FINAL

WATER QUALITY STATUS AND TRENDS IN THE CLARK FORK-PEND OREILLE WATERSHED

TIME TRENDS ANALYSIS FOR THE 1984-2007 PERIOD

Prepared for:

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

FIGURES

TABLE OF CONTENTS (continued)

FIGURES (continued)

TABLES

TABLE OF CONTENTS (continued)

APPENDICES [Bound Separately]

CLARK FORK-PEND OREILLE WATERSHED MONITORING, 1984-2007

EXECUTIVE SUMMARY

This report summarizes water quality data collected in the Clark Fork-Pend Oreille Basin over a ten-year period from 1998-2007 by the Tri-State Water Quality Council and by state agencies prior to 1998. Analyses presented in the report describe the spatial and temporal variability in concentrations of algal nutrients (nitrogen and phosphorus) and periphyton (attached algae) in the Clark Fork River and selected tributaries, and in Lake Pend Oreille Lake and the Pend Oreille River.

The Tri-State Water Quality Council established seven priority water quality monitoring objectives for the Clark Fork-Pend Oreille watershed in 1998. These include:

1) Evaluating time trends in nutrient concentrations in the mainstem Clark Fork River and selected tributaries;
2) evaluating time trends for algal standing crops in the Clark Fork River;
3) monitoring compliance with established summer nutrient concentration target levels in the Clark Fork River;
4) estimating nutrient loading rates to Lake Pend Oreille from the Clark Fork River;
5) evaluating time trends for algal standing crops in near-shore areas of Lake Pend Oreille;
6) evaluating time trends for Secchi transparency in Lake Pend Oreille; and
7) evaluating time trends for nutrient concentrations in the Pend Oreille River.

Nutrient constituents monitored over the past 10 years have included total phosphorus, total nitrogen, total soluble inorganic nitrogen, and soluble reactive phosphorus. Levels of attached algae are measured in terms of chlorophyll *a* and ash-free dry weight from natural substrate samples. Water quality monitoring results for the above parameters for 15 river stations and 9 lake stations are analyzed in this report.

This report focuses on water quality status, spatial patterns and statistically significant temporal trends reflected in instream and in-lake concentrations of the selected monitoring variables. The report also provides an appraisal of nutrient loading to Lake Pend Oreille.

Overall, water quality with respect to nutrients and attached algae showed no trends, or improving trends in the Clark Fork-Pend Oreille Watershed:

- In general, water quality with respect to total phosphorus and nitrogen for riverine stations of the Clark Fork-Pend Oreille watershed either showed no trend, or improving status with respect to total nitrogen and total phosphorus during the summer monitoring period.
- From 1998 to 2007, riverine monitoring stations showed increasing trends for attached algae at two upper river sites (Clark Fork above Little Blackfoot and Clark Fork at Bonita). The remaining 5 river stations showed no trend, or decreasing trends in periphyton metrics.

- Loading of total phosphorus to Lake Pend Oreille measured at the Cabinet Gorge site averaged 209,000 kg/yr from 1984 to 2007. The loading target of 259,500 kg/yr has been exceeded 5 times during this 23 yr period. From 2000 to 2007, this target has been exceeded once.
- Trophic status in Lake Pend Oreille indicates oligotrophic conditions at most open water and near-shore sites based on total phosphorus concentrations, chlorophyll *a* values, and Secchi transparency in 2007.
- No statistically significant trends are apparent in summer Secchi transparency at stations monitored from 1953-2007. This suggests a stable trophic state for the lake.
- Periphyton monitoring in Lake Pend Oreille indicated either a decrease or no change in algal standing crop at all five stations. The sole exception was Springy Point which showed an increase in chlorophyll *a*, but not ash-free dry weight.
- Exceedance of total phosphorus targets in Lake Pend Oreille for open water (7.3 µg/l) and near-shore (9 µg/l) monitoring sites have been infrequent at most sites. Oden Bay and Midlake stations have had the most frequent excursions (28 and 25%). Along with Oden Bay, the Sunnyside monitoring site tended to have elevated nutrient concentrations and algal biomass.
- With a handful of exceptions, water quality monitoring in the Clark Fork-Pend Oreille watershed demonstrated stable or improving conditions with respect to nutrients and attached algae from 1984-2007.

1.0 INTRODUCTION

The Tri-State Water Quality Council was created in 1993 with a mission to develop and implement a management strategy to restore and protect designated water uses within the greater Clark Fork-Pend Oreille Basin. The Council is a successful partnership of citizens, businesses, industries, tribes, government, and environmental groups working together to improve and protect water quality throughout the 26,000 square mile Clark Fork-Pend Oreille watershed. The watershed includes the Clark Fork River in western Montana, Lake Pend Oreille in northern Idaho, and the Pend Oreille River in eastern Washington. The Council accomplishes its work through a series of focused work groups and committees, who report back to the full Council at biennial meetings scheduled around the watershed.

Beginning in 1996, the Council's Water Quality Monitoring Committee has worked to design and implement a monitoring program capable of evaluating basin-wide water quality status and trends and the effectiveness of a three-state nutrient management plan. The initial monitoring strategy was finalized and implemented beginning in 1998 and replaced former state agency monitoring efforts dating back to 1984. Year-to-year water quality status and attainment of water quality management goals has been evaluated since 1988 in a series of annual interpretive reports. In 2003, water quality trends over the five-year 1998-2002 time period were statistically evaluated and reported and some changes were made to the monitoring program (Land & Water 2004).

This report evaluates and describes temporal trends in water quality in the Clark Fork-Pend Oreille Basin for a second five-year period beginning in 2003 and ending in 2007. The analysis builds on the earlier five-year trends assessment, and some of the evaluations examine long-term trends in water quality over the 1984-2007 period. The purpose of this analysis is to provide feedback to the Council on the effectiveness and overall success of its actions, to identify the need for any adjustments to the three-state water quality management plan, and to help optimize the water quality monitoring program for maximum sensitivity and cost effectiveness.

2.0 MONITORING PROGRAM DESCRIPTION

2.1 Program Overview

The Tri-State Water Quality Council has operated the Water Quality Status and Trends Monitoring System for the Clark Fork-Pend Oreille Watershed since 1998 under sponsorship of the following entities:

Avista Corporation	Plum Creek Timber Company
City of Sandpoint, Idaho	Stimson Lumber Company
Idaho Department of Environmental Quality	University of Montana
City of Missoula Wastewater Treatment Plant	U. S. Forest Service
Missoula County Water Quality Protection District	U. S. Environmental Protection Agency
Montana Department of Environmental Quality	Washington Department of Ecology

The Council's Clark Fork-Pend Oreille Watershed water quality monitoring program employs a statistically-based sampling design derived from an analysis of previous water quality monitoring data collected for the watershed by state agencies. Through this design approach, sampling frequencies and monitoring locations have been optimized to provide reliable information for watershed management decision-making while minimizing operational costs.

The monitoring program focuses on nutrients (nitrogen and phosphorus variables), algal growth, and heavy metals. A variety of short-term special studies have also been conducted to evaluate the potential effects of proposed developments in the watershed. Other groups and agencies also collect data on a wide variety of water quality issues. The Council is working with those groups to make a more complete picture of water quality available to the public and scientific communities.

The Council's monitoring network consists of a series of fixed river, tributary and lake monitoring stations that are monitored on a regular schedule, either monthly or seasonally. The locations selected for monitoring provide distributed spatial coverage for assessment of point and non-point pollution inputs, serve as reference points above and below major communities, and offer information about input from tributaries. Individual management-monitoring goals are outlined with applicable statistical criteria in Section 2.2 of this report.

PBS&J (formerly Land & Water Consulting) has been contracted since 1998 to conduct year-round monthly monitoring along the Clark Fork River and in 2007 to conduct monthly summer monitoring in Lake Pend Oreille. The City of Missoula conducts biweekly summer nutrient monitoring at a network of upper and middle Clark Fork River and tributary stations. The University of Montana Watershed Health Clinic performs summer periphyton (attached algae) standing crop sampling at the Clark Fork River monitoring sites. Avista Corporation cooperates with the Council to conduct biweekly spring runoff monitoring for nutrients and metals in the Clark Fork River below Cabinet Gorge Dam during the peak runoff months of May and June. Lastly, Washington Department of Ecology monitors water quality on a monthly basis in the Pend Oreille River. PBS&J currently manages all of the program data, produces annual interpretive summary reports, and has been charged with conducting the periodic five-year trends analyses.

2.2 Management Goals and Monitoring Objectives

The Tri-State Water Quality Council has established four primary water quality management goals and seven associated water quality monitoring goals for the Clark Fork-Pend Oreille Watershed, as follows:

<u>Management Goals:</u>

- Control nuisance algae in the Clark Fork River by reducing nutrient concentrations.
- Protect Lake Pend Oreille water quality by maintaining or reducing current rates of nutrient loading from the Clark Fork River.
- Reduce near-shore eutrophication in Lake Pend Oreille by reducing nutrient loading from local sources.

- Improve Pend Oreille River water quality through macrophyte management and tributary non-point source controls.

Monitoring Objectives:

1) Evaluating time trends in nutrient concentrations in the mainstem Clark Fork River and selected tributaries;
2) Evaluating time trends for periphyton (algae) standing crops in the Clark Fork River;
3) Monitoring compliance with established summer nutrient and periphyton target levels in the Clark Fork River;
4) Estimating nutrient loading rates to Lake Pend Oreille from the Clark Fork River;
5) Evaluating time trends for periphyton densities in near-shore areas of Lake Pend Oreille;
6) Evaluating time trends for Secchi transparency in Lake Pend Oreille; and
7) Evaluating time trends for nutrient concentrations in the Pend Oreille River.

Trend detection evaluation criteria associated with these goals are described below:

2.2.1 Clark Fork River - Nutrient Trend Detection

MANAGEMENT GOAL:	Reduce instream nutrient concentrations
MONITORING GOAL:	Detect significant trends in nutrient concentrations
DEFINITION OF NUTRIENTS:	TP, TN, SRP, TSIN concentrations
STATISTICAL METHODOLOGY:	Mann-Kendall with Sen slope estimate
STATISTICAL HYPOTHESIS:	Ho: No trend exists; Ha: Trend exists (α=0.05)
DATA ANALYSIS RESULT:	Conclusions regarding presence of trends Provide estimate of trend magnitude
INFORMATION PRODUCT:	Management goal met when trend indicates decreasing concentrations

2.2.2 Clark Fork Rive - Nuisance Algae

MANAGEMENT GOAL:	Reduce instream periphyton (attached algae) densities
MONITORING GOAL:	Detect significant trends in summer periphyton standing crops
DEFINITION OF PERIPHYTON:	Chlorophyll *a* (mg/m^2) and biomass (AFDW g/m^2) natural substrates
STATISTICAL METHODOLOGY:	Kendall with Sen slope estimate
STATISTICAL HYPOTHESIS:	Ho: No trend exists; Ha: Trend exists (α=0.05)
DATA ANALYSIS RESULT:	Conclusions regarding presence of trends Provide estimate of trend magnitude
INFORMATION PRODUCT:	Management goal met when trend indicates decreasing densities

2.2.3 Clark Fork River - Instream Nutrient Targets

MANAGEMENT GOAL:	Attain and maintain instream nutrient targets
MONITORING GOAL:	Evaluate frequency of excursions of summer nutrient targets
DEFINITION OF NUTRIENT TARGETS:	TP 20-39 µg/l; TN 300 µg/l; SRP 6µg/l; TSIN 30 µg/l
STATISTICAL HYPOTHESIS:	Ho: Proportion <= .05; Ha: Proportion > .05
DATA ANALYSIS RESULT:	Conclusions regarding attainment of targets
INFORMATION PRODUCT:	Management goal met when target levels achieved

2.2.4 Lake Pend Oreille - Nuisance Algae

MANAGEMENT GOAL:	Maintain or reduce periphyton (attached algae) densities
MONITORING GOAL:	Detect significant trends in summer periphyton standing crops
DEFINITION OF PERIPHYTON:	Chlorophyll *a* (mg/m^2) and biomass (AFDW g/m^2) natural substrates
STATISTICAL METHODOLOGY:	Kendall's tau with Sen slope estimate
STATISTICAL HYPOTHESIS:	Ho: No trend exists; Ha: Trend exists (α=0.05)
DATA ANALYSIS RESULT:	Conclusions regarding presence of trends Provide estimate of trend magnitude
INFORMATION PRODUCT:	Management goal met when no trend exists, or trend indicates decreasing densities

2.2.5 Lake Pend Oreille - Nutrient Loading

MANAGEMENT GOAL:	Maintain or reduce nutrient loading rates to Lake Pend Oreille
MONITORING GOAL:	Detect significant trends in nutrient loads at MT-ID border
DEFINITION OF NUTRIENTS:	TP, TN, SRP, TSIN annual loads
STATISTICAL METHODOLOGY:	Mann-Kendall with Sen slope estimate
STATISTICAL HYPOTHESIS:	Ho: No trend exists; Ha: Trend Exists (α=0.05)
DATA ANALYSIS RESULT:	Conclusions regarding presence of trends Provide estimate of trend magnitude
INFORMATION PRODUCT:	Management goal met when no trend exists, or trend indicates decreasing loads

2.2.6 Lake Pend Oreille - Trophic Status

MANAGEMENT GOAL:	Maintain present trophic status
MONITORING GOAL:	Detect significant trends in summer water clarity
DEFINITION OF TROPHIC STATUS:	Secchi transparency (meters)
STATISTICAL METHODOLOGY:	Seasonal Kendall with Sen slope estimate
STATISTICAL HYPOTHESIS:	Ho: No trend exists; Ha: Trend exists
DATA ANALYSIS RESULT:	Conclusions regarding presence of trends Provide estimate of trend magnitude
INFORMATION PRODUCT:	Management goal met when no trend exists, or trend indicates improving water clarity

2.2.7 Pend Oreille River - Nutrient Trend Detection

MANAGEMENT GOAL:	Maintain or reduce instream nutrient concentrations
MONITORING GOAL:	Detect significant trends in nutrient concentrations
DEFINITION OF NUTRIENTS:	TP, TN, SRP, TSIN concentrations
STATISTICAL METHODOLOGY:	Seasonal Kendall with Sen slope estimate
STATISTICAL HYPOTHESIS:	Ho: No trend exists; Ha: Trend exists (α=0.05)
DATA ANALYSIS RESULT:	Conclusions regarding presence of trends Provide estimate of trend magnitude
INFORMATION PRODUCT:	Management goal met when no trend exists, or trend indicates deceasing concentrations

The statistical design criteria for testing the stated hypotheses will generally be reported at the 5% significance levels.

2.3 Monitoring Network

The Clark Fork-Pend Oreille Watershed monitoring network includes 15 stations on the Clark Fork River, selected tributaries, Pend Oreille Lake, and the Pend Oreille River in western Montana, northern Idaho, and northeastern Washington (**Figure 2-1**). Lake monitoring stations cover 14 near-shore and open water locations. The locations selected for water quality monitoring provide distributed spatial coverage for evaluating the effects of point and non-point pollution sources, and the influences of major population centers and tributary inflows. A summary of monitoring locations and associated sampling frequencies are provided in **Table 2-1**. Several lake sites which are not a part of the regular monitoring network were included for completeness. Riverine and Lake Pend Oreille monitoring sites are depicted on **Figures 2-1** and **2-2**.

Table 2-1. *Clark Fork-Pend Oreille Watershed* monitoring *locations and sampling frequency.*

Station	Name	Sampling Frequency
2.5	Silver Bow Creek at Opportunity	S10
07	Clark Fork below Warm Springs Creek	S10
09	Clark Fork at Deer Lodge	P10, S10
10	Clark Fork above Little Blackfoot River	P10, S10
12	Clark Fork at Bonita	P10, S10
15.5	Clark Fork above Missoula	P10, S10
18	Clark Fork below Missoula (Shuffields)	P10, S10
22	Clark Fork at Huson	P10, S10
25	Clark Fork above Flathead	P10, S10
27.5	Thompson River near mouth	N12
28*	Clark Fork below Thompson Falls	NM12
29*	Clark Fork at Noxon Bridge	NM12
30*	Clark Fork below Cabinet Gorge Dam	NM18
50	Pend Oreille River at Newport, WA	N12
55	Pend Oreille River at Metaline Falls, WA	N12
	Pend Oreille Lake: Lakeview	P10, NSD
	Pend Oreille Lake: Talache	P10, NSD
	Pend Oreille Lake: Midlake	NSD
	Pend Oreille Lake: Trestle	P10, NSD
	Pend Oreille Lake: Garfield Bay	P10, NSD
	Pend Oreille Lake: Bayview open water	NSD
	Pend Oreille Lake: Bayview nearshore	P10, NSD
	Pend Oreille Lake: Oden Bay	P10, NSD
	Pend Oreille Lake: Sunnyside	P10, NSD
	Pend Oreille Lake: PDO North	NSD
	Pend Oreille Lake: Kootenai	P10, NSD
	Pend Oreille Lake: Springy Point	P10, NSD
X	Pend Oreille Lake: Granite Open Water	Secchi only, TP (2003)
X	Pend Oreille Lake: Hope	Secchi only

N12 = Nutrient and field constituents, monthly samples
NM12 = Nutrient, metal and field constituents, monthly samples
NM18 = Nutrient, metal and field constituents, monthly samples and 6 peak flow samples
P10 = Periphyton, 10 replicates per site, August and September
S10 = Summer nutrient and field constituents, 10 samples during 3 months in summer
NSD = Nutrients, chlorophyll *a*, Secchi depth and field constituents, monthly during June –September
X = Not a part of the regular monitoring network in 2007, but included for completeness
* These sites sponsored by Avista Corp., pursuant to 401 certification requirement

Figure 2-1. ***Clark Fork and Pend Oreille River monitoring sites.***

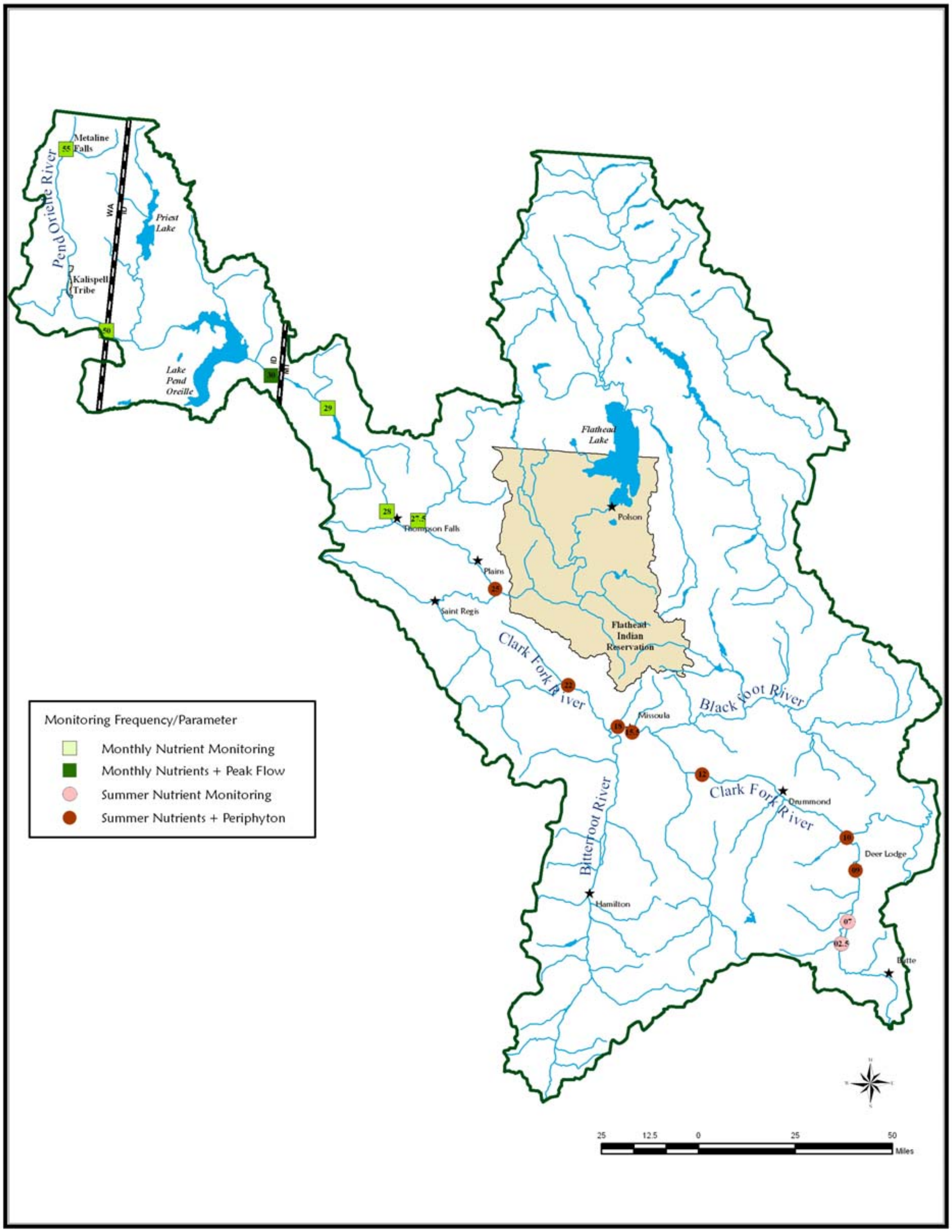
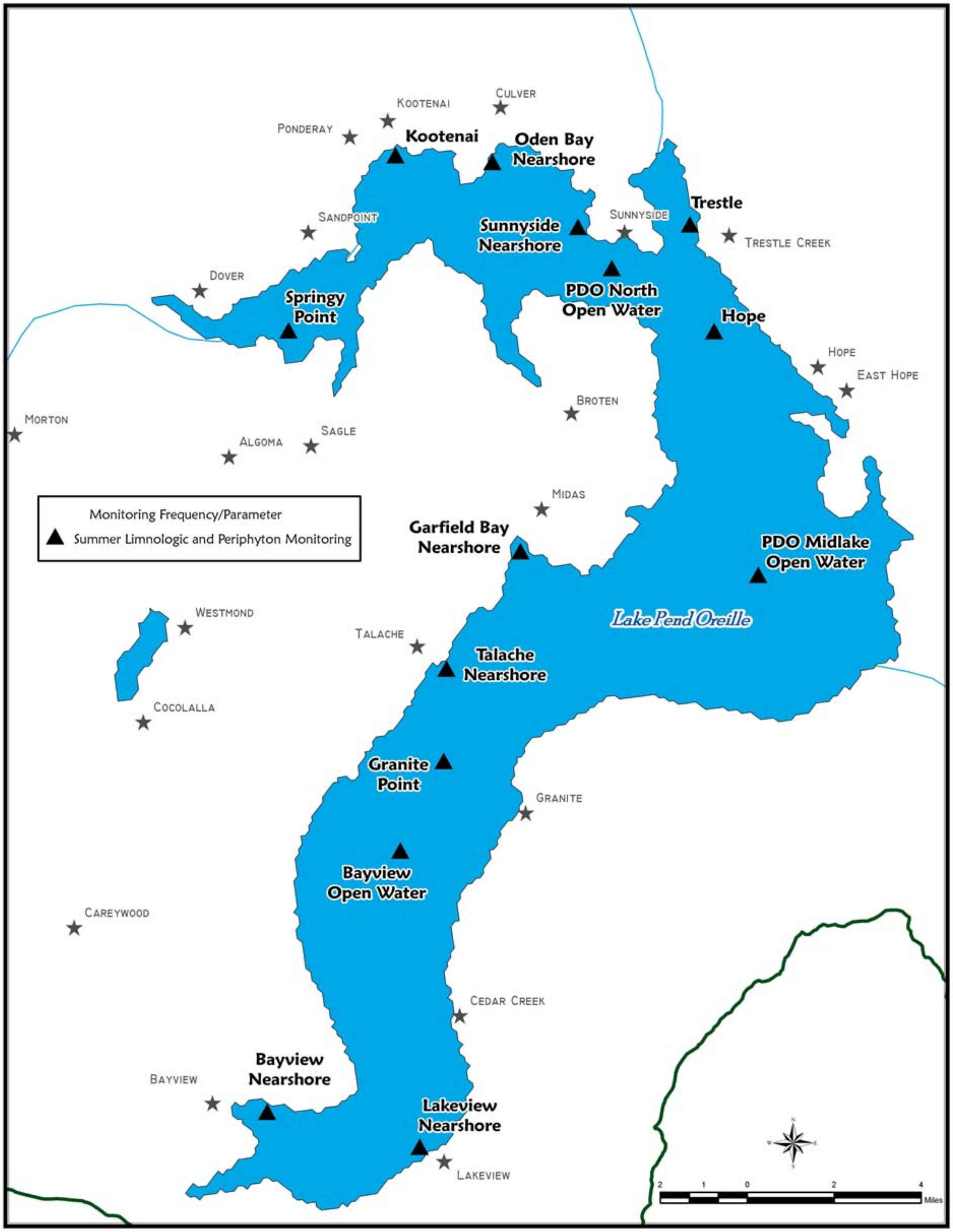


Figure 2-2. ***Lake Pend Oreille monitoring sites.***



2.4 Sampling and Analysis Methods

The 2003-2007 Clark Fork-Pend Oreille Watershed basic monitoring program included each of the tasks described below:

1. Monthly collection of nutrient and heavy metals samples and field measurements at three lower Clark Fork River sites, and monthly collection of nutrient samples and field measurements at a single site on the Thompson River and two sites on the Pend Oreille River (January-December);
2. Summer collection of periphyton standing crop samples at seven Clark Fork River sites (July, August and September);
3. Summer collection of nutrient samples and field constituents at nine sites on Silver Bow Creek and the Clark Fork River (10 samples over 3 months);
4. Spring collection of nutrient and heavy metals samples at the Clark Fork River below Cabinet Gorge Dam during spring peak flow (six samples over a one-month period from May to June);
5. Summer collection of nutrient samples and field measurements at nine Lake Pend Oreille sites (monthly from June-September); and
6. Summer collection of periphyton standing crop samples at nine Lake Pend Oreille sites (September).

Monitored field constituents included: water temperature (˚C), pH (standard units), specific conductance (µs/cm), dissolved oxygen (mg/l), turbidity (NTU) and, in the case of Lake Pend Oreille, Secchi transparency (m). Streamflow (instantaneous, cubic feet per second (cfs)) and river stage (ft) were also recorded where gauging stations coincided with monitoring stations. Nutrient constituents included: total phosphorus (TP), total Kjeldahl nitrogen (TKN) or total persulfate nitrogen (TPN, Lake Pend Oreille and Pend Oreille River sites), nitrate + nitrite nitrogen (NO_3+NO_2), total ammonia nitrogen (NH_3+NH_4), and soluble reactive phosphorus (SRP). Heavy metal constituents included dissolved and total recoverable fractions of copper (Cu), zinc (Zn), cadmium (Cd), lead (Pb) and arsenic (As). Water samples from metals stations were also analyzed for hardness (mg/L as $CaCO_3$). Values for total nitrogen (TN) and total soluble inorganic nitrogen (TSIN) were calculated as follows:

$$\text{TN} = \text{TKN plus } NO_3\text{+}NO_2\text{-N} \qquad \text{TSIN} = NO_3\text{+}NO_2\text{-N plus } NH_3\text{+}NH_4\text{-N}$$

Periphyton samples from natural substrates were analyzed for chlorophyll *a* (mg/m^2) and ash-free dry weight (AFDW, g/m^2). Secchi transparency was recorded in meters (m).

Field sampling, field measurements, sample handling and laboratory analysis methods are described briefly in the following sections. More complete details are provided or referenced in the following documents:

▪ Clark Fork-Pend Oreille Watershed Water Quality Monitoring Program Quality Assurance Project Plan (PBS&J 2005);
▪ Lake Pend Oreille Water Quality Monitoring Program Quality Assurance Project Plan (IDEQ 2006); and

▪ Quality Assurance Monitoring Plan: Stream Ambient Water Quality Monitoring (WDOE 2003).

2.4.1 Field Constituents - Clark Fork River

Field constituents, including water temperature (˚C), pH (standard units), conductivity (µs/cm), and dissolved oxygen (mg/L) were measured on site using a portable Hach® water quality probe. Turbidity (NTU) levels were measured using a Hach® portable turbidimeter. All field instruments were calibrated each morning and monitored throughout the day to ensure proper performance. Field constituents were recorded on a field form before leaving the site.

2.4.2 Nutrients and Metals - Clark Fork River

Water samples for nutrient and metal constituents were collected using a grab sampling technique by wading in a well-mixed portion of the river. Samples were taken in the upstream direction to avoid entrainment of sediment disturbed by wading.

Water samples for total nutrients (TP and TKN) and total recoverable metals (As, Cd, Cu, Pb, and Zn) were collected directly from the stream in separate polyethylene bottles. Bottles were rinsed three times with native water prior to sampling. During sampling, the sample bottle was positioned to face upstream and was drawn through the water column once, carefully avoiding disturbance of bottom sediments. Samples were acidified with concentrated sulfuric acid (H_2SO_4) for nutrient samples and concentrated nitric acid (HNO_3) for metal samples. Nutrient samples were stored on ice and delivered to the analytical laboratory within 48 hours of collection. Metals samples were delivered to the analytical laboratory within their allowable holding time.

Water for soluble nutrients (NO_3+NO_2-N, NH_3+NH_4-N and SRP) and dissolved metals (dissolved As, Cd, Cu, Pb and Zn) were filtered in the field through a 0.45 µm filter into polyethylene bottles. Bottles were rinsed three times with filtered water, and a small volume of filtrate (30-50 ml) was discarded prior to sample collection to ensure the filter was properly rinsed. Dissolved nutrient samples (NO_3+NO_2-N, NH_3+NH_4-N and SRP) were frozen or stored on ice and transported to the analytical laboratory within 48 hours of collection. Dissolved metals samples were acidified with concentrated nitric acid (HNO_3) and delivered to the laboratory for analysis within their allowable holding time.

Samples were clearly labeled with a waterproof marker or pre-printed labels. Label information included the site identification number, date and time, sample type, preservative, and sampler's initials. Each bottle was recorded on a chain-of-custody form before leaving the site. A summary of sampling protocols is provided in **Table 2-2**.

Table 2-2. *Nutrient and metals sampling protocols.*

Constituent	Sample Volume	Container	Preservation	Holding Time
TP and TKN	250 ml	Acid-washed polyethylene	H_2SO_4, cool to 4°C	28 days
Total Recoverable Cu, Zn, Cd, Pb, As	250 ml	Acid-washed polyethylene	HNO_3	6 months
Dissolved Cu, Zn, Cd, Pb, As	250 ml	Acid-washed polyethylene	Filter, HNO_3	6 months
NO_3+NO_2 and NH_3+NH_4	250 ml	Acid-washed polyethylene	Filter, cool to 4°C or freeze	28 days (if frozen)
SRP	250 ml	Acid-washed polyethylene	Filter, cool to 4°C or freeze	48 hours

2.4.3 Field Constituents and Nutrients – Lake Pend Oreille

Field measurements were performed and water quality samples were collected for nutrient and chlorophyll *a* analysis at three open water and nine near-shore locations on Lake Pend Oreille. Depth profile information for field constituents including water temperature and dissolved oxygen was recorded at each lake monitoring site. Field measurements also included pH, conductivity and Secchi transparency. Secchi depth was determined with a standard 20 cm Secchi disc and readings were taken on the side of the boat with the least amount of surface roughness. Water transparency was evaluated by lowering the Secchi disc over the side of the boat until the markings were no longer visible. The depth was read after the disc was lowered past the extinction point, and then raised until just visible. Depth was recorded in meters. The sampler also noted time of day, weather, water surface conditions, and any other variables that may have affected the reading. Nutrient and water column chlorophyll samples were depth composited at each site with the use of a Van Dorn depth sampler and a sample churn splitter. The number and depths of individual samples was determined during each sampling event based on the presence or absence of lake stratification and/or anoxic conditions in bottom waters.

2.4.4 Field Constituents and Nutrients - Pend Oreille River

The Washington Department of Ecology collected the water quality samples for field constituents and nutrients at the two monitoring stations on the Pend Oreille River. Sampling protocols were similar, though not identical, to those described above for the Clark Fork stations. Stream sampling protocols, and the Quality Assurance Plan for the river and stream water quality monitoring program in Washington, can be found on the world wide web at www.ecy.wa.gov/programs/eap/fw_riv/rv_main.html.

2.4.5 Periphyton – Clark Fork River and Lake Pend Oreille

Two types of periphyton samples were collected: hoop samples (a bulk sampling method) and template samples (a rock scraping method). Hoop samples were collected for filamentous green algae (*Cladophora)* dominated sites (sites above Missoula) and template samples were collected for diatom dominated sites (sites below Missoula). Periphyton samples on Lake Pend Oreille were taken using the template method. Both chlorophyll *a* and ash-free dry weight (AFDW) were measured from the hoop and template samples. Clark Fork River periphyton samples were collected on two to three separate sampling events, once in July, August, and September for the upper three sites and in August and September for the remainder of the downstream sites, in an attempt to document peak algal standing crops. Lake Pend Oreille periphyton samples were collected in September.

2.4.6 Analytical Methods

State-certified laboratories, including the Montana Department of Public Health and Human Services chemistry laboratory (Clark Fork River metals analyses), the Missoula wastewater treatment plant laboratory (Clark Fork River nutrient analyses), the SVL Laboratory (Lake Pend Oreille nutrient and chlorophyll analyses) and the Washington Department of Ecology Manchester laboratory (Pend Oreille River nutrient analyses) performed all water chemistry analyses using standard methods.

The University of Montana biology laboratory performed the Clark Fork and Lake Pend Oreille periphyton sample analyses. The method of analyzing for chlorophyll *a* is the same as the American Public Health Association's standard method 1002G for spectrophotometric analysis (APHA 1981), except that 95% ethanol (warmed to 78 degrees C) is substituted for acetone as the solvent, as suggested by Sartory (1982) and Sartory and Grobbelaar (1984). This modification produces similar results for diatoms, and a better extraction for filamentous green algae. To determine accuracy of the method, a Sigma chlorophyll standard is run by the lab once or twice a year, yielding results within 5% of the known value. Precision of the laboratory method is determined by repeat analyses of the same sample which are within 5% of the same value. To assure consistency and comparability, these standard methods are used, and an internal standard is run at the beginning and end of every run to ensure that the spectrophotometer is running consistently from year to year, from analytical day to day, from beginning to end of each run.

For benthic algae, the limit of detection (LOD) and limit of reliable quantification (LORQ) are functions of the sensitivity of the spectrophotometer, the area sampled, and the volume of solvent used to extract. A 2 inch by 2 inch area (0.00258 sq. meters) and extracted in as little as 20 ml if samples were small. This yields an LOD of 1 mg/sq. meter and an LORQ of 7 mg/sq meter. For water column chlorophyll *a*, the detection limit is 1µg/L and the limit of reliable quantification is 5-10 µg/L when 1L is filtered (and the sample is extracted in 10 ml of solvent). We filtered 1.5 L, giving detection limits of 0.7 µg/L and LORQ of 3-7 µg/L. The benthic algae AFDW analysis is APHA's Standard Method. The analytical balance used is tested with a National Bureau of Standards set of standards before each use and is calibrated annually by a certified testing lab. The balance reliably detects differences of 1 mg and given the area sampled, the LORQ of this method is about 0.5 g/sq. meter.

The analytical methods and detection limits are listed in **Table 2-3**. Methods used by the Washington Department of Ecology Manchester Laboratory are comparable though somewhat different and are described at: www.ecy.wa.gov/programs/eap/fw_riv/rv_main.html.

Table 2-3. ***Analytical methods and detection limits.***

Analyte	Method	Detection Limit
Clark Fork River Monitoring Stations (MT DPHHS, Missoula WWTP, UM Labs)		
Total Phosphorus (TP)	EPA 365.3	4 µg/l
Total Kjeldahl Nitrogen (TKN)	EPA 351.2	100 µg/l
Nitrate + Nitrite-Nitrogen (NO_2NO_3)	EPA 353.2	2 µg/l
Total Ammonia-Nitrogen (NH_3+NH_4)	EPA 350.1	10 µg/l
Soluble Reactive Phosphorus (SRP)	EPA 365.3	4 µg/l
Total Recoverable and Dissolved Copper (Cu)	EPA 200.7	1 µg/l
Total Recoverable and Dissolved Zinc (Zn)	EPA 200.7	0.5 µg/l
Total Recoverable and Dissolved Cadmium (Cd)	EPA 200.7	0.1 µg/l
Total Recoverable and Dissolved Lead (Pb)	EPA 200.7	1 µg/l
Total Recoverable and Dissolved Arsenic (As)	EPA 200.7	1 µg/l
Chlorophyll *a* (Chl-*a*)	SM 10200H	See discussion
Lake Pend Oreille Monitoring Stations (SVL Lab)		
Total Nitrogen (TN)	ASTM D-5176	1 µg/l
Total Phosphorus (TP)	SM 4500-P-E	2 µg/l
Chlorophyll *a* (Chl-*a*)	SM 10200H	See discussion

2.5 Quality Assurance

The quality of the monitoring data generated and reported under the Council's Clark Fork-Pend Oreille Watershed water quality monitoring program since its inception in 1998 has depended on many factors, including: 1) sampling design; 2) selection of parameters; 3) sampling technique and procedures; 4) analytical methodologies; and 5) data review, assessment and data management. Each of these factors was carefully considered and defined within the respective quality assurance project plans (QAPPs) referenced earlier.

Following their collection, data generated under this program were subjected to a data validation procedure outlined in the project QAPPs. The data validation process involves an assessment and documentation of the quality of the generated data in relation to the specific data quality objectives that were established in the respective QAPPs. The data validation process included the following elements: 1) data verification; 2) systems audits and review procedures; 3) performance evaluations; 4) review of laboratory credentials; and 5) quality control checks and corrective action.

Data validation and data quality objectives established for the Clark Fork-Pend Oreille monitoring program and reviewed for their attainment address sample handling, laboratory precision and accuracy, sample representativeness, sample completeness, sample comparability, and field precision and accuracy. The results of the quality assurance/quality control reviews have been reported as a standard component of the annual interpretive summary water quality reports beginning in 2007. The QA/QC reviews describe the outcomes and corrective actions that were taken to address any identified deficiencies.

Overall, the Clark Fork-Pend Oreille monitoring program QA/QC reviews have shown good or excellent conformance with data quality objectives established in the project QAPP. For example, more than 90% of all analysis results for the 2007 monitoring program were validated without a need for qualifiers or annotations.

It should be noted that the data which were evaluated as a part of the first (1998-2002) and the present (2003-2007) five-year water quality trends analysis included agency and university monitoring data extending back to 1984. Documentation is not readily available to vouch for the quality of the entire historical data set. In the case of the Clark Fork River historical data set for the period extending from 1984-1996 collected by the Montana Department of Environmental Quality (and its predecessor, the Department of Health and Environmental Sciences), those data are known to have been collected and validated in accordance with an approved quality assurance project plan (MDEQ archives). All Pend Oreille River monitoring data collected by the Washington Department of Ecology have been similarly validated. However, historical data for Lake Pend Oreille collected by university researchers and contractors to Idaho DEQ may not have been similarly validated. Unknown monitoring data quality for that water body could influence the outcomes of long term lake water quality trends analyses presented in this report.

2.6 Data Interpretation and Reporting

Completion of monitoring in December 2007 represented the fifth year of a second five-year monitoring program managed by the Council. Results of each of the ten consecutive monitoring years since 1998 have been summarized in annual interpretive reports (Land & Water/PBS&J, 1999-2008). The first five-year monitoring program, conducted from 1998-2002, provided the basis for a statistical analysis of water quality time trends reflected in the Council's and the state agencies' data (Land & Water 2004). This report reflects a second statistical analysis of time trends in water quality in the Clark Fork-Pend Oreille Watershed. The results presented in this report will be used to evaluate the Council's water quality improvement efforts since its inception in 1993, to identify any emerging problems and the need for adjustments to the three-state water quality management plan, and to provide recommendations for improving the sensitivity and cost effectiveness of the monitoring program.

3.0 TRENDS ANALYSIS METHODS

3.1 Overview

Prior to 2003, data analysis and reporting for water quality data collected on the Clark Fork-Pend Oreille watershed was limited to various agency monitoring reports, analysis of variability for optimizing the monitoring network (Land & Water 1995), and data queries for specific monitoring objectives (e.g. VNRP targets, Clark Fork loading model). The first basin-wide analysis and interpretation of temporal trends in water quality and statistical analysis of spatial differences from 1984-2002 was undertaken in 2003 by the Tri-State Water Quality Council (TSWQC) and Land & Water Consulting (now PBS&J, Inc).

Trend analysis typically requires seven years or more of monthly monitoring to begin to discern trends in naturally highly variable water quality data. The current effort is intended to build upon the 2003 report and provide a continuing comprehensive analysis of spatial and temporal trends. With nearly 20 years of water quality data available for numerous stations within the Clark Fork-Pend Oreille watershed, this interpretation will provide a document characterizing watershed health with respect to nutrient and eutrophication related impairments.

3.2 Management Objective Specific Queries

The present trends analysis effort has been designed around a series of queries that attempt to evaluate progress at attaining the basin-wide water quality management goals described in **Section 2.2** of this report and reiterated below. Specific data sets and analyses that were performed are described below, by management goal:

Management Goal 1: Control nuisance algae in the Clark Fork River by reducing nutrient concentrations

- All available summer nutrient concentration monitoring data available in the Council's historical database were analyzed for flow adjusted time trends. This analysis was intended to address whether summer nutrient concentrations have declined, remained the same, or increased during the 1984-2007 period in relation to pollution source controls after the possible influences of streamflow effects have been considered. The summer period was defined as late-June through September and nutrient variables considered included total nitrogen (TN) and total phosphorus (TP).
- All available summer nutrient concentration data were analyzed for non-flow adjusted trends in TN and TP. This analysis was intended to address whether actual instream nutrient concentrations have changed regardless of streamflow effects and to provide insight into possible water supply/drought influences on in-river nutrient concentrations.
- Time trends in river periphyton (attached algae) densities were analyzed for the available period of record to determine if significant declining, static or increasing trends could be detected.

Management Goal 2: Protect Pend Oreille Lake water quality by maintaining or reducing current rates of nutrient loading from the Clark Fork River.

- The data analysis focused on evaluating cumulative annual nutrient loading rates over time at the Montana/Idaho border (Cabinet Gorge monitoring station). Specific queries performed included: 1) evaluation of annual nutrient loads for the 1984-2007 period of record, 2) examination of the influences of nutrient (TN, TP) concentrations versus streamflows on the observed trends (i.e. which factor appeared to be driving the observed time trend, if any), and 3) separate examinations of streamflow adjusted time trends in nutrient concentrations at the border station during the spring runoff versus summer baseflow periods to provide possible insight into the relative importance of point vs. non-point source pollution inputs on observed loading time trends.
- The computed annual nutrient loads for the period of record were compared to numerical loading targets established in the Montana and Idaho Border Nutrient Load Memorandum of Agreement (2001).

Management Goal 3: Reduce near-shore eutrophication in Pend Oreille Lake by reducing nutrient loading from local sources. Tasks include:

- Spatial and temporal trends in lake water quality were evaluated based on the available 2003-2007 data set for TP, TN, chlorophyll *a*, and Secchi depth. Current conditions were compared to the available historical lake data.
- Spatial and temporal trends in near-shore periphyton densities were evaluated based on the available 2003-2007 data set.
- The 2003-2007 lake water quality data for near-shore and open water monitoring sites were compared to the numerical water quality targets for the lake established within the MT-ID Nutrient Load MOA and the TMDL for nutrients for near-shore water of Lake Pend Oreille (2002), respectively.
- Carlson's trophic status index values were computed for key lake monitoring variables (TP, chlorophyll *a*, Secchi depth) for the 2007 monitoring year to provide a present-day, overall assessment of lake trophic status and establish a basis for later comparisons.

Management Goal 4: Improve Pend Oreille River water quality through macrophyte management and tributary non-point source controls. Tasks include:

- Nutrient (TN, TP) concentration time trends in the river were assessed for the available period of record (summer data) using both the Council's (WDOE) historical dataset and the Army Corps of Engineers recent three-year data set for a site above Albeni Falls Dam.

Following the completion of each of these management plan oriented analyses, an attempt was made to collectively synthesize the findings to provide an overview of watershed health with respect to nutrients, periphyton and eutrophication issues within the Clark Fork-Pend Oreille watershed. Additional technical details of the trends analysis methods are provided in the next section.

3.3 Temporal and Spatial Analysis

Trend evaluation for river monitoring stations was conducted on either raw data or flow-adjusted data as appropriate. Raw data were used when no significant flow effects were present. Where concentrations were statistically related to discharge, interpretation of trends in water quality accounted for the effect of discharge by performing trend analysis on "flow-adjusted" concentrations. Modeling of flow-concentration relationships commonly takes the form of a power function $Y=aX^b$ for positively correlated variables such as total phosphorus. A relationship between instantaneous discharge and concentration provides the model to "adjust" concentrations and account for flow effects.

Because analysis was limited to summer data rather than the entire period of record, the ranges of both discharge and concentration were truncated. These "censored" data ranges result in very weak models for concentration/discharge relationships based paired instantaneous observations. As an alternative, the mean annual concentration was regressed against mean annual discharge. Because of the relatively narrow range in values, concentration-discharge relationships were modeled with a linear function $Y=a + bX$ for all constituents. Flow-adjusted concentrations are derived from the unstandardized residuals of the regression of concentration on discharge, and trend analysis is performed on the residuals.

Since discharge is related to season, deseasonalizing data can provide a substitute for flow adjustment. Deseasonalization can be accomplished by subtracting seasonal (quarterly or monthly) means from the concentrations. One advantage of deseasonalization is simplicity; estimation of a concentration-discharge model is unnecessary. Because analyses for river monitoring stations were limited to summer data (in contrast to the full annual record), seasonality was largely removed from the data set. No deseasonalization was required for data analysis of river stations in this study.

A least-squares regression of concentration on time is appropriate if data are normal, independent, and not autocorrelated. For non-normal data, the Mann-Kendall trend test with a Sen slope estimate is performed. This study relied on Mann-Kendall/Sen slope tests for trend using a 5% significance level (i.e. error rate of α=0.05). The Mann-Kendall/Sen slope method is widely accepted as an appropriate and state-of-the-art analysis for water quality time series. Non-parametric methods provide a robust means of trend analysis because slope estimates are generally less biased by outliers than parametric methods. It should be noted that Sen slope computations rely on annual average summer values for nutrient variables. For periphyton data that do not meet assumptions of normality and are not seasonal or flow dependent, the non-parametric Kendall's Tau-b was employed. Examples and explanations of the Kendall test and Sen slope estimate can be found in Hirsch et al. 1982, Smith et al. 1982, Gilbert 1987 and Hirsch et al. 1991.

For purposes of non-parametric analyses, values below detection limits were set at half the detection limit. Large proportions of non-detect values make Sen slope estimates approximate, thus if more than 25% of the values are below detection, slope should be interpreted with caution. For most analyses, constituent concentrations were above detection limits and unlikely to be affected by a small fraction of below-detect observations. Trend analyses with more than 25% non-detect values were infrequent, and are noted in the results. The monitoring stations at Newport and Metaline Falls had a change in TP detection limit from 10 µg/L to 1 µg/L during the course of the study. This likely influenced trend analyses as discussed in **Section 4.1.**

Nutrient trend analyses are intended to detect changes in underlying watershed process and nutrient sources (exclusive of trends in flow or loading). It should be recognized that trends in flow alone can potentially result in increasing nutrients concentrations/loads in a receiving water body. From a biological standpoint, particularly for a receiving water body such as Lake Pend Oreille, trends in watershed nutrient sources and loading are both of interest. Both trends in concentration and loading were evaluated in this case.

4.0 TEMPORAL TRENDS IN WATER QUALITY

4.1 Trend Analysis for Clark Fork River and Pend Oreille River Nutrient Concentrations

One of the principal objectives of the Tri-State Water Quality Monitoring Program is to evaluate trends in nutrient concentration in the Clark Fork-Pend Oreille watershed. Baseline data collected by the Montana Department of Health and Environmental Sciences from 1984 to 1996, and Tri-State Council data collected from 1998-2007, provide a significant body of data to evaluate long term temporal trends.

Trend analysis was undertaken for nutrients to evaluate whether statistically significant trends were present at network monitoring stations during the summer monitoring period. The summer period was defined as June 15 through September 15. As discussed in the statistical methodology section, concentrations for constituents were adjusted for flow effects prior to performing trend analyses. Raw data were used when no significant flow effects were present.

Annual average total phosphorus concentration was positively correlated to annual average flow at 7 of 15 sites (**Table 4-1**). Total nitrogen concentration was positively correlated to flow at 1 of 15 sites. Total phosphorus was positively correlated to flow at most sites within the watershed. Total nitrogen versus flow correlations were weak for most monitoring locations and did not show a strong relationship to discharge.

Table 4-1. ***Number of stations with statistically significant nutrient/flow correlations.***

Constituent	Positive (+)	Negative (-)	% of Stations Significant
Total P	7	0	47%
Total N	1	0	7%

For those constituents with statistically significant concentration/flow correlations, the raw data were adjusted for the effect of flow for trend analysis. Because data were limited to the summer period, no adjustments were made for seasonality.

Statistically significant temporal trends (α=0.05) were identified throughout the Clark Fork-Pend Oreille watershed for both total phosphorus and total nitrogen. Significant temporal trends for each station/constituent combination (**Table 4-2**) reflect the combined results of raw or flow adjusted as appropriate. Data analyzed are found in **Appendix A**. Plots for individual trend analyses of raw data or flow adjusted time series for all station/constituent combinations are found in **Appendix B**. The nonparametric Sen slope method generally provided a similar outcome as simple linear regression for detecting statistically significant trends, however, slope estimates would be expected to be less biased by outlier observations. Sen slope and Mann-Kendall test results are reported in **Appendix C**.

Table 4-2. ***Number of statistically significant trends from 1984 to 2007.***

Constituent	Positive (+)	Negative (-)	% Total
Total P	3	4	46%
Total N	0	4	27%

The majority of stations showed no trend in either total phosphorous or total nitrogen. Total phosphorus showed a decreasing trend at about four of the 15 sites, mainly in the upper river or immediately below Missoula. Two stations showed an increasing trend for total phosphorus. A third station showed an increasing trend with raw data, but not flow adjusted data. Total nitrogen also showed a decreasing trend at four of the 15 sites distributed along the mainstem of the Clark Fork and Pend Oreille rivers.

A summary of temporal trends for flow adjusted and non-flow adjusted raw data is presented in **Table 4-3**. Values in **bold** indicate a statistically significant trend. Negative slope values indicate decreasing trends, and positive slope values indicate increasing trends. The single "*" denotes that the value has been adjusted for the effect of flow. Statistical significance is reported at the 5% level. Trend analyses with greater than 25% of values below detection limits are flagged with the symbol "#", and greater than 50% non-detect values are flagged with the symbol "##".

Table 4-3. ***Trends for key nutrient variables in the Clark Fork-Pend Oreille Basin, 1984-2007 using raw data (flow adjustments reported where applicable).***

Sen Slope in µg/L/Year and %					
Station	**Station Number**	**Total Phosphorus µg/L/yr**	**%**	**Total Nitrogen µg/L/yr**	**%**
SBC at Opportunity	2.5	**+10.1**	**4.9%**	53.2	2.3%
CFR below Warm Springs	07	-1.0	-1.9%	**-7.8**	**-2.0%**
CFR at Deer Lodge	09	0.2/0.00*	0.6%	-3.9	-0.9%
CFR above Little Blackfoot	10	**-1.7**	**-2.8%**	-4.1	-1.0%
CFR at Bonita	12	-1.0/ **-1.2***	-1.9%/**-2.3%**	-5.3	-1.5%
CFR above Missoula	15.5	0.3/**0.7***	1.1%/**2.6%**	-3.7	-1.5%
CFR below Missoula	18	**-0.7**	**-1.7%**	-3.1	-0.9%
CFR at Huson	22	-0.3	-1.0%	**-4.6**	**-1.6%**
CFR above Flathead	25	-0.1/-0.1*	-0.5%	-4.6	-2.0%
Thompson River	27.5	-0.1/0.0*	-0.9%	-1.1##	-0.9%
CFR below Thompson Falls	28	-0.1/0.0*	-0.7%	**-4.4#**	**-2.4%**
CFR at Noxon	29	0.0	0.0%	-1.9	-1.2%
CFR below Cabinet Gorge	30	**+0.2**/0.0*	**1.7%**/0%	-1.9#	-1.1%
POR at Newport	50	**-0.8#**	**-4.8%**	0.1	0.1%
POR at Metaline Falls	55	**-1.1**	**-11.6%**	-0.8/**-1.1***	**-1.1%**

Values in **bold** indicate a significant temporal trend at α=0.05
* - indicates that the value has been adjusted for flow
# - indicates >25% of values below detection limit
##- indicates >50% of values below detection limit

Five stations showed decreasing trends in total phosphorus. These included the Clark Fork River above the Little Blackfoot (raw data), Clark Fork at Bonita (flow adjusted data), Clark Fork below Missoula (raw data), Pend Oreille River at Newport (raw data), and Pend Oreille River at Metaline Falls (raw data). Silver Bow Creek at Opportunity and the Clark Fork above Missoula showed an increasing trend in total phosphorus based on raw data.

The uppermost station on the Clark Fork River (Silver Bow at Opportunity) had the greatest percent increase in total phosphorus and averaged about 10 µg/L (or 5%) per year. This may be related to comprehensive and on-going CERCLA restoration/construction activities on the stream channel, and possibly loading from the Butte Metro wastewater treatment plant. Extensive channel reconstruction related to mine-tailings removal has been in progress over the last several years. Sediment release associated with channel restoration could increase total phosphorus levels during baseflow.

The Clark Fork river stations at Bonita (flow adjusted) and below Missoula (raw data) both showed decreasing trends for total phosphorus on the order of 2% (1 µg/L) per year. Interestingly, results for the Clark Fork above Missoula indicated an increasing trend of the same magnitude. This suggests that improvements at the Missoula wastewater treatment plant may be offsetting increases in total phosphorus observed at the station immediately upstream of Missoula. Restoration activities at Milltown Dam may have influenced total phosphorus concentrations.

Raw data for the Clark Fork River below Cabinet Gorge suggested an increasing trend in total phosphorus (0.2 µg/L or 1.7%/yr), however, when these data were corrected for the effect of flow, no statistically significant trend was apparent.

Four stations showed statistically significant decreasing trends in total nitrogen. These included the Clark Fork River below Warm Springs (raw data), Clark Fork at Huson (raw data), Clark Fork below Thompson Falls (raw data), and Pend Oreille River at Metaline Falls (flow adjusted data). With the exception of the upper most site (Silver Bow at Opportunity), no site showed any tendency for increasing trends in total nitrogen. The apparent trend in total nitrogen at Silver Bow was not statistically significant.

These results suggested that (with several exceptions) overall water quality either improved or remained stable from 1984 to 2007 with respect to total nitrogen and phosphorus. Silver Bow at Opportunity and the Clark Fork above Missoula were the primary exceptions with respect to total phosphorus.

Examples of statistically significant decreasing or increasing trends on the Clark Fork river are shown below (**Figures 4-1** to **4-10**), and illustrate a nutrient time series typical of the Clark Fork River mainstem monitoring stations.

It should be noted that with the exception of the Clark Fork below Cabinet Gorge, no trends in flow were apparent 1984-2007 based on summer sampling dates. The Cabinet Gorge site showed a tendency for higher flows during this period. Flow adjustment resulted in a minimal change in the number of statistically significant trends from those based upon raw data.

Figure 4-1. ***Silver Bow at Opportunity – Total Phosphorus (Increasing Trend).***

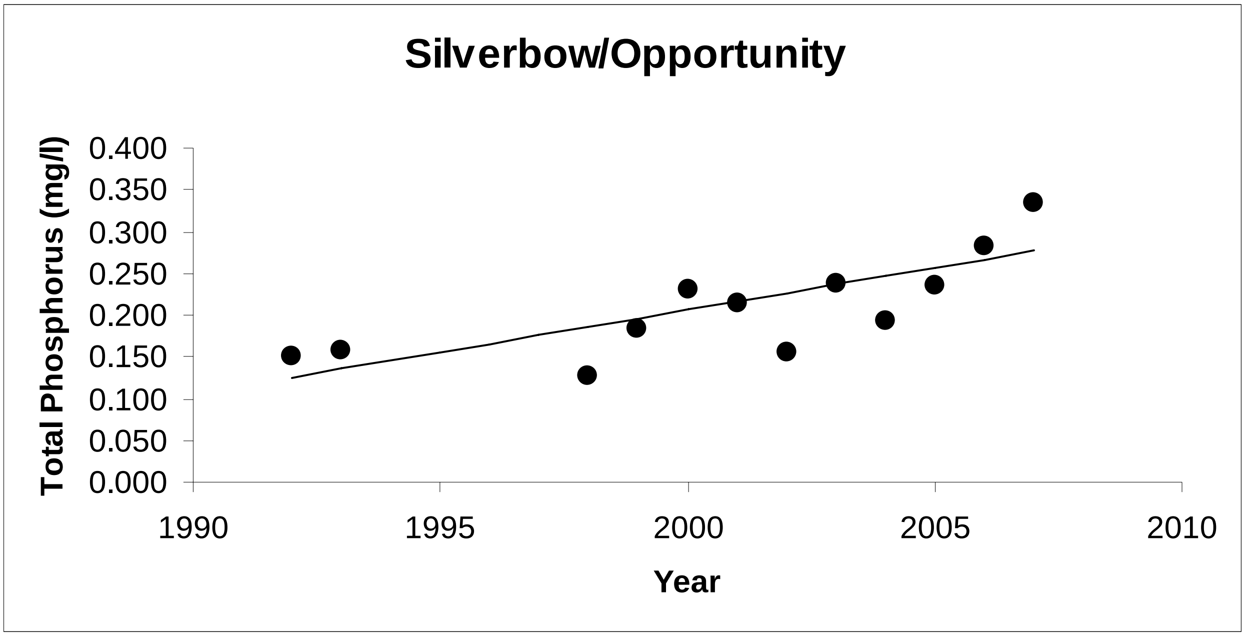


Figure 4-2. ***Clark Fork above Little Blackfoot – Total Phosphorus (Decreasing Trend).***

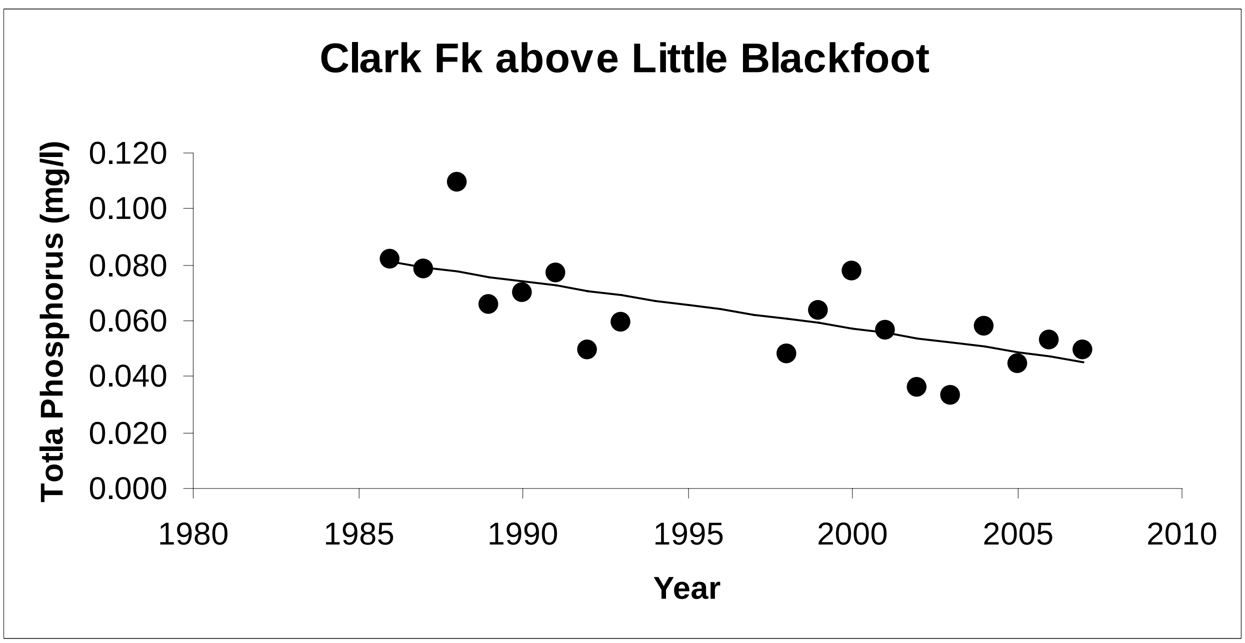
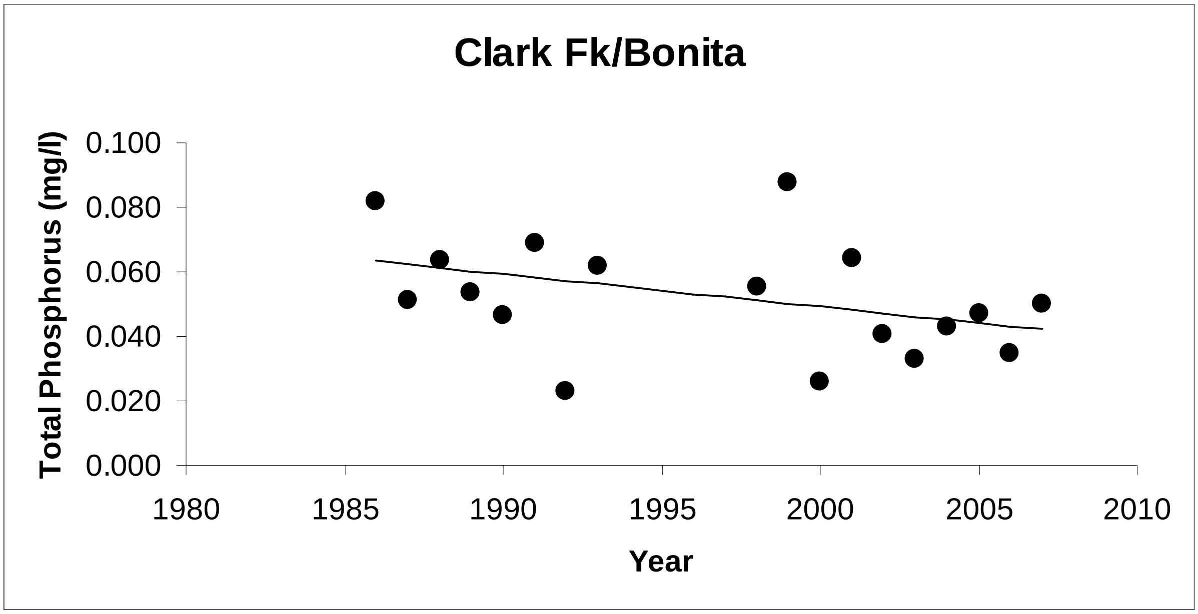


Figure 4-3. ***Clark Fork at Bonita – Total Phosphorus (Decreasing Trend).***



The Clark Fork above Missoula showed an increasing trend in summer total phosphorus from 1989-2007 (**Figure 4-4b**). Note that this trend was not statistically significant with raw data (**Figure 4-4a**), but was significant when data were adjusted for the effect of flow. This station served as a control for the City of Missoula point and nonpoint source nutrient loading. The Clark Fork below Missoula showed a statistically significant decreasing trend in total phosphorus over the same period (**Figure 4-5**). This decreasing trend is probably attributable to improvements in the Missoula Wastewater Treatment Plant operations, increasing sewer hookups (decreased nonpoint), and water quality improvement due to the phosphate ban that went into effect in 1989. It is worthwhile to note that improvements below Missoula appear to offsetting increases in total phosphorus observed upstream of town.

Figure 4-4a. ***Clark Fork above Missoula – Total Phosphorus (Static Trend, raw data).***

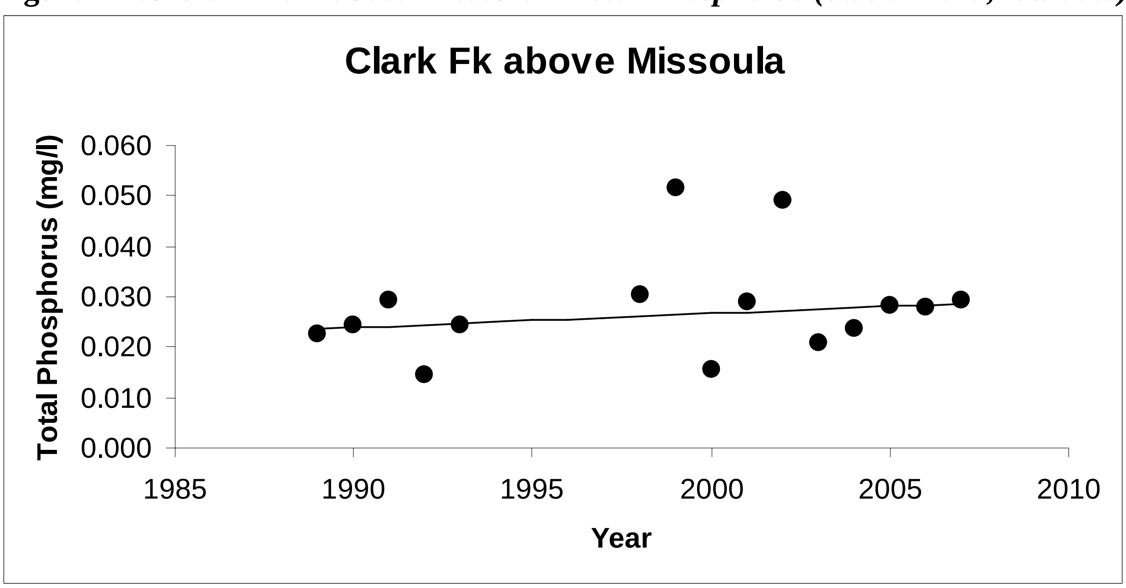


Figure 4-4b. ***Clark Fork above Missoula – Total Phosphorus (Increasing Trend, flow adjusted data).***

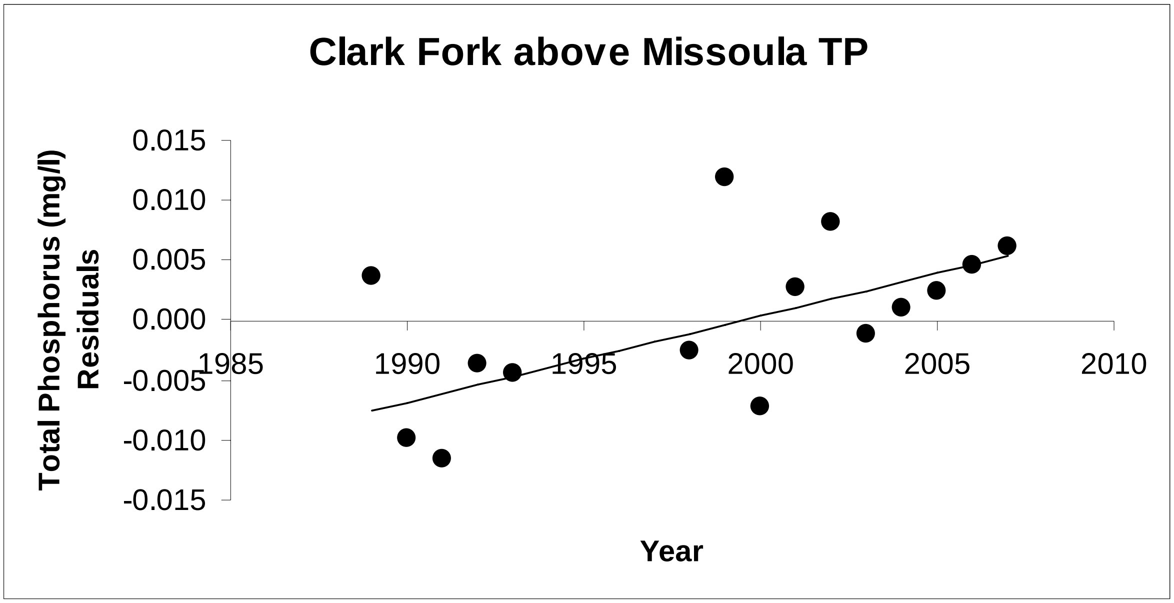
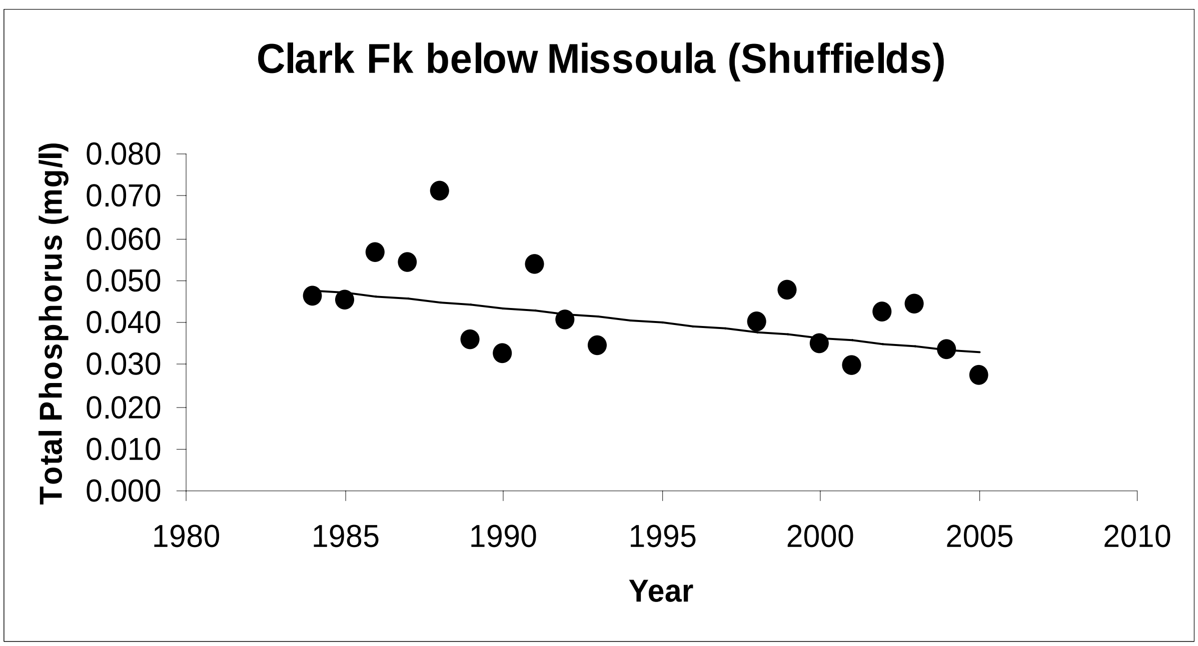


Figure 4-5. ***Clark Fork below Missoula – Total Phosphorus (Decreasing Trend).***



Decreasing trends in total nitrogen were observed on the Clark Fork River below Warm Springs, at Huson, and below Thompson Falls (**Figures 4-6** to **4-8**). No statistically significant increasing trends were observed for total nitrogen. Note that more than 25% of the values for TKN were below the detection limit for the Thompson Falls station (**Figure 4-8**), so the trend in TN should interpreted with caution.

Figure 4-6. ***Clark Fork below Warm Springs – Total Nitrogen (Decreasing Trend).***

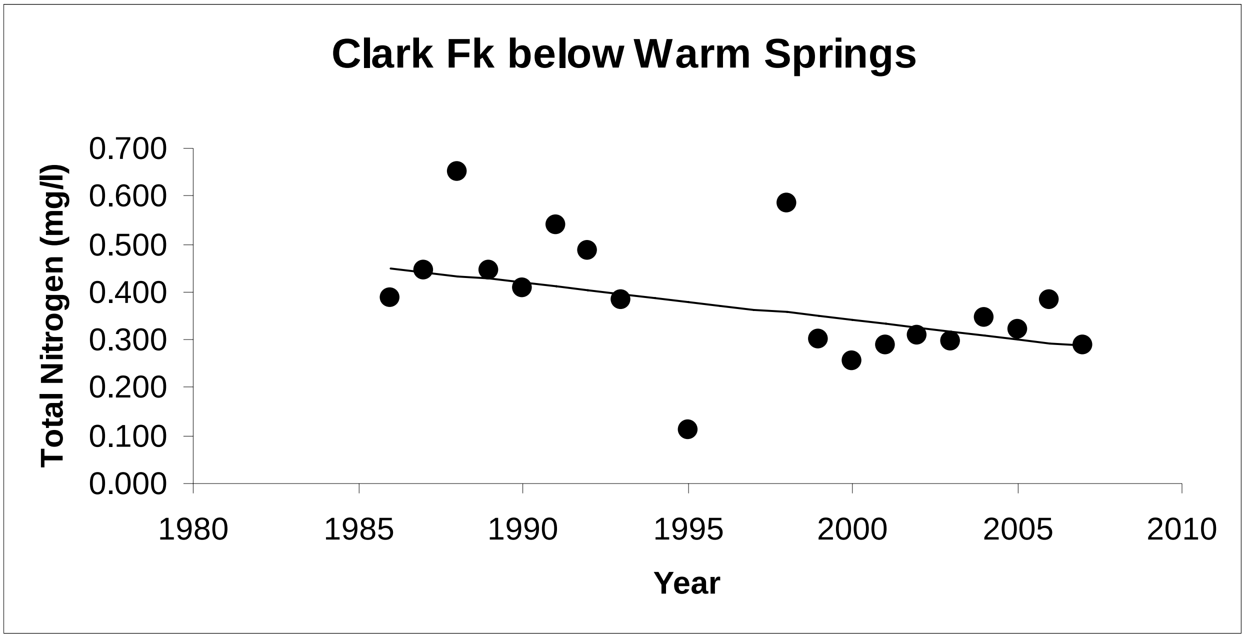


Figure 4-7. ***Clark Fork at Huson – Total Nitrogen (Decreasing Trend).***

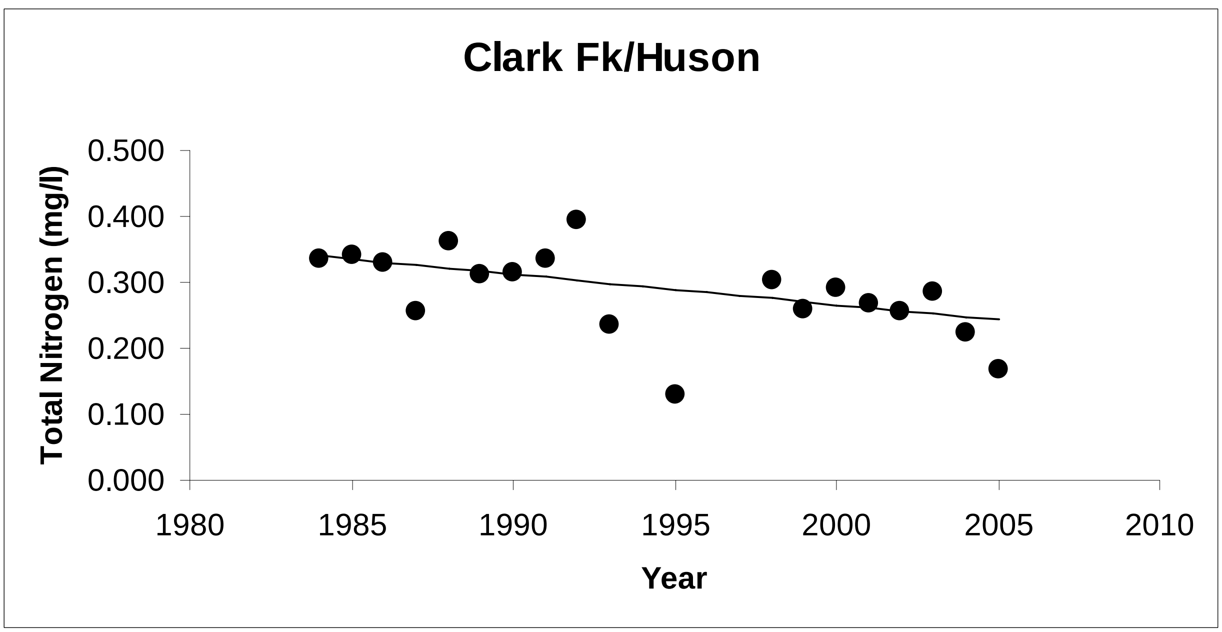
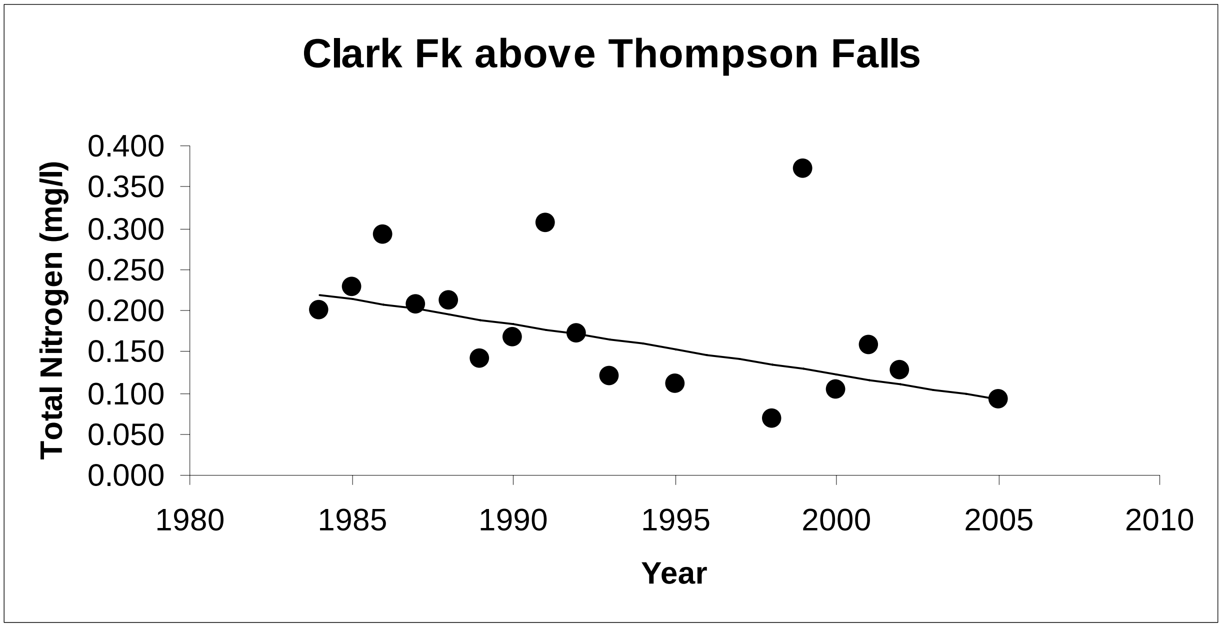


Figure 4-8. ***Clark Fork below Thompson Falls – Total Nitrogen (Decreasing Trend).***



The Clark Fork below Cabinet Gorge Dam showed an increasing trend for total phosphorus based on raw data (**Figure 4-9a**). However, when these data were corrected for the positive correlation with flow, no statistically significant trend was apparent (**Figure 4-9b**).

Figure 4-9a. ***Clark Fork below Cabinet Gorge Dam – Total Phosphorus (Increasing Trend, raw data).***

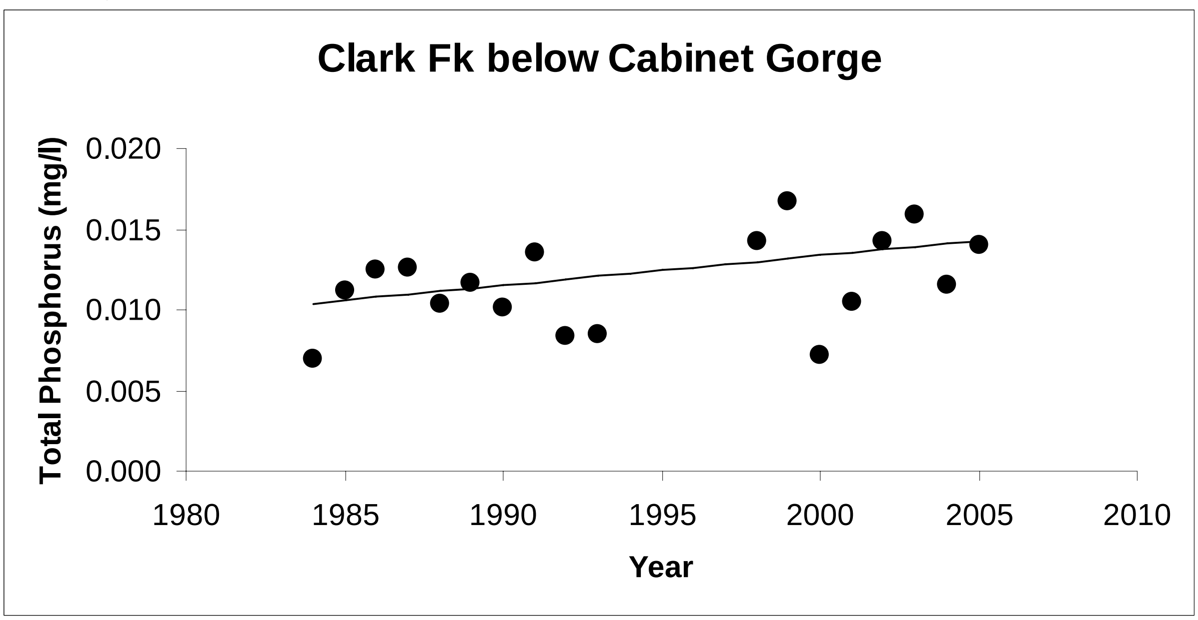
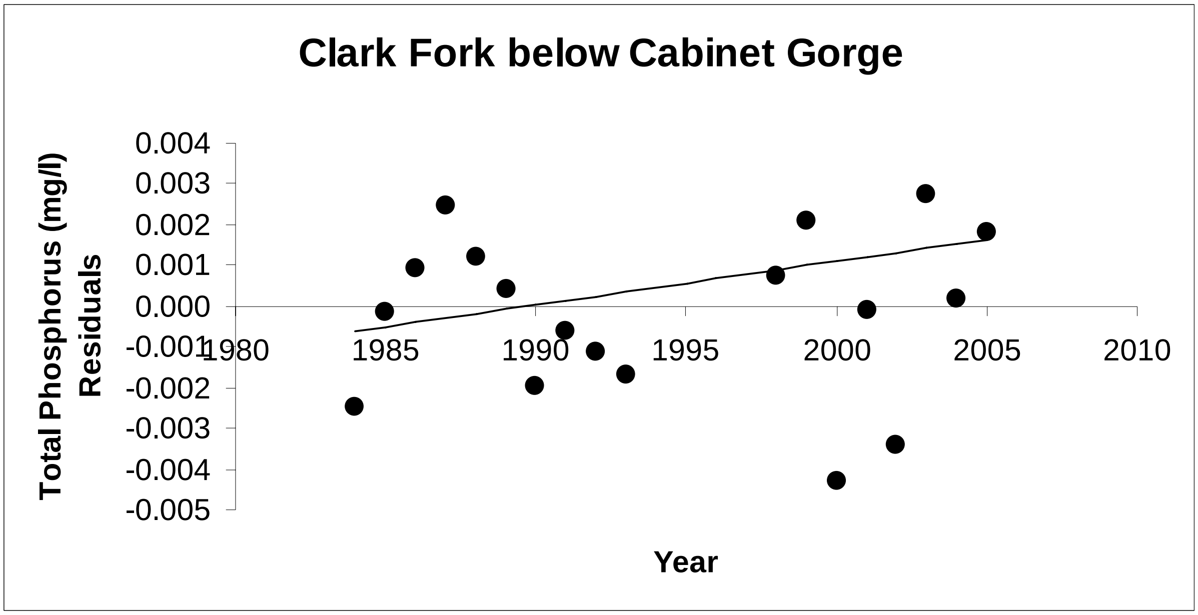


Figure 4-9b. ***Clark Fork below Cabinet Gorge Dam – Total Phosphorus (Static Trend, flow adjusted data).***



Additional investigation of trends in soluble reactive phosphorous (SRP) and total soluble inorganic nitrogen (TSIN) was conducted for the Clark Fork River at Noxon and the Clark Fork River below Cabinet Gorge. This analysis showed no trend in SRP for either site (**Table 4-4**).

Table 4-4. ***Trends for key nutrient variables in the Clark Fork below Cabinet Gorge, 1984-2007 using raw data and flow adjustments as applicable.***

Sen Slope in µg/L/Year and %					
Station	**Station Number**	**Soluble Reactive Phosphorus µg/L/yr**	**%**	**Total Soluble Nitrogen µg/L/yr**	**%**
CFR at Noxon	29	0.1/0.1*	NA	**1.7##**	3.7%
CFR below Cabinet Gorge	30	0.0#	NA	**2.0/1.3*##**	2.8%

Values in **Bold** indicate a significant temporal trend at α=0.05

Values not in **Bold** indicate a no significant temporal trend at α=0.05

* - indicates that the value has been adjusted for flow

\# - indicates >25% of values below detection limit

\##- indicates >50% of values below detection limit

Figure 4-10. ***Clark Fork at Noxon – Total Soluble Inorganic Nitrogen (Increasing Trend, raw data).***

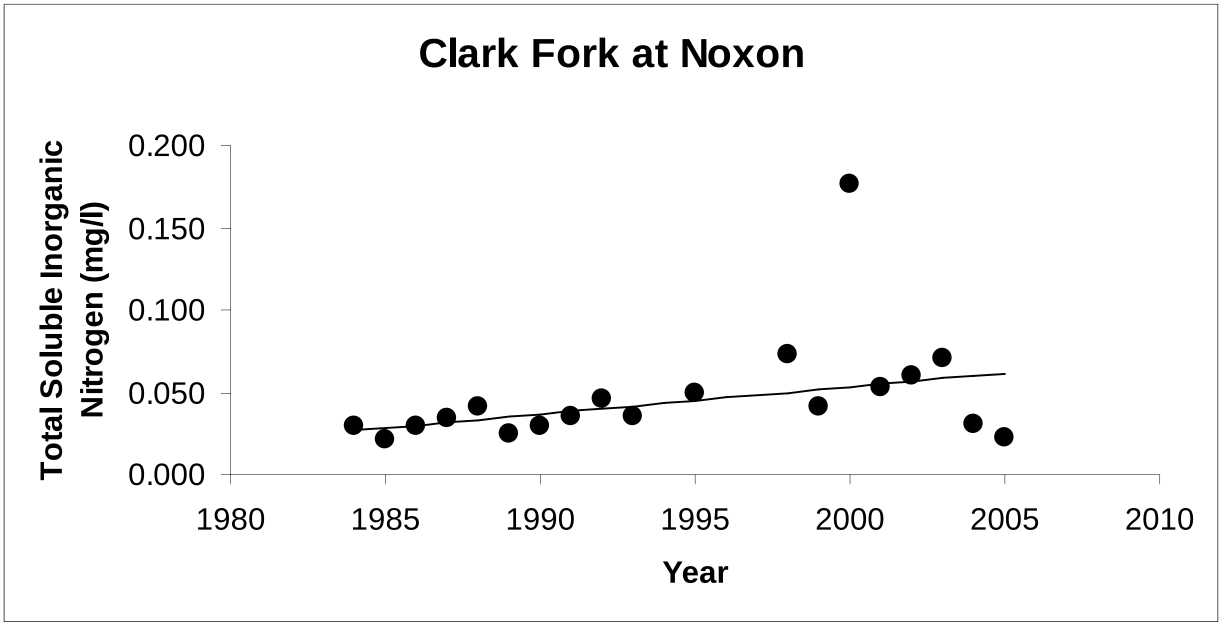
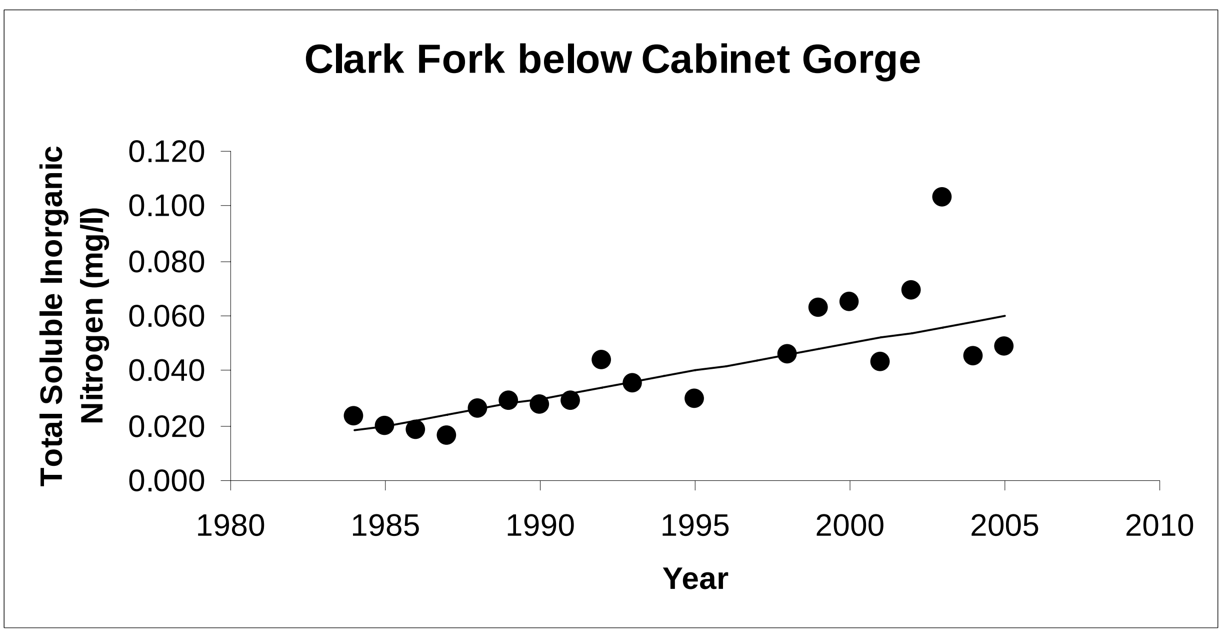


Figure 4-11. ***Clark Fork below Cabinet Gorge Dam – Total Soluble Inorganic Nitrogen (Increasing Trend).***



Total phosphorus data on the Pend Oreille River at Newport (**Figure 4-12**) and Metaline Falls (**Figure 4-14**) suggested decreasing trends from 1998-2007. Apparent trends should be interpreted with caution at the Newport and Metaline Falls stations. Two high outlier data points prior to 2004 tend to skew the dataset at the Newport station. The detection limit was changed from100 µg/L to 1 µg/L in 2003. More than 25% of the TP values were below the higher detection limit. The change in detection limit is of concern because while the higher detection limit of 10 µg/L showed many values above the detection limit, the subsequent change to a 1 µg/L detection limit showed most values were in fact below 10 µg/L. Apparent trends are likely to be an artifact of the change in detection limit rather than changes in underlying nutrient concentration.

Figure 4-12. ***Pend Oreille River at Newport – Total Phosphorus (Decreasing Trend).***

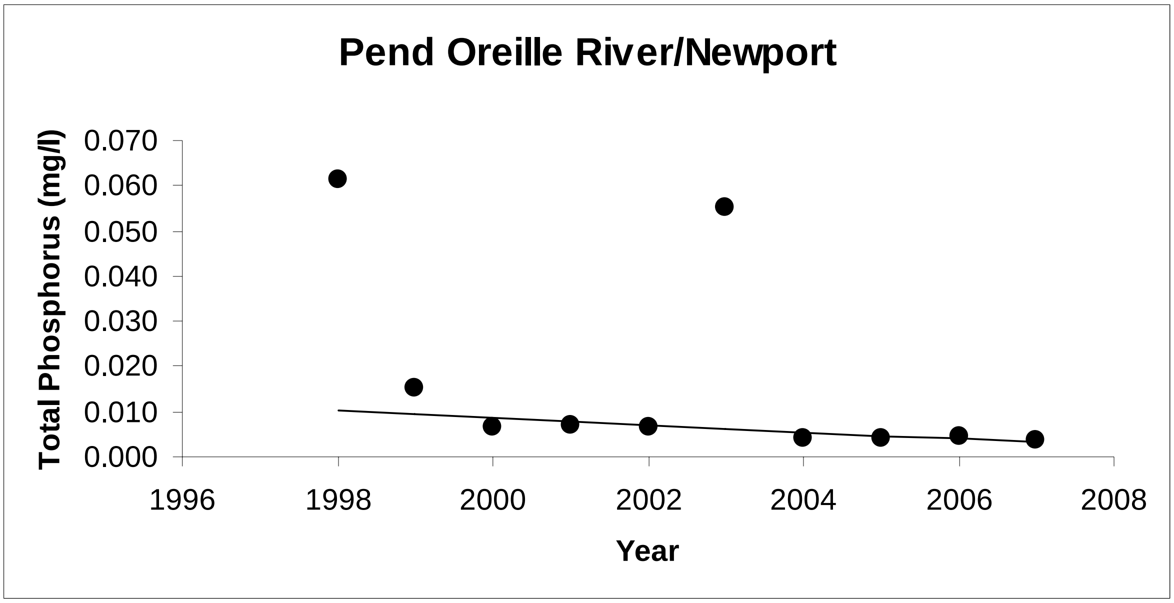
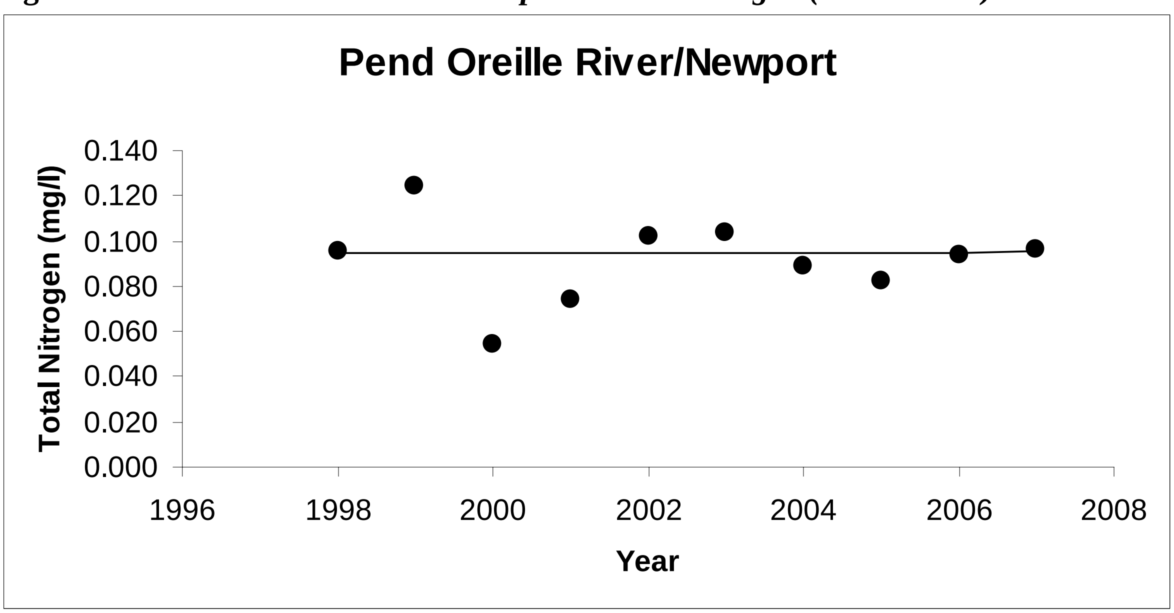


Figure 4-13. ***Pend Oreille River at Newport – Total Nitrogen (Static Trend).***



Total nitrogen data showed no trend at the Newport station (**Figure 4-13**), and a decreasing trend for the flow adjusted data at the Metaline Falls station (**Figure 4-15**).

Figure 4-14. ***Pend Oreille River at Metaline Falls – Total Phosphorus (Decreasing Trend).***

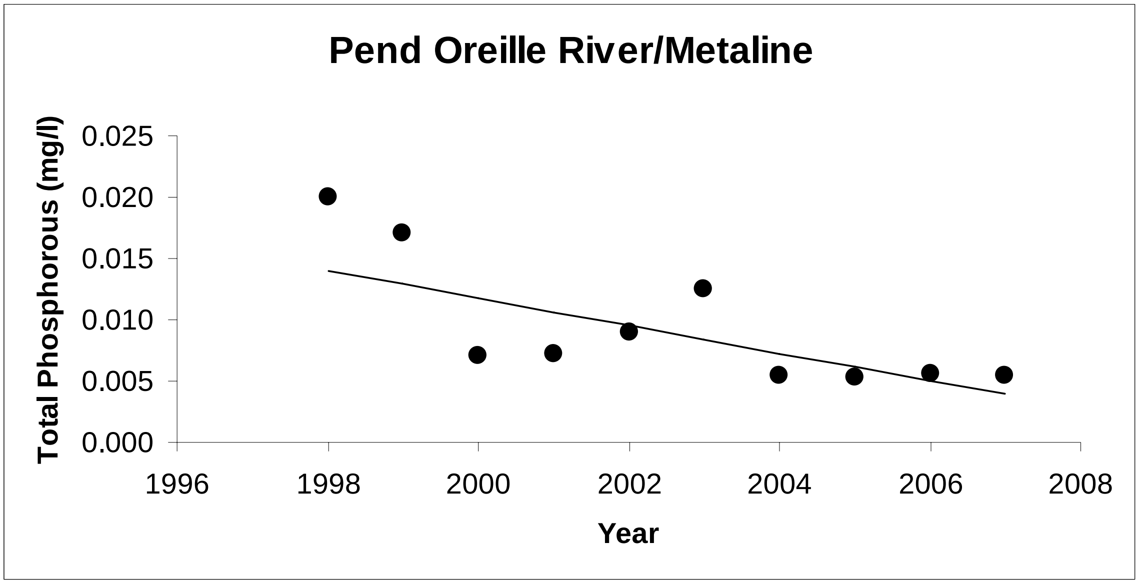
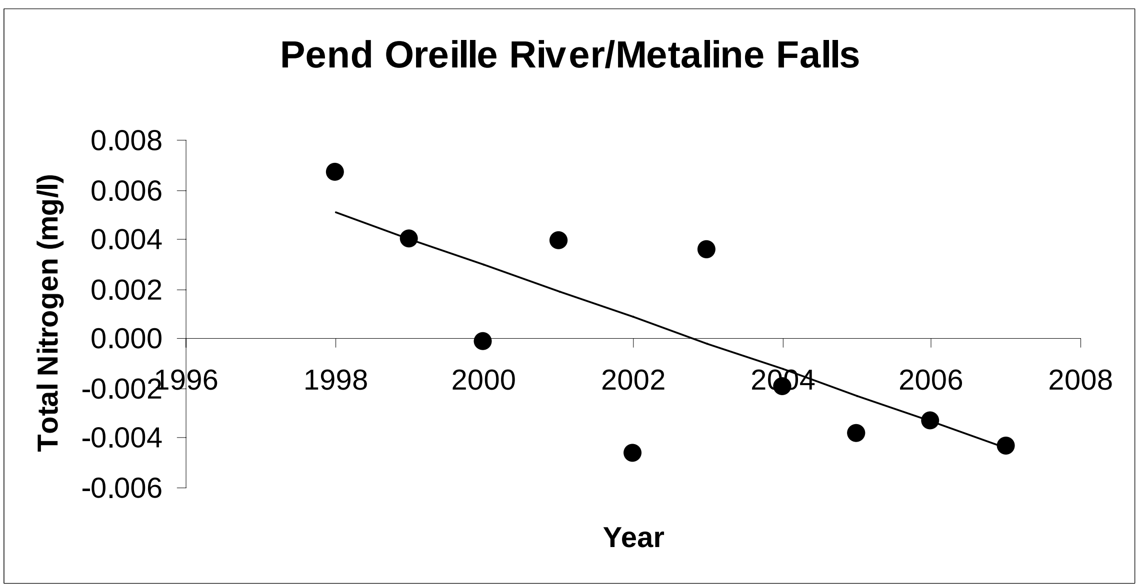


Figure 4-15. ***Pend Oreille River at Metaline Falls – Total Nitrogen (Decreasing Trend).***



5.0 CLARK FORK RIVER PERIPHYTON

Seven Clark Fork River stations were monitored for periphyton for five years from 1998-2007. Sites included Clark Fork River at Deer Lodge, Clark Fork River above the Little Blackfoot River, Clark Fork River at Bonita, Clark Fork River above Missoula, Clark Fork River below Missoula, Clark Fork River at Huson, and Clark Fork River above the Flathead River. Ten replicate samples were collected in each sampling event at each station and were analyzed for two algal constituents, 1) Chlorophyll *a* (Chl-*a*) (mg/m^2) and 2) ash-free dry weight (AFDW) (g/m^2). Data and statistical test results are found in **Appendix D**.

5.1 Temporal Trends

Periphyton density results for the Clark Fork River stations were evaluated to determine if significant trends were apparent for chlorophyll *a* or biomass (measured as ash-free dry weight, AFDW) during the monitoring period. Clark Fork River stations above the Little Blackfoot and at Bonita showed statistically significant increasing trends ($\alpha = 0.05$) in periphyton densities over the 10-year period from 1998-2007 (**Table 5-1**). The station immediately above Missoula and all downstream stations showed either static trends or decreasing trends over the same period. Boxplots for chlorophyll *a* are shown in **Figures 5-1** to **5-7**; boxplots for biomass are similar and are found in **Appendix D** along with statistical test results.

Table 5-1. ***Statistically significant trends in chlorophyll a and biomass at Clark Fork mainstem sites.***

Site	Trend in Chlorophyll *a*	Trend in Biomass (AFDW)
Clark Fork at Deer Lodge	Static	Static
Clark Fork above Little Blackfoot	Increasing	Increasing
Clark Fork at Bonita	Increasing	Increasing
Clark Fork above Missoula	Static	Static
Clark Fork at Shuffield's	Decreasing	Decreasing
Clark Fork at Huson	Static	Static
Clark Fork above Flathead	Decreasing	Decreasing

This presence of increasing trends for periphyton is somewhat unusual since summer total nutrient concentrations have generally shown a decreasing trend at most of these same stations. This may be a function of increased nutrient uptake by periphyton, though the reasons for this are uncertain. Potential factors such as changes copper concentration (an algaecide), changes in ambient water temperature, flow duration/timing, or scouring floods clearly have the potential to influence periphyton communities and standing crops. Detailed analyses of these factors were beyond the scope of this study, but certainly merit consideration.

This analysis included all 10 replicate values for each individual summer sampling event. The reported statistical significance of these trends is influenced by including all replicates (e.g. larger sample size), and potential lack of sample independence. Replicate samples from a single site may not be truly independent samples either spatially or temporally. It is worthwhile to note that variability within a site was frequently as great as variability between sites/years, however, so lack of spatial/temporal independence is likely to be a moot point. The increased sample size using all replicates can nevertheless inflate the statistical significance of results.

Figure 5-1. ***Clark Fork at Deer Lodge – Chlorophyll a (Static Trend).***

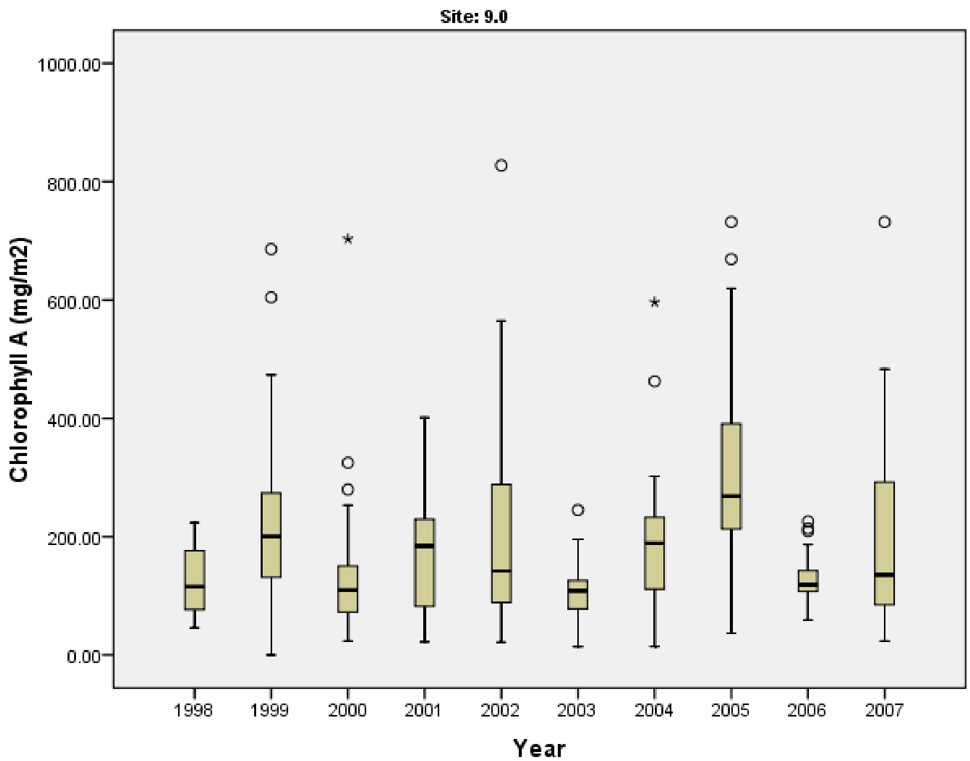


Figure 5-2. ***Clark Fork above Little Blackfoot – Chlorophyll a (Increasing Trend).***

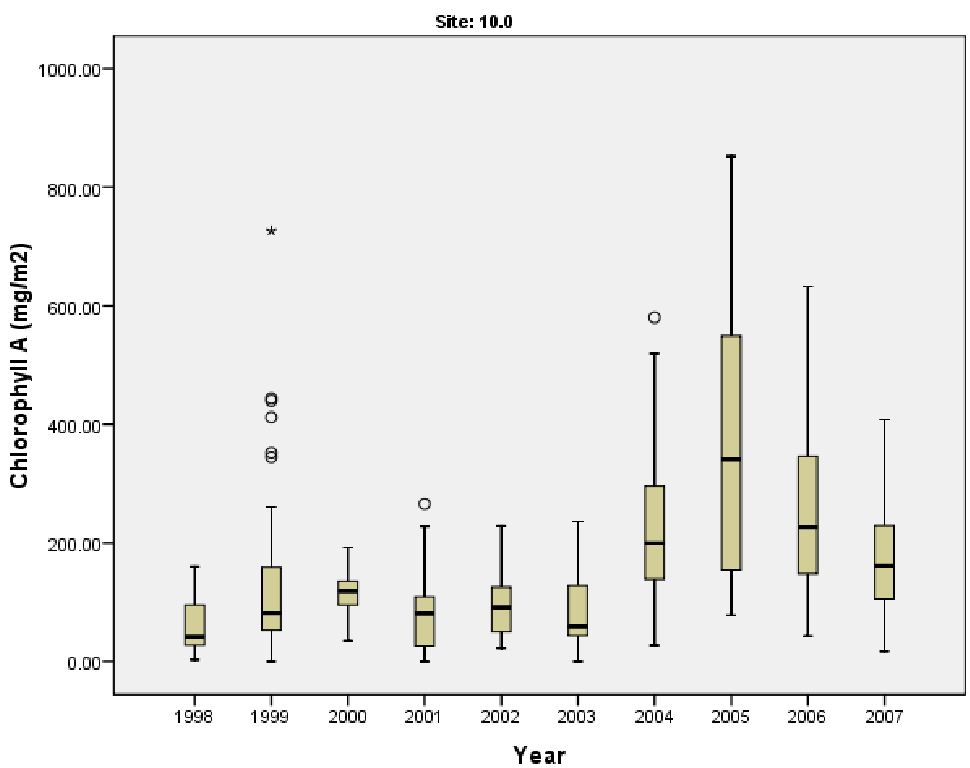


Figure 5-3. ***Clark Fork at Bonita – Chlorophyll a (Increasing Trend).***

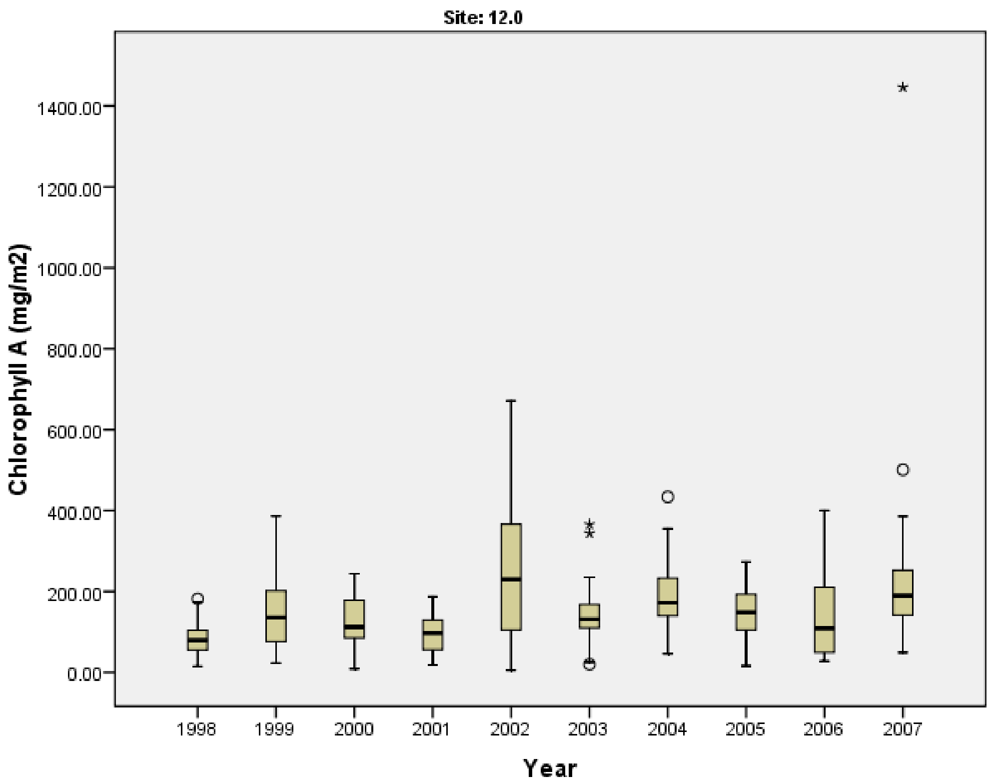


Figure 5-4. ***Clark Fork above Missoula – Chlorophyll a (Static Trend).***

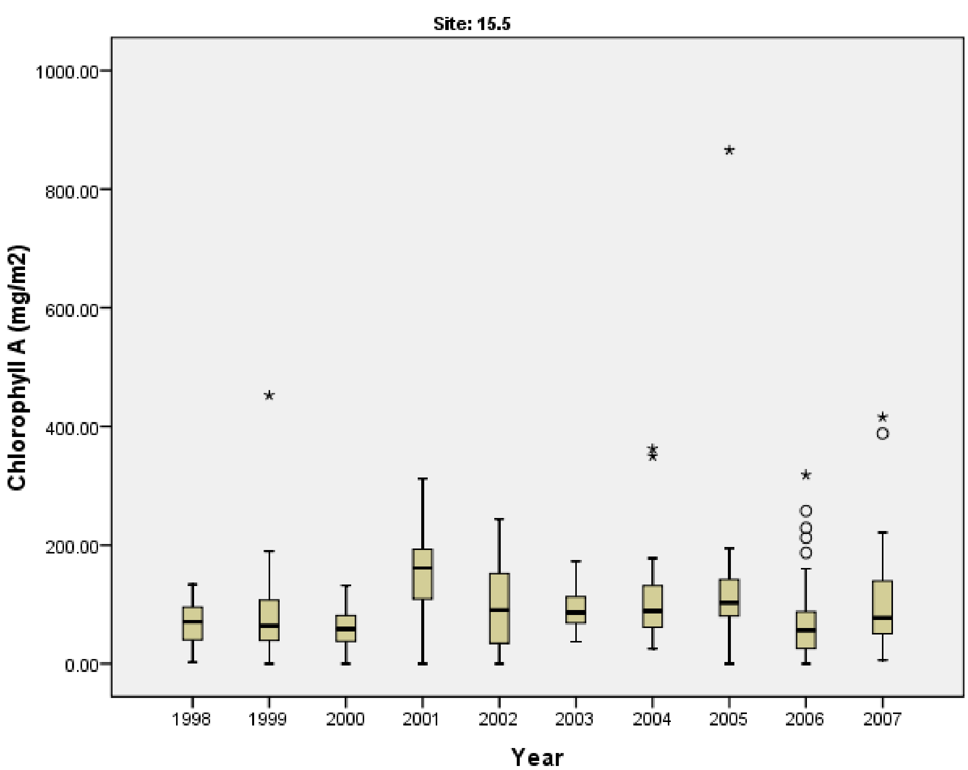


Figure 5-5. ***Clark Fork at Shuffields – Chlorophyll a (Decreasing Trend).***

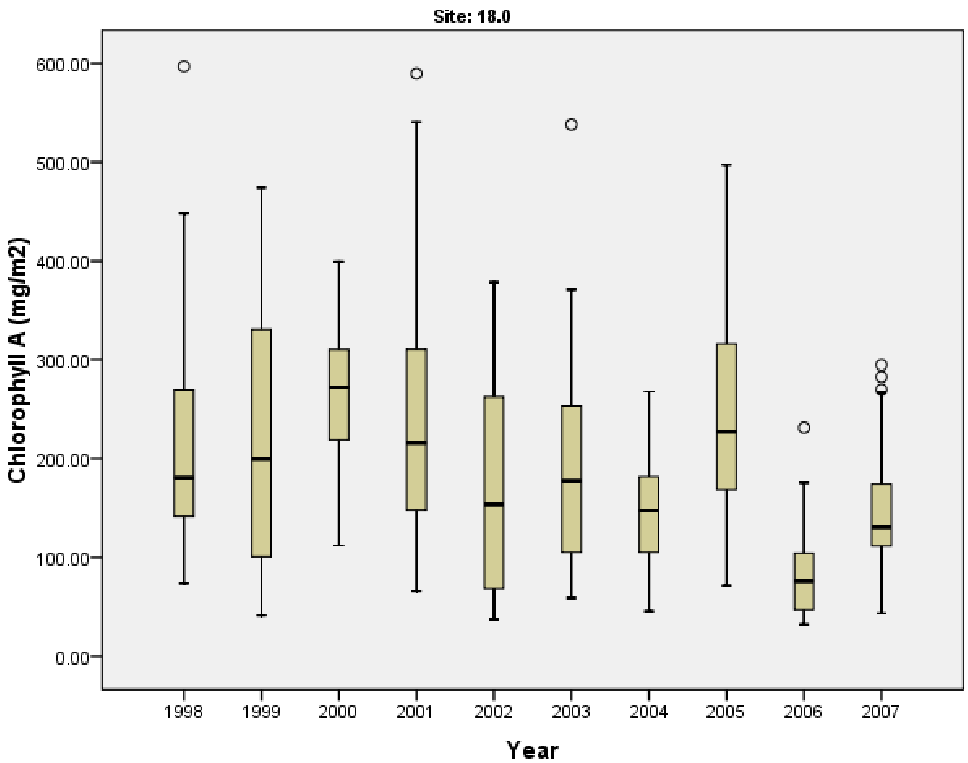


Figure 5-6. ***Clark Fork at Huson – Chlorophyll a (Static Trend).***

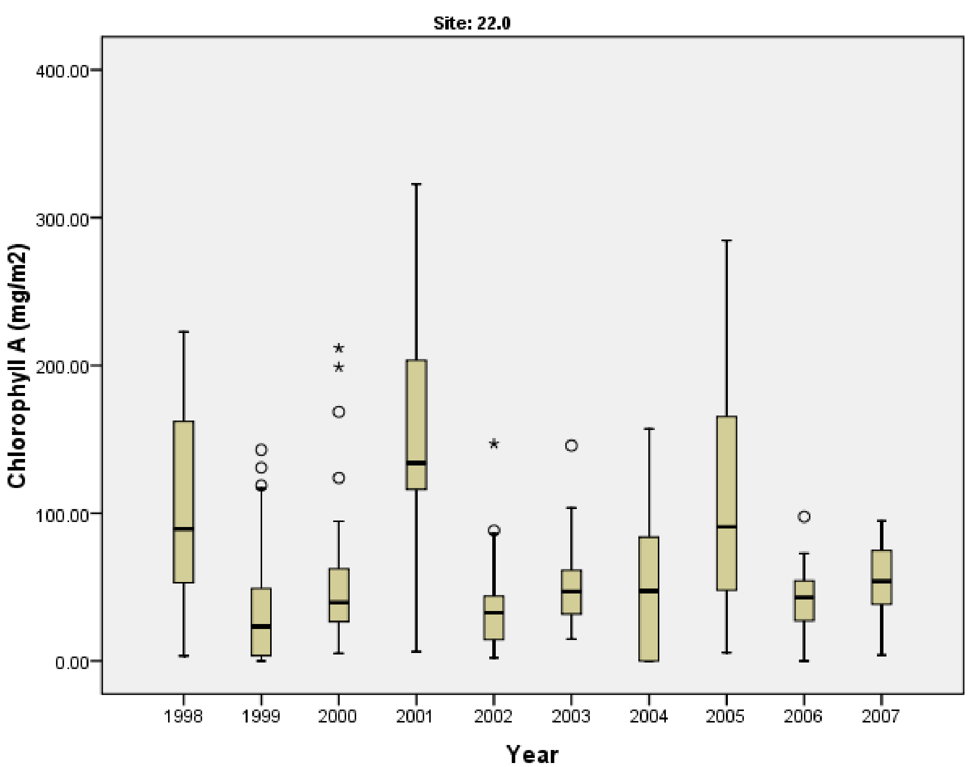
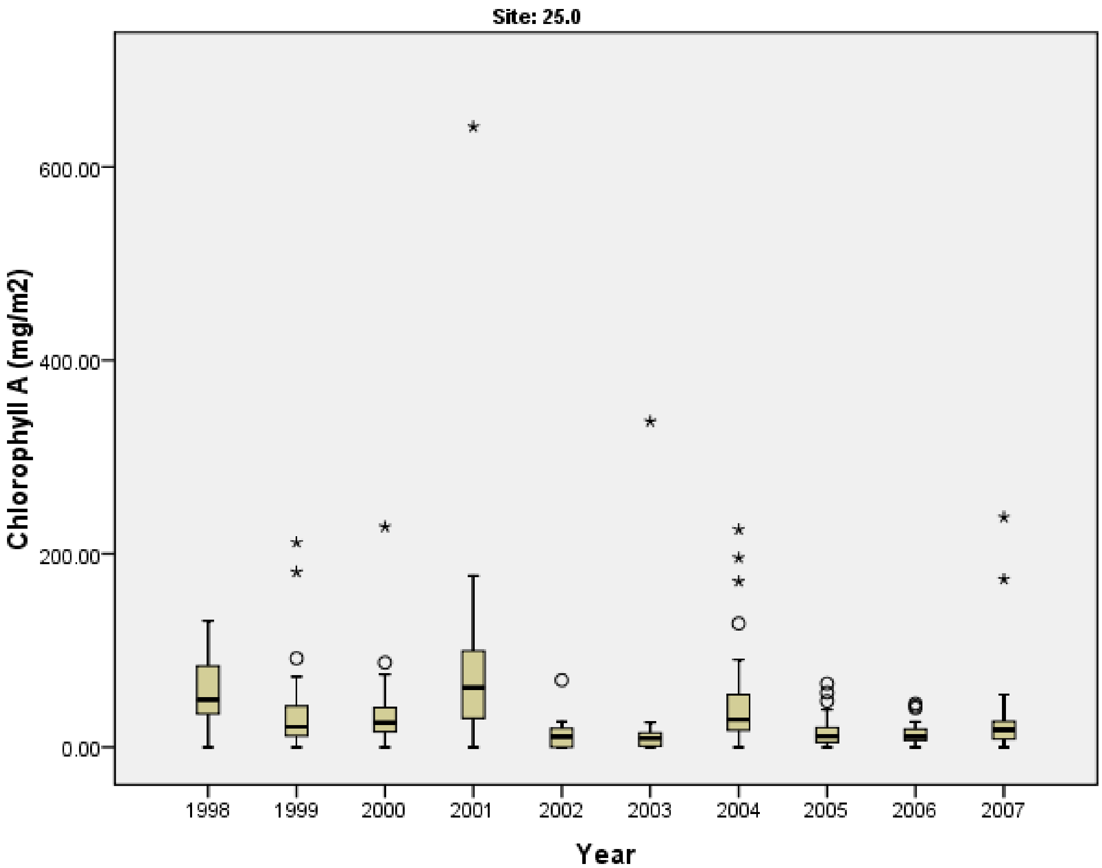


Figure 5-7. ***Clark Fork above Flathead – Chlorophyll a (Decreasing Trend).***



6.0 LAKE PEND OREILLE PERIPHYTON

Five Lake Pend Oreille (LPO) stations were monitored from 1998-2007 for periphyton densities. The sites included Bayview, Kootenai, Springy Point, Sunnyside, and Trestle. Ten replicate samples were collected in each sampling event at each station and were analyzed for two algal constituents:

- Chlorophyll *a* (mg/m^2)
- Biomass (AFDW (g/m^2)

Lake Pend Oreille periphyton samples were collected in September only. Data are presented in **Appendix E**. Long-term Secchi disk readings were taken at three locations on Lake Pend Oreille. Data are presented in **Appendix F**.

6.1 Spatial Distribution of Near-Shore Periphyton

The spatial distribution of Chl-*a* and AFDW in Lake Pend Oreille was documented in previous annual reports (e.g. Land & Water/PBS&J 2002-2008).

Figure 6-1. ***Spatial distribution of near-shore periphyton chlorophyll a in Lake Pend Oreille from 1998-2007.***

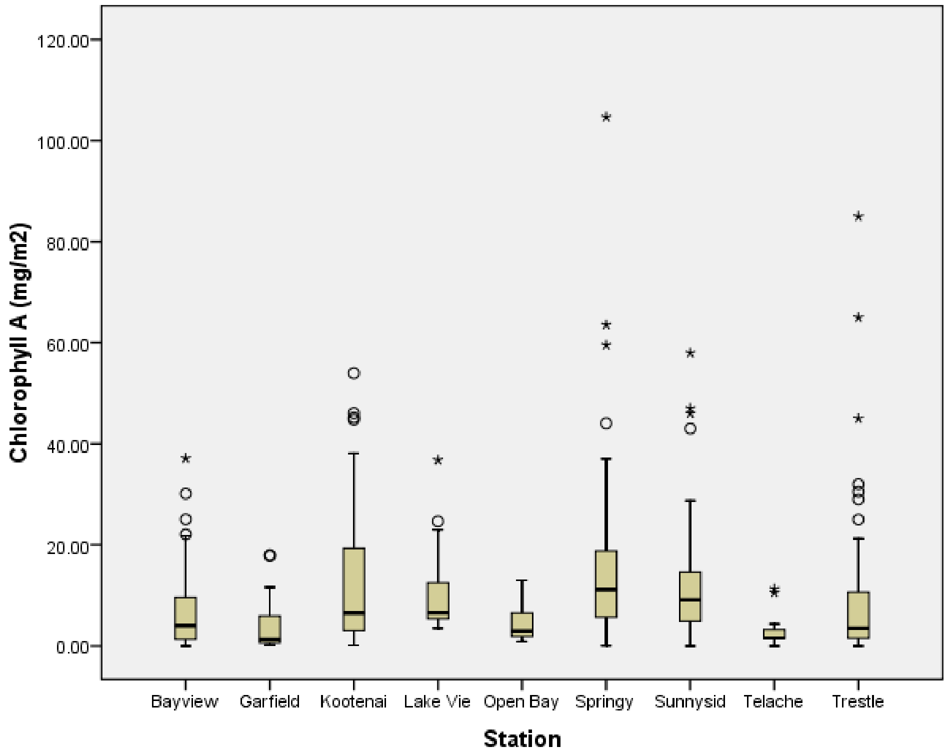
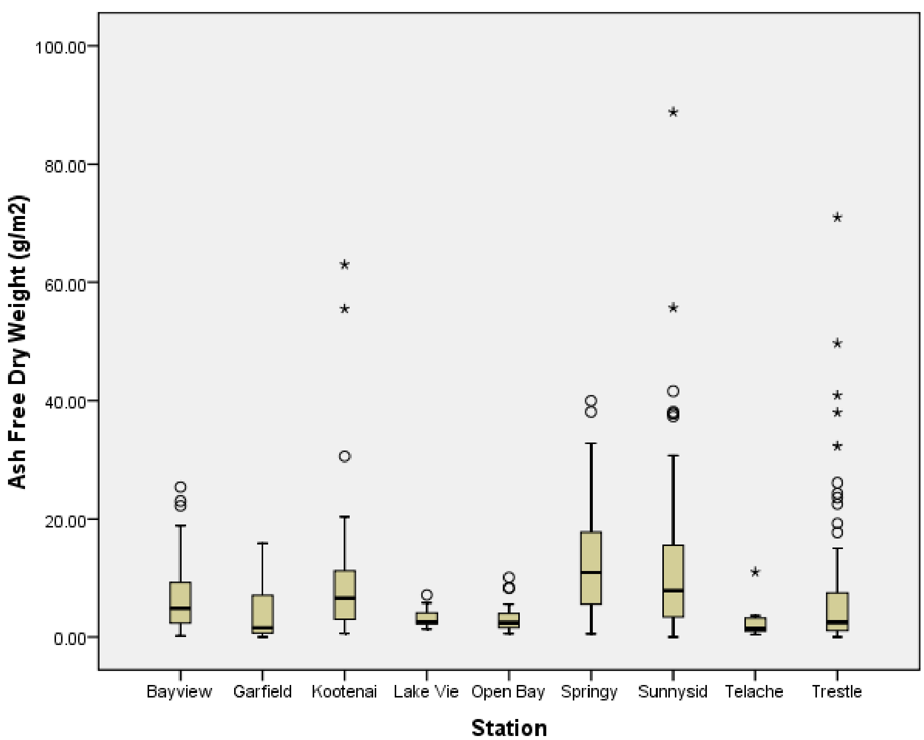


Figure 6-2. ***Spatial distribution of near-shore algal biomass in Lake Pend Oreille from 1998-2007.***



6.2 Temporal Trends for Near-Shore Periphyton

Five stations with long-term records on Lake Pend Oreille were sampled each September from 1998-2007 to document status and trends in near-shore periphyton. Ten replicate samples were collected from natural substrate during each sampling event. Temporal boxplots Lake Pend Oreille periphyton data show changes over time (**Appendix E**).

Statistically significant decreasing trends in attached algae metrics were noted two monitoring sites (Sunnyside and Trestle). Springy point showed an increasing trend in chlorophyll *a* from 1998-2007. The remainder of the sites showed no trend in attached algae metrics (**Table 6-1**).

Table 6-1. ***Statistically significant (0.05) trends in periphyton chlorophyll a and biomass at Lake Pend Oreille near-shore sites, 1998-2007.***

Site	Trend in Chlorophyll *a*	Trend in Ash-Free Dry Weight
Bayview	None	None
Kootenai	None	None
Springy Point	Increasing	None
Sunnyside	Decreasing	Decreasing
Trestle	Decreasing	Decreasing

Figure 6-3. ***Temporal trend in near-shore periphyton chlorophyll a -- Bayview site.***

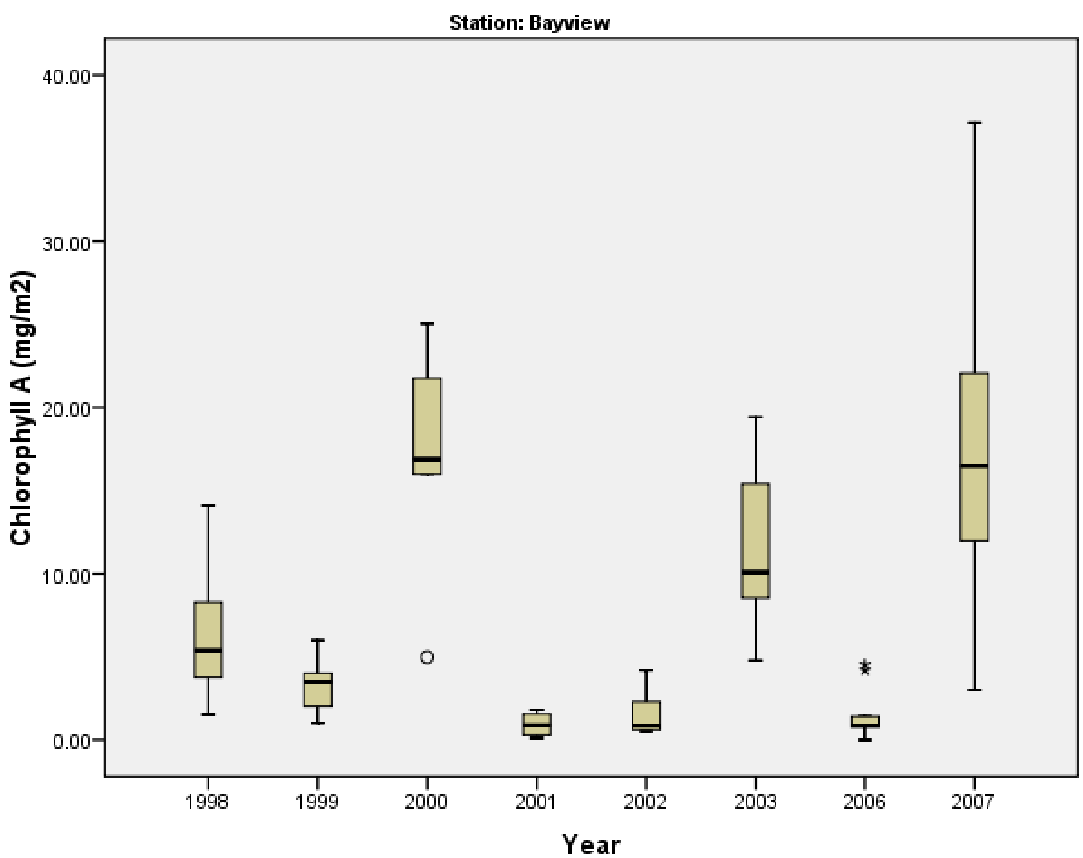


Figure 6-4. ***Temporal trend in near-shore periphyton chlorophyll a -- Kootenai site.***

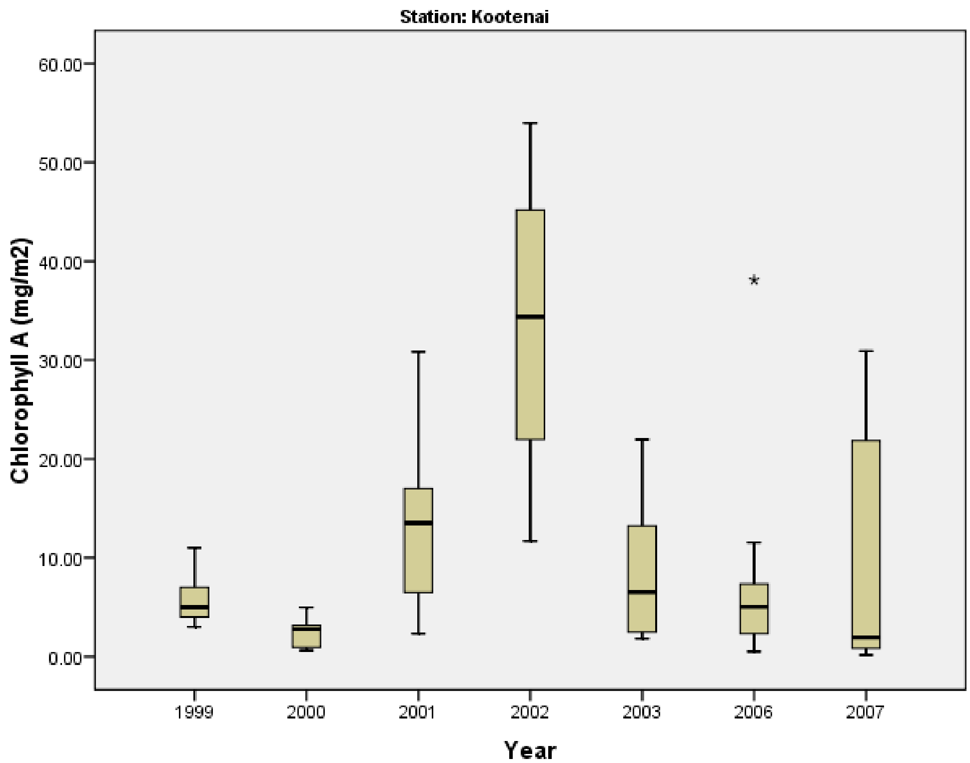


Figure 6-5. ***Temporal trend in near-shore periphyton chlorophyll a -- Springy Point site.***

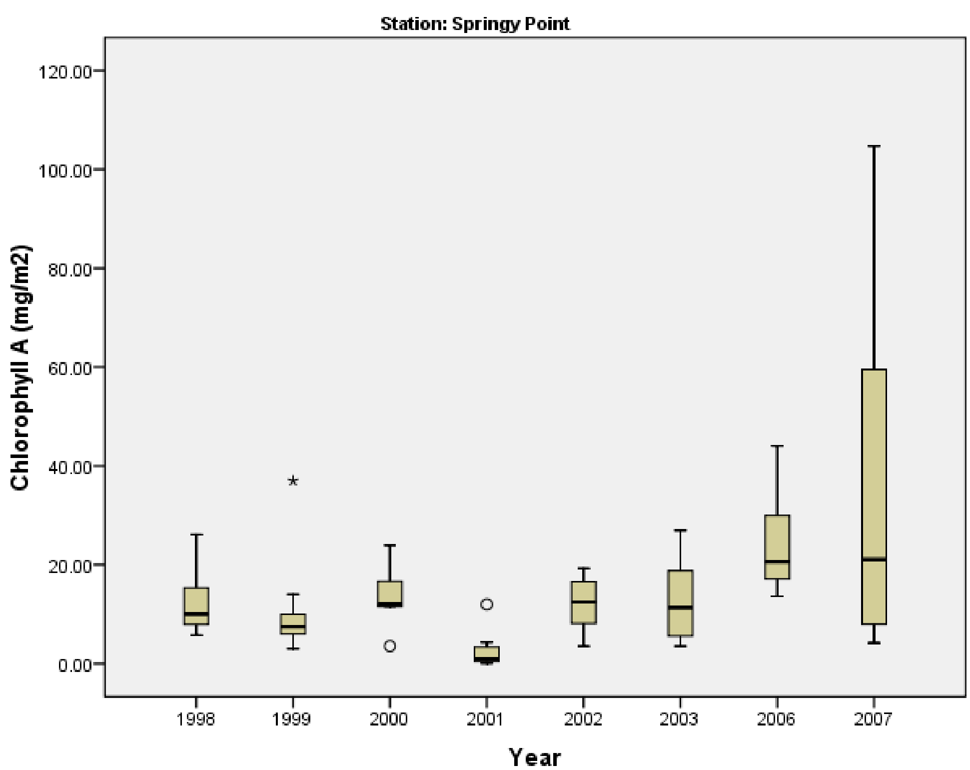


Figure 6-6. ***Temporal trend in near-shore periphyton chlorophyll a -- Sunnyside site.***

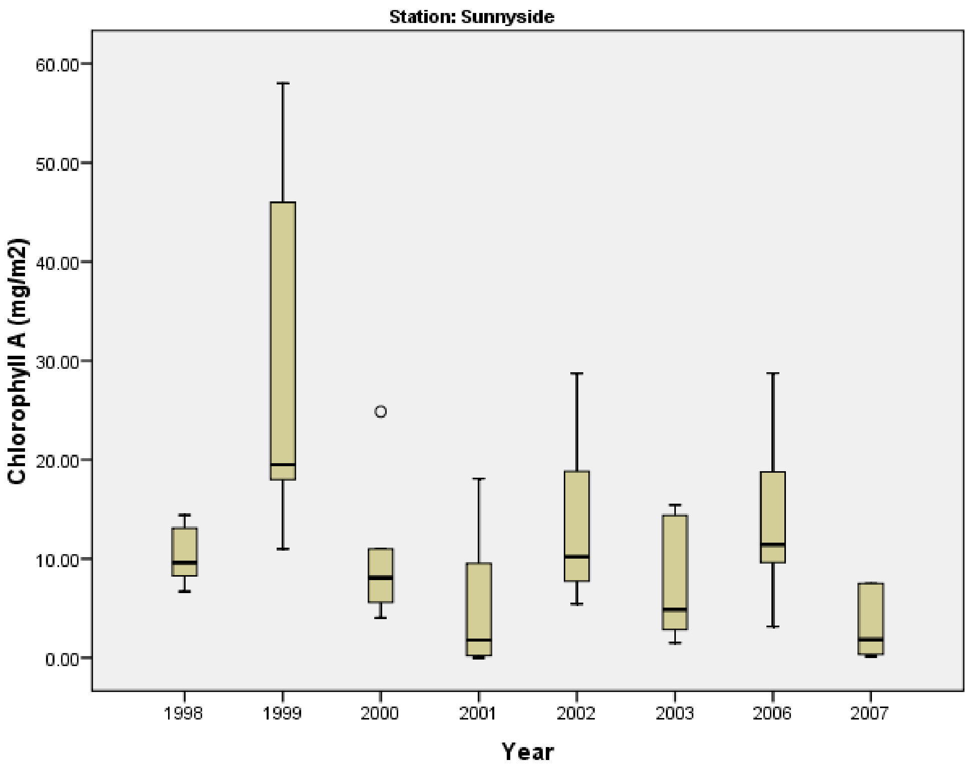
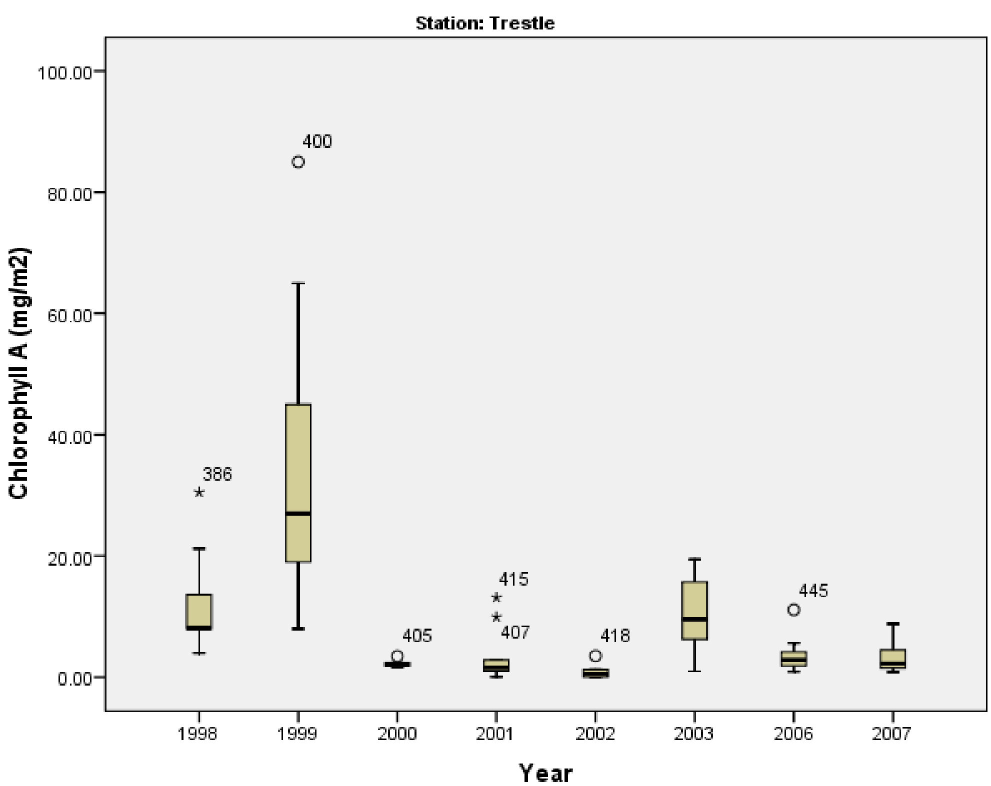


Figure 6-7. ***Temporal trend in near-shore periphyton chlorophyll a -- Trestle site.***



7.0 LAKE PEND OREILLE NUTRIENT LOADING/TROPHIC STATUS

7.1 Lake Pend Oreille Nutrient Loading

Nutrient loading into Lake Pend Oreille was evaluated using a U.S. Army Corps of Engineers computer model (FLUX), one of three models that make up the BATHTUB Eutrophication model (Walker 1999). The Clark Fork River provides more than 90% of Lake Pend Oreille's water and 75 % of its total nutrient loading (Tri-State Water Quality Council 998). Daily flow values were taken at the USGS gauging station on the Clark Fork River less than one mile below Cabinet Gorge Dam, and grab samples were gathered by the State of Montana (MDHES) and the Tri-State Water Quality Council. Nutrients (total nitrogen, total soluble inorganic nitrogen, total phosphorus, and soluble reactive phosphorus) were sampled by MDHES monthly from July 1984 through August 1993. The Tri-State Water Quality Council sampled monthly at the same locations starting in June 1998. During high river flows (June and part of July) additional samples were taken by both organizations. This resulted in 18 samples annually. These data were used in the model to determine annual loading to Lake Pend Oreille from 1984 through 2007.

The model used grab-sample nutrient concentrations, corresponding flow measurements and complete flow records for the period of interest. The FLUX model uses six calculation techniques to map the flow/concentration relationship developed from the sample record onto the entire flow record. Method 6, *Regression Applied to Individual Flows* was used in this study. Method 6 is generally preferred over the other regression-based methods when the flow/concentration relationship is well defined.

Method 6 – Regression Applied to Individual Flows

$$W_6 = \sum_j \exp\left[a + (b+1)\ln(Q_j) + SE^2/2\right]$$

where W_6 = estimated mean flux over N days, method 6 (kg/year)
c = measured concentration in sample (mg/m^3)
a= intercept of ln(c) versus ln(q) regression
b= slope of ln(c) versus ln(q) regression
Q_j = mean flow on day j (hm^3/year)
$\sum_j$ = sum over N dates in daily flow record
SE= Standard error of estimate for ln(c) versus ln(q) regression

Sample concentrations in mg/L were converted to mg/m^3.
Flows in CFS were converted to hm^3/year (cubic hectometers per year) (Walker 1999).

Annual loadings for each constituent were calculated applying nutrient concentration-flow regressions to daily flow values (**Table 7-1, Figures 7-1 and 7-2, Appendix G**). The flow data was stratified to develop separate regression equations and improve estimates of loading. These stratifications were developed by the model (separated at QMEAN) to lower the coefficient of variation (CV) for the loading calculations. For each stratum, the C/Q regression equation is applied individually to each daily flow value. The sum of daily loads provides the annual estimate. Constituents with a laboratory value below equipment detection limits were given a value of one-half the detection limit.

Table 7-1. ***Estimated Lake Pend Oreille nutrient loads via Clark Fork River inflow, 1984-2007.***

Year	Volume (hm3)	% of Avg Yr (1929-2007)	TN (kg x 1000)	TP (kg x 1000)
1984	17757	92	3848	114.3
1985	18270	93	2945	189.8
1986	19177	97	3163	216.3
1987	14329	72	2292	128.1
1988	13488	67	2169	126.2
1989	19451	99	3171	213.1
1990	22655	115	3792	279.9
1991	23620	121	4029	309.2
1992	12714	63	2012	106.7
1993	16714	84	2687	167.5
1994	12384	62	2006	116.6
1995	18817	95	3109	210.0
1996	28156	147	5114	426.9
1997	30503	158	5573	502.7
1998	17529	89	2912	193.9
1999	20124	102	3392	241.9
2000	16643	84	2744	170.9
2001	10275	51	1740	99.2
2002	20681	105	3679	289.1
2003	15697	82	2664	176.7
2004	15846	82	2564	152.6
2005	15958	83	2694	173.4
2006	20020	104	3474	259.3
2007	14213	74	2357	157.1
Average	18,126		2950	209.2
Median	17,643		2828	183.2

Figure 7-1. Cabinet Gorge total nitrogen loads, 1984-2007.

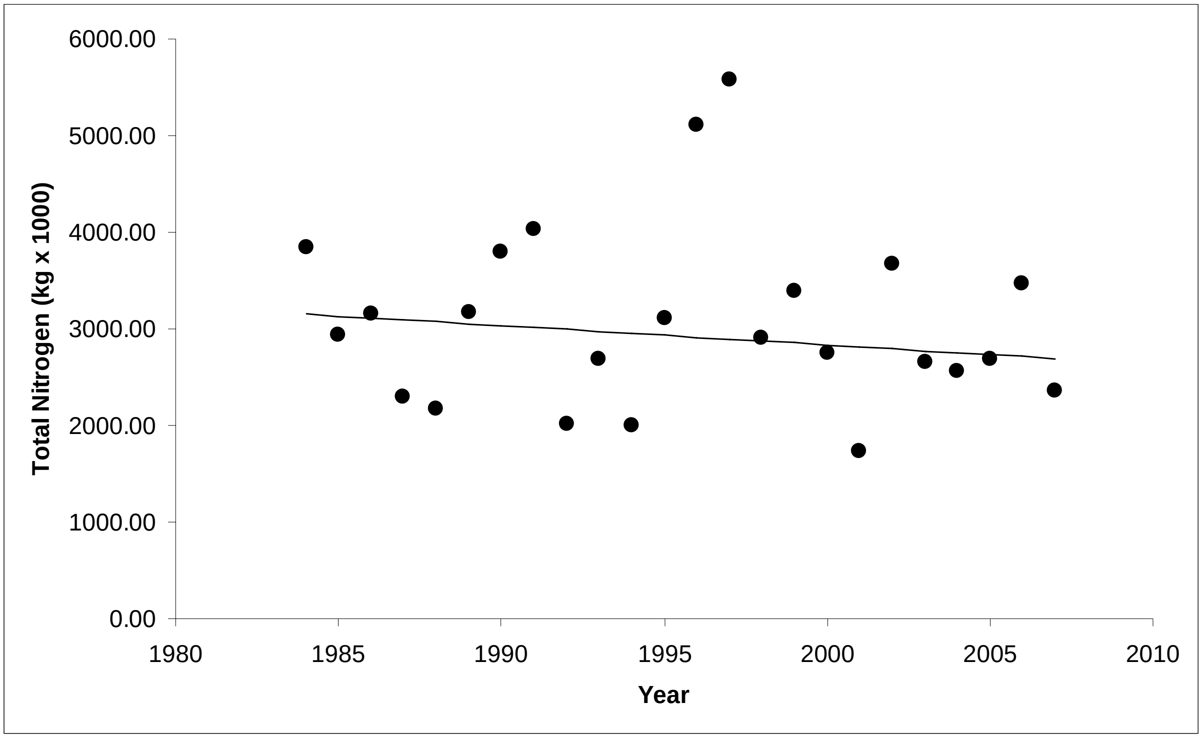
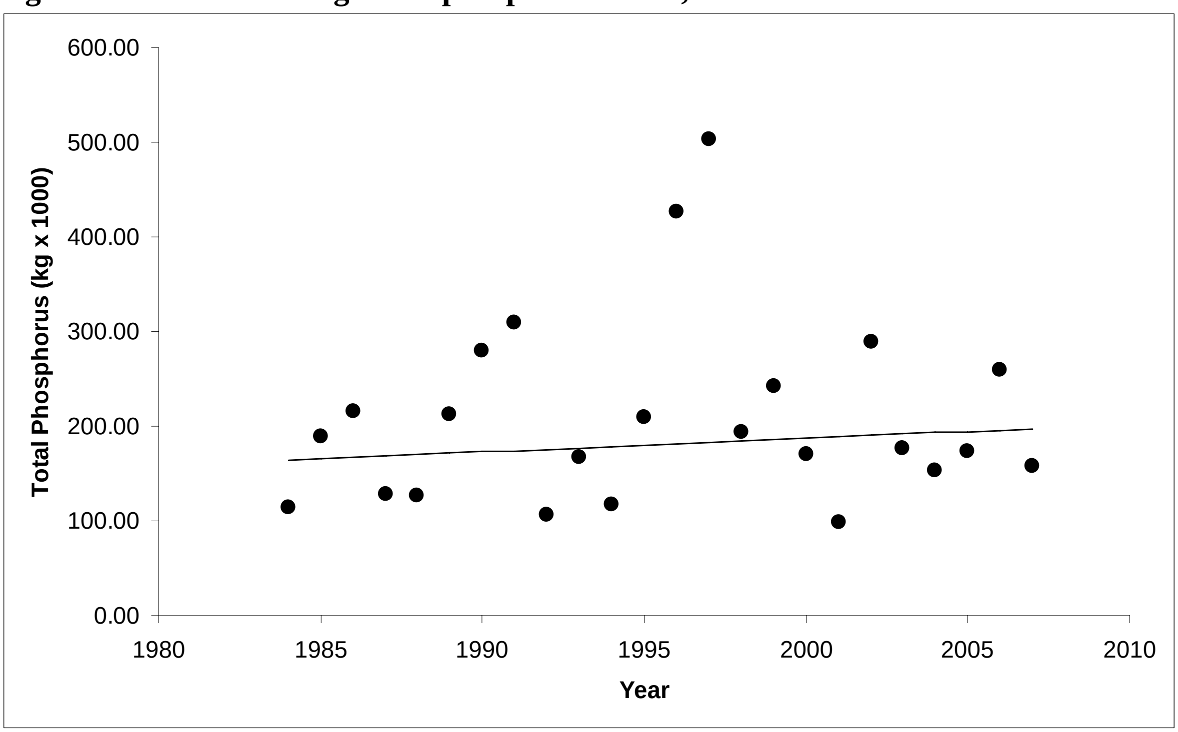
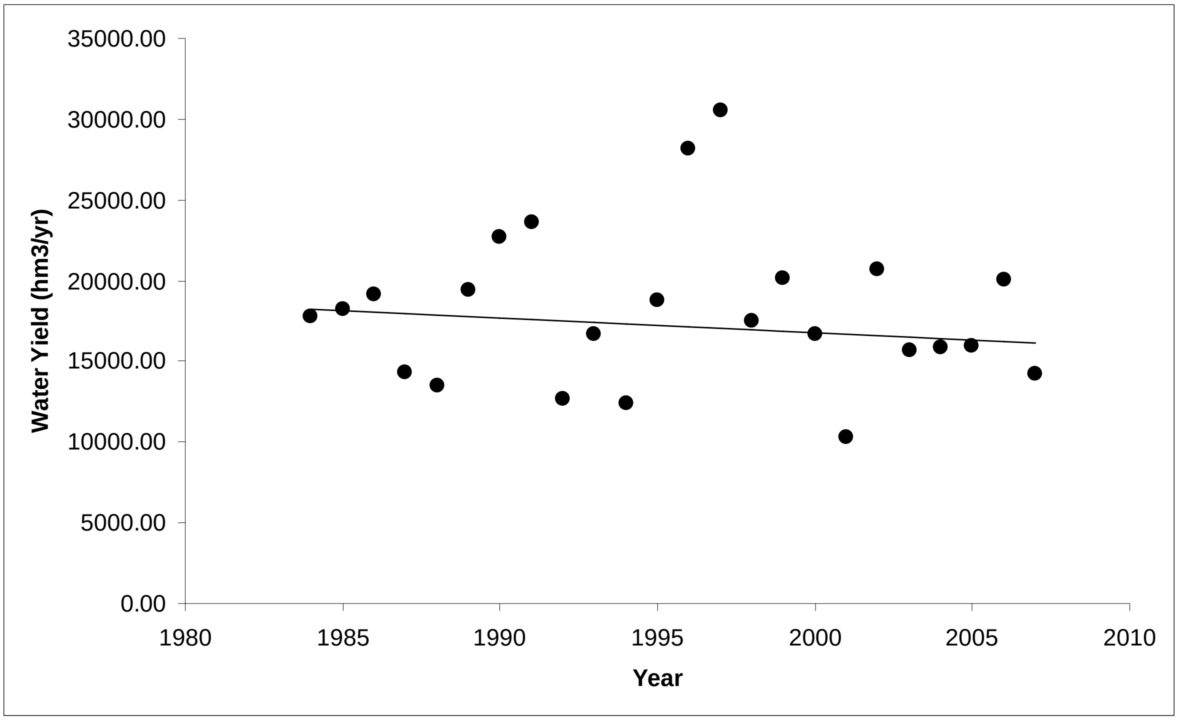


Figure 7-2. Cabinet Gorge total phosphorus loads, 1984-2007.



Trend analysis of estimated loads showed no significant trend in either TN or TP to Lake Pend Oreille from the Cabinet Gorge site. No statistically significant trend in annual water yield (i.e. flow volumes) was present from 1984-2007 (**Figure 7-3**).

Figure 7-3. Cabinet Gorge Annual Flow Volume, 1984-2007.



It should be noted that loads in this analysis were developed using the long-term record of daily flows from USGS station 12392000 Clark Fork River at Whitehorse Rapids. This station includes an assumed 600 cfs groundwater inflow derived from seepage around the Cabinet Gorge Dam. Since October 1995, the USGS has begun publishing data for the upstream station 12391950 Clark Fork River below Cabinet Gorge Dam. Because this record is short term and previous load analyses relied on the Whitehorse records, the present loading analysis also used Whitehorse to maintain consistency.

In September 2001, the Tri-State Water Quality Council recommended nutrient targets and apportioning loads to Lake Pend Oreille for an agreement between the states of Montana and Idaho (Tri-State 2001). The targets were developed out of concern for maintaining the water quality of open waters of Pend Oreille Lake. To achieve this goal, an area-weighted euphotic zone concentration target of 7.3 µg/L was recommended for total phosphorus in Lake Pend Oreille. To meet this target, a total load of 328,651 kg/year total phosphorus was recommended to be allocated as follows:

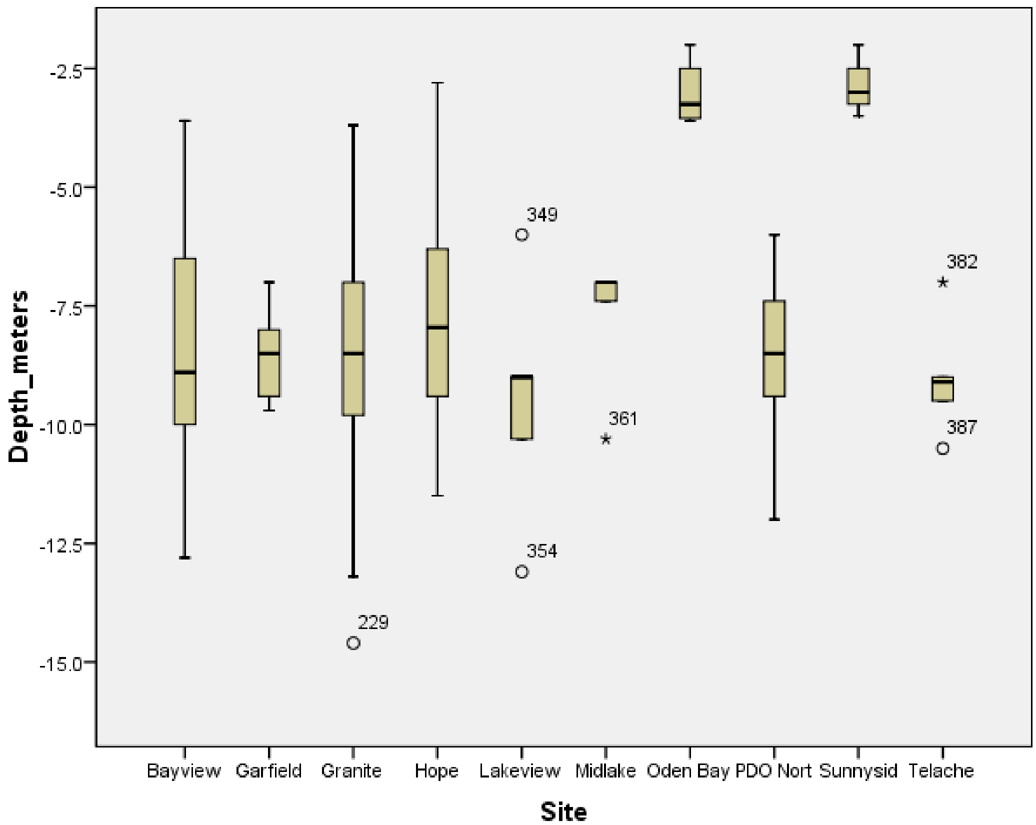
- 259,500 kg/year total phosphorus from Montana (as measured at Clark Fork River below Cabinet Gorge Dam) and,
- 69,151 kg/year total phosphorus from Lake Pend Oreille watershed in Idaho.
- Greater than 15:1 total nitrogen to total phosphorus ratio
- Although no targets were established for total nitrogen loading to Lake Pend Oreille, they are reported in **Table 7-1**.

Analysis of Lake Pend Oreille water quality is found in **Section 7.2** which follows.

7.2 Lake Pend Oreille Trophic Status

Secchi depths observed in Lake Pend Oreille during the July-September season are shown in **Figure 7-4**. Open water sites Bayview, Hope and Granite have long-term records from 1953-2002 or longer (Granite to 2005, and Bayview to 2007). The remaining stations are limited to 2006-2007 data (**Appendix F**).

Figure 7-4. ***Lake Pend Oreille Secchi depth (July-September) by site.***



Median summer Secchi depths for all stations were typically 8-9 meters with the exception of Oden Bay and Sunnyside which were comparable at 3 meters. Pooled data for all seasons show a similar pattern with Oden Bay and Sunnyside having the lowest transparencies.

Individual box plots for Bayview, Granite, and Hope sites for summer Secchi transparency by year are shown in **Figures 7-5, 7-6,** and **7-7**.

Figure 7-5. ***Bayview Secchi depth (July-September).***

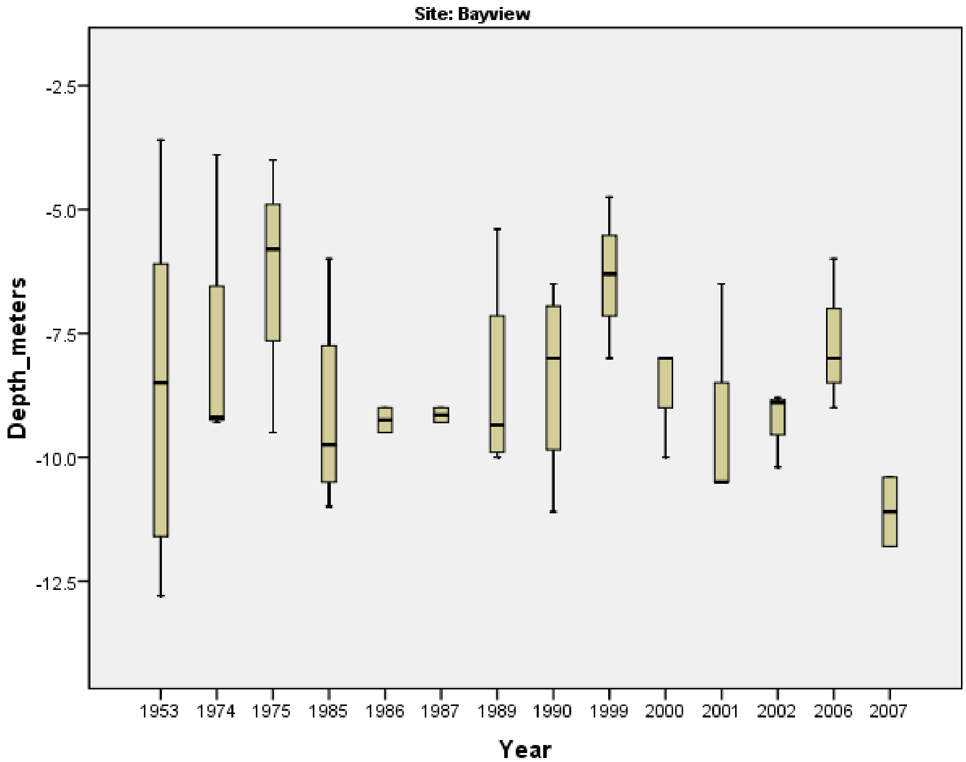


Figure 7-6. ***Granite Secchi depth (July-September).***

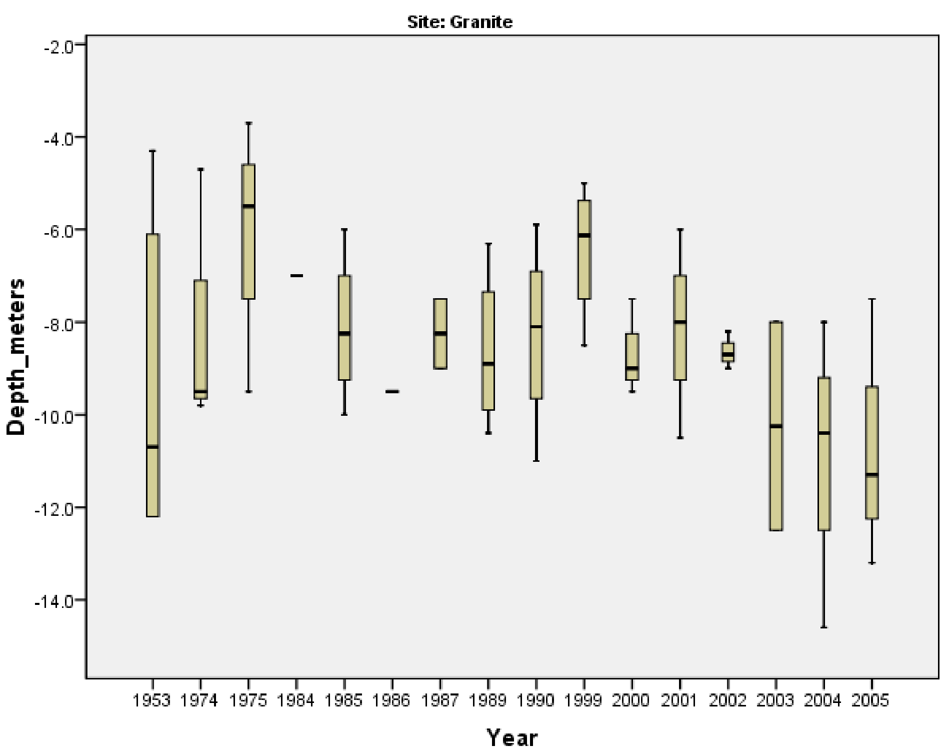
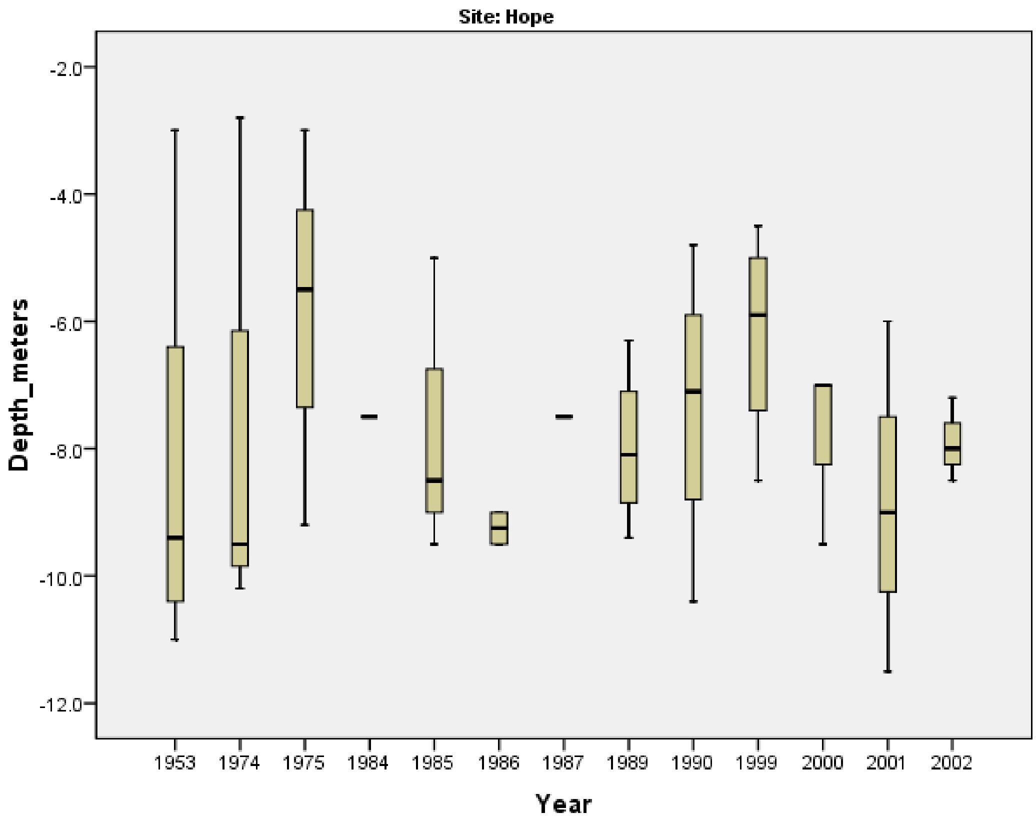


Figure 7-7. ***Hope Secchi depth (July-September).***



Trend analysis was conducted for the summer season using Kendall's tau (alpha= 0.05) which correlates Secchi depth with year. Note that no deseasonalization was performed as data were limited to a single season (i.e. summer-July to Sept). Analysis of Secchi depth over time showed no significant changes in summer lake transparency at any station for the period of record. The box plots do not visually portray a tendency for reduced summer Secchi transparency. This metric suggests that trophic status of Pend Oreille lake has remained stable since 1993.

Carlson's indices provide convenient metrics to assess the trophic state of a water body. Carlson's Trophic Index (TSI) was computed from Secchi disk (SD), chlorophyll *a* (Chl-*a*), and total phosphorus (TP) using the equations below (Carlson and Simpson 1996).

1) TSI(SD) = 60 - 14.41 ln(SD)
2) TSI(Chl-*a*) = 9.81 ln(CHL) + 30.6
3) TSI(TP) = 14.42 ln(TP) + 4.15

In general, metric values <30 indicate an oligotrophic condition. Values from 30-40 suggest a tendency towards mesotrophy, with potential for anoxic conditions in the hypolimnia of shallow water bodies. Values of 4-50 indicate mesotrophic conditions and nutrient enrichment.

Results for Carlson's Secchi, chlorophyll *a*, and total phosphorus TSI values are shown in **Table 7-2**.

Table 7-2. *Carlson's Trophic Status Index Values for Lake Pend Oreille sites, 2007.*

Site	Secchi TSI	Chl *a* TSI	TP TSI
Bayview	25.3	36.3	19.6
Bayview Nearshore	27.1	33.2	23.9
Granite (2005)	26.3	NA	NA
Hope (2002)	30.3	NA	NA
Garfield Bay	27.5	32.2	24.9
Lakeview	24.7	35.1	21.4
Sunnyside	44.2	32.7	26.1
Talache	27.1	32.5	23.1
Midlake	28.8	35.3	23.9
PDO North	29.4	32.8	25.3
Oden Bay	41.5	31.6	29.1

Carlson's index for Secchi transparency (Secchi TSI) indicated that most stations were oligotrophic (i.e. index <30). Exceptions were Sunnyside and Oden Bay with Secchi index values greater than 40. These values potentially suggest mild to moderate mesotrophic conditions for these two sites in 2007.

Carlson's index for total phosphorus (TP TSI) also suggested that most stations were oligotrophic with index values below 30 in 2007. Sunnyside and Oden Bay had the highest values of 26.1 and 29.1, respectively. A value exceeding 30 potentially indicates some tendency for mesotrophy in shallow water bodies. All stations were within the range considered oligotrophic, although Oden Bay approached the upper boundary for this classification.

Carlson's index for water column chlorophyll *a* (CHL TSI) suggested that most stations were transitional between oligotrophic and mesotrophic conditions with index values falling between 30 and 40 in 2006. A value exceeding 30 potentially indicates some tendency for mesotrophy in shallow water bodies. Index values between 30 and 40 typically correspond to a range of 0.95 to 2.6 µg/l of chlorophyll *a*. To achieve a value of 30 or less, chlorophyll must be less than 1 µg/l. Because the laboratory detection limit was 1 µg/l, achieving any meaningful resolution for this index is difficult. Also note that the chlorophyll *a* Carlson index was based on the available data (2006). Direct comparison to the other indices developed using 2007 data may not be a useful exercise.

7.3 Lake Pend Oreille Nutrient Targets

The TMDL established a target level of 9µg/L total phosphorus in the near-shore areas of the lake with an action threshold of 12 µg/L total phosphorus during critical conditions, which are the summer months of June through September. Open water sites have targets of 7.3 µg/l for total phosphorus. Monitoring data for eight sites on Lake Pend Oreille were evaluated (**Table 7-3, Appendix H**).

Table 7-3. *Lake Pend Oreille TP concentrations, 2003-2007.*

Site	Mean TP (µg/l)	Min (µg/l)	Max (µg/l)	# of samples >7.3 µg/l	# of samples >=9 µg/l	Total Sample Size (n)
Bayview	5.19	1	9	NA	1	19
Bayview Open	4.75	1	7	0	NA	8
Garfield Bay	5.65	3	10	NA	1	17
Granite**	7.33	4	10	NA	2	3
Kootenai**	6.4	3	8	NA	0	3
Lakeview	4.27	1	6	NA	0	11
Sunnyside	6.19	2	11	NA	1	10
Talache	4.86	2	9	NA	1	11
Midlake Open	5.87	3	10	2	NA	8*
PDO North Open	5.00	3	7	0	NA	8*
Oden Bay	7.29	5	12	NA	2	7

*Sampled in 2006-2007 only; **Sampled in 2003.

Sampling results indicated the near-shore target value of 9µg/l TP was exceeded at least once at most near-shore stations during the period of record with the exception of Lakeview and Kootenai. Granite had 2 of 3 observations exceed 9µg/l in 2003. Oden Bay and Midlake had 2 of 7 and 2 of 8 samples greater than 9 µg/l. The remaining stations had a single exceedance.

Results for the open water target of 7.3 µg/l were exceeded twice at Midlake, and no exceedances were observed at Bayview open and PDO North open.

Note that sample size differs between sites. This reflects varying sampling frequency within a given year and also between years. Granite and Kootenai had data for 2003 data only. Bayview Open, PDO North, Midlake, Oden Bay had 2006-2007 data. The remainder of the stations had variable data collection over the period 1989-2007. Direct comparison of mean values is biased by these differences. Data from 2003 to 2007 were considered in the present analysis to aid in comparability between stations/analyses. Additional data collected as early as 1984 (Lake Pend Oreille 525 study) includes sites which in some cases overlap. Including this data would result in an extended dataset, but in general the number of years (less than 7) for stations precludes a meaningful analysis of trends at this time. These data may prove useful for evaluating trends in future analyses.

8.0 CONCLUSIONS

- With several exceptions, riverine monitoring stations of the Clark Fork-Pend Oreille watershed either showed no trend, or improving status with respect to total nitrogen and total phosphorus during the summer monitoring period.
- Over the ten year period from 1998 to 2007, riverine monitoring stations showed increasing trends for attached algae at two upper river sites (Clark Fork above Little Blackfoot and Clark Fork at Bonita). The remaining 5 river stations showed no trend, or decreasing trends in periphyton metrics.
- Loading of total phosphorus to Lake Pend Oreille measured at the Cabinet Gorge site averaged 209,186 kg/yr from 1984 to 2007. The loading target of 259,500 kg/yr has been

exceeded 5 times during this 23 yr period. From 2000 to 2007, this target has been exceeded once.

- Trophic status in Lake Pend Oreille indicates oligotrophic conditions at most open water and near-shore sites based on total phosphorus concentrations, chlorophyll *a* values, and Secchi transparency in 2007.
- No statistically significant trends are apparent in summer Secchi transparency at stations monitored from 1953-2007. This suggests a stable trophic state for the lake.
- Periphyton monitoring in Lake Pend Oreille indicated either a decrease or no change in algal standing crop at all five stations. The sole exception was Springy Point which showed an increase in chlorophyll *a*, but not ash-free dry weight.
- Exceedance of total phosphorus targets in Lake Pend Oreille for open water (7.3 µg/l) and near-shore (9 µg/l) monitoring sites have been infrequent at most sites. Oden Bay and Midlake stations have had the most frequent excursions (28% and 25%). Along with Oden Bay, the Sunnyside monitoring site tended to have elevated nutrient concentrations and algal biomass.
- With a handful of exceptions, water quality monitoring in the Clark Fork-Pend Oreille watershed demonstrated stable or improving conditions with respect to nutrients and attached algae from 1984-2007.

9.0 MONITORING RECOMENDATIONS

- Periphyton in the upper and lower reaches of the Clark Fork (i.e. above and below Missoula) have distinctly different algal populations. Variability between sites, and also from year to year, is high. Additional investigation into causative factors would be worthwhile, especially an analysis of potential variables controlling standing crop. This investigation might include statistical analysis of variables such as copper concentration, water temperature, water depth, channel shear stress/scour, nutrients, heating degree days, or other factors in addition to nutrients that might help explain spatial and temporal trends in algal biomass.
- Monitoring in Lake Pend Oreille has a limited dataset for nutrient concentrations, in most locations six years or fewer. In addition, variable site locations and sampling frequencies hamper meaningful analysis of trends. Maintaining a consistent monitoring strategy at a set of core near-shore and open water stations is important to evaluate potential shifts in water quality. Synoptic spatial sampling is useful for identifying near-shore sources of nutrient loading, but has limitations for evaluating trends. Trend analysis will become meaningful once 10 years of annual data have been consistently collected at individual stations.

- Detection limits have shifted for some monitoring parameters/stations over time. A review of method detection limits and adoption of a consistent standard for monitoring would be beneficial.

10.0 REFERENCES

American Public Health Association. 1981. Standard Methods for the Examination of Water and Wastewater. 15th edition. American Public Health Association.

APHA/AWWA/WEF. 1998. Standard Methods for the Examination of Water and Wastewater, 20^{th} Ed. American Public Health Association. Washington, D.C.

Carlson, R.E. and J. Simpson. 1996. A Coordinator's Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society. 96 pp.

Dodds, W. K. and V. H. Smith. 1995. Managing excess chlorophyll levels in the Clark Fork River with nutrient controls. Report to the Montana Department of Health and Environmental Sciences. April 1995.

Gilbert, R. O. 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Rienhold Company, Inc., New York.

Hirsch, R. M., J.R. Slack, and R.A. Smith. 1982. Techniques of trend analysis for monthly water quality data, Water Resources Research: 18:107-121.

Hirsch, R. M., R. B. Alexander, and R.A. Smith. 1991. Selection of methods for the detection and estimation of trends in water quality, Water Resources Research: 27:803-813.

Land & Water Consulting, Inc. 1995. Water quality status and trends monitoring system for the Clark Fork- Pend Oreille Watershed, prepared for Tri-State Implementation Council. 123p.

Land & Water Consulting, Inc. 1997. Clark Fork- Pend Oreille watershed monitoring program, sampling and analysis plan. Prepared for the Montana Department of Environmental Quality, Monitoring and Data Management Bureau. 27p.

Land & Water Consulting, Inc. 2002. Water quality status and trends in the Clark Fork-Pend Oreille Watershed. Annual report prepared for Tri-State Implementation Council, Sandpoint, Idaho.

MDHES. 1992. Assessment of phosphorus and nitrogen sources in the Clark Fork River Basin. State of Montana Department of Health and Environmental Sciences 1988-1991. Helena, Montana.

Sartory, D. P. 1982. Spectrophotometric analysis of chlorophylls in freshwater phytoplankton. Hydrological Research Institute, Dept of Env. Affairs, Pretoria, South Africa, Technical Report TR115. 163 pp.

Sartory, D. P., and J. U. Grobbelaar. 1984. Extraction of chlorophyll *a* from freshwater phytoplankton for spectrophotometric analysis. Hydrobiologia: 114: 177-187.

Smith, R. A., R. M. Hirsch, and J. R. Slack. 1982. A study of trends in total phosphorus measurements at NASQAN stations. U.S. Geological Survey Water Supply Paper 2190, U.S. Geological Survey, Alexandria, Virginia.

Tri-State Implementation Council (Tri-State Water Quality Council). 1998. Clark Fork River Voluntary Nutrient Reduction Program, August. Sandpoint, Idaho.

Tri-State Water Quality Council. 2001. Montana and Idaho Border Nutrient Load Agreement Technical Guidance. Sandpoint, Idaho.

Walker, W.W. 1999. Simplified Procedures for Eutrophication Assessment and Prediction: User Manual. updated April. Instruction Report W-96-2, US Army Corps of Engineers Waterways Experiment Station.