 Rest Area	KR17923	179.2	X	X		X	X
Klamath R. at Walker Bridge Road	KR15750	157.5	X	X			X





**Figure 1. The locations of PacifiCorp water quality sampling sites during 2007 in the vicinity of the Klamath River Hydroelectric Project.**

Samples were collected at multiple depths in Iron Gate, Copco, and J. C. Boyle reservoirs, and from a single off-shore location at river sites. Temperature data loggers were installed at seven locations in the Klamath River between Keno Dam and the I-5 freeway. A continuous-recording multiprobe data sonde was installed in the Klamath River just below Iron Gate dam.

Results for chemistry sampling and physical measurements are described in this report. Data sonde data are available at the PacifiCorp website. Thermograph data will be made available on the PacifiCorp website.

For the purpose of public health monitoring, samples also were collected at nine of the river and reservoir sites to determine the presence and abundance of the cyanobacteria species *Microcystis aeruginosa* (MSAE) and microcystin, which is a potential toxin that MSAE is capable of producing. Samples for MSAE and microcystin were also collected at eight additional shoreline sites, two each in Copco and Iron Gate reservoirs, and four in Upper Klamath Lake. Samples for chemical analysis were not collected at these additional eight shoreline sites.

### ***Schedule***

Samples for the 2008 water quality monitoring program were collected in January and in April through November. Samples were collected once per month in January, April, May, and November, and every two weeks in June through October.

## **METHODS**

### **Field Methods**

Sampling included instantaneous field measurements of physical parameters (with multi-probe instrumentation) and collection of grab samples for laboratory analysis of water chemistry. Physical measurements for water temperature, pH, conductivity, dissolved oxygen, and oxidation-reduction potential were made using an In-Situ MiniTroll 9000 multiparameter data sonde calibrated according to the manufacturer's instructions prior to each sampling event. Calibration was verified at the close of each sampling event.

In each reservoir, *in situ* depth profile measurements were made to the bottom, at 1 m intervals in J. C. Boyle reservoir, 2 m intervals in Copco reservoir, and 3 m intervals in Iron Gate reservoir. The measurements were taken by lowering a multi-probe sensor unit to the depth intervals indicated above. Measurements at river sites were made by placing the sensor in the flow either by suspending it from a bridge or other structure or by placing it some distance away from the bank.

Water samples were collected using a Kemmerer water sampler. Grab samples from the river sites were collected by lowering the sampler into the current from a bridge, or by tossing the sampler into the current from the shore. The sampler was closed, retrieved, and emptied into a churn splitter that had been well-rinsed with sample water. Repeated casts with the sampler were made to obtain sufficient sample to fill all required sample containers.

Grab samples from the reservoir sites were collected at discrete depths in the reservoirs using a Kemmerer sampler. The sampler was lowered to the desired depth, retrieved, and emptied into the churn splitter for distribution to the sample containers. Four samples were taken from the deepest site in Copco reservoir near the log boom, including at 0.5, 9, 18, and 27 meters below the surface. Five samples were taken from the deepest site in Iron Gate reservoir near the log boom, including at 0.5, 10, 20, 30, and 40 meters below the surface. Two samples were taken from J. C. Boyle reservoir, 0.5 m below the surface and approximately 1 m above the bottom.

In the reservoirs, three phytoplankton samples were collected at each site. One sample, at 0.5 m depth was collected over a horizontal transect, approximately 50 m long, using a modified integrating sampler. A second sample, integrated over a depth of 8 m was collected by lowering a tube to 8 m, closing and retrieving the tube, emptying the tube into a container, mixing, and dispensing the sample into sample containers. A third sample was collected at the surface for public health monitoring.

Phytoplankton samples for public health monitoring (for potentially toxigenic cyanobacteria such as *Microcystis* and microcystin) at the eight shoreline sites and the open reservoir sites in Copco and Iron Gate reservoirs were collected according to the method described by Ahn et al. (2008). The Kemmerer sampler was lowered into the water carefully so as not to disturb any algal scum

that might be present. The sampler was closed to capture a “core” of water extending from the surface to 25 cm depth. The sample was gently mixed in the sampler and dispensed directly into sample containers.

All samples were kept on ice, in the dark, in coolers, and shipped, or hand delivered, to the laboratories to meet specified holding times.

Samples were analyzed for ammonia (NH<sub>3</sub>), nitrate + nitrite (NO<sub>3</sub>), total nitrogen (NT) as N, total phosphorous (PT), orthophosphate (PO<sub>4</sub>) as P, dissolved organic carbon (DOC), total suspended solids (TSS), and volatile suspended solids (VSS) using methods as summarized in Table 2. Samples were also analyzed for algae speciation, density, biovolume, and chlorophyll *a*.

### Lab Methods

Water samples were analyzed for a variety of constituents by the CH2M Hill Applied Sciences Laboratory in Corvallis, Oregon. Phytoplankton samples were analyzed for abundance and species composition by Aquatic Analysts of White Salmon, Washington. Some constituents with

**Table 2. Analytical methods for 2008 water quality sampling.**

Constituent Name	Constituent Code	Analysis Method	MDL	MRL	Units
Dissolved organic carbon	DOC	EPA415.1	0.036	0.5	mg/L
Total nitrogen	NT	SM4500-N B	0.018	0.20	mg/L
Ammonia nitrogen (as N)	NH <sub>3</sub>	EPA350.1	0.0078	0.10	mg/L
Nitrate+nitrite nitrogen (as N)	NO <sub>3</sub>	EPA353.2	0.0057	0.01	mg/L
Total phosphorus (as P)	PT	EPA365.1	0.0078	0.05	mg/L
Orthophosphate (as P)	PO <sub>4</sub>	Field spectrophotometer (EPA365.1)	NA	0.05	mg/L
Total suspended solids	TSS	EPA160.2	1.23	2.0	mg/L
Volatile suspended solids	VSS	EPA160.4	2.46	2.0	mg/L
Chlorophyll <i>a</i>	CHLA	SM10200H.3	0.00001	0.02	µg/L
Alkalinity	ALKT	EPA310.1	2.17	5	mg/L
Phytoplankton abundance	PPLK	SM10200F	1	1	count
Microcystin	MYCN	ELISA	NA	0.16	mg/L
Water temperature	TEMP	In-situ probe	NA	NA	°C
Dissolved oxygen	DOCON	In-situ probe	NA	1.0	mg/L
Specific conductance	SPC	In-situ probe	NA	5	µS/cm
pH	PH	In-situ probe	NA	0.1	units
Color	COLOR	Field spectrophotometer	NA	5	PCU
Turbidity	TURB	Field spectrophotometer (EPA180.1)	NA	0.1	NTU

short hold times were analyzed in the field by E&S Environmental Chemistry using a Hach Model DR2400 field spectrophotometer. The constituents measured and methods used are shown in Table 2.

### **Statistical Methods**

Water quality data gathered in 2008 were examined using a variety of graphical and numerical methods. Graphics methods included boxplots, scatterplots, and bar graphs. Numerical methods included calculation of summary statistics, comparison of confidence intervals, linear and non-linear regression. Graphical and numerical methods were carried out using a variety of statistical software including Minitab<sup>®</sup>, Statistix9<sup>®</sup>, XLStat<sup>®</sup>, and SigmaPlot<sup>®</sup>.

### **Quality Assurance**

The Klamath relicensing water quality activities follow a defined quality control program (PacifiCorp 2008d) that includes internal quality control by the laboratories, external quality control by field crews, and functional quality control by administrative oversight.

The laboratory internal quality control follows the guidelines of the National Environmental Laboratory Accreditation Conference (EPA 2003), and includes the scrutiny of samples when delivered, and analysis of internal blanks and reference standards. When discrepancies are noted, or internal checks are not met, exception reports are generated and samples are reanalyzed.

The external quality assurance (QA) program operates through the use of field blanks, replicate samples, spikes, and reference standards. Field blanks, replicates, spikes, and reference standards are submitted to the lab at least once for every sample batch, and comprise approximately 10 percent of all samples analyzed. If data quality objectives are not met for the QA samples, they are reanalyzed. All external QA check samples submitted to the laboratories are blind samples (sample is not identified as an external check sample). If the original analysis is not confirmed the entire batch may be reanalyzed.

The functional quality control (QC) program operates through careful training of field workers, careful scrutiny of data and field practice, and active laboratory oversight. When data are received they are examined for any anomalous values. If a suspected outlier is identified, the field notes are examined to verify that all is in order, the field staff are interviewed to identify any conditions that may have affected the sample, the laboratory results sheets are examined, and the laboratory program manager contacted to verify the result. If no explanation for the anomalous value can be found, it is retained in the data set.

Data quality objectives are established for the external QA check samples submitted to the laboratories with the regular samples. These objectives establish whether data generated from the laboratory analyses are reliable. For this program, data quality objectives are established for accuracy, precision, and completeness.

Accuracy is a measure of the degree of agreement of a measurement with an accepted reference or true value. It is most frequently expressed as percent recovery. Percent recovery is a measure of accuracy determined from comparison of a reported spike value to its true spike concentration. For spike sample analysis, recovery should be 80 to 120 percent except when sample value

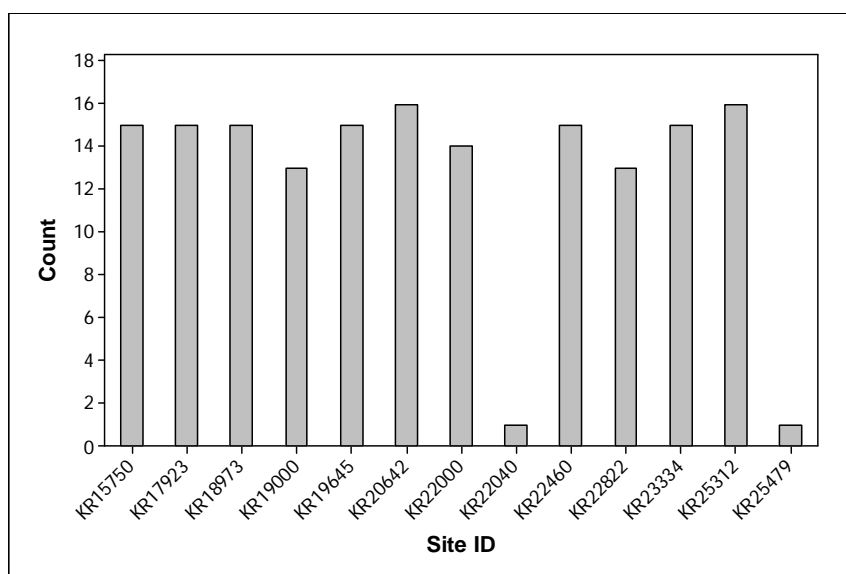
exceeds spike concentration by more than five times. For reference materials, recovery should be 80 to 120 percent of certified value for values more than 20 times the method reporting limit (MRL). For values less than 20 times the MRL, recovery should be  $\pm$  two times the MRL from the certified value. Blank concentration should be less than 10 percent of lowest sample concentration or less than or equal to two times the MRL.

Precision is a measure of the mutual agreement (or variability) among individual measurements of the same property, and is usually expressed as relative percent difference (RPD). For duplicates, the RPD should be 20 percent or less for values greater than five times the MRL. For values less than or equal to five times the MRL, values may vary  $\pm$  the MRL.

Completeness is the measure of the number of valid measurements obtained from a measurement system compared to the total number of measurements that was expected to be obtained under correct normal sampling conditions. It is usually expressed as a percentage. For sampling and analysis under this program, a completeness objective of at least 90 percent has been established.

## RESULTS

This section presents the results obtained during 2008 of physical water quality measurements and analysis of water chemistry. The results are presented below in separate sections for river sites and reservoir sites. There were a total of 490 samples collected for water quality and phytoplankton analyses in 2008. There were 15 planned sampling events, although the number of sample visits to each site varied somewhat as shown in Figure 2. Sampling in the Iron Gate dam tailrace (KR19000) started in June, the J. C. Boyle bypass reach (KR22040) and Upper Klamath Lake at Fremont Bridge (KR25479) were sampled only in January, and access to the sites below J. C. Boyle powerhouse (KR22000) and above J. C. Boyle reservoir (KR22822) was occasionally blocked by deep snow or mud.



**Figure 2. The number of sampling visits to sites on the Klamath River during 2008.**



## River Sites

Water quality conditions at the river sites varied by season and through the Project area. Mean and median values for constituents measured in 2008 are shown in Table 3. Additional summary statistics are provided in Appendix A.

### Temperature

Water temperatures measured in the Klamath River in the vicinity of the Project ranged from a minimum of 0.3 °C below J.C. Boyle dam in January to a maximum of 23.7 °C below J. C. Boyle dam in June. Mean temperature for all sites and dates was 16.1 °C. Temperature tends to increase with distance downstream from Link River, but the trend is inconsistent between months, and is not statistically significant ( $P = 0.223$ ) as seen in Figure 3a. Water temperature exhibited a clear seasonal cycle (Figure 3b).

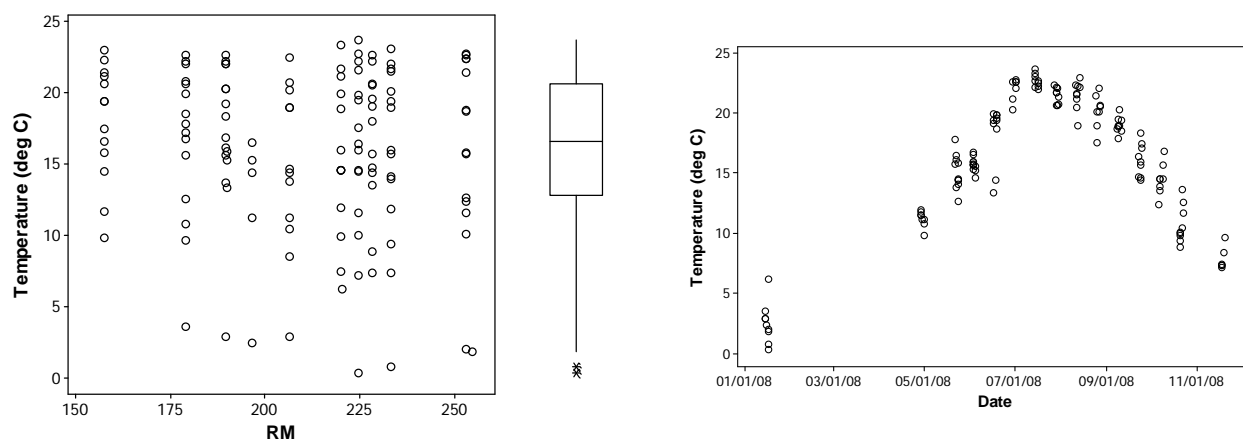
**Table 3. Mean and median values for constituents measured at sites in the Klamath River in 2008.**

Variable	Variable Code	Units	N	Mean	Median
Alkalinity	ALKT	mg/L as CaCO <sub>3</sub>	152	67.2	66.3
Chlorophyll a	CHLA	µg/L	107	20.26	4.37
Apparent color	COLOR	Pt-Co units	151	87	74
Dissolved organic carbon	DOC	mg/L	144	7.6	7.1
Dissolved oxygen concentration	DOCON	mg/L	133	9.1	9.1
Dissolved oxygen saturation	DOPER	Percent	133	102	102
Ammonia nitrogen	NH3N	mg/L as N	151	0.18	0.05
Nitrate plus nitrite nitrogen	NO3N	mg/L as N	151	0.53	0.60
Total nitrogen	NT	mg/L as N	143	1.28	1.20
pH	pH	units	133	8.1	8.1
Orthophosphate phosphorus	PO4P	mg/L as P	127	0.15	0.15
Total phosphorus	PT	mg/L as P	149	0.16	0.14
Specific conductance	SPC	µS/cm at 25°C	131	179	174
Water temperature	TEMP	°C	132	16.1	16.6
Total suspended solids	TSS	mg/L	152	4.73	3.60
Turbidity	TURB	NTU	148	3.8	2.5
Volatile suspended solids	VSS	mg/L	152	2.29	1.60

**Table 4. Summary statistics for water temperature (°C) measured in the Klamath River in 2008.**

N	132	SE Mean	0.5	1st Quartile	12.8	Maximum	23.7
Mean	16.1	C.V.	35.2	Median	16.6	MAD <sup>a</sup>	4.0
Std Deviation	5.6	Minimum	0.3	3rd Quartile	20.64		

<sup>a</sup> MAD = median absolute deviation



**Figure 3. Water temperature values measured at various sites in the Klamath River in 2008, plotted against river mile (left) and date (right). Site ID and locations are listed in Table 1.**

### *pH*

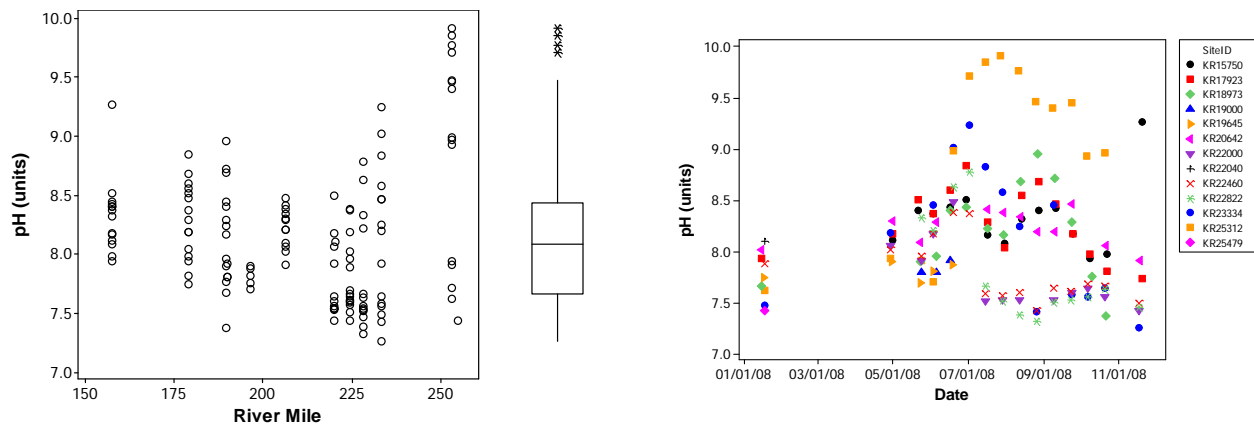
Values for pH in 2008 ranged from a low of 7.3 on November 18 below Keno dam (KR23334) to a high 9.9 at the mouth of Link River (KR25312) on July 28. Average pH for all sites and dates was 8.1. There was no trend in magnitude of pH with distance downstream from Link River, but the variability of pH values tended to decrease with distance downstream. Winter and fall values for pH tended to be lower and less variable among the sites than summer values as shown in Figure 4b. Beginning in late June, pH values at Link River (KR25312) were notably higher than values elsewhere in the Project. At the same time pH values in the Klamath River above J. C. Boyle reservoir (KR22822), below J. C. Boyle dam (KR22460), and below J. C. Boyle powerhouse (KR22000) were noticeably lower than at sites farther downstream.

**Table 5. Summary statistics for pH (units) measured in the Klamath River in 2008.**

N	133	SE Mean	0.05	1st Quartile	7.7	Maximum	9.9
Mean	8.1	C.V.	7.0	Median	8.1	MAD	0.4
Std Deviation	6.6	Minimum	7.3	3rd Quartile	8.4		

### *Dissolved Oxygen*

The lowest dissolved oxygen concentration in 2008 was 5.2 mg/L recorded below Keno dam (KR23334) on July 15. The highest dissolved oxygen concentration recorded in 2008 was 13.4 mg/L below J. C. Boyle dam (KR22460) on January 17. Average dissolved oxygen concentration for all sites and dates was 9.1 mg/L. Dissolved oxygen concentration exhibited both seasonal



**Figure 4.** pH values measured at various sites in the Klamath River in 2008, plotted against river mile (left) and date (right). Site ID and locations are listed in Table 1.

and spatial trends, increasing with distance downstream from Link River, and decreasing from January through October (Figures 5a and 5b). These trends may result from the increase in the partial pressure of dissolved in the atmosphere at lower elevation and the decrease in the solubility of oxygen in water at higher temperatures. Values for dissolved oxygen as percent saturation would not exhibit such change with elevation or temperature

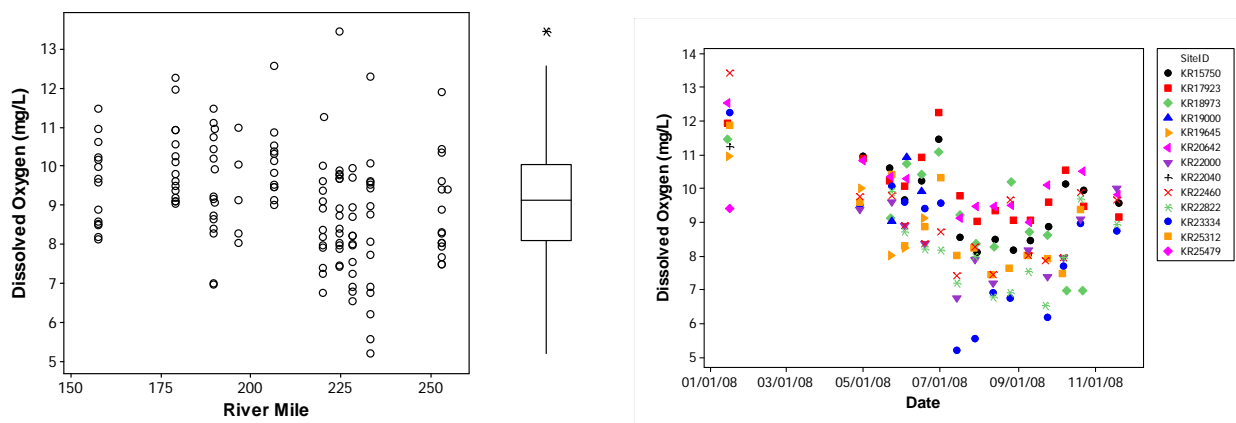
**Table 6.** Summary statistics for dissolved oxygen concentration (mg/L) measured in the Klamath River in 2008.

N	133	SE Mean	0.12	1st Quartile	8.1	Maximum	13.4
Mean	9.1	C.V.	15.8	Median	9.1	MAD	0.95
Std Deviation	1.44	Minimum	5.2	3rd Quartile	10.0		

Dissolved oxygen percent saturation ranged from a low of 70.6 percent measured below Keno dam (KR23334) on July 15 to a high of 153.8 percent measured at the I-5 freeway (KR17923) on June 30. Average percent saturation for all sites and dates was 102.2 percent. Percent saturation showed statistically significant trends with both distance downstream<sup>2</sup> and season<sup>3</sup>. As seen in Figure 6a, percent saturation was high at Link River (RM 253), was lower in the reach between Keno dam and below J. C. Boyle powerhouse (RM 233 – 220) and then increased to a local maximum near the I-5 freeway (RM 179). Seasonally, percent saturation was highest in mid summer and low during the winter (Figure 6b).

<sup>2</sup> DOPer = - 826.1 + 14.26 RM - 0.07135 RM\*\*2 + 0.000116 RM\*\*3, P = 0.005

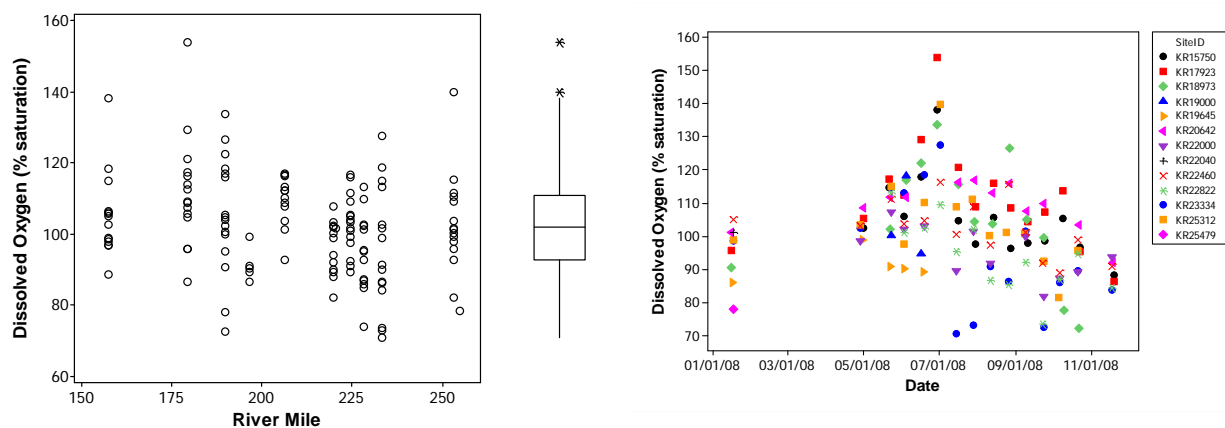
<sup>3</sup> DOPer = - 1249026 + 63.09 Date - 0.000797 Date\*\*2, P = 0.000



**Figure 5.** Dissolved oxygen concentration values measured at various sites in the Klamath River in 2008, plotted against river mile (left) and date (right). Site ID and locations are listed in Table 1.

**Table 7.** Summary statistics for dissolved oxygen saturation (percent) measured in the Klamath River in 2008.

N	133	SE Mean	1.2	1st Quartile	92.4	Maximum	153.8
Mean	102.2	C.V.	13.6	Median	101.7	MAD	9.3
Std Deviation	13.9	Minimum	70.6	3rd Quartile	110.8		



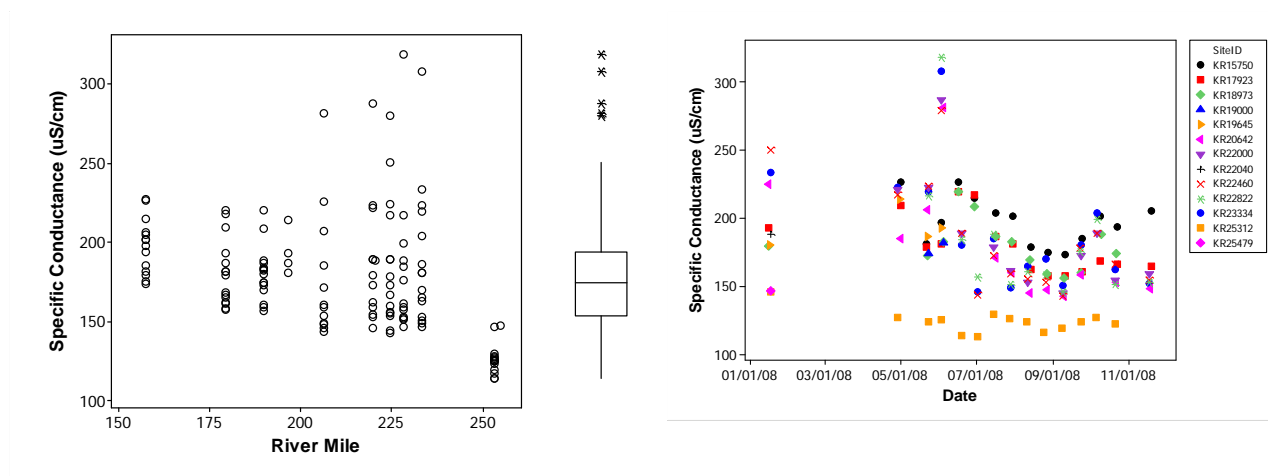
**Figure 6.** Dissolved oxygen saturation values measured at various sites in the Klamath River in 2008, plotted against river mile (left) and date (right). Site ID and locations are listed in Table 1.

### Specific Conductance

Specific conductance<sup>4</sup> (SPC) values ranged from a minimum of 114  $\mu\text{S}/\text{cm}$  measured at Link River (KR25312) on July 2 to a maximum of 319  $\mu\text{S}/\text{cm}$  measured above J. C. Boyle reservoir (KR22822) on June 3. Mean SPC for all sites and dates was 178  $\mu\text{S}/\text{cm}$ . Figure 7a illustrates the increase in SPC with distance downstream from Link River<sup>5</sup>. The change in SPC between Link River (RM 253) and Keno dam (RM 233) is particularly notable, and suggests that there is a source of water with high dissolved solids into Lake Ewauna or Keno reservoir. SPC decreases through the year from April into September<sup>6</sup>, but then increases at most sites below Link River in October as shown in Figure 7b. The range of difference in SPC between Link River and Keno dam frequently exceeds the range of all other sites on a given date, with the exception of the site at Walker Bridge (KR15750, RM 157).

**Table 8. Summary statistics for specific conductance ( $\mu\text{S}/\text{cm}$ ) measured in the Klamath River in 2008.**

N	131	SE Mean	3.2	1st Quartile	153	Maximum	319
Mean	178	C.V.	20.9	Median	174	MAD	20.1
Std Deviation	37.2	Minimum	114	3rd Quartile	194		



**Figure 7. Specific conductance values measured at various sites in the Klamath River in 2008, plotted against river mile (left) and date (right). Site ID and locations are listed in Table 1.**

<sup>4</sup> Specific conductance is conductivity adjusted to 25°C to remove the effect of temperature variation between measurements.

<sup>5</sup>  $\text{SPC} = 265.2 - 0.4144 \text{ RM}$ ,  $P = 0.000$

<sup>6</sup>  $\text{SPC} = 7489 - 0.1844 \text{ Date}$ ,  $P = 0.000$

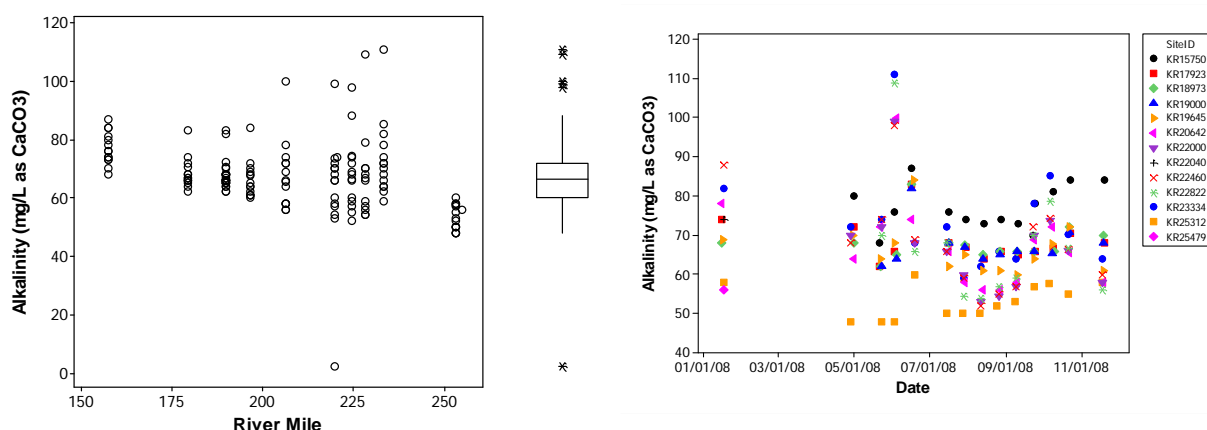


## Alkalinity

The minimum value for alkalinity, aside from one very low outlier, was 48 mg/L (as CaCO<sub>3</sub>) measured at Link River (RM 253) on May 24. The maximum value was 111 mg/L measured below Keno dam (RM 233) on June 3. The average alkalinity for all sites and dates was 67.2 mg/L. Alkalinity is largely a function dissolved ions, so the patterns of alkalinity were similar to the patterns of SPC, which is also a function of dissolved ions. The changes in alkalinity with time and distance were not as pronounced as SPC, but the patterns were the same. Link River typically had the lowest alkalinity and the Klamath River at Walker Bridge road typically had the highest (Figure 8).

**Table 9. Summary statistics for alkalinity (mg/L as CaCO<sub>3</sub>) measured in the Klamath River in 2008.**

N	152	SE Mean	0.9	1st Quartile	60	Maximum	111
Mean	67	C.V.	18	Median	66	MAD	5.7
Std Deviation	12.0	Minimum	2	3rd Quartile	72		



**Figure 8. Alkalinity values measured at various sites in the Klamath River in 2008, plotted against river mile (left) and date (right). Site ID and locations are listed in Table 1.**

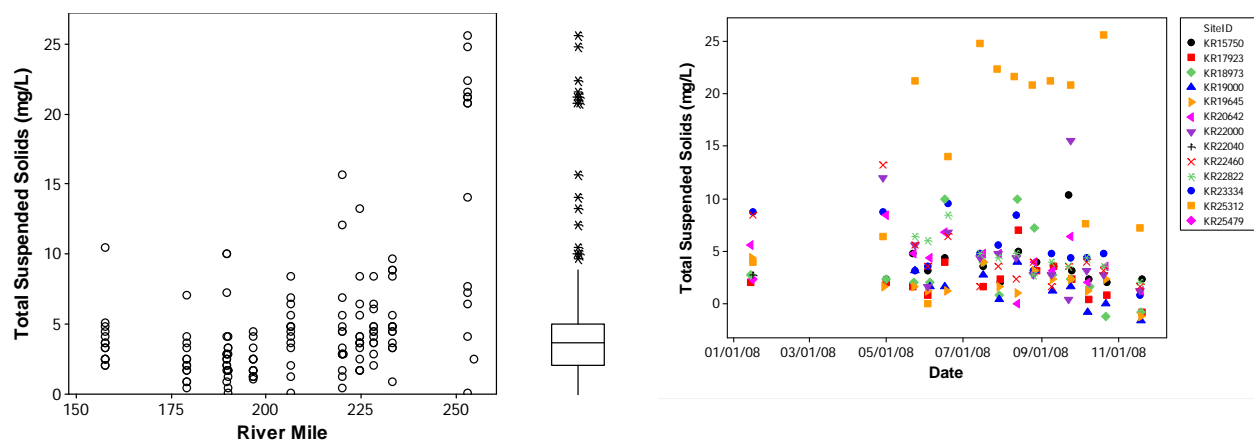
## Suspended Solids

Total suspended solids values in 2008 ranged from 0 mg/L to 25.6 mg/L (Table 10). The lowest value was recorded in the Iron Gate dam tailrace (KR19000) on November 19. The highest value was measured in Link River on October 21. The eight highest values for TSS, all greater than 20 mg/L were measured in Link River between June and October (Figure 9). The average suspended solids for all samples was 4.7 mg/L. A strong seasonal trend was not observed in the TSS data, but there was a highly significant decrease in TSS with distance downstream from Link River<sup>7</sup>.

<sup>7</sup> TSS = 98.89 - 1.028 RM + 0.002722 RM\*\*2, P = 0.000.

**Table 10. Summary statistics for total suspended solids (mg/L) measured in the Klamath River in 2008.**

N	152	SE Mean	0.4	1st Quartile	2.0	Maximum	25.6
Mean	4.7	C.V.	107.1	Median	3.6	MAD	1.6
Std Deviation	5.1	Minimum	-1.6 <sup>8</sup>	3rd Quartile	4.95		



**Figure 9. Total suspended solids values measured at various sites in the Klamath River in 2008, plotted against river mile (left) and date (right). Site ID and locations are listed in Table 1.**

### Color

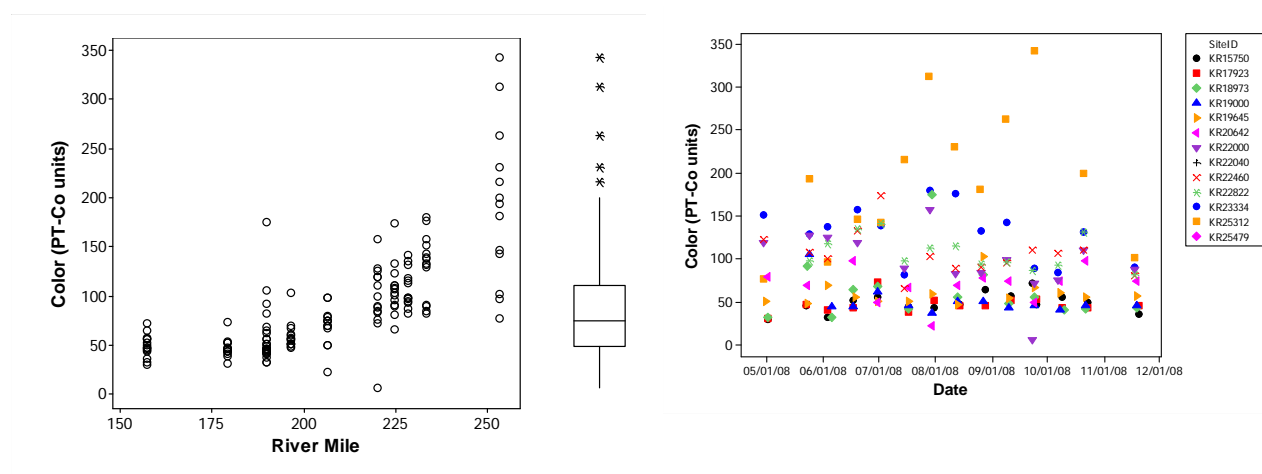
Color ranged from 6 Pt-Co units, measured below the J. C. Boyle powerhouse (KR22000, RM 220) on September 23, to 342 units measured at Link River on September 22 (Table 11). The seven highest values for color were obtained on samples from Link River. The low value for color was measured below the J. C. Boyle powerhouse. Based on values for other constituents, this measurement was taken when the generator units were shut down, and thus represents ground water from the bypass reach (Figure 10). The mean value for color for all samples was 87.2 Pt-Co units. There was no seasonal trend in the color data, but there was a highly significant decrease in color with distance downstream from Link River<sup>9</sup>.

<sup>8</sup> Users of environmental data sets must resolve the problem of censored data; data that are reported as “not detected” or “less than” some value. Statistical analysis of such data requires that the censored data be given a value. Many procedures have been used, but all present difficulties (Helsel 2006). Based on experience and statistical advice, we have chosen the actual value returned by the analytical method as the best estimator of low values. Values reported by the laboratory are reported in the data set. Values that are below the MRL are considered estimated values. Occasionally, with samples of very low concentration, the laboratory analytical procedure will return a negative value. These values are retained in the data set, and may be treated as desired by users of the data (for example, marked as ND, considered as zero values, or defined by some other method).

<sup>9</sup> Color = 694.4 - 7.538 RM + 0.02190 RM\*\*2, P = 0.000.

**Table 11. Summary statistics for color (Pt-Co units) measured in the Klamath River in 2008.**

N	151	SE Mean	4.3	1st Quartile	48	Maximum	342
Mean	87.2	C.V.	60.8	Median	74	MAD	27
Std Deviation	53.0	Minimum	6	3rd Quartile	110		

**Figure 10. Color values measured at various sites in the Klamath River in 2008, plotted against river mile (left) and date (right). Site ID and locations are listed in Table 1.**

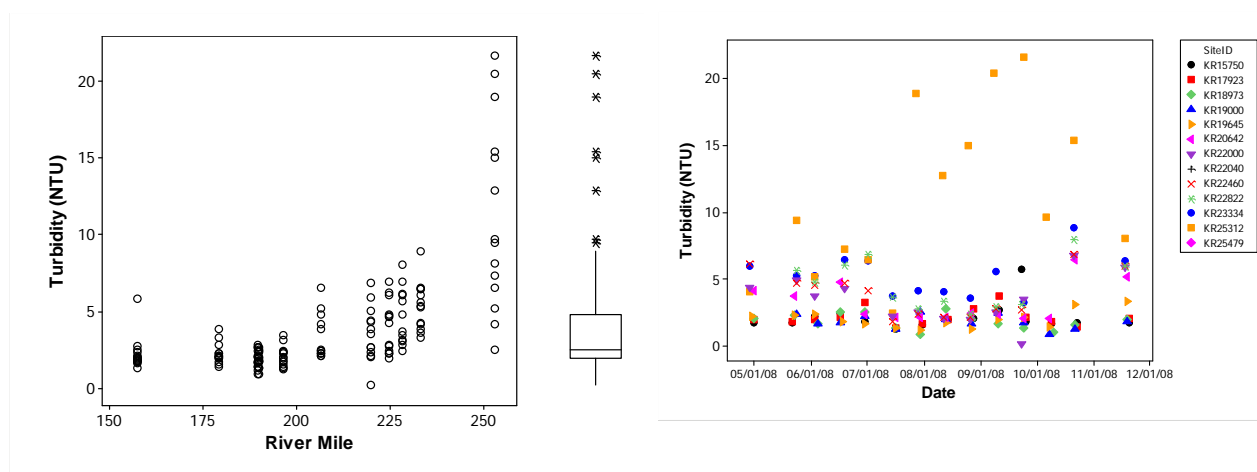
### ***Turbidity***

The minimum turbidity value in 2008, 0.2 NTU, was measured below the J. C. Boyle powerhouse on September 23 (Table 12). The maximum value, 21.6 NTU was measured at Link River on September 22. The eight highest turbidity values in 2008, ranging from 9.4 to 21 NTU, were measured at Link River. The average turbidity for all samples was 3.8 NTU. Other than a shift at Link River from relatively low values in the early summer to high values in August through October, there was no significant seasonal pattern in turbidity values (Figure 11). There was, however, a highly significant decrease in turbidity with distance downstream from Link River<sup>10</sup>.

**Table 12. Summary statistics for turbidity (NTU) measured in the Klamath River in 2008.**

N	148	SE Mean	0.28	1st Quartile	1.9	Maximum	21.6
Mean	3.8	C.V.	90.0	Median	2.5	MAD	0.8
Std Deviation	3.4	Minimum	0.2	3rd Quartile	4.7		

<sup>10</sup> Turbidity = 62.52 - 0.6645 RM + 0.001811 RM\*\*2, P = 0.000.



**Figure 11.** Turbidity values measured at various sites in the Klamath River in 2008, plotted against river mile (left) and date (right). Site ID and locations are listed in Table 1.

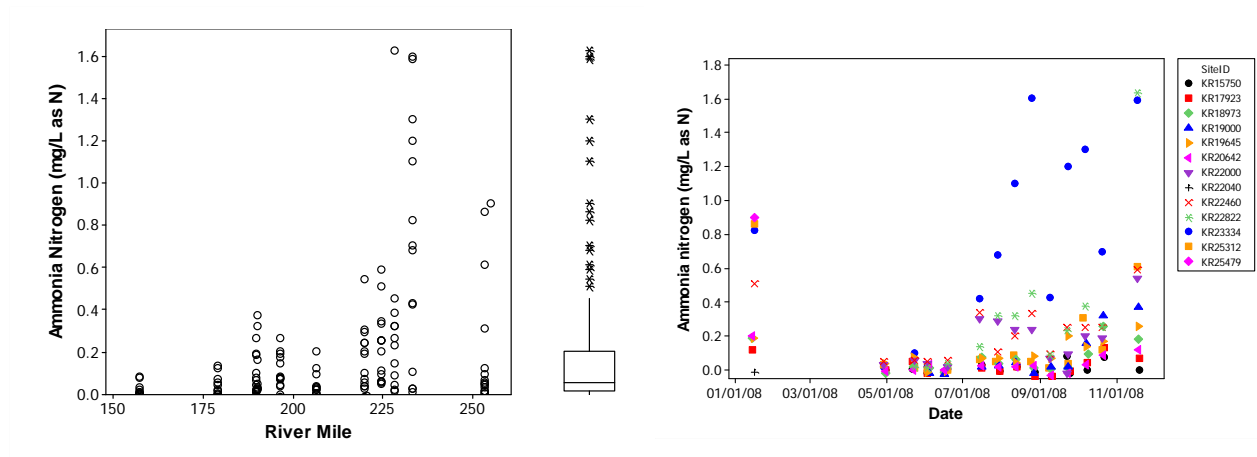
### *Ammonia Nitrogen*

Ammonia nitrogen (NH<sub>3</sub>) ranged from 0 mg/L (as N) to 1.63 mg/L (Table 13). The minimum value was recorded at Walker Bridge Road on September 11; the maximum value was measured above J. C. Boyle reservoir (KR22822, RM 228) on November 18. With two exceptions in January and November the highest NH<sub>3</sub> values on any date were measured at the site below Keno dam (KR23334, RB 233; Figure 12). In November the NH<sub>3</sub> values below Keno dam and above J. C. Boyle reservoir were nearly equal. The average NH<sub>3</sub> value for all sites and dates was 0.176 mg/L. NH<sub>3</sub> exhibited a statistically significant seasonal pattern with high values in the winter (January and November) decreasing to low values in April through June. As with several other constituents, NH<sub>3</sub> values experienced a significant decrease with distance below Link River<sup>11</sup>

**Table 13. Summary statistics for ammonia-nitrogen (mg/L as N) measured in the Klamath River in 2008.**

N	151	SE Mean	0.026	1st Quartile	0.01	Maximum	1.63
Mean	0.18	C.V.	177.82	Median	0.05	MAD	0.058
Std Deviation	0.31	Minimum	-0.04	3rd Quartile	0.20		

<sup>11</sup> NH<sub>3</sub> = - 0.7844 + 0.004626 RM, P = 0.000.



**Figure 12. Ammonia nitrogen values measured at various sites in the Klamath River in 2008, plotted against river mile (left) and date (right). Site ID and locations are listed in Table 1.**

### *Nitrate plus Nitrite Nitrogen*

Nitrate plus nitrite nitrogen (NO<sub>3</sub>) ranged from 0 mg/L (as N) to 1.05 mg/L (Table 14). The lowest value was measured below Keno dam (KR23334, RM 233) on July 15. One very high value of 2.44 mg/L was measured in the Klamath River above Shovel Creek (KR20643, RM 206) on November 19. The next highest value, 1.05 mg/L, was measured above J. C. Boyle reservoir on August 26. The average of all NO<sub>3</sub> values was 0.56 mg/L as N. NO<sub>3</sub> showed statistically significant trends with both distance downstream from Link River<sup>12</sup> and time of year<sup>13</sup>. NO<sub>3</sub> was generally quite low in Link River and below Keno dam, but increased substantially above J. C. Boyle reservoir. From above J. C. Boyle reservoir NO<sub>3</sub> decreased steadily to the I-5 freeway (Figure 13a). Seasonally, NO<sub>3</sub> was relatively high in January, and low in April. Values increased from May through November, except at Link River (KR23512) and Keno dam (KR23334), which remained low (Figure 13b).

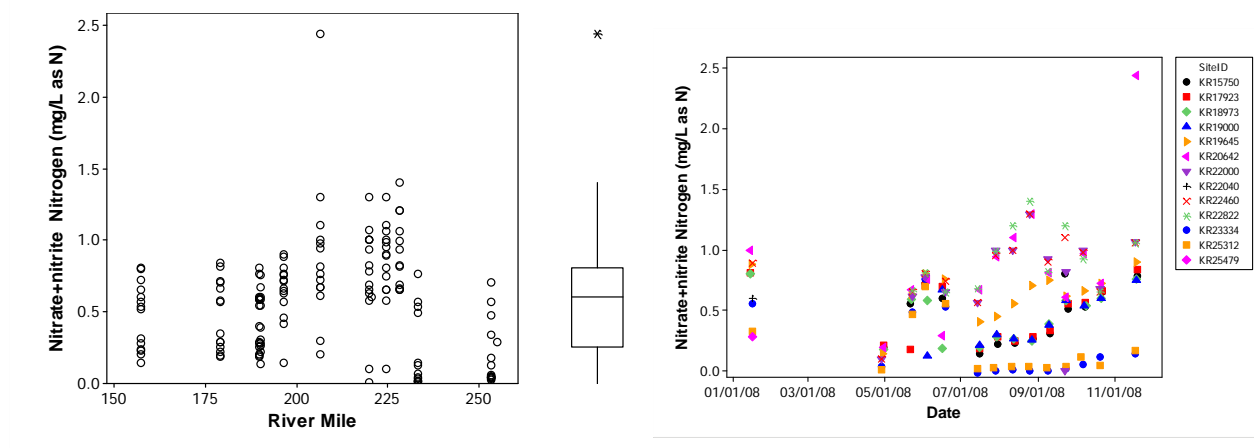
**Table 14. Summary statistics for nitrate+nitrite nitrogen (mg/L as N) measured in the Klamath River in 2008.**

N	151	SE Mean	0.031	1st Quartile	0.25	Maximum	2.44
Mean	0.56	C.V.	66.78	Median	0.60	MAD	0.29
Std Deviation	0.376	Minimum	-0.016	3rd Quartile	0.80		

<sup>12</sup> NO<sub>3</sub> = - 6.723 + 0.07255 RM - 0.000177 RM\*\*2, P = 0.000

<sup>13</sup> NO<sub>3</sub> = 17377 - 0.8776 Date + 0.000011 Date\*\*2, P = 0.005





**Figure 13. Nitrate + nitrite nitrogen values measured at various sites in the Klamath River in 2008, plotted against river mile (left) and date (right). Site ID and locations are listed in Table 1.**

### Total Nitrogen

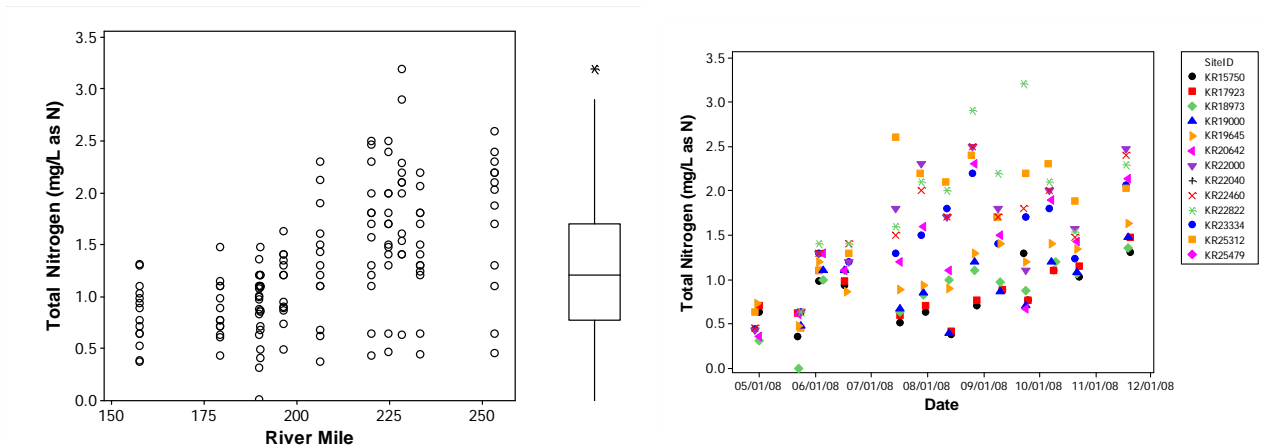
Total nitrogen ranged from 0 mg/L (as N) to 3.20 mg/L (Table 15). The lowest value was measured below J. C. Boyle powerhouse on September 23, when the generator units were shut down and the water was primarily ground water from the bypass reach. The next lowest value, 0.03 mg/L, was measured at the hatchery bridge below Iron Gate dam (KR18973) on May 1. The maximum value was measured above J. C. Boyle reservoir (KR22822, RM 228) on September 23. The average total nitrogen value for all samples was 1.28 mg/L. Total nitrogen showed a statistically significant seasonal trend<sup>14</sup>, increasing from May through November, and a significant decreasing trend from Link River to Walker Bridge<sup>15</sup> (Figure 14).

**Table 15. Summary statistics for total nitrogen (mg/L as N) measured in the Klamath River in 2008.**

N	143	SE Mean	0.053	1st Quartile	0.77	Maximum	3.20
Mean	1.28	C.V.	49.29	Median	1.20	MAD	0.43
Std Deviation	0.63	Minimum	-0.30	3rd Quartile	1.70		

<sup>14</sup> NT = - 200.1 + 0.005075 Date, P = 0.000

<sup>15</sup> NT = - 1.300 + 0.01247 RM, P = 0.000



**Figure 14.** Total nitrogen values measured at various sites in the Klamath River in 2008, plotted against river mile (left) and date (right). Site ID and locations are listed in Table 1.

### *Orthophosphate Phosphorus*

The lowest orthophosphate (PO<sub>4</sub>) value was 0.02 mg/L (as P) measured below the J. C. Boyle powerhouse on September 23, and on January 17 at Link River (KR25312) and in Upper Klamath Lake at the Fremont Street bridge (KR25479). The highest value was 0.42 mg/L measured at the I-5 freeway on May 22 (Table 16). The next highest value, 0.29 mg/L was measured downstream at Walker Bridge, also on May 22. The average PO<sub>4</sub> values for all samples in 2008 was 0.15 mg/L. Values for PO<sub>4</sub> increased noticeably between Link River and Keno dam, but otherwise showed no significant trend with distance (Figure 15). PO<sub>4</sub> values did have a significant seasonal trend, increasing from low values in the winter to higher values in the summer, and then decreasing again in the late fall.<sup>16</sup>

**Table 16.** Summary statistics for orthophosphate (mg/L as P) measured in the Klamath River in 2008.

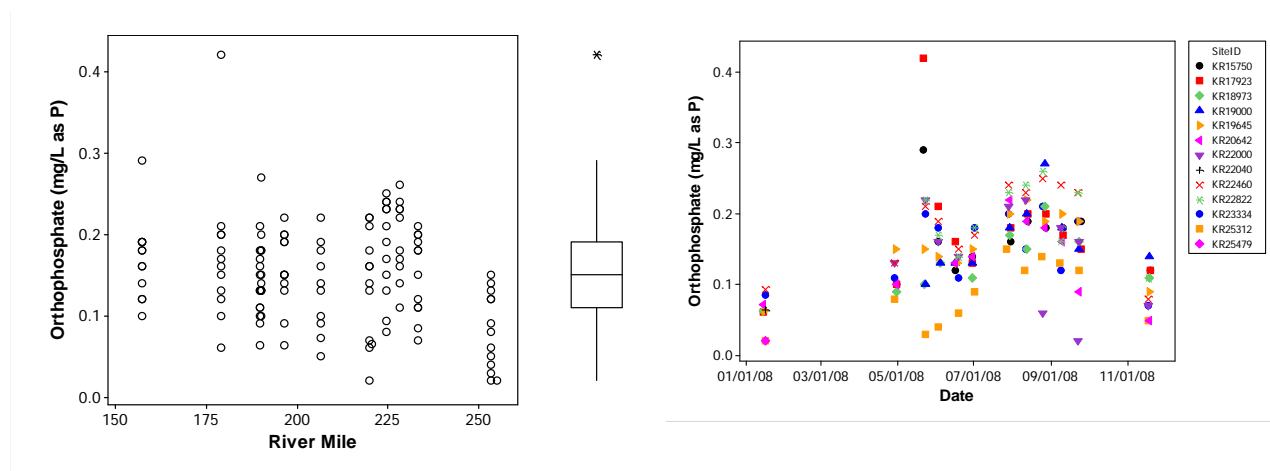
N	127	SE Mean	0.03	1st Quartile	0.11	Maximum	0.42
Mean	0.15	C.V.	41.20	Median	0.15	MAD	0.04
Std Deviation	0.06	Minimum	0.02	3rd Quartile	0.19		

### *Total Phosphorus*

The lowest total phosphorus value was measured below J. C. Boyle powerhouse on September 23 in water that was mostly ground water from the J. C. Boyle bypass reach. The next lowest value, 0.023 mg/L (as P) was measured at Link River on June 3 (Table 17). The highest value, 0.72 mg/L, was measured above J. C. Boyle reservoir on September 23. In contrast with PO<sub>4</sub>, total phosphorus showed a strong decreasing trend with distance downstream from Link River<sup>17</sup>, but had a weak seasonal association similar to PO<sub>4</sub>. Lower values were observed in the winter and fall and higher values in the summer (Figures 16a and 16b).

<sup>16</sup> PO<sub>4</sub> = - 5740 + 0.2895 Date - 0.000004 Date\*\*2, P = 0.000

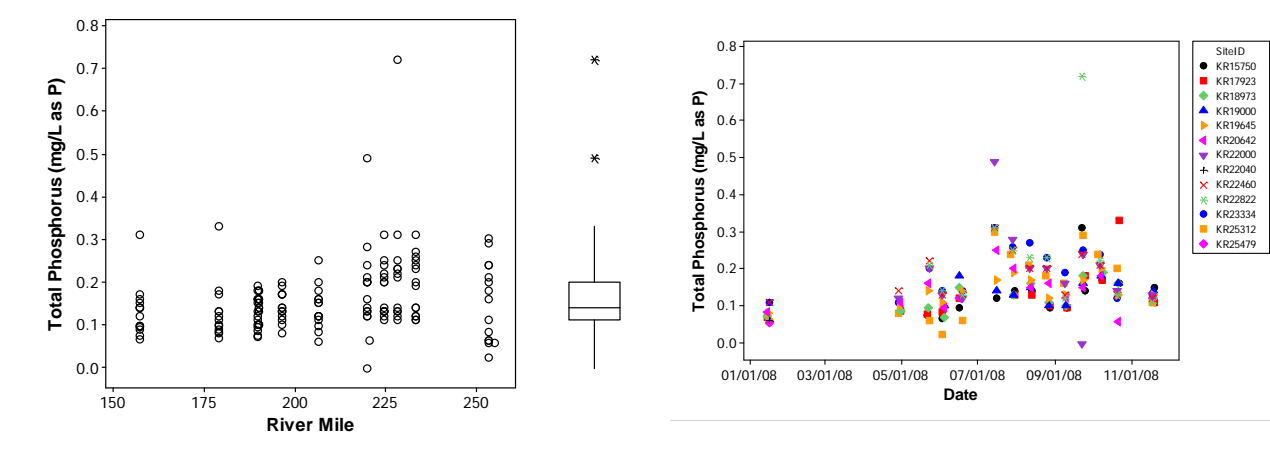
<sup>17</sup> PT = 0.00585 + 0.000733 RM, P = 0.004



**Figure 15. Orthophosphate values measured at various sites in the Klamath River in 2008, plotted against river mile (left) and date (right). Site ID and locations are listed in Table 1.**

**Table 17. Summary statistics for total phosphorus (mg/L as P) measured in the Klamath River in 2008.**

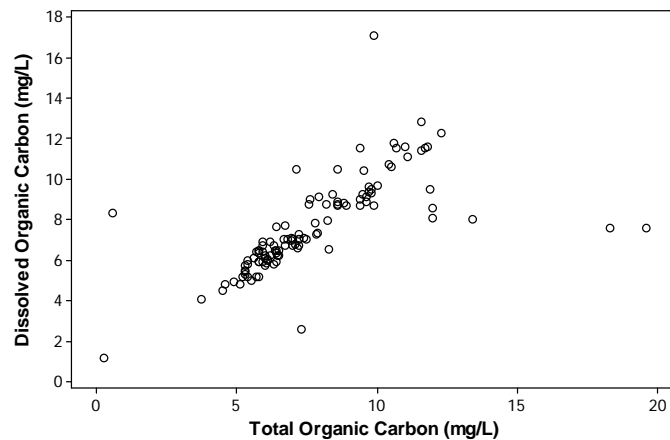
N	149	SE Mean	0.007	1st Quartile	0.11	Maximum	0.72
Mean	0.158	C.V.	52.820	Median	0.14	MAD	0.04
Std Deviation	0.084	Minimum	-0.003	3rd Quartile	0.2		



**Figure 16. Total phosphorus values measured at various sites in the Klamath River in 2008, plotted against river mile (left) and date (right). Site ID and locations are listed in Table 1.**

### ***Dissolved and Total Organic Carbon***

Dissolved organic carbon (DOC) and total organic carbon (TOC) have been measured for several years on samples from the Project as part of the water quality monitoring program. Past measurements for TOC have been unreliable because of the inability of the analytical method to adequately accommodate samples with significant particulate matter. In 2008, modifications were made to the instrument in an attempt to resolve the problem. The attempt was apparently unsuccessful. A majority (54 percent) of the TOC values were equal to or less than DOC; an unlikely result in a system with such high algal populations (Figure 17). TOC will not be considered further.



**Figure 17. Scatterplot showing the relationship between dissolved organic carbon and total organic carbon measured on samples from the Klamath River during 2008. The nearly 1:1 ratio suggests that the analytical method did not accurately assess TOC concentration.**

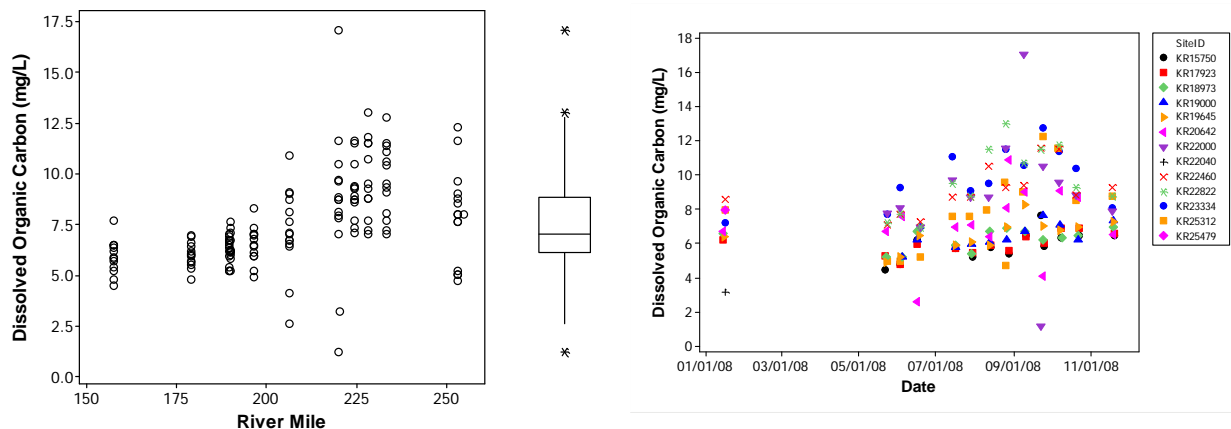
The lowest value for DOC, 1.2 mg/L, was recorded below J. C. Boyle powerhouse on September 23 when flow was dominated by input from the J. C. Boyle bypass reach where substantial groundwater accretion occurs. The highest value, 17.1 mg/L, was recorded below J. C. Boyle powerhouse on September 9 when flow was dominated by releases from the J. C. Boyle powerhouse. The average DOC value for all samples was 7.57 mg/L. DOC showed a significant seasonal trend<sup>18</sup>, increasing through the year with markedly greater variability among sites in the late summer (Figure 18b). DOC decreased with distance below Link River<sup>19</sup> (Figure 18a).

**Table 18. Summary statistics for dissolved organic carbon (mg/L) measured in the Klamath River in 2008.**

N	144	SE Mean	0.19	1st Quartile	6.12	Maximum	17.1
Mean	7.6	C.V.	29.3	Median	7.1	MAD	1.2
Std Deviation	2.25	Minimum	1.2	3rd Quartile	8.8		

<sup>18</sup> DOC = - 325.6 + 0.008400 Date, P = 0.001

<sup>19</sup> DOC = - 1.193 + 0.04218 RM, P = 0.000



**Figure 18.** Dissolved organic carbon values measured at various sites in the Klamath River in 2008, plotted against river mile (left) and date (right). Site ID and locations are listed in Table 1.

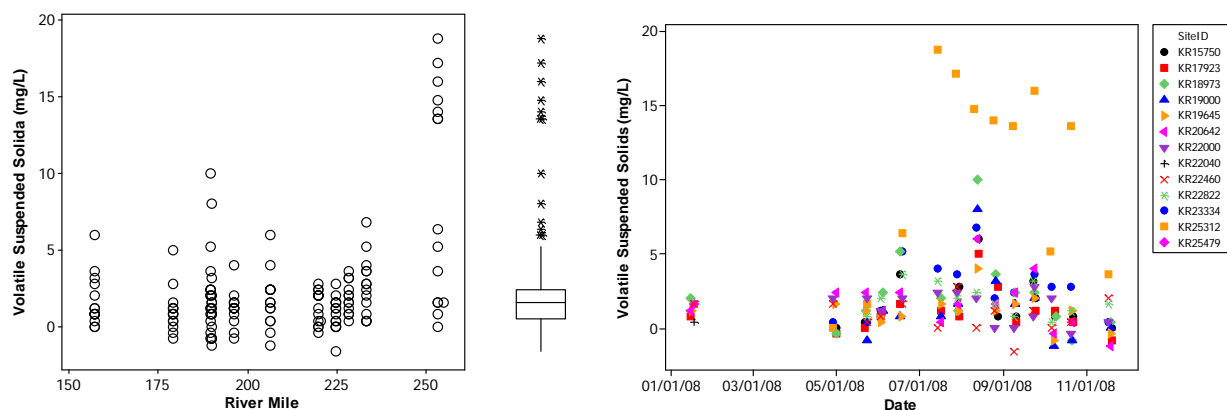
### *Volatile Suspended Solids*

Volatile suspended solids (VSS) were measured in 2008 as an estimator of TOC. The results are presented in Figures 19a and 19b. Summertime values for VSS at Link River (KR25312) were markedly higher than at other sites. No significant trends with distance or season were noted.

**Table 18. Summary statistics for volatile suspended solids (mg/L) measured in the Klamath River in 2008.**

N	152	SE Mean	0.26	1st Quartile	0.7	Maximum	18.8
Mean	2.3	C.V.	1.48	Median	1.6	MAD	0.8
Std Deviation	3.4	Minimum	-1.2	3rd Quartile	8.8		





**Figure 19. Volatile suspended solids values measured at various sites in the Klamath River in 2008, plotted against river mile (left) and date (right). Site ID and locations are listed in Table 1.**

## Reservoir Sites

Measurements of physical variables were made in J. C. Boyle, Copco, and Iron Gate reservoirs in 2008. In each reservoir, measurements were made for water temperature, SPC, dissolved oxygen concentration, dissolved oxygen saturation, and pH at intervals from the surface to the bottom; 1 m intervals in J. C. Boyle reservoir, 2 m in Copco reservoir, and 3 m in Iron Gate reservoir. Measurements were made at the log boom or cable line near the dam at approximately the deepest point in the reservoir. Water samples were also collected at this location from various depths in each reservoir (0.5 and 8 m in J. C. Boyle reservoir, 0.5, 9, 18, and 27 m in Copco reservoir, and 0.5, 10, 20, 30, and 40 m in Iron Gate reservoir) and analyzed for water chemistry constituents (i.e., nutrients, suspended solids, and dissolved organic carbon). Results from each reservoir are presented in the following sections.

### *J. C. Boyle Reservoir*

Summary statistics for the water quality constituents measured in J. C. Boyle reservoir are provided in Table 19.

#### *Physical Conditions*

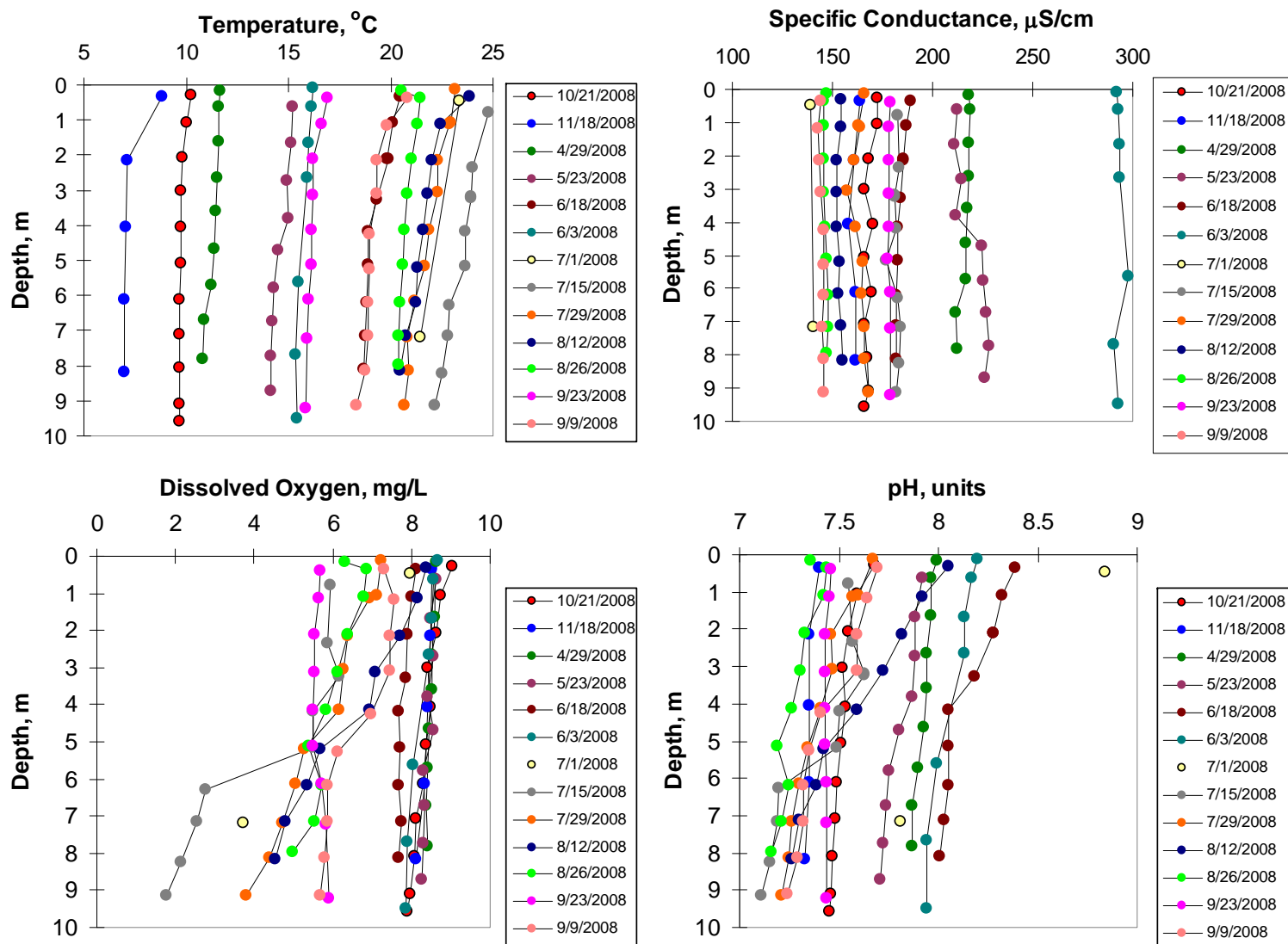
Results of vertical profile measurements in J. C. Boyle reservoir are presented in Figure 20. J. C. Boyle reservoir has a short residence time, on the order of hours, and is typically well-mixed vertically. This well-mixed condition was reflected in 2008 by the changes in SPC from one sampling event to the next, and in the vertical uniformity of the SPC profiles. SPC values were generally in the range of 150-190  $\mu\text{S}/\text{cm}$ , with higher values in the spring, and one notably high value near 300  $\mu\text{S}/\text{cm}$  on June 3.

**Table 19. Summary statistics for water quality constituents measured in J. C. Boyle reservoir in 2008.**

Constituent	N	Mean	Std. Dev.	SE Mean	C.V.	Minimum	1st Quartile	Median	3rd Quartile	Maximum	MAD
ALKT	24	66	12	2.51	18.52	54	56.50	66.40	70	101	6.9
CHLA	10	21.46	23.36	7.39	108.85	1.06	1.81	8.22	44.22	59.56	7.07
COLOR	26	107	23	4.62	21.95	71	89	107.50	119	169	15
DOC	22	9.33	1.86	0.40	19.97	6.1	7.7	9.6	10.6	13	1.36
DOCON	112	6.94	1.60	0.15	23.10	1.8	5.75	7.5	8.4	9.1	1.04
DOPER	112	82.26	16.58	1.57	20.16	23.3	73.0	84.4	94.4	114.2	10.4
MCYN	6	0.10	0.04	0.02	38.37	0.05	0.06	0.10	0.13	0.16	0.03
NH3	24	0.23	0.19	0.04	84.45	0.02	0.05	0.26	0.30	0.69	0.176
NO3	24	0.79	0.30	0.06	37.96	0.09	0.60	0.82	1.00	1.30	0.18
NT	24	1.61	0.60	0.12	37.02	0.57	1.15	1.58	2.27	2.60	0.55
PHYCO	12	0.05	0.02	0.01	41.56	0.02	0.04	0.06	0.06	0.11	0.00
PO4	22	0.17	0.07	0.02	40.78	0.00	0.14	0.19	0.23	0.25	0.04
PT	24	0.19	0.06	0.01	33.12	0.12	0.13	0.19	0.24	0.34	0.05
SPC	112	181	37	3.6	20.7	139	154	171	185	297	16.3
TSS	24	4.0	2.2	0.46	55.8	0.8	2.1	3.6	5.5	8.8	1.6
TEMP	112	17.4	4.8	0.46	27.9	7.0	14.2	18.9	21.2	24.8	3.1
PH	112	7.63	0.33	0.03	4.34	7.1	7.4	7.5	7.9	8.8	0.22

A similar pattern was observed in temperature values with generally uniform temperatures vertically that change from one sampling period to the next. Temperatures increased from approximately 11 °C on April 29 to between 23 to 25 °C on July 15, then decreased to a seasonal low of approximately 7 °C on November 18. J. C. Boyle reservoir was not sampled in January 2008 because the surface was frozen. Although J. C. Boyle reservoir does not stratify in the classical sense of a temperature driven density gradient that develops through surface warming and isolates the deeper water from contact with the atmosphere, a relatively small temperature gradient of 1-3 °C persisted from mid June through mid September. This gradient may result from density-driven interflow of Klamath River water at different depths through the reservoir as a result of the diurnal fluctuation in river water temperature.

As a result of the high oxygen demand of the inflow from the Klamath River, dissolved oxygen saturation in J. C. Boyle was less than 100 percent at all depths and for all measurement events with the exception of near surface values in May and June and on August 12. An example of the effect of that oxygen demand can be seen in the dissolved oxygen profile from September 23 when the entire depth of the profile was below 70 percent saturation (6 mg/L) while the profiles of September 9 and October 21 are generally well above 70 percent saturation. The combination of the high oxygen demand and the resistance to vertical mixing imposed by the summertime temperature gradient resulted in a vertical gradient in dissolved oxygen that persisted from early July into mid September. Dissolved oxygen concentration at depth decreased rapidly from June 18 to a minimum of less than 2 mg/L on July 15 then increased through the rest of the year.



**Figure 20. The results of vertical profile measurements for water temperature, specific conductance, dissolved oxygen, and pH taken in J. C. Boyle reservoir in 2008.**

Values of pH exhibited a slight vertical gradient throughout the year. From July 15 through November, pH values generally ranged between 7.1 and 7.7 at all depths. In May through June, especially above 6 m depth, pH values were higher, generally greater than 7.8. On June 3 and June 18 pH exceeded 8.0 at depths less than 6 m. One value exceeded 8.5; 8.8 was measured at the surface on July 1.

### *Nutrients*

Nutrients (N and P) were measured on samples collected from J. C. Boyle reservoir throughout the year at 0.5 m and 8 m depths. The results of analysis for nutrients are presented in Figure 21. The values for nitrate-nitrogen and total nitrogen at 0.5 m and 8 m track closely with few exceptions. On June 19 both nitrate-nitrogen and total nitrogen at 8 m were lower than at 0.5 m. Ammonia nitrogen, however, showed a systematic difference between 0.5 m samples and 8 m samples. Ammonia nitrogen at 8 m depth increased relative to the concentration at 0.5 m during the period in July and August when a temperature gradient persisted in the reservoir and dissolved oxygen at depth fell to low levels.

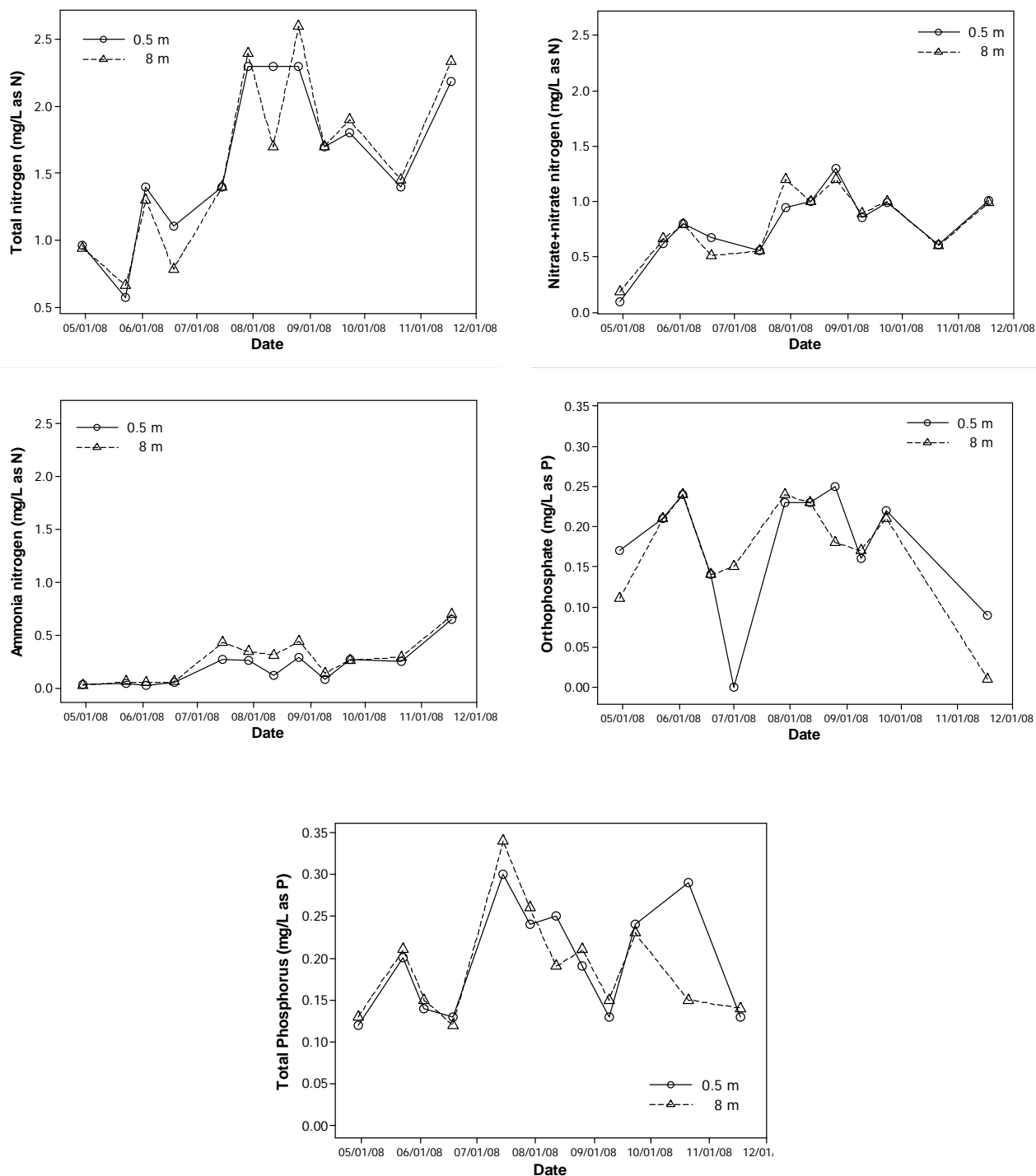
Total phosphorus values at 0.5 m and 8 m were also quite similar through the year with the notable exception of October 21 when total P concentration near the surface was nearly twice as high as at 8 m. Orthophosphate values at 8 m were lower than near the surface during the winter (January and November) but similar during the rest of the year with the exception of July 1 when PO<sub>4</sub> at the surface was markedly lower than at 8 m.

### *Other Constituents*

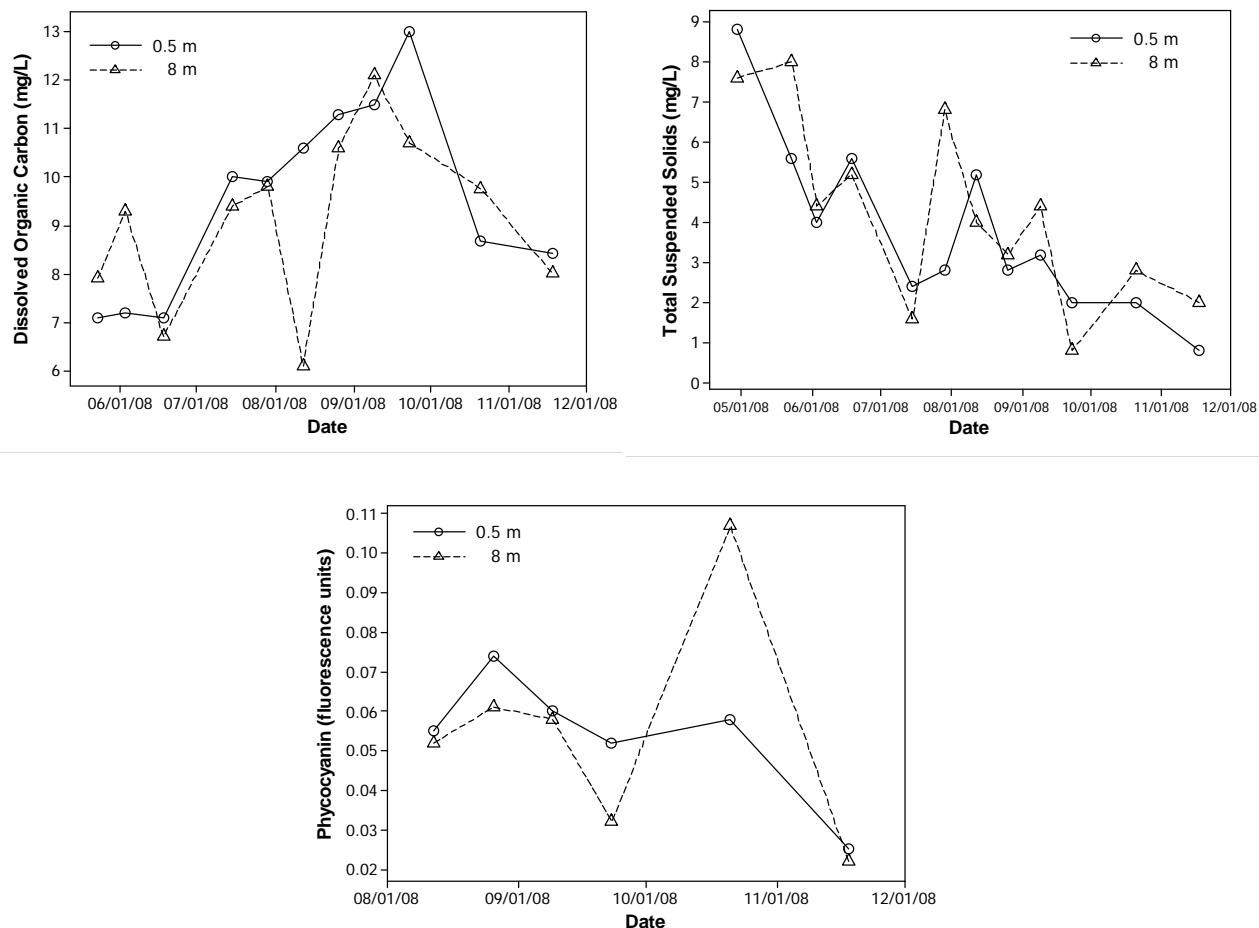
Total suspended solids, dissolved organic carbon, and phycocyanin, a cyanobacterial pigment, were also measured in J. C. Boyle reservoir. The data for these constituents are presented in Figure 22. Dissolved organic carbon increased steadily in the surface of J. C. Boyle reservoir from May through late September when it started to decline. The pattern was similar, but more variable, at 8 m. DOC reached its seasonal peak and began declining two weeks earlier than near the surface, and one low value (6.12 mg/L) was recorded at depth on August 12.

The trend for TSS, at both 0.5 m and 8 m, was the opposite of that for DOC—a steady, if irregular, decline from June through November. Suspended solids increased sharply both at the surface and at depth in late August and early September.

Phycocyanin, a pigment found in cyanobacteria, was measured in J. C. Boyle reservoir beginning in August. The overall trends at both 0.5 m and 8 m were similar although the magnitude of the changes from one sampling event to the next varied between 0.5 and 8 m. A notable feature of the seasonal pattern of phycocyanin concentration is the dramatic increase in concentration at 8 m between September 23 and October 21. This could be the effect of a late season release of cyanobacteria from Upper Klamath Lake.



**Figure 21. The results of analysis for nitrogen and phosphorus of water samples collected at 0.5 m and 8 m depths in J. C. Boyle reservoir in 2008.**



**Figure 22. The results of analysis for dissolved organic carbon, total suspended solids, and phycocyanin of water samples collected at 0.5 m and 8 m depths in J. C. Boyle reservoir in 2008.**

### ***Copco and Iron Gate Reservoirs***

Measurements were made in Copco and Iron Gate reservoirs to support the development of reservoir management plans, and to continue the development of a baseline water quality data base to better understand the conditions that influence water quality in the reservoirs. Summary statistics for the constituents measured in Copco and Iron Gate reservoirs are provided in Tables 20 and 21.

**Table 20. Summary statistics for constituents measured in Copco Reservoir in 2008.**

Constituent	N	Mean	Std. Dev.	SE Mean	C.V.	Minimum	1st Quartile	Median	3rd Quartile	Maximum	MAD
ALKT	56	72	11	1.4	15	60	64	69	79.5	101	6.5
CHLA	23	21.79	22.17	4.62	101.73	0.03	2.13	19.30	32.04	99.30	15.40
COLOR	56	65	32	4.2	49	32	47	58	98	226	11
DOC	52	6.4	0.9	0.12	13.4	4.2	5.8	6.4	7.1	7.9	0.6
DOCON	218	6.0	3.6	0.2	60	0.3	2.6	7.2	8.6	13.2	2.3
DOPER	218	64.6	39.2	2.7	60.8	2.9	28.8	73.6	94.8	167	27.6
MCYN	11	4.06	7.76	2.34	191.2	0.05	0.11	0.18	2.71	23.08	0.13
NH3	56	0.36	0.59	0.08	162.67	-0.02	0.05	0.15	0.33	2.80	0.10
NO3	56	0.53	0.30	0.04	55.78	-0.02	0.29	0.64	0.75	0.89	0.18
NT	52	1.07	0.35	0.05	32.73	0.32	0.82	1.10	1.30	1.80	0.24
PHYCO	28	0.14	0.29	0.06	207.81	0.01	0.02	0.03	0.06	10.1	0.01
PO4	48	0.32	0.30	0.04	94	0.06	0.14	0.19	0.36	1.36	0.08
PT	55	0.24	0.24	0.03	99.4	0.07	0.13	0.16	0.25	1.20	0.05
SPC	218	194	29	2	15	150	171	086	219	302	20
TKN	4	1.38	0.10	0.05	6.96	1.30	1.30	1.35	1.48	1.50	0.05
TSS	56	3.21	5.47	0.73	170	-.080	1.20	1.60	3.20	38	0.80
TEMP	218	14.2	4.9	0.3	34.4	2.4	11.1	13.2	17.9	23.4	3.1
PH	218	7.6	0.5	0.03	6.3	6.8	7.2	7.6	7.8	9.0	0.3

**Table 21. Summary statistics for constituents measured in Iron Gate Reservoir in 2008.**

Constituent	N	Mean	Std. Dev.	SE Mean	C.V.	Minimum	1st Quartile	Median	3rd Quartile	Maximum	MAD
ALKT	70	75	7.8	.93	10.4	60	67	74.5	82	86	7.5
CHLA	31	20.26	26.34	4.73	130.00	0.24	2.00	19.94	22.84	128.00	13.62
COLOR	69	81	52	6.3	65	31	46	61	97	247	19
DOC	64	5.7	0.8	0.1	13.7	4.2	5.2	5.5	6.2	7.8	0.5
DOCON	222	4.9	4.4	0.3	89.0	0.2	0.8	4.2	7.4	23.1	3.4
DOPER	222	51.2	46.8	3.1	91.3	2.0	7.9	42.6	80.1	219.8	34.8
MCYN	15	6.12	15.33	3.96	250	0.04	-0.10	0.14	2.34	57.37	0.09
NH3	70	0.09	0.13	0.02	141	-0.1	0.00	0.03	0.20	0.44	0.06
NO3	70	0.72	0.37	0.04	50.72	-0.02	0.54	0.68	0.91	1.6	0.16
NT	64	1.05	0.44	0.06	41.84	0.15	0.82	1	1.30	2.10	0.29
PHYCO	34	0.04	0.07	0.01	174	0.01	0.01	0.02	0.02	0.28	0.00
PO4	59	0.16	0.05	0.01	34.48	0.06	0.12	0.16	0.20	0.33	0.04
PT	69	0.13	0.05	0.01	37.67	-0.02	0.09	0.13	0.17	0.25	0.04
SPC	222	213	34	2	162	156	182	219	240	410	28
TKN	6	1.32	0.08	0.3	5.72	1.2	1.28	1.3	1.4	1.4	0.05
TSS	70	2.18	2.52	.30	115.90	-0.8	0.4	1.6	2.8	14	1.2
TEMP	222	10.8	5.7	0.4	52.6	2.8	6.6	8.4	15.8	26.2	2.3
PH	222	7.5	0.5	0.03	7.0	7.0	7.1	7.3	7.6	9.3	0.2



## *Physical Conditions*

### Temperature and Specific Conductance

#### Temperature

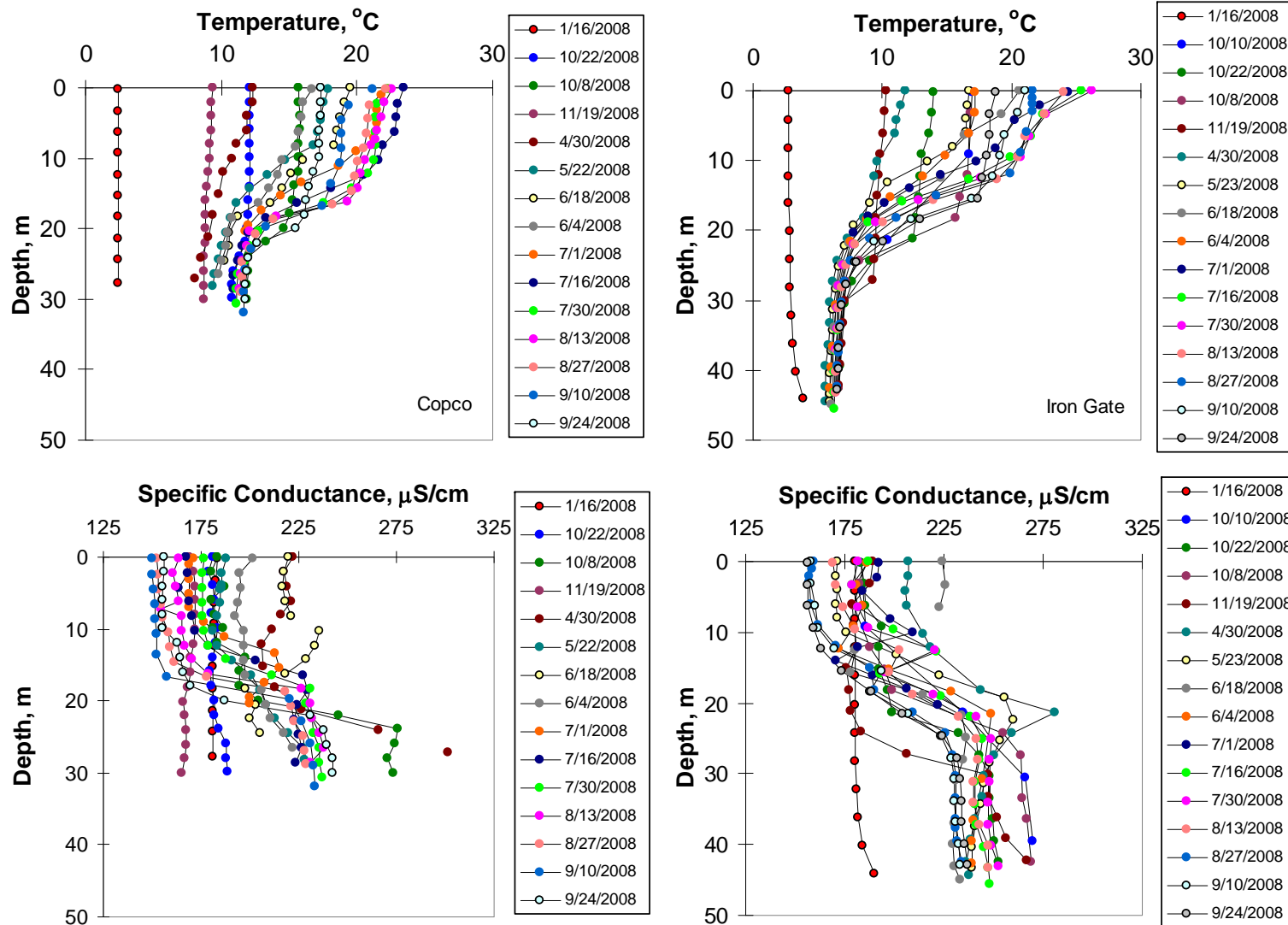
The results of vertical profile measurements for temperature and SPC made in Copco and Iron Gate reservoirs in 2008 are shown in Figure 23. The temperature profiles of Copco and Iron Gate reservoirs were similar in many respects, and were similar to profiles measured in prior years. Both reservoirs became thermally stratified during the summer. Both reservoirs developed a zone above about 10 m depth (epilimnion) that varies in temperature according to the ambient air temperature and stays largely isothermal except for short term gradients in the very warmest weather. In this regard, Iron Gate reservoir was more prone to develop a thermal gradient in this upper zone than was Copco reservoir. Both reservoirs had a zone of rapid temperature change with depth (metalimnion), and both reservoirs developed a stable, cold, largely isothermal deep layer (hypolimnion). The thermocline, or plane of maximum temperature change with depth, occurred at about 19 m in both reservoirs.

The differences between the reservoirs occurred in the length of time of stratification, the temperature of the hypolimnion, and the dynamics of the epilimnion. In Copco reservoir, a vertical temperature gradient was present by April 30, but a thermally stable hypolimnion was not fully established until July 1. The hypolimnion extended from approximately 22 m to the bottom at approximately 30 m. After it was established, the hypolimnion warmed gradually from about 11 °C to 12.5 °C through the summer. The epilimnion of Copco reservoir was somewhat deeper than Iron Gate reservoir, extending occasionally to as deep as 15 m. Thermal stratification began to break down in Copco reservoir in September, and the reservoir was essentially isothermal throughout by the end of October.

In Iron Gate reservoir, a thermally stable hypolimnion was well established from 30 m depth to the bottom at 45 m on April 30, and remained until mid November. The metalimnion in Iron Gate reservoir was broader than in Copco reservoir, extending from about 10 m to about 27 m. After about July 1, vertical mixing in the epilimnion appeared to largely cease and a secondary temperature gradient developed that extended from the surface to about 10 m. By late August, the surface of the reservoir had begun to cool and the isothermal epilimnion deepened. By mid November the reservoir was isothermal at about 10 °C to approximately 20 m, but still warmer than the 6.5 °C of the hypolimnion.

#### Specific Conductance

The pattern of changes in SPC in Copco reservoir was complex. SPC in the epilimnion of Copco reservoir increased or decreased between every sampling event, sometimes changing by as much as 25 percent, in response to changes in the SPC of the inflow from upstream. The change in epilimnetic SPC from approximately 180  $\mu\text{S}/\text{cm}$  on May 22 to 220  $\mu\text{S}/\text{cm}$  on June 18, and back to about 170  $\mu\text{S}/\text{cm}$  on July 1 was particularly striking. A metalimnetic increase in SPC on June 18 may have been a reflection of the very high SPC of the inflow at Keno dam on June 4, and suggests that incoming water was moving through the reservoir as an interflow at about 10 m depth.



**Figure 23. The results of vertical profile measurements for water temperature and specific conductance taken in Copco (left) and Iron Gate (right) reservoirs in 2008.**

The pattern of changes in SPC in Iron Gate reservoir was similar to that in Copco, including the pattern of substantial increase and subsequent decrease between May 22 and July 1. The suggestion of a high SPC interflow is also present at about 12 m depth on July 16.

Changes in hypolimnetic SPC were not as dramatic, suggesting that the hypolimnia in the two reservoirs are well isolated from the surface water. Once thermal stratification was established SPC values fluctuated around  $225 \pm 10$  SPC in Copco reservoir and  $240 \pm 10$  in Iron Gate reservoir. The changes that occurred, with one exception, appeared to be related to the breakdown of thermal stratification and vertical mixing of the reservoirs. In Copco reservoir, however, high SPC in the hypolimnion on October 8 appeared to be related to changes resulting from prolonged anoxia, including, possibly, the release of dissolved phosphorus from the sediment into the small volume of water below 25 m depth.

### Dissolved Oxygen and pH

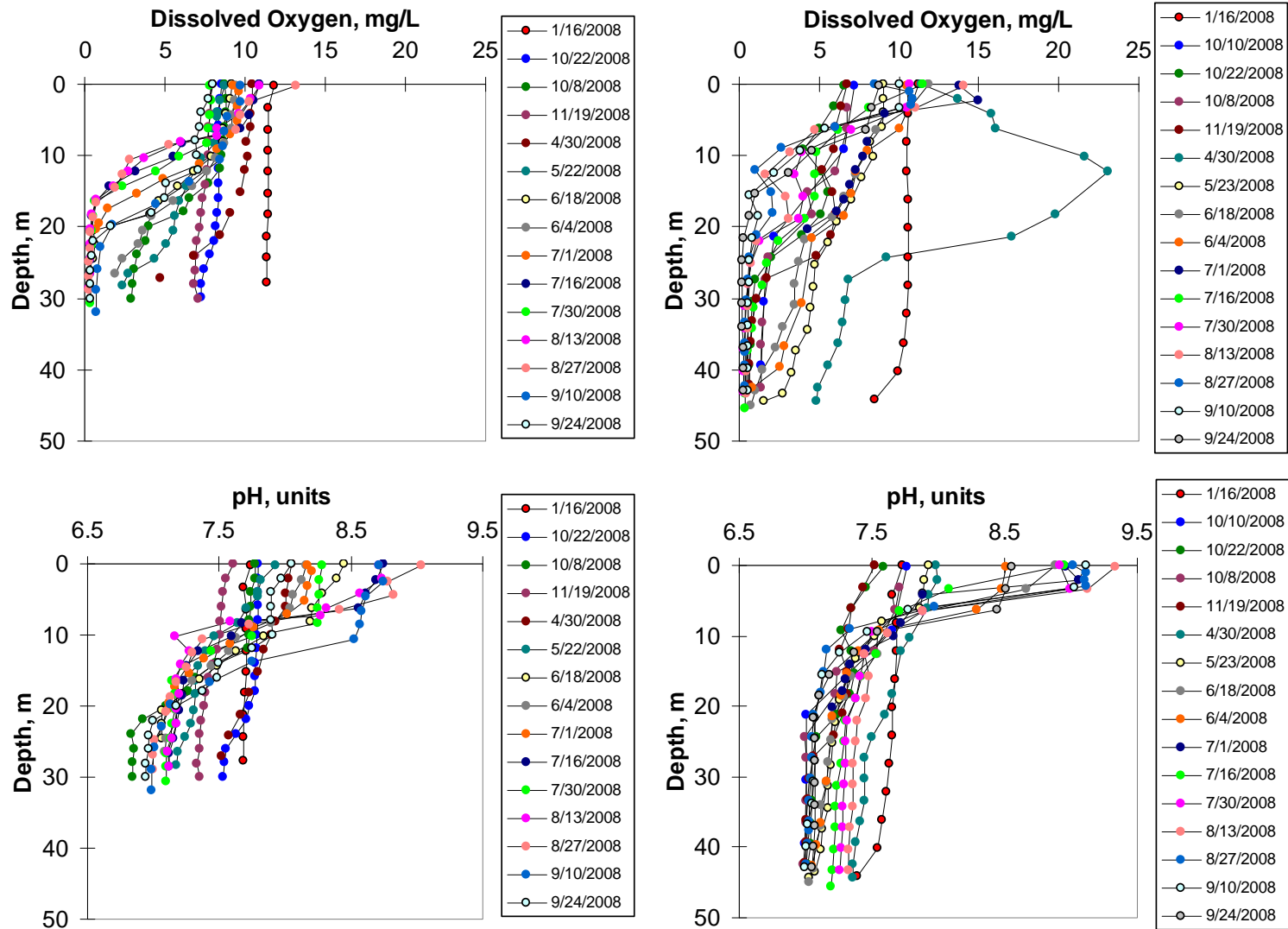
#### Dissolved Oxygen

The results of measurements for dissolved oxygen and pH in Copco and Iron Gate reservoirs in 2008 are presented in Figure 24. Thermal stratification isolates the hypolimnion from contact with the atmosphere preventing reaeration of the deeper water. Respiratory processes in the hypolimnion consume oxygen, and can cause an oxygen deficit in the hypolimnion. In Copco reservoir in 2008, this resulted in near complete anoxia from 20 to 30 m depth, about 4 percent of the volume of the reservoir, lasting from at least July 1 through September 24. At the same time the epilimnion of Copco reservoir above 10 m was nearly continually supersaturated with oxygen from June 4 through September 10 as the result of photosynthetic activity by phytoplankton.

Hypolimnetic anoxia in Iron Gate reservoir was not as intense, but of longer duration than in Copco reservoir. Dissolved oxygen was less than 20 percent saturation below approximately 20 m depth to the bottom from approximately July 16 through mid November. Supersaturated dissolved oxygen conditions prevailed in Iron Gate reservoir above 5 m depth from April 30 through September 10. In prior years, Iron Gate reservoir has exhibited a dissolved oxygen minimum at about 10-12 m depth. This was also the case in 2008, although the minimum was perhaps not as pronounced as in some earlier years. A notable feature of dissolved oxygen conditions in Iron Gate reservoir in 2008 was a metalimnetic peak in dissolved oxygen concentration measured on April 30, possibly the result of photosynthesis by planktonic diatoms.

#### pH

The Klamath River and reservoirs are low in alkalinity and consequently have little capacity to buffer changes in pH that result from fluctuations in CO<sub>2</sub> caused by photosynthesis and respiration by algae and other organisms. Because photosynthesis and respiration also influence dissolved oxygen concentration, pH changes tend to track changes in dissolved oxygen. In Copco reservoir, the pH in the hypolimnion during stratification ranged from approximately 6.8 to 7.3. In the epilimnion during the same period, pH remained above 7.5. Above 10 m depth, pH remained above 8.0 on April 20 and from June 4 through September 10, and exceeded 8.5 from August 13 through September 10.



**Figure 24. The results of vertical profile measurements for dissolved oxygen and pH taken in Copco (left) and Iron Gate (right) reservoirs in 2008.**

In Iron Gate reservoir, hypolimnetic pH ranged from approximately 7.0 to 7.5 while epilimnetic pH was typically greater than 7.5. Above 6 m depth pH remained above 8.0 from June 6 through September 24. On July 1 and from August 13 through September 10, pH in the upper 4 m of Iron Gate reservoir was greater than 9.0.

## *Nutrients*

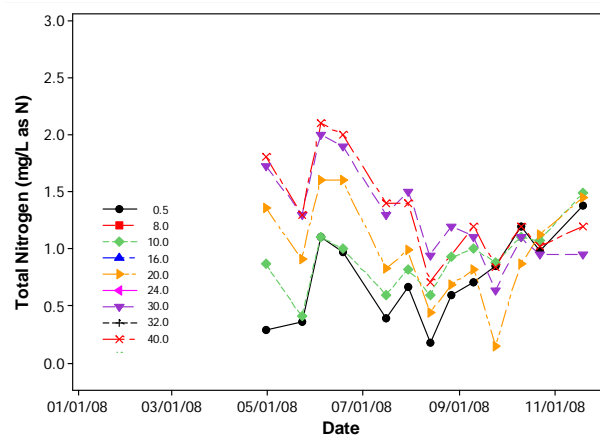
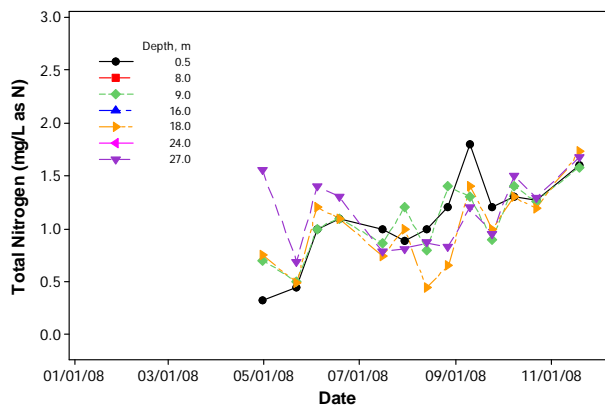
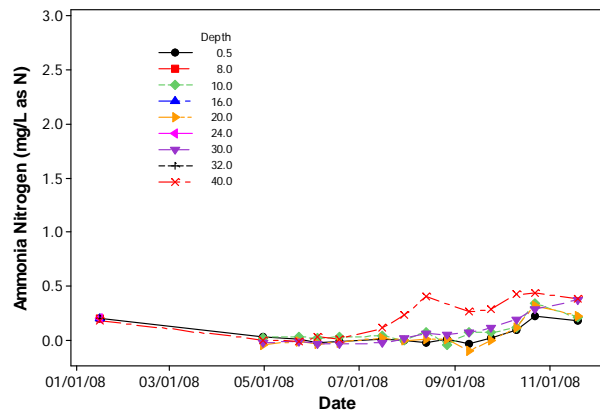
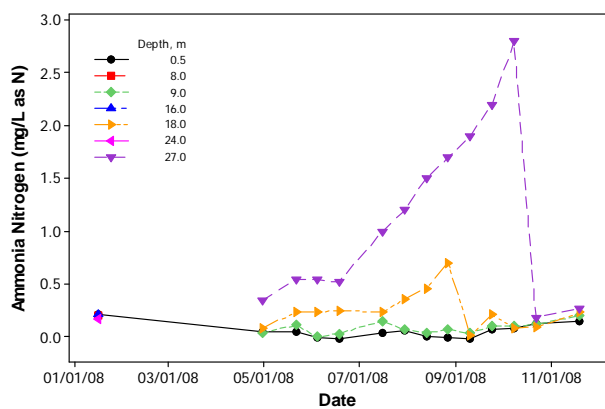
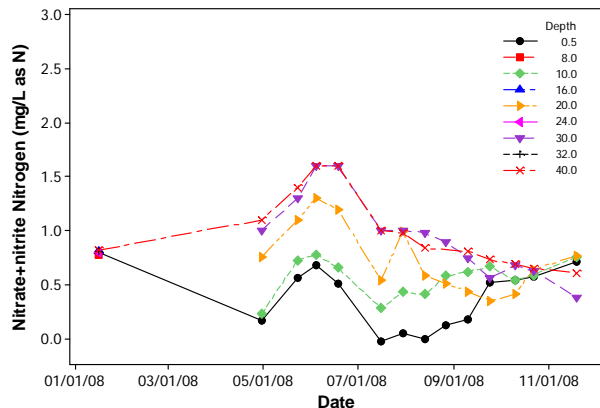
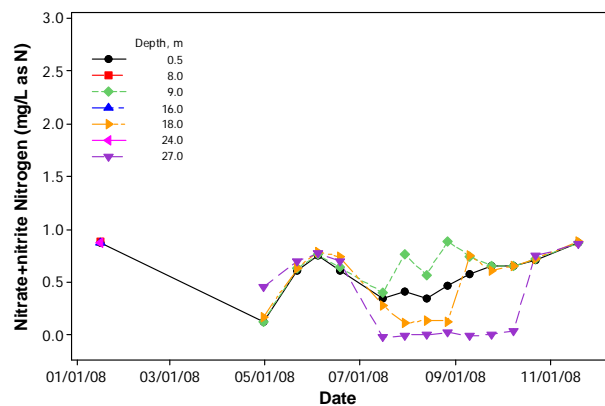
### Nitrogen

The results of nitrogen measurements in Copco and Iron Gate reservoirs are presented in Figure 25. The resistance to vertical mixing during the summer allows nutrients and other constituents to follow different seasonal paths at different depths in the reservoirs. NO<sub>3</sub> concentration in Copco reservoir was uniform with depth in January, but by April 20 concentration at 27 m was higher than at other depths. NO<sub>3</sub> concentration increased to a peak on June 4, when concentration was again uniform throughout the depth of the reservoir. By July 16, NO<sub>3</sub> concentrations at various depths had diverged. NO<sub>3</sub> was virtually absent at 27 m, and remained near zero until October 8. At the surface, NO<sub>3</sub> concentration was typically intermediate between the low values at 18 and 27 m and the higher values at 9 m. By October 22, when the reservoir was well mixed, NO<sub>3</sub> concentrations were the same at all depths. NO<sub>3</sub> concentrations at the surface increased gradually from mid July to mid November.

In Iron Gate reservoir, NO<sub>3</sub> concentration followed a similar overall pattern with a peak on June 4, a decrease to July 10, and a gradual increase in the epilimnion through the rest of the season. NO<sub>3</sub> concentrations at depths 20 m and below tended to decrease through the summer. Iron Gate reservoir differed from Copco reservoir in that a vertical gradient of NO<sub>3</sub> concentration was maintained throughout most of the year. NO<sub>3</sub> concentration increased with depth. NO<sub>3</sub> concentrations in the top 10 m of Iron Gate reservoir were somewhat lower than in the top 10 m of Copco reservoir, while concentrations below 10 m were higher than at the corresponding depths in Copco reservoir. Median values for NO<sub>3</sub> at all depths in Copco reservoir were 0.295 mg/L compared to 0.535 mg/L in Iron Gate reservoir.

Ammonia nitrogen (NH<sub>3</sub>) was uniform with depth in Copco reservoir in January. By April 30, a vertical concentration gradient had developed and continued with a dramatic increase in NH<sub>3</sub> concentration at 27 m. NH<sub>3</sub> concentrations remained near zero in the epilimnion. By October 8, when thermal stratification largely disappeared, the vertical concentration gradient had disappeared and NH<sub>3</sub> concentration at 27 m was the similar to the other depths. The high concentrations measured at 27 m had little effect on the overall NH<sub>3</sub> concentration in the reservoir because the volume of water contained below 25 m in Copco reservoir is less than two percent of the total volume.

In Iron Gate reservoir, NH<sub>3</sub> concentration was uniform with depth and the same as January concentration in Copco reservoir. NH<sub>3</sub> concentration decreased to near zero by April 30, and remained uniform with depth. By July 16, NH<sub>3</sub> concentration at 40 m began to increase, and a small vertical concentration gradient developed. The range of concentrations remained small except for 40 m which was noticeably higher, and reached a peak on August 16. After mid September, NH<sub>3</sub> concentrations began to increase to levels similar to those seen in January.



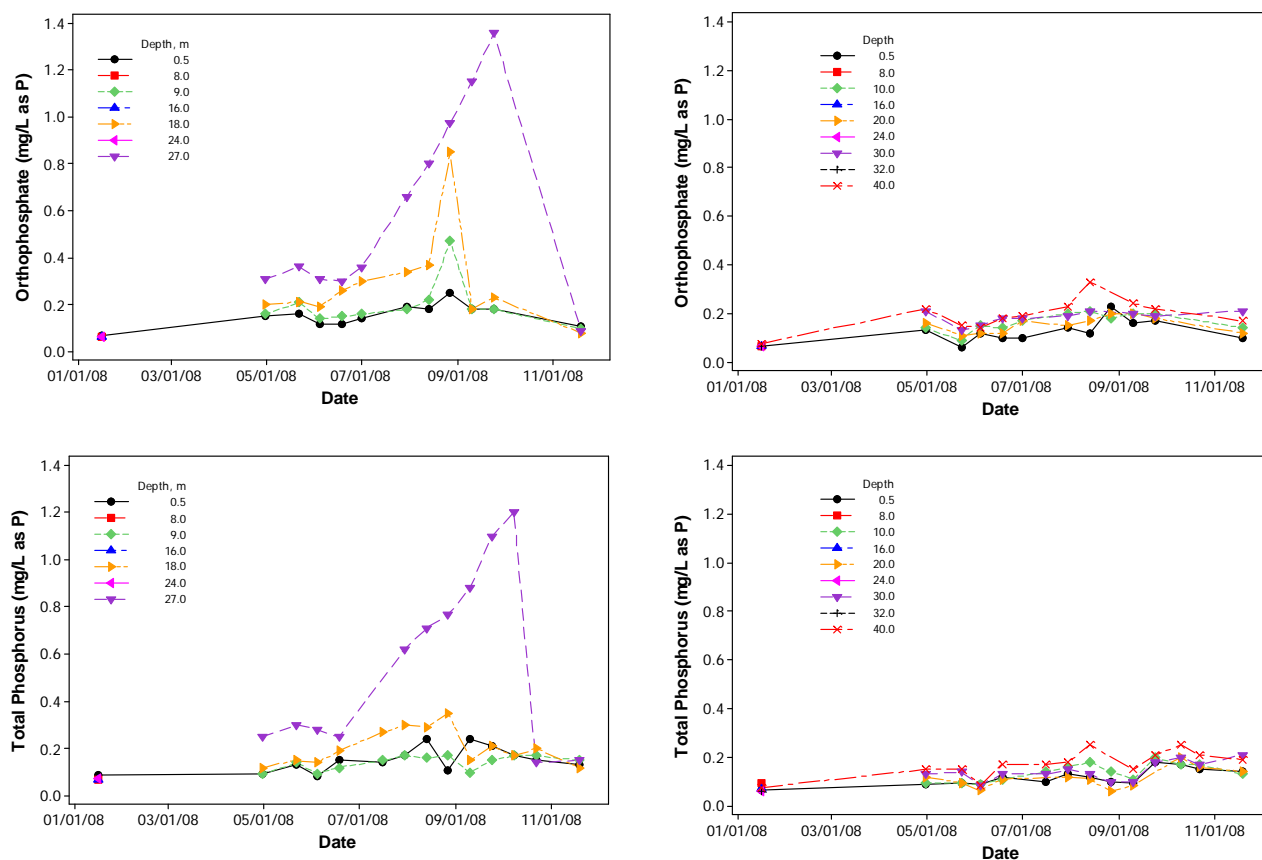
**Figure 25. The results of analysis for forms of nitrogen of water samples collected at various depths in Copco (left) and Iron Gate (right) reservoirs in 2008.**

In Copco reservoir, there was a gradient of increasing total nitrogen concentration with depth on April 30, but the difference became smaller and inconsistent as the season progressed. On August 13, the lowest total N concentration was observed at 18 m depth and on September 10, the highest total N concentration was observed at 0.5 m.

A vertical concentration gradient of total N, similar but somewhat larger than that in Copco reservoir, was observed in Iron Gate reservoir on April 30. However, unlike in Copco reservoir, the gradient in Iron Gate reservoir was generally maintained at least into mid September although the magnitude decreased in late August. Median values for total N at all depths were the same (0.82 mg/L) in Copco and Iron Gate reservoirs.

## Phosphorus

The results of phosphorus measurements in Copco and Iron Gate reservoirs are presented in Figure 26. The seasonal trend of orthophosphate (PO<sub>4</sub>) in Copco reservoir was similar to that of NH<sub>3</sub>. PO<sub>4</sub> was vertically uniform in January. A vertical concentration gradient of increasing PO<sub>4</sub> concentration with depth developed by April 30 and remained until late October when the reservoir mixed. A dramatic increase in concentration was observed at 27 m, with a brief



**Figure 26. The results of analysis for forms of phosphorus of water samples collected at various depths in Copco (left) and Iron Gate (right) reservoirs in 2008.**



increase at 18m and 9 m, as a result of release of PO<sub>4</sub> from reservoir sediments under anoxic conditions. When oxygen was restored to those depths, the concentration of PO<sub>4</sub> fell rapidly. PO<sub>4</sub> concentration was vertically uniform in mid November, and similar to the concentration observed in January. The pattern of total phosphorus concentration in Copco reservoir is similar to that of PO<sub>4</sub>.

In Iron Gate reservoir, the seasonal trend of PO<sub>4</sub> was different. A vertical concentration gradient, increasing with depth, was present on April 30. As the season progressed, the difference in PO<sub>4</sub> concentration between 0.5 m and 40 m increased slightly. At the intermediate depths, however, the gradient broke down, with PO<sub>4</sub> concentration at 10 and 30 m quite similar and at 20 m intermediate between those two depths and the surface. In mid November, PO<sub>4</sub> concentrations at different depths had not converged, but rather varied irregularly from depth to depth. The seasonal pattern of total phosphorus concentrations in Iron Gate reservoir was similar to that for orthophosphate.

#### *Other Constituents*

The results of measurements for phycocyanin, dissolved organic carbon, and total suspended solids are presented in Figure 27.

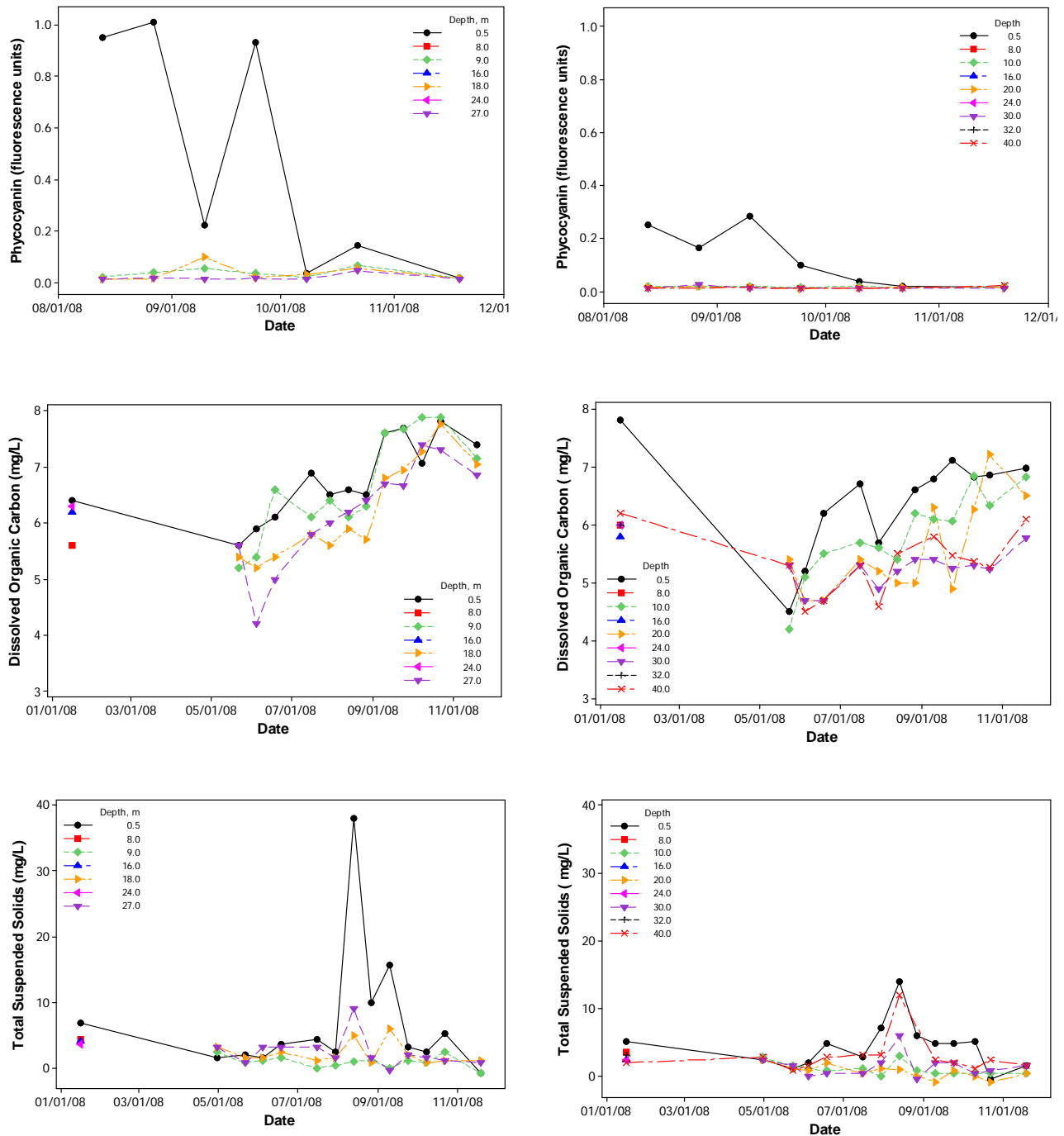
#### Phycocyanin

Starting in August, phycocyanin, a pigment specific to cyanobacteria, was measured at multiple depths in Copco and Iron Gate reservoirs. The instrument was calibrated to a fluorescence standard, but has not yet been calibrated to cyanobacterial cell count, so the results represent relative fluorescence units. The results from mid August through mid November, 2008 show that cyanobacteria were more abundant and more variable in Copco reservoir than in Iron Gate reservoir. In Iron Gate reservoir, cyanobacteria were generally not present at depths greater than 9 or 10 m. However in Copco reservoir, phycocyanin was measured on occasion in relatively low quantities at depths up to 27 m.

Phycocyanin concentration was high in both Copco and Iron Gate reservoirs in August and September. Cyanobacteria can reach very high abundance in Copco and Iron Gate reservoir, and tend to have a very patchy distribution when near the surface. This is reflected in the variability of phycocyanin concentration from one sampling period to the next.

#### Total Suspended Solids

Total suspended solids (TSS) were higher at the surface than at greater depths in both Copco and Iron Gate reservoirs. Peak values of TSS were reached on August 13 in both reservoirs, a date that corresponds to high concentrations of phycocyanin. There were differences in concentration among the depths sampled. The differences did not form a stable concentration gradient. Rather, the order of concentration with depth changed from sample time to sample time.



**Figure 27. The results of analysis for dissolved organic carbon, total suspended solids, and phycocyanin of water samples collected at various depths in Copco (left) and Iron Gate (right) reservoirs in 2008.**

## Dissolved Organic Carbon

Dissolved organic carbon (DOC) concentration was relatively high in January, especially in Iron Gate reservoir. By April 30, DOC concentrations in the two reservoirs were comparable. DOC concentrations increased in both reservoirs from May through October. In November, DOC continued to increase in Iron Gate reservoir, but decreased in Copco reservoir. DOC varied among depths in both reservoirs, although the highest concentrations were generally measured near the surface. There was a general trend of decreasing DOC concentration with depth through most of the season in both reservoirs, but there were occasions when samples at a lower depth had higher concentration than samples at shallower depth.

## ***Reservoir Curtain***

In June 2008, an impervious curtain was installed along the log boom near the dam in Iron Gate reservoir. The curtain extended approximately 3 m deep into the water. The intent of the installation was to see if such a measure would be effective in preventing surface accumulations of cyanobacteria from reaching the dam, thus reducing the possible entrainment of cyanobacteria into the penstock intakes and subsequent release to the Klamath River below Iron Gate dam. Following the original installation, a portion of the curtain became wrapped over the log boom, which allowed surface waters to leak around this portion of the curtain.

By early August, the curtain was disentangled, repositioned inside the log boom, and then functioned as intended (Figure 28 a, b).

Based on comparison of all data collected inside and outside of the curtain, the curtain did not appear to be effective. Visual evidence (Figure 28, c-f) suggested that surface accumulation of cyanobacteria inside the curtain was similar to that outside the curtain. On September 10, measurements were taken at several depths in the forebay inside the log boom. Comparison with the profile measurements made the same day outside the log boom show virtually no difference among the constituents measured between the two locations (Table 22).

<b>Table 22. Comparison of profiles inside and outside the algae curtain.</b>								
<b>Location</b>	<b>Inside</b>	<b>Outside</b>	<b>Inside</b>	<b>Outside</b>	<b>Inside</b>	<b>Outside</b>	<b>Inside</b>	<b>Outside</b>
Depth	0.00	0.00	10.01	9.35	20.14	21.60	30.29	30.78
DOCON	9.63	10.02	4.15	3.83	0.79	0.78	0.38	0.57
DOPER	115.50	122.00	48.20	46.00	7.80	7.80	3.50	5.50
pH	9.10	9.12	7.55	7.47	7.07	7.07	7.04	7.06
SPC	129.70	158.10	160.40	161.70	191.00	207.30	228.20	230.40
TEMP	20.42	21.10	19.00	19.09	10.84	9.34	6.99	6.92



**Figure 28. Photographs of the algal barrier curtain in Iron Gate reservoir taken in 2008 (a, b – top row; c, d – middle row; e, f – bottom row).**

## DISCUSSION

The water quality conditions observed in the vicinity of the Project in 2008 were similar to conditions observed in prior years. The characteristics of conductivity, alkalinity, nutrients, suspended solids, and organic matter were largely determined by the concentration and timing of material contributed to the Project area from upstream via the Klamath River.

### Trends in Water Quality

The values for eight of the constituents measured in 2008 (i.e., ALKT, DOC, NH<sub>3</sub>, NO<sub>3</sub>, PO<sub>4</sub>, PT, SPC, TSS) were compared to the values measured in 2000 through 2007 to determine if 2008 was different from previous years. Of these constituents, only NO<sub>3</sub> and PO<sub>4</sub> showed any significant difference. The 2008 values for NO<sub>3</sub> and PO<sub>4</sub> are compared to the 2000-2007 values in Figure 29 as means and 95 percent confidence intervals. Lack of overlap of the confidence intervals of any two pairs indicates that they are significantly different. It is noteworthy that PO<sub>4</sub> concentrations at Keno dam (KR23334) and above J. C. Boyle reservoir (KR22822) were significantly higher in 2008 than the average of earlier years. Concentrations of NO<sub>3</sub> in 2008 were significantly higher than the average of earlier years at every site from above J.C. Boyle reservoir to Walker Bridge (KR15750).<sup>20</sup>

The differences between 2008 and earlier years raised the possibility that there might be a longer term trend in some constituents. This was tested for NO<sub>3</sub> and PO<sub>4</sub>, the two constituents that showed some differences between 2008 and earlier years. The results are shown in Figure 30.

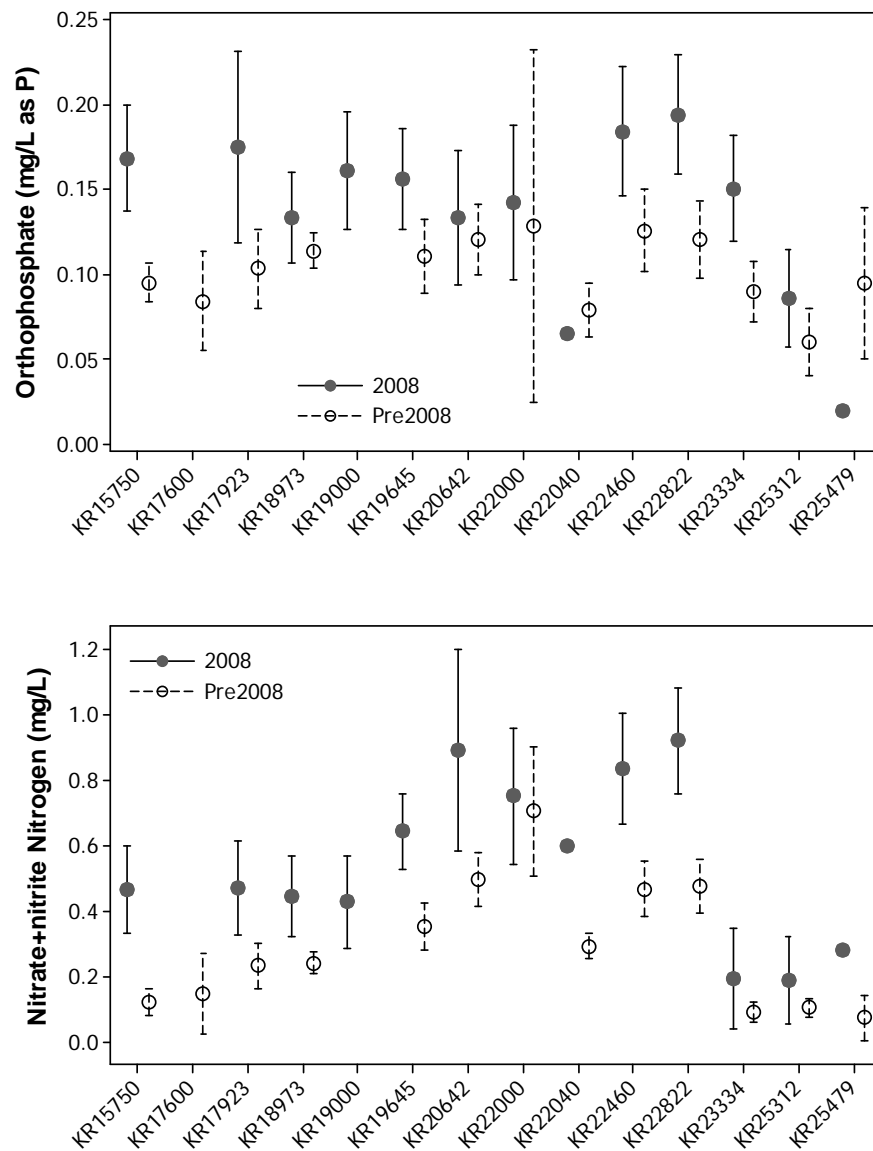
The tests were conducted on data gathered at the site above J. C. Boyle reservoir (KR22822, RM 228). The data were examined for trends by regressing the residuals of a fitted curve of concentration versus day of year against calendar date. A slope in the regression line indicates a trend in the data. No trend was detected in the PO<sub>4</sub> data, but the NO<sub>3</sub> data showed a statistically significant ( $P = 0.000$ ) positive slope with calendar date suggesting that there has been an increasing trend in NO<sub>3</sub> concentration entering the Project area during the past several years.

### Effects of Varying Inflow Quality

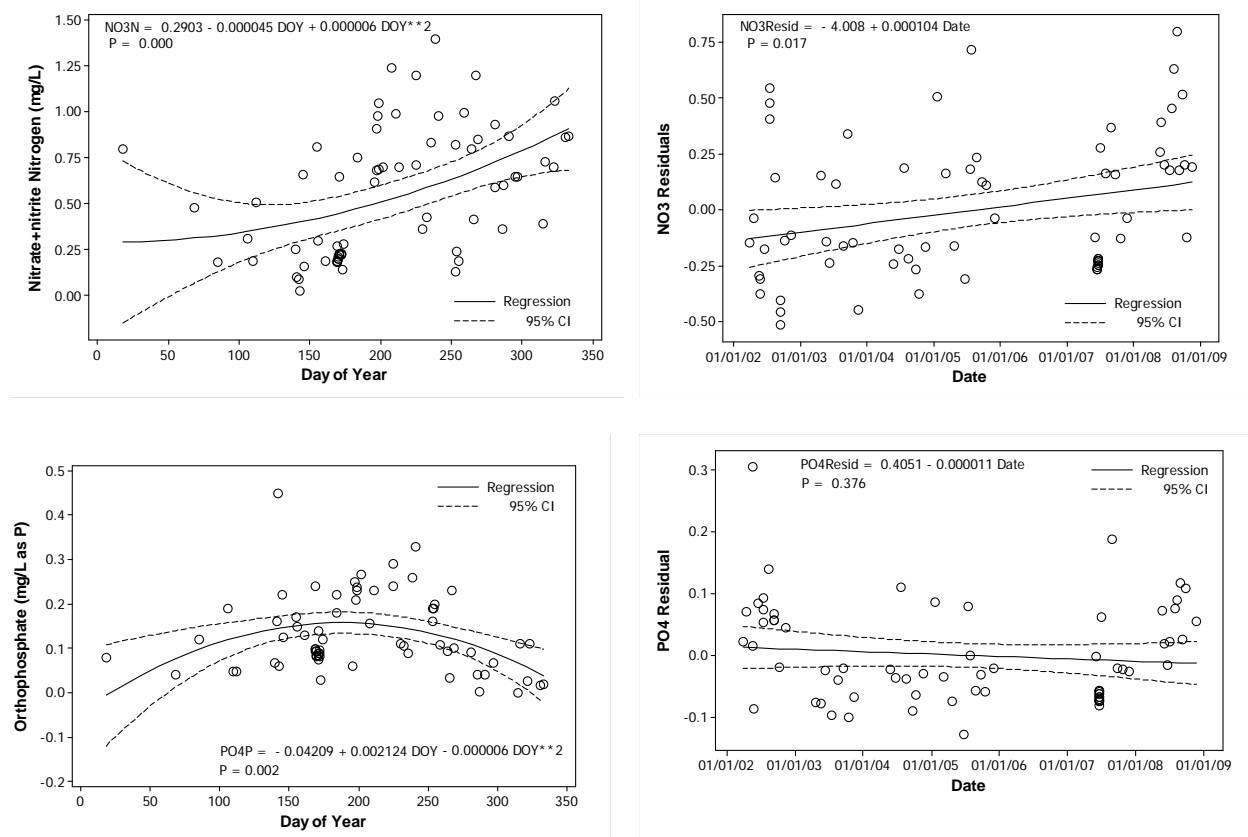
Water quality in the vicinity of the Project is controlled largely by the input of various constituents from upstream via the Klamath River. In 2008, it was possible to discern to some extent how inputs from upstream move through the Project. On June 3, unusually high values for NO<sub>3</sub> concentration and SPC were recorded at the upstream end of the Project below Keno dam. Samples analyzed from subsequent sampling events provide some insight into how water and the load of nutrients and organic matter it carries move through the Project area. Figure 31 illustrates the values measured for six constituents (NH<sub>3</sub>, NO<sub>3</sub>, NT, PO<sub>4</sub>, PT, and SPC) at four sites on the Klamath River; including below Keno dam (KR23334, RM 233), near Shovel Creek above Copco reservoir (KR20643, RM 206), below Copco 2 powerhouse above Iron Gate reservoir (KR19642, RM 196), and at the hatchery bridge below Iron Gate dam (KR18973, RM 189).

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<sup>20</sup> The comparison at Walker Bridge is based on two years of data rather than 7 years as at the other sites.



**Figure 29. Graphs comparing the mean and 95 percent confidence interval of orthophosphate and nitrate nitrogen values measured at various sites in the Klamath River in 2008 to values measured in 2001 through 2007.**

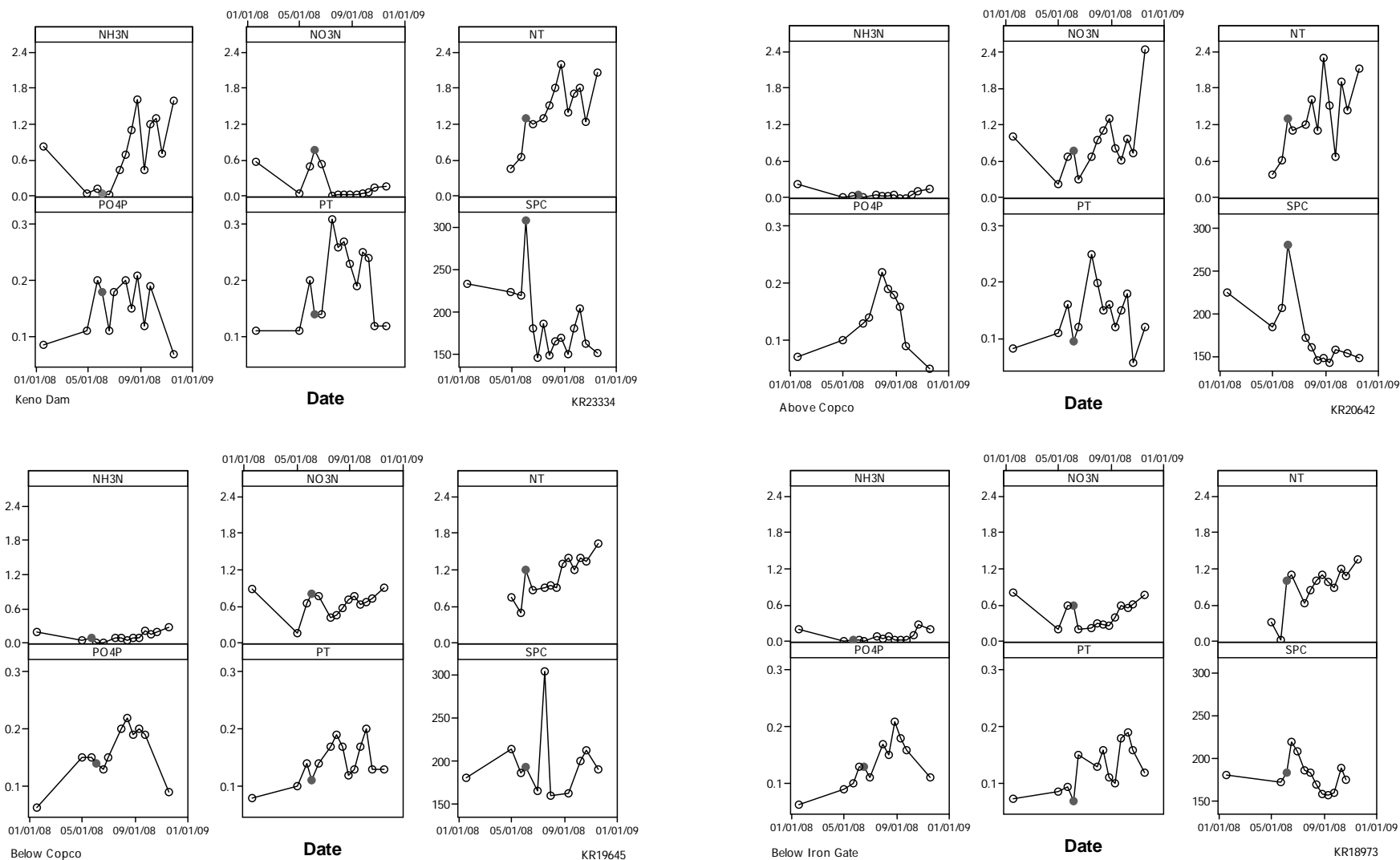


**Figure 30. Graphs showing a fitted curve of nitrate nitrogen and orthophosphate data from 2001-2008 plotted against day of the year (left), and the residuals of that fit plotted against calendar date (right). The statistically significant positive slope of the regression line of the residuals suggests that there has been a trend of increasing nitrate concentration from 2001 through 2008.**

The high SPC value measured at Keno dam was also measured above Copco reservoir on the same day, and below Copco reservoir two weeks later. A smaller peak in SPC was also observed in Iron Gate reservoir one week following the peak at Keno dam. It is not clear if this peak was related to the peak at Keno dam. Also, on June 3 at Keno dam, NO<sub>3</sub> values reached the peak of a several week long excursion that began after April 30 and lasted until July 15. This peak can be observed down the river at each site with diminishing maximum concentration, but with little time lag. The peak occurs on the same date at every river site.

The conversion of ammonia-nitrogen to nitrate-nitrogen was clearly illustrated by the decrease in NH<sub>3</sub> and increase in NO<sub>3</sub> from below Keno dam to above Copco reservoir. The pattern of NO<sub>3</sub> above Copco reservoir closely mirrored the pattern of NH<sub>3</sub> at Keno dam. Below Copco reservoir and Iron Gate reservoir, the pattern of NO<sub>3</sub> concentration was similar to that above Copco reservoir, but of smaller magnitude and lagged by approximately a week. A similar pattern was seen in the phosphorus data.





**Figure 31. Graphs showing the seasonal changes in values of specific conductance, and forms of nitrogen and phosphorus measured at four sites in the Klamath River above and below the reservoirs of the Klamath Hydroelectric Project.**



## CONCLUSION

Water quality in the vicinity of the Project in 2008 was similar to years past, and was controlled largely by the inflow of nutrients and organic matter from Upper Klamath Lake and Keno reservoir. Water quality of the Klamath River improved as it flowed through the Project area with reductions in color, turbidity, suspended solids, dissolved organic carbon, nitrate nitrogen and total nitrogen. Although most constituents were present in 2008 in concentrations similar to past years, NO<sub>3</sub> concentrations measured in 2008 were significantly higher than average. Nitrogen species continued a pattern of high wintertime values that decreased toward a minimum in late spring and then increased through the summer and fall. It appears that there has been an increase in the concentration of NO<sub>3</sub> in the water flowing into the Project area.

## REFERENCES

Ahn, C. Y., S. H. Joung, C. S. Park, H. S. Kim, B. D. Youn, and H. M. Oh. 2008. Comparison of sampling and analytical methods for monitoring of cyanobacterial-dominated surface waters. *Hydrobiologia*: 413-421.

EPA, 2003. 2003 NELAC Standard. National Environmental Laboratory Accreditation Conference, June 5, 2003. EPA/600/R-04/003.

Helsel, D. R., 2006. Fabricating data: How substituting values for nondetects can ruin results, and what can be done about it. *Chemosphere*, 65: 2434–2439.

PacifiCorp. 2004a. Final License Application. Volume 2. Exhibit E. Klamath Hydroelectric Project (FERC Project No. 2082). PacifiCorp, Portland, Oregon. February 2004.

PacifiCorp. 2004b. Final Technical Report, Water Resources. Klamath Hydroelectric Project (FERC Project No. 2082). February 2004.

PacifiCorp. 2006. Causes and Effects of Nutrient Conditions in the Upper Klamath River. Klamath Hydroelectric Project (FERC Project No. 2082). PacifiCorp, Portland, Oregon. November 2006. 77 pp.

PacifiCorp. 2007a. Application for Water Quality Certification Pursuant to Section 401 of the Federal Clean Water Act for the Relicensing of the Klamath Hydroelectric Project (FERC No.2082) in Klamath County, Oregon. Klamath Hydroelectric Project (FERC Project No. 2082). Prepared for: Oregon Department of Environmental Quality, Portland. Prepared by: PacifiCorp, Portland, Oregon. February 2007.

PacifiCorp. 2007b. Application for Water Quality Certification Pursuant to Section 401 of the Federal Clean Water Act for the Relicensing of the Klamath Hydroelectric Project (FERC No.2082) in Siskiyou County, California. Klamath Hydroelectric Project (FERC Project No. 2082). Prepared for: State Water Resources Control Board, Division of Water Quality, Water Quality Certification Unit, Sacramento. Prepared by: PacifiCorp, Portland, Oregon. February 2007.

PacifiCorp. 2008a. Water Quality Studies for Year 2008 for the Klamath Hydroelectric Project. April 22, 2008. Attachment to a letter from Linda Prendergast (PacifiCorp) to Chris Stine (Oregon Department of Environmental Quality) and Jennifer Watt (California State Water Resources Control Board).

PacifiCorp. 2008b. Application for Water Quality Certification Pursuant to Section 401 of the Federal Clean Water Act for the Relicensing of the Klamath Hydroelectric Project (FERC No.2082) in Klamath County, Oregon. Klamath Hydroelectric Project (FERC Project No. 2082). Prepared for: Oregon Department of Environmental Quality, Portland. Prepared by: PacifiCorp, Portland, Oregon. February 2008.

PacifiCorp. 2008c. Application for Water Quality Certification Pursuant to Section 401 of the Federal Clean Water Act for the Relicensing of the Klamath Hydroelectric Project (FERC No.2082) in Siskiyou County, California. Klamath Hydroelectric Project (FERC Project No. 2082). Prepared for: State Water Resources Control Board, Division of Water Quality, Water Quality Certification Unit, Sacramento. Prepared by: PacifiCorp, Portland, Oregon. February, 2008.

PacifiCorp. 2008d. 2008 Water Quality Sampling Plan, Klamath Hydroelectric Project (FERC Project No. 2082). PacifiCorp Energy, Portland.

Raymond, R. B. 2008. Water Quality Conditions During 2007 in the Vicinity of the Klamath Hydroelectric Project. Prepared for: PacifiCorp Energy Portland, Oregon, October 9, 2008. Prepared by: E&S Environmental Chemistry, Inc. Corvallis, Oregon.

## APPENDIX A

### SUMMARY STATISTICS

#### **Descriptive Statistics for SiteID = KR15750**

	ALKT	CHLA	DOC	DOCon	DOPer	MCYN	NH3	NO3
N	14	13	13	14	14	12	14	14
Mean	77.014	11.432	5.9154	9.5271	105.16	0.5723	7.73E-03	0.4664
SD	5.5997	24.158	0.8382	1.0875	12.171	0.837	0.0339	0.2327
SE Mean	1.4966	6.7002	0.2325	0.2906	3.2529	0.2416	9.07E-03	0.0622
C.V.	7.271	211.32	14.169	11.415	11.574	146.26	439.12	49.882
Minimum	68	-6.59E-03	4.5	8.11	88.4	0.044	-0.044	0.14
1st Quarti	73	1.11	5.3	8.5025	97.55	0.0832	-0.0113	0.2275
Median	76	2.136	5.85	9.635	103.65	0.13	1.70E-03	0.52
3rd Quarti	81.9	8.1293	6.45	10.325	108.3	1.045	0.0205	0.6675
Maximum	87	87.89	7.69	11.46	138.1	2.4871	0.079	0.8
MAD	3.5	1.335	0.6	1.02	5.65	0.0544	0.0132	0.23
N	NT	PHYCO	PO4	PT	SPC	TSS	Temp	pH
Mean	14	8	12	14	14	14	13	14
SD	0.8254	0.0516	0.1683	0.1316	197.6	3.8143	17.936	8.3264
SE Mean	0.3053	0.0298	0.0493	0.0611	17.566	2.1404	4.1089	0.3267
C.V.	0.0816	0.0105	0.0142	0.0163	4.6948	0.572	1.1396	0.0873
Minimum	36.984	57.75	29.304	46.416	8.8899	56.115	22.909	3.9236
1st Quarti	0.36	0.02	0.1	0.065	173.5	2	9.8	7.94
Median	0.6067	0.023	0.125	0.0923	180.55	2.4	15.155	8.1025
3rd Quarti	0.83	0.05	0.17	0.13	199.4	3.4	19.41	8.345
Maximum	1.0475	0.0688	0.19	0.1525	208.2	4.5	21.305	8.425
MAD	1.31	0.108	0.29	0.31	226.9	10.4	22.98	9.27
	0.1972	0.0205	0.02	0.034	14.85	1	2.82	0.17

#### **Descriptive Statistics for SiteID = KR17923**

	ALKT	CHLA	DOC	DOCon	DOPer	MCYN	NH3N	NO3
N	14	12	13	15	15	11	14	14
Mean	68.45	16.103	5.99	10.102	111.78	1.2798	0.0226	0.47
SD	5.2375	38.449	0.6246	1.0338	15.797	1.8962	0.0535	0.2457
SE Mean	1.3998	11.099	0.1732	0.2669	4.0788	0.5717	0.0143	0.0657
C.V.	7.6516	238.78	10.427	10.234	14.132	148.17	236.62	52.277
Minimum	62	-0.1021	4.8	9.03	86.5	0.027	-0.041	0.18
1st Quarti	65.75	1.0025	5.55	9.18	104.6	0.103	-0.0165	0.24
Median	66.85	2.9846	6	9.8	109.1	0.16	4.97E-03	0.45
3rd Quarti	70.95	5.31	6.495	10.91	117.3	2.4573	0.0543	0.7025
Maximum	83	135	6.93	12.26	153.8	6.19	0.13	0.84
MAD	1.5	2.035	0.4	0.72	7.1	0.133	0.03	0.225
	NT	PHYCO	PO4	PT	SPC	TSS	Temp	pH
N	13	7	12	13	15	14	15	15
Mean	0.8699	0.0804	0.1751	0.1293	180.45	2.2143	16.712	8.2787
SD	0.2849	0.0596	0.089	0.0691	21.195	1.8867	5.4566	0.3319
SE Mean	0.079	0.0225	0.0257	0.0192	5.4725	0.5043	1.4089	0.0857
C.V.	32.75	74.083	50.815	53.438	11.745	85.208	32.651	4.0085
Minimum	0.42	0.018	0.061	0.069	157.5	-0.8	3.57	7.74

1st Quarti	0.6687	0.019	0.1225	0.0845	162.2	0.8	12.58	7.98
Median	0.77	0.091	0.165	0.11	179.2	2	17.81	8.29
3rd Quarti	1.1	0.146	0.2	0.15	193	3.3	20.78	8.55
Maximum	1.48	0.15	0.42	0.33	219.8	7	22.66	8.84
MAD	0.17	0.059	0.035	0.023	14.1	1.2	2.97	0.26

**Descriptive Statistics for SiteID = KR18973**

	ALKT	CHLA	DOC	DOCon	DOPer	MCYN	NH3	NO3
N	14	14	13	13	13	11	14	14
Mean	68.05	20.647	6.2538	9.2515	105.48	0.9839	0.0667	0.4436
SD	4.9298	35.273	0.6337	1.4596	18.027	1.4931	0.0855	0.2166
SE Mean	1.3175	9.4272	0.1758	0.4048	4.9997	0.4502	0.0229	0.0579
C.V.	7.2443	170.84	10.134	15.777	17.091	151.76	128.18	48.832
Minimum	62	0.44	5.2	6.97	72.2	0.033	-0.017	0.18
1st Quarti	65.75	2.2	5.65	8.335	95.2	0.082	9.83E-03	0.2375
Median	66.8	4.1155	6.46	9.15	104.4	0.172	0.0275	0.465
3rd Quarti	68.5	23.26	6.7	10.59	119.6	1.64	0.1177	0.5925
Maximum	83	119.6	7	11.46	133.7	4.9	0.26	0.8
MAD	1.2	3.6355	0.26	1.05	12.6	0.118	0.0365	0.19

	NT	PHYCO	PO4	PT	SPC	TSS	Temp	pH
N	13	7	12	13	13	14	13	13
Mean	0.8792	0.1246	0.1336	0.1248	180.19	3.2857	17.872	8.1962
SD	0.3725	0.1245	0.042	0.0402	18.484	3.4771	5.346	0.4571
SE Mean	0.1033	0.0471	0.0121	0.0112	5.1266	0.9293	1.4827	0.1268
C.V.	42.362	99.971	31.466	32.235	10.258	105.83	29.912	5.5768
Minimum	0	0.014	0.063	0.07	156.5	-1.2	2.87	7.37
1st Quarti	0.73	0.016	0.1025	0.09	165	1.4	15.885	7.83
Median	0.99	0.09	0.13	0.12	180	2.4	19.19	8.23
3rd Quarti	1.1	0.172	0.1675	0.16	187.55	4.8	22.065	8.565
Maximum	1.36	0.374	0.21	0.19	219.9	10	22.67	8.96
MAD	0.12	0.074	0.03	0.034	8.4	1.2	2.88	0.33

**Descriptive Statistics for SiteID = KR19000**

	ALKT	CHLA	DOC	DOCon	DOPer	MCYN	NH3	NO3
N	12	12	11	3	3	9	11	11
Mean	67.333	17.369	6.4118	9.9733	104.57	0.9573	0.0835	0.4264
SD	5.1456	28.134	0.7194	0.9511	12.196	1.1598	0.1391	0.2087
SE Mean	1.4854	8.1216	0.2169	0.5491	7.0414	0.3866	0.0419	0.0629
C.V.	7.6419	161.98	11.22	9.5367	11.663	121.15	166.47	48.954
Minimum	62	0.14	5.2	9.05	95	0.041	-0.027	0.13
1st Quarti	64.25	1.7125	6	9.05	95	0.0825	-0.017	0.26
Median	66	3.5352	6.2	9.92	100.4	0.132	0.022	0.38
3rd Quarti	68	27.09	7.11	10.95	118.3	1.715	0.16	0.6
Maximum	82	85.19	7.65	10.95	118.3	3.32	0.37	0.75
MAD	2	3.3102	0.4	0.87	5.4	0.091	0.039	0.17

	NT	PHYCO	PO4	PT	SPC	TSS	Temp	pH
N	12	7	10	11	2	12	3	3
Mean	0.9267	0.0703	0.161	0.14	178	1.4333	14.81	7.84
SD	0.3203	0.0485	0.0486	0.03	5.374	1.7095	1.3018	0.0693
SE Mean	0.0925	0.0183	0.0154	9.05E-03	3.8	0.4935	0.7516	0.04

C.V.	34.561	68.979	30.209	21.429	3.0191	119.27	8.7903	0.8837
Minimum	0.4	0.014	0.1	0.1	174.2	-1.6	13.35	7.8
1st Quarti	0.68	0.028	0.13	0.1	M	0.1	13.35	7.8
Median	0.97	0.075	0.145	0.14	178	1.6	15.23	7.8
3rd Quarti	1.175	0.125	0.185	0.16	M	3.1	15.85	7.92
Maximum	1.47	0.137	0.27	0.18	181.8	4	15.85	7.92
MAD	0.23	0.047	0.025	0.02	3.8	1.4	0.62	0

#### **Descriptive Statistics for SiteID = KR19645**

	ALKT	CHLA	DOC	DOCon	DOPer	MCYN	NH3	NO3
N	14	5	13	5	5	3	14	14
Mean	66.343	22.459	6.48	9.284	91.2	0.7727	0.0986	0.6429
SD	6.3645	32.629	0.9042	1.227	4.7666	0.5337	0.0815	0.2028
SE Mean	1.701	14.592	0.2508	0.5487	2.1317	0.3081	0.0218	0.0542
C.V.	9.5934	145.28	13.953	13.216	5.2265	69.071	82.651	31.547
Minimum	60	1.5	4.9	8.04	86.3	0.178	-0.015	0.14
1st Quarti	61	1.6	5.9	8.15	87.8	0.178	0.0403	0.5325
Median	64.5	4.4636	6.5	9.12	90.3	0.93	0.073	0.685
3rd Quarti	69.25	52.315	7.01	10.5	95.05	1.21	0.175	0.77
Maximum	84	77.63	8.3	10.97	99.1	1.21	0.26	0.9
MAD	3.5	2.9636	0.52	0.91	1	0.28	0.0525	0.095

	NT	PHYCO	PO4	PT	SPC	TSS	Temp	pH
N	13	7	12	14	4	14	5	5
Mean	1.0981	0.0753	0.1561	0.1414	193.65	1.9286	11.966	7.806
SD	0.3245	0.0418	0.047	0.0347	14.452	1.3936	5.7029	0.0826
SE Mean	0.09	0.0158	0.0136	9.29E-03	7.2261	0.3725	2.5504	0.037
C.V.	29.551	55.564	30.128	24.581	7.463	72.262	47.66	1.0587
Minimum	0.48	0.016	0.063	0.079	180.8	-1.2	2.4	7.7
1st Quarti	0.875	0.031	0.1325	0.1175	182.3	1.2	6.79	7.725
Median	1.2	0.08	0.15	0.135	189.9	1.6	14.42	7.81
3rd Quarti	1.37	0.095	0.1975	0.17	208.75	2.6	15.915	7.885
Maximum	1.63	0.142	0.22	0.2	214	4.4	16.53	7.9
MAD	0.26	0.015	0.04	0.03	6.1	0.7	2.11	0.06

#### **Descriptive Statistics for SiteID = KR20642**

	ALKT	CHLA	DOC	DOCon	DOPer	MCYN	NH3	NO3
N	14	13	14	12	12	11	14	14
Mean	67.621	6.8106	7.1836	10.096	109.13	0.0799	0.0356	0.8914
SD	11.781	11.085	2.0828	0.9657	7.2222	0.042	0.0622	0.5334
SE Mean	3.1486	3.0745	0.5566	0.2788	2.0849	0.0127	0.0166	0.1426
C.V.	17.422	162.76	28.993	9.5656	6.6178	52.522	174.4	59.84
Minimum	56	0.56	2.6	9	92.4	0.037	-0.034	0.2
1st Quarti	58	1.5265	6.5125	9.47	104.48	0.0535	-1.03E-03	0.655
Median	65.85	2.14	7.05	9.97	110.9	0.0675	0.0205	0.785
3rd Quarti	72.5	6.337	8.7975	10.487	115.28	0.096	0.0468	1.025
Maximum	100	39.73	10.9	12.56	117	0.185	0.2	2.44
MAD	7.85	1.04	0.85	0.5	4.15	0.0165	0.0205	0.18

	NT	PHYCO	PO4	PT	SPC	TSS	Temp	pH
N	13	7	10	14	12	14	12	12

Mean	1.3231	0.038	0.1332	0.1398	177.24	4.2857	14.768	8.2225
SD	0.5799	0.0131	0.0551	0.0499	41.77	2.2377	5.8309	0.173
SE Mean	0.1608	4.96E-03	0.0174	0.0133	12.058	0.5981	1.6832	0.0499
C.V.	43.83	34.546	41.395	35.663	23.567	52.214	39.485	2.104
Minimum	0.36	0.021	0.05	0.058	143.3	0	2.87	7.91
1st Quarti	0.885	0.022	0.0855	0.1065	147.85	2.9	10.652	8.0675
Median	1.3	0.04	0.135	0.135	159.55	4.6	14.525	8.245
3rd Quarti	1.75	0.047	0.1825	0.165	201.25	5.8	19.883	8.37
Maximum	2.3	0.056	0.22	0.25	281.4	8.4	22.52	8.47
MAD	0.3	7.00E-03	0.045	0.025	13.15	1.2	4.465	0.145

#### **Descriptive Statistics for SiteID = KR22000**

	ALKT	CHLA	DOC	DOCon	DOPer	MCYN	NH3	NO3
N	14	11	13	12	12	8	14	14
Mean	62.086	7.8266	8.9827	8.3983	95.617	0.0938	0.1639	0.7513
SD	20.73	16.251	3.4651	1.0169	7.6956	0.0258	0.1522	0.3596
SE Mean	5.5402	4.8999	0.961	0.2935	2.2215	2.80E-02	0.0407	0.0961
C.V.	33.389	207.64	38.575	12.108	8.0483	27.512	92.898	47.86
Minimum	2	0.088	1.19	6.75	81.9	0.0574	-0.016	1.80E-03
1st Quarti	56.35	1.5828	7.8625	7.5275	89.4	0.0734	0.0348	0.6075
Median	66.05	3.094	8.7	8.265	96.2	0.0914	0.143	0.8
3rd Quarti	70.5	4.52	10.1	9.3075	102.15	0.1192	0.2525	1
Maximum	99	56.54	17.1	10.02	107.5	0.13	0.54	1.3
MAD	6.85	1.426	0.91	0.845	6.3	0.018	0.1025	0.2

	NT	PHYCO	PO4	PT	SPC	TSS	Temp	pH
N	14	8	11	14	12	14	12	12
Mean	1.465	0.059	0.1427	0.1869	186.38	4.8857	16.156	7.7483
SD	0.8064	0.0444	0.0677	0.1105	40.699	4.2104	4.9537	0.3331
SE Mean	9.1 0.2155	0.0157	0.0204	0.0295	11.749	1.1253	1.43	0.0961
C.V.	55.043	75.245	47.426	59.129	21.836	86.178	30.662	4.2984
Minimum	-0.3	-1.00E-03	0.02	-3.00E-03	145.6	0.4	7.43	7.43
1st Quarti	0.985	0.029	0.07	0.1275	155.57	2.5	12.598	7.53
Median	1.635	0.059	0.16	0.18	176	3.8	15.27	7.58
3rd Quarti	2.075	0.0715	0.21	0.2175	213.53	5.9	20.852	8.025
Maximum	2.5	0.151	0.22	0.49	287.5	15.6	23.35	8.49
MAD	0.485	0.0165	0.05	0.05	19.25	1.4	4.11	0.06

#### **Descriptive Statistics for SiteID = KR22040**

	ALKT	CHLA	DOC	DOCon	DOPer	MCYN	NH3	NO3
N	1	0	1	1	1	0	1	1
Mean	74	M	3.2	11.25	101.4	M	-0.013	0.6
SD	M	M	M	M	M	M	M	M
SE Mean	M	M	M	M	M	M	M	M
C.V.	M	M	M	M	M	M	M	M
Minimum	74	M	3.2	11.25	101.4	M	-0.013	0.6
1st Quarti	M	M	M	M	M	M	M	M
Median	74	M	3.2	11.25	101.4	M	-0.013	0.6
3rd Quarti	M	M	M	M	M	M	M	M
Maximum	74	M	3.2	11.25	101.4	M	-0.013	0.6
MAD	0	M	0	0	0	M	0	0

	NT	PHYCO	PO4	PT	SPC	TSS	Temp	pH
N	0	0	1	1	1	1	1	1
Mean	M	M	0.065	0.061	188.2	2.8	6.18	8.1
SD	M	M	M	M	M	M	M	M
SE Mean	M	M	M	M	M	M	M	M
C.V.	M	M	M	M	M	M	M	M
Minimum	M	M	0.065	0.061	188.2	2.8	6.18	8.1
1st Quarti	M	M	M	M	M	M	M	M
Median	M	M	0.065	0.061	188.2	2.8	6.18	8.1
3rd Quarti	M	M	M	M	M	M	M	M
Maximum	M	M	0.065	0.061	188.2	2.8	6.18	8.1
MAD	M	M	0	0	0	0	0	0

**Descriptive Statistics for SiteID = KR22460**

	ALKT	CHLA	DOC	DOCon	DOPer	MCYN	NH3	NO3
N	14	2	13	15	15	0	14	14
Mean	68.486	40.16	9.1185	9.014	102.67	M	0.2237	0.8347
SD	12.669	0.7354	1.4127	1.5059	8.3288	M	0.1735	0.291
SE Mean	3.386	0.52	0.3918	0.3888	2.1505	M	0.0464	0.0778
C.V.	18.499	1.8312	15.492	16.706	8.112	M	77.538	34.862
Minimum	52	39.64	7.1	7.42	89.1	M	0.048	0.096
1st Quarti	58.5	M	8.15	7.96	97.3	M	0.0565	0.65
Median	67.25	40.16	8.87	8.73	103.2	M	0.225	0.895
3rd Quarti	74.075	M	9.95	9.76	109	M	0.3325	1.015
Maximum	98	40.68	11.6	13.44	116.5	M	0.59	1.3
MAD	7.15	0.52	0.53	0.93	5.8	M	0.124	0.16

	NT	PHYCO	PO4	PT	SPC	TSS	Temp	pH
N	13	7	12	14	15	14	15	15
Mean	1.6054	0.0497	0.1844	0.18	185.06	4.4857	15.838	7.8053
SD	0.5922	0.0158	0.0595	0.0613	40.74	3.162	6.4877	0.3097
SE Mean	0.1642	5.98E-03	0.0172	0.0164	10.519	0.8451	1.6751	0.08
C.V.	36.885	31.841	32.261	34.038	22.014	70.49	40.963	3.9681
Minimum	0.46	0.022	0.08	0.11	142.6	1.6	0.31	7.43
1st Quarti	1.35	0.037	0.135	0.13	154.9	2.2	11.53	7.59
Median	1.7	0.057	0.2	0.17	172.9	3.6	16.39	7.66
3rd Quarti	2	0.061	0.2375	0.225	217.1	5.8	21.64	8.02
Maximum	2.5	0.066	0.25	0.31	279.6	13.2	23.7	8.38
MAD	0.3	9.00E-03	0.04	0.04	18	1.6	4.86	0.16

**Descriptive Statistics for SiteID = KR22822**

	ALKT	CHLA	DOC	DOCon	DOPer	MCYN	NH3	NO3
N	12	2	12	13	13	0	12	12
Mean	67.417	73.36	9.7283	8.0485	94.562	M	0.3237	0.9208
SD	15.178	33.446	1.9587	1.0699	11.072	M	0.437	0.2531
SE Mean	4.3814	23.65	0.5654	0.2967	3.0707	M	0.1261	0.0731
C.V.	22.513	45.592	20.134	13.294	11.708	M	134.97	27.491
Minimum	54	49.71	7	6.53	73.7	M	0.012	0.65
1st Quarti	56.25	M	7.97	7.065	86.25	M	0.0513	0.665
Median	66.4	73.36	9.38	7.98	94.9	M	0.245	0.875
3rd Quarti	70	M	11.5	8.82	102.4	M	0.365	1.165



Maximum	109	97.01	13	9.94	113.1	M	1.63	1.4
MAD	8.4	23.65	1.9	0.76	7.9	M	0.1475	0.205
	NT	PHYCO	PO4	PT	SPC	TSS	Temp	pH
N	12	7	10	12	13	12	13	13
Mean	1.9458	0.1123	0.194	0.2333	181.65	4.6	16.701	7.8092
SD	0.6965	0.0782	0.049	0.1657	46.461	1.7099	4.8316	0.4967
SE Mean	0.2011	0.0295	0.0155	0.0478	12.886	0.4936	1.3401	0.1378
C.V.	35.796	69.61	25.276	70.996	25.578	37.171	28.931	6.361
Minimum	0.63	0.026	0.11	0.11	146.1	2	7.33	7.32
1st Quarti	1.4325	0.043	0.155	0.13	152.1	3.6	13.975	7.485
Median	2.05	0.123	0.2	0.215	161.1	4.4	17.96	7.56
3rd Quarti	2.2675	0.127	0.2325	0.245	193.75	5.7	20.57	8.27
Maximum	3.2	0.263	0.26	0.72	318.7	8.4	22.63	8.78
MAD	0.485	0.045	0.035	0.08	14.8	0.8	3.23	0.1

#### **Descriptive Statistics for SiteID = KR23334**

	ALKT	CHLA	DOC	DOCon	DOPer	MCYN	NH3	NO3
N	14	9	13	15	15	7	14	14
Mean	73.393	23.653	9.6677	8.3053	95.413	0.1492	0.7134	0.1944
SD	13.194	20.845	1.8191	1.929	17.595	0.114	0.5751	0.2664
SE Mean	3.5262	6.9482	0.5045	0.4981	4.543	0.0431	0.1537	0.0712
C.V.	17.977	88.125	18.817	23.226	18.441	76.359	80.615	137
Minimum	59	2.0954	7	5.2	70.6	0.07	5.70E-03	-0.016
1st Quarti	64	8.5025	7.89	6.75	84	0.0962	0.0805	6.15E-03
Median	71.1	15.721	9.5	8.76	91.1	0.1	0.69	0.0455
3rd Quarti	79	44.53	11.25	9.57	113.1	0.16	1.225	0.5
Maximum	111	59.52	12.8	12.28	127.6	0.4	1.6	0.76
MAD	7	9.3163	1.6	1.05	11.5	0.0195	0.55	0.0531

	NT	PHYCO	PO4	PT	SPC	TSS	Temp	pH
N	13	7	12	14	15	14	15	15
Mean	1.4292	0.2999	0.1504	0.1921	188.67	5.3714	15.731	8.126
SD	0.5057	0.3063	0.0493	0.0685	43.527	2.5862	6.342	0.6295
SE Mean	0.1403	0.1158	0.0142	0.0183	11.239	0.6912	1.6375	0.1625
C.V.	35.386	102.14	32.768	35.661	23.071	48.147	40.315	7.7464
Minimum	0.44	0.023	0.07	0.11	146.4	0.8	0.73	7.26
1st Quarti	1.22	0.107	0.11	0.12	152.2	3.5	11.8	7.56
Median	1.4	0.184	0.165	0.195	180.4	4.8	15.97	8.19
3rd Quarti	1.8	0.388	0.1975	0.2525	219.6	8.5	21.52	8.58
Maximum	2.2	0.933	0.21	0.31	308	9.6	23.11	9.24
MAD	0.3	0.142	0.04	0.06	28.2	1.4	4.17	0.61

#### **Descriptive Statistics for SiteID = KR25312**

	ALKT	CHLA	DOC	DOCon	DOPer	MCYN	NH3	NO3
N	14	13	14	14	14	11	14	14
Mean	53.186	46.044	7.9236	8.84	104.17	0.4656	0.1602	0.1861
SD	4.3254	38.539	2.3679	1.3302	13.305	0.417	0.2606	0.2321
SE Mean	1.156	10.689	0.6328	0.3555	3.5559	0.1257	0.0696	0.062
C.V.	8.1326	83.701	29.884	15.048	12.772	89.557	162.63	124.71
Minimum	48	1.0535	4.7	7.47	81.8	0.054	-2.20E-03	0.013
1st Quarti	49.5	7.226	5.15	7.8525	97.3	0.16	0.0107	0.0325

Median	52.5	43.705	8	8.285	101.2	0.33	0.05	0.044
3rd Quarti	57.775	79.92	9.15	9.8025	110.53	0.674	0.1675	0.365
Maximum	60	122	12.3	11.9	139.7	1.4812	0.86	0.7
MAD	4.5	31.795	1.3	0.715	6.6	0.235	0.0402	0.026

	NT	PHYCO	PO4	PT	SPC	TSS	Temp	pH
N	13	7	12	14	14	14	14	14
Mean	1.7615	1.0816	0.0859	0.1581	124.35	15.543	16.362	8.9743
SD	0.6843	0.7104	0.0455	0.0926	8.0757	8.6971	6.129	0.8374
SE Mean	0.1898	0.2685	0.0131	0.0247	2.1583	2.3244	1.6381	0.2238
C.V.	38.845	65.682	52.945	58.58	6.4943	55.956	37.459	9.3315
Minimum	0.45	0.03	0.021	0.023	113.5	0	1.98	7.62
1st Quarti	1.2	0.488	0.0425	0.061	118.47	7	12.19	7.9325
Median	2.03	1.408	0.085	0.17	124.4	20.8	17.225	9.195
3rd Quarti	2.25	1.676	0.1275	0.24	127.08	21.8	22.355	9.725
Maximum	2.6	1.824	0.15	0.3	146.3	25.6	22.72	9.91
MAD	0.33	0.416	0.04	0.0795	2.85	4.4	4.975	0.545

**Descriptive Statistics for SiteID = KR25479**

	ALKT	CHLA	DOC	DOCon	DOPer	MCYN	NH3	NO3
N	1	1	1	1	1	0	1	1
Mean	56	3.4	8	9.41	78.2	M	0.9	0.28
SD	M	M	M	M	M	M	M	M
SE Mean	M	M	M	M	M	M	M	M
C.V.	M	M	M	M	M	M	M	M
Minimum	56	3.4	8	9.41	78.2	M	0.9	0.28
1st Quarti	M	M	M	M	M	M	M	M
Median	56	3.4	8	9.41	78.2	M	0.9	0.28
3rd Quarti	M	M	M	M	M	M	M	M
Maximum	56	3.4	8	9.41	78.2	M	0.9	0.28
MAD	0	0	0	0	0	M	0	0

	NT	PHYCO	PO4	PT	SPC	TSS	Temp	pH
N	0	0	1	1	1	1	1	1
Mean	M	M	0.02	0.055	147.1	2.4	1.82	7.43
SD	M	M	M	M	M	M	M	M
SE Mean	M	M	M	M	M	M	M	M
C.V.	M	M	M	M	M	M	M	M
Minimum	M	M	0.02	0.055	147.1	2.4	1.82	7.43
1st Quarti	M	M	M	M	M	M	M	M
Median	M	M	0.02	0.055	147.1	2.4	1.82	7.43
3rd Quarti	M	M	M	M	M	M	M	M
Maximum	M	M	0.02	0.055	147.1	2.4	1.82	7.43
MAD	M	M	0	0	0	0	0	0

## APPENDIX B

### 2008 QUALITY ASSURANCE REPORT

#### SUMMARY

The data quality objectives for the 2008 PacifiCorp basic water quality monitoring program are described in detail below. The general objective for the program was 90 percent completeness, applied to the number of samples analyzed of the total planned, and also to the number of quality assurance measurements that met criteria. The overall completeness of the 2008 monitoring program for the number of samples analyzed was 92 percent. The overall completeness of the program for samples meeting QA criteria was 93 percent. The completeness for samples analyzed for individual constituents is provided in Table B-1. The completeness for meeting QA criteria for individual constituents is provided in Table B-2.

**Table B-1. Sampling completeness for each constituent**

Constituent	NH4	NO3	PT	NT	TSS	VSS	ALKT	TOC	DOC	MCYN	CHLA	PHEO
Planned Samples	417	417	417	416	417	417	417	362	418	374	388	388
Analyzed Samples	403	403	403	387	400	385	400	348	377	336	348	292
Completeness	97%	97%	97%	93%	96%	92%	96%	96%	90%	90%	90%	75%
Total Completeness	91%											

**Table B-2. Analytical quality control completeness for each constituent**

Constituent	NH4	NO3	PT	NT	TSS	VSS	ALKT	DOC	MCYN	CHLA	PHEO
Analyzed	79	79	79	77	75	60	70	56	36	43	35
Missed	0	9	2	2	4	1	1	5	3	18	12
Confirmed		4	0	0			1	2			
Percent complete	100	94	97	97	95	98	100	95	92	58	66

Completeness criteria were met for all constituents with the exception of chlorophyll *a* and pheophytin. The QA results for chlorophyll *a* and pheophytin are based on blanks and replicates. In the Klamath River with its abundance of algal species that form large colonies, close agreement between replicate samples is particularly hard to achieve, even when comparing well-mixed samples.

#### INTRODUCTION

The Klamath River 2008 (KR2008) water quality sampling included external quality assurance (QA) samples. The sampling occurred between April 2008 and January 2009 and field work was performed by E & S Environmental Chemistry, Inc. Watercourse Engineering, Inc. assisted in laboratory oversight and post-laboratory quality assurance. Sampling dates are presented in Table B-3. During the course of the year there were fifteen sampling sessions and field personnel

collected 4,482 samples of water for analysis from 25 sites along the Klamath River and in Upper Klamath Lake. 742 of these samples were external QA samples from five sites. Sampling sites are presented in Table B-4 below. Sample results were reported to Watercourse Engineering, Inc. (Watercourse) by CH2M Hill Applied Sciences Laboratory in Corvallis, Oregon, the analytical lab chosen for the project. Water samples were analyzed for ammonia (NH<sub>4</sub>), nitrate-nitrite (NO<sub>3</sub>), total phosphorus (PT), total nitrogen (NT), total suspended solids (TSS) volatile suspended solids (VSS), alkalinity (ALK), dissolved organic carbon (DOC), microcystin (MCYN), chlorophyll-a (CHLA) and pheophytin (PHEO). The project incorporated external quality assurance samples (QA samples) as per the Quality Assurance Project Plan (QAPP) adopted by E&S Environmental, Watercourse, and PacifiCorp: ten percent of samples for spikes and duplicates and five percent of samples for blanks per sampling session throughout the sampling period.

**Table B-3. Sampling dates for KR2008**

Collection Weeks	
4/27/2008	8/18/2008
5/19/2008	8/25/2008
6/2/2008	9/8/2008
6/16/2008	9/15/2008
6/23/2008	9/22/2008
6/30/2008	9/29/2008
7/7/2008	10/6/2008
7/14/2008	10/13/2008
7/21/2008	10/20/2008
7/28/2008	11/17/2008
8/4/2008	1/12/2009
8/11/2008	

**Table B-4. External QA sampling sites of KR2008 (bold indicates external QA site)**

Site ID	Site Name	Approximate River Mile
<b>KR15750</b>	<b>Klamath River at Walker Road Bridge</b>	<b>157.50</b>
KR17923	Klamath River at the I-5 rest area	176
KR18973	Klamath River below Iron Gate dam	189.73
KR19000	Iron Gate Reservoir tailrace	190
KR19010	Iron Gate Reservoir fore bay	190.1
KR19019	Iron Gate Reservoir at the lower end near the log boom	190.19
KR19100	Iron Gate Reservoir at boat Launch	191
KR19200	Iron Gate Reservoir at Camp Creek	192
IRJW	Iron Gate Reservoir at Mirror Cove (Jay Williams)	-
KR19645	Klamath River below Copco No. 2 powerhouse	196.45
KR19873	Klamath River below Iron Gate dam	198.73
KR19874	Copco Reservoir at the lower end near the log boom	198.74
KR19890	Copco Reservoir - Copco Cove	198.9
<b>KR19950</b>	<b>Copco Reservoir - Mallard Cove</b>	<b>199.5</b>
<b>KR20642</b>	<b>Klamath River above Shovel Creek</b>	<b>206.42</b>
<b>KR22000</b>	<b>Klamath River below J.C. Boyle powerhouse</b>	<b>220.4</b>
KR22460	Klamath River below JC Boyle Dam	224.6
KR22478	J.C. Boyle Reservoir at the lower end near the log boom	224.78
KR22822	Klamath River above J.C. Boyle reservoir	228.22
<b>KR23334</b>	<b>Klamath River below Keno Dam</b>	<b>233.3</b>
KR25312	Link River	253.12
UKER	Upper Klamath Lake near Eagle Ridge ramp	-
UKHP	Upper Klamath Lake near Hagelstein Park	-
UKPB	Upper Klamath Lake at Pelican Bay ramp	-
UKWB	Upper Klamath Lake at Wocus Bay	-

## QUALITY ASSURANCE REVIEW

Laboratory results for external QA samples were usually acceptable for most parameters. QA samples exceeding the adopted acceptance criteria were submitted for reanalysis when appropriate. Reanalysis results which confirmed the original results for the QA samples indicate one of several possibilities: a manufacture error in QA spikes, uncertainty introduced in field procedures, or uncertainty in laboratory practices and procedures. The quality assurance project plan (QAPP) guidelines accept the original results of a QA sample as reliable when the laboratory is able to confirm the original result with reanalysis. If the laboratory is unable to confirm the original results for a QA sample, QA guidelines assert the need to submit the whole sample batch of production and QA samples for reanalysis. However, the CH2M Hill laboratory was unable to confirm original results in a timely manner due to unexpected workloads during the field season in 2008. This increased process time limited the ability for reanalyzing entire sampling batches within acceptable sample hold times. Thus entire batch reanalysis was not performed for this project.

### Quality Assurance Criteria

There were several criteria, or QA assessment values, used to determine the acceptability of sample results. Blank sample concentration criteria required that sample concentration be less than ten percent of the lowest sample concentration reported in its batch or less than or equal to twice the method reporting limit (MRL). Duplicate sample criteria were (a) for concentrations greater than or equal to five times the MRL, the Relative Percent Difference (RPD) should be less than 20% (Equation ( 1 ) or (b) for concentrations less than five times the MRL, values of the duplicate sample and regular sample should vary not more than plus or minus the MRL. Finally, spike sample criteria were (a) for sample concentrations that do not exceed five times the spike concentration, the recovery should fall between 80 and 120% (Equations ( 2 ) and ( 3 )), or (b) for sample concentrations that exceed five times the spike concentration, there are no criteria to determine the acceptability of the result. Due to lab turn-around time and data QA processing time, most samples were reanalyzed at or just beyond the identified hold times.

$$RPD = \frac{[Regular] - [Duplicate]}{[M]} \times 100 \quad (1)$$

$$\text{Recovery for Added Spike} = \frac{[Spike] - [M]}{[Spike \text{ Material Added}]} \times 100 \quad (2)$$

$$\text{Recovery for Reference Solution} = \frac{[Spike]}{[Reference \text{ Solution}]} \times 100 \quad (3)$$

where:

M	= Mean of Regular and Duplicate Concentrations.
Regular	= Concentration of regular sample
Duplicate	= Concentration of duplicate sample
Spike	= Concentration of either spiked sample or reference solution

The criteria presented above are often used as guidelines in quality assurance processes and QA that fall close to the criteria may be identified as acceptable. The extent to which the acceptable limits are expanded is dependent on several things, including the laboratory performance of the specified constituent's QA assessment during the course of the current or previous studies, the type of QA sample involved, and the adherence to the SOP during the sample collection. During the Klamath River 2008 project the criteria were relaxed for samples relatively close to meeting QA requirements. For example, the RPD value limit was allowed to extend up to 26 percent, and the spike / reference solution recovery limits were accepted over the range from 74 percent to 131 percent. During the QA summaries for the different studies of the Klamath River 2008 project all approximately acceptable QA assessment values are included as acceptable. The completeness of the project was also calculated (Equation ( 4 )). Completeness was calculated per project and also per constituent.

$$\text{Completeness} = \frac{\text{samples that were planned to be collected and analyzed}}{\text{samples that were actually collected and analyzed}} \quad (4)$$

## **Quality Assurance Issues of the Klamath River 2008 Project**

During the QA assessment process for the Klamath River 2008 project, some issues pertaining to the QA samples were identified. These are discussed below.

### *Instrument for pheophytin analysis availability*

During the initial period of sampling, the instrument for pheophytin analysis was not available for use at the laboratory.

### *Blank water NO<sub>3</sub> contamination*

During the initial period of sampling, it was determined that the water that the field crew was using to create blank samples was contaminated with NO<sub>3</sub>. This problem was corrected as quickly as possible, but seven blanks were sent to the lab for analysis prior to the discovery and correction of the contamination.

### *Delay between sample collection and quality assurance assessment*

On one occasion the time period between sample collection and quality assurance assessment was considered longer than hold times.

### *New Total Nitrogen (NT) analysis method for laboratory*

The analysis method use for determining the NT concentrations of the samples was a new test for the lab. The laboratory staff was still working on methods and procedures associated with the method during the KR2008 sample collections. Almost all of the NT spike concentrations were below acceptable limits of recovery. There was no explanation regarding low recoveries.

### *New TOC analysis method for laboratory*

A TOC analysis method used during this project was experimental to determine if the laboratory could overcome interference with particulate matter. Therefore there was no reanalysis of TOC samples that did not fall within acceptable QA limits. Constituent specific TOC and DOC spikes also were explored in 2008, but low spike values precluded formally including these investigative results in the QA summary.

## **KR2008 QA Assessment Summary**

During the KR2008 sampling collection there were a total of 742 QA samples analyzed.

### ***Quality Assurance Sample Type Summary***

#### **Blanks**

There were a total of 318 QA blank samples. Of those samples, eighteen had QA assessment results outside of the acceptable QA limits, including the seven blank samples affected by the nitrate-nitrite contamination. Of these eighteen samples, twelve were reanalyzed and ten original results were confirmed.

#### **Regulars / Duplicates**

There were 318 sets of regular and duplicate samples. Of these samples, 44 sets had RPD values above acceptable limits. Of those 44, eight sets were reanalyzed and one of the original results was confirmed.

### **Spikes**

There were 106 QA spike samples available during 2008. Of these samples, twenty had recoveries outside of acceptable limits. Of those twenty, two were reanalyzed and both results were confirmed.

### **Laboratory QC Reports**

All internal laboratory QC reports were acceptable.

### ***Constituent Summary***

#### **Ammonia**

There were a total of 79 QA samples for ammonia. Of those samples, none had QA assessment values outside of acceptable limits.

#### **Nitrate - Nitrite**

There were a total of 79 QA samples for nitrate-nitrite. Of those samples, nine had QA assessment values outside of acceptable limits. Seven samples were reanalyzed and four of the original results were confirmed.

#### **Total Phosphorus (PT)**

There were a total of 79 QA samples for total phosphorus. Of those samples, two had QA assessment values outside of acceptable limits. Both samples were reanalyzed but neither of the original results was confirmed.

#### **Total Nitrogen (NT)**

There were a total of 77 QA samples for analyzed for total nitrogen. Of those samples, 25 had QA assessment values outside of acceptable limits. Seven of those samples were reanalyzed and six of the original results were confirmed.

#### **Total Suspended Solids (TSS)**

There were 75 QA samples analyzed for TSS. Of those samples, four had QA assessment values outside of acceptable limits. No reanalysis was completed on TSS due to the short hold time.

#### **Volatile Suspended Solids (VSS)**

There were 60 QA blank and regular / duplicate samples for VSS in 2008. One of the VSS samples had a QA assessment value outside of acceptable limits. No reanalysis was completed on VSS due to the short hold time. No sample spikes were available for VSS, thus only the regular / duplicate and blank samples were assessed.

#### **Alkalinity (Alk)**

There were a total of 70 QA samples for analyzed for alkalinity. Of those samples, one had a QA assessment value outside of acceptable limits. The sample was reanalyzed and the original result was confirmed.



### **Dissolved Organic Carbon (DOC)**

There were 56 QA samples analyzed for DOC. Of those samples, five had QA assessment values outside of acceptable limits. All five samples were reanalyzed and two original results were confirmed. DOC sample spikes were not included in 2008, thus only the regular / duplicate and blank samples were assessed.

### **Microcystin (MCYN)**

There were 36 QA samples for microcystin in 2008. Three of the microcystin samples had QA assessment values outside of acceptable limits. Microcystin samples were not reanalyzed during 2008. No sample spikes were available for MCYN, thus only the regular / duplicate and blank samples were assessed.

### **Chlorophyll-a (CHLA)**

There were 43 QA samples for chlorophyll-a in 2008. Eighteen of the chlorophyll-a samples had QA assessment values outside of acceptable limits. Chlorophyll-a samples were not reanalyzed in 2008. No sample spikes were available for CHLA, thus only the regular / duplicate and blank samples were assessed.

### **Pheophytin (PHEO)**

There were 35 QA samples for pheophytin in 2008. Twelve of the pheophytin samples had QA assessment values outside of acceptable limits. Pheophytin samples were not reanalyzed in 2008. No sample spikes were available for PHEO, thus only the regular / duplicate and blank samples were assessed.

### **Completeness**

The KR2008 sampling program was 92 percent complete overall and ranged from 75 percent to 97 percent for the individual constituents collected. Table presents the individual constituent completeness values.

**Table B-5. KR2008 completeness for each constituent**

	NH4	NO3	PT	NT	TSS	VSS	ALKT	TOC	DOC	MCYN	CHLA	PHEO
Planned Samples	417	417	417	416	417	417	417	362	418	374	388	388
Analyzed Samples	403	403	403	387	400	385	400	348	377	336	348	292
Completeness	97%	97%	97%	93%	96%	92%	96%	96%	90%	90%	90%	75%
Total Completeness	91%											