WATER QUALITY STATUS REPORT NO. 93

LAKE CREEK

Kootenai County, Idaho

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Idaho Department of Health and Welfare
Division of Environmental Quality
Water Quality Bureau
1410 N. Hilton
Boise, Idaho 83706-1253

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ABSTRACT

The Kootenai-Shoshone Soil Conservation District (KSSCD) received planning grant funds from the Agricultural Water Quality Program to study, in part, water quality of the Lake Creek watershed. The study was conducted for one year starting in December 1989.

The objective was to provide the KSSCD additional information toward identifying critical erosion areas within the watershed. The impact of sediment and nutrient loads on Windy Bay of Coeur d'Alene Lake is also addressed.

The Lake Creek watershed drains 24,856 acres; 5,722 acres of primarily woodland lie in Washington with 73% of the remaining 19,134 acres in Idaho devoted solely to agricultural practices. The watershed has an average gradient of 232 ft/mi and classic dendritic pattern. Watershed efficiency combined with deep, highly erodible soils produce severe soil erosion potential. Lake Creek is subject to annual discharge extremes. Mean daily flows for Lake Creek at station LC-2 ranged from 0.6 to 460 CFS. An instantaneous peak of 565 CFS occurred March 10, 1989.

Total sediment load at the mouths of tributaries during the March storm ranged from 0.03 tons in tributary HR-1 to 12 tons in Kruse Creek HR-6. Station LC-1 delivered 55.5 tons of sediment following the March storm event. A trend in increasing sediment loads was observed in Lake Creek proceeding downstream. Fluctuations in suspended sediment levels could be traced to agricultural practices and stream bank erosion. Station WB1 near the mouth of Lake Creek had higher suspended sediment concentrations throughout the study period than ambient station WB2. The stratigraphic horizon left by the 1980 eruption of Mt. Saint Helens was used to determine average yearly accumulation of sediment in Windy Bay. Sediment core samples reveal an average of 0.09 ft/yr of sediment deposition near the mouth of Lake Creek.

All sites except background station BC had mean inorganic nitrogen concentrations exceeding the 0.3 mg/l instream criterion. Nitrogen concentrations increase with downstream progression out of forested regions into primarily agricultural lands and are associated with sediment runoff. Peak concentrations of nitrogen in Windy Bay occurred following

runoff events in the spring and attenuated the remainder of the survey. Total phosphorus concentrations were generally positively correlated with suspended sediment concentrations at all sites. Mean annual total phosphorus concentrations in Lake Creek exceeded 0.05 mg/l criteria at all sites except background station BC. Approximately 190 pounds of phosphorus were lost from the watershed on March 15, 1989 as recorded at station LC-1.

All ambient stations had fecal coliform geometric means well below the 200/100 ml standard. In the upper watershed, station LC-3 had consistently higher fecal coliform counts than any other station. These higher counts are most likely due to cattle grazing in West Lake Creek. Fecal streptococci numbers were generally higher in comparison to fecal coliforms. All FC/FS ratios fell below 0.8 which suggests pollution is due primarily to nonhuman sources. Bacterial contamination appears not to be a problem in Windy Bay.

Data indicate Windy Bay as mesotrophic or a moderately enriched ecosystem. Existing beneficial uses of Lake Creek are agriculture water supply and secondary contact recreation. Utilization by cold water biota and as a salmonid spawning habitat are limited by current water quality (extremes in flows, excessive sediment, and elevated temperatures). Agricultural nonpoint source pollution contributes to the limitations imposed by water quality.

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INTRODUCTION

The Kootenai-Shoshone Soil Conservation District (KSSCD) signed an Idaho Agriculture Nonpoint Source Pollution Abatement planning grant agreement with the Idaho Division of Environmental Quality on September 12, 1989. The planning grant process is being used to determine the suitability of the Lake Creek watershed for implementation of cost-shared Best Management Practices (BMPs) to reduce water pollution caused by agricultural practices. Part of this planning process included a water quality monitoring study of Lake Creek during the period of December 1988 to November 1989.

Lake Creek has been identified as having nonpoint pollution problems associated with agricultural activities by the Idaho Agricultural Pollution Abatement Plan (ISSCC, 1979). A tributary to Coeur d' Alene Lake, Lake Creek is considered to have significant water quality impact to the lake which is protected for the following beneficial uses: 1) domestic water supply; 2) cold water biota; 3) salmonid spawning; 4) primary/secondary contact recreation; and is classified as a special resource water (Idaho Water Quality Standards, IDHW-DEQ).

Current beneficial uses of the stream are as agricultural water supply, and secondary contact recreation. Salmonid spawning habitat and cold water biota are present but are limited by water quality.

BACKGROUND

Lake Creek is located in southwestern Kootenai County in northern Idaho. It originates on the southeastern slopes of Mica Peak, Washington, and flows southeasterly into Windy Bay of Coeur d' Alene Lake (Figure 1). The elevation ranges from 5,000 feet at Mica Peak dropping nearly 3,000 feet in 12.3 miles to normal lake pool elevation of 2,128 feet. The average stream gradient of Lake Creek is 232 feet/mile. There are two perennial tributaries to Lake Creek; West Lake Creek originating on the southern slopes of Mica Peak in Washington and Bozard Creek originating on the southwestern slopes of Twin Peaks in Idaho.

Lake Creek has a classic dendritic drainage pattern and is a fourth order tributary to Coeur d' Alene Lake. The total area of the watershed is

24,856 acres with 17,374 acres in private ownership, 1,600 acres owned by the Coeur d'Alene Indian Tribe and 160 acres in state ownership (KSSCD,1987). Nearly one quarter of the watershed (5,722 acres) is located in Washington and is primarily forested land. The remaining three quarters of the watershed reside in Idaho (19,134 acres) and 23 operators have divided the private lands into the following uses: 11,391 acres of cropland, 2,487 acres of hay and pasture, and 3,496 acres of woodland. The state and tribal lands are all woodland.

The geology of the Lake Creek basin consists of three basic parent rock formations: 1) the Prichard formation, located in the headwaters, comprised of metamorphosed rocks including mica shist, quartz plagioclase, biotite gneiss and quartzite; 2) the Palouse formation, located in the mid to lower watershed, consisting primarily of loess deposits; 3) the Latah formation, basalt flows found in the stream corridor. The soil types found in the Lake Creek drainage are classified as highly erodible and include Taney, Santa, Kruse-Ulricher Assoc., and Vassar silt loam (KSSCD, 1987).

STUDY OBJECTIVES

The objectives of the planning study were to: 1) determine the areas within the Lake Creek watershed which are sources of pollutants; 2) identify the stream reaches within the Lake Creek watershed which have significant sources of pollutants; 3) compare observed water quality results (both spatial and seasonal) among the subdrainages with different practices; 4) determine the impact of pollutants transported from the Lake Creek watershed on Windy Bay of Coeur d' Alene Lake; 5) determine if water quality standards and criteria are met within Lake Creek and Windy Bay; and 6) determine if the water quality of Lake Creek will meet the needs for a cutthroat and bull trout fish hatchery.

STREAM CLASSIFICATION

Using Rosgen's (1986) morphological stream classification system Lake Creek can be described as two distinct stream types. The upper and lower reaches of Lake Creek, as it descends from the headwaters of Mica Mountain and then again as it makes its descent to Lake Coeur D'Alene, are of a steeper gradient and can be defined as a B3 stream type. The C4 classification, however, more accurately describes the middle reach, a slow moving section of water that meanders through an open agricultural valley.

From just below the Bozard Creek station to LC2, a distance of five miles, Lake Creek is a C4 sream type. This is a deep water, slow moving section characterized by a gradient of 1.0 percent or less, a sinuosity of 2.5, a width-to-depth ratio averaging 10, and a bottom substrate consisting of sand, silt, and some gravel. The stream in this stretch is moderately entrenched, with slight valley confinement and has unstable banks of unconsolidated, noncohesive soils. Flood terraces are of fine textured alluvium. Stream sub-type modifiers on this section of Lake Creek are 1) organic debris is moderately frequent and affects <10 percent of the active channel (D3); 2) riparian vegetation is primarily grass and low brush with some coniferous groves of trees (V5,6,8); 3) stream size at bankful stage is 15-30 feet (S4); 4) the flow regimen is perennial, dominated by snowmelt runoff (P-1); 5) depositional features include point bars with some mid-channel bars (B-2); and 6) meander patterns are generally regular (M-1).

The upper and lower reaches of Lake Creek are of the B3 classification as the stream gradient increases to about 2.5 percent. Sinuosity averages 1.3-1.5, the width-to-depth ratio 10-20, and the substrate is characterized as a cobble bed with a mixture of sand and gravel and containing some small boulders. The channel is moderately entrenched and well confined by valley walls. The banks have moderate to steep slopes of coarse, unconsolidated material. Stream sub-type modifiers include 1) organic debris infrequent (D-2); 2) riparian vegetation consisting of grass, brush, deciduous trees and conifers (V-5,6,8,9); 3) stream size 15-30 feet at bankful stage (S-4); 4) flow regimen perennial and dominated primarily by snowmelt runoff (P-1); and 5) depositional features include point bar formation (B-2), with irregular meander.

MATERIAL & METHODS

A variety of parameters were chosen to monitor sediment, nutrients and bacteria throughout the basin. A listing of the physical, chemical and bacterial parameters is provided (Table 1). The determination of total amounts of solutes contributed during a single day (total load) was calculated by assuming that an individual sample was representative for that day. Sample dates were selected for the purpose of comparing different subwatersheds on the same date.

Field parameters were analyzed on site with portable meters which were calibrated prior to each survey. Specific conductance was measured with a YSI Model 33 meter. Dissolved oxygen and temperature were measured with a YSI Model 50 meter. Turbidity was measured with a portable Hach Model 16800 meter. The pH was determined with a Corning Model 610-A meter.

The mid section method was used during this study to determine discharge (USGS WATER-SUPPLY PAPER 2175). Direct measurement of velocity was made with a Marsh McBirney 201-D current meter. Staff gages were installed on most stations and rating curves calculated for stations so equipped. A stilling well was constructed at station LC2 and a Stevens "F" type continuous recorder installed to provide mean daily discharge.

Water samples were collected using a DH-48 suspended sediment sampler by the procedures in IDHW-DEQ Technical Procedures Manual (Ralston and Brown, 1976). In well-mixed reaches, three verticals were selected and depth integrated samples were composited in a churn splitter. Samples for chemical analysis were collected in 1 liter cubitainers. Nutrient samples were preserved with 2 ml H_2SO_4. Water samples for dissolved total and ortho-phosphorus were filtered using 0.45 micron filters. Bacterial grab samples were collected in sterile 250 ml Nalgene polyethylene bottles. All samples were placed on ice and cooled to 4 degrees C. Chemical, nutrient and bacterial analyses were conducted by the Idaho Department of Health and Welfare, Bureau of Laboratories, Coeur d'Alene (December 1988-February 1989), and Eastern Washington University (March-November 1989) following standard methods (American Public Health Association 1985).

Lake water samples were collected with a Kemmerer sampler from the surface, mid-depth and bottom, then composited in a churn splitter for subsampling of chemical and nutrient parameters. Vertical profiles of temperature and dissolved oxygen were measured to determine biological productivity and thermocline elevation. Secchi-disk visibility was used as a gross measure of the quantity of plankton in the water. Bacterial samples were collected at a depth of 1 foot below the water surface. All samples were placed on ice and cooled to 4 degrees C.

SAMPLE STATIONS

A total of 12 sample stations are included in this study comprising three types: 1) ambient sites (4); 2) high runoff sites (8); and 3) lake sites (2).

The ambient sites were selected to divide the entire watershed into four main segments.

Station LC1, SWSE, Sec. 21, T48N, R5W. Elevation 2,400 ft. River mile 3.4. The lower end of the watershed, approximately 3 3/4 miles upstream of the mouth and 3/4 mile downstream from the Highway 95 bridge.

Station LC2, NENE, Sec. 20, T48N, R5W. Elevation 2,460 ft. River mile 4.5. The middle of the watershed, approximately 1/4 mile upstream of the Highway 95 bridge at the "Ford" bridge.

Station LC3, SWNE, Sec. 12, T48N, R6W. Elevation 2,560 ft. River mile 7.4. The upper middle of the watershed, at the Lake Creek road crossing just below the confluence of Lake Creek and Bozard Creek.

Station BC, SENE, Sec. 36, T49N, R6W. Elevation 2,660 ft. River mile 9.7. The upper end of the watershed at the Weller road crossing.

High runoff sites were selected to gather information on the water quality impact from a variety of individual sub-basins and their associated agricultural practices.

Station HR1, NWNW, Sec. 27, T48N, R5W. Elevation 2,600 ft. River mile 3.1. The lower end of the subdrainage east of Lake Creek with its outflow approximately 1/4 mile below LC1, along Ness road where the creek nears the road.

Station HR2, SWSE, Sec. 21, T48N, R5W. Elevation 2,420 ft. River mile 3.6. The lower end of the subdrainage east of Lake Creek with its outflow just upstream of LC1, at the culvert crossing on the road adjacent to Lake Creek.

Station HR3, NWSW, Sec. 21, T48N, R5W. Elevation 2,450 ft. River mile 4.2. The lower end of the subdrainage southwest of Lake Creek with its outflow immediately downstream of the highway 95 bridge crossing.

Station HR4, SWNW, Sec. 17, T48N, R5W. Elevation 2,570 ft. River mile 6.2. The southern branch, at the Weller road culvert crossing,

near the middle of the subdrainage southwest of Lake Creek with its outflow approximately 1 mile downstream of LC3.

Station HR5, NENE, Sec. 13, T48N, R6W. Elevation 2,570 ft. River mile 6.2. The northern branch, at the Weller road culvert crossing, near the middle of the subdrainage southwest of Lake Creek with its outflow approximately 0.9 mile downstream of LC3.

Station HR6, NWSW, Sec. 8, T48N, R5W. Elevation 2,550 ft. River mile 6.6. The lower end of the Kruse Creek subdrainage northeast of Lake Creek, at the culvert crossing on Lake Creek road.

Station HR7, SESE, Sec. 8, T48N, R5W. Elevation 2,560 ft. River mile 5.7. The middle of the subdrainage northeast of Lake Creek with its outflow approximately 1 mile upstream of LC2, at the Lake Creek road crossing.

Station HR8, NWSW, Sec. 16, T48N, R5W. Elevation 2,520 ft. River mile 5.5. The lower end of the subdrainage northeast of Lake Creek with its outfow approximately 3/4 mile upstream of LC2, at the Lake Creek road crossing.

Lake sites in Windy Bay of Coeur d' Alene Lake were selected to provide information of Lake Creek's impact on water quality of the bay, and to differentiate that from the lake as a whole.

Station WB1, NENE, Sec. 35, T48N., R5W. Windy Bay near the mouth of Lake Creek.

Station WB2, SWSE, Sec. 25, T48N, R5W. One mile northeast from WB1 toward main body of Coeur d'Alene Lake.

FREQUENCY

The study was designed to monitor water quality most frequently during storm runoff events when the maximum influx of nutrients and sediment typically occur. These peak events normally occur in the spring when warm southwesterly winds deliver heavy rains that accelerate snow pack melting.

The schedule was designed to provide flexibility to respond to storm events as they occurred. The sampling frequency for the various station types was as follows:

> Main stem: December 1988 (once per month); January-May 1989 (twice per month); June-November 1989 (once per month).
>
> High runoff: January-May 1989 (twice per month); June-November 1989 (once per month).
>
> Lake sites: March-May 1989 (twice per month); June-November (once per month).

QUALITY ASSURANCE

Duplicate and spiked water samples were collected at station LC1 on different dates to assess the accuracy and precision of the data collected. The quality assurance (QA) element of the field work follows Bauer (1986) and Bauer et al. (1986a, 1986b) guidelines.

Duplicate samples were collected to assess precision. At station LC1 these QA samples were collected from the same composite collected for routine water chemistry samples. Duplicate bacteria samples were collected simultaneously adjacent to each other.

Three sets of spiked samples were collected during the study from station LC1. Chemical spikes were prepared by the IDHW-Bureau of Laboratories, Boise, and sealed in Kimble 10 ml glass ampules. Spikes were prepared for ammonia, nitrate-nitrite, ortho-phosphate, total phosphorus and total Kjeldahl nitrogen. Celite was used for suspended solids spiking and was pre-weighed into plastic vials. In the field, these vials were opened and their contents mixed with 900 ml of sample water in 1 liter containers. All QA samples were then stored on ice at 4 degrees C and delivered to the IDHW-Bureau of Laboratories in Coeur d'Alene for analysis following Standard Methods (American Public Health Association 1985). Percent recovery for spikes was determined by subtracting background concentrations (determined from routine samples) from known spike values.

RESULTS & DISCUSSION

This section of the report is divided into two parts. The first part discusses Lake Creek water quality and also includes general comments pertaining to each water quality parameter. The second part discusses the water quality of Windy Bay of Coeur d' Alene Lake.

LAKE CREEK

Discharge

Lake Creek is a fourth order stream with a total length of 12.3 miles and an average gradient of 232 feet per mile. The gradient of Lake Creek in addition to land use practices subjects the drainage basin to annual discharge extremes. Mean daily flows for Lake Creek at station (LC-2) ranged from 0.6 to 470 cubic feet per second (CFS) (Table 2). The major runoff period lasted about ten days in early March with an instantaneous peak of 565 CFS occurring on March 10, 1989.* Nearly half (49%, 71.4 CFS) of the total measured flow during the high runoff period came from Lake Creek and its two perennial tributaries, Bozard Creek and West Lake Creek. Flows from the intermittent tributaries ranged from 0.39 CFS to10.28 CFS in the same period (Figure 2). By mid June all intermittent tributaries went dry.

Suspended Sediment

Suspended sediment concentrations vary in response to discharge volumes. Peak suspended sediment concentrations occur over a short period in the water year when warmer temperatures, precipitation, melting snow, and frozen ground create conditions for high sediment runoff. In 1989, the highest sediment concentrations occurred during late February and early March (Figure 3). Estimated sediment loads for a single day following the March storm event ranged from 0.03 tons in tributary HR-1 to 55.5 tons, at Lake Creek station LC-1 (Table 3). Suspended sediment concentrations fell considerably following the storm period and remained low the rest of the year. Some sediment is deposited at lower gradient channel reaches but most is transported and deposited in Windy Bay of Coeur d'Alene Lake. The sediment reduces habitat for cold water biota and provides a reservoir of sediment to be transported during the next storm event.

One of the survey objectives was to determine the areas within the Lake Creek watershed which are sources of pollutants. The data can be analysed several ways to accomplish this. One method compares tributaries in the watershed through suspended sediment concentrations, not accounting for watershed size or discharge volume. Sediment concentration data for the ambient stations increases in downstream direction from 32 mg/l in the Lake Creek upper watershed (LC-3) to 140 mg/l in Lake Creek near the mouth (LC-1) following the March storm event. This reflects the increasing cumulative total of cropland in the drainage. Suspended sediment concentrations of tributaries ranged higher from 13 mg/l in (HR-1) to 446 mg/l in (HR-6) (Figure 4). If land management changes were based on suspended sediment alone, priority should be given to these areas:

1. Kruse Creek (HR-6)
2. Unnamed tributary (HR-5)
3. Unnamed tributary (HR-7)
4. Unnamed tributary (HR-2)

A second method compares sediment load in tons per day which combines the elements of flow and concentration. Total sediment load at the mouths of tributaries varied from 0.03 tons per day in Unnamed tributary (HR-1) to 12 tons per day in Kruse Creek (HR-6). Ambient stations ranged from 6 tons per day at (LC-3) to 55.5 tons per day near the mouth at (LC-1) (Figure 5). Based on sediment loadings in tons per day, priorities change to include three ambient stations:

1. Lake Creek, near mouth (LC-1)
2. Lake Creek, mid watershed (LC-2)
3. Kruse Creek (HR-6)
4. Lake Creek, upper watershed (LC-3)

Nitrogen

Nitrogen is an essential element for maximum potential plant growth and may enrich aquatic communities by increasing primary production. A concentration of 0.3 mg/l total inorganic nitrogen (NH_3, NO_2, and NO_3) is considered the instream criteria for limiting nuisance growths of aquatic plants and algae (IDHW 1980). Ordinarily, ammonia and nitrite are oxidized

to nitrate, and nitrate is consequently the principle form considered when comparisions to this limit are made.

The influx of inorganic nitrogen was a seasonal trend. The highest concentrations of inorganic nitrogen for ambient stations occurred during spring runoff (Figure 6). All stations except Bozard Creek (BC) had mean inorganic nitrogen concentrations exceeding the instream criterion (Table 4). Average inorganic nitrogen concentrations ranged from 0.16 mg/l at station BC to 10.89 mg/l at tributary HR-4. Highest concentrations were recorded at HR-4 (20.34 mg/l) and at tributary HR-1 (15.14 mg/l).

Organic nitrogen concentrations increase with downstream progression out of forested regions into primarily agricultural lands. Average concentrations of organic nitrogen ranged from 0.13 mg/l at station BC to 1.14 mg/l at tributary HR-4. Peak concentrations where noted at HR-2 (1.89 mg/l) and HR-6 (1.69 mg/l) (Table 4).

Phosphorus

Phosphorus availability is generally believed to be a critical factor in eutrophication of water bodies, as the nutrient in shortest supply will tend to be the control on production rates. To attenuate primary productivity, the recommended total phosphorus concentration for streams is 0.1 mg/l (Mackenthum 1973). Streams that discharge into lakes or impoundments are recommended not to exceed 0.05 mg/l (U.S. EPA 1977). A more site-specific criteria is to compare the concentration of phosphorus from a background station to other stations in the watershed. In the Lake Creek basin, Bozard Creek is considered the background station and had a mean concentration of 0.02 mg/l total phosphorus.

Analyzed forms of phosphorus include: total phosphorus, total dissolved phosphorus and dissolved ortho phosphorus. Calculated from these forms were particulate total phosphorus and dissolved hydrolyzable phosphorus.

The phosphorus concentrations and loading are event related. Mean annual total phosphorus concentrations in Lake Creek exceeded the 0.05 mg/l recommended standard at all stations except BC. Nine of the twelve sites monitored had mean annual total phosphorus concentrations above the 0.1 mg/l standard (Table 4). Total phosphorus concentrations were generally positively correlated with suspended sediment concentrations at all sites (Figures 7-10). Approximately 190 pounds of phosphorus were lost from

the watershed on March 15, 1989 as recorded at station LC-1. Tributaries that contributed large amounts of phosphorus to Lake Creek during the same period include HR-6 (23 lbs), HR-3 (23 lbs), HR-2 (8.8 lbs), and HR-8 (8.8 lbs). Phosphorus load data is summarized for the March storm event in Table 3.

Particulate phosphorus generally made up the greatest percentage of total phosphorus throughout the study (Figures 11-14). During the March storm, total phosphorus consisted largely of particulate phosphorus (79%) versus the total dissolved fraction (21%) (Figure 15).

The total dissolved fraction consisted largely of dissolved ortho phosphorus. Station LC-1 near the mouth of Lake Creek had an average throughout the survey of 77% dissolved ortho phosphorus of the total dissolved fraction.

Bacteria

The presence of fecal coliform and fecal streptococcus bacteria are used as indicators of fecal contamination. Lake Creek is protected for secondary contact recreation which may include fishing, boating, wading, and other activities where ingestion of raw water is not probable. Water quality standards stipulate that fecal coliform numbers not exceed 800/100 ml at any time or exceed a geometric mean of 200/100 ml.

All ambient stations had geometric means well below the 200/100 ml standard with annual mean fecal coliform densities ranging from 7/100 ml at BC to 45/100 ml at LC3 (Table 5). Although station BC had one violation occur on July 24, 1989 of 1500/100 ml, station LC3 had consistently higher fecal coliform counts than any other station (Figure 16). Densities of fecal coliform and fecal strep bacteria were highly variable between stations and sampling dates (Figures 17-20).

The ratio of fecal coliform to fecal streptococci (FC/FS ratio) may provide information on possible sources of pollutants in stream water pollution studies. Ratios greater than 4.1 are considered indicative of pollution derived from anthropogenic sources whereas ratios less than 0.7 suggest pollution due to nonhuman sources (American Public Health Association 1985). Fecal streptococci numbers are generally higher in comparison to fecal coliforms and all ratios fell below 0.8. The data suggest this pollution is due primarily to nonhuman sources.

Physical Parameters

Other parameters expected to be impacted in an agricultural watershed were sampled on a regular basis. These included dissolved oxygen, temperature, pH, conductivity, and turbidity. In addition, minerals, and total metals were sampled at station LC1 during high and low flows and all ambient stations at low flow conditions. These parameters were included to establish baseline conditions, ascertain if water quality standards were being met and determine if water quality would meet the requirements for a cutthroat and bull trout fish hatchery.

Dissolved oxygen concentrations were generally well above the minimum standard of 6 mg/l and ranged from 7.87 mg/l at LC3 to 14.8 mg/l at LC1 and LC2 (Table 6).

Temperatures did not exceed the cold water biota standard of 22 degrees centigrade and extremes varied between 0 degrees at LC3 to 21.8 degrees at LC1. Mean annual temperatures ranged from 5.7 degrees at LC3 to 7.9 degrees at LC1 (Table 6).

The pH of water is a measure of its hydrogen ion concentration. Many chemical reactions are affected by pH. Annual mean pH varied between 6.9 at LC3 to 7.4 at LC1 (Table 6). These pH values fall within the cold water biota beneficial use range of 6.5 - 9.0 for freshwater aquatic life (IdahoWater Quality Standards, IDHW-DEQ).

Conductivity is a numerical expression of the ability of a water sample to carry an electrical current. Conductivity is generally 0.55 - 0.75 of the total dissolved solids concentration (USGS Water Supply Paper 2254). Conductivity was generally low in Lake Creek. Elevated levels were found in several of the tributaries during low flows due to concentration of salts derived from agricultural fertilizers (Table 6). The EPA has no established conductivity criteria for freshwater aquatic life.

Average turbidity at the mouth of Lake Creek LC1 was more than five times greater than background station BC. Turbidities ranged from1 NTU at BC to 350 NTU at station HR2 (Table 6). Suspended sediment concentrations were

generally positively correlated with turbidities at all ambient stations (Figures 21-24).

Samples collected from the four ambient sites reveal a general increase in common ion concentrations as one proceeds downstream (Table 7). An exception was silica, where concentrations were highest (26.8 mg/l) in the upper watershed at ambient station BC. Concentration values for hardness ranged from 11.8 mg/l at LC3 to 20.2 mg/l at LC1. Based on the USGS scale (USGS Water Supply Paper 2254) the water in Lake Creek is "soft". All common ion values were within EPA criteria for freshwater aquatic life.

Metals

Samples were collected for total metals at the four ambient Lake Creek stations. All total metals except iron were well below recommended criteria for aquatic life (Table 8). Total iron criteria recommended by EPA (1976) for freshwater aquatic life is 1.0 mg/l. The American Fisheries Society (AFS) suggest a criteria of 0.30 mg/l for total iron due to a decrease in embryo survival and spawning substrate quality (Thurston 1979). A high of 2.5 mg/l total iron occurred at LC1 during March high flows when sediment concentrations were highest. During the low flow period the AFS criteria of 0.30 mg/l was exceeded at all ambient stations except BC (Figure 25).

Suspended sediment and the associated iron during early spring would need to be mitigated if Lake Creek was utilized as a water supply for a trout hatchery. All other parameters monitored reveal that Lake Creek has water quality sufficient for a hatchery water supply.

WINDY BAY

Suspended Sediment

As expected, station WB1 at the mouth of Lake Creek had higher suspended sediment concentrations throughout the study period than ambient lake station WB2 (Figure 26). Suspended sediment at WB1 ranged from 30 mg/l following the runoff period in March to <2 mg/l in July and August. Concentrations at WB2 were lowerer ranging from 12 mg/l in March to <2 mg/l (June - November).

Nitrogen

A concentration of 0.3 mg/l total inorganic nitrogen is considered a criteria for the prevention of excessive growths of aquatic plants and algae (IDHW 1980). Station WB1 exceeded the criteria 27% of the time with a peak concentration of 0.5 mg/l following the spring runoff period. Station WB2 reached a higher peak of 0.75 mg/l but only exceeded the criteria 18% throughout the sampling period.

Waters designated for use as a cold water biota have an established criterion of 0.04 mg/l un-ionized ammonia. At station WB1, nearly half (45%) of the samples tested exceeded the criteria during the sampling period. Station WB2 had fewer violations with only 27% of the samples tested exceeding the criteria.

Peak concentrations of various forms of nitrogen occurred during the runoff period and dropped off during the remainder of the year. Nitrogen concentrations were highest at WB1 where Lake Creek flows into Windy Bay of Coeur d' Alene Lake.

Phosphorus

Phosphorus is often the limiting nutrient for primary production in aquatic systems. To prevent excessive aquatic plant and algae growth, a criteria of 0.05 mg/l total phosphorus is recommended where streams discharge into an impoundment (U.S EPA 1977).

Thick ice on Windy Bay delayed our sampling efforts on the lake until late March. As a result, only the first sample set in March was representative of a runoff event. Both lake sites had total phosphorus concentrations twice that of the 0.05 mg/l criterion following the spring runoff in late March (Tables 9-10). Total phosphorus samples collected in March indicate that 77-81% consisted of particulate phosphorus at sites WB2 and WB1, respectively (Figure 27). The remainder of sampling events (Apr-Nov, 1989) remain <0.05 mg/l total phosphorus criteria. Mean annual total phosphorus concentrations ranged from 0.026 mg/l to 0.027 mg/l at stations WB2 and WB1, respectively. Using mean total phosphorus as a criterion, Windy Bay would be classified as mesotrophic (Falter and Hallock 1987).

Chlorophyll a

One method of estimating primary productivity is an assessment of the standing plant crop. Chlorophyll *a* is used as an algal biomass indicator (American Public Health Association 1985). All green plants contain chlorophyll *a* and, for planktonic algae, it represents about 1 to 2% of the dry weight. It appears that algal biomass peaked in September with a lessor peak occurring in late March following spring runoff (Figure 28). Values for chlorophyll *a* indicate that Windy Bay is classified as mesotrophic (Falter and Hallock 1987).

Bacteria

Coeur d'Alene Lake is protected for primary contact recreation. The standards specify that fecal coliform not exceed a geometric mean of 50/100 ml or exceed 500/100 ml at any time. Bacterial contamination appears not to be a problem in Windy Bay. Fecal coliform geometric means at both stations were <2. Ratios of fecal coliform to fecal streptococcus indicate wastes of mixed human and animal sources.

Physical Parameters

Other parameters expected to impact Windy bay were sampled on a regular basis. These included dissolved oxygen, temperature, secchi-disc depth, pH, conductivity, and turbidity. In addition, lake sediment cores were collected in August and minerals were sampled once in late October. These parameters were included to establish baseline conditions and to determine if water quality standards were being met (Tables 9-10).

Water temperature/dissolved oxygen profiles were used at station WB2 to determine adherence to water quality standards, presence or absence of thermal stratification, depth of thermocline, and possible anaerobic conditions in the hypolimnion (Figures 29-38). The water column at station WB2 was thermally stratified from June through September with a thermocline range of 4 -15 meters (Table 10). Water quality violations of dissolved oxygen and temperature coincided with the period of stratification that occurred. As previously mentioned, a beneficial use of Coeur d'Alene Lake is salmonid spawning which specifies that waters must not exceed a temperature of 13 degrees centigrade and remain above 6 mg/l dissolved oxygen. Station WB2 exceeded the temperature standard June - September and the dissolved oxygen standard once in September. The water

column at station WB1 had an average depth of 3.4 meters and did not stratify. While temperatures violated water quality standards June - September, expected violations of dissolved oxygen did not occur. It is likely that dissolved oxygen remained above the 6 mg/l standard due to recharge from Lake Creek and from the respiration of immersed plants. However, no diurnal studies were performed to estimate the percentage of oxygen contributed by immersed plants. The lack of thermal stratification at WB1 and infrequency at WB2 was largely a result of their shallowness, which allowed frequent wind to induce full-depth circulation of the water columns.

Secchi-disc visibility is the depth at which a black and white disc (8 inches diameter) disappears from view when lowered into the water. Secchi-disc visibility is a measure of water transparency and has been widely used as an indicator of trophic-state. Average secchi depths measured 2.2 and 3.6 meters at WB1 and WB2, respectively. The average Secchi depths measured at both stations were representative of a mesotrophic lake classification (Falter and Hallock 1987).

The pH of water is a measure of its hydrogen ion concentration. Annual mean pH varied between 6.7 at WB1 to 6.8 at WB2. These values fall within the cold water biota beneficial use range of 6.5 - 9.0 for freshwater aquatic life (Idaho Water Quality Standards, IDHW-DEQ).

Conductivity was generally low in Windy Bay. Annual mean conductivities ranged from 34 umhos/cm at WB1 to 45 umhos/cm at WB2. The EPA has no established conductivity criteria for freshwater aquatic life.

Turbidity was highest following the spring runoff season and generally dropped off the remainder of the year. Mean annual turbidity ranged from 5.9 NTU at station WB1 to 4.7 NTU at station WB2. Turbidity values ranged from 0.8 - 23 NTU to 1.2 - 15 NTU at stations WB1 and WB2, respectively. Generally, a positive correlation exists between turbidity and suspended sediment (Figures 39-40).

A single tube sediment corer was used to sample sediment cores at sites #1-3 near the mouth of Lake Creek and site #4, an area of Windy Bay not affected by Lake Creek deposition. The three objectives for this effort were: 1) Identify the Mt. Saint Helens volcanic ash layer in the various sediment cores, 2) Determine the average depth of sediment deposited over the volcanic ash layer near the mouth of Lake Creek at sites #1-3, and 3)

Determine the average depth of sediment deposited over the volcanic ash layer at site #4.

The volcanic ash layer was identified in cores taken at all sites except site #3. The ash layer had an average thickness measuring 0.2 ft. The average depth of sediment deposited over the ash layer at sites #1-3 was 1 foot. Site #4 unaffected by Lake Creek deposition had 0.2 ft. of sediment above the ash layer. Assuming site #4 had average sediment deposition for the lake, then Lake Creek delivered 0.8 ft of sediment in a nine-year period or 0.09 ft/yr. (Avg. Sed. Depth ft. #1-3) - (Avg. Sed. Depth ft. #4) = Sediment deposited from Lake Creek/9 yrs.

Common ion samples were collected in the fall of 1989 at both lake sites (Table 11). No significant differences were noted between the two sites. Much lower silica concentrations were noted at the lake sites vs the ambient stream sites. This difference was likely due to sediment held in solution by stream turbulence. All common ion values were within EPA criteria for freshwater aquatic life.

CONCLUSIONS

Lake Creek is a relatively small drainage totaling 24,856 acres. Of the 19,134 acres in Idaho 73% is devoted to agricultural practices. Nearly one-quarter of the watershed (5,722 acres) is in Washington and is primarily woodland. The Lake Creek watershed is very efficient due to an average gradient of 232 ft/mile and dendritic pattern. This efficiency combined with deep soils classified as highly erodible (Taney, Santa, Kruse-Ulricher association, and Vassar silt loam) produce a high potential for soil erosion.

The gradient of Lake Creek in addition to land use practices subjects the drainage basin to annual discharge extremes. Mean daily flows for Lake Creek at station LC-2 ranged from 0.6 to 470 cubic feet per second. The major runoff period lasted about ten days in early March with an instantaneous peak of 565 CFS occurring on March 10, 1989. Nearly half of the total measured flow during the high runoff period came from Lake Creek and its two perennial tributaries- Bozard Creek and West Lake Creek. Flows from intermittent tributaries ranged from 0.3% to 7% in the same period.

Suspended sediment load increased substantially during the spring runoff season. Total sediment load at the mouths of tributaries during the March

storm ranged from 0.03 tons in tributary HR-1 to 12 tons in Kruse Creek HR-6. The highest sediment load (55.5 tons) was measured at the mouth of Lake Creek LC-1. A trend in increasing sediment loads was observed in Lake Creek proceeding downstream. Fluctuations in suspended sediment levels could be traced agricultural practices and stream bank erosion.

Station WB1 near the mouth of Lake Creek had higher suspended sediment concentrations throughout the study period than ambient station WB2. Sediment concentrations peaked following the spring runoff events. The stratigraphic horizon left by the 1980 eruption of Mt. Saint Helens was used to determine average yearly accumulation of sediment in Windy Bay. Sediment core samples reveal an average of 0.09 ft/yr of sediment deposition near the mouth of Lake Creek.

The highest concentrations of inorganic nitrogen for ambient stations occurred during the spring runoff. All sites except background station BC had mean inorganic nitrogen concentrations exceeding the 0.3 mg/l instream criterion. Nitrogen concentrations increase with downstream progression out of forested regions into primarily agricultural lands and are associated with sediment runoff and percolation of agricultural fertilizers. Inorganic nitrogen criteria was exceeded 27% and 18% of the total samples taken at lake sites WB1 and WB2, respectively. Nearly half of the samples taken at WB1 exceeded the un-ionized ammonia criteria of 0.04 mg/l. Peak concentrations of nitrogen in Windy Bay occurred following runoff events in the spring and attenuated the remainder of the survey.

Phosphorus concentrations and loading are event related. Total phosphorus concentrations were generally positively correlated with suspended sediment concentrations at all sites. Mean annual total phosphorus concentrations in Lake Creek exceeded 0.05 mg/l criteria at all sites except background station BC. Approximately 190 pounds of phosphorus were lost from the watershed on March 15, 1989, as recorded at station LC-1. Tributaries that contributed large amounts of phosphorus to Lake Creek during the same period include HR-6 (23 lbs), HR-3 (23 lbs), HR-2 (8.8 lbs), and HR-8 (8.8 lbs). A majority of the phosphorus transported in Lake Creek is particulate phosphorus. Average total phosphorus concentrations ranged from 0.026 mg/l to 0.027 mg/l at lake sites WB2 and WB1, respectively. Lake sites exceeded the 0.05 mg/l phosphorus criteria once following the storm event in late March. Agricultural BMP implementation projects to reduce soil erosion could be expected to reduce instream levels of phosphorus.

All ambient stations had fecal coliform geometric means well below the 200/100 ml standard. In the upper watershed, station LC-3 had consistently higher fecal coliform counts than any other station. These higher counts are most likely due to cattle grazing in West Lake Creek. Fecal streptococci numbers were generally higher in comparison to fecal coliforms. All FC/FS ratios fell below 0.8 which suggests pollution is due primarily to nonhuman sources. Bacterial contamination appears not to be a problem in Windy Bay.

Existing beneficial uses of Lake Creek are agriculture water supply and secondary contact recreation. Utilization by cold water biota and as a salmonid spawning habitat are limited by current water quality (extremes in flows, excessive sediment, and elevated temperatures). Agricultural nonpoint source pollution contributes to the limitations imposed by water quality.

Data indicate Windy Bay as mesotrophic or a moderately enriched ecosystem.

RECOMMENDATIONS

1. To improve water quality and protect benefical uses, it is recommended that the Kootenai-Shoshone SCD apply for funding to implement BMPs in the Lake Creek watershed. Such a project in the watershed should reduce soil erosion from dryland crop acreages, stabilize stream bank areas prone to mass-wasting, enhance biotic potential, and decrease the sediment and nutrient loads delivered to Windy Bay.

2. Based upon this water quality survey, Best Management Practices should be implemented on those subbasins in the watershed which contribute the largest loads of agricultural pollutants to Lake Creek, and ultimately Windy Bay. Loading data indicate priorities for land management changes be placed on the following subbasins:

1) Lake Creek above LC-1.
2) Lake Creek above LC-2.
3) Kruse Creek HR-6
4) West Lake Creek above LC-3
5) Tributary HR-3.

3. Inclusion of Lake Creek into the Idaho Water Quality Standards will provide a means for protecting future designated beneficial uses of the stream. Designated uses should include cold water biota, salmonid spawning, and secondary contact recreation.

4. Water quality data, sediment accumulation in Windy Bay, and estimated loadings presented in this report should be used as a standard for comparison of water quality conditions following BMP implementation projects.

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Table 1. Lake Creek Project Water Quality Parameters

STORET	Parameter	Units
Field Measurements		
00061	Flow	CFS
00010	Water Temperature	C
00299	Dissolved Oxygen	mg/l
00095	Conductivity	umhos/cm
00076	Turbidity	NTU
00403	pH	S.U.
00035	Wind Velocity	mph
00078	Secchi Disk Transparency	m
Laboratory Analysis		
00610	Total Ammonia (NH3)	mg/l
00630	Total Nitrite/Nitrate (N02+N03)	mg/l
00625	Total Kjeldahl Nitrogen (TKN)	mg/l
00665	Total Phosphorus (T.P.)	mg/l
00666	Total Dissolved Phosphorus (D'P04)	mg/l
00671	Dissolved Orthophosphate (0'P04)	mg/l
80154	Suspended Sediment (S.S.)	mg/l
31679	Fecal Streptococcus	#/100 ml
31616	Fecal Coliform	#/100 ml
Total Metals		
01002	Total Arsenic	mg/l
01027	Total Cadmium	mg/l
01034	Total Chromium	mg/l
01042	Total Copper	mg/l
01045	Total Iron	mg/l
01051	Total Lead	mg/l
01055	Total Manganese	mg/l
71900	Total Mercury	mg/l
01067	Total Nickel	mg/l
01077	Total Silver	mg/l
01092	Total Zinc	mg/l
Common Ions		
00410	Total Alkalinity	mg/l
00916	Total Calcium	mg/l
00927	Total Magnesium	mg/l
00929	Total Sodium	mg/l
00937	Total Potassium	mg/l
00940	Total Chloride	mg/l
00951	Total Fluoride	mg/l
00945	Total Sulfate	mg/l
00956	Total Silica	mg/l

Table 2. DISCHARGE RECORD FOR STATION (LC-2) AT FORD, IDAHO

DISCHARGE IN CUBIC FEET PER SECOND
MEAN VALUES

DAY	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV
1	---	76	---	19	3.8	0.6	1.3	---	1.6
2	---	68	52	14	4	0.7	1.6	---	1.6
3	---	60	50	18	3.5	0.6	2.3	---	1.8
4	---	52	42	15	---	0.7	2	---	3.5
5	---	---	37	14	---	0.6	---	---	3.2
6	---	81	35	13	---	0.7	---	---	2.9
7	156	88	34	12	2.8	0.6	---	---	2.5
8	158	101	31	11	2.8	0.6	---	---	2.5
9	240	92	27	10	2.5	1.3	---	---	2.3
10	470	83	29	10	2.5	3	---	---	2.3
11	---	---	26	9.2	2.3	1.6	---	---	2.3
12	---	81	23	8.3	2	1.2	---	---	4.1
13	312	87	21	7.5	1.8	1.2	1.1	---	6.3
14	181	98	19	7.2	1.4	1.2	1.1	---	4.9
15	124	105	17	8	1.2	1.2	1	---	4.1
16	101	103	16	7.2	1.8	1.1	1.2	---	3.6
17	86	92	18	8	2.3	1.2	1.8	---	3.5
18	89	84	17	7.2	1.8	1	1.6	---	3.5
19	126	85	15	6.9	1.1	0.9	---	---	3.8
20	97	90	14	6.6	1.4	1.3	---	---	3.8
21	139	100	13	6.6	1.1	2	---	---	3.6
22	103	97	12	6.3	1	3	---	---	---
23	103	83	14	6.3	0.9	6.3	---	---	---
24	79	70	16	---	0.8	16	---	3	---
25	125	63	15	---	0.7	8	---	2.8	---
26	151	57	12	4.6	---	---	---	2.3	---
27	116	55	---	4.3	---	---	---	2.3	---
28	111	48	---	4.1	---	---	---	2.3	---
29	108	44	---	4	---	2	---	2	---
30	86	---	16	4	---	1.6	---	1.6	---
31	81	---	16	---	0.6	1.2	---	1.6	---
TOTAL	3322	2143	637	252.3	44.1	61.4	15	17.9	67.7
MEAN	144	79	24	9.0	1.9	2.2	1.5	2.2	3.2
MAX	470	105	52	19	4	16	2.3	3	6.3
MIN	79	44	12	4	0.6	0.6	1	1.6	1.6

Table 3. Discharge, Sediment, and Phosphorus Produced 3/15/89

Station	Discharge (cfs)	Suspended Sediment (mg/l)	Suspended Sediment Load (t/day)	Phosphorus (mg/l)	Phosphorus Load (lbs/day)
Bozard Creek (BC)	*	*	*	*	*
Lake Creek (LC-3)	71	32	6	0.13	50
Kruse Creek (HR-6)	9.7	446	12	0.44	23
Unnamed Tributary (HR-5)	1.7	209	1	0.42	3.9
Unnamed Tributary (HR-4)	0.39	75	0.08	0.36	0.7
Unnamed Tributary (HR-7)	2.3	157	1	0.32	3.9
Unnamed Tributary (HR-8)	7.1	79	1.5	0.23	8.8
Lake Creek (LC-2)	125	88	30	0.21	143
Unnamed Tributary (HR-3)	10	98	2.6	0.41	23
Unnamed Tributary (HR-2)	4.9	155	2	0.33	8.8
Lake Creek (LC-1)	147	140	55.5	0.24	190
Unnamed Tributary (HR-1)	0.87	13	0.03	0.19	0.9

* = No data available

Table 4. A Summary of Nitrogen and Phosphorus in the Lake Creek Watershed.

Station		Inorganic Nitrogen* (mg/l)	Organic Nitrogen** (mg/l)	Total Phosphorus (mg/l)	Dissolved Total Phosphorus (mg/l)	Dissolved Ortho Phosphorus (mg/l)	Particulate Total Phosphorus (mg/l)
Bozard Creek	Mean	0.16	0.13	0.02	0.01	0.008	0.007
(BC)	Range	0.063 - 0.24	0.005 -0.23	0.008 - 0.052	0.006 - 0.01	0.002 - 0.01	0 - 0.039
	Number	13	13	13	13	13	13
Lake Creek	Mean	0.46	0.24	0.07	0.03	0.02	0.04
(LC-3)	Range	0.13 - 3.164	0.115 - 0.866	0.019 - 0.25	0.013 - 0.103	0.004 - 0.067	0 - 0.147
	Number	17	17	17	17	17	17
Kruse Creek	Mean	1.93	0.43	0.12	0.05	0.03	0.08
(HR-6)	Range	0.26 - 6.29	0.16 - 1.69	0.05 - 0.44	0.02 - 0.07	0.02 - 0.052	0.012 - 0.37
	Number	10	10	10	10	10	10
Unnamed Trib.	Mean	3.64	1.13	0.29	0.11	0.09	0.18
(HR-5)	Range	0.68 - 11.319	0.77 - 1.67	0.106 - 0.42	0.02 - 0.19	0.05 - 0.19	0.025 - 0.31
	Number	7	7	7	7	7	7
Unnamed Trib.	Mean	10.89	1.14	0.23	0.1	0.08	0.13
(HR-4)	Range	4.48 - 20.34	0.45 - 1.643	0.05 - 0.36	0.02 - 0.21	0.02 - 0.18	0.03 - 0.27
	Number	4	4	4	4	4	4
Unnamed Trib.	Mean	4.26	0.82	0.17	0.07	0.05	0.1
(HR-7)	Range	0.13 - 11.288	0.42 - 1.50	0.077 - 0.32	0.03 - 0.13	0.02 - 0.12	0.025 - 0.25
	Number	8	8	8	8	8	8
Unnamed Trib.	Mean	3.21	0.63	0.12	0.07	0.06	0.05
(HR-8)	Range	0.11 - 9.636	0.338 - 1.37	0.05 - 0.24	0.03 - 0.18	0.03 - 0.15	0.005 - 0.15
	Number	10	10	10	10	10	10
Lake Creek	Mean	1.37	0.32	0.09	0.04	0.03	0.05
(LC-2)	Range	0.11 - 8.40	0.095 - 0.962	0.02 - 0.23	0.01 - 0.092	0.008 - 0.058	0 - 0.17
	Number	18	18	18	18	18	18
Unnamed Trib.	Mean	4.36	0.63	0.19	0.11	0.11	0.08
(HR-3)	Range	1.07 - 7.66	0.252 - 1.23	0.05 - 0.41	0.051 - 0.33	0.042 - 0.29	0 - 0.29
	Number	8	8	8	8	7	8
Unnamed Trib.	Mean	4.47	0.74	0.19	0.08	0.07	0.11
(HR-2)	Range	0.86 - 8.98	0.16 - 1.887	0.039 - 0.68	0.02 - 0.30	0.025 - 0.25	0.003 - 0.38
	Number	8	8	8	8	8	8
Lake Creek	Mean	1.07	0.32	0.1	0.04	0.03	0.06
(LC-1)	Range	0.15 - 4.24	0.07 - 1.189	0.02 - 0.56	0.005 - 0.17	0.009 - 0.15	0.007 - 0.39
	Number	17	17	17	17	17	17
Unnamed Trib.	Mean	9.39	0.56	0.23	0.16	0.14	0.07
(HR-1)	Range	5.27 - 15.143	0.207 - 1.29	0.05 - 0.94	0.04 - 0.64	0.032 - 0.58	0.01 - 0.30
	Number	7	6	7	7	7	7

* Inorganic N = (NO_2 + NO_3 + NH_3)

** Organic N = (Kjeldahl N - NH_3)

Table 5. Fecal Coliform Bacteria in Lake Creek 1988-1989.

Station	Number of Samples	Fecal Coliform /100 ml (log mean)	Minimum-Maximum /100 ml	% Violation*	FC/FS ratio (log mean)
BC	13	7	1 - 1500	8	0.4
LC3	17	45	8 - 600	0	0.8
LC2	17	18	1 - 190	0	0.4
LC1	16	11	0 - 64	0	0.3

* % violation based on 800/100 ml. water quality standard.

Table 6. Water quality data for the Lake Creek stream survey stations, 1988-1989.

Station		Dissolved Oxygen (mg/l)	Temperature (C)	pH	Conductivity (umhos/cm)	Turbidity (NTU)
Bozard Creek (BC)	Mean	12.2	6.1	7	26	5.6
	Range	9.9 - 14.0	0.1 - 13.6	6.2 - 7.4	1.6 - 35	1 - 33
	Number	13	13	6	11	13
Lake Creek (LC-3)	Mean	11.2	5.7	6.9	30	24
	Range	7.9 - 13.4	0 - 14.5	6.6 - 7.3	21 - 56	1.8 - 146
	Number	16	16	6	16	17
Krose Creek (HR-6)	Mean				49	45
	Range				38 - 72	9.5 - 236
	Number				10	10
Unnamed Trib. (HR-5)	Mean				73	81
	Range				46 - 115	8.5 - 241
	Number				7	7
Unnamed Trib. (HR-4)	Mean				108	81
	Range				92 - 115	8.2 - 242
	Number				4	4
Unnamed Trib. (HR-7)	Mean				92	56
	Range				49 - 152	8 - 200
	Number				8	8
Unnamed Trib. (HR-8)	Mean				93	27
	Range				49 - 150	4.2 - 100
	Number				10	10
Lake Creek (LC-2)	Mean	12.1	7.2	7.1	41	22
	Range	9 - 14.8	0 - 21.8	6.6 - 7.5	24 - 65	1.8 - 81
	Number	17	17	6	17	22
Unnamed Trib. (HR-3)	Mean				114	43
	Range				80 - 143	2.6 - 172
	Number				8	8
Unnamed Trib. (HR-2)	Mean				88	88
	Range				62 - 100	4.9 - 350
	Number				7	7
Lake Creek (LC-1)	Mean	12.2	7.9	7.4	42	30
	Range	9.8 - 14.8	0 - 21.8	7.0 - 8.0	23 - 60	1.5 - 220
	Number	17	17	6	16	17
Unnamed Trib. (HR-1)	Mean				96	33
	Range				51 - 140	8.9 - 108
	Number				7	7

Table 7. Common Ion concentrations in Lake Creek ambient stations, 1989.

Station		Alkalinity (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)
Bozard Creek (BC)	Mean	19.5	3.68	1.56	0.01	0.01
	Range	-	-	-	-	-
	Number	1	1	1	1	1
Lake Creek (LC-3)	Mean	15	2.4	1.41	0.06	0.06
	Range	-	-	-	-	-
	Number	1	1	1	1	1
Lake Creek (LC-2)	Mean	24	4.8	1.41	0.05	0.05
	Range	-	-	-	-	-
	Number	1	1	1	1	1
Lake Creek (LC-1)	Mean	18	4.8	2.1	1.8	1.24
	Range	10.0 - 26.0	-	1.99 - 2.2	0.09 - 3.5	0.09 - 2.4
	Number	2	1	2	2	2

Station		Chloride (mg/l)	Flouride (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Silica (mg/l)
Bozard Creek (BC)	Mean	1.3	0.05	15.6	0.01	26.8
	Range	-	-	-	-	-
	Number	1	1	1	1	1
Lake Creek (LC-3)	Mean	1.35	0.05	11.8	0.59	22.2
	Range	-	-	-	-	-
	Number	1	1	1	1	1
Lake Creek (LC-2)	Mean	1.75	0.06	17.8	2.06	23.1
	Range	-	-	-	-	-
	Number	1	1	1	1	1
Lake Creek (LC-1)	Mean	1.38	0.12	20.2	3.16	20
	Range	1 - 1.75	0.06 - 0.17	-	1.81 - 4.5	18 - 22.1
	Number	2	2	1	2	2

Table 8. Total metal concentrations in Lake Creek ambient stations, 1989.

Station		Arsenic (mg/l)	Cadmium (mg/l)	Chromium (mg/l)	Copper (mg/l)	Iron (mg/l)	Lead (mg/l)
Bozard Creek (BC)	Mean	0.01	0.0005	0.01	0.01	0.29	0.005
	Range	-	-	-	-	-	-
	Number	1	1	1	1	1	1
Lake Creek (LC-3)	Mean	0.01	0.0005	0.01	0.01	0.68	0.005
	Range	-	-	-	-	-	-
	Number	1	1	1	1	1	1
Lake Creek (LC-2)	Mean	0.01	0.0005	0.01	0.01	0.65	0.005
	Range	-	-	-	-	-	-
	Number	1	1	1	1	1	1
Lake Creek (LC-1)	Mean	0.01	0.0008	0.01	0.018	1.79	0.006
	Range	0.01 - 0.01	0.0005 - 0.001	0.01 - 0.01	0.01 - 0.025	0.98 - 2.6	0.005 - 0.008
	Number	2	2	2	2	2	2

Station		Manganese (mg/l)	Mercury (mg/l)	Nickel (mg/l)	Silver (mg/l)	Zinc (mg/l)
Bozard Creek (BC)	Mean	0.01	0.0005	0.02	0.001	0.01
	Range	-	-	-	-	-
	Number	1	1	1	1	1
Lake Creek (LC-3)	Mean	0.01	0.0005	0.02	0.001	0.01
	Range	-	-	-	-	-
	Number	1	1	1	1	1
Lake Creek (LC-2)	Mean	0.01	0.0005	0.02	0.001	0.01
	Range	-	-	-	-	-
	Number	1	1	1	1	1
Lake Creek (LC-1)	Mean	0.045	0.00045	0.02	0.001	0.015
	Range	0.01 - 0.08	0.0004-0.0005	0.02 - 0.02	0.001 - 0.001	0.01 - 0.02
	Number	2	2	2	2	2

Table 9. Water quality data for the Windy Bay survey station WB1, 1989.

Sample date	Time	Depth (m)	Conductivity (umhos/cm)	Turbidity (NTU)	Diss. solids (mg/l)	pH (SU)	Chl a (mg/l)
3/27/89	14:45	9	51	23	30	-	0.01194
4/6/89	13:11	1.5	49	7.8	8	-	0.0074
4/19/89	10:50	2.1	35	6.2	8	-	0.02265
5/17/89	11:00	1.6	38	5.5	6	-	0.00279
5/31/89	11:00	3.5	40	3.8	4	-	0.00906
6/7/89	9:35	2.8	38	2.5	2	6.7	0.00407
7/12/89	10:35	2.9	36	2.5	2	-	-
8/16/89	9:50	5.2	46	1.2	<2	-	0.00254
9/27/89	10:10	6.8	50	0.8	<2	-	0.6
10/25/89	10:00	1.5	-	-	2	-	-
11/28/89	9:45	1	-	-	2	-	0.00311

Total N (mg/l)	Total K. N (mg/l)	Total NH3 N (mg/l)	Total Org. N (mg/l)	NO3+NO2 N (mg/l)	Bacteria FC/100 ml	Bacteria FS/100 ml	Bacteria FC/FS ratio
0.73	0.27	0.04	0.23	0.46	-	-	-
0.67	0.26	0.072	0.168	0.41	-	-	-
0.61	0.4	0.04	0.36	0.21	10	72	0.1
0.35	0.21	0.05	0.16	0.14	1	1	1
0.31	0.22	0.07	0.15	0.09	6	<1	6
0.48	0.18	0.02	0.16	0.3	2	<1	2
0.37	0.29	0.14	0.15	0.08	<1	1	<1
0.19	0.13	0.03	0.1	0.06	<1	<1	<1
0.112	0.11	0.015	0.096	0.002	<1	<1	<1
0.24	0.17	0.02	0.15	0.07	<1	60	0.01
0.33	0.22	0.05	0.17	0.11	1	1	1

Total P (mg/l)	Diss. Total P (mg/l)	Part. Total P (mg/l)	Diss. Ortho P (mg/l)	Diss. Hydro. P (mg/l)	Secchi depth (m)	Thermocline (m)	Wind speed (mph)
0.11	0.02	0.09	<0.01	0.01	0.6	*	13
0.026	0.01	0.016	0.002	0.008	0.9	*	8
0.02	0.01	0.01	0.01	0	1.1	*	15
0.02	0.01	0.01	<0.01	<0.01	1.3	*	5
0.05	0.04	0.01	0.02	0	2	*	<2
0.01	<0.01	<0.01	<0.01	<0.01	2.6	*	41
0.01	<0.01	<0.01	<0.01	<0.01	2.2	*	7
0.01	<0.01	<0.01	<0.01	<0.01	5.2	*	7
0.01	0.006	0.004	0.001	0.005	6	*	8
0.01	0.01	0	0.01	0	1.5	*	<2
0.02	<0.01	0.01	<0.01	<0.01	1	*	<1

* Station not thermally stratified

Table 10. Water quality data for the Windy Bay survey station WB2, 1989.

Sample date	Time	Depth (m)	Conductivity (umhos/cm)	Turbidity (NTU)	Diss. solids (mg/l)	pH (SU)	Chl a (mg/l)
3/27/89	15:00	16	53	15	12	–	0.01343
4/6/89	13:31	16	48	7.9	5	–	0.0087
4/19/89	11:15	16.5	46	6.4	9	–	0.00826
5/17/89	11:15	16.1	40	3.5	2	–	0.00735
5/31/89	11:45	15.6	41	3.3	4	–	0.00648
6/7/89	10:05	15.5	40	1.6	<2	6.8	0.00438
7/12/89	11:10	15.5	38	2.5	<2	–	–
8/16/89	10:20	16.5	48	1.2	<2	–	0.0029
9/27/89	10:40	16.5	48	1.2	<2	–	0.6
10/25/89	10:30	15	–	–	<2	–	–
11/28/89	10:30	16	–	–	<2	–	0.00311

Total N (mg/l)	Total K. N (mg/l)	Total NH3 N (mg/l)	Total Org. N (mg/l)	NO3+NO2 N (mg/l)	Bacteria FC/100 ml	Bacteria FS/100 ml	Bacteria FC/FS ratio
1	0.29	0.04	0.25	0.71	–	–	–
0.574	0.19	0.092	0.098	0.364	–	–	–
0.42	0.24	0.02	0.22	0.18	9	5	1.8
0.32	0.16	0.04	0.12	0.16	<1	<1	<1
0.26	0.18	0.06	0.12	0.08	3	4	0.75
0.24	0.16	0.05	0.11	0.08	<1	<1	<1
0.33	0.27	0.04	0.23	0.06	<1	<1	<1
0.19	0.14	<0.01	0.13	0.05	<1	<1	<1
0.096	0.09	0.032	0.058	0.006	<1	<1	<1
0.22	0.17	0.02	0.15	0.05	2	<1	2
0.27	0.18	0.01	0.17	0.09	1	<1	1

Total P (mg/l)	Diss. Total P (mg/l)	Part. Total P (mg/l)	Diss. Ortho P (mg/l)	Diss. Hydro. P (mg/l)	Secchi depth (m)	Thermocline (m)	Wind speed (mph)
0.13	0.03	0.1	0.01	0.02	0.8	*	13
0.025	0.008	0.017	0.001	0.007	1.2	*	<2
0.02	0.01	0.01	<0.01	<0.01	1.3	*	16
0.02	0.01	0.01	<0.01	<0.01	2.1	*	10
0.02	<0.01	<0.01	0.01	0	2.1	*	5.5
0.01	<0.01	<0.01	<0.01	<0.01	3	4	5
<0.01	<0.01	<0.01	<0.01	<0.01	4.5	15	7
0.01	<0.01	<0.01	<0.01	<0.01	8	13	5
0.011	0.005	0.006	0.001	0.004	6.5	14	4.5
0.01	<0.01	<0.01	<0.01	<0.01	6	*	<2
0.01	<0.01	<0.01	<0.01	<0.01	4	*	<1

* Station not thermally stratified

Table 11. Common ion concentrations for the Windy Bay survey stations, 1989.

WB1 Summary

Sample date	Time	Alkalinity (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)
10/25/89	10:00	20.5	6.16	1.7	0.13	0.13

Chloride (mg/l)	Flouride (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Silica (mg/l)
1.4	0.05	22.4	5.67	8

WB2 Summary

Sample date	Time	Alkalinity (mg/l)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)
10/25/89	10:30	20.5	6.24	1.7	*	*

Chloride (mg/l)	Flouride (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Silica (mg/l)
0.8	0.05	22.6	5.67	8.1

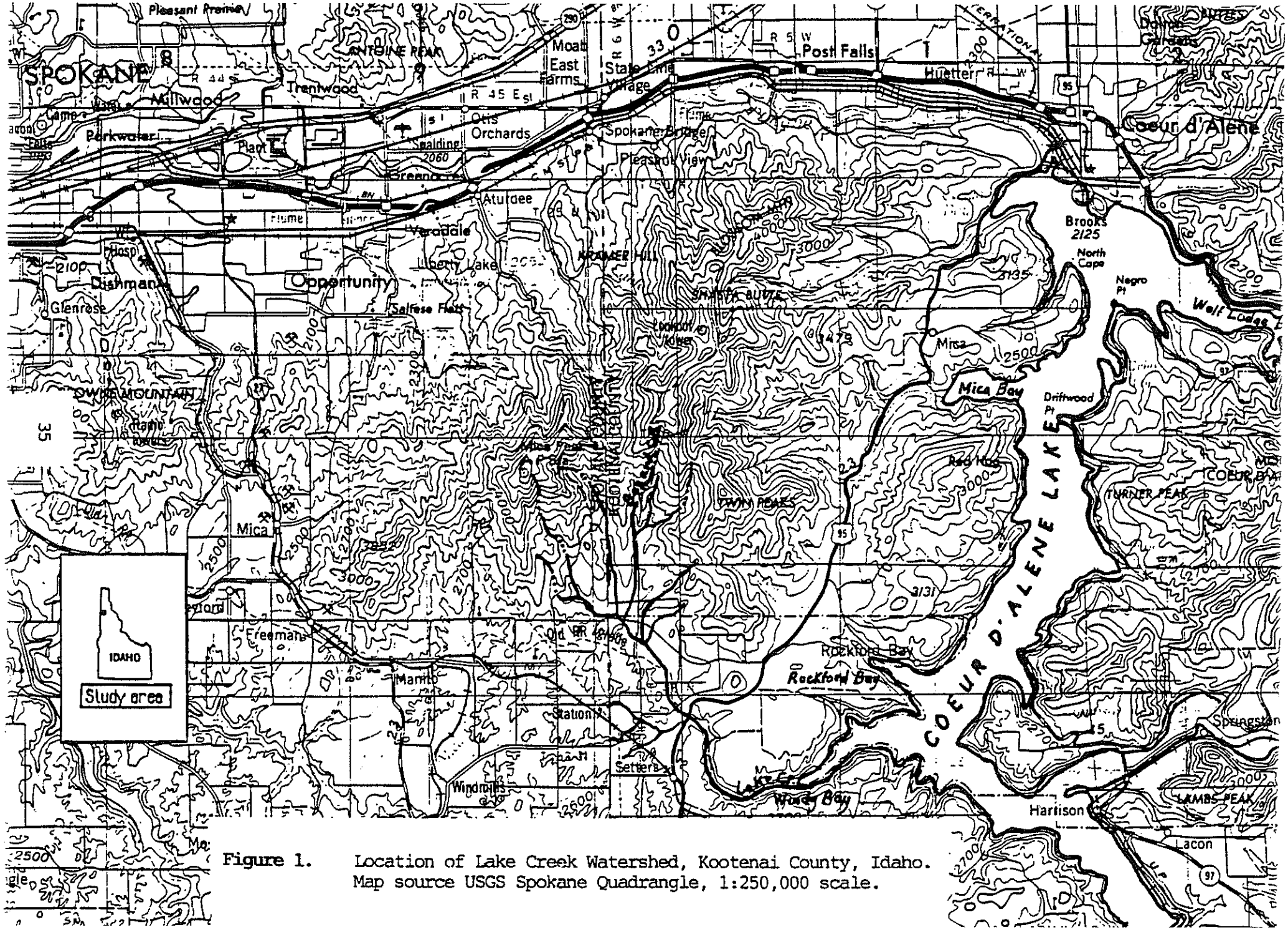


Figure 1. Location of Lake Creek Watershed, Kootenai County, Idaho. Map source USGS Spokane Quadrangle, 1:250,000 scale.

Figure 2. WATER BUDGET FOR THE LAKE CREEK WATERSHED
March 15, 1989

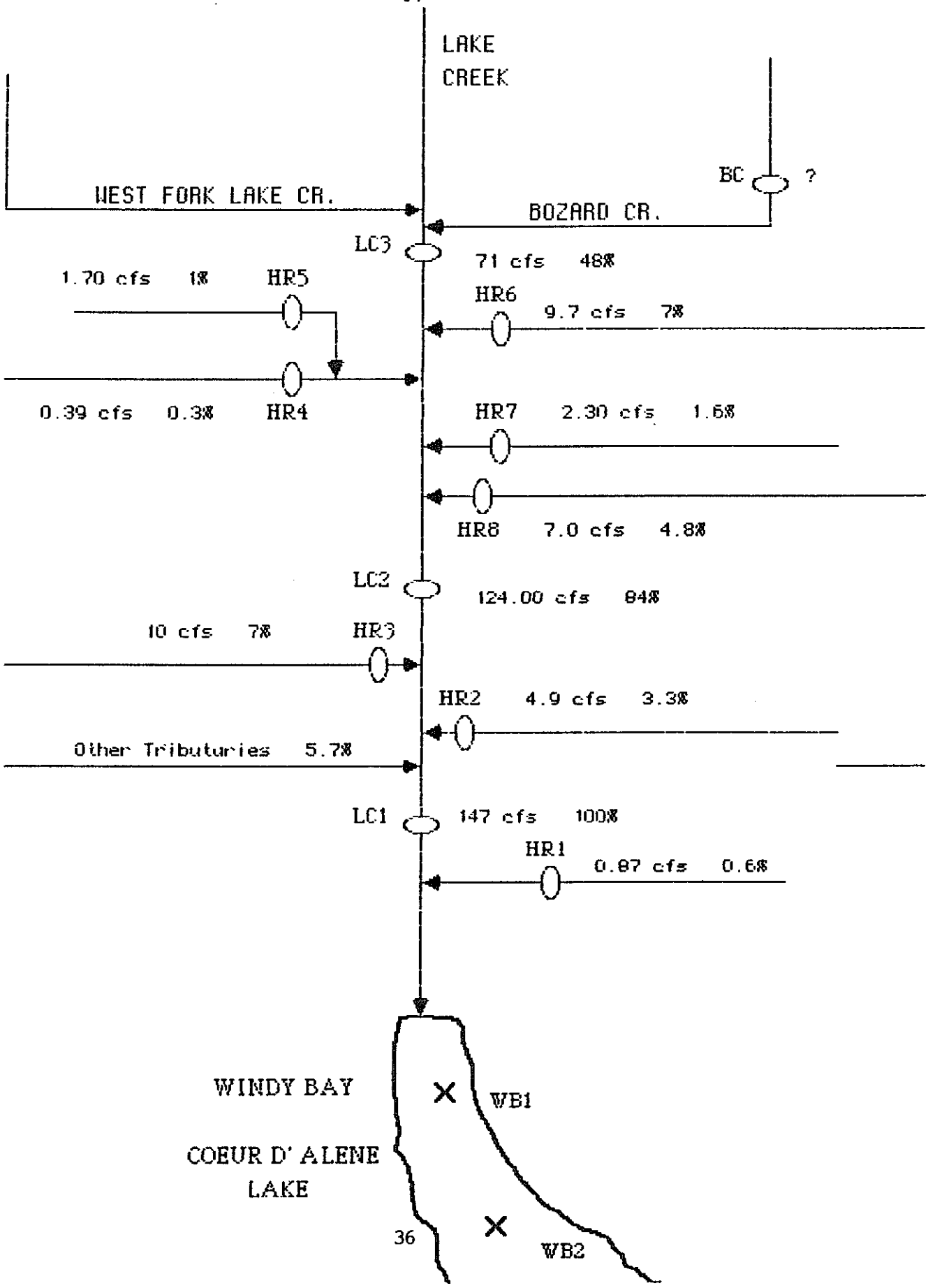


Figure 3. Suspended Sediment Ambient Stations

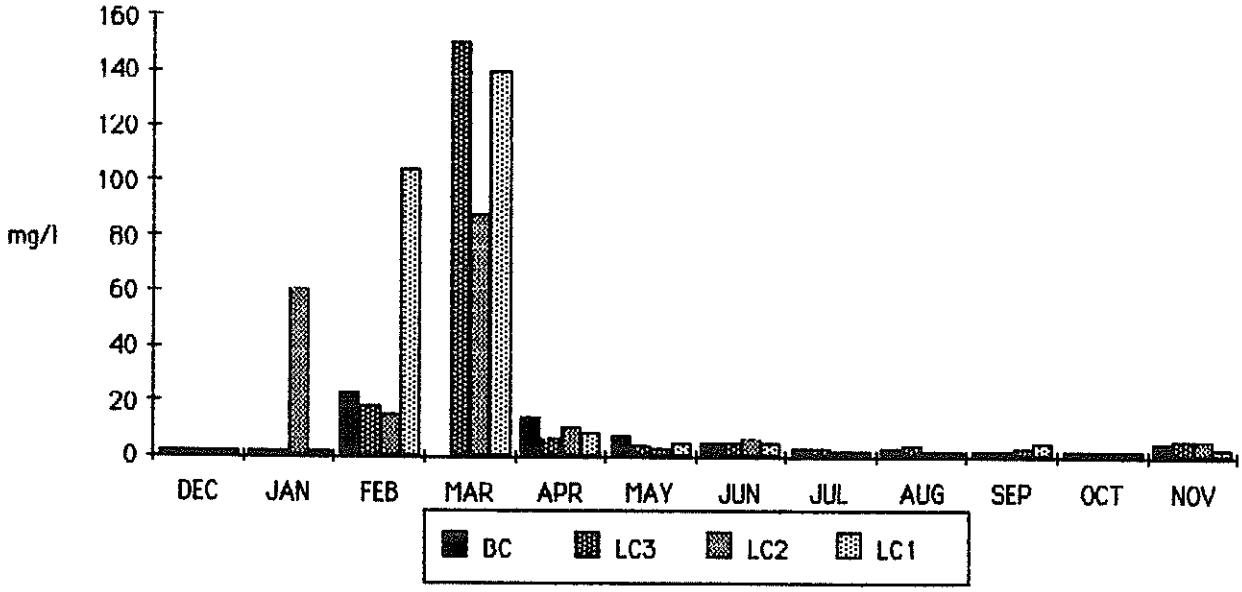


Figure 4. Suspended Sediment Concentrations in Lake Creek 3/15/89.

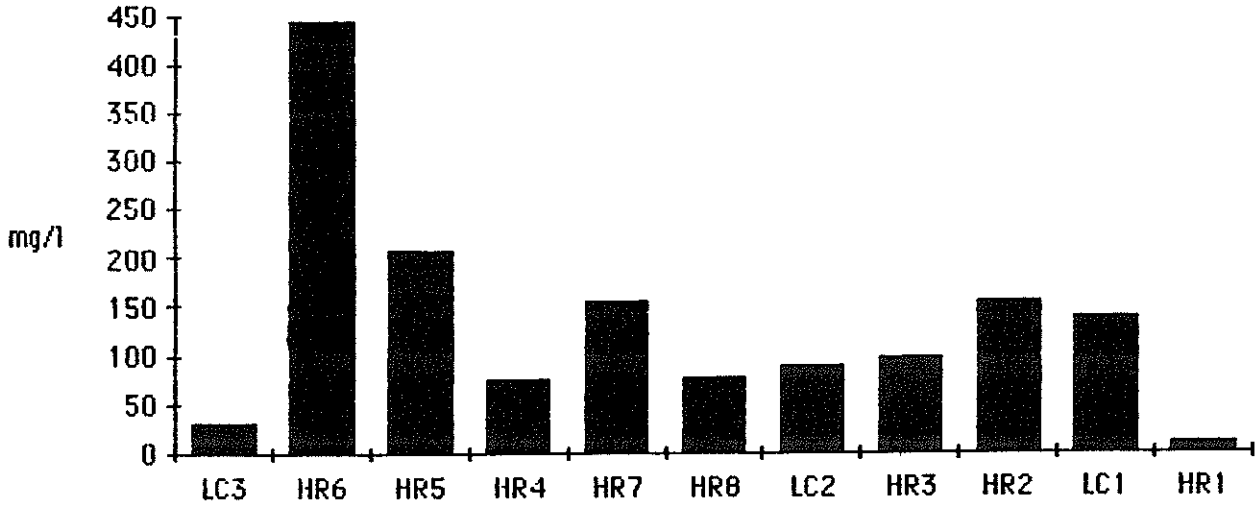


Figure 5. Suspended Sediment Loads in Lake Creek 3/15/89.

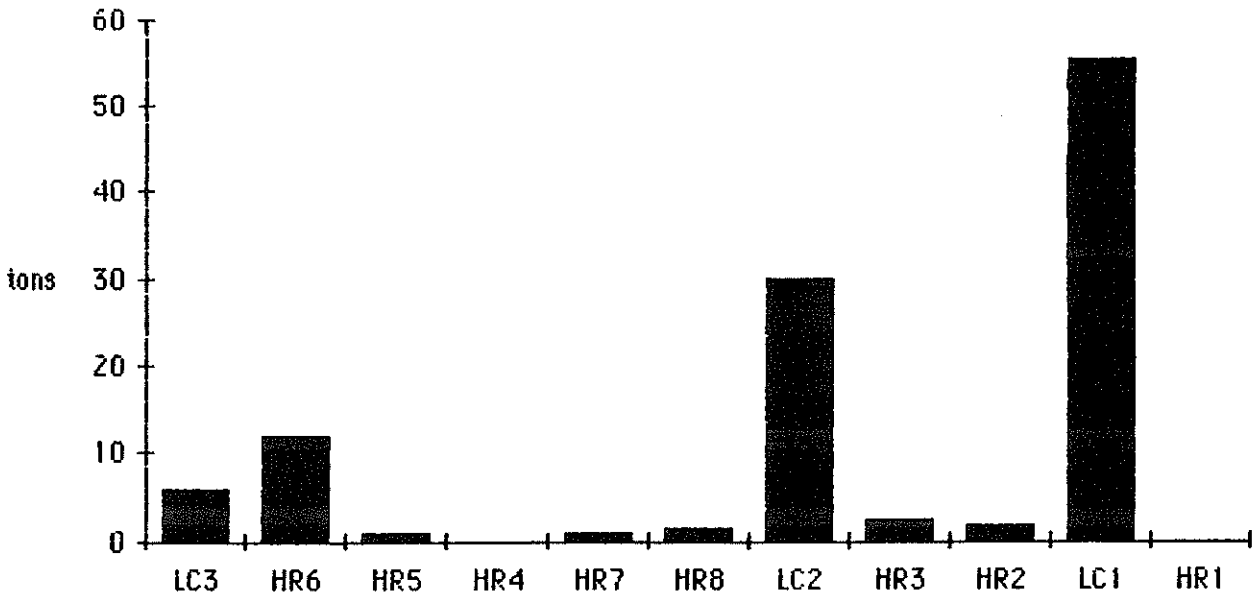


Figure 6. Inorganic Nitrogen Ambient Stations.

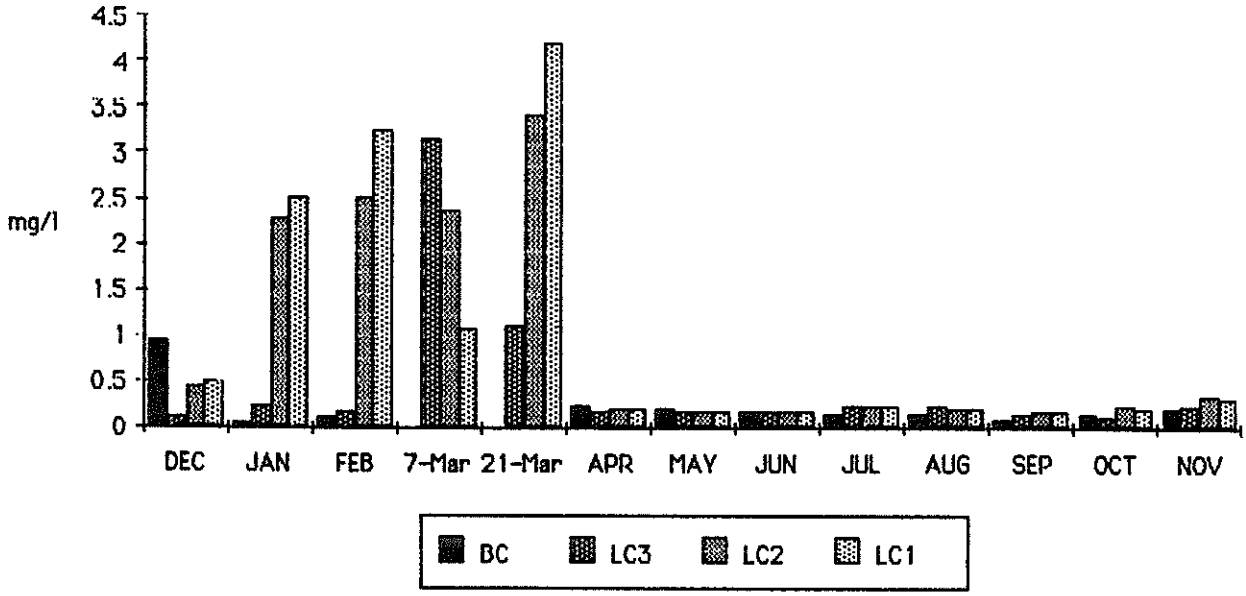


Figure 7. Total Phosphorus and Suspended Sediment concentrations at Lake Creek station BC.

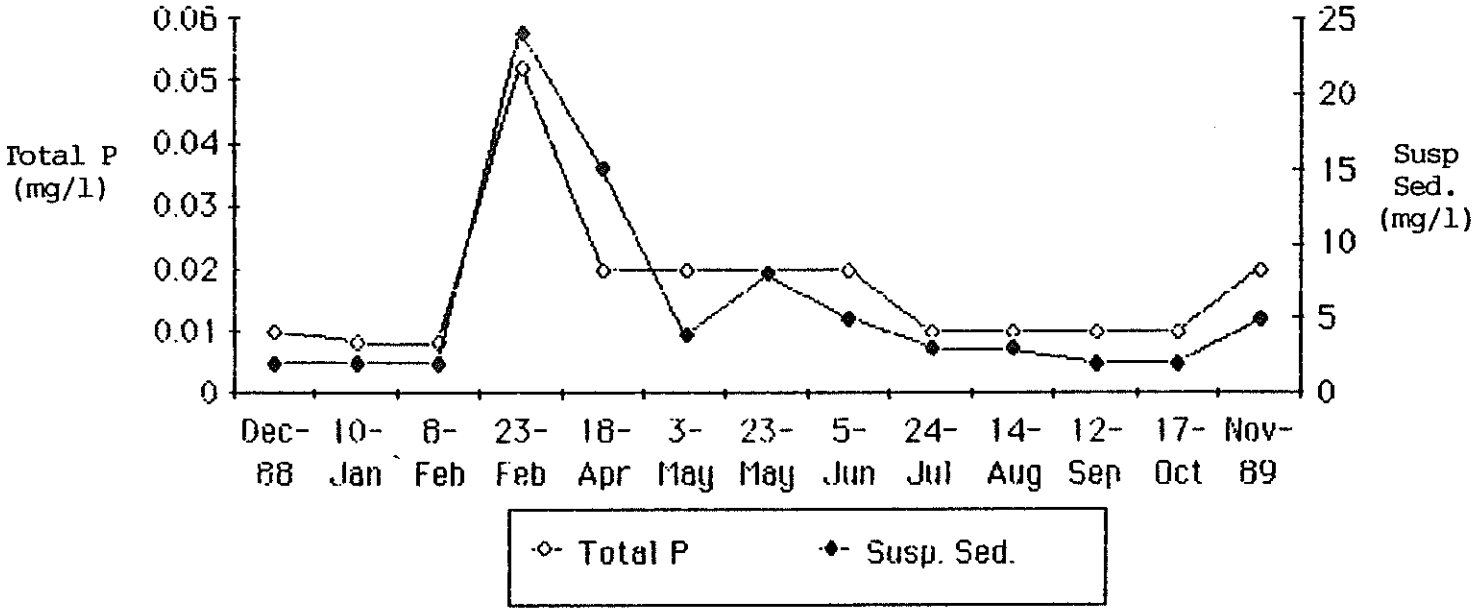


Figure 8. Total Phosphorus and Suspended Sediment concentrations at Lake Creek station LC-3.

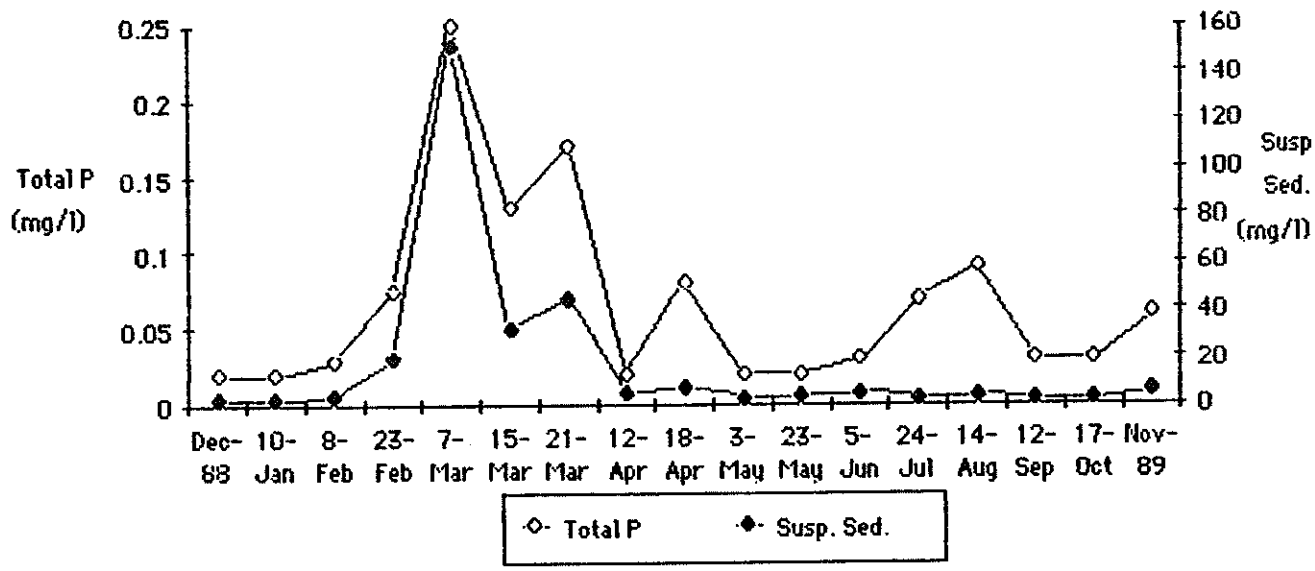


Figure 9. Total Phosphorus and Suspended Sediment concentrations at Lake Creek station LC-2.

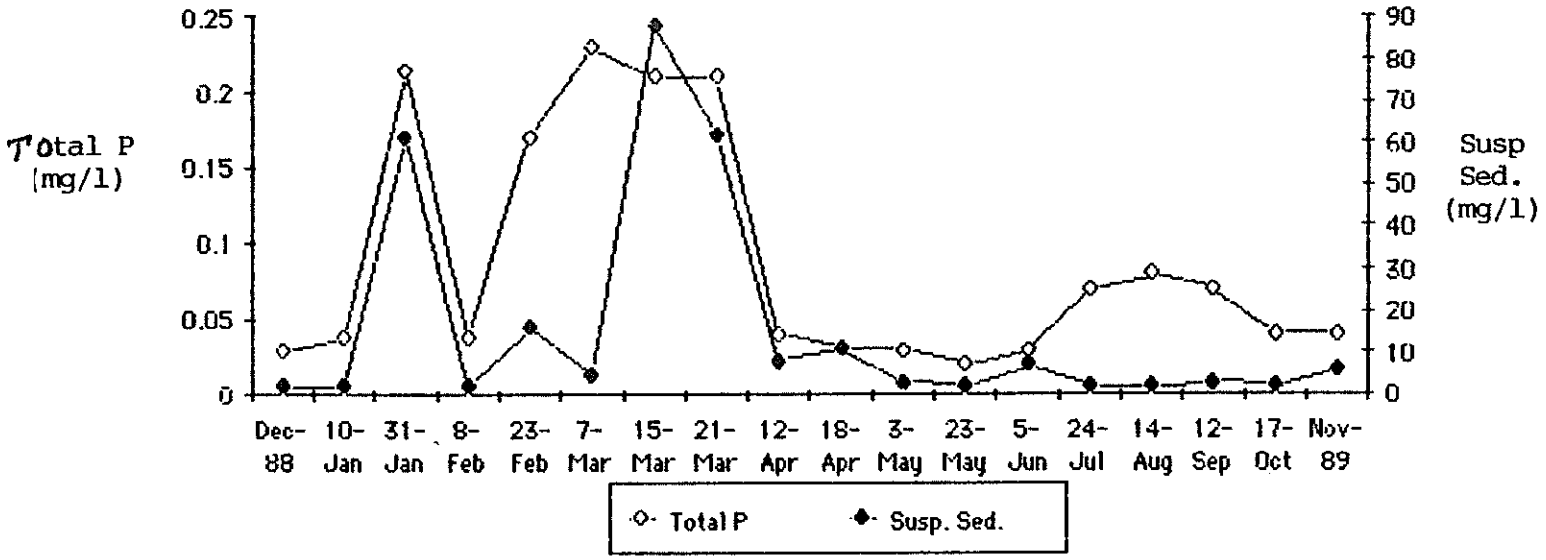


Figure 10. Total Phosphorus and Suspended Sediment concentrations at Lake Creek station LC-1.

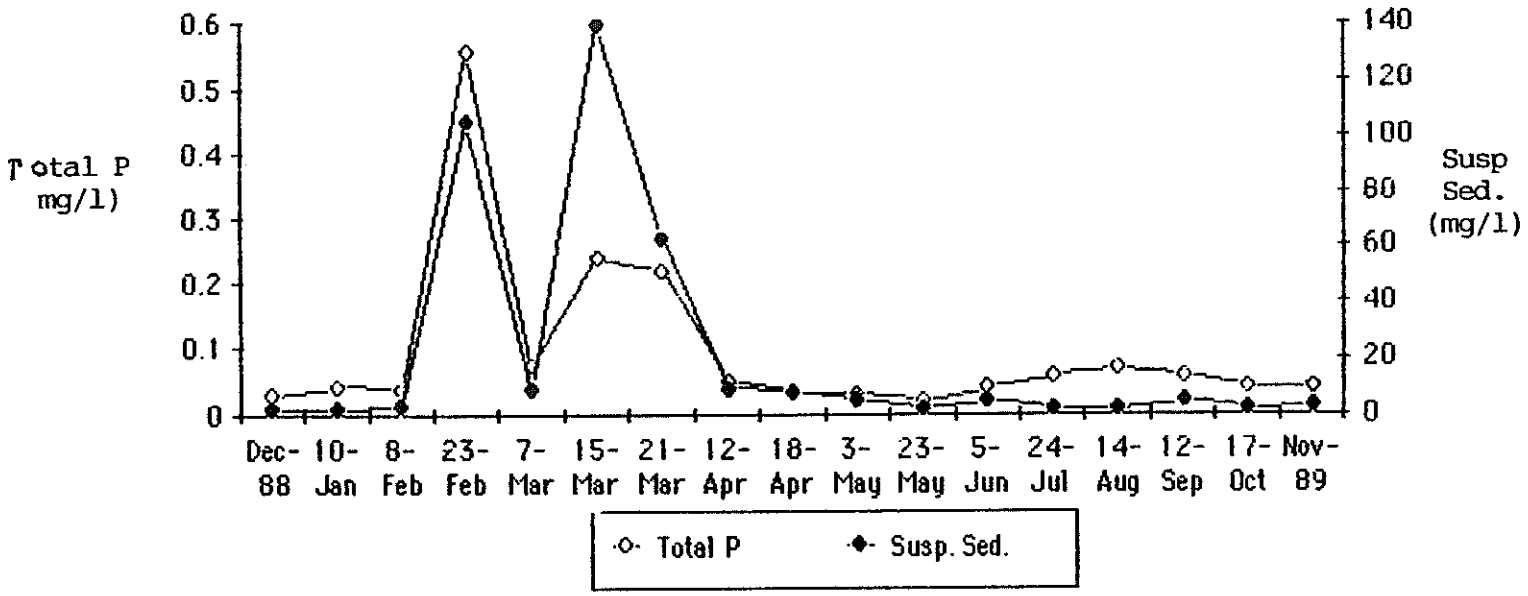


Figure 11. Phosphorus distribution at station BC.

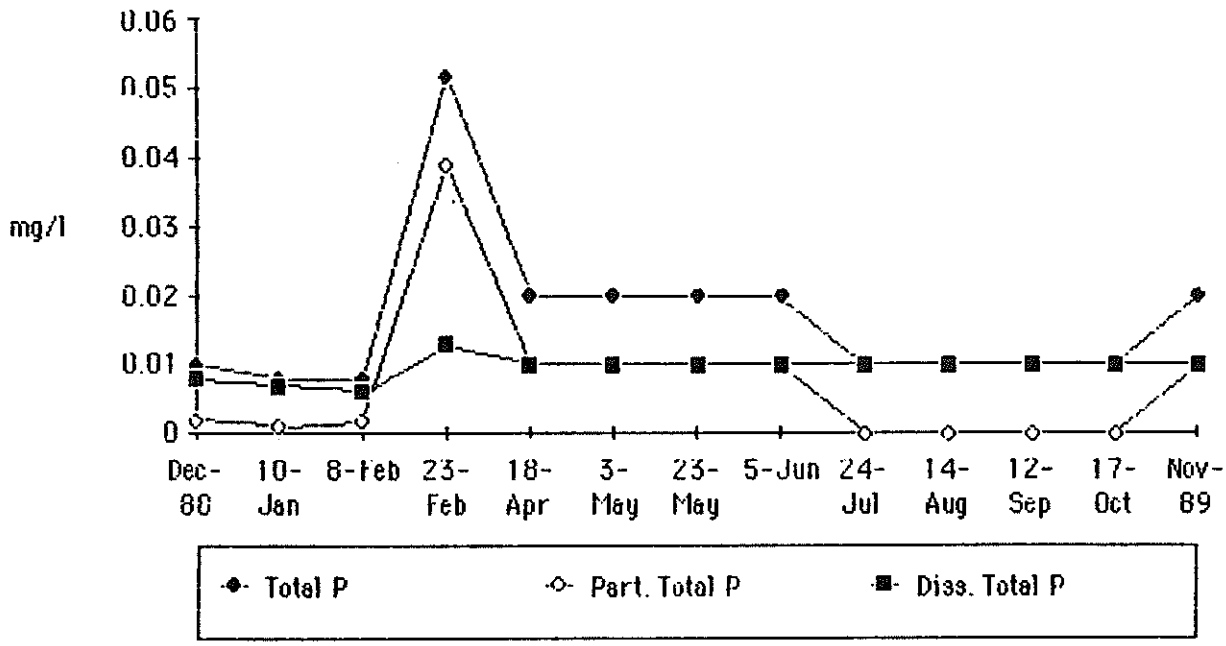


Figure 12. Phosphorus distribution at station LC-3.

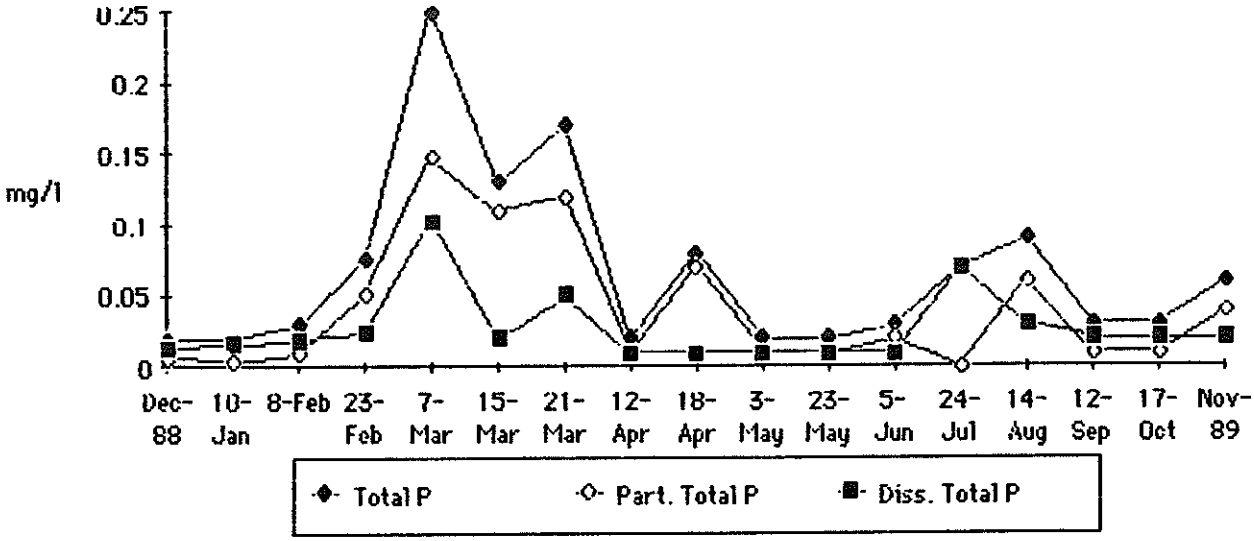


Figure 13. Phosphorus distribution at station LC-2.

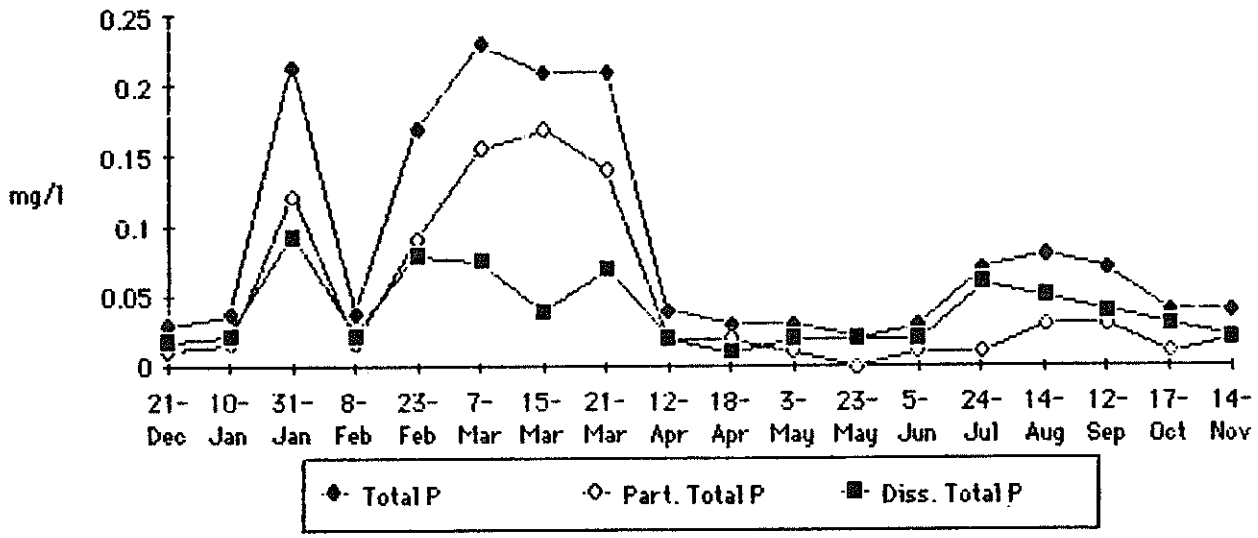


Figure 14. Phosphorus distribution at station LC-1.

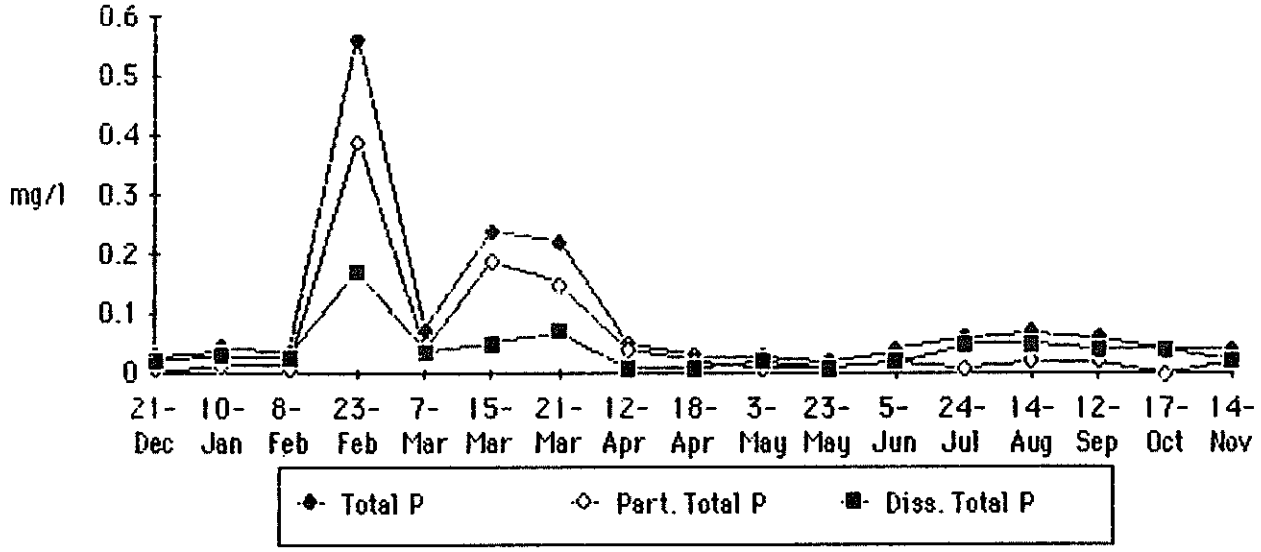


Figure 15. Distribution of particulate and dissolved phosphorus at Lake Creek station LC-1, March 15, 1989.

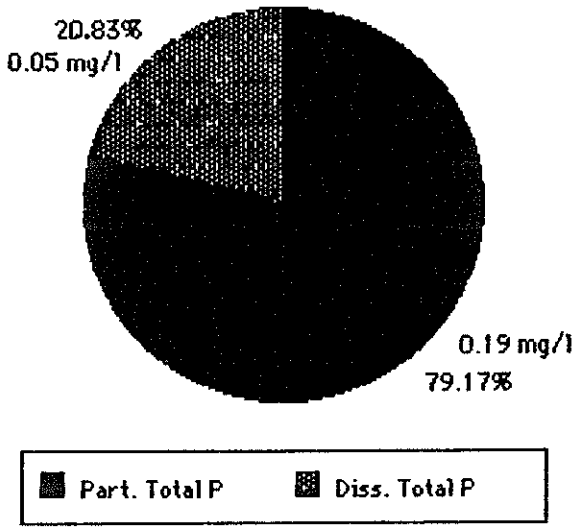


Figure 16. Bacteria densities at Lake Creek ambient stations.

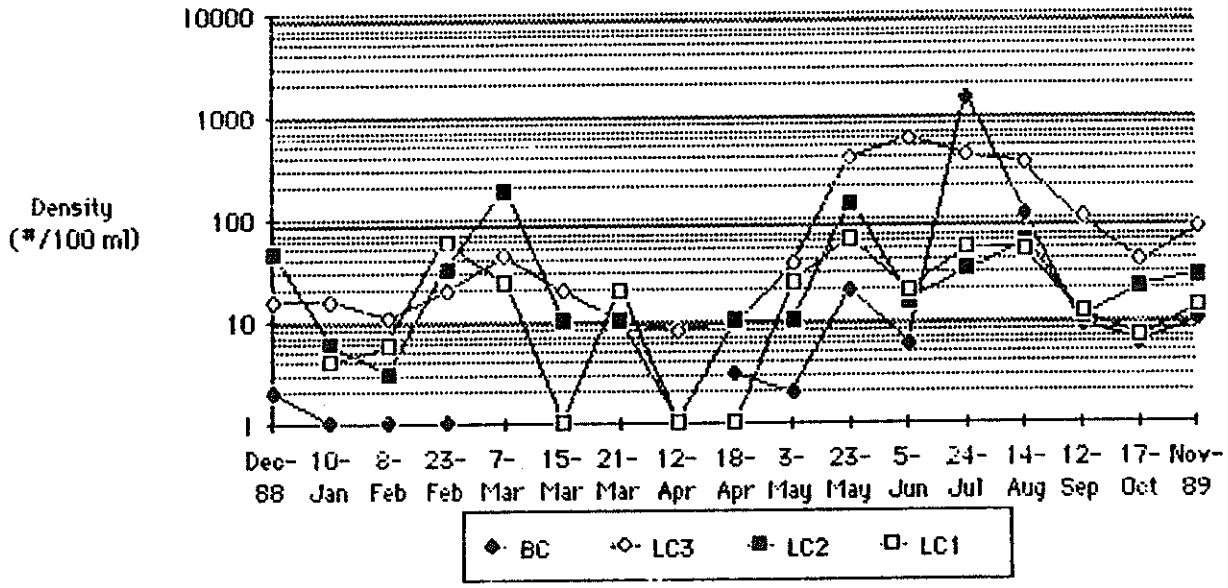


Figure 17. Bacteria densities at Lake Creek station BC.

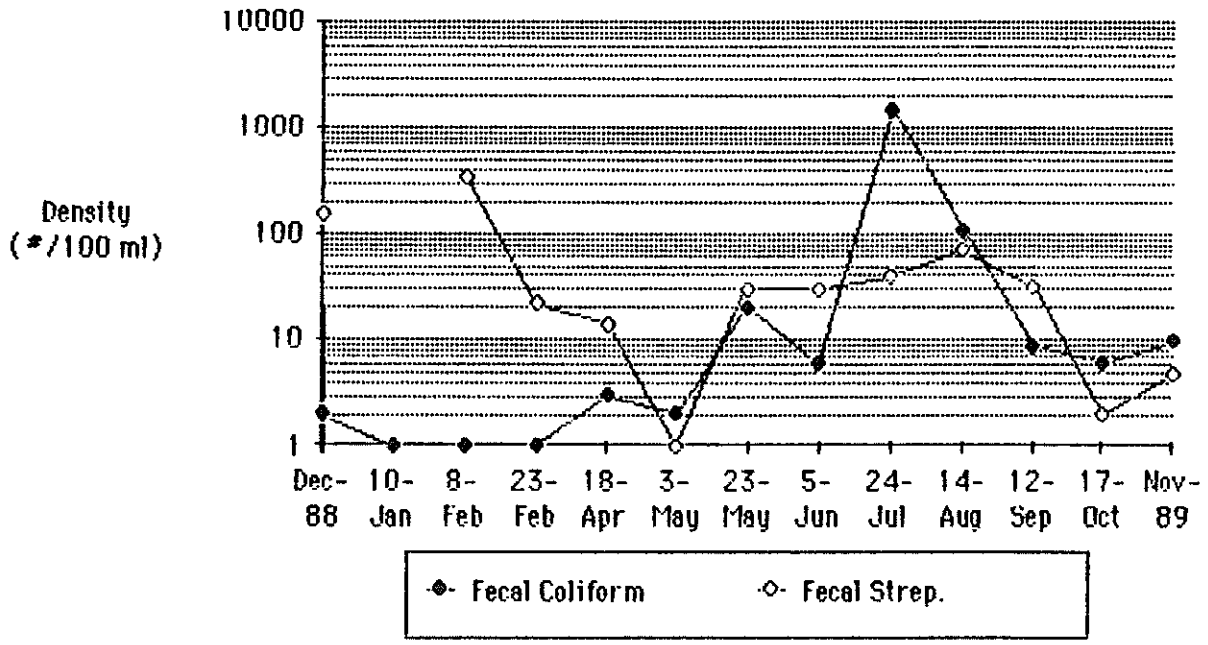


Figure 18. Bacteria Densities at Lake Creek Station LC-3.

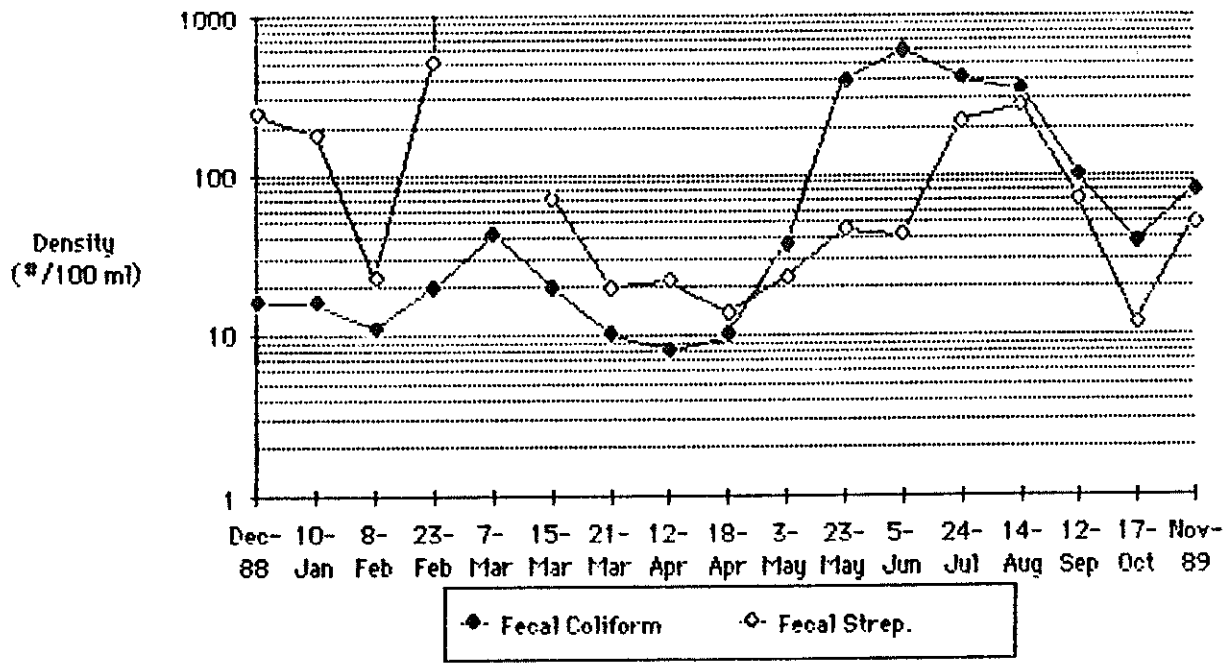


Figure 19. Bacteria densities at Lake Creek station LC-2.

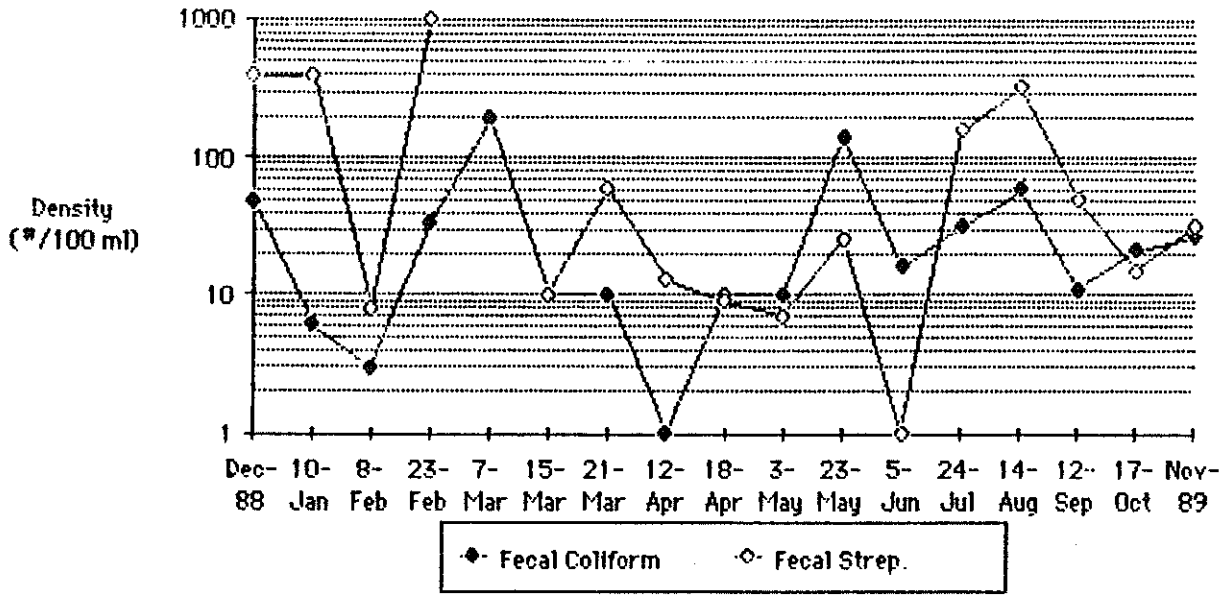


Figure 20. Bacteria densities at Lake Creek station LC-1.

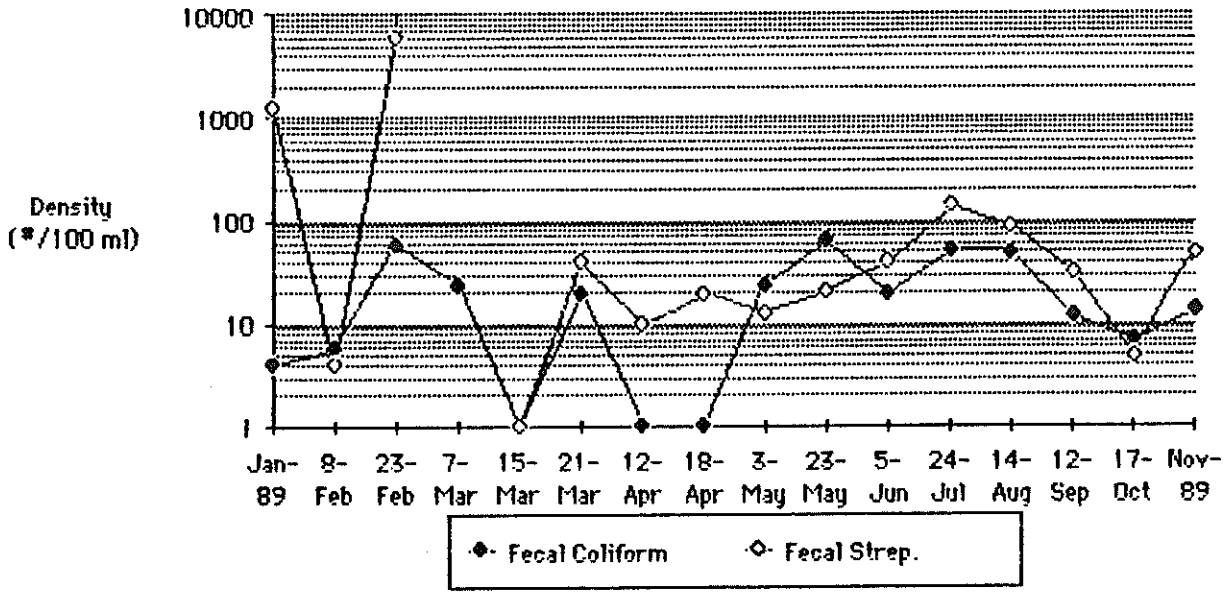


Figure 21. Suspended Sediment and Turbidity Concentrations in Lake Creek Station BC.

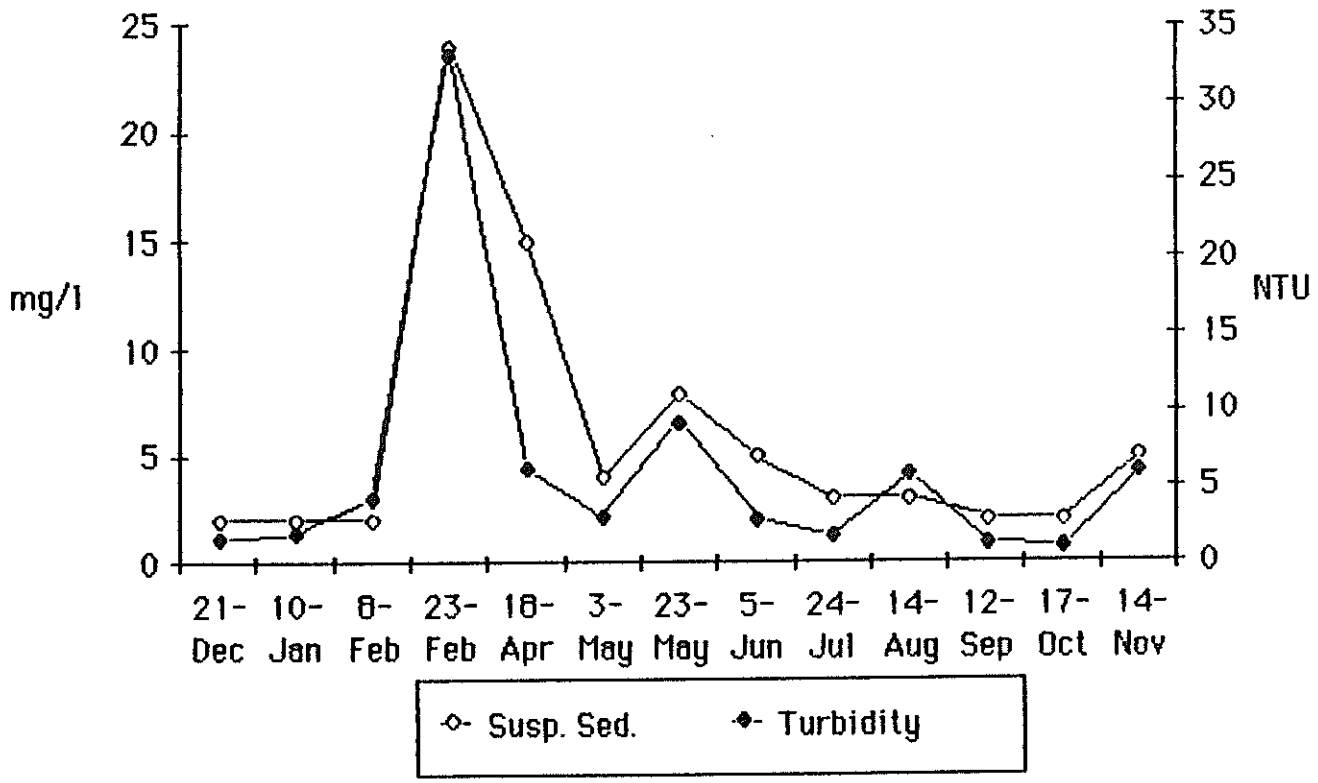


Figure 22. Suspended Sediment and Turbidity Concentrations in Lake Creek Station LC-3.

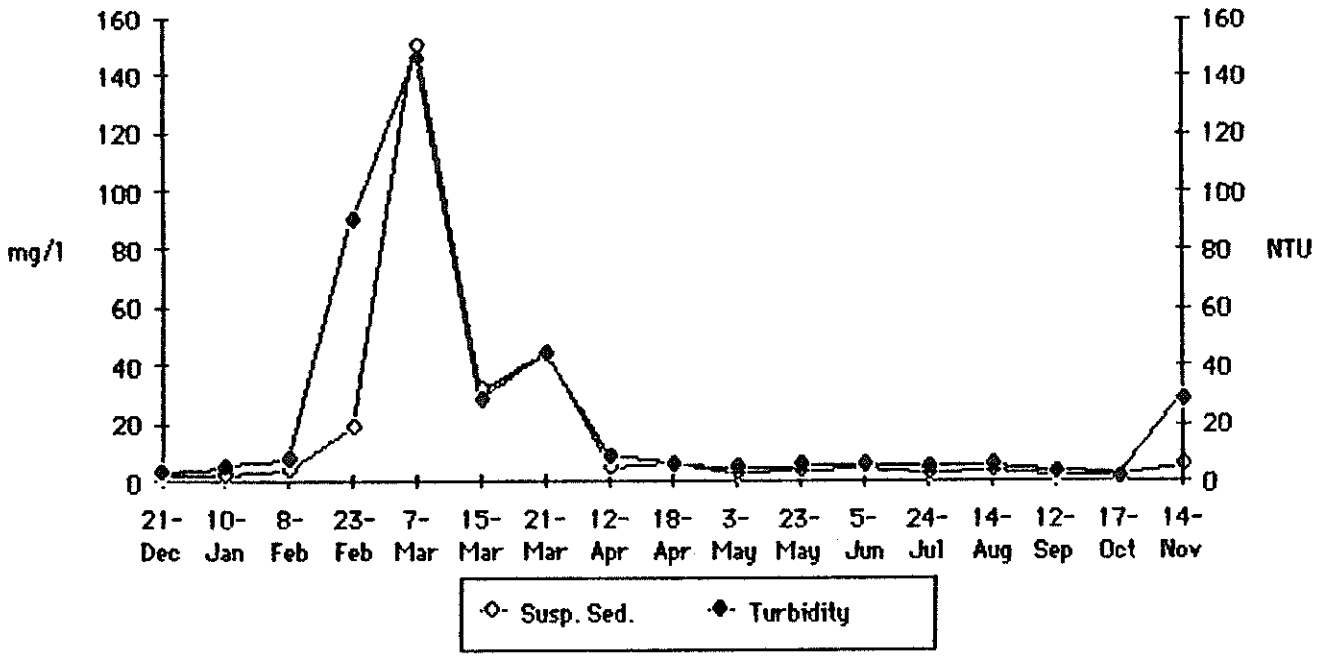


Figure 23. Suspended Sediment and Turbidity Concentrations in Lake Creek Station LC-2.

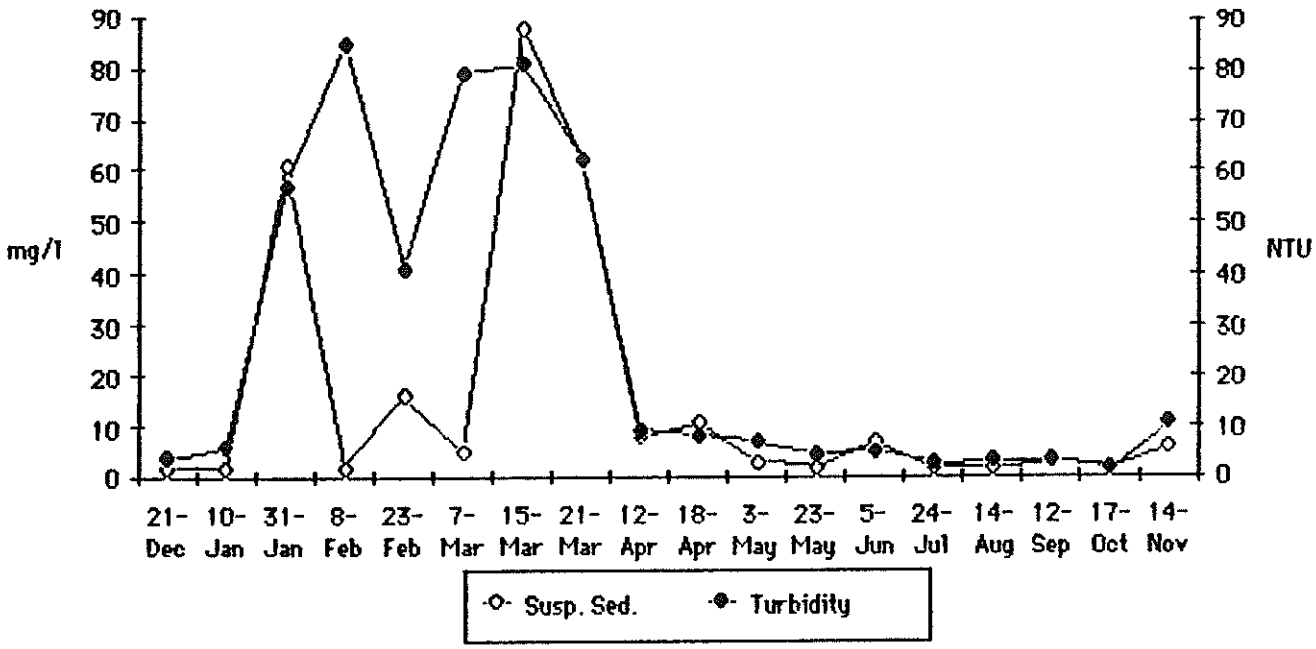


Figure 24. Suspended Sediment and Turbidity Concentrations in Lake Creek Station LC-1.

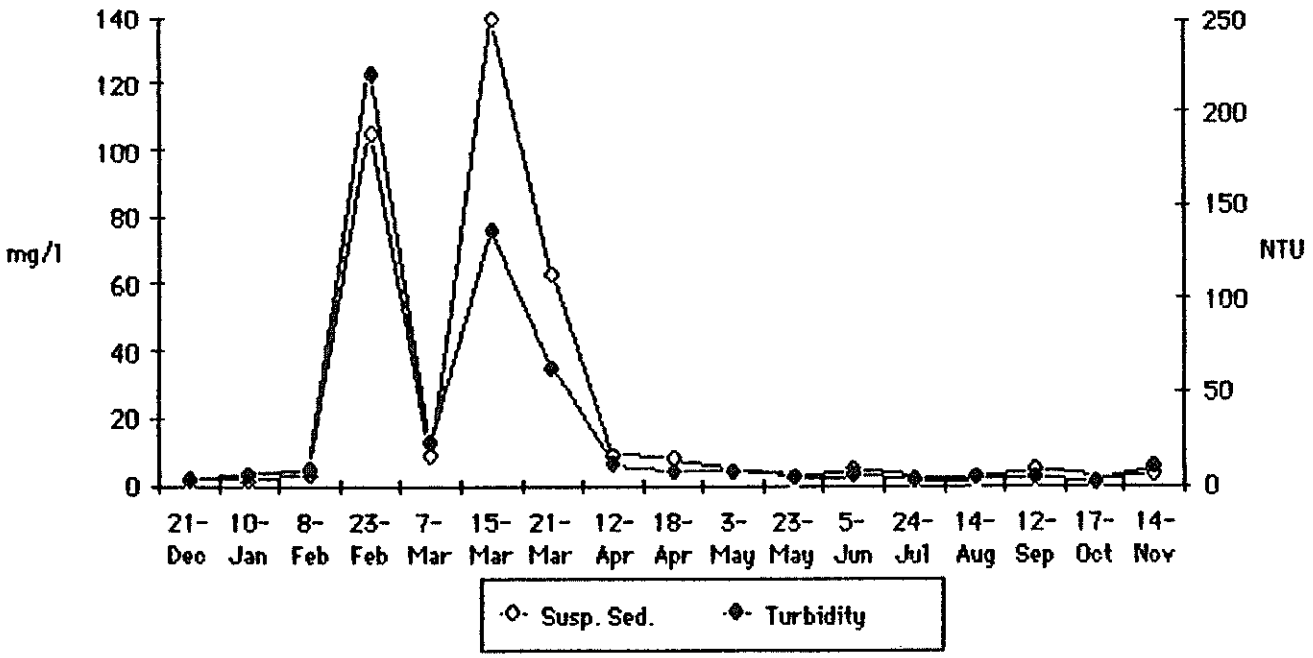
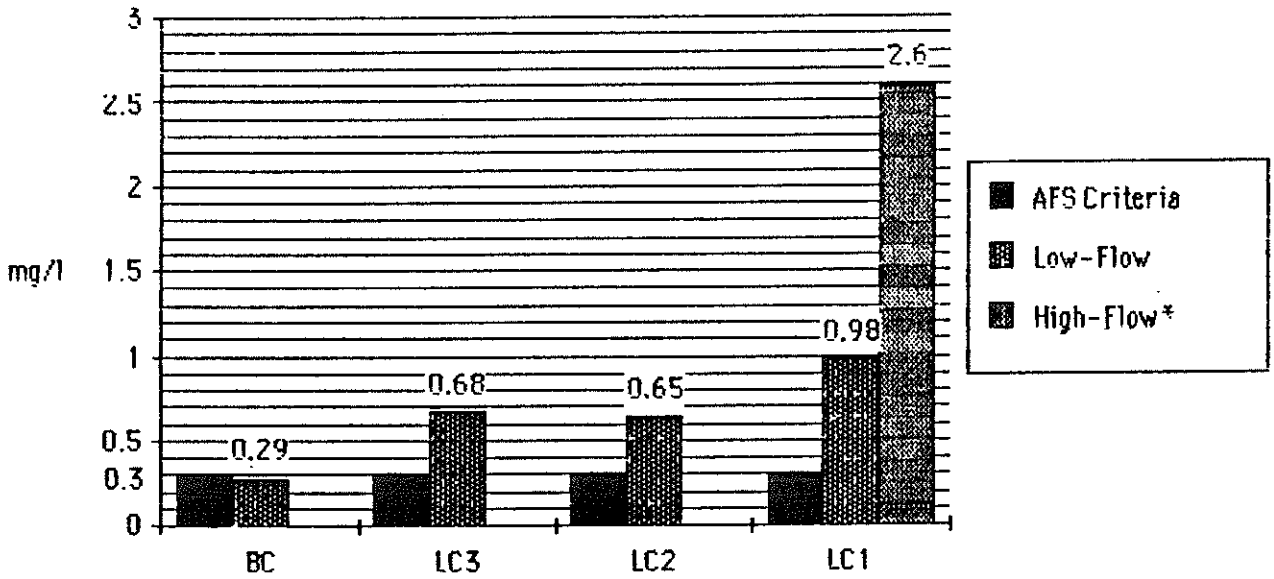


Figure 25. Total iron in Lake Creek ambient stations, 1989.



*Highflow data for LC-1 only.

Figure 26. Suspended Sediment in Windy Bay.

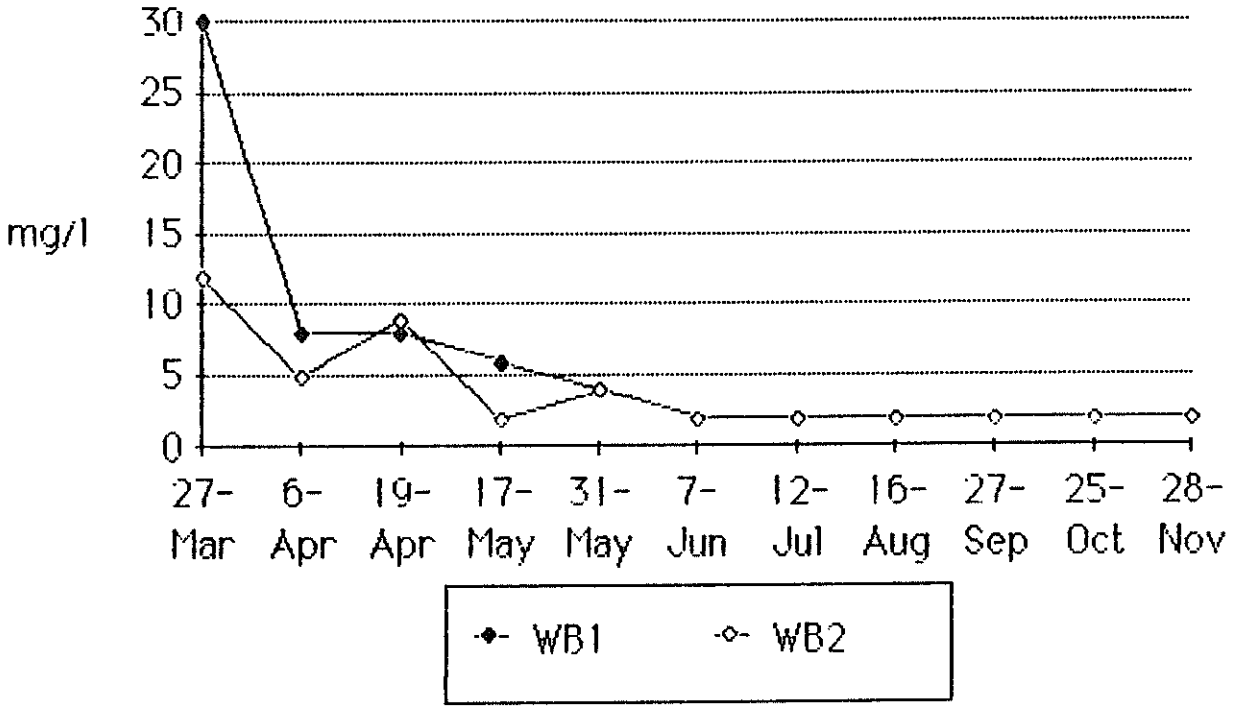


Figure 27. Distribution of Phosphorus in Windy Bay, 1989.

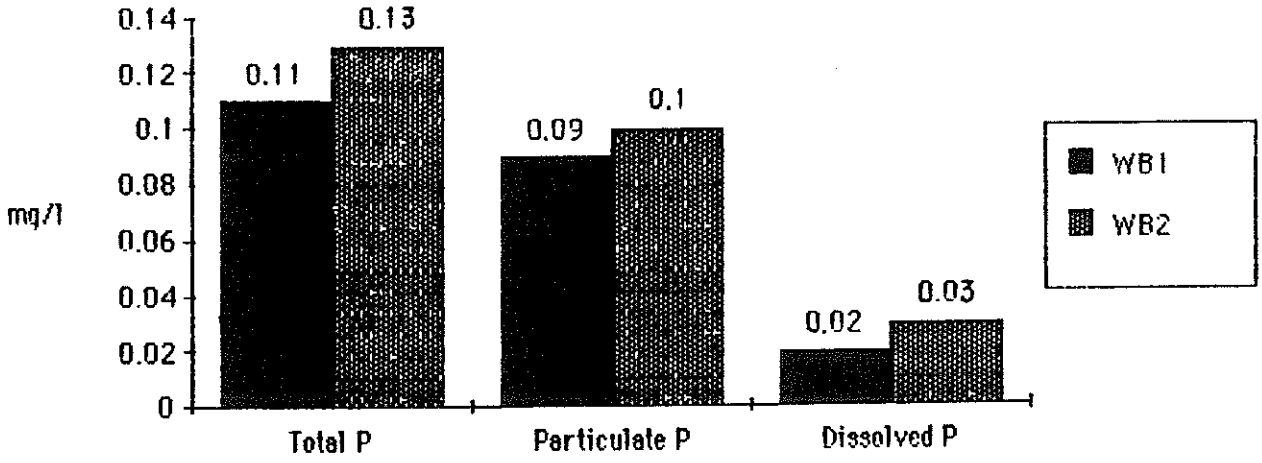


Figure 28. Chlorophyll a in Windy Bay, 1989.

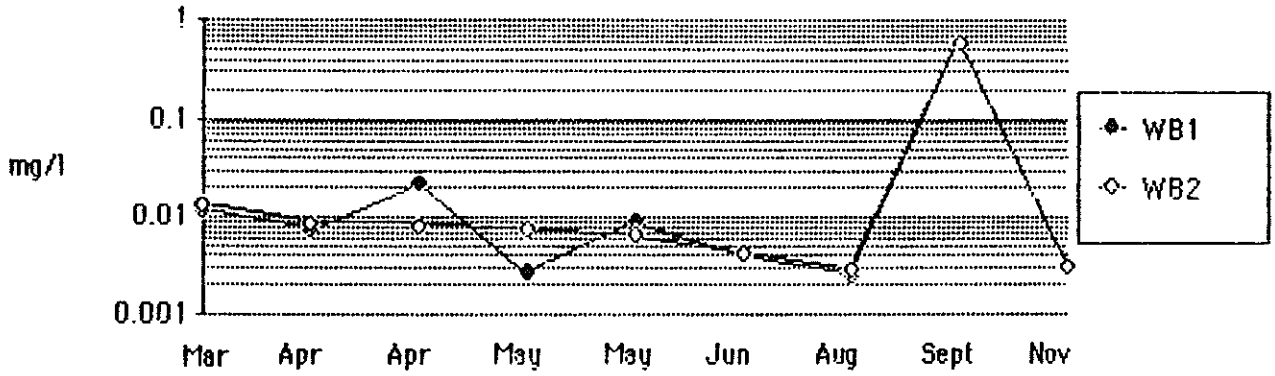


Figure 29. Temperature/DO Profile
Station WB2 4/6/89

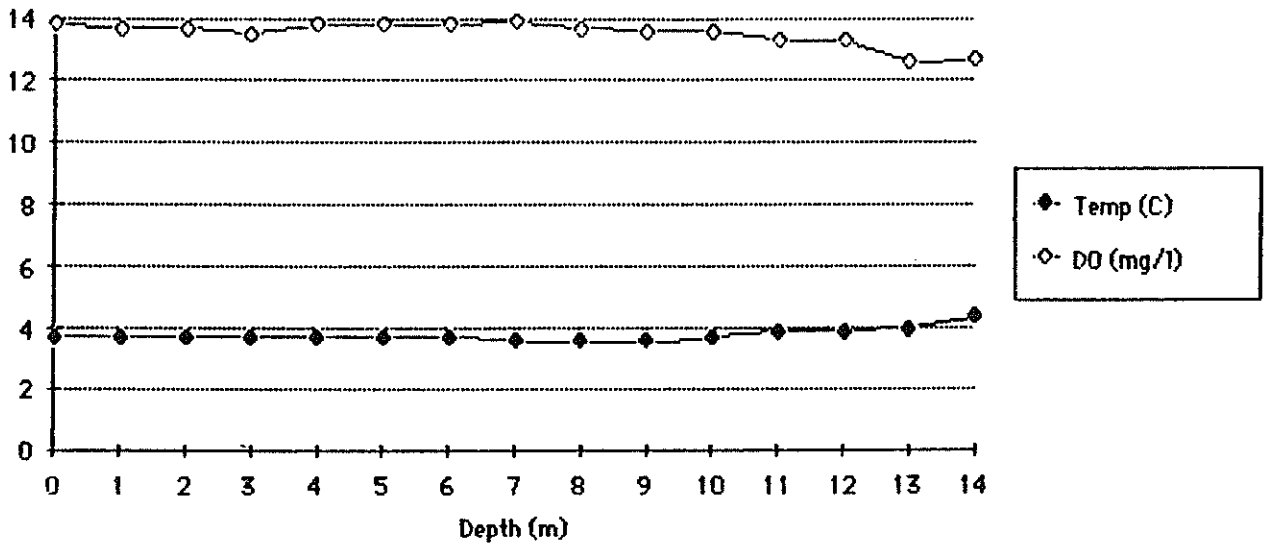


Figure 30. Temperature/DO Profile
Station WB2 4/19/89

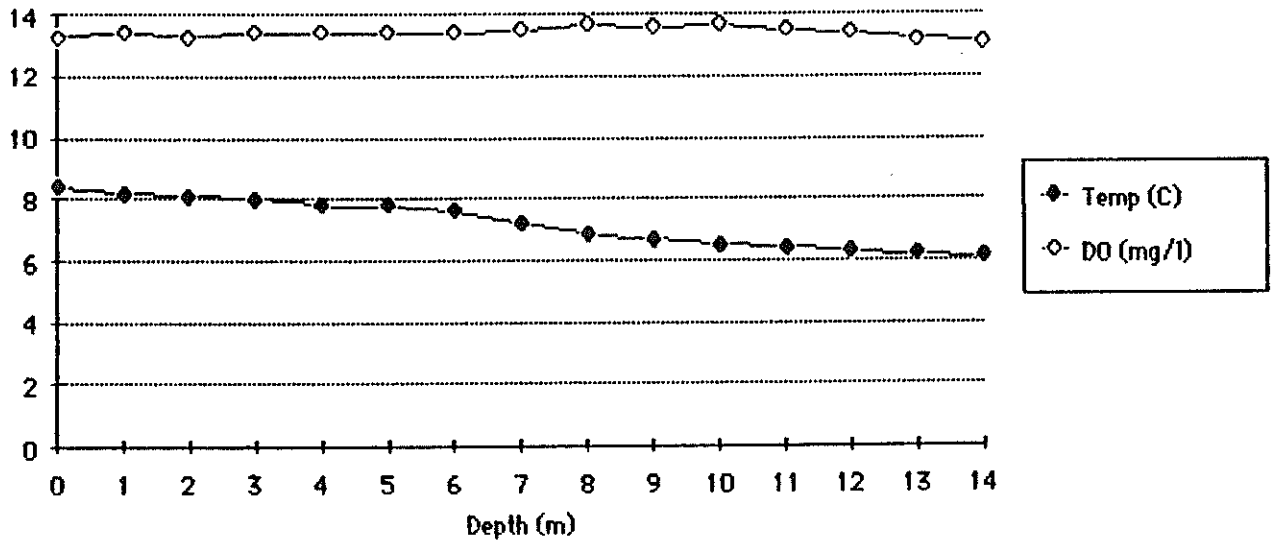


Figure 31. Temperature/DO Profile
Station WB2 5/17/89

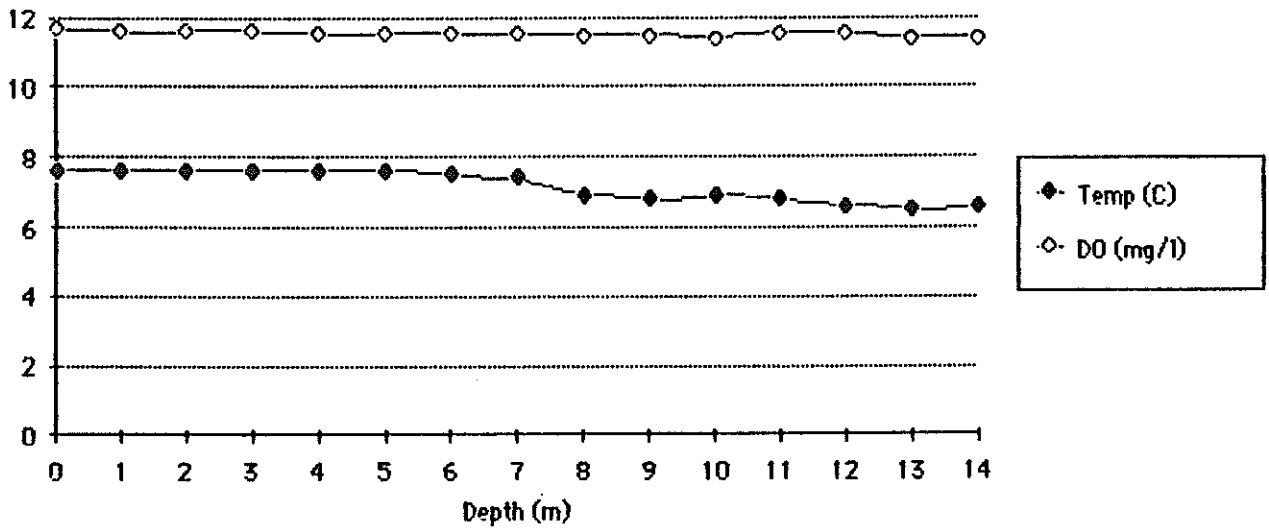


Figure 32. Temperature/DO Profile
Station WB2 5/31/89

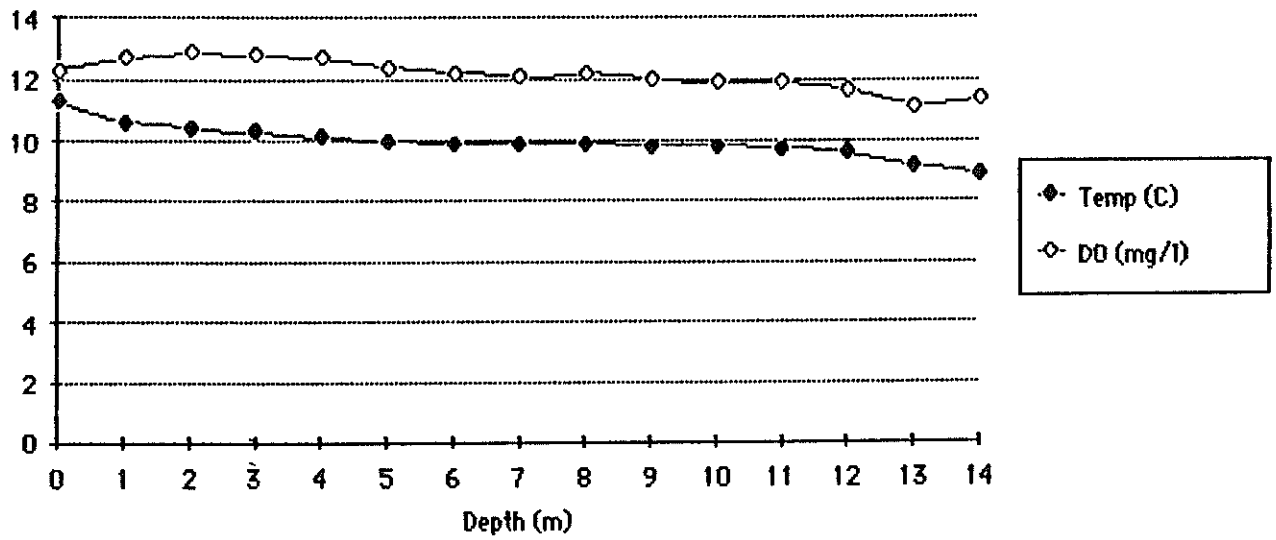


Figure 33. Temperature/DO Profile
Station WB2 6/7/89

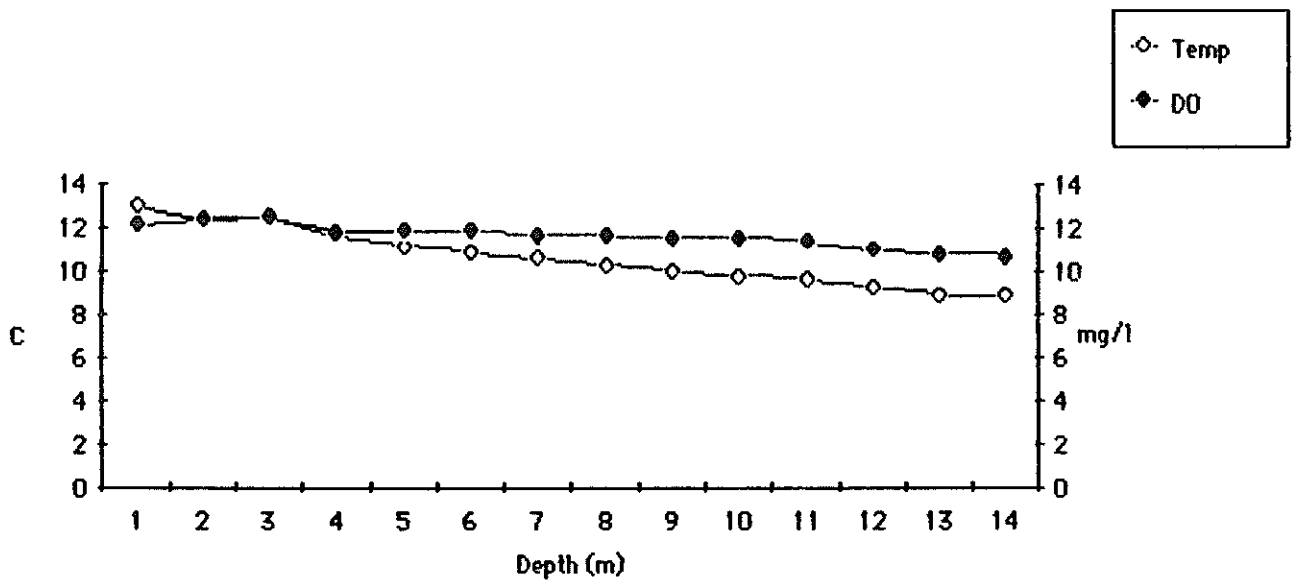
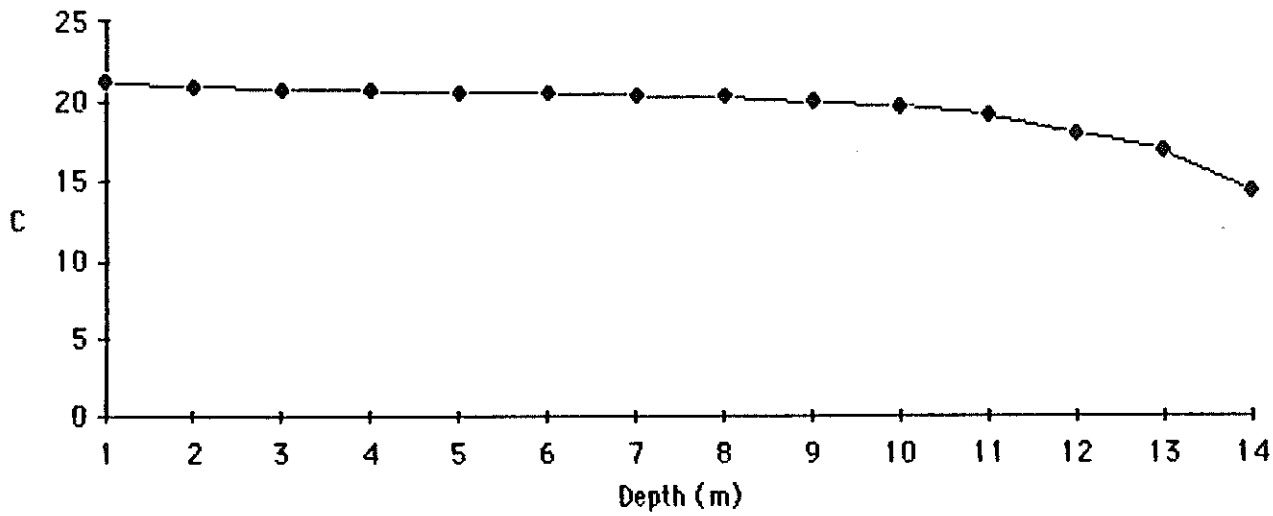


Figure 34. Temperature Profile
Station WB2 7/12/89



* No dissolved oxygen data

Figure 35. Temperature/DO Profile
Station WB2 8/16/89

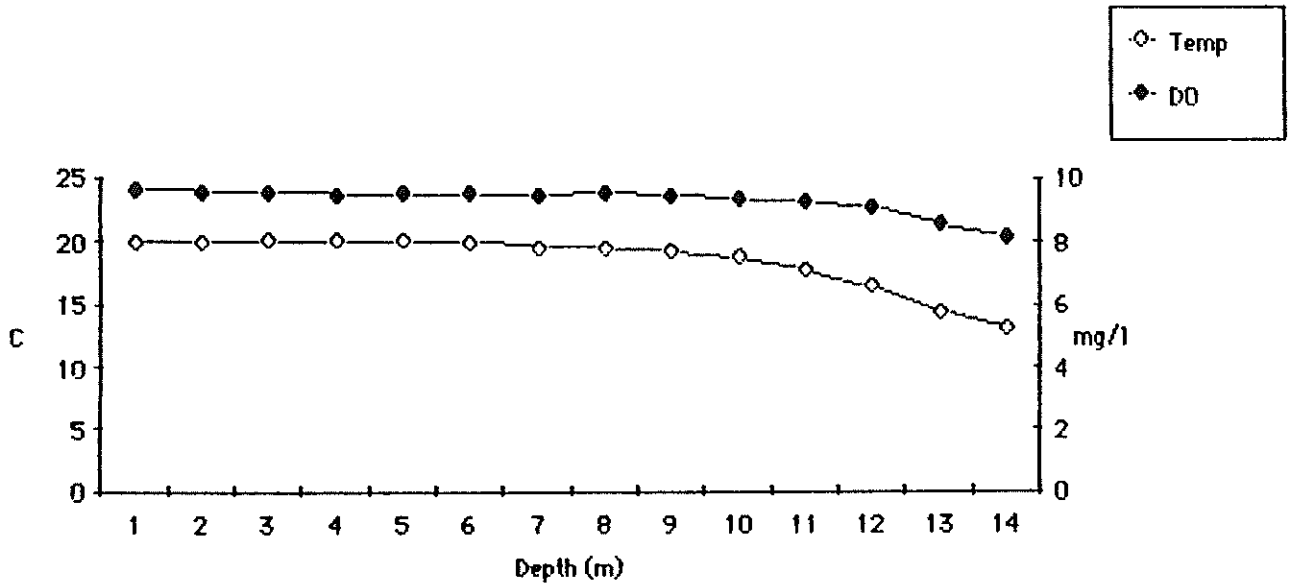


Figure 36. Temperature/DO Profile
Station WB2 9/27/89

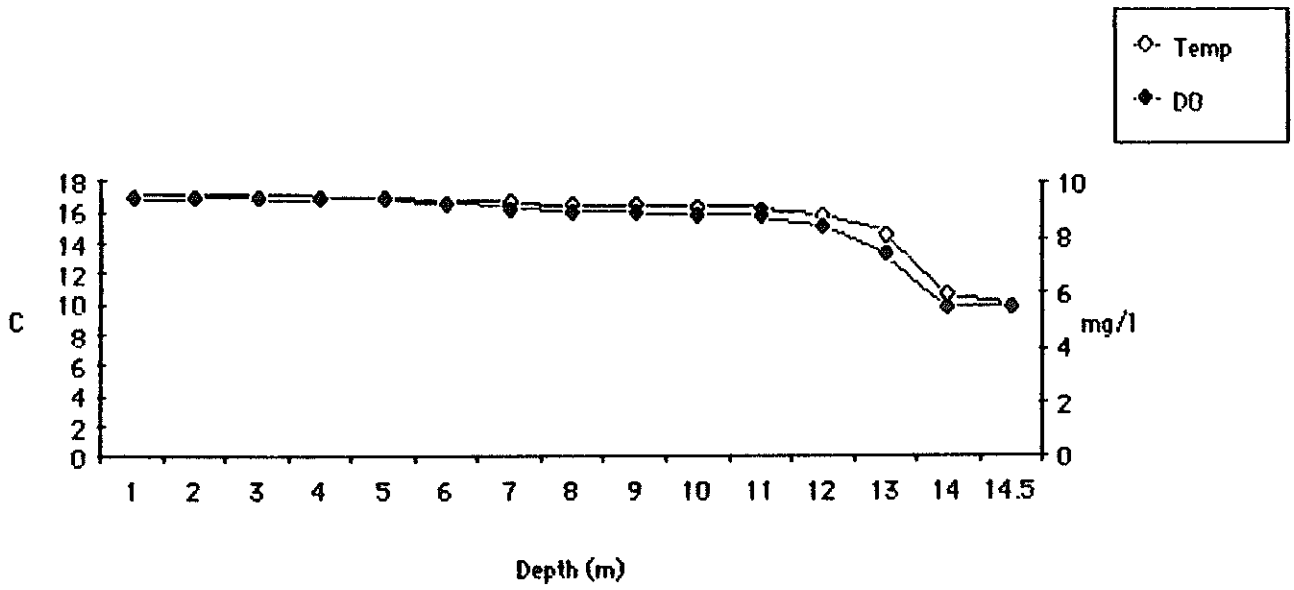


Figure 37. Temperature/DO Profile
Station WB2 10/25/89

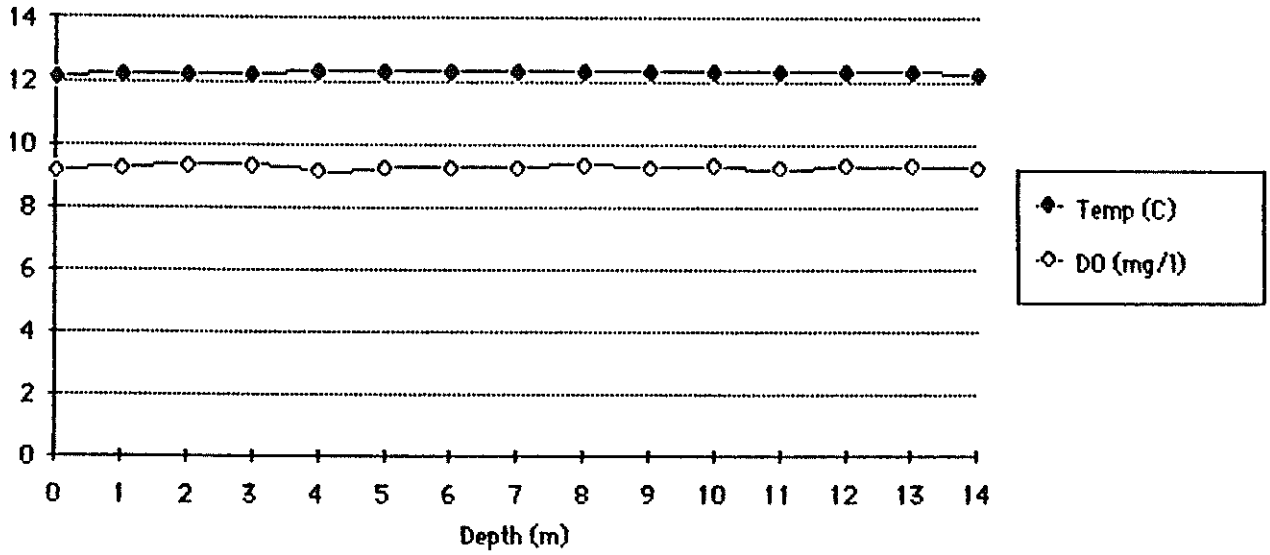


Figure 38. Temperature/DO Profile
Station WB2 11/28/89

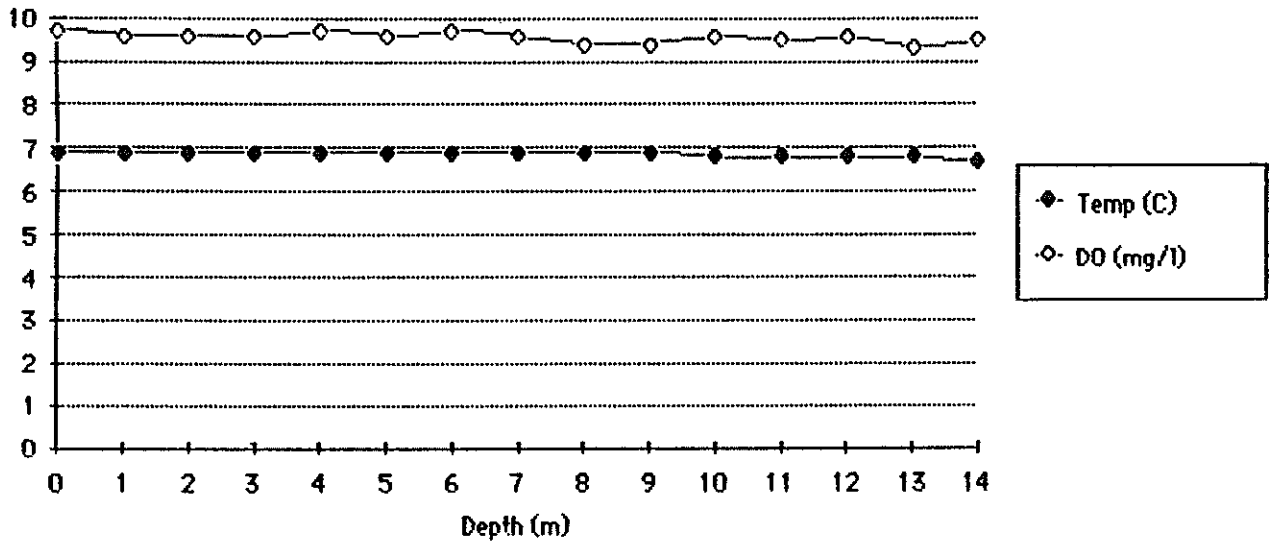


Figure 39. Suspended Sediment and Turbidity at station WB1, 1989.

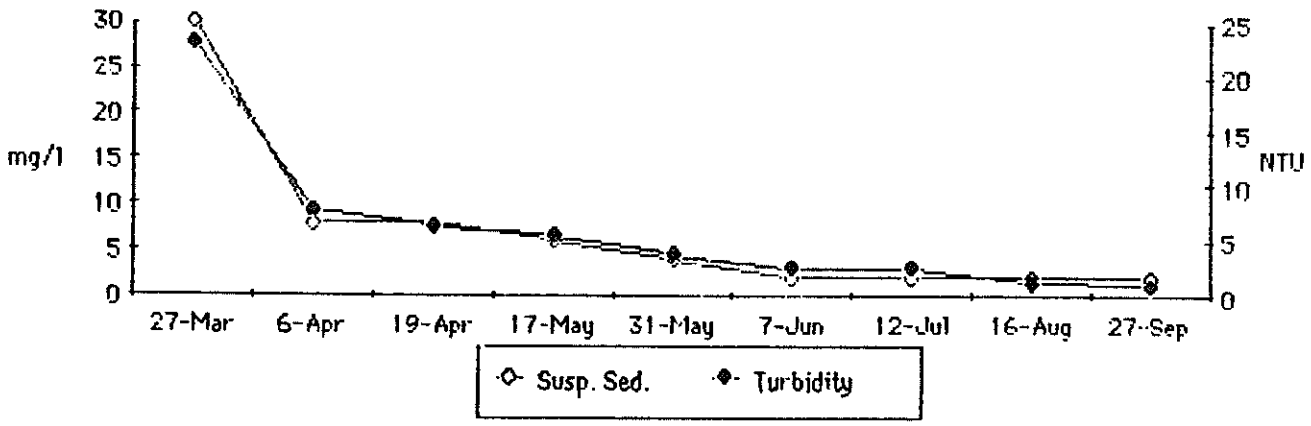
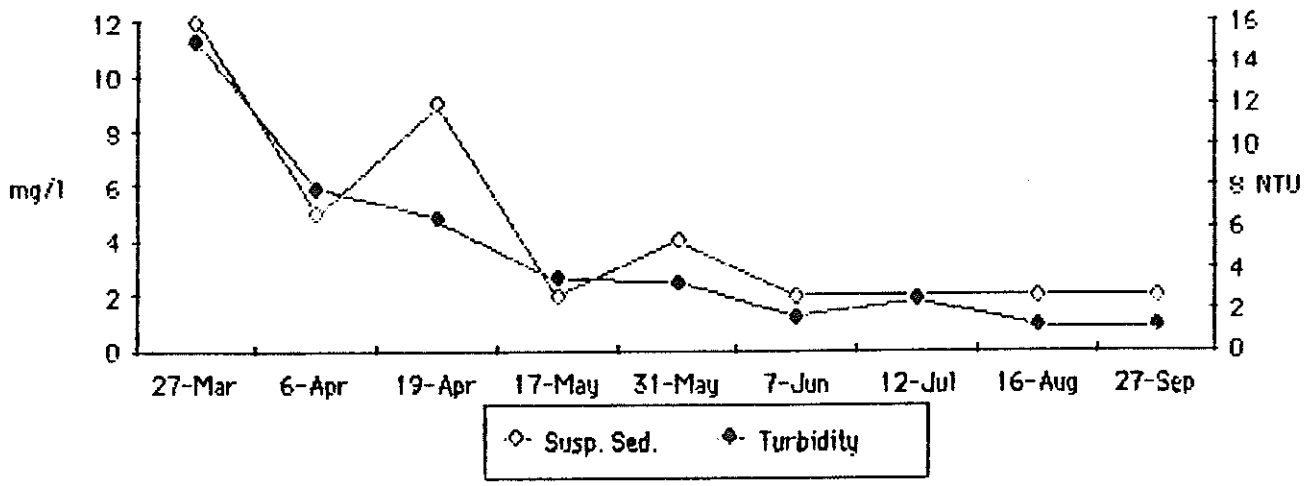



Figure 40. Suspended Sediment and Turbidity at station WB2, 1989.