DIAGNOSTIC/FEASIBILITY STUDY REPORT
LAKE CAMPBELL/BATTLE CREEK WATERSHED
BROOKINGS, LAKE AND MOODY COUNTIES, SOUTH DAKOTA

SOUTH DAKOTA CLEAN LAKES PROGRAM
DIVISION OF WATER RESOURCES MANAGEMENT
SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
EAST DAKOTA WATER DEVELOPMENT DISTRICT
January 1993

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EXECUTIVE SUMMARY

Lake Campbell is a glacial outwash lake located five miles southwest of Brookings, South Dakota. The surface area of the lake is approximately 800 acres. Battle Creek discharges into the south end of the lake, and accounts for nearly all the runoff from a watershed area of 112,560 acres. Land use in the watershed is over 90% agricultural, involving either livestock or crop production.

During recent years, property owners and recreational users of the lake have expressed concerns about declining water quality. Other concerns relate to excessive algae blooms and decreasing depth of the lake caused by sedimentation.

In 1986, the Lake Campbell Association entered into an agreement with the State of South Dakota to begin dredging of the lake. The dredging project began in 1987, and continued through 1989. During that period, approximately 190,000 cubic yards of sediment were removed from the lake at a total cost of $414,000.

In 1989, the dredging at Lake Campbell was suspended so that an application could be made to the U.S. Environmental Protection Agency to conduct a Phase I Diagnostic/Feasibility Study. Completion of the study would allow watershed restoration to occur in conjunction with any future in-lake work.

The application and funding for a Diagnostic/Feasibility Study of Lake Campbell was approved by the U.S. Environmental Protection Agency on June 5, 1990. The study period for the Phase I grant extended from July 1, 1990 to May 30, 1992.

Key elements of the study included water quality monitoring of the lake and watershed, an analysis of land uses and nonpoint sources of pollution in the watershed, a socio-economic study of the potential user population, a shoreline erosion survey, a septic system survey, and a survey and analysis of the bottom sediments of the lake.

Based on the results of the Phase I Study, the following conclusions have been drawn:

1. Water Quality

   The water quality of Lake Campbell and Battle Creek is in need of improvement. The results of in-lake sampling indicated that State Water Quality Standards were not met on a number of occasions for dissolved oxygen, pH, and un-ionized ammonia. In addition, water quality monitoring of the lake showed high levels of nutrients, which would cause excessive algae and weed growth. The results of the tributary sampling on Battle Creek indicated increasing cumulative loads of sediment and nutrients flowing downstream in Battle Creek to Lake Campbell. However, mean concentrations of sediment and nutrients

were higher at some of the upstream monitoring sites. This would indicate that these areas may be contributing greater loadings of sediment and nutrients on a per acre basis.

2. Watershed Analysis

The analysis of the Battle Creek watershed indicated that two areas contributed relatively greater amounts of sediment on a per acre basis. One of these areas is located immediately adjacent to the lake. Because of its location, this area has the potential to directly contribute significant loadings of sediment and nutrients to the lake. The analysis of the watershed also indicated that implementation of best management conservation practices could significantly reduce discharges of sediment and nutrients to Lake Campbell.

3. Shoreline Erosion

A survey of shoreline erosion around Lake Campbell was conducted. A total of 4,155 feet of shoreline were found to be in categories of minor to moderate/severe erosion. These areas of shoreline erosion represent direct loadings of sediment into Lake Campbell.

4. Septic Systems

A survey of the septic wastewater disposal systems around Lake Campbell was conducted on May 19, 1991. About 10% of the septic systems around Lake Campbell are known to be out of compliance with current construction requirements.

5. Sediment Analysis and Survey

A sample of the sediment from Lake Campbell was collected and analyzed for metals, pesticides, and other potentially toxic chemicals. The results of the analysis indicated dredging activities that would disturb the bottom sediments sampled would not release excessive levels of chemicals. A survey of the bottom sediment in Lake Campbell indicated that the estimated sediment volume in Lake Campbell is 7,840,000 cubic yards.

In order to address the water quality problems in Lake Campbell and the Battle Creek watershed, it is recommended that restoration activities be implemented in the following areas:

1. Information/Education Program to Promote Best Management Practices
2. Feedlot Runoff Control
3. Shoreline Erosion Control
4. Sanitary District Establishment
5. Wetlands Evaluation, Restoration, and Establishment
6. Dredging

Further information on implementing these restoration activities is included in the RESTORATION ALTERNATIVES AND RECOMMENDATIONS section at the end of this report.

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INTRODUCTION

The Phase I Diagnostic/Feasibility Study of Lake Campbell was initiated at the request of the Lake Campbell Association. The purpose of conducting the Phase I Study was to determine the sources of water quality problems in Lake Campbell and its watershed area, and to recommend alternatives for lake restoration activities.

The Phase I Study was undertaken as a cooperative effort between the South Dakota Department of Environment and Natural Resources, the East Dakota Water Development District, and the Lake Campbell Association. A local project coordinator was hired by the East Dakota Water Development District to conduct water quality monitoring, and to assist with the development of background information for the study. The interpretation of data, recommendations for feasible lake restoration alternatives, and compilation of the final report have been the responsibility of the South Dakota Department of Environment and Natural Resources.

The remainder of this report will present the findings of the Phase I Diagnostic/Feasibility Study for Lake Campbell, and discuss the rationale for selection of recommended restoration alternatives.

LAKE IDENTIFICATION AND LOCATION

Lake Name: Lake Campbell

State: South Dakota

County: Brookings County, SD

Nearest Municipality: Brookings, SD

Latitude: 44 deg. 12 min. 36 sec. N.

Longitude: 96 deg. 50 min. 42 sec. N.

EPA Region: VIII

Major Tributary: Battle Creek

Receiving Body of Water: Big Sioux River

Please see Figure 1 and Figure 2 for maps showing the location of Lake Campbell and the Battle Creek watershed.

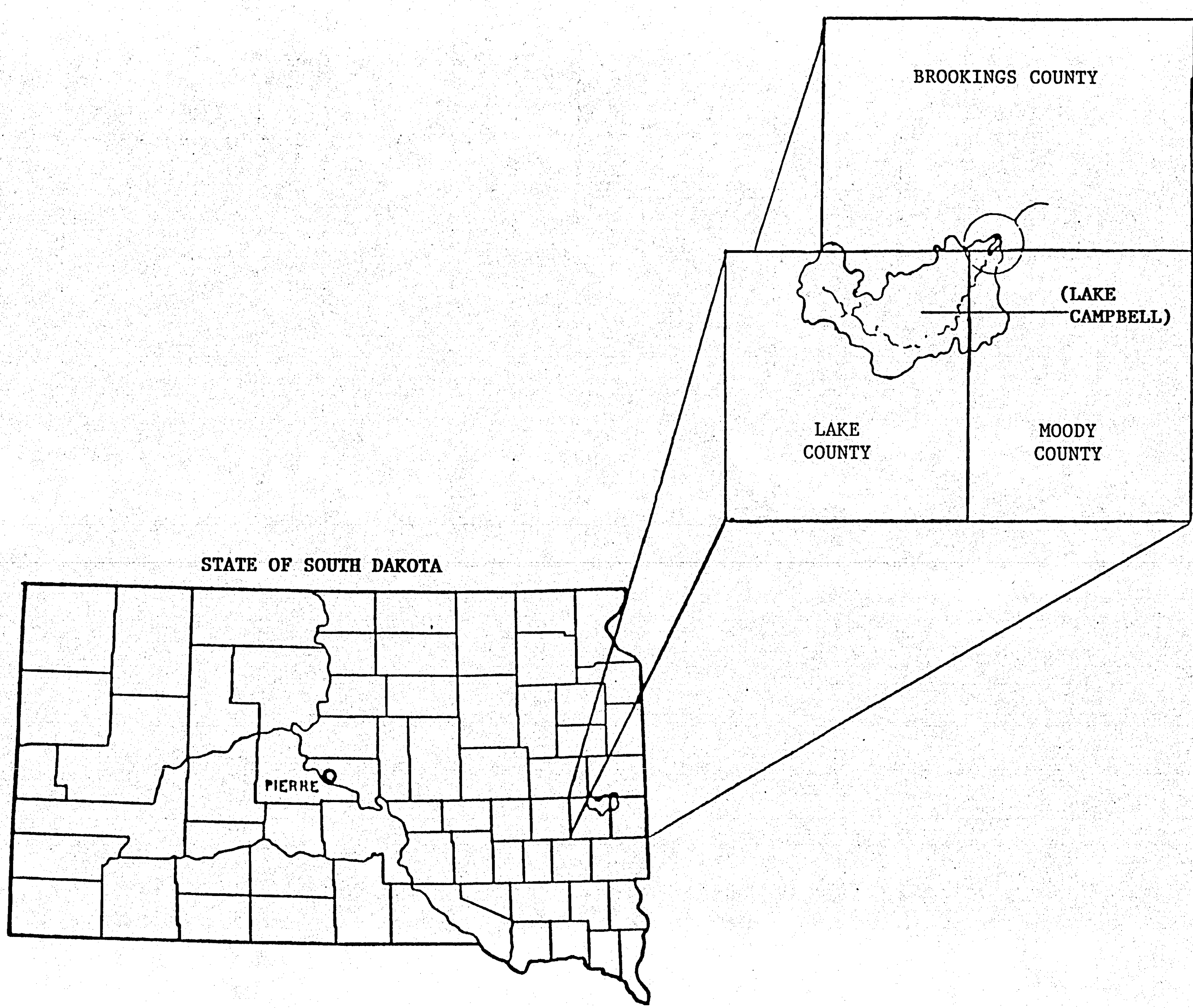
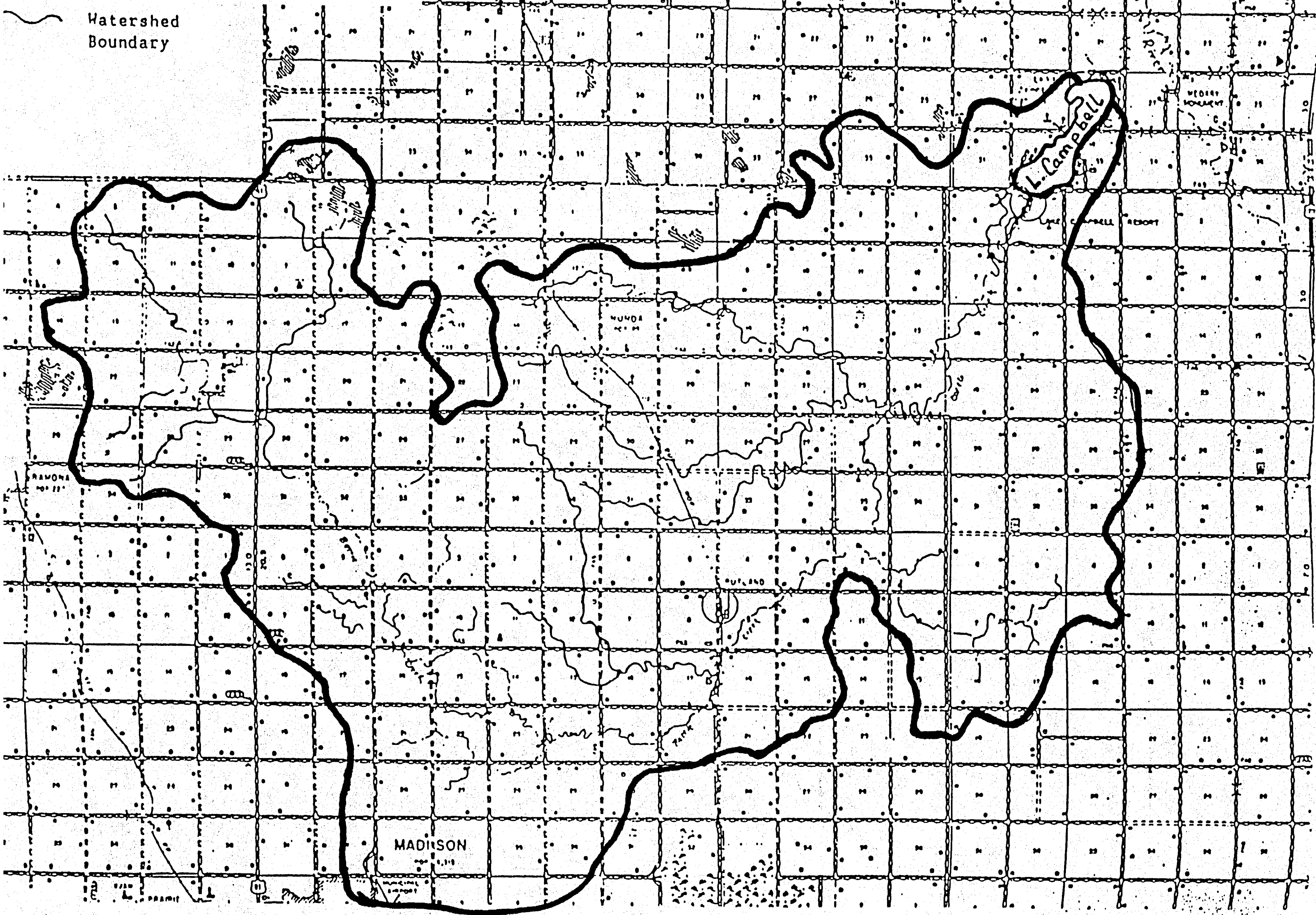


Figure 1. Lake Campbell Location Map

Figure 2. Lake Campbell/Battle Creek Watershed Boundary



WATER QUALITY STANDARDS

The water quality standards for Lake Campbell are shown below:

1. Designated Uses

   a. Warm Water Marginal Fish Life Propagation: lakes and streams which will support aquatic life and more tolerant species of warmwater fish naturally or by frequent stocking and intensive management but which suffer frequent fish kills because of critical natural conditions.

   b. Immersion Recreation: waters which are suitable for uses where the human body may come in direct contact with the water to the point of complete submersion and where water may be ingested accidentally or where certain sensitive organs such as the eyes, ears and nose may be exposed to the water.

   c. Limited Contact Recreation: waters which are suitable for boating, fishing and other recreation where contact maybe made with the water but the person's eyes, mouth and ears would not likely be immersed.

   d. Wildlife Propagation and Stock Watering: lakes and streams which are satisfactory as habitat for aquatic and semi-aquatic wild animals and fowl and are suitable quality for watering of domestic and wild animals.

2. Applicable Criteria

   Water quality criteria for the maintenance of these beneficial uses are contained in Table 1, Lake Campbell Water Quality Standards.

DESCRIPTION OF PUBLIC ACCESS

Access to Lake Campbell is excellent, with three ramps evenly distributed around the lake (Figure 3). One ramp, located on the north end of the lake, is accessible by a newly graveled and widened road, entering from a paved county highway. A second ramp is located on the east side of the lake. Although the road to the east access is of marginal quality, the ramp itself is one of the best on the lake. The Department of Game, Fish, and Parks has tentative plans to acquire an easement and maintain the road. The third access is a double-wide cement ramp on the south side of the lake. There is direct access to this ramp from a paved county road.

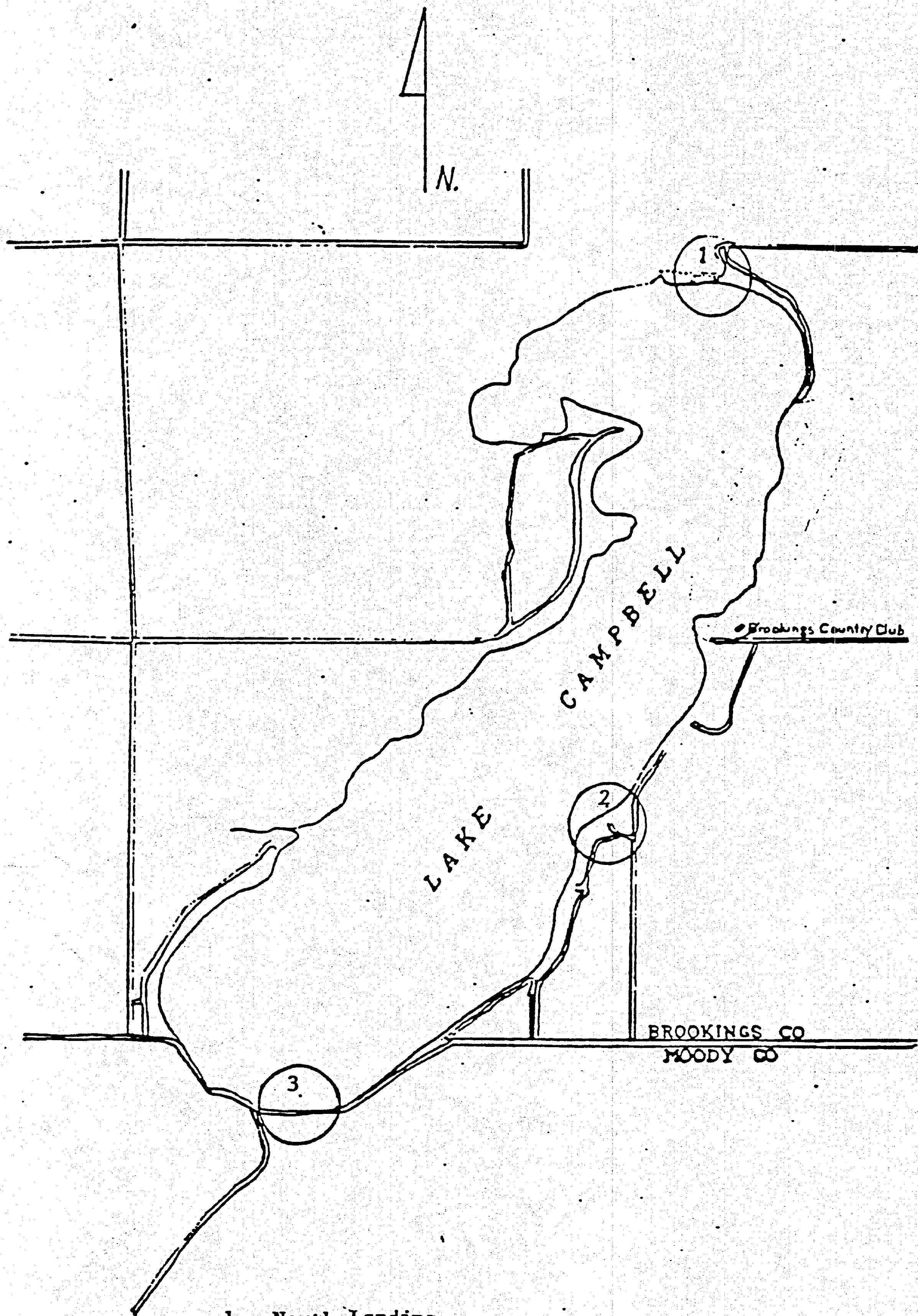
All three lake accesses provide free boat launching and shoreline use. The south access has camping facilities, a small store, and rental spaces for campers. The rental fees are used for facility upkeep.

There are no public transportation systems serving Lake Campbell. The lake is within close proximity of Brookings, SD, and many other rural communities (Figure 4). Private transportation is a convenient and preferred choice of travel. Facilities and accesses available at Lake Campbell are described in Table 2.

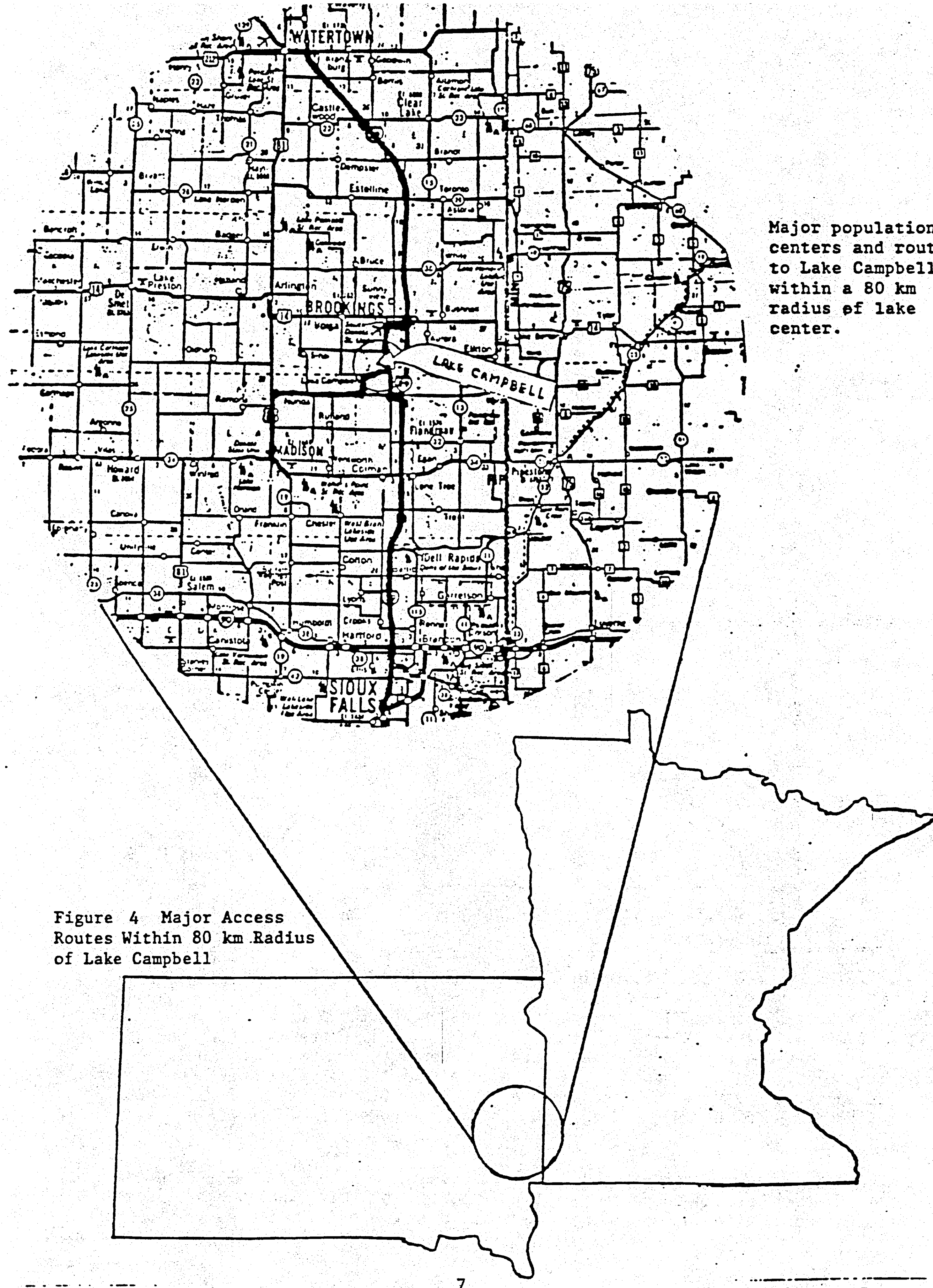
Table 1.
Lake Campbell Water Quality Standards

Parameter	Standard
Total Chlorine Residual	<0.02 mg/L
Un-Ionized Ammonia	<0.05 mg/L
Total Cyanide	<0.02 mg/L
Free Cyanide	<0.005 mg/L
Dissolved Oxygen	>5.0 mg/L
Undisassociated Hydrogen Sulfide	<0.002 mg/L
pH	>6.5 & <8.3 units
Suspended Solids	<150 mg/L
Temperature	<90° F
Polychlorinated Biphenyls	<0.000001 mg/L
Fecal Coliform Organisms	<200 per 100 mL
Total Alkalinity	<750 mg/L
Total Dissolved Solids	<2500 mg/L
Conductivity	<4000 micromhos/cm
Nitrates	<50 mg/L
Sodium absorption ratio	<10:1

Figure 3 Accesses to Lake Campbell



1. North Landing
2. Dance Land
3. South Shore



Major population centers and rout to Lake Campbell within a 80 km radius of lake center.

Figure 4 Major Access Routes Within 80 km Radius of Lake Campbell

Table 2. Facilities and Accesses at Lake Campbell

Name:	North Landing	Dance Land	South Shore
Responsible Agency:	SD Game, Fish, and Parks	Privately owned access road and parking.	South Dakota Game, Fish and Parks. Privately owned launch and pier.
Type:	Boat Launch	Boat Launch	Park
Land area: (ha)	4.86	.12	6.48
Lake Frontage: (m)	230	39	295
Facility type and capacities:	Launching ramp with capacity for 20-ft. and smaller boats, parking for 10, 200 m. public shoreline.	Launching ramp for small boats, parking for 10.	10 campsites, 1 camper rental, small boat launch, all-year store, swimming beach, 50 m. public beach, bath house. Parking for 400+
Fees:	None.	None.	Campsites $8.00* Campers $10.00*

*Some of the fees collected at South Shore go toward facility maintenance.

DESCRIPTION OF SIZE AND ECONOMIC STRUCTURE OF POTENTIAL USER POPULATION

A description of the size and economic structure of the potential user population for Lake Campbell was completed by Dr. Jim Satterlee, Director of the Census Data Center at South Dakota State University, Brookings, South Dakota (Satterlee, 1991). In conducting his analysis of the potential user population, Dr. Satterlee examined two areas surrounding Lake Campbell. The first area included a 50 mile radius of the lake, and the second area included just a 20 mile radius of the lake.

It was found that the total population represented within a 50 mile radius of Lake Campbell is 264,000 persons. Eighty percent of this population resides in South Dakota, with the remaining 20% residing in Minnesota. Seventy-six percent of these residents live in communities ranging in size from less than 50 persons to a metropolitan area of over 100,000 population. The remainder of this population lives on farms or acreages outside of incorporated city boundaries.

The total population living within a 20 mile radius of Lake Campbell is 40,180. Seventy-four percent of these residents live in communities ranging from 60 persons (Nunda) to the largest community (Brookings) directly adjacent to the lake with 16,253 persons.

Brookings is the home of the State's largest university (South Dakota State University) which has an enrollment of 7,500 students. The large number of young adults places a high demand on Lake Campbell for summer water sports and winter sports such as cross-country skiing, snowmobiling and ice fishing. Nearly 43% of the population within a 20 mile radius of the lake is between 15 and 24 years of age.

In examining the economic characteristics of the potential user population within a 50 mile radius of Lake Campbell, it was found that most persons are employed in non-manufacturing type occupations (77%). These occupations include agriculture, ag business, education, and service industries. The unemployment rate for this area is similar to the state average (3.4%), and well below the national average of 5.8%. The per capita income for the 50 mile radius around Lake Campbell is $8,626, which is substantially below the national average of $11,923, and slightly less than the State average of $8,910.

Complete copies of Dr. Satterlee's report on the Socio-Economic Characteristics of the Lake Campbell User Population are available from the South Dakota Department of Environment and Natural Resources.

SUMMARY OF HISTORICAL LAKE USES

Lake Campbell has occupied a unique niche in the history of southeastern South Dakota. It filled the recreational needs of early settlements with a resort and meeting place called the Hagensick Resort. Later Dance Land opened, which consisted of a dance hall and restaurant.

The Hagensick Resort was created in 1917 when William and Mary Hagensick filed for a government permit to establish a park on the south shore of Lake Campbell. The resort was enlarged to include 46 acres through subsequent purchases. It became one of the most popular resorts in South Dakota, and included amenities such as a swimming beach, a boat launch with complete motor service shop, and row boat rentals. In addition, there were baseball diamonds, picnic grounds, a roller skating rink, dance hall, gas station, restaurant, and a water slide.

The water slide, roller skating rink, and boat rentals were the main attraction at the Hagensick Resort. The water slide was constructed of wood and had an arch in it to project the riders 100 feet or more out into the water. The riders would climb to the top of the slide, and then pull up a toboggan. Two or three riders would sit in the toboggan for the ride down. It was not designed for the faint of heart.

During the 1930's, 1940's, and 1950's, thousands of families from throughout eastern South Dakota and western Minnesota drove to Hagensick's Resort regularly to spend days of rest and relaxation. In 1952, the resort was sold, and the ownership changed many more times after that. It became known as Johnson's Park in 1952. It finally closed in 1984, due to unfavorable water conditions. It was reopened under a new name, and on a much smaller scale, in 1989. Known as South Shore, the facility now consists of a small convenience store, bathhouse, and picnic ground.

The other major recreational center at Lake Campbell is Dance Land. In 1937, J.G. McClemans bought a parcel of land on the east side of Lake Campbell to build a hunting lodge. Eventually the facility expanded to contain two bars, a restaurant, and a dance hall. The dance hall and supper club operated until 1986 when it burned to the ground. The business was failing even before the fire, with the supper club open only by reservation.

Parents and grandparents of current residents can remember traveling to Lake Campbell to go fishing, skating, or dancing. It was the meeting place for many social happenings from approximately 1920 through the late 1950's. Shortly after that time the lake usage started to decline.

Actual usage data have never been kept on Lake Campbell, so an accurate estimate of loss in beneficial hours is difficult to assess. However, when comparing facilities that previously were maintained, to present-day facilities, it can be assumed that economic and recreational losses have been substantial.

It is speculated that declining water quality in Lake Campbell has been a factor in decreased usage of business establishments around the lake. A chronological listing of facility openings and closures at Lake Campbell is shown in Table 3.

Table 3. Facility Openings and Closures at Lake Campbell

Date Opened-Closed	Name	Facilities
1917 - 1952	Hagensick Resort	Roller Skating, Store, Boat Rental, Swimming, Camping, Water Slide, Gas Station, Bar
1937 - 1986	Dance Land	Restaurant, Bar, Dinner Cruises, Dance Hall
1952 - 1984	Johnsons Resort	Roller skating, Store, Bar, Swimming, Camping, Store, Gas Station
1989 -	South shore	Store, Gas, Camping, Bath House

Wildlife Propagation

At the south end of Lake Campbell is a large wetland that is owned by the U.S. Fish and Wildlife Service (Figure 5). This wetland, which is maintained as a Waterfowl Production Area, is directly connected to Lake Campbell. It is a natural habitat for nesting and migrating waterfowl. Non-game species also use this area for reproduction, feeding, and resting. This wetland area is directly affected by the water quality within Lake Campbell.

Lake Campbell functions as a staging area for many types of waterfowl, including pelicans and Canada geese. The large, permanent wetlands at the south end of the lake are essential to waterfowl during droughts and migrational periods.

The shoreline of Lake Campbell is wooded, providing a home to great horned owls and other raptors. Bald eagles have been observed resting in these trees during migratory periods.

Research and Education

Lake Campbell is within a ten-minute drive of South Dakota State University at Brookings, South Dakota. South Dakota State University has Natural Science and Wildlife Science Departments. The lake serves as a living laboratory for the for the university and its students.

In 1976, James Hayden used Lake Campbell for his thesis research on coteau lakes. Marlene Schwienforth completed a masters degree thesis on Lake Campbell algae populations in 1984. According to Dr. Charles Scalet, professor of biology and fisheries at South Dakota State University, limnology labs are conducted at the lake every year.

Sport Fishing

The first recorded fish stocking of Lake Campbell occurred in 1959, with the introduction of 250,000 northern pike fry. Since then numerous northerns, perch, and crappies have been stocked (Table 4). Because periodic winter and summer fish-kills are experienced, state agencies stock fish that are tolerant to low oxygen.

Natural stocking of fish from the Big Sioux River occurs during periods of high water. Lake Campbell also has good, to fair, natural reproduction of game fish.

The potential for Lake Campbell to become a high quality fishery is hindered by the periodic fish-kills that occur. Because of occasional low oxygen levels, and the present rate of sedimentation in the lake (0.5 to 1.2 inches per year), it is anticipated that fish-kills will continue to be a recurring problem (Payne, 1983).

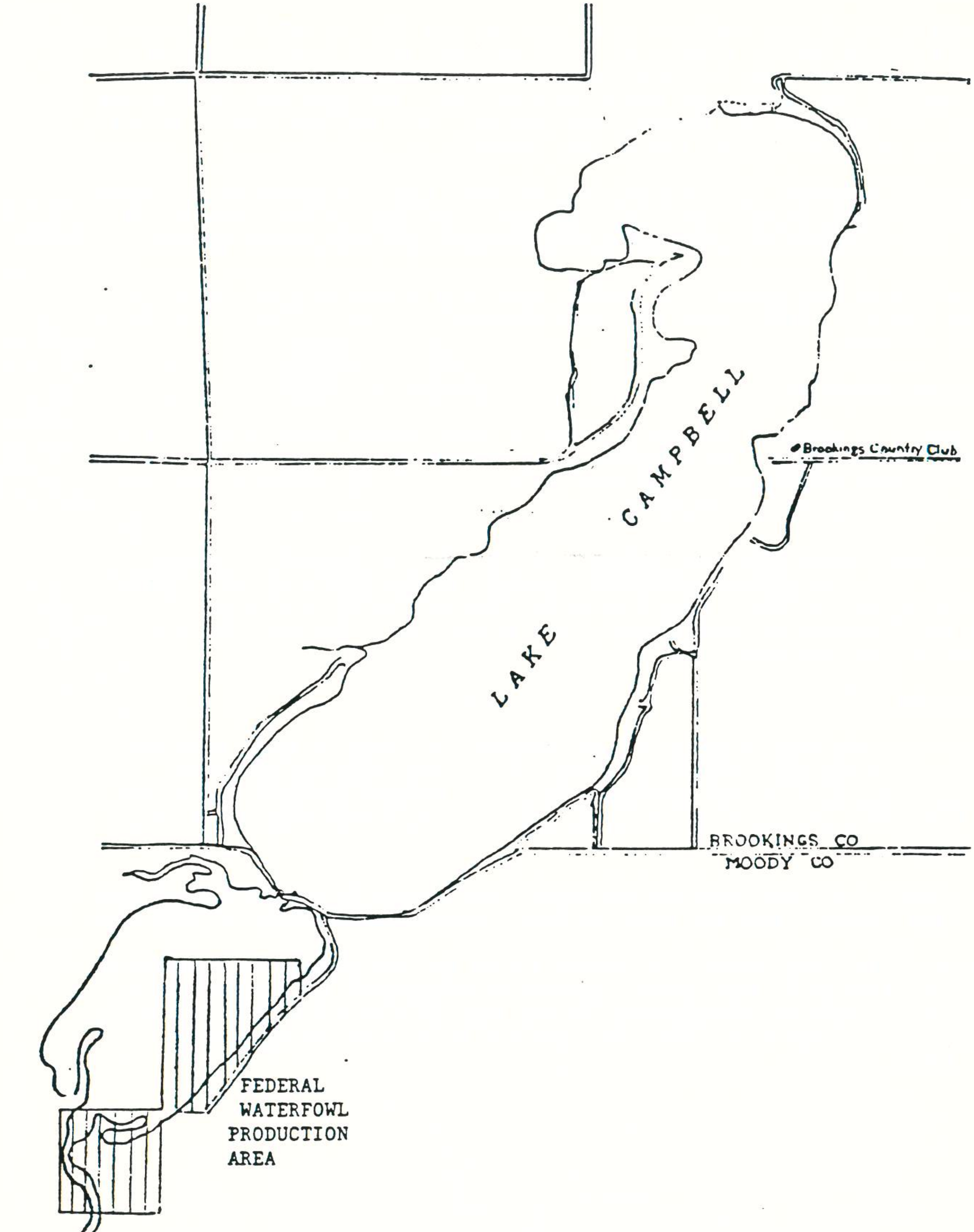


Figure 5 Federal Waterfowl Production Area Adjacent to Lake Campbell

Table 4.

Fish Stocking Records For Lake Campbell

Year	Number	Species	Size
1959	250,000	Northern Pike	Fry
1960	500,000	Northern Pike	Fry
	5,000	White Crappie	Adult
	3,000	Yellow Perch	Adult
1961	500,000	Northern Pike	Fry
	2,500	Yellow Perch	Adult
1962	300,000	Walleye	Fry
1963	3,500	Yellow Perch	Adult
1965	250,000	Northern Pike	Fry
	3,000	Yellow Perch	Adult
1967	160,000	Northern Pike	Fry
1968	500,000	Northern Pike	Fry
	2,000	Yellow Perch	Adult
1969	500,000	Northern Pike	Fry
	12,000	Yellow Perch	Adult
1970	500,000	Northern Pike	Fry
1971	500,000	Northern Pike	Fry
	1,500	Yellow Perch	Adult
1978	500,000	Northern pike	Fry
	300	Yellow Perch	Adult
	5	Black Crappie	Adult
1983	1,000,000	Northern Pike	Fry
1984	300	White Crappie	Adult
1986	500,000	Northern Pike	Fry
1988	31	Blue Gill	Fry
1989	500,000	Northern Pike	Fry

South Dakota Department of Game, Fish and Parks

POPULATION SEGMENTS ADVERSELY AFFECTED BY LAKE DEGRADATION

The population segments most deprived by the loss of suitable water conditions at Lake Campbell are those within a core area of approximately 20 miles. Within this area is the City of Brookings, which supports 7,000 university students each year. Lake Campbell has served as a major recreation area for these students. With the loss of facilities and declining water quality, the viability for beneficial uses has decreased. Permanent Brookings residents (population 14,000) could also lose a valuable alternative for recreational activities.

A list of businesses that would be affected by a change in water quality is contained in Table 5. This list contains only establishments within a ten-mile radius of the lake itself. Establishments further away might still be affected, but the effects would be more difficult to measure.

Table 5.

Type And Number of Businesses Affected By Lake Campbell Water Quality

Businesses	Number Within Ten-mile Radius
Bait Vendors	3
Boat Dealers	3
Sporting Goods Stores	4
Convenience Store*	1
Golf Course	1
Recreational Vehicle Dealer	1
Total	13

* actually on the lake

COMPARISON OF LAKE USES TO USES OF OTHER LAKES IN THE REGION

Lake Campbell is a small to medium-sized lake when compared to neighboring lakes in the region. Like most of the Prairie Coteau lakes, Lake Campbell was formed by glacial melting during the late Wisconsin Era, and is currently in a hypereutrophic condition.

The Prairie Coteau and surrounding region contain approximately two-thirds of all the lakes in South Dakota. Many of these lakes are too shallow and eutrophic to offer water-based recreation. Therefore, lakes that support recreational opportunities are valuable, based on their permanence and accessibility.

Listed in Table 6 are all the state park and recreation areas within an eighty-kilometer (50-mile) radius of Lake Campbell. Table 7 lists all area lakes that support permanent recreational opportunities, and the municipalities nearest to the lakes. A summary of lake accesses and recreational resources available to the public is contained in Table 8.

When compared with lakes of similar size in the the region, Lake Campbell compares very favorably in terms of recreational facilities available, such as boat ramps and public access areas. As indicated in Table 6, there are many park facilities within a 50 mile radius of Lake Campbell which attract people to the area for recreational activities. Lake Campbell provides a very important water-based recreational resource within this area.

TABLE 6

PARK FACILITIES FOR LAKES IN A 80 km RADIUS OF LAKE CAMPBELL

NAME	Acreage	User's Fee	Canoeing	Swimming	Boating	Fishing	Hiking Trail	Playground	Drinking Water	Paved Roads	Visitor Center	Concession & Food Center	Lodging	Campsites	Camping Fee	Comfort Station	Electrical Outlets	Dumping Station	Interpretive Program	Historic Site	LOCATION
STATE PARKS																					
Lake Herman	176	x	x	x	x	x	x	x	x	x		x*		69	x	x	x	x	R	x	2 mi. W Madison off SD 34
Oakwood Lakes	255	x	x	x	x	x	x	x	x	x	x	x*	x*	74	x	x	x	x	R	x	7 mi. N, 3 mi. W Volga off US 14
RECREATION AREAS																					
Cochrane Lake	88	x	x	x	x	x			x	x		x*		15	x						10 mi. E Clear Lake off SD 22
Pelican Lake	539		x	x	x	x			x				x	12							7 mi. SW Watertown US 212
Lake Vermillion	245	x	x	x	x	x	x	x	x			x*		49	x	x			R		5 mi. S off I-90 at Montrose exit
Lake Poinsett	151	x	x	x	x	x	x	x	x			x*		97	x	x	x	x	R		12 mi. N, 2 E Arlington off US 81
Walkers Point (Lake Madison)	37	x	x	x	x	x			x					44	x	x	x				2 mi. SE, 2S, 5E Madison off SD 19
LAKE USE AREAS																					
West Brant Lake																					5 mi. S Wentworth off SD 34
Lake Hendricks																					9 mi. 3 N White off SD 30
Lake Carthage																					1 mi. N Carthage

*Available outside park within 3 miles
R-Programs scheduled on a weekly basis

Source: S.D. Department of Game, Fish & Parks, Divsion of Parks & Recreation, 1990 State Park Guide

Table 7. Recreational Areas and Municipalities Within 80 Km. of Lake Campbell

Body of Water	Parks	Ramps	Uses	Nearest Municipality
Lake Hendricks	1	4	Swimming Boating Camping Fishing Picnicking	Hendricks, MN
Whitewood Lake		2	Boating Fishing	Lake Preston, SD
Spirit Lake		1	Fishing	Bancroft, SD
Lake Albert		1	Fishing	Lake Norden, SD
Lake Shaokatan		3	Swimming Boating Fishing Picnicking	Ivanhoe, MN
Lake Thompson		2	Boating Fishing Picnicking	Lake Preston, SD
Lake Benton	1	2	Boating Fishing Camping Picnicking Swimming	Lake Benton, MN
Lake Sinai		1	Boating Fishing	Sinai, SD
Lake Preston			Fishing	Lake Preston, SD
Lake Poinsett	1	6	Boating Fishing Swimming Camping Picnicking	Estelline, SD
Lake Herman	1	3	Boating Fishing Swimming Camping Picnicking	Madison, SD
Lake Madison	1	4	Boating Fishing Swimming Camping Picnicking	Madison, SD

Table 7. Recreational Areas and Municipalities Within 80 Km. of Lake Campbell (continued)

Body of Water	Parks	Ramps	Nearest Uses	Municipality
Brant Lake	1	3	Boating Fishing Swimming camping Picnicking	Chester, SD
Oak Lake			Fishing	Astoria, SD
Oakwoods Lake		1	Boating Fishing Swimming Picnicking	Bruce, SD
Tetonkaha	1	2	Boating Fishing Swimming Camping Picnicking	Bruce, SD
Wall lake		1	Boating	Hartford SD
Lake Carthage	1	2	Boating	Carthage, SD
Lake Cochrane	1	1	Boating Fishing Swimming Camping Picnicking	Brandt, SD

Table 8. Summary of Public Accesses/Recreational Resources Within 80 Km. Radius of Lake Campbell

Description of Public Accesses		Recreational Uses Available to the Public
County/City Parks	2	Swimming, Fishing, Camping, Picnicking
State Parks and Recreation Areas	7	Swimming, Fishing, Camping, Picnicking
Public Landings	39	Boat Launching

INVENTORY OF POINT SOURCE POLLUTION DISCHARGES

There are no known point source discharges of pollution to Lake Campbell.

GEOLOGICAL AND SOILS DESCRIPTION OF DRAINAGE BASIN

Geology

Lake Campbell and its surrounding watershed are located on the Coteau des Prairie. The prairie coteau area is an erosion remnant, irregularly covered with glacial drift. This drift is the parent material of the soils and shallow aquifers in the Lake Campbell watershed. The drift material consists of till and outwash laid down during the Wisconsin age. The till is composed of a heterogeneous mixture of material deposited directly by the glacier. It has a loamy texture consisting of about 40% sand, 34% silt, and 26% clay (Soil Survey, Moody County, 1989).

Lake Campbell is a glacial outwash lake located on a broad drift sheet that trends north and south, parallel to the Big Sioux River. There are no closed basins in this sheet. Water flows in an integral pattern to the Big Sioux River.

Eastern South Dakota was glaciated at least four times during the Pleistocene Epoch. Deposits left by these four ice sheets are from youngest to oldest: Wisconsin, Illinoian, Kansan, and Nebraskan. The Wisconsin age has been sub-divided into four sub-stages. The four sub-stages, in ascending order, are the Iowan, Tazewell, Cary, and Mankato (Figure 6).

No deposits older than the Wisconsin glacier are preserved in the Lake Campbell area. Little is known about pre-Wisconsin ice sheets; however, an accepted theory is that the glaciers entered from the northeast (Baldwin, 1951).

Much more is known about the Wisconsin age ice sheets because the till remained on the surface. Of the four Wisconsin glacial sub-stages in eastern South Dakota, the predominant remnants on the surface in the Lake Campbell area are from the Iowan and Cary ages.

Iowan deposits are generally referred to as till or boulder clays that are older than Tazewell deposits. Iowan deposits are characterized by level to slightly sloping topography upon which an intricate pattern of dendritic drainage is developed. The smooth till surface is partly due to mantling of the former rough topography of the earliest Wisconsin age.

Cary deposits are comprised of till, outwash, and glacial lake sediments. The Cary till is similar to Iowan till, but is differentiated by topography, absence of loess, and absence of well-defined drainage.

Cary till is characterized by knob and kettle topography which contains many filled depressions. The local relief varies greatly from ground to end moraine. In end moraine areas, the terrain is rugged with maximum slopes ranging from six to greater than ten percent. The ground moraine is also rugged, but slopes are usually less than six percent. Cary till varies from ten to seventy feet thick. The soil is normally poorly developed, and often only six inches thick. However, in some instances, the soil may reach a few feet in thickness.

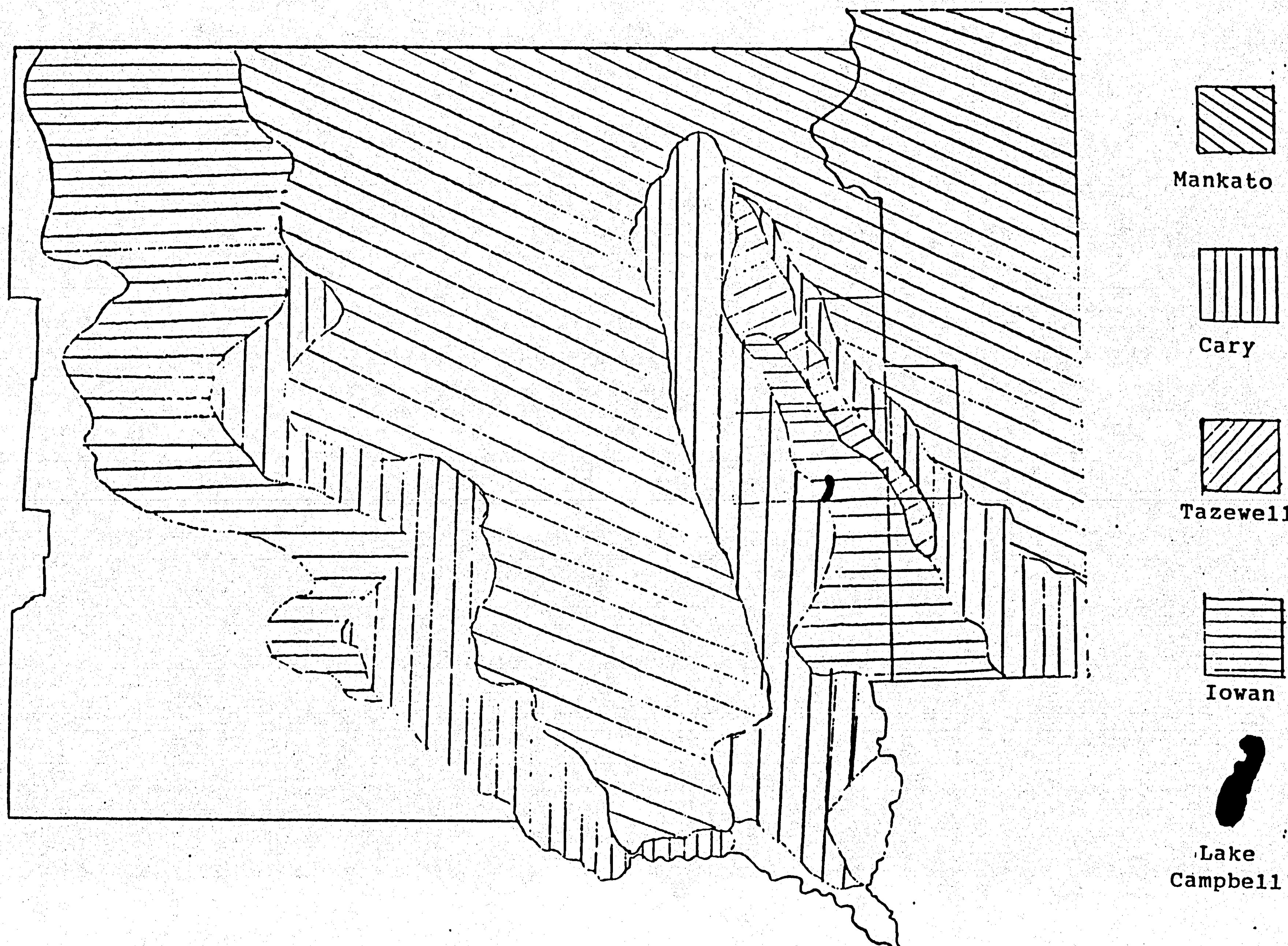


Figure 6. Glaciation of the Lake Campbell Watershed

Cary outwash sediments are expressed as three topographical types: valley train deposits, terrace remnants, and collapsed material (Steece, 1958). The more common valley trains are characterized by level, to nearly level, gently undulating topography. They occupy low areas, and are confined to stream valleys. The material consists primarily of poorly sorted sands and gravels, with carbonate rocks predominating.

The terraces are thin deposits of sand and gravel, ranging from eight to twenty feet in thickness (Tipton, 1958). The collapsed Cary outwash is difficult to distinguish from Cary till because the surface is rough and undrained. The outwash surface is closely underlain by sands and gravels, whereas the till is mostly a mixture of clay.

No bedrock is exposed in the Lake Campbell watershed and surrounding area. However, data obtained from well logs in the vicinity reveal Precambrian rocks beneath the surface deposits, unconformably overlain by rocks of the Cretaceous Age. Since the bedrock is beneath the unconfined aquifers in the Lake Campbell drainage area, it has little or no effect on the lake.

Topography

The Lake Campbell watershed is on an undulating and gently rolling glacial plain with many small depressions. The drainage pattern is poorly defined in most areas, but is well-defined along Battle Creek.

Slopes in the watershed generally vary between 0 and 6 percent, although two small areas less than 10 acres in size have slopes between 8 and 9 percent. A few areas less than 5 acres in size have slopes above 10 percent. Slopes range from 0 to 12.76 percent, and average 1.01 percent.

Soils

Soils that predominate in the Lake Campbell watershed are deep and well-drained. These predominant soils were formed over glacial till, and are found in the uplands and valleys of the watershed. The three primary soil types found in the Lake Campbell watershed are Egan, Wentworth-Sinai, and Dempster (Figure 7).

Egan soils have a silty clay and loam surface layer, approximately seven inches thick. The subsoil is silty clay loam, about 24 inches thick. The underlying material is a calcareous clay loam glacial till. Moderate organic matter characterizes the Egan soils, giving them medium to high fertility. Surface runoff is slow to medium. Permeability is moderate in the subsoil, and moderately slow in the underlying material. The available water capacity is high. The Egan soil slopes vary between 2 to 6 percent (Soil Survey of Moody County, SD, 1989).

Wentworth-Sinai soils are found on slightly higher ground, and are closer to the western end of the watershed. These soils are also deep and well-drained The surface layer is a silty clay loam, about seven inches thick. The subsoil is silty clay loam, about 27 inches thick. The underlying material is a calcareous silty clay loam. (Soil Survey of Lake County, SD, 1973).

Dempster soils are found along Battle Creek and its floodplain, on nearly level to slightly sloping surfaces. These soils have silty texture and are moderately

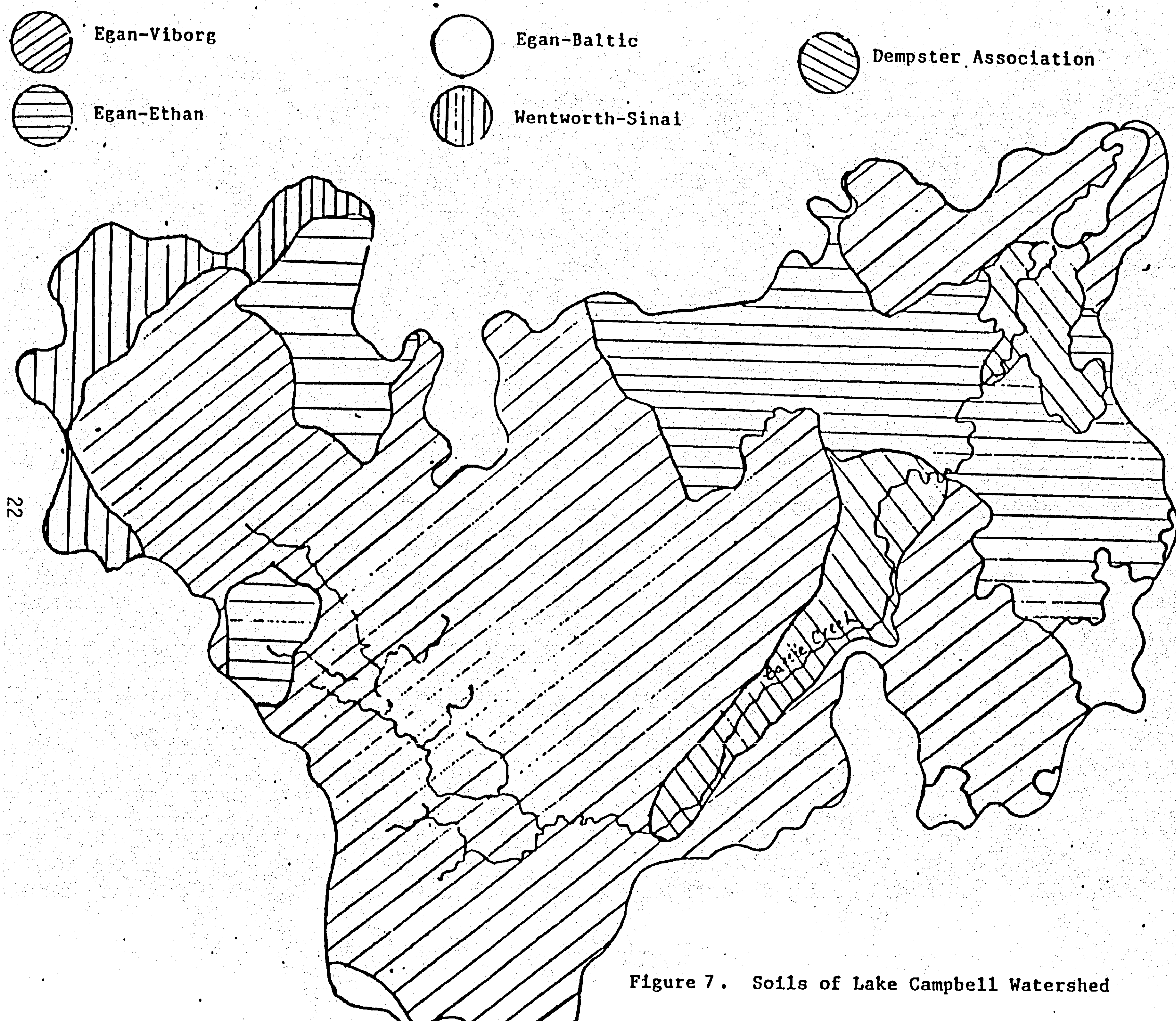


Figure 7. Soils of Lake Campbell Watershed

deep, lying over sand and gravel layers. Moderate organic content and medium fertility are typical of these soils. Surface runoff is slow to medium, and permeability is moderate above the underlying sand and gravel. Water erosion is a problem in sloping areas. Slopes range from 0-2 percent (Soil Survey of Lake County, SD, 1973).

Groundwater Hydrology

Lake Campbell lies where two shallow unconfined aquifers merge. The Battle Creek and Big Sioux Aquifers are both glacial in origin. Glacial aquifers, as a rule, are unconsolidated sand and gravel outwashes deposited by melt water from receding glaciers.

The Battle Creek Aquifer is composed of fine to medium sand with some fine gravel, and is underlain by till. This aquifer is located only in the Battle Creek floodplain.

The Battle Creek Aquifer is recharged by precipitation and snow melt. Reported water levels indicate that the ground water flow follows Battle Creek through Lake Campbell into the Big Sioux Aquifer. The Battle Creek Aquifer discharges approximately 0.3 acre-feet per day through private wells, evapotranspiration, and flow to the Big Sioux Aquifer (Water Resources of Lake and Moody County, 1986).

The following are some of the characteristics of the Battle Creek Aquifer, based upon information from Water Resources of Lake and Moody Counties, 1986:

Areal extent: 19.45 hectares
Maximum thickness: 8 meters
Average thickness: 4.25 meters
Depth below surface: 0-1 meter
Ground water level below land surface: 0-3 meters
Estimated water storage volume: 34,000 acre-feet
Well discharge: 1-3 gallons per minute
Suitability for irrigation: poor

The Big Sioux Aquifer runs in a southerly direction through the Big Sioux floodplain. Aquifer material is composed of fine to medium poorly sorted sand to well sorted medium gravel. Aquifer recharge is by infiltration of rain water and snow melt through the 0.3 to 6.0 meters of top soil (Water Resources of Brookings County, 1989).

Water quality in the Big Sioux Aquifer is similar to the Battle Creek Aquifer with calcium bicarbonate and sulfate predominating. The average calcium concentration is 100 mg/L, the average bicarbonate concentration is 260 mg/L, and the average dissolved sulfate concentration is 180 mg/L.

Aquifer recharge by Lake Campbell usually only occurs during spring runoff and extreme high water periods. The remainder of the year, the aquifer is recharging Lake Campbell. The ground/surface water connection is moderate between Lake Campbell and the aquifers (Classification-Preservation-Restoration of Lakes in Northeastern SD, 1977).

LAND USES AND NONPOINT POLLUTANT LOADINGS

Watershed Analysis

Lake Campbell and its surrounding watershed are located on the Prairie Coteau in Brookings, Lake, and Moody Counties of South Dakota. This region is characterized by gently rolling hills composed of glacial drift interspersed with many small potholes and intermittent streams.

The contributing watershed consists of approximately 112,560 acres. Battle Creek drains nearly 100 percent of the watershed and discharges into Lake Campbell from the south. Land use in the watershed area is 91% agricultural, involving either livestock or crop production. The table below provides a summary of land uses and percentages for the entire watershed.

Table 9.
1992 Land Use Percentages For Lake Campbell Watershed

Land Use	Hectares	Acres	%Watershed
Agricultural Cultivated	33,636	83,052	73.8
Agricultural Non-Cultivated	6,922	17,091	15.2
Water	1,686	4,16	33.7
Transportation	1,094	2,701	2.4
Farmstead	957	2,363	2.1
Forest	501	1,237	1.1
CRP	456	1,126	1.0
High Density Residential	273	674	0.6
Low Density Residential	62	153	0.1
Total	45,587	112,560	100.0

Most of the pasture, CRP, and farmsteads are located on or near the un-named tributaries to Battle Creek and Battle Creek itself. The cultivated lands are evenly distributed throughout the watershed with many extending to the very edges of the creeks.

A study conducted by the Water Resources Institute at South Dakota State University (Ullery, 1989) was undertaken to identify areas within the watershed that contributed the largest amount of sediment, and where application of conservation and best management practices should be focused to reduce delivery of sediment to Lake Campbell.

The Lake Campbell watershed was divided into six subwatersheds (Figure 8). The six subwatersheds were analyzed using the Agricultural Nonpoint Source (AGNPS) Runoff model. The results of the analysis indicated that two areas, 5 and 6, contributed the largest amount of sediment and nutrient loads to the Lake Campbell watershed (338-348 kg/hectare). The other areas contributed smaller loadings (74-143 kg/hectare).

The recommendations of the Water Resources Institute study for reduction of nutrient discharges to Lake Campbell include reductions in nitrogen and phosphorus fertilization, and improved application methods such as injection. It was recommended that these best management practices be targeted at the subwatersheds contributing the greatest loadings (5 and 6).

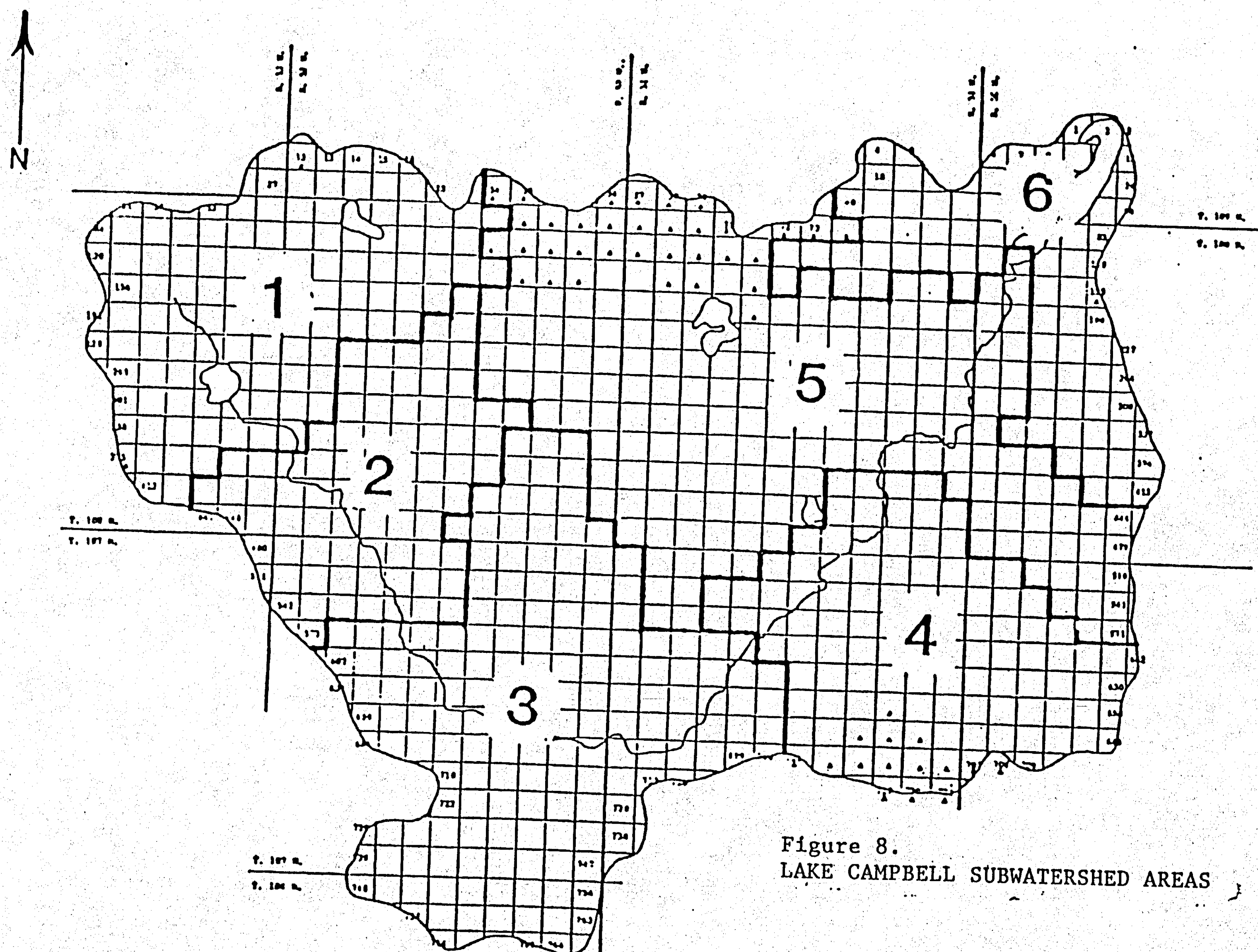


Figure 8.
LAKE CAMPBELL SUBWATERSHED AREAS

To reduce the sediment discharge to Lake Campbell, the building of sediment retention basins was investigated. Seven sites were identified (Figure 9), with four of them selected as potentially feasible. The criteria used for deciding feasibility were:

1. Able to store 50 year, 24-hour rainfall event
2. Submerge less than 150 acres of flood plain when full
3. Maximum depth less than 25 feet
4. Only a short dam face would be required

Drainage areas for the four sites range from 648 hectares (1,600 acres) to 1,814 hectares (4,900 acres). The table below summarizes information on the seven potential sediment retention basins that were identified.

Table 10. Seven Potential Sediment Retention Basins Identified

Site	Legal Description	Drainage Area (ac)	Surface Area (ac)	Dam Length (ft)
A*	T109N, R50W, Sec 32, NW 1/4, SE 1/4	700	35	1,600
B*	T108N, R51W, Sec 15, SE 1/4, NE 1/4	3,040	100	1,900
C	T108N, R51W, Sec 14, SE 1/4, SW 1/4	1,920	85	300
D	T108N, R50W, Sec 19, SW 1/4, NE 1/4	480	150	200
E	T108N, R50W, Sec 28, Ne 1/4, SE 1/4	1,600	80	300
F	T108N, R51W, Sec 27, NW 1/4, NE 1/4	4,900	127	200
G*	T107N, R51W, Sec 17, NW 1/4, SE 1/4	7,840	155	1,600

*locations rejected due to dam length
Ullery, 1989

In summary, the evaluation of the watershed has indicated that the greatest potential loadings of sediment and nutrients are derived from two subwatershed areas, 5 and 6. Consequently, best management practices such as fertilization reduction and improved application (injection) should be implemented in these areas. In addition, the watershed evaluation identified potential sites for construction of sediment retention basins. Potentially feasible sites should be further investigated.

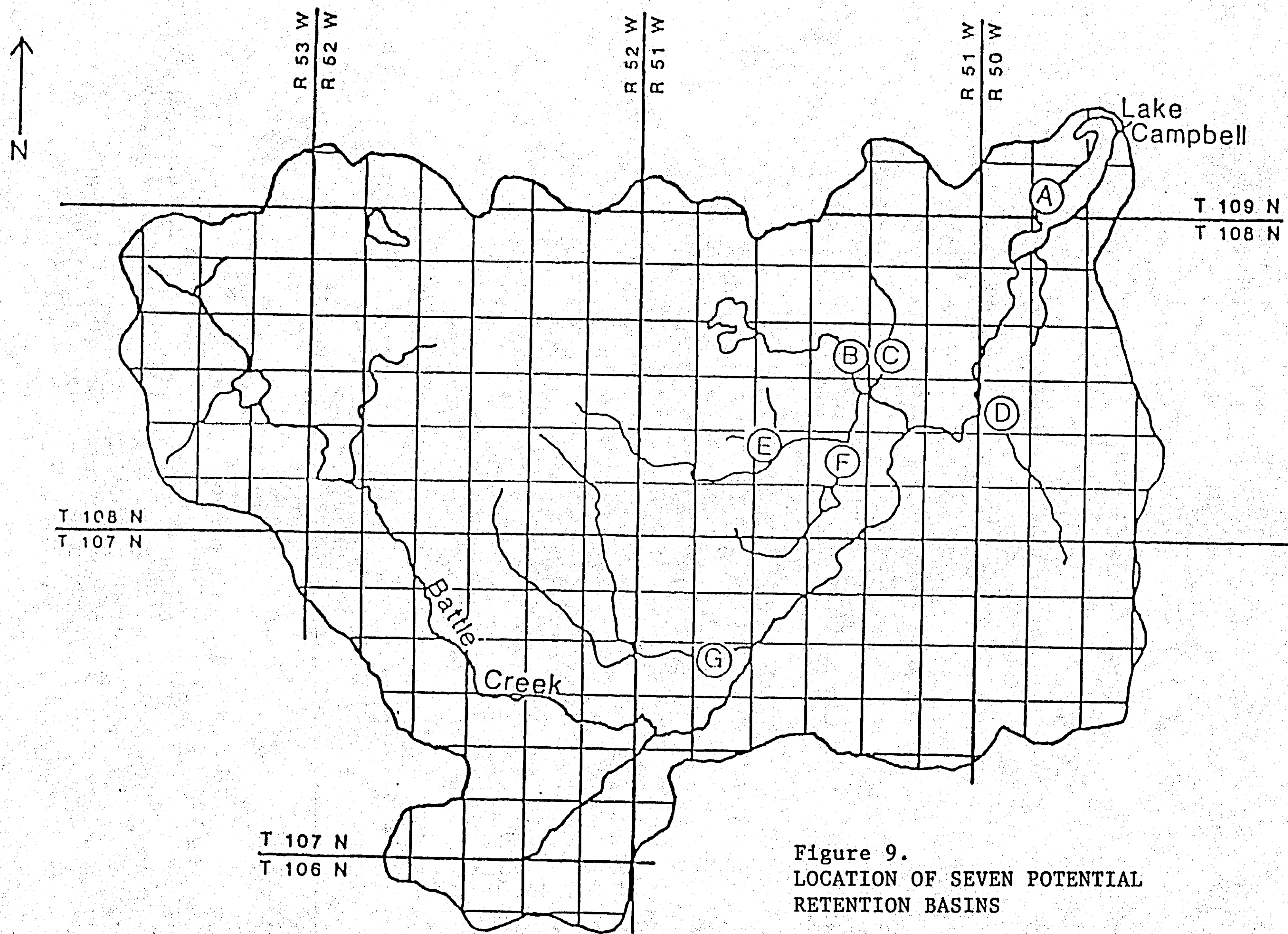


Figure 9.
LOCATION OF SEVEN POTENTIAL
RETENTION BASINS

Shoreline Erosion Survey

A survey of the Lake Campbell shoreline was conducted on September 26, 1990. A pontoon was used to survey the entire shoreline around the lake. Areas of erosion were recorded on videotape. In addition, the areas of erosion were recorded on an aerial photograph of the lake. For each area of erosion, an estimate was made of the length, height, and severity. The categories for severity of erosion were as follows:

Minor　　Minor/Moderate　　Moderate　　Moderate/Severe　　Severe

Generally, the shoreline around Lake Campbell is in good condition, with most exposed areas already rip-rapped or controlled by some other method. However, a total of 4,155 feet of the shoreline was found to have some degree of erosion. Of that total, 785 feet were found to be in the Moderate erosion category, and 580 feet were in the Moderate/Severe erosion category. The remaining areas were found to be in the Minor and Minor/Moderate categories. No areas of Severe erosion were observed.

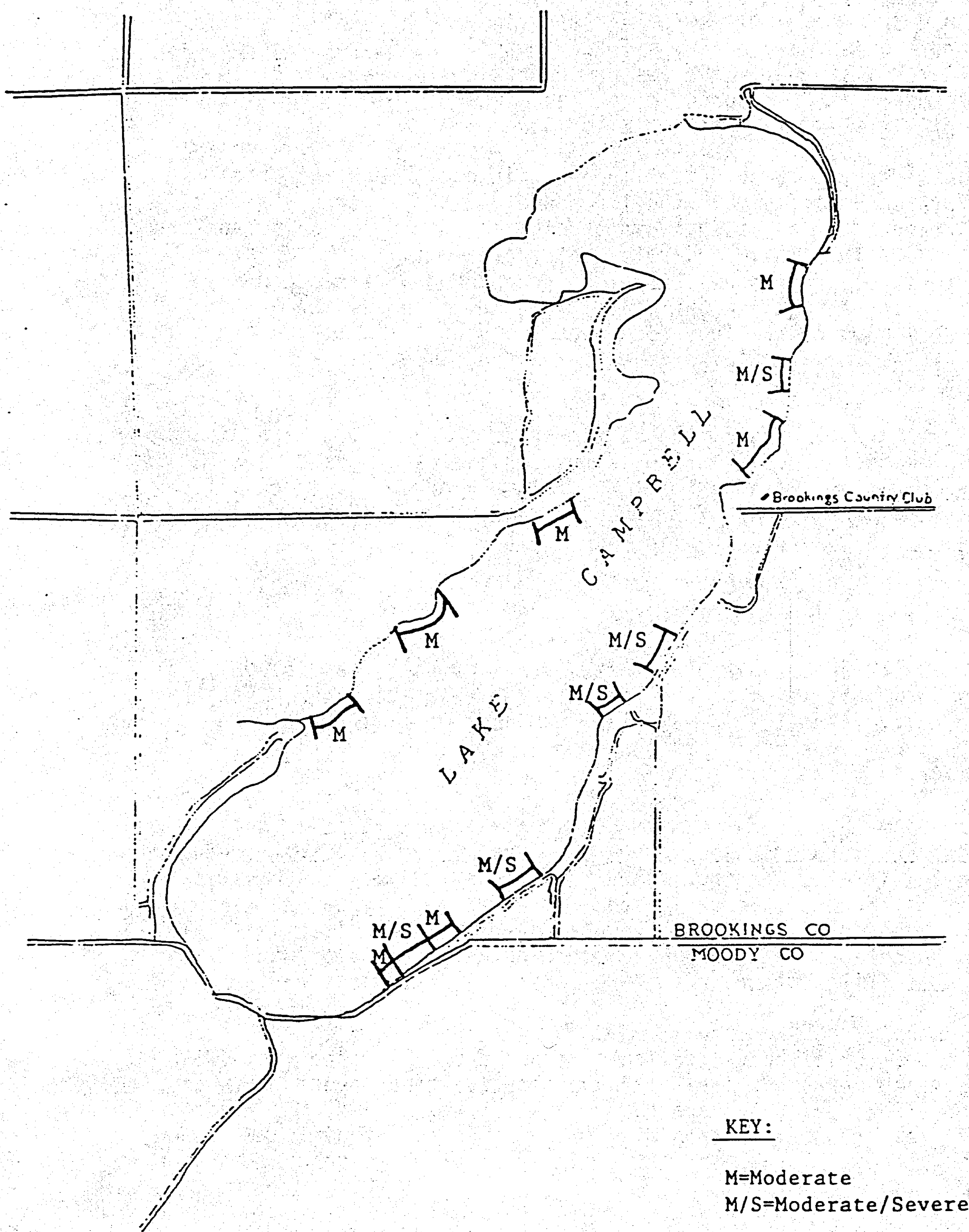
A summary of the length (L) and height (H) of erosion, in feet, within each category is found below:

Table 11. Lake Campbell Shoreline Erosion Categories

	Minor	Minor/Moderate	Moderate	Moderate/Severe
	L/H	L/H	L/H	L/H
	200/3	40/6	125/6	200/10
	25/3	50/6	30/8	50/5
	75/2	60/6	100/6	80/15
	30/3	100/4	200/8	20/12
	150/2	120/4	60/4	30/12
	200/3	350/5	250/4	200/16
	250/4	500/4	20/6	
	30/8		160/12	
	150/4			
	40/4			
	300/1			
	120/1			
Total Length	1,570	1,220	785	580
Ave. Height	2.5	4.4	5.7	12.5

Figure 10 is a map showing the areas of Moderate and Moderate/Severe erosion around the Lake Campbell shoreline. It should be noted that all the areas with Moderate/Severe erosion are on the exposed shoreline facing northwest, between the Brookings Country Club and the south shore of the lake. All of the areas in the Moderate and Moderate/Severe erosion categories represent significant potential loadings of sediment to Lake Campbell, and should be corrected as soon as possible.

Lake Campbell Shoreline Erosion
Figure 10.



Septic System Survey

A survey of septic wastewater disposal systems was conducted at Lake Campbell on May 19, 1991. Members of the Lake Campbell Association and Phase I Project staff conducted the survey. Residents who were not home were contacted later to obtain the necessary information concerning their wastewater disposal systems. A total of 87 survey reports were obtained for Lake Campbell. Of the 87 reports, 68 (78%) had documented dates for construction of the septic systems. In checking the construction dates, it was found that of the 68 reported dates, 20 were 1977 or older. This would make 29% of the systems 15 years old, or older. A total of 28 of the 68 reported dates were 1982, or older. This would make 41% of the septic systems ten years old, or older.

Of the 87 total septic system reports that were obtained, 73 (84%) had the distance from the system drainfield to the lake documented. Of the 73 reports with documented distances, 7 indicated a distance of less than 100 feet from the drainfield to the lake. This would indicate that approximately 10% of the systems have a distance of less than 100 feet between the drainfield and the lake. The minimum distance required between a drainfield and a lake, under current state rules, is 100 feet. Therefore, about 10% of the existing wastewater septic systems have drainfields that would not meet present construction standards.

Given the age and location of many of the septic systems around the lake, it can be assumed that a significant number of these systems are causing a direct impairment on water quality. Because the lake is in a hypereutrophic condition as a result of existing high levels of nutrients, measures should be taken to eliminate these direct sources of contamination to the lake.

BASELINE LIMNOLOGICAL DATA

The first record of water quality sampling within Lake Campbell was in 1967. The analytical results from this sampling are found in Table 12, together with other subsequent water quality data that was available. Sampling time frames and chemical parameters are inconsistent between samples, making accurate interpretation difficult.

The data listed in Table 12 are the results of samples that were collected and analyzed with little consistency. Samples were not collected on a set schedule, were not always tested for the same parameters, and were analyzed using various laboratory procedures. However, general trends in water quality can be determined when the data are viewed as a whole. Based upon the historical data, there is a strong indication that there have been increases in chloride, sulfate, and phosphorus, indicating increasing levels of contamination to the lake over the years.

Figure 11 has all the chloride concentrations graphed for the period from 1967 to 1983. All monitoring results after 1983 were affected by dredging operations, and therefore were not graphed.

Chloride is a good indicator of trends in man-made pollution because metabolic utilization does not cause significant variations in the spatial and seasonal distribution within a lake. It has been shown that pollution sources can significantly modify the natural chloride concentrations (Wetzel, 1975).

In a natural system, chloride concentrations should be relatively consistent, and vary little during the natural aging process of a lake. Figure 11 shows a general increase in chloride concentrations over time. This would suggest that external sources, such as failing septic systems, may be contributing pollution to Lake Campbell.

Figure 12 is a graph containing total phosphorus concentrations for the years 1972 through 1983. These results show a general rise in phosphorus levels over the years, suggesting increased loadings of phosphorus to Lake Campbell.

Table 12.
Baseline Water Quality Data For Lake Campbell
(All parameters in mg/L unless otherwise stated)

Date	pH (su)	SD (cm)	DO	Na	K	Mg	Ca	SO4	Cl	Ref.
3/67	7.8	18	10.2	15	10			118	5.5	a.
2/68	8.2			21	16			193	5.0	a.
4/68	8.2	41	10.6	15	9			143	3.0	a.
7/72								160	3.5	b
8/72								182	5.5	c.
1/73								235	6.2	d.
8/76										d.
9/76	8.9	30	10.3	75	29	124	134	836	26.0	e.
11/76		53	14.7	60	26	99	107	675	17.0	e.
1/77	7.8		5.9	146	59	260	270	1705	44.7	f.
3/77	9.5		12.0	28	15	48	56	334	9.0	b.
8/77			5.4	146	59	53	264	1670	44.2	b.
8/78			9.5							b.
8/79										b.
11/83	8.3		9.4							g.

Table 12. (Continued)

Date	Total Alk.	Cond. (umhos)	TDS	Total P	Ortho P	NO2-N NO3-N	NH3-N	Fecal Coliform (MPN/100mL)	Ref.
3/67	214	560	395				1.70		a.
2/68	281	800	627				0.23		a.
4/68	174	540	527				0.08		a.
7/72				.200	.100	2.05			b.
8/72				.100	.020	1.42	0.07		c.
1/73				.260	.240		0.56		d.
8/76		1189	998						d.
9/76	164	1268	1514	.280	.180		2.75		e.
11/76	99	1346	1258	.180			0.02		e.
1/77	339	2940	3038	.153	.004		7.20	3	f.
3/77	80	710	639	.155	.015		0.22	13	b.
8/77	330	3080	3101	.219	.101		6.40	3	b.
8/78			659	.263	.143	0.12	0.38	27	b.
8/79			883	.330	.120		1.1		b.
11/83			918	.310	.110	2.29	1.1		g.

a. Gloss, 1969.
b. East Dakota Conservancy Sub-District, 1976-1979. (Unpublished)
c. South Dakota Department of Game, Fish and Parks, 1972. (Unpublished)
d. South Dakota Department of Game Fish, and Parks, 1973. (Unpublished)
e. Hayden, 1976.
f. Hayden, 1977.
g. South Dakota Department of Water and Natural Resources, 1985.

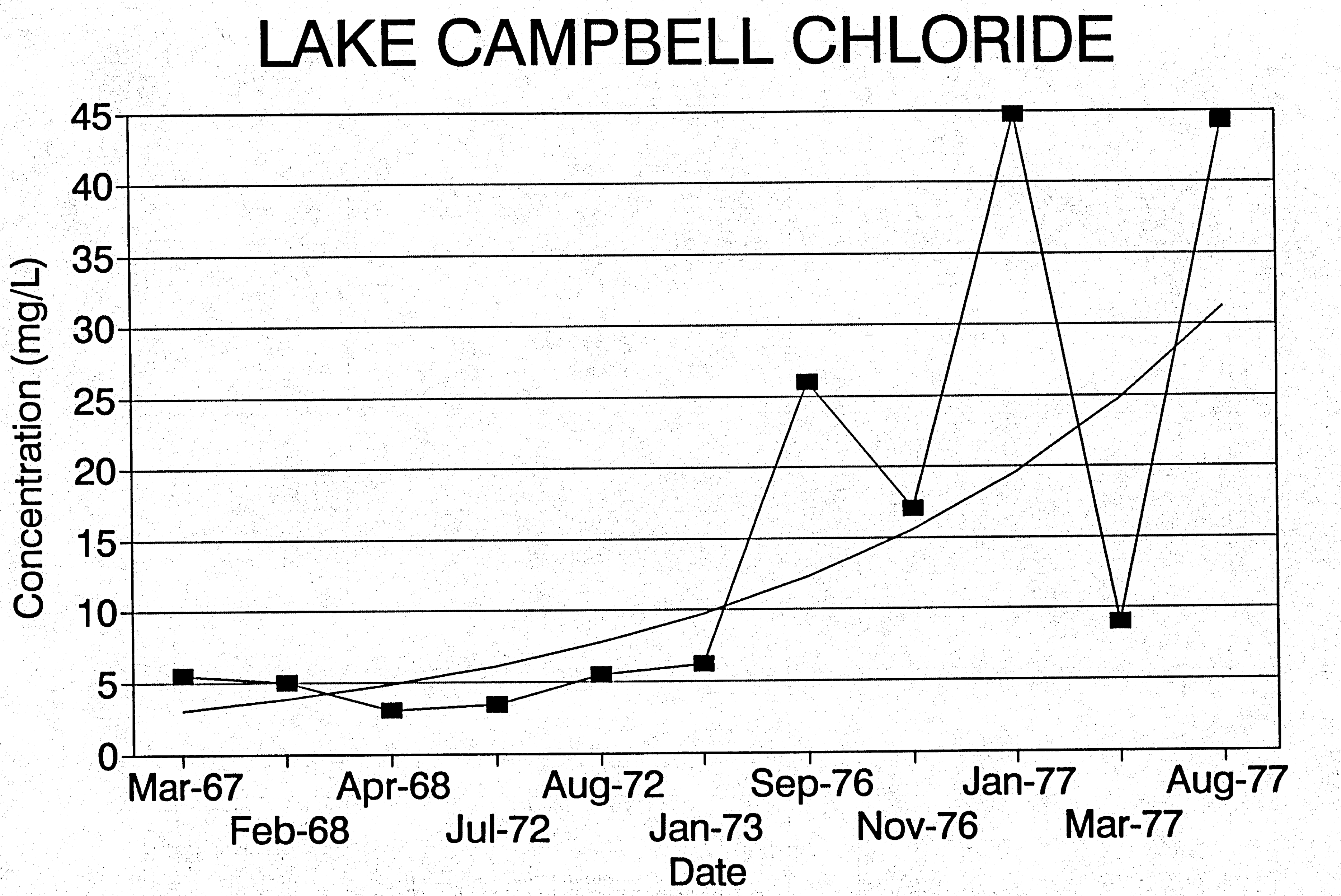


Figure 11. Lake Campbell Chlorides

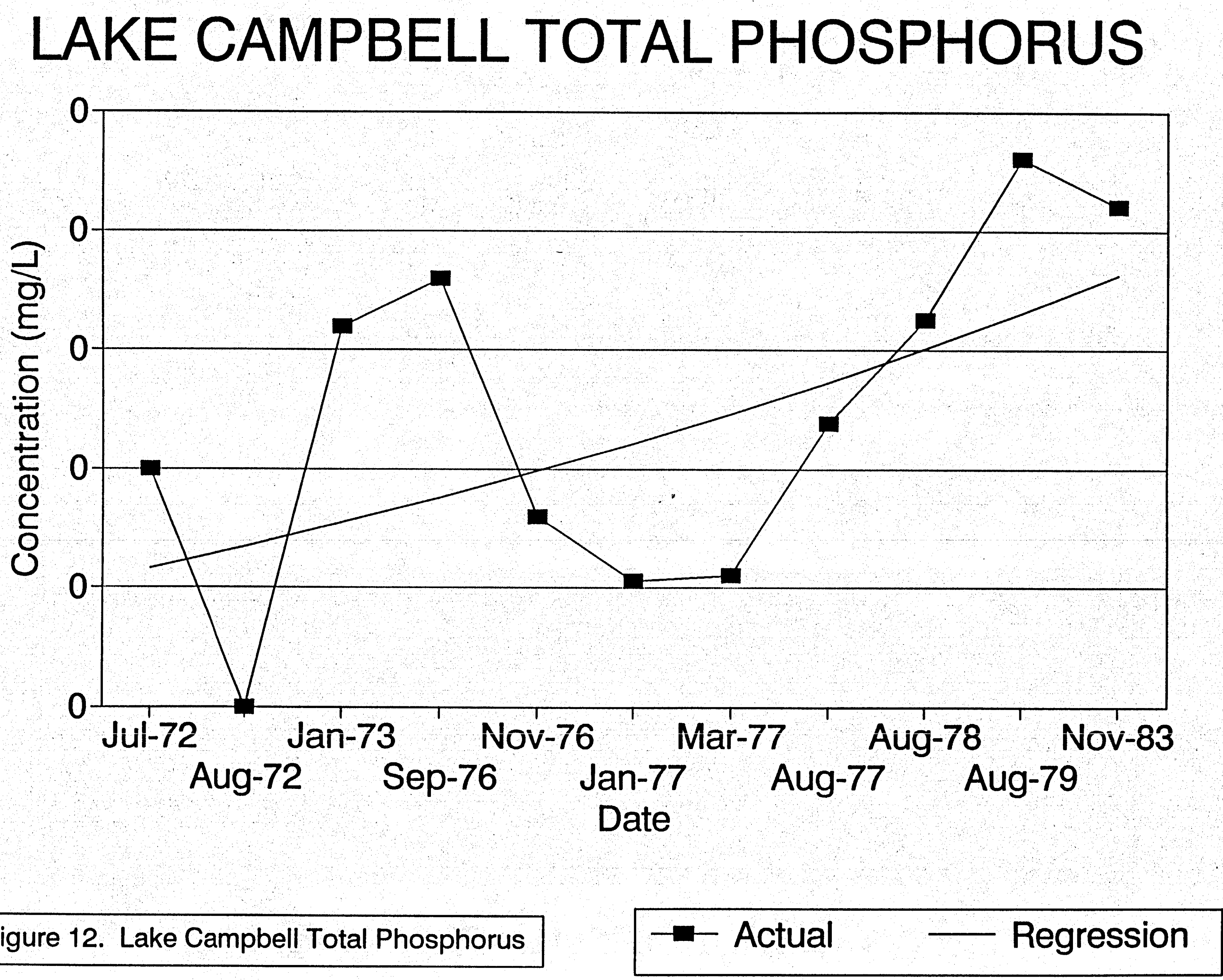


Figure 12. Lake Campbell Total Phosphorus

CURRENT IN-LAKE DATA

In-lake samples were collected from Lake Campbell at three sites (Figure 13, Lake Campbell In-Lake Monitoring Sites). Site CL-1 was located in the middle of the north end of the lake. The average depth at this site over the one-year sampling period was 7.8 feet. Site CL-2 was located in the middle of the lake. The average depth at Site CL-2 over the sampling period was 5.8 feet. Site CL-3 was located in the middle of the south end of the lake. Site CL-3 was in an area of the lake that had been previously dredged, therefore the average depth at this site was 10.9 feet. Because of the water depth at Site CL-3, both surface and bottom samples were collected at that site. Only surface water samples were collected at Sites CL-1 and CL-2.

Summaries of the results from the in-lake monitoring program are included in Table 13 (Sites CL-1 and CL-2) and Table 14 (Site CL-3). Generally speaking, the concentrations of the in-lake parameters tested were within the limits of the Surface Water Quality Standards set forth by the State of South Dakota. It should be noted, however, that the State Standards do not include parameters such as total phosphorus and total nitrogen. For that reason, the determination of a lake's water quality should not be based solely on the State Surface Water Quality Standards. Rather, the determination of water quality should be based on levels of other parameters, as well, that may not be included in the State Standards.

Trophic Status Index

Carlson (1977) proposed a Trophic State Index that compares lakes on a scale of 0 to 100 based on their trophic state, with 0 being the least productive. Each change of ten in the scale represents approximately a doubling of the algal biomass for the index. Lakes with values over 50 are considered to be eutrophic.

Trophic Status Indices (TSI) were calculated for Secchi disc transparency and total phosphorus from measurements taken at the three in-lake sites. A TSI has not been calculated for chlorophyll a as the chlorophyll samples have not yet been analyzed. The chlorophyll TSI results will be added to this report as an addendum when the chlorophyll results become available.

The mean Secchi disk TSI from all three in-lake monitoring sites is 75. The mean total phosphorus TSI from all three sites is 83. Both of these values are near the top of Carlson's scale, which would place Lake Campbell in a hyper-eutrophic classification.

Results and Discussion

In the following discussion, parameters have been selected which either showed violations of state standards, or which may be impairing the beneficial uses designated for Lake Campbell. Summaries and graphs of other Lake Campbell in-lake data can be found in APPENDIX A, LAKE CAMPBELL IN-LAKE WATER QUALITY DATA. It should be noted that on the graphs, only the mean of the three surface samples were plotted for each date. This provides a clearer picture of the surface water quality trends versus the bottom sample results at site CL-3.

Dissolved Oxygen

The state standard for dissolved oxygen in Lake Campbell is 5.0 mg/L. The results of the in-lake sampling indicate that the level of dissolved oxygen fell below the state standard on three sampling dates (Figure 14). During two of the

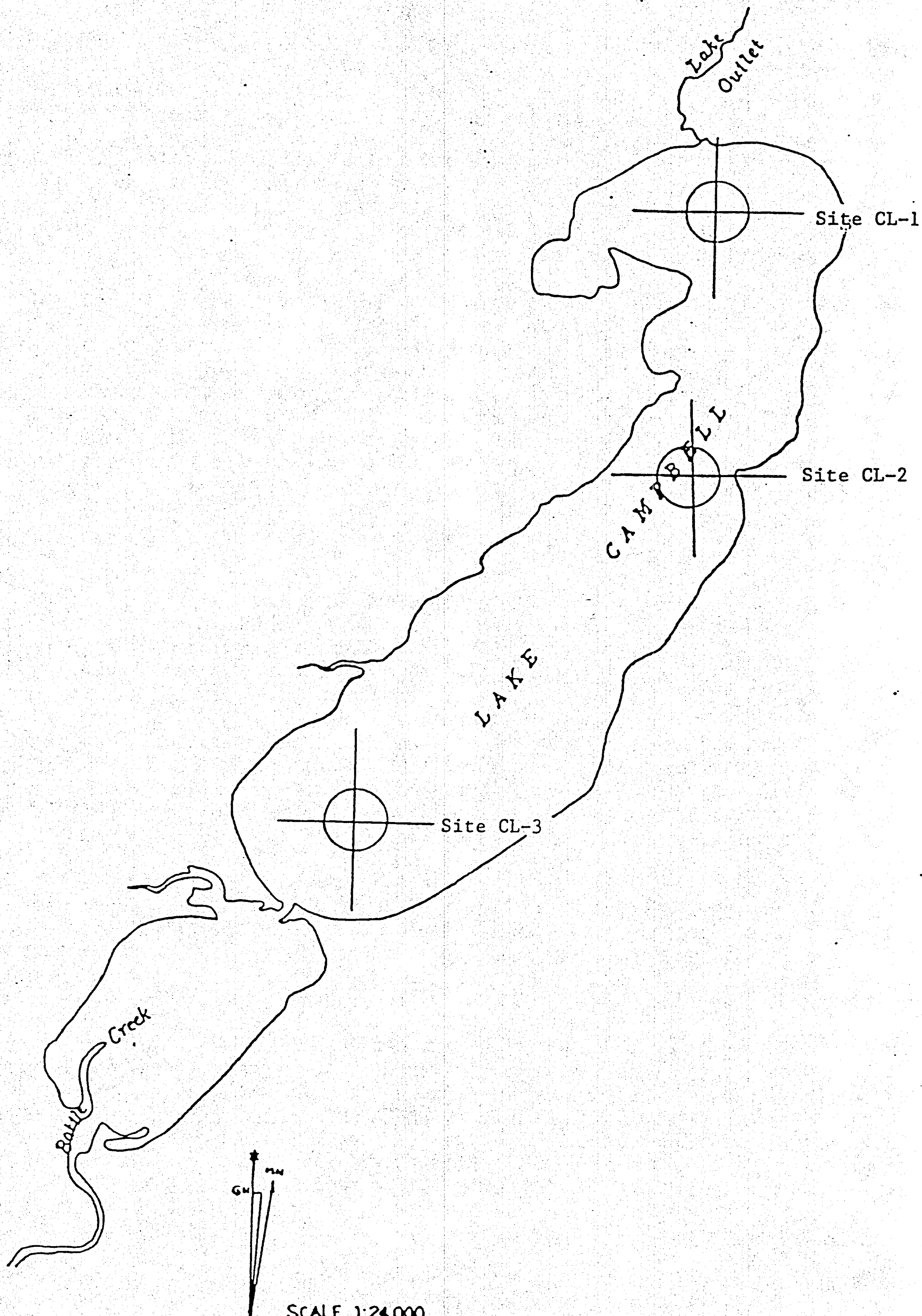


Figure 13   Lake Campbell In-Lake Monitoring Sites

Table 13. Lake Campbell In-Lake Data, Sites CL-1 and CL-2

SAMPLE DATA FOR LAKE CAMPBELL FOR 1991-1992, SITE CL-1

DATE	TIME	SAMP	DEPTH Feet	WTEMP SURF C	WTEMP BOTT C	ATEMP C	SDISK M	SDISK TSI	DISOX SURF mg/L	DISOX BOTT mg/L	FECAL COLIFORM per 100mL	LABPH units	TALKA mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	VOLSO mg/L	FIXSOL mg/L	AMMONIA mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TOTAL-N mg/L	TPO4 mg/L	TPO4 TSI	TDPO4 mg/L	TDPO4 %	NITR. PHOS. RATIO
01/23/91	1130	GRAB	7.5	2.00		-2.00			9.5		10	8.00	205	988	983	5	1	4	1.64	0.0159	0.1	4.28	4.38	0.264	85	0.122	46.2	16.59
02/12/91	1410	GRAB	6.0	4.00		4.00			15.0		10	8.50	59	311	283	28	9	19	0.11	0.0039	0.1	2.60	2.70	0.339	86	0.054	15.9	7.96
04/17/91	1100	GRAB	9.0	9.00	8.00	10.00	0.3	77	9.0		10	7.84	128	711	657	54	20	34	0.66	0.0078	0.1	1.92	2.02	0.214	82	0.085	39.7	9.44
04/24/91	1100	GRAB	8.0	10.75	10.50	10.60	0.5	70	10.4	10.0	4	8.06	134	770	706	64	8	56	0.62	0.0138	0.1	2.39	2.49	0.237	83	0.058	24.5	10.51
05/28/91	1030	GRAB	8.0	22.00	22.00	22.00	0.3	77	7.8	6.8	36	7.95	147	757	687	70	18	52	0.82	0.0322	0.1	2.56	2.66	0.251	84	0.064	25.5	10.60
06/10/91	1315	GRAB	9.0	23.75	22.25	26.00	0.4	73	10.0	8.2	10	8.81	136	776	752	24	22	2	0.16	0.0403	0.7	1.15	1.85	0.115	73	0.034	29.6	16.09
06/26/91	1400	GRAB	9.0	26.00	25.00	31.00	0.4	73	10.6	9.2	30	8.69	144	767	717	50	18	32	0.32	0.0737	0.7	1.72	2.42	0.146	76	0.034	23.3	16.58
07/09/91	1330	GRAB	8.0	24.00	23.00	22.00	0.4	73	7.3	6.6	10	8.44	153	802	770	32	8	24	0.36	0.0459	0.5	1.66	2.16	0.217	82	0.129	59.4	10.05
07/23/91	830	GRAB	8.0	25.00	26.00	20.00	0.4	73	8.2	7.3	10	8.71	145	754	734	20	4	16	0.02	0.0045	0.5	1.90	2.40	0.180	79	0.064	35.6	13.33
08/12/91	1030	GRAB	7.0	22.25	22.25	24.00	0.4	73	11.6	11.6	10	8.91	131	774	732	42	24	18	0.02	0.0055	0.7	1.23	1.93	0.186	80	0.068	36.6	10.38
08/19/91	1500	GRAB	7.0	25.00	24.00	23.00	0.4	73	7.8	7.8	10	8.69	133	768	742	26	10	16	0.12	0.0262	0.7	1.86	2.56	0.159	77	0.098	61.6	16.10
09/10/91	1330	GRAB	8.0	21.00	21.00	20.00	0.4	73	9.0	8.4	15	8.32	139	906	878	28	10	18	0.37	0.0303	0.1	2.02	2.12	0.170	78	0.088	51.8	12.47
09/23/91	1430	GRAB	7.5	11.00	11.00	16.00	0.3	77	8.8	8.6	60	8.60	146	816	770	46	38	8	0.03	0.0022	0.1	2.13	2.23	0.210	81	0.186	88.6	10.62
10/16/91	930	GRAB	7.0	8.00	8.00	10.00	0.2	82	9.6	9.4	10	8.44	156	881	853	28			0.03	0.0013	0.1	3.02	3.12	0.359	89	0.058	16.2	8.69
12/09/91	1100	GRAB	7.0	1.00		10.00			3.4		2	7.73	205	961	979	2			1.86	0.0069	0.1	3.65	3.75	0.369	89	0.325	88.1	10.16
01/13/92	1130	GRAB	9.0	4.00		4.00			10.2		10	9.24	170	847	845	2			0.30	0.0501	0.2	2.54	2.74	0.485	83	0.236	48.7	11.61
CL1 - 16 SAMPLES		MIN.	6.0	1.00	8.00	-2.00	0.2	70	3.4	6.6	2	7.73	59	311	283	2	1	2	0.02	0.0013	0.1	1.15	1.65	0.115	73	0.034	15.9	7.96
		MAX.	9.0	26.00	26.00	31.00	0.5	82	15.0	11.6	60	9.24	205	988	983	70	38	56	1.86	0.0737	0.7	4.28	4.38	0.485	89	0.325	88.6	16.59
		MEAN	7.8	14.92	18.58	15.66	0.4	75	9.3	8.5	15	8.43	146	788	756	33	15	23	0.47	0.0226	0.3	2.29	2.60	0.244	82	0.106	43.2	11.95
		MEDIAN	8.0	16.00	22.13	16.00	0.4	73	9.3	8.4	10	8.47	145	775	747	28	10	18	0.31	0.0148	0.1	2.08	2.46	0.218	82	0.077	38.2	10.61

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SAMPLE DATA FOR LAKE CAMPBELL FOR 1991-1992, SITE CL-2

DATE	TIME	SAMP	DEPTH Feet	WTEMP SURF C	WTEMP BOTT C	ATEMP C	SDISK M	SDISK TSI	DISOX SURF mg/L	DISOX BOTT mg/L	FECAL COLIFORM per 100mL	LABPH units	TALKA mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	VOLSO mg/L	FIXSOL mg/L	AMMONIA mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TOTAL-N mg/L	TPO4 mg/L	TPO4 TSI	TDPO4 mg/L	TDPO4 %	NITR. PHOS. RATIO
01/23/91	1045	GRAB	6.6	2.00		-2.00			5.3		10	7.80	204	894	887	7	1	6	2.41	0.0093	0.1	4.40	4.50	0.346	88	0.318	91.9	13.01
02/12/91	1330	GRAB	6.6	3.90		4.00			11.5		10	8.50	26	143	120	23	10	13	0.14	0.0049	0.1	1.71	1.81	0.400	91	0.047	11.8	4.53
04/17/91	1020	GRAB	4.0	8.00		9.00	0.3	77	9.5		10	7.82	125	782	736	46	14	32	0.62	0.0081	0.1	1.96	2.06	0.200	81	0.095	47.5	10.30
04/24/91	1030	GRAB	6.0	10.25	10.25	18.50	0.5	70	10.5	10.5	6	8.07	127	759	719	40	4	36	0.63	0.0138	0.1	2.30	2.40	0.203	81	0.058	28.6	11.82
05/28/91	1115	GRAB	6.0	22.00	22.00	23.00	0.3	77	7.6	7.4	114	7.71	144	763	697	66	18	48	0.83	0.0191	0.1	2.04	2.14	0.271	85	0.088	32.5	7.90
06/10/91	1345	GRAB	6.0	24.00	23.75	27.00	0.3	77	7.2	6.9	10	8.72	144	790	766	24	22	2	0.43	0.0936	0.7	1.59	2.29	0.136	75	0.047	34.6	16.84
06/26/91	1430	GRAB	6.0	26.50	26.00	32.00	0.4	73	11.4	10.8	20	8.71	142	766	724	42	12	30	0.19	0.0465	0.6	1.96	2.56	0.278	85	0.068	24.5	9.21
07/09/91	1400	GRAB	6.0	23.00	23.00	22.00	0.6	66	6.0	5.2	50	8.28	153	786	760	26	0	26	0.47	0.0404	0.6	1.21	1.81	0.183	79	0.173	94.5	9.89
07/23/91	900	GRAB	6.0	26.00	26.00	22.00	0.4	73	8.4	7.6	10	8.44	140	751	731	20	6	14	0.18	0.0259	0.5	1.83	2.33	0.200	81	0.078	39.0	11.65
08/12/91	1000	GRAB	6.0	22.25	22.00	23.00	0.4	73	12.0	6.9	10	8.91	130	761	723	38	28	10	0.03	0.0083	0.7	1.55	2.25	0.166	78	0.112	67.5	13.55
08/19/91	1430	GRAB	6.0	24.00	24.00	23.00	0.4	73	5.6	5.6	10	8.85	130	764	738	26	6	20	0.04	0.0109	0.7	1.85	2.55	0.183	79	0.102	55.7	13.93
09/10/91	1400	GRAB	5.0	21.00	21.00	21.00	0.5	70	7.6	6.4	20	8.33	145	922	864	58	36	22	0.24	0.0201	0.1	1.51	1.61	0.373	77	0.152	40.8	10.59
09/23/91	1415	GRAB	6.0	11.00	11.00	16.00	0.4	73	7.2	7.2	40	8.63	148	814	764	50	26	24	0.10	0.0079	0.1	2.77	2.87	0.247	84	0.085	34.4	11.62
10/16/91	1000	GRAB	6.0	8.00	8.00	13.00	0.2	82	9.4	9.4	10	8.72	156	871	809	62	36	26	0.02	0.0015	0.1	2.99	3.09	0.312	87	0.085	27.2	9.90
12/09/91	1000	GRAB	5.5	3.00	2.00	10.00			3.6	7.6	2	7.93	198	951	949	2			1.46	0.0131	0.1	3.79	3.89	0.386	90	0.274	71.0	10.08
01/13/92	1300	GRAB	5.0	2.00	2.00	0.00			17.0	0.0	4	8.60	205	1004	1002	2			0.69	0.0258	0.1	3.62	3.72	0.352	89			10.57
CL2 - 16 SAMPLES		MIN.	4.0	2.00	2.00	-2.00	0.2	66	3.6	0.0	2	7.60	26	143	120	2	0	2	0.02	0.0015	0.1	1.21	1.61	0.136	75	0.047	11.8	4.52
		MAX.	6.6	26.50	26.00	32.00	0.6	82	17.0	10.8	114	8.91	205	1004	1002	66	36	48	2.41	0.0936	0.7	4.40	4.50	0.400	91	0.373	94.5	16.84
		MEAN	5.8	14.81	17.00	16.34	0.4	74	8.8	7.4	21	8.37	145	783	749	33	16	22	0.53	0.0218	0.3	2.32	2.62	0.251	83	0.134	46.6	10.96
		MEDIAN	6.0	16.00	22.00	19.75	0.4	73	8.1	7.6	10	8.47	144	784	749	32	13	23	0.34	0.0134	0.1	1.96	2.37	0.225	83	0.088	39.1	10.58

Table 14. Lake Campbell In-Lake Data, Site CL-3

SAMPLE DATA FOR LAKE CAMPBELL FOR 1991-1992, SITE CL-3 (SURFACE)

DATE	TIME	SAMP	DEPTH Feet	WTEMP SURF C	WTEMP BOTT C	ATEMP C	SDISK M	SDISK TSI	DISOX SURF mg/L	DISOX BOTT mg/L	FECAL COLIFORM per 100mL	LABPH units	TALKA mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	VOLSO mg/L	FIXSOL mg/L	AMMONIA mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TOTAL-N mg/L	TPO4 mg/L	TPO4 TSI	TDPO4 mg/L	TDPO4 %	NITR. PHOS. RATIO
01/23/91	1020	GRAB	13.1	0.50		-2.00			7.8		10	7.00	209	3729	3714	15	2	13	2.83	0.0024	0.1	5.21	5.31	0.414	91	0.224	54.1	12.83
02/12/91	1200	GRAB	13.0	4.00		4.00			20.0		10	8.60	85	489	427	62	20	42	0.19	0.0083	0.1	3.81	3.91	0.827	101	0.054	6.5	4.73
04/17/91	900	GRAB	12.0	8.50	8.00	9.00	0.4	73	10.0	9.5	10	7.78	139	703	589	114	16	98	0.61	0.0060	0.1	1.82	1.92	0.322	87	0.092	28.6	5.96
04/24/92	945	GRAB	13.0	10.25	10.25	18.50	0.4	73	10.6	10.0	2	8.12	133	763	717	46	10	36	0.57	0.0139	0.1	2.23	2.33	0.227	82	0.058	25.6	10.26
05/28/91	1200	GRAB	12.0	22.00	21.00	25.00	0.3	77	7.8	8.0	92	7.97	154	824	744	80	22	58	0.70	0.0288	0.1	2.00	2.10	0.288	86	0.095	33.0	7.29
06/10/91	1412	GRAB	10.0	25.25	22.00	28.00	0.4	73	12.0	7.8	10	8.77	147	770	750	20	18	2	0.51	0.1297	0.6	1.38	1.98	0.075	66	0.020	26.7	26.40
06/26/91	1515	GRAB	13.0	27.25	23.50	30.00	0.4	73	13.2	9.2	10	8.76	144	763	727	36	16	20	0.11	0.0305	0.7	1.80	2.50	0.312	87	0.068	21.8	8.01
07/09/91	1440	GRAB	10.0	23.00	22.00	23.00	0.5	70	5.2	6.7	10	8.55	179	799	763	36	22	14	0.25	0.0373	0.6	1.13	1.73	0.180	79	0.088	48.9	9.61
07/23/91	930	GRAB	10.0	26.50	26.00	29.00	0.3	77	7.4	6.3	10	8.20	130	732	712	20	10	10	0.41	0.0373	0.5	1.82	2.32	0.173	78	0.115	66.5	13.41
08/12/91	915	GRAB	10.0	22.50	21.75	20.00	0.4	73	11.7	1.4	10	8.92	125	757	721	36	18	18	0.03	0.0085	0.7	1.77	2.47	0.159	77	0.044	27.7	15.53
08/19/91	1400	GRAB	9.0	24.00	23.00	23.00	0.4	73	8.4	4.6	10	8.82	134	772	740	32	8	24	0.05	0.0130	0.7	1.57	2.27	0.170	78	0.115	67.6	13.35
09/10/91	1430	GRAB	11.0	21.00	21.00	22.00	0.4	73	8.2	7.5	20	8.29	142	950	912	38	10	28	0.25	0.0192	0.1	1.64	1.74	0.190	80	0.149	78.4	9.16
09/23/91	1345	GRAB	9.0	11.00	11.00	18.00	0.3	77	10.2		90	8.71	147	815	761	54	14	40	0.09	0.0084	0.1	2.59	2.69	0.247	84	0.064	25.9	10.89
10/16/91	1030	GRAB	10.0	8.25	8.50	18.00	0.2	82	10.8	10.2	10	8.75	157	853	789	64	38	26	0.03	0.0025	0.1	2.78	2.88	0.373	90	0.074	19.8	7.72
12/09/91	1200	GRAB	12.5	3.00		10.00			6.4		2	7.84	186	929	928	1	1	0	1.21	0.0088	0.1	4.60	4.70	0.654	87	0.305	46.6	15.41
01/13/92	1200	GRAB	8.0	4.00		0.00			18.5		2	8.41	208	1002	1000	2			0.78	0.0224	0.1	3.47	3.57	0.262	84			13.63
CL3(SURFACE) - 16		MIN.	8.0	0.50	8.00	-2.00	0.2	70	5.2	1.4	2	7.00	85	489	427	1	1	0	0.03	0.0024	0.1	1.13	1.73	0.075	66	0.020	6.5	4.73
		MAX.	13.1	27.25	26.00	30.00	0.5	82	20.0	10.2	92	8.92	209	3729	3714	114	38	98	2.83	0.1297	0.7	5.21	5.31	0.827	101	0.305	78.4	26.40
		MEAN	11.0	15.06	18.17	16.97	0.4	75	10.4	7.4	19	8.34	152	978	937	41	15	29	0.54	0.0236	0.3	2.48	2.78	0.305	84	0.104	38.5	11.51
		MEDIAN	10.5	16.00	21.38	19.25	0.4	73	10.1	7.8	10	8.48	148	786	747	36	16	24	0.33	0.0134	0.1	1.91	2.40	0.255	84	0.088	28.6	10.58

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SAMPLE DATA FOR LAKE CAMPBELL FOR 1991-1992, SITE CL-3 (BOTTOM)

DATE	TIME	SAMP	DEPTH Feet	WTEMP SURF C	WTEMP BOTT C	ATEMP C	SDISK M	SDISK TSI	DISOX SURF mg/L	DISOX BOTT mg/L	FECAL COLIFORM per 100mL	LABPH units	TALKA mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	VOLSO mg/L	FIXSOL mg/L	AMMONIA mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TOTAL-N mg/L	TPO4 mg/L	TPO4 TSI	TDPO4 mg/L	TDPO4 %	NITR. PHOS. RATIO
01/23/91	950	GRAB	13.1	2.00		-2.00			3.3		10	7.00	244	1129	1123	6	1	5	2.48	0.0024	0.1	4.28	4.38	0.360	89	0.306	85.0	12.17
02/12/91	1210	GRAB	13.0	3.00		2.00			8.5		10	8.70	250	1179	1161	18	9	9	2.75	0.1389	0.1	4.24	4.34	0.366	89	0.061	16.7	11.86
04/17/91	900	GRAB	12.0	8.50	8.00	9.00	0.4	73	10.0	9.5	10	7.80	129	740	680	60	12	48	0.58	0.0058	0.1	1.83	1.93	0.278	85	0.068	24.5	6.94
04/24/91	945	GRAB	13.0	10.25	10.25	18.50	0.4	73	10.6	10.0	2	8.10	131	778	724	52	6	46	0.58	0.0135	0.1	2.02	2.12	0.254	84	0.051	20.1	8.35
05/28/91	1215	GRAB	12.0	22.00	21.00	25.00	0.3	77	7.8	0.8	100	8.01	152	821	749	72	18	54	0.60	0.0251	0.1	1.94	2.04	0.288	86	0.088	30.6	7.08
06/10/91	1412	GRAB	10.0	25.25	22.00	28.00	0.4	73	12.0	7.8	30	8.57	151	786	746	40	30	10	0.53	0.0773	0.6	2.78	3.38	0.112	72	0.031	27.7	30.16
06/26/91	1515	GRAB	13.0	27.25	23.50	30.00	0.4	73	13.2	9.2	10	8.75	147	766	724	42	8	34	0.28	0.0626	0.6	1.83	2.43	0.224	82	0.058	25.9	10.85
07/09/91	1400	GRAB	10.0	23.00	22.00	23.00	0.5	70	6.7	5.2	20	8.54	171	826	782	44	16	28	0.26	0.0357	0.6	1.43	2.03	0.207	81	0.092	44.4	9.81
07/23/91	930	GRAB	10.0	26.25	26.00	29.00	0.3	77	7.4	6.3	10	8.41	128	746	730	16	6	10	0.32	0.0434	0.5	2.19	2.69	0.200	81	0.098	49.0	13.45
08/12/91	915	GRAB	10.0	22.50	21.75	20.00	0.5	70	11.7	1.4	10	8.48	135	793	733	60	24	36	0.04	0.0048	0.7	1.99	2.69	0.264	85	0.068	25.8	10.19
08/19/91	1400	GRAD	9.0	24.00	23.00	23.00	0.4	73	8.4	4.6	10	8.69	134	766	732	34	2	32	0.04	0.0078	0.7	1.72	2.42	0.214	82	0.068	31.8	11.31
09/10/91	1445	GRAB	11.0	21.00	21.00	22.00	0.4	73	8.2	7.5	26	8.28	145	941	901	40	10	30	0.19	0.0143	0.1	1.75	1.85	0.236	81	0.203	86.0	9.11
09/23/91	1045	GRAB	9.0	11.00	11.00	16.00	0.3	77	10.2	8.6	170	8.55	147	817	769	48	34	14	0.15	0.0100	0.1	2.83	2.93	0.261	84	0.119	45.6	11.23
10/16/91	1030	GRAB	9.0	8.25	8.50	16.00	0.2	82	10.8	10.2	10	8.53	153	859	809	50			0.03	0.0016	0.1	3.10	3.20	0.319	87	0.071	22.3	10.03
12/09/91	1430	GRAB	12.5	3.00	3.00	10.00			6.4	10.5	2	7.91	216	1044	1038	6	5	1	0.97	0.0083	0.1	2.86	2.96	0.630	86	0.285	45.2	10.39
01/13/92	1200	GRAB	8.0	4.00	4.00	0.00			16.5	8.5	4	8.09	218	1040	1030	10			0.71	0.0099	0.1	2.80	2.90	0.266	86			10.14
CL3(BOTTOM) - 16		MIN.	8.0	2.00	3.00	-2.00	0.2	70	3.3	0.8	2	7.00	128	740	680	6	1	1	0.03	0.0016	0.1	1.43	1.85	0.112	72	0.031	16.7	6.94
		MAX.	13.1	27.25	26.00	30.00	0.5	82	16.5	10.5	170	8.75	250	1179	1161	72	34	54	2.75	0.1389	0.7	4.28	4.38	0.630	89	0.306	86.0	30.16
		MEAN	10.9	15.08	18.07	16.84	0.4	75	9.5	7.2	27	8.28	166	877	839	37	13	26	0.66	0.0286	0.3	2.47	2.77	0.281	84	0.111	38.7	11.44
		MEDIAN	10.5	16.00	21.00	19.25	0.4	73	9.3	8.2	10	8.45	149	819	759	41	10	29	0.43	0.0118	0.1	2.11	2.69	0.263	85	0.071	30.6	10.29

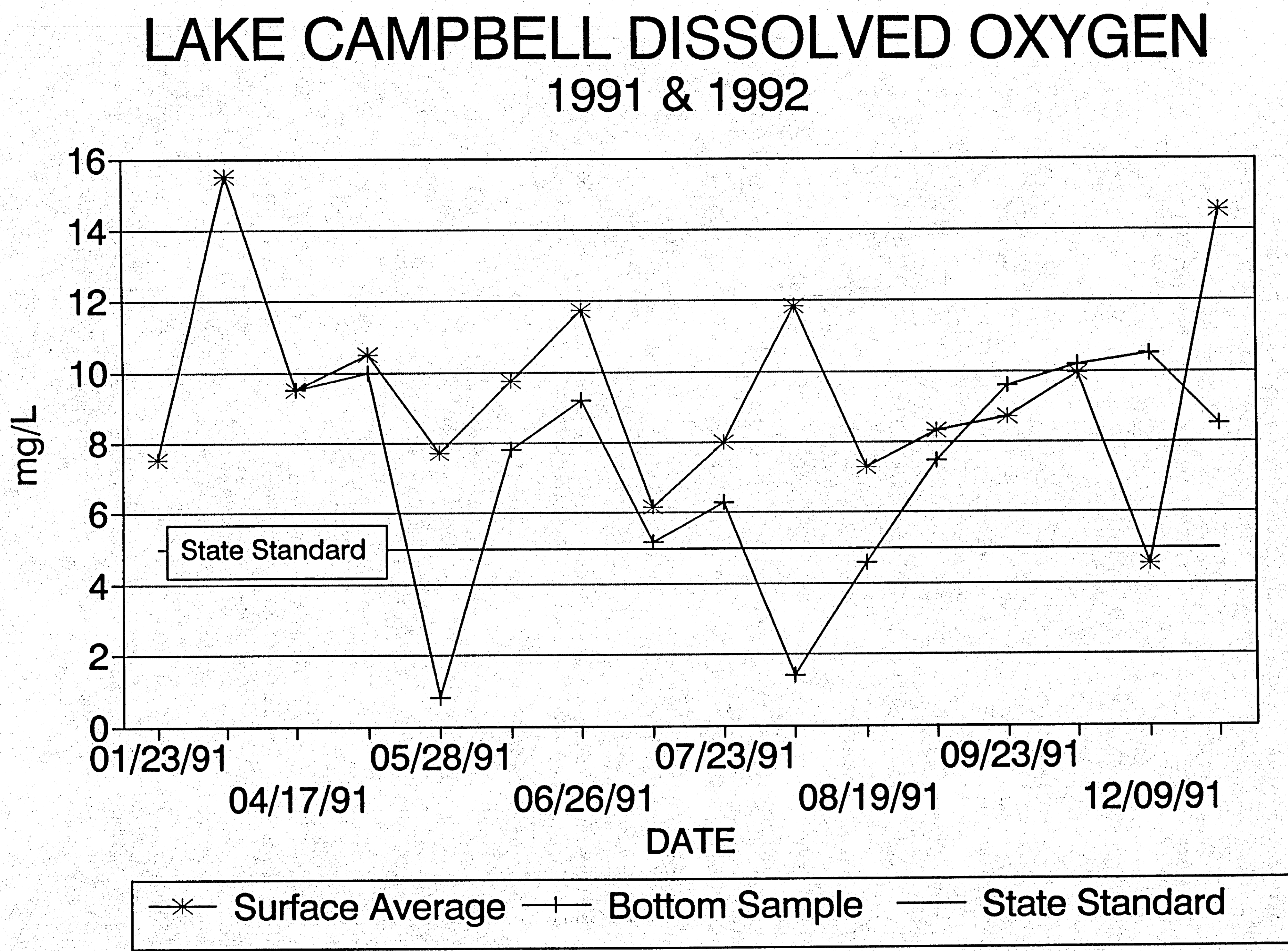


Figure 14. Dissolved Oxygen In-lake

sampling dates (May 28, 1991 and August 12, 1991) the dissolved oxygen level fell below the standard only for the bottom sample at Site CL-3. The decreased oxygen levels in these deeper water depths may be resulting from the decomposition of organic matter in the bottom sediments, together with a lack of mixing with higher oxygenated water near the surface.

It has been found that as oxygen levels decline near the sediment interface, phosphorus and other nutrients have a greater potential to be released from the sediment into the water column (Wetzel, 1983). The release of nutrients from the sediment in the lake, referred to as internal loading, can lead to detrimental effects on water quality. This can, in turn, result in an impairment of the beneficial uses of the lake.

In addition to causing an increase in internal loadings of nutrients, decreased oxygen levels can also cause fish kills. For example, most game fish cannot survive when oxygen levels fall below 3.5 mg/L (Cole, 1983). Oxygen levels did fall below that level at Site CL-3 on 5/28/91 and 8/12/91. However, on both occasions, oxygen levels near the surface of the lake were 7.8 mg/L and 11.7 mg/L respectively. It is not felt that the bottom oxygen is low (<1 mg/L) frequently enough to have a serious impact on the benthic organisms. Generally, there should be adequate mixing in this relatively shallow lake to prevent anoxic conditions at the bottom over long periods. As a result, there should not be an adverse impact on the food chain or the fishery of the lake.

The only other time that the dissolved oxygen fell below the state standard of 5.0 mg/L during the sampling period was on December 9, 1991. At that time the mean oxygen level of the surface samples at all three site fell slightly below the standard (3.4 mg/L, 3.5 mg/L, and 3.8 mg/L respectively). Snow cover over the ice at these sites may have accounted for the decreased levels of oxygen.

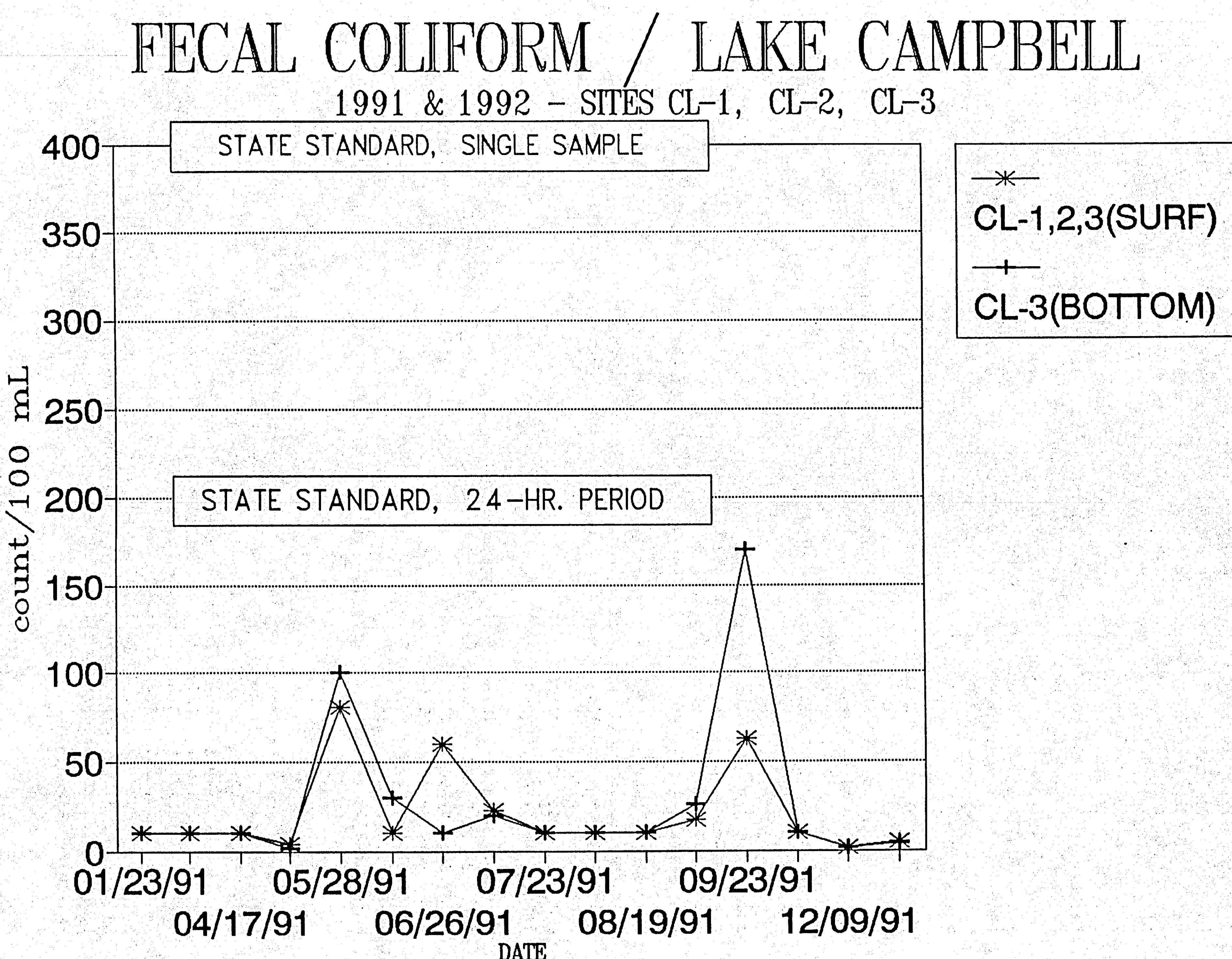
Oxygen levels at the surface above 14 mg/L were observed on two occasions; February 12, 1991 and January 13, 1992. Most likely there were algae blooms under the ice which accounted for the relatively high oxygen levels. High pH levels were also found on these occasions, further indicating the presence of algae blooms. The bottom oxygen was not measured on February 12, 1991; but on January 13, 1992, the bottom oxygen at Site CL-3 was found to be 8.5 mg/L.

Overall, the oxygen levels in the lake were sufficient for fish life (> 3.5 mg/L) on most sample dates during the monitoring period. Nevertheless, decreased oxygen levels near the bottom of the lake during the summer months may be causing an increase of internal nutrient loadings. An increase of the nutrient levels in the water can lead to increased growth of algae and weeds. This could in turn lead to an impairment of beneficial uses for the lake such as swimming and boating.

Fecal Coliform Bacteria

Fecal coliform bacteria are referred to as indicator organisms. Although these types of bacteria do not usually cause disease, they can be an indication of the presence of other types of organisms that could potentially cause disease. As can be seen from the graph for fecal coliform results (Figure 15), the state standards were never exceeded during the sampling period. However, increased levels of fecal coliform bacteria were found on three sampling dates (May 28, 1991; June 26, 1991; and September 23, 1991). The high fecal coliform levels on May 28 and June 26 correspond to high runoff flows in Battle Creek on those dates. There does not appear to be a correlation between runoff and the high fecal coliform on September 23, as there was virtually no flow in Battle Creek at that time.

Figure 15


FECAL COLIFORM / LAKE CAMPBELL
1991 & 1992 - SITES CL-1, CL-2, CL-3
STATE STANDARD, SINGLE SAMPLE
STATE STANDARD, 24-HR. PERIOD
CL-1,2,3(SURF)
CL-3(BOTTOM)
count/100 mL
400
350
300
250
200
150
100
50
0
01/23/91
04/17/91
05/28/91
06/26/91
07/23/91
08/19/91
09/23/91
12/09/91
DATE

Sources of fecal coliform bacteria would include human and animal wastes. Failing septic systems and runoff from livestock operations in the watershed could lead to elevated levels of fecal coliform bacteria. Approximately 10 percent of the septic systems for private homes around the lake shore are known to be out of compliance with existing standards. Many of the systems have drainfields closer than 100 feet from the lake and are not in compliance with the current regulations.

Because none of the results for fecal coliform bacteria exceeded state standards during the year-long sampling period, it can most likely be assumed that Lake Campbell is safe from a health standpoint for recreational activities such as swimming and skiing. However, because increased levels of fecal coliform were observed on at least three occasions, an effort should be made to control potential sources such as failing septic systems and runoff from livestock operations.

pH

The pH standard for Lake Campbell is between the range of 6.5 and 8.3 units. The upper level of this range was exceeded on numerous occasions (Figure 16). The highest pH reading of 9.24 occurred at Site CL-1 on January 13, 1992. This high pH value may be the result of an algae bloom under the ice. None of the results during the sampling period fell below the lower limit of 6.5 units.

The values for pH can be affected by many factors including geology, temperature, photosynthesis of aquatic plants, decomposition of organic matter, and water hardness. Hard water can act as a buffer to pH. However, photosynthesis may counteract the buffering action of the hard water, and result in higher pH levels (Vallentyne, 1974).

Although the pH levels quite often exceeded the established state standards, they should not be at levels high enough to be of concern for the fisheries habitat of the lake.

Total Ammonia/Un-ionized Ammonia

The highest levels of both forms of ammonia were found in the bottom sample on February 12, 1991. Elevations in both ammonia forms were observed in the samples on December 9, 1991 and January 13, 1992. Total ammonia concentrations are higher in winter than in summer in Lake Campbell (Figure 17). The maximum concentration was found at Site Cl-3 on January 23, 1991. This high concentration was the result of a snow-melt event in the watershed. The percent of un-ionized ammonia concentration, relative to total ammonia, is generally higher during the summer months.

Un-ionized ammonia is dependent on water temperature, pH, and the total ammonia concentration. Unionized ammonia is used for the water quality standard because it is the toxic fraction of total ammonia. As can be seen from the graph for un-ionized ammonia (Figure 18), the state standard was exceeded on three sampling occasions. The first high value for un-ionized ammonia (0.1389 mg/L) was found in the bottom sample collected at Site CL-3 on February 12, 1991. This was the highest level of un-ionized ammonia found during the sampling period. The total ammonia concentration at Site Cl-3 on this sample date was 2.75 mg/L. At the same time, an algae bloom occurred under the ice which caused an increase in pH. The increased concentrations of these two parameters may have caused the increase in the un-ionized ammonia fraction. High levels of un-ionized ammonia occurred at all in-lake sites on June 10, 1991, and June 26, 1991.

Figure 16

LABORATORY pH / LAKE CAMPBELL

1991 & 1992 - SITES CL-1, CL-2, CL-3

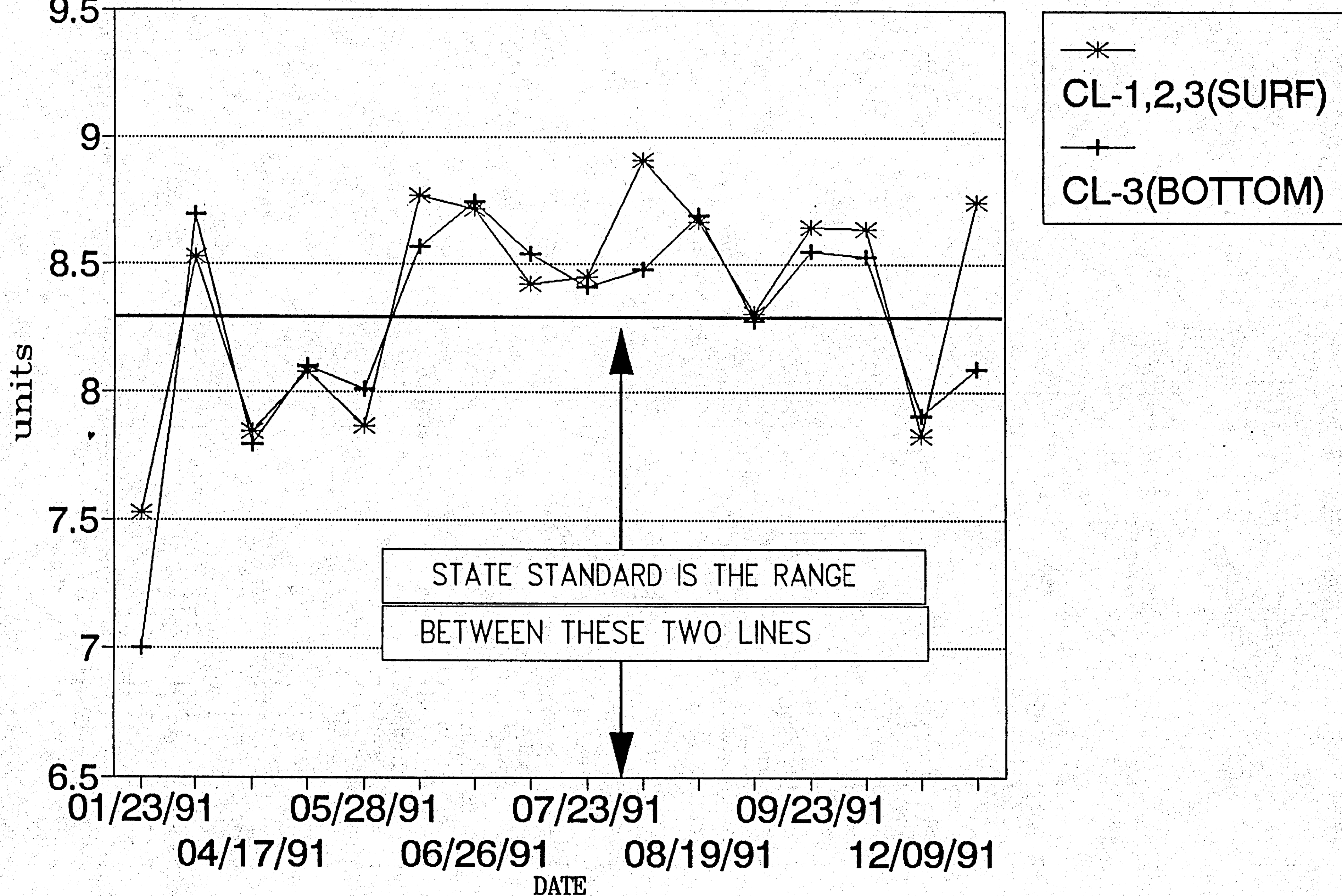


Figure 17

AMMONIA / LAKE CAMPBELL

1991 & 1992 - SITES CL-1, CL-2, CL-3

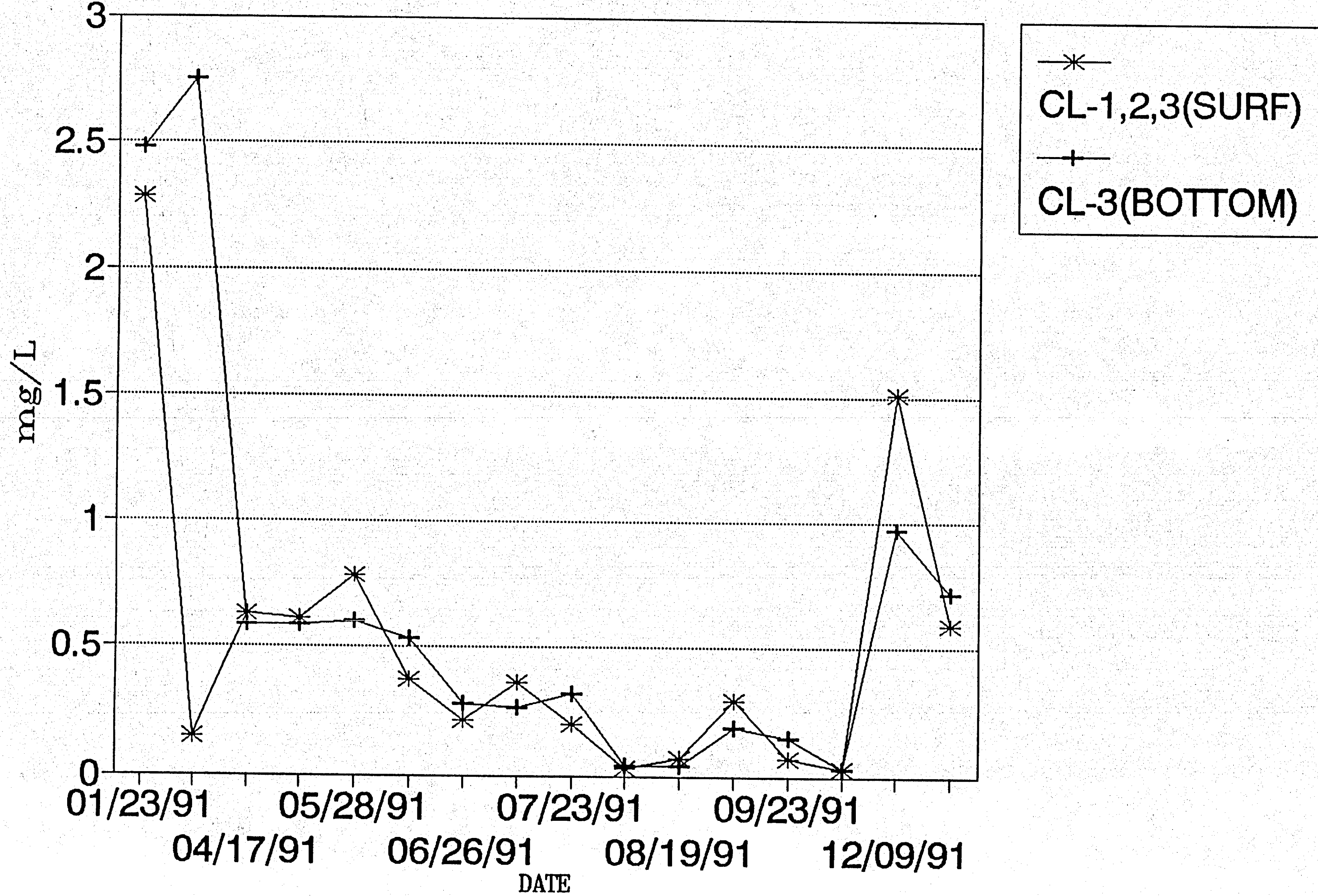
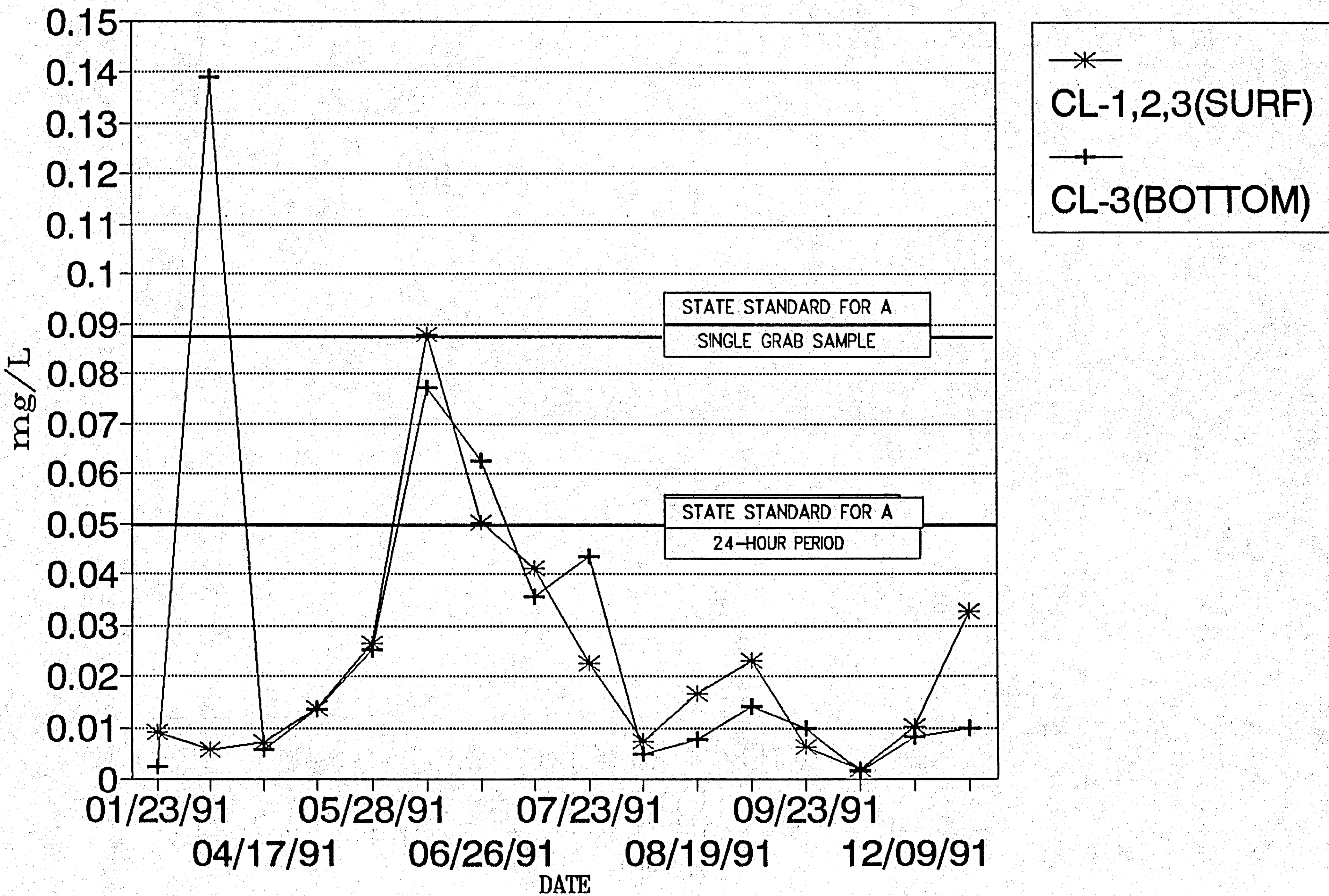


Figure 18

UN-IONIZED AMMONIA / LAKE CAMPBELL

1991 & 1992 - SITES CL-1, CL-2, CL-3



In general, concentrations of un-ionized ammonia found during the sampling period are are due to a number of factors. The decomposition of organic matter occurring in the lake and there also appears to be a correlation with runoff events in February and June of 1991. At high levels, un-ionized ammonia is toxic to fish and may result in fish-kills.

Efforts should be made to limit the amount of organic matter and ammonia entering the lake. Potential sources include failing septic systems, lawn and crop fertilizers, and livestock feedlot runoff.

Phosphorus

The State of South Dakota does not include phosphorus in its state water quality standards. However, levels of total phosphorus were found in Lake Campbell that may be leading to impairment of the beneficial uses of the lake (Figure 19). For example, the minimum level of total phosphorus found during the sampling period (0.075 mg/L) was from the surface sample at Site CL-3 on June 10, 1991. Even at this minimum amount, the level of total phosphorus is approximately four times the 0.02 mg/L level needed for optimum growth of many algae species (Wetzel, 1983).

The maximum concentration of total phosphorus (0.827 mg/L) was found in the surface sample taken at Site CL-3 on February 12, 1991. This corresponds with a snow-melt event in the watershed. At this high concentration, the phosphorus level is over forty times the level needed by many species of algae for optimum growth.

Total dissolved phosphorus was also analyzed (Figure 20). The reason for measuring total dissolved phosphorus is to have an idea of how much (%) of the total phosphorus pool is the most readily available form. The particulate phosphorus (total phosphorus - dissolved phosphorus = particulate phosphorus) usually represents the least available fraction. Total dissolved phosphorus is the form of phosphorus most readily available for algae and plant growth (as compared to the particulate phosphorus fraction). The mean percentage of total dissolved phosphorus, compared to total phosphorus, for all the lake samples is 41.8%. This compares to a mean total dissolved phosphorus level percentage of 33.4% for the lake outlet (Site CT1). The mean total dissolved phosphorus percentage level for Battle Creek at Site CT-3, the last monitoring site before the lake, is 49.6%. These results indicate that levels of total dissolved phosphorus are highest at the lake inlet, decrease in the lake, and are lowest at the lake outlet. The percentage of dissolved phosphorus versus particulate phosphorus entering the lake is relatively high. The dissolved phosphorus concentration remains high in the lake and is available for vegetation resulting in severe blue-green algae blooms.

The high levels of phosphorus in Lake Campbell would classify it as being in a hypereutrophic condition. Hypereutrophic lakes have an over-abundance of nutrients which can result in nuisance blooms of algae, and extensive weed growth.

Possible sources of phosphorus can include lawn and crop fertilizers, failing septic systems, feedlot runoff, internal loading from organic bottom sediments, and decaying aquatic vegetation. The majority of the total phosphorus in Lake Campbell is believed to have originated from agricultural nonpoint sources in the Battle Creek watershed. Efforts should be taken to control these sources of phosphorus.

Figure 19

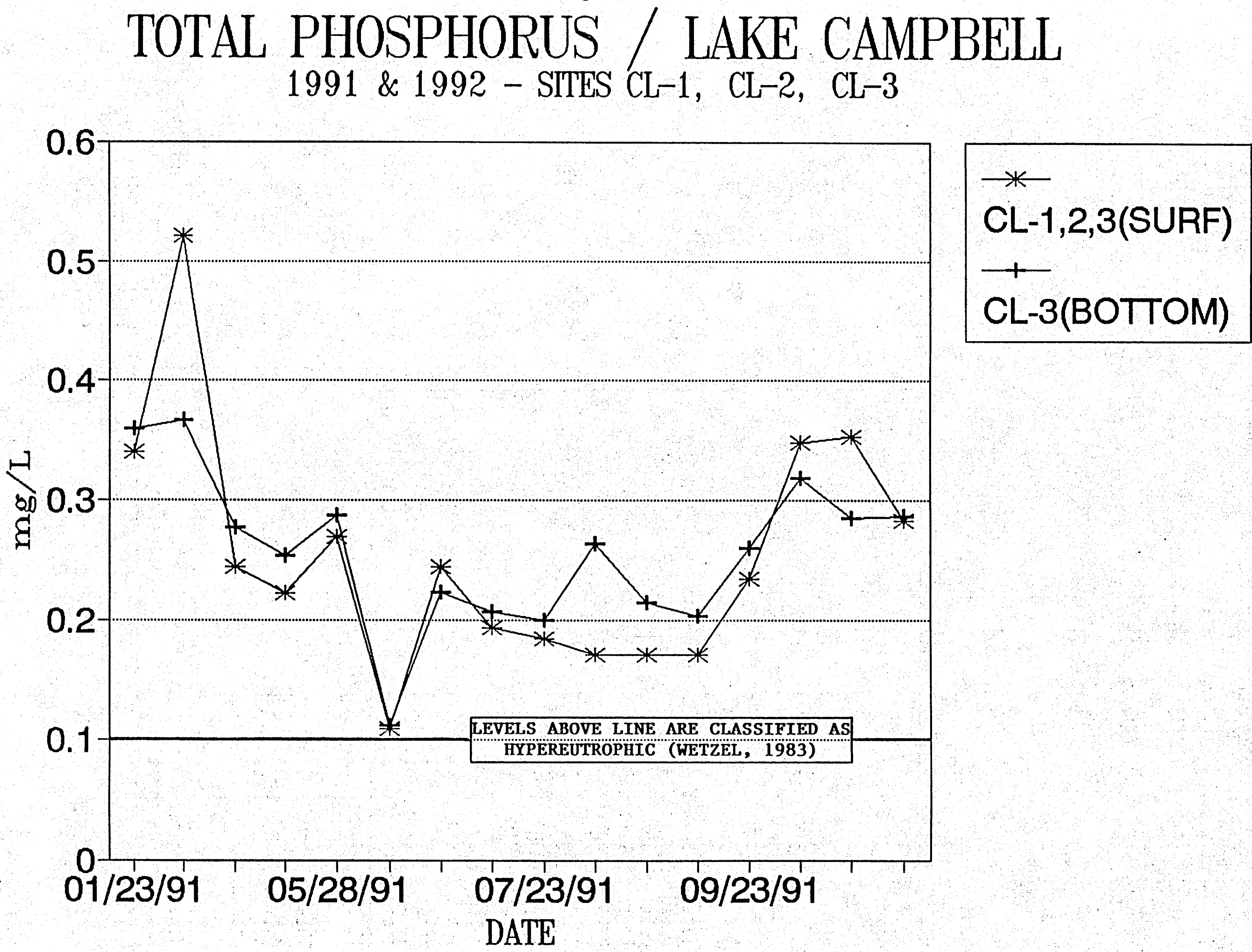
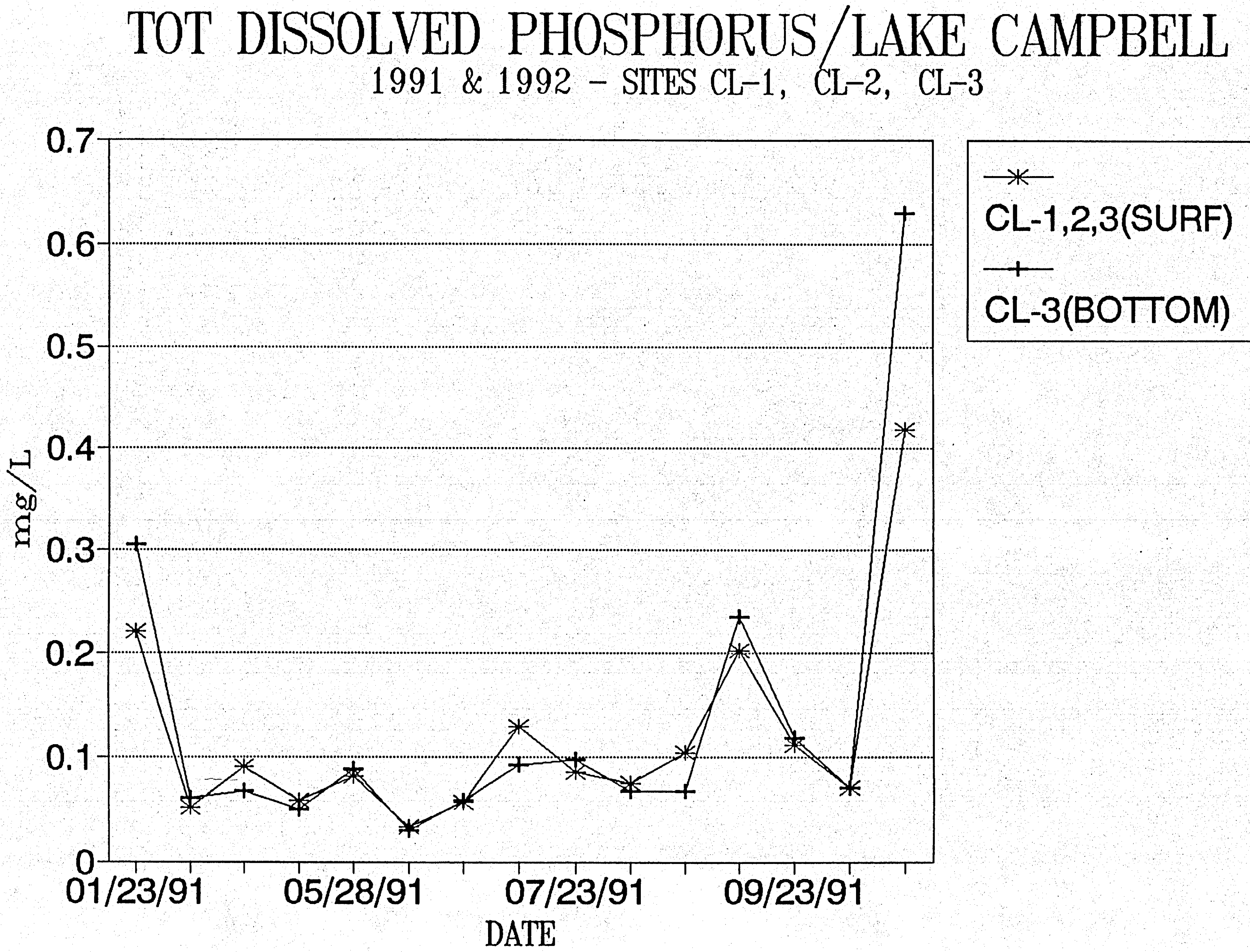

TOTAL PHOSPHORUS / LAKE CAMPBELL
1991 & 1992 - SITES CL-1, CL-2, CL-3
0.6
0.5
0.4
0.3
0.2
0.1
0
mg/L
01/23/91
05/28/91
07/23/91
09/23/91
DATE
CL-1,2,3(SURF)
CL-3(BOTTOM)
LEVELS ABOVE LINE ARE CLASSIFIED AS
HYPEREUTROPHIC (WETZEL, 1983)

Figure 20


TOT DISSOLVED PHOSPHORUS/LAKE CAMPBELL
1991 & 1992 - SITES CL-1, CL-2, CL-3
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
mg/L
01/23/91
05/28/91
07/23/91
09/23/91
DATE
CL-1,2,3(SURF)
CL-3(BOTTOM)

Nitrate+Nitrite

Nitrate+nitrite is an inorganic form of nitrogen which can be utilized by plants for growth. Plants can assimilate nitrate and reduce it to a more useable nitrogen form, ammonia. In Lake Campbell the ammonia concentrations dropped (>0.5 mg/L) in the summer and the nitrate+nitrite concentration increased (<0.6 mg/L) which is typical since plants uptake ammonia before nitrate+nitrite.

Nitrate+nitrite ranged from 0.10 mg/L to 0.70 mg/L during the sampling period. Nitrate+nitrite increases can be caused by breakdown of organic matter or by nitrification of ammonia. Nitrification is the process of adding oxygen to ammonia which converts it to nitrate or nitrite depending on how far the oxidation proceeds. Intensive agricultural activities are probably responsible for most of the nitrogen input to the lake.

Total Kjeldhal Nitrogen

Total Kjeldhal nitrogen (TKN) is used to derive the amount of organic nitrogen which is present in the lake. The ammonia concentration is subtracted from the TKN concentration to acquire the organic component of nitrogen. The values for organic nitrogen increased in the winter, probably due to the increased decaying organic matter from the previous summer. The maximum concentration sampled was on October 16, 1991, (3.07 mg/L). The lower concentrations in the summer of 1991 were fairly stable (between 0.98 mg/L and 1.69 mg/L on surface samples). The minimum concentration sampled was on July 9, 1991, (0.98 mg/L).

Total Nitrogen

The highest total nitrogen values (3.20 mg/L to 4.73 mg/L) samples were found in the winter of 1991. Excluding these samples the nitrogen level remained fairly stable. The percentage of organic to inorganic nitrogen was slightly greater in the surface sample as opposed to the bottom sample (mean 70% & 68% respectively). The remaining 30 percent of the total nitrogen is immediately available to vegetation. The organic nitrogen which is unavailable for uptake by vegetation will eventually be broken down and utilized to complete the nitrogen cycle.

Total Solids

The in-lake samples were also analyzed for Total Solids, Total Dissolved Solids, Total Suspended Solids, Volatile Solids, and Fixed Solids. As can be seen from the graph (Figure 21), the highest concentration for total solids (1,870 mg/L) occurred during the sampling period on January 23, 1991. The majority of concentrations sampled had concentrations between 700 mg/L and 1000 mg/L.

Total Dissolved Solids

Total dissolved solids (TDS) consist of organic salts, small amounts of organic matter, and other dissolved material. The state water quality standard under the beneficial use of wildlife propagation and stock watering is 2,500 mg/L. No exceedences of the standards was found during the sampling. Most of the concentrations for TDS ranged between 661 mg/L and 951 mg/L (Figure 22). Larger concentrations were found in the winter months (maximum concentration 1,861 mg/L). The cause of this extremely high concentration is undetermined at this time.

Figure 21

TOTAL SOLIDS / LAKE CAMPBELL

1991 & 1992 - SITES CL-1, CL-2, CL-3

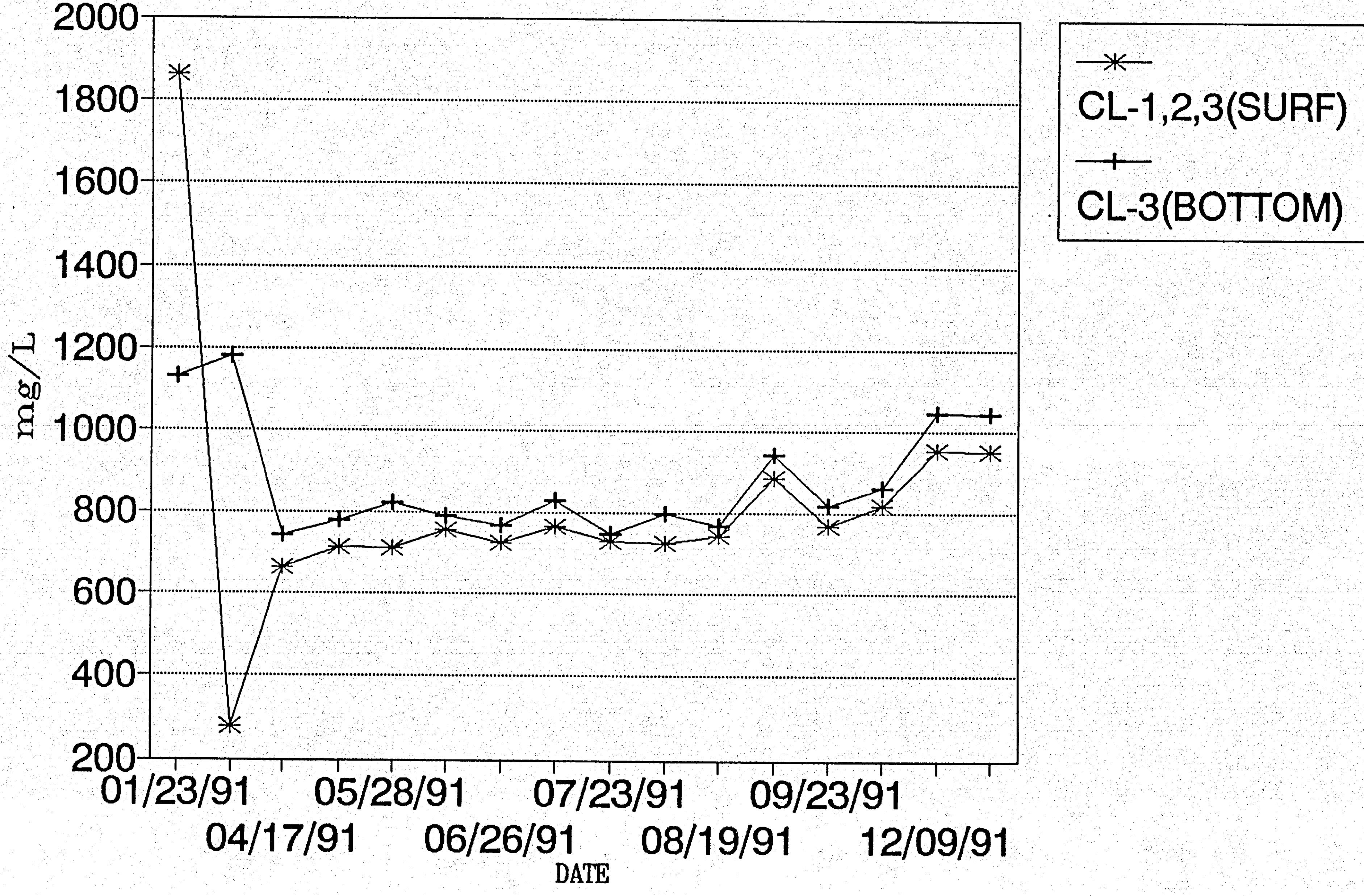
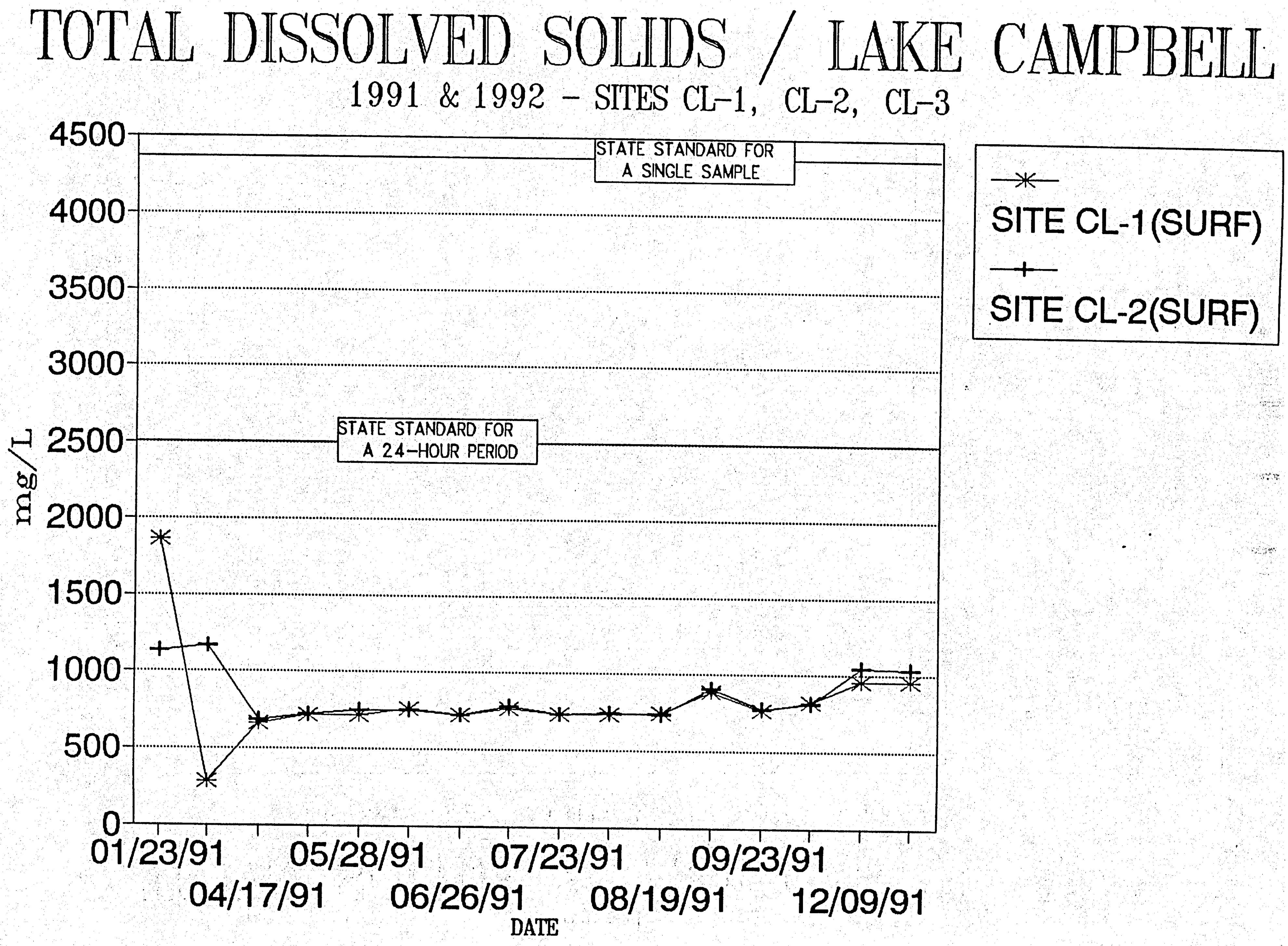


Figure 22



TOTAL DISSOLVED SOLIDS / LAKE CAMPBELL
1991 & 1992 - SITES CL-1, CL-2, CL-3
4500
4000
3500
3000
2500
2000
1500
1000
500
0
mg/L
STATE STANDARD FOR A SINGLE SAMPLE
STATE STANDARD FOR A 24-HOUR PERIOD
SITE CL-1(SURF)
SITE CL-2(SURF)
01/23/91
04/17/91
05/28/91
06/26/91
07/23/91
08/19/91
09/23/91
12/09/91
DATE

Total Suspended Solids

Total suspended solids (TSS) are all other solids in the water column which are not considered dissolved. There are two components of TSS, volatile and non-volatile solids which will be discussed later in this section. The state water quality standard under the beneficial use of warm water marginal fish-life propagation is 150 mg/L. No exceedences of the standards were found in the samples taken during the study. The concentrations of TSS decreased in the winter (seasonal mean 5.8 mg/L) and increased when ice cover leaves the lake (seasonal mean 43.6 mg/L). The most probable reason for the increase in the TSS is the resuspension of bottom sediments from wind, waves, and boat propellers.

Volatile suspended sediments are the component of TSS which were or are organic matter (living things). Non-volatile suspended solids are the component of TSS which are inorganic (sediment). Based on percentages the majority of the TSS are of the non-volatile component (approximately 62%). On June 10, 1991, however, the majority of the TSS were volatile solids (91.2%). This can be explained by an algal bloom at that time. The majority of the non-volatile solids could also be due to colloidal solids suspended in the water column.

Limiting Nutrient

Phosphorus is believed to be the limiting nutrient for algal growth if the ratio of total nitrogen to total phosphorus is greater than 10:1 (mean approximately 11.5:1). As will be noted in the graph of the nitrogen to phosphorus (N:P) ratio (Figure 24), the ratio in Lake Campbell during the sampling period was generally greater than 10:1. This would indicate that phosphorus is the limiting nutrient for algae growth during most times of the year. However, there are times in the sample data when the lake appears to be nitrogen limited. The date which the samples showed Lake Campbell to be most nitrogen limited was on February 12, 1991 (ratio 5.57:1). This was probably due to the first snow-melt which could carry a large load of phosphorus (phosphorus concentration in the lake on the same date was 0.522 mg/L).

According to the limiting nutrient concept, the growth of algae can be controlled if the limiting nutrient can be controlled (Wetzel, 1983). Consequently, in Lake Campbell, during most times of the year, the best measure to control algae growth would be to limit the amount of available phosphorus. This would require reducing sources of phosphorus such as failing septic systems, crop and lawn fertilizers, and feedlot runoff.

Quality Assurance/Quality Control

The quality assurance/quality control (QA/QC) monitoring program approved by the EPA was followed as closely as possible. Three different QA/QC samples were to be taken: 1) Field Duplicate, 2) Blank (distilled water), and 3) Phosphorus Spike. Because the spike solution arrived near the end of the sampling season only three were taken. A total of 147 water samples were taken during 1991 and 1992, along with 15 QA/QC sample sets (Tables 15 and 16).

Large concentrations of dissolved phosphorus were found during the first samples for the blank QA/QC sample set. To correct the problem the State Health Lab stopped adding acid (preservative) to the bottle. Apparently the liner in the dissolved phosphorus bottle was being eaten away by the acid, causing the higher concentrations. Also the distilled water on certain occasions became contaminated such as the blank sample taken on September 10, 1991.

Figure 23

TOTAL SUSPENDED SOLIDS / LAKE CAMPBELL

1991 & 1992 - SITES CL-1, CL-2, CL-3

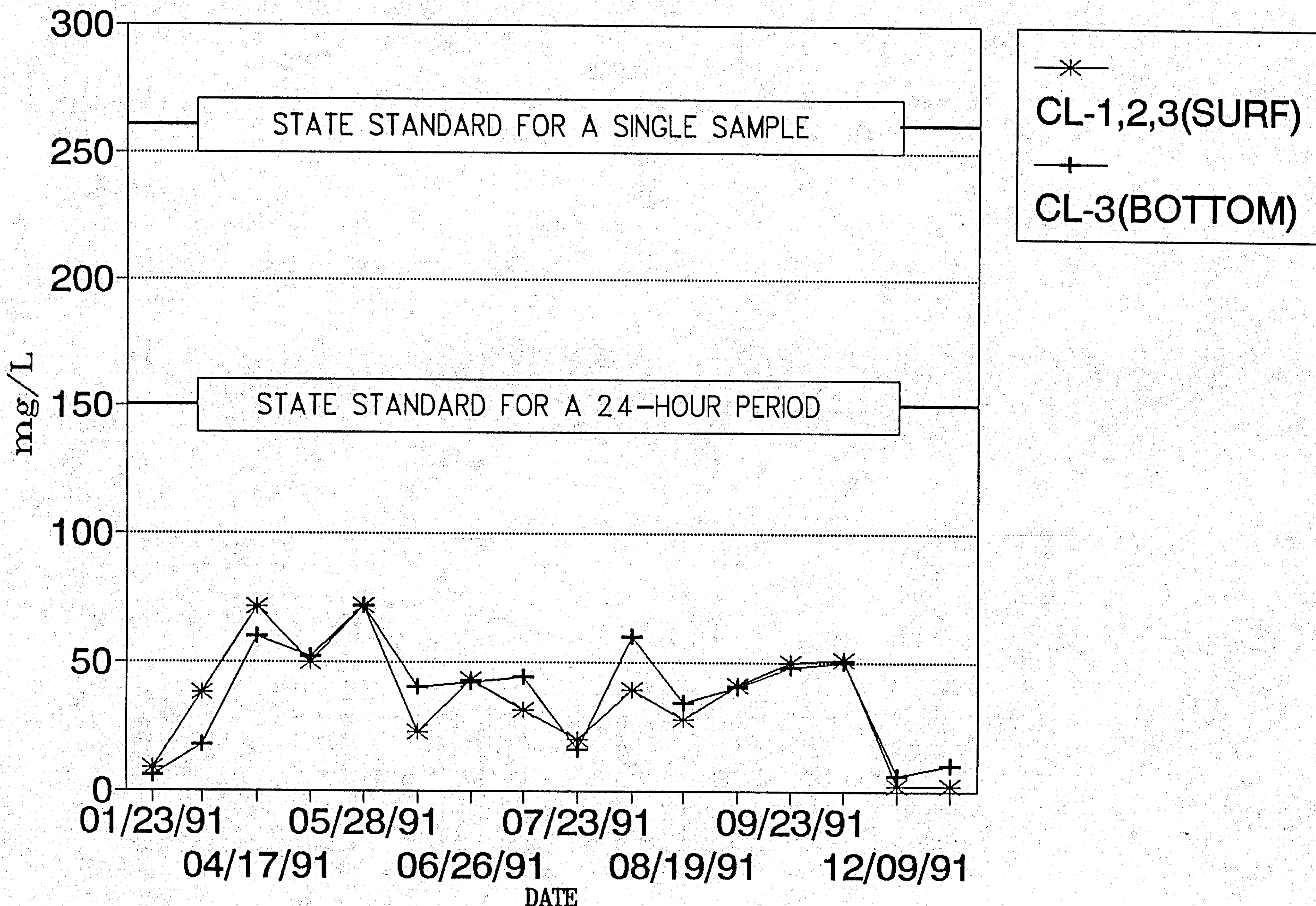


Figure 24

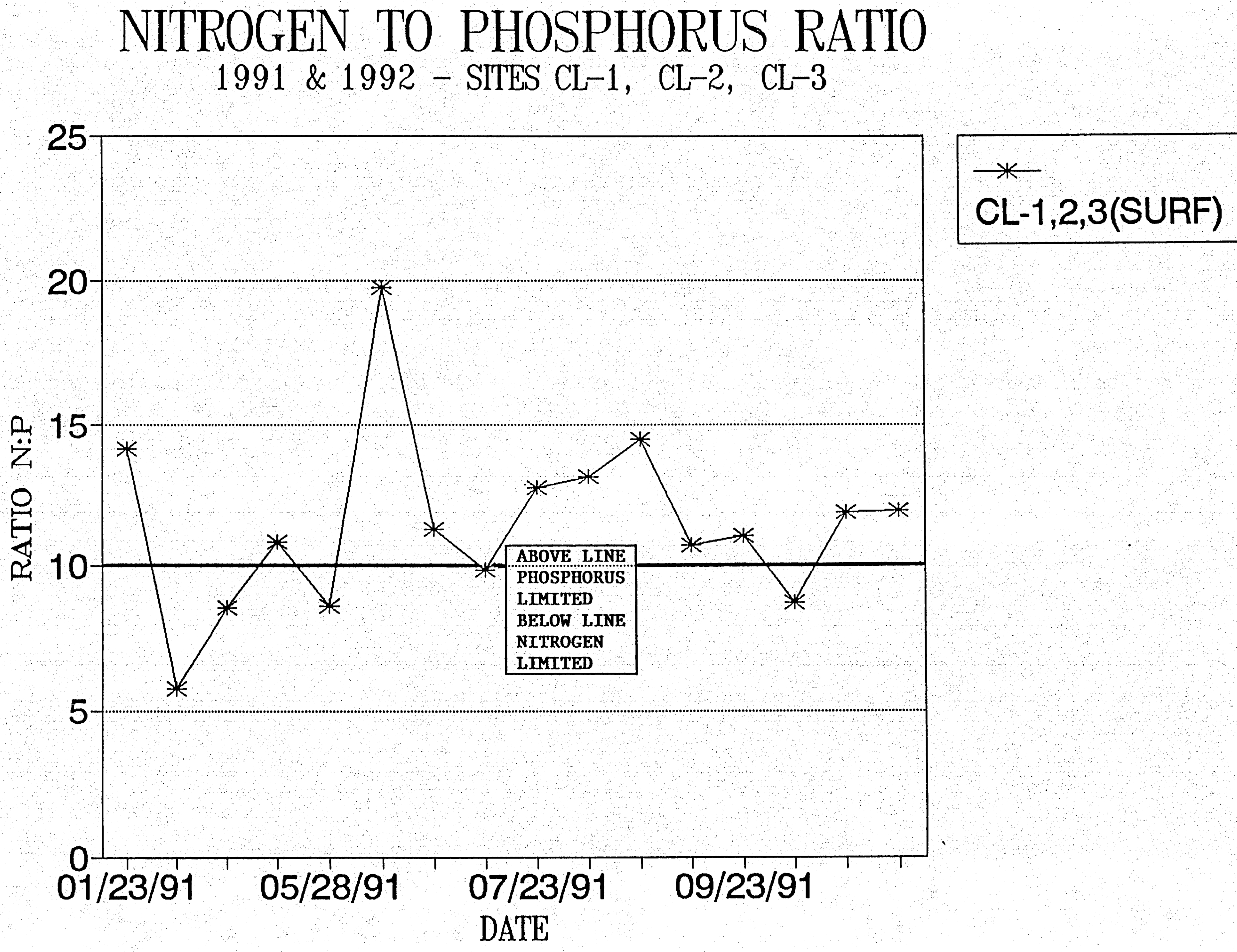

NITROGEN TO PHOSPHORUS RATIO
1991 & 1992 - SITES CL-1, CL-2, CL-3
25
20
15
10
5
0
RATIO N:P
01/23/91
05/28/91
07/23/91
09/23/91
DATE
ABOVE LINE
PHOSPHORUS
LIMITED
BELOW LINE
NITROGEN
LIMITED
CL-1,2,3(SURF)

Table 15. Quality Assurance/Quality Control for Lake Campbell : Blanks and Phosphorus Spikes

-BLANK-

DATE	TIME	SITE	SAMP	DEPTH	WTEMP C	ATEMP C	LABPH su	FECAL /100ml	TALKAL mg/l	TSOL mg/l	TDSOL mg/l	TSSOL mg/l	VOLATILE SOLIDS mg/l	FIXED SOLIDS mg/l	AMMON mg/l	UNIONIZED AMMONIA mg/l	NO3+2 mg/l	TKN-N mg/l	TPO4P mg/l	TOTAL DISS. PO4 mg/l
03/25/91	1430	CT-3B	GRAB	SURFACE	5	16	7.60	2	1.6	5	3	2	2	0	0.04	0.00020	0.1	0.11	0.020	0.020
04/30/91	930	CT-3B	GRAB	SURFACE	9	14	8.58	2	2.0	3	1	2	0	2	0.03	0.00184	0.1	0.10	0.020	0.031
05/28/91	1030	CL-1B	GRAB	SURFACE	22	22	8.43	2	3.4	2	0	2	0	2	0.02	0.00220	0.1	0.10	0.014	0.031
05/29/91	1430	CT-1B	GRAB	SURFACE	25	30	8.70	10	1.6	3	1	2	0	2	0.02	0.00444	0.1	0.10	0.010	0.037
06/21/91	1430	CT-3B	GRAB	SURFACE	22.5	23	8.04	2	2.4	8	0	8	6	2	0.02	0.00099	0.6	0.10	0.006	0.020
06/26/91	1415	CL-1B	GRAB	SURFACE	26	31	8.72	10	2.4	8	6	2	2	0	0.07	0.01699	0.7	0.14	0.005	0.034
08/12/91	1000	CL-2B	GRAB	SURFACE	22.3	23	7.68	10	2.2	7	1	6	2	4	0.02	0.00044	0.8	0.10	0.005	0.005
09/10/91	1345	CL-1B	GRAB	SURFACE	21	20	8.56	2	3.6	12	10	2	0	2	0.02	0.00269	0.1	0.10	0.005	0.005
12/09/91	1200	CL-3B	GRAB	SURFACE	3	10	7.01	2	3.6	1	0	1	0	1	0.14	0.00015	0.1	0.14	0.005	0.060
02/19/92	1400	CT-3B	GRAB	SURFACE	0	20	8.40	2	2.2	7	5	2			0.04	0.00081	0.1	0.14	0.005	
03/11/92	915	CT-3B	GRAB	SURFACE	0	2	8.27	2	2.8	6	2	4			0.02	0.00030	0.1	0.16	0.005	0.005
03/11/92	1230	CT-1B	GRAB	SURFACE	1	3	8.29	2	2.8	5	3	2			0.02	0.00034	0.2	0.32	0.001	0.043
03/24/92	1400	CT-5B	GRAB	SURFACE	9	17	8.46	2	2.8	13	11	2			0.02	0.00095	0.1	0.70	0.005	0.005

-PHOSPHORUS SPIKE-

DATE	TIME	SITE	SAMP	DEPTH	TPO4 mg/L	DIFFERENCE mg/L
03/11/92	1230	CT-1S	GRAB	SURFACE	0.591	0.206
03/11/92	1230	CT-1	GRAB	SURFACE	0.385	
03/11/92	915	CT-3S	GRAB	SURFACE	0.787	0.422
03/11/92	915	CT-3	GRAB	SURFACE	0.365	
03/24/92	1400	CT-5S	GRAB	SURFACE	0.369	0.200
03/24/92	1400	CT-5	GRAB	SURFACE	0.169	

Underlined concentrations have exceeded the EPA holding time.

Table 16. Quality Assurance/Quality Control for Lake Campbell : Field Duplicates

-FIELD DUPLICATE-

DATE	TIME	SITE	SAMP	DEPTH	WTEMP C	ATEMP C	LABPH su	FECAL /100ml	TALKAL mg/l	TSOL mg/l	TDSOL mg/l	TSSOL mg/l	VOLATILE SOLIDS mg/l	FIXED SOLIDS mg/l	AMMON mg/l	UNIONIZED AMMONIA mg/l	NO3+2 mg/l	TKN-N mg/l	TPO4P mg/l	TOTAL DISS. PO4 mg/l
03/25/91	1430	CT-3D	GRAB	SURFACE	5	16	8.14	2	156	653	629	24	24	0	0.02	0.00034	0.1	0.55	0.203	0.068
03/25/91	1430	CT-3	GRAB	SURFACE	5	16	7.92	2	158	655	631	24	18	6	0.02	0.00021	0.1	0.60	0.176	0.054
04/17/91	1100	CL-1D	GRAB	SURFACE	8	10	7.85	10	126	713	669	44	16	28	0.65	0.00724	0.1	1.96	0.214	0.088
04/17/91	1100	CL-1	GRAB	SURFACE	8	10	7.84	10	126	711	657	54	20	34	0.66	0.00719	0.1	1.92	0.214	0.085
04/30/91	930	CT-3D	GRAB	SURFACE	9	14	8.17	48	266	1214	1190	24	22	2	0.03	0.00075	0.1	0.59	0.241	0.122
04/30/91	930	CT-3	GRAB	SURFACE	9	14	8.16	50	265	1214	1188	26	20	6	0.03	0.00073	0.1	0.69	0.237	0.122
05/28/91	1030	CL-1D	GRAB	SURFACE	22	22	7.81	24	148	752	684	66	22	46	0.81	0.02333	0.1	2.22	0.254	0.078
05/28/91	1030	CL-1	GRAB	SURFACE	22	22	7.95	36	147	757	687	70	18	52	0.82	0.03225	0.1	2.56	0.251	0.064
05/29/91	1400	CT-1D	GRAB	SURFACE	25	30	8.31	96	141	746	662	64	34	30	0.73	0.07599	0.2	1.96	0.271	0.078
05/29/91	1400	CT-1	GRAB	SURFACE	25	30	8.35	96	141	771	701	70	32	38	0.72	0.08136	0.1	1.58	0.275	0.071
06/04/91	1300	CT-1D	GRAB	SURFACE	22.8	26	7.98	60	143	768	704	64	2	62	0.72	0.03197	0.1	1.72	0.244	0.092
06/04/91	1300	CT-1	GRAB	SURFACE	22.8	26	8.01	30	144	735	665	70	2	68	0.74	0.03510	0.1	1.46	0.264	0.095
06/21/91	1400	CT-4D	GRAB	SURFACE	22.5	22	7.95		214	826	764	62	20	42	0.17	0.00692	1.1	1.37	0.441	0.256
06/21/91	1400	CT-4	GRAB	SURFACE	22.5	22	7.95		213	827	767	60	18	42	0.14	0.00570	1.1	1.35	0.447	0.261
06/26/91	1400	CL-1D	GRAB	SURFACE	26	31	8.73	40	144	762	718	44	14	30	0.06	0.01975	0.6	1.71	0.271	0.061
06/26/91	1400	CL-1	GRAB	SURFACE	26	31	8.69	30	144	767	717	50	18	32	0.32	0.07367	0.7	1.72	0.146	0.034
08/12/91	1000	CL-2D	GRAB	SURFACE	22.3	23	8.90	10	130	766	724	42	24	18	0.03	0.00615	0.7	1.39	0.176	0.044
08/12/91	1000	CL-2	GRAB	SURFACE	22.3	23	8.91	10	130	761	723	38	28	10	0.03	0.00628	0.7	1.55	0.166	0.112
09/10/91	1330	CL-1D	GRAB	SURFACE	21	20	8.40		139	937	907	30	12	18	0.33	0.03196	0.1	1.91	0.159	0.088
09/10/91	1330	CL-1	GRAB	SURFACE	21	20	8.32		139	906	878	28	10	18	0.37	0.03032	0.1	2.02	0.170	0.088
12/09/91	1200	CL-3D	GRAB	SURFACE	3	10	7.82	2	194	926	925	1	0	1	1.25	0.00671	0.1	4.63	0.292	0.75
12/09/91	1200	CL-3	GRAB	SURFACE	3	10	7.84	2	196	929	928	1	1	0	1.21	0.00662	0.1	4.60	0.305	0.654
02/19/92	1400	CT-3D	GRAB	SURFACE	0	20	7.64	580	67	315	247	68			0.71	0.00255	1.0	3.03	0.813	
02/19/92	1400	CT-3	GRAB	SURFACE	0	20	7.95	700	66	320	256	64			0.71	0.00519	1.0	2.38	0.830	
03/11/92	915	CT-3D	GRAB	SURFACE	0	2	7.86	4	164	911	829	82			0.22	0.00131	1.1	3.89	0.365	0.252
03/11/92	915	CT-3	GRAB	SURFACE	0	2	7.86	20	166	902	840	62			0.24	0.00143	1.1	0.97	0.365	0.252
03/11/92	1230	CT-1D	GRAB	SURFACE	1	3	7.71	6	122	510	486	24			0.89	0.00409	0.3	1.93	0.362	0.279
03/11/92	1230	CT-1	GRAB	SURFACE	1	3	7.60	10	122	503	469	34			0.89	0.00317	0.4	1.72	0.385	0.359
03/24/92	1400	CT-5D	GRAB	SURFACE	9	17	8.25	6	207	1085	1063	22			0.02	0.00059	0.1	1.12	0.149	0.103
03/24/92	1400	CT-5	GRAB	SURFACE	9	17	8.22	2	206	1091	1063	28			0.02	0.00056	0.1	0.69	0.169	0.093

Underlined concentrations have exceeded the EPA holding time.

TRIBUTARY DATA

Tributary samples were collected at five sites in the Lake Campbell watershed (Figure 25, Lake Campbell Tributary Monitoring Sites). All of the monitoring sites were located on Battle Creek, the main tributary to Lake Campbell. A description of the sites is as follows:

Site CT-1 Lake Campbell outlet, located at the northeast end of the lake.

Site CT-3 Battle Creek, located approximately two miles upstream from the entrance to Lake Campbell.

Site CT-4 Battle Creek, at the confluence of an unnamed tributary entering approximately three miles south of Lake Campbell.

Site CT-5 Battle Creek, at the confluence of another unnamed tributary, approximately eight miles south and five miles west of Lake Campbell.

Site CT-6 Battle Creek, located eight miles south and eleven miles west of Lake Campbell.

It should be noted that tributary samples were not collected from September, 1991 through January, 1992. This was because flow had discontinued in Battle Creek, and sampling equipment was removed for the winter.

The beneficial uses designated for Battle Creek are the following:

1. Warmwater marginal fish life propagation

2. Limited contact recreation

3. Wildlife propagation and stock watering

4. Irrigation

The water quality criteria designated for maintenance of these beneficial uses can be found in Table 17, Battle Creek Water Quality Standards.

Samples from Battle Creek were tested for the same parameters as the in-lake samples from Lake Campbell. The following discussion will center around the more significant results of the tributary sampling. Tables 18 through 22 contain the concentration results of tributary sampling for 1991 - 1992. Graphs for some of the 1991 tributary results will be discussed below. The following discussion will summarize the results of the tributary sampling completed during 1991.

<u>Dissolved Oxygen</u>

The water quality standards for Battle Creek require that dissolved oxygen be maintained at a level greater than 5.0 mg/L. The oxygen level did not fall below the set standard in any of the samples collected from the monitoring sites on Battle Creek.

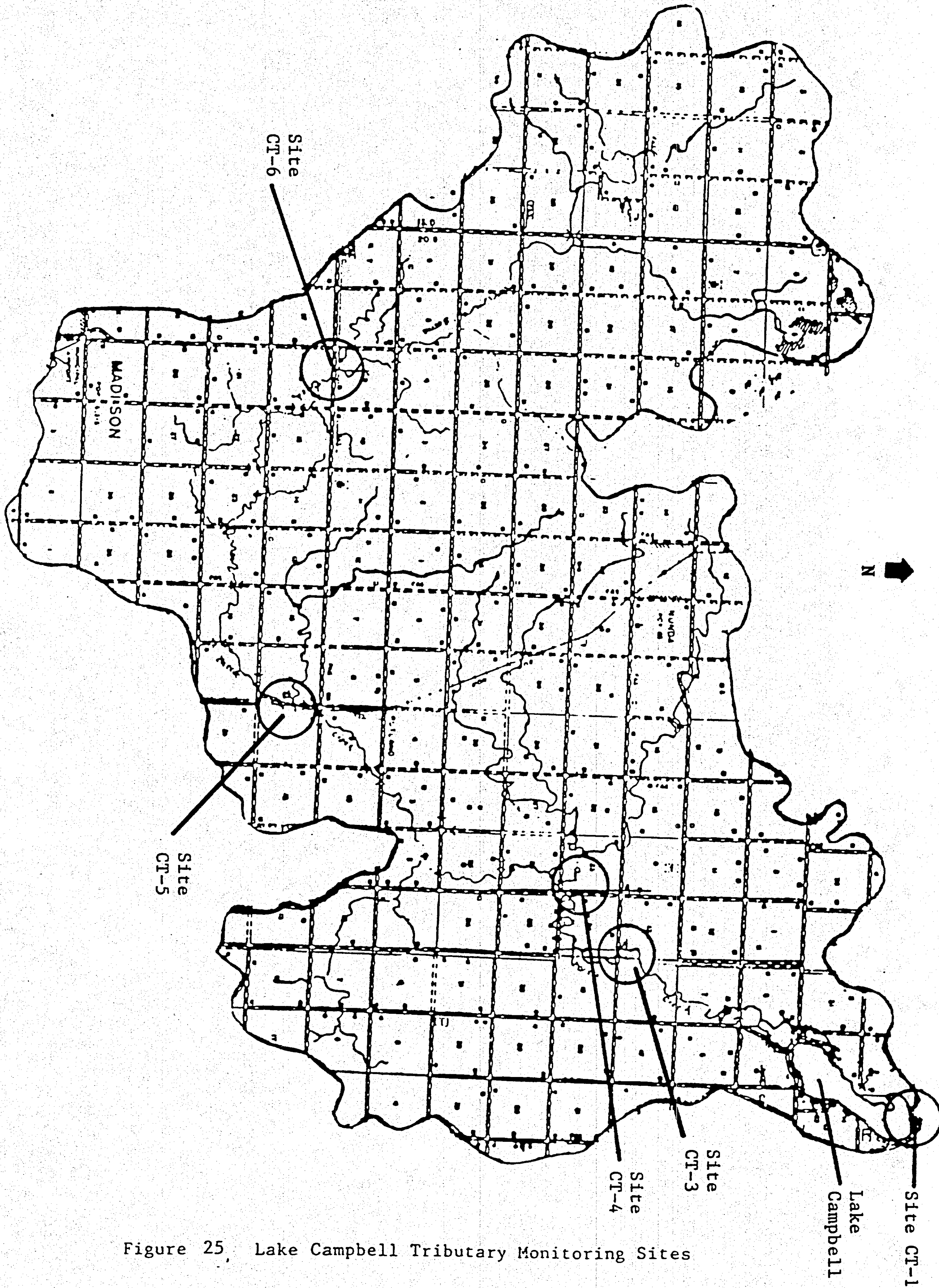


Figure 25. Lake Campbell Tributary Monitoring Sites

Table 17
Battle Creek Water Quality Standards

Parameter	Standard
Total Chlorine Residual	<0.02 mg/L
Un-Ionized Ammonia	<0.05 mg/L
Total Cyanide	<0.02 mg/L
Free Cyanide	<0.005 mg/L
Dissolved Oxygen	>5.0 mg/L
Undisassociated Hydrogen Sulfide	<0.002 mg/L
pH	>6.0 & <9.0 units
Suspended Solids	<150 mg/L
Temperature	<90° F
Polychlorinated Biphenyls	<0.000001 mg/L
Fecal Coliform Organisms	<1000 /100 mL
Total Alkalinity	<750 mg/L
Total Dissolved Solids	<2500 mg/L
Conductivity	<4000 micromhos/cm
Nitrates	<50 mg/L
Sodium asborption ratio	<10:1

TABLE 18. 1991-92 TRIBUTARY CONCENTRATIONS - CT1

1992 SUMMARY OF RESULTS LAKE CAMPBELL PROJECT
ESTIMATED TRIBUTARY CONCENTRATIONS
ALL CONCENTRATIONS IN MILLIGRAMS PER LITER

SAMPLE DATA FOR LAKE CAMPBELL OUTLET (CT1), 1991
12 SAMPLES

DATE	SAMP	WTEMP C	DISOX mg/L	FECAL COLIFORM per 100mL	LABPH su	TALKAL mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	VOLATILE SOLIDS mg/L	FIXED SOLIDS mg/L	AMMON mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	ORGANIC mg/L	TOTAL-N mg/L	TPO4P mg/L	TOTAL DISS. PO mg/L
18-Mar-91	GRAB	1.0	12.0	2		136	599	584	15	6	9	0.58	0.00327	0.1	1.38	0.80	1.48	0.061	0.020
20-Mar-91	GRAB	5.0	13.2	2	8.50	125	584	556	28	14	14	0.57	0.02168	0.1	1.79	1.22	1.89	0.136	0.054
03-Apr-91	GRAB	14.0	20.0	2	8.95	125	748	556	192	56	136	0.02	0.00369	0.1	1.85	1.83	1.95	0.359	0.085
15-Apr-91	GRAB	7.0	10.8	6	8.04	130	742	662	80	20	60	0.62	0.00983	0.1	2.08	1.46	2.18	0.359	0.244
30-Apr-91	GRAB	9.3	9.6	60	8.19	150	813	673	140	38	102	0.45	0.01192	0.5	1.53	1.08	2.03	0.390	0.051
17-May-91	GRAB	17.0	8.0	2	8.00	136	816	764	52	10	42	0.39	0.01076	0.1	1.85	1.46	1.95	0.288	0.085
29-May-91	GRAB	25.3	9.8	96	8.35	141	771	701	70	32	38	0.72	0.02523	0.1	1.58	0.86	1.68	0.275	0.071
04-Jun-91	GRAB	22.8	13.2	30	8.01	144	735	665	70	2	68	0.74	0.03498	0.1	1.46	0.72	1.56	0.264	0.095
21-Jun-91	GRAB	22.5	9.2	20	8.54	134	746	710	36	8	28	0.07	0.00992	0.6	1.78	1.71	2.38	0.200	0.054
24-Jun-91	GRAB	22.0	11.2	20	8.86	140	863	815	48	26	22	0.04	0.00999	0.7	1.57	1.53	2.27	0.217	0.037
31-Jul-91	GRAB	27.5	11.8	6	8.26	134	826	770	56	22	34	0.02	0.00220	0.5	1.61	1.59	2.11	0.197	0.108
08-Aug-91	GRAB	20.0	9.3	20	8.65	134	745	701	44	12	32	0.02	0.00301	0.7	1.37	1.35	2.07	0.193	0.064
MINIMUM		1.0	8.0	2	8.00	125	584	556	15	2	9	0.02	0.00220	0.1	1.37	0.72	1.48	0.061	0.020
MAXIMUM		27.5	20.0	96	8.95	150	863	815	192	56	136	0.74	0.03498	0.7	2.08	1.83	2.38	0.390	0.244
MEAN		16.1	11.5	22	8.40	136	749	680	69	21	49	0.35	0.01221	0.3	1.65	1.30	1.96	0.245	0.081

SAMPLE DATA FOR LAKE CAMPBELL OUTLET (CT1), 1992
9 SAMPLES

DATE	SAMP	WTEMP C	DISOX mg/L	FECAL COLIFORM per 100mL	LABPH units	TALKAL mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	AMMONIA mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TPO4 mg/L
04-Feb-92	GRAB	1.0	15.0	2	8.54	117	593	583	10	0.160	0.00568	0.200	1.120	0.120
19-Feb-92	GRAB	0.0	14.9	2	8.68	182	918	848	70	0.440	0.01675	0.100	3.950	0.452
26-Feb-92	GRAB	3.0	15.6	32	8.31	177	832	816	16	0.790	0.01676	0.200	3.210	0.415
02-Mar-92	GRAB	3.0	13.4	30	7.78	104	446	430	16	0.820	0.00521	0.600	2.530	0.478
04-Mar-92	GRAB	4.0	11.0	10	8.20	88	345	335	10	0.460	0.00825	0.500	2.230	0.392
11-Mar-92	GRAB	1.0	12.4	10	7.60	122	503	469	34	0.890	0.00317	0.400	1.720	0.385
16-Mar-92	GRAB	7.0	12.2	4	7.90	128	519	495	24	0.900	0.01038	0.500	2.460	0.369
24-Mar-92	GRAB	8.0	15.8	2	8.59	137	582	566	16	0.350	0.02040	0.500	1.770	0.226
30-Mar-92	GRAB	6.0	16.1	2	9.04	143	655	609	46	0.020	0.00259	0.700	2.050	0.312
MIN		0.0	11.0	2	7.60	88	345	335	10	0.020	0.00259	0.100	1.120	0.120
MAX		8.0	16.1	32	9.04	182	918	848	70	0.900	0.02040	0.700	3.950	0.478
MEAN		3.7	14.0	10	8.29	133	599	572	27	0.537	0.00991	0.411	2.338	0.350

TABLE 19. 1991-92 TRIBUTARY CONCENTRATIONS - CT3

1991-92 SUMMARY OF RESULTS LAKE CAMPBELL PROJECT
ESTIMATED TRIBUTARY CONCENTRATIONS
ALL CONCENTRATIONS IN MILLIGRAMS PER LITER

SAMPLE DATA FOR BATTLE CREEK (CT3), 1991
14 SAMPLES

DATE	SAMP	WTEMP C	DISOX mg/L	FECAL COLIFORM /100mL	LABPH su	TALKAL mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	VOLATILE SOLIDS mg/L	FIXED SOLIDS mg/L	AMMON mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	ORGANIC mg/L	TOTAL-N mg/L	TPO4P mg/L	TOTAL DISS. PO4 mg/L
06-Mar-91	GRAB	1.0	11.9	2		200	863	847	16	12	4	0.03	0.0002	0.10	0.89	0.86	0.99	0.237	0.210
18-Mar-91	GRAB	1.0	13.8	12		81	344	332	12	4	8	0.02	0.0002	0.10	0.73	0.71	0.83	0.122	0.068
20-Mar-91	GRAB	2.0	13.2	2	8.36	152	672	631	41	30	11	0.02	0.0000	0.10	0.53	0.51	0.63	0.142	0.047
25-Mar-91	GRAB	5.0	12.4	2	7.92	158	655	631	24	18	6	0.02	0.0002	0.10	0.60	0.58	0.70	0.176	0.054
01-Apr-91	GRAB	6.0	11.7	4	8.26	201	860	820	40	25	15	0.02	0.0005	0.10	0.95	0.93	1.05	0.217	0.044
09-Apr-91	GRAB	8.3	9.1	82	8.11	255	974	944	30	26	4	0.02	0.0004	0.10	0.86	0.84	0.96	0.200	0.054
15-Apr-91	GRAB	9.0	11.2	84	8.22	257	1,052	1,004	48	16	32	0.02	0.0006	0.10	0.80	0.78	0.90	0.241	0.088
30-Apr-91	GRAB	9.0	7.8	50	8.16	265	1,214	1,188	26	20	6	0.03	0.0007	0.10	0.69	0.66	0.79	0.237	0.122
29-May-91	GRAB	28.0	9.0	354	9.00	259	1,287	1,199	88	24	64	0.02	0.0015	0.10	1.78	1.76	1.88	0.356	0.136
04-Jun-91	GRAB	21.5	6.5	1400	7.73	269	1,292	1,218	74	8	66	0.22	0.0051	0.10	1.49	1.27	1.59	0.400	0.203
21-Jun-91	GRAB	22.5	7.2		7.98	205	839	775	64	22	42	0.18	0.0078	1.00	1.47	1.29	2.47	0.417	0.214
24-Jun-91	GRAB	19.5	6.9	780	8.19	128	620	524	96	24	72	0.10	0.0057	0.10	1.25	1.15	1.35	0.634	0.305
31-Jul-91	GRAB	27.5	11.8	440	8.55	266	1,134	1,084	50	12	38	0.02	0.0039	0.50	1.34	1.32	1.84	0.312	0.264
09-Aug-91	GRAB	19.3	9.6		8.19	254	986	938	48	8	40	0.04	0.0022	0.80	1.02	0.98	1.82	0.281	0.180
MIN		1.0	6.5	2	7.73	81	344	332	12	4	4	0.020	0.00001	0.100	0.530	0.510	0.630	0.122	0.044
MAX		28.0	13.8	1400	9.00	269	1292	1218	96	30	72	0.220	0.00783	1.000	1.780	1.760	2.470	0.634	0.305
MEAN		12.8	10.2	268	8.22	211	914	867	47	18	29	0.054	0.00208	0.243	1.029	0.974	1.271	0.284	0.142

SAMPLE DATA FOR BATTLE CREEK (CT3), 1992
8 SAMPLES

DATE	SAMP	WTEMP C	DISOX mg/L	FECAL COLIFORM per 100mL	LABPH units	TALKAL mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	AMMONIA mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TPO4 mg/L
19-Feb-92	GRAB	0.0	11.9	700	7.95	66	320	256	64	0.710	0.00519	1.000	2.380	0.830
26-Feb-92	GRAB	4.0	16.0	10	7.73	101	412	348	64	0.590	0.00363	0.700	2.460	0.591
02-Mar-92	GRAB	4.0	9.8	28	7.61	89	352	306	46	0.480	0.00224	1.000	1.990	0.508
04-Mar-92	GRAB	5.0	10.2	30	7.76	116	502	458	44	0.330	0.00236	0.800	2.000	0.422
11-Mar-92	GRAB	0.0	13.0	20	7.86	166	902	840	62	0.240	0.00143	1.100	0.970	0.365
16-Mar-92	GRAB	3.0	12.4	10	7.98	185	981	949	32	0.100	0.00100	0.900	1.330	0.302
24-Mar-92	GRAB	8.0	12.0	14	8.16	211	1128	1044	84	0.020	0.00045	0.400	0.770	0.266
30-Mar-92	GRAB	5.0	11.8	16	8.28	229	1182	1094	88	0.020	0.00047	0.100	1.570	0.289
MIN		0.0	9.8	10	7.61	66	320	256	32	0.020	0.00045	0.100	0.770	0.266
MAX		8.0	16.0	700	8.28	229	1182	1094	88	0.710	0.00519	1.100	2.460	0.830
MEAN		3.6	12.1	104	7.92	145	722	662	61	0.311	0.00210	0.750	1.684	0.447

TABLE 20. 1991-92 TRIBUTARY CONCENTRATIONS - CT4

1991-92 SUMMARY OF RESULTS LAKE CAMPBELL PROJECT
ESTIMATED TRIBUTARY CONCENTRATIONS
ALL CONCENTRATIONS IN MILLIGRAMS PER LITER

SAMPLE DATA FOR BATTLE CREEK (CT4), 1991
12 SAMPLES

DATE	SAMP	WTEMP C	DISOX mg/L	FECAL COLIFORM per 100mL	LABPH units	TALKAL mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	VOLATILE SOLIDS mg/l	FIXED SOLIDS mg/l	AMMONIA mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TPO4 mg/L	TOTAL DISS. PO4 mg/l
15-Apr-91	GRAB	7.5	11.2	8	8.17	273	1093	1037	56	16	40	0.020	0.00044	0.100	0.960	0.237	0.088
30-Apr-91	GRAB	7.0	8.0	200	8.01	289	1229	1211	18	12	6	0.020	0.00030	0.100	0.640	0.234	0.146
29-May-91	GRAB	27.0	10.2	350	8.11	264	1245	1187	58	32	26	0.040	0.00311	0.100	0.910	0.264	0.139
04-Jun-91	GRAB	21.5	7.0	1500	7.74	289	1350	1272	78	18	60	0.250	0.00594	0.200	1.420	0.414	0.210
21-Jun-91	GRAB	22.5	7.4	0	7.95	213	827	767	60	18	42	0.140	0.00570	1.100	1.350	0.447	0.261
24-Jun-91	GRAB	20.0	6.9	770	7.99	125	587	537	50	20	30	0.070	0.00262	1.200	0.900	0.407	0.281
08-Aug-91	GRAB	19.0	8.6	0	7.96	272	1112	1062	50	10	40	0.140	0.00456	0.800	1.000	0.383	0.193
MIN		7.0	6.9	0	7.74	125	587	537	18	10	6	0.020	0.00030	0.100	0.640	0.234	0.088
MAX		27.0	11.2	1500	8.17	289	1350	1272	78	32	60	0.250	0.00594	1.200	1.420	0.447	0.281
MEAN		17.8	8.5	404	7.99	246	1063	1010	53	18	35	0.097	0.00324	0.514	1.026	0.341	0.188

SAMPLE DATA FOR BATTLE CREEK, RUTLAND, (CT4), 1992
14 SAMPLES

DATE	SAMP	WTEMP C	DISOX mg/L	FECAL COLIFORM per 100mL	LABPH units	TALKAL mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	AMMONIA mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TPO4 mg/L
02-Mar-92	GRAB	4.0	8.4	32	7.59	87	341	311	30	0.480	0.00214	1.000	2.150	0.458
04-Mar-92	GRAB	5.3	9.8	20	7.73	119	506	484	22	0.310	0.00211	0.700	1.730	0.408
11-Mar-92	GRAB	0.0	12.0	10	7.81	161	849	827	22	0.170	0.00090	1.100	3.810	0.302
24-Mar-92	GRAB	9.0	11.8	54	8.24	210	1081	1049	32	0.020	0.00058	0.200	1.100	0.229
30-Mar-92	GRAB	4.0	11.8	10	8.43	230	1161	1125	36	0.020	0.00060	0.100	1.350	0.206
MIN		0.0	8.4	10	7.59	87	341	311	22	0.020	0.00058	0.100	1.100	0.206
MAX		9.0	12.0	54	8.43	230	1161	1125	36	0.480	0.00214	1.100	3.810	0.458
MEAN		4.5	10.8	25	7.96	161	788	759	28	0.200	0.00127	0.620	2.028	0.321

TABLE 21. 1991-92 TRIBUTARY CONCENTRATIONS - CT5

1991-92 SUMMARY OF RESULTS LAKE CAMPBELL PROJECT
ESTIMATED TRIBUTARY CONCENTRATIONS
ALL CONCENTRATIONS IN MILLIGRAMS PER LITER

SAMPLE DATA FOR BATTLE CREEK, RUTLAND, (CT5), 1991
8 SAMPLES

DATE	SAMP	WTEMP	DISOX	FECAL COLIFORM	LABPH	TALKAL	TSOL	TDSOL	TSSOL	VOLSOL	FIXSOL	AMMONIA	UNIONIZED AMMONIA	NO3+2	TKN-N	TPO4	TDPO4
		C	mg/L	per 100mL	units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
04-Apr-91	GRAB	14.0	12.2	14	8.16	340	1016	994	22	2	20	0.020	0.00010	0.1	1.37	0.427	0.18
09-Apr-91	GRAB	6.0	9.2	250	7.98	331	947	931	16	14	2	0.020	0.00000	0.1	1.23	0.268	0.136
15-Apr-91	GRAB	9.0	9.2	270	7.93	270	1123	1091	32	16	16	0.050	0.00035	0.1	0.93	0.193	0.119
30-Apr-91	GRAB	8.3	8.2	40000	7.90	274	1334	1314	20	16	4	0.060	0.00040	0.1	1.34	0.383	0.275
29-May-91	GRAB	26.8	8.8	158	8.02	261	1201	1149	52	34	18	0.050	0.00035	0.1	1.1	0.329	0.244
04-Jun-91	GRAB	20.5	6.0	20000	7.74	282	1186	1150	36	6	30	0.090	0.00041	0.2	1.86	0.346	0.312
21-Jun-91	GRAB	22.0	6.8	200	7.71	124	580	470	110	24	86	0.120	0.00051	1.8	0.95	0.556	0.319
08-Aug-91	GRAB	20.0	7.2	200	7.90	252	919	851	68	16	52	0.070	0.00046	1	1.34	0.603	0.261
MIN		6.0	6.0	14	7.71	124	580	470	16	2	2	0.020	0.00000	0.100	0.930	0.193	0.119
MAX		26.8	12.2	40000	8.16	340	1334	1314	110	34	86	0.120	0.00051	1.800	1.860	0.603	0.319
MEAN		15.8	8.5	7637	7.92	267	1038	994	45	16	29	0.060	0.00032	0.438	1.265	0.388	0.231

SAMPLE DATA FOR BATTLE CREEK, RUTLAND, (CT5), 1992
6 SAMPLES

DATE	SAMP	WTEMP	DISOX	FECAL COLIFORM	LABPH	TALKAL	TSOL	TDSOL	TSSOL	AMMONIA	UNIONIZED AMMONIA	NO3+2	TKN-N	TPO4
		C	mg/L	per 100mL	units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
02-Mar-92	GRAB	4.3	8.4	38	7.48	97	418	398	20	0.450	0.00159	0.900	1.970	0.458
04-Mar-92	GRAB	5.5	9.8	30	7.66	117	517	507	10	0.310	0.00183	0.700	2.270	0.385
11-Mar-92	GRAB	2.5	11.6	8	7.71	168	888	872	16	0.130	0.00068	1.100	1.260	0.279
16-Mar-92	GRAB	2.0	12.8	2	7.87	184	963	957	6	0.020	0.00014	0.700	0.840	0.206
24-Mar-92	GRAB	9.0	14.8	2	8.22	206	1091	1063	28	0.020	0.00056	0.100	0.690	0.169
30-Mar-92	GRAB	4.0	12.9	2	8.31	220	1147	1133	14	0.020	0.00046	0.100	1.140	0.123
MIN		2.0	8.4	2	7.48	97	418	398	6	0.020	0.00014	0.100	0.690	0.123
MAX		9.0	14.8	38	8.31	220	1147	1133	28	0.450	0.00183	1.100	2.270	0.458
MEAN		4.5	11.7	14	7.88	165	837	822	16	0.158	0.00088	0.600	1.362	0.270

TABLE 22. 1991-92 TRIBUTARY CONCENTRATIONS - CT6

1991-92 SUMMARY OF RESULTS LAKE CAMPBELL PROJECT
ESTIMATED TRIBUTARY CONCENTRATIONS
ALL CONCENTRATIONS IN MILLIGRAMS PER LITER

SAMPLE DATA FOR BATTLE CREEK (CT6), 1991
7 SAMPLES

DATE	SAMP	WTEMP C	DISOX mg/L	FECAL COLIFORM per 100mL	LABPH UNITS	TALKAL mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	VOLATILE SOLIDS mg/l	FIXED SOLIDS mg/l	AMMONIA mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TPO4 mg/L	TOTAL DISS. PO mg/l
06-Mar-91	GRAB	1.0	11.2	200		690	618	578	40	22	18	3.120	0.01113	2.900	6.580	1.530	1.480
15-Apr-91	GRAB	8.0	11.6	12	8.26	157	1390	1366	24	10	14	0.020	0.00056	0.100	1.490	0.224	0.142
30-Apr-91	GRAB	7.8	9.6	180	7.98	183	1390	1382	8	6	2	0.020	0.00029	0.100	0.920	0.193	0.136
29-May-91	GRAB	28.0	10.8	150	8.22	240	1174	1154	20	12	8	0.020	0.00209	0.100	2.000	0.451	0.393
04-Jun-91	GRAB	20.5	6.4	890	7.67	250	1185	1147	38	14	24	0.050	0.00095	0.100	1.320	0.522	0.468
21-Jun-91	GRAB	21.5	6.4		7.58	124	747	591	156	24	132	0.400	0.00663	2.000	1.870	0.753	0.719
08-Aug-91	GRAB	19.8	8.5	200	8.16	293	891	845	46	6	40	0.040	0.00213	0.800	1.050	0.546	0.458
MIN		1.0	6.4	0	7.58	124	618	578	8	6	2	0.020	0.00029	0.100	0.920	0.193	0.136
MAX		28.0	11.6	890	8.26	690	1390	1382	156	24	132	3.120	0.01113	2.900	6.580	1.530	1.480
MEAN		15.2	9.2	272	7.98	277	1056	1009	47	13	34	0.524	0.00340	0.871	2.176	0.603	0.542

SAMPLE DATA FOR BATTLE CREEK (CT6), 1992
6 SAMPLES

DATE	SAMP	WTEMP C	DISOX mg/L	FECAL COLIFORM per 100mL	LABPH UNITS	TALKAL mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	AMMONIA mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TPO4 mg/L
02-Mar-92	GRAB	5.3	9.2	100	7.49	111	540	510	30	0.390	0.00153	0.600	2.100	0.501
04-Mar-92	GRAB	4.0	10.4	30	7.63	104	460	434	26	0.360	0.00176	0.600	2.340	0.468
11-Mar-92	GRAB	0.0	12.6	34	7.72	144	817	807	10	0.100	0.00043	0.700	1.310	0.325
16-Mar-92	GRAB	2.3	13.0	2	7.89	154	891	881	10	0.020	0.00015	0.500	0.990	0.242
24-Mar-92	GRAB	9.0	11.8	2	8.39	182	1049	1035	14	0.020	0.00081	0.100	1.330	0.199
30-Mar-92	GRAB	4.0	12.6	12	8.23	197	1099	1087	12	0.020	0.00038	0.100	1.220	0.173
MIN		0.0	9.2	2	7.49	104	460	434	10	0.020	0.00015	0.100	0.990	0.173
MAX		9.0	13.0	100	8.39	197	1099	1087	30	0.390	0.00176	0.700	2.340	0.501
MEAN		4.1	11.6	30	7.89	149	809	792	17	0.152	0.00085	0.433	1.548	0.318

Fecal Coliform Bacteria

The water quality standard for fecal coliform bacteria on Battle Creek is a concentration of 1,000 colonies per 100 milliliters of water (1000/100 mL). As can be seen from the graph for 1991 (Figure 26), the mean concentration at Site CT-5 greatly exceeded the water quality standard. The median concentration, however was only 200 counts per 100 mL. The highest count on an individual sample at Site CT-5 was 40,000 fecal coliform organisms per 100/mL. The standard for fecal coliform bacteria was also exceeded on one occasion at Site CT-3 (June 4, 1991 1,400 colonies) and on two occasions at Site CT-4 (June 4, 1991 and June 21, 1991 had 1,500 and 1,200 colonies respectively.

These high levels of fecal coliform bacteria are an indication of problems in the Lake Campbell watershed with animal waste from livestock feeding operations. Potential sources also include septic systems. These sources must be controlled in order to improve the water quality in Battle Creek and ultimately Lake Campbell.

pH

The water quality standards for Battle Creek state that pH shall be greater than 6.0 units, and less than 9.0 units. The results of all the samples collected from Battle Creek during 1991 were within this range of pH units.

Nutrient Concentrations

The graph (Figure 27) showing a comparison of mean nutrient concentrations at the tributary sites during 1991 generally indicates that higher concentrations for all the nutrients were found at monitoring Site CT-6. Site CT-6 was the farthest upstream site in the Battle Creek watershed. The results of the samples collected at the sites downstream generally indicate lower concentrations closer to the lake. This indicates that the upper portion of the watershed is a major contributing area for sediment/nutrient loadings to Battle Creek. The mean concentrations of total phosphorus levels at the tributary sites range from 0.319 mg/L to 0.6 mg/L. These concentrations are 16 to 30 times the amount of total phosphorus needed for optimum algae growth.

Given these high levels of phosphorus in the tributary samples, and the fact that phosphorus is generally the limiting nutrient for algae growth in Lake Campbell, it is evident that there is a need to control the amount of phosphorus entering the tributaries to Lake Campbell. This would point to the need for controlling sources of phosphorus in the watershed such as fertilizer runoff from croplands, drainage from septic systems, and livestock feedlot runoff.

There were no exceedences of the state water quality standards for nutrient parameters in the tributary samples. Site CT-1 (outlet) did exceed the un-iononized ammonia standard once during the project period on May 29, 1991 (0.084 mg/L).

The mean concentrations of phosphorus during the sampling period in 1992 (February 4, to March 30, 1992) ranged from 0.270 mg/L to 0.447 mg/L. The maximum concentration was found at Site CT-3 on February 19, 1992 (0.830 mg/L). This high concentration is most likely the result of a flushing effect from agricultural sources above the site.

There were no exceedences of the state water quality standards for any nutrient parameter during the 1992 sampling period.

Figure 26

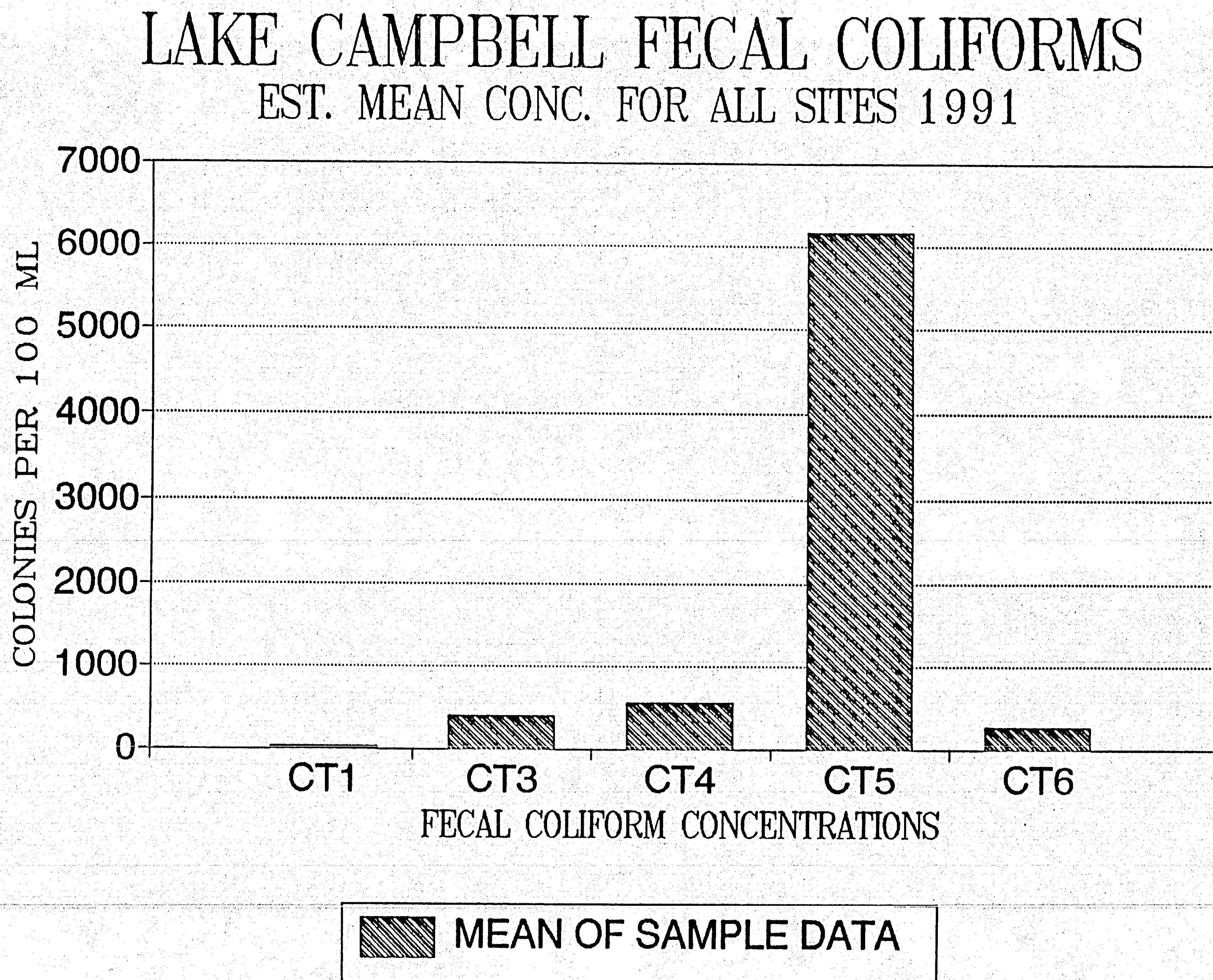
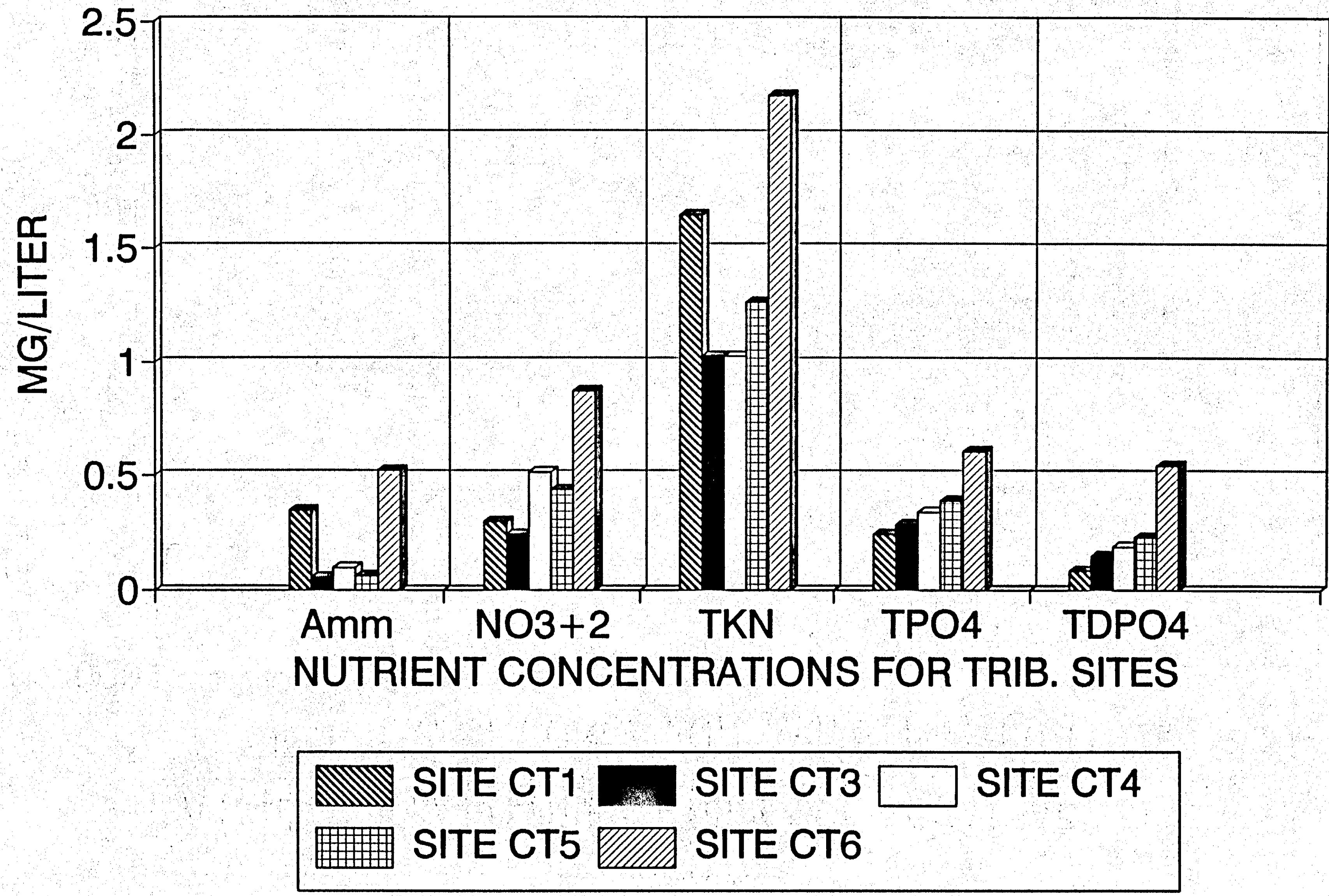

LAKE CAMPBELL FECAL COLIFORMS
EST. MEAN CONC. FOR ALL SITES 1991
COLONIES PER 100 ML
7000
6000
5000
4000
3000
2000
1000
0
CT1
CT3
CT4
CT5
CT6
FECAL COLIFORM CONCENTRATIONS
MEAN OF SAMPLE DATA

Figure 27

LAKE CAMPBELL D/F - TRIB SITE RESULTS
MEAN NUTRIENT CONCENTRATIONS - 1991



Solids Concentrations

The graph of mean solids concentrations for the tributary sites during 1991 (Figure 28) indicates that the highest mean concentrations of total solids (1,056 mg/L) and total dissolved solids (1,009 mg/L) were found at Site CT-6. The highest mean concentration of total suspended solids (Figure 29) in the Battle Creek watershed was located at Site CT-5 (64 mg/L). The maximum suspended solid concentration took place on Jne 21, 1991 at CT-6 (156 mg/L). The watershed above Site CT-6 appears to be one of the largest contributors of solids to Battle Creek.

Volatile suspended solids and non-volatile suspended solids were also analyzed. Higher concentrations of non-volatile suspended solids indicate that more sediment than organic matter is entering the creek. On June 21, 1991, 80% of the 156 mg/L of total suspended solids were non-volatile. Erosion from agricultural land is the most probable sources of these higher non-volatile concentrations. The concentrations of non-volatile suspended solids were generally higher than the volatile concentrations. The data shows that measures should be taken to control the sediment input, especially at Sites CT-5 and CT-6. The largest concentrations appeared in June when crops were first planted before there was adequate canopy cover to protect the soil.

The 1992 spring run-off data generally shows lower concentrations of total solids (mean range from 722 mg/L to 837 mg/L). The 1992 samples revealed the site with the highest concentration as CT-3 (88 mg/L). Average suspended solids ranged from 16 mg/l at CT-6 to 61 mg/L at CT-3. As opposed to the 1991 samples, the 1992 samples had the highest concentrations closer to the lake. The probable reasons for this difference is that the samples in 1992 were taken before agricultural land was broken for planting.

In 1991 outlet (CT-1) had the highest mean concentration of total suspended solids (69 mg/L). The high concentrations was probably due to the resuspension of sediment from wind, waves, and boat motors. Also increased populations organic matter may have added to the increase of total suspended solids.

Annual Loads

The nutrient loads from Battle Creek to Lake Campbell increased as they passed through sites CT-6 and CT-5 (Figure 30). Although the amount of water increased as expected at CT-4 the total nutrient load drops below that of CT-5. The reason for the lower loads is the lower concentrations found at CT-4. At Site CT-3 the water load again increased along with the nutrient load. It appears that the watershed located between Sites CT-5 and CT-4 has less nutrient input than other areas in the watershed.

Through June 21 to June 24, 1991, a storm event caused a sharp increase in loadings in the Battle Creek watershed. The sources of the loadings were agricultural.

The graph titled LAKE CAMPBELL NUTRIENT LOAD COMPARISON (Figure 31) indicates that greater loadings of nutrients are flowing into Lake Campbell from Battle Creek (Site CT-3) than are flowing out of the lake from the outlet (Site CT-1) during the study period. All nutrient loadings from the watershed are greater than the loadings leaving the outlet except ammonia. Nitrogen (especially nitrate+nitrite) is a nutrient which changes to a different form by chemical and biological processes. Some form of nitrogen may have been converted to ammonia

Figure 28

LAKE CAMPBELL D/F - TRIB SITE RESULTS
TOTAL SOLIDS AND TOTAL DISSOLVED SOLIDS

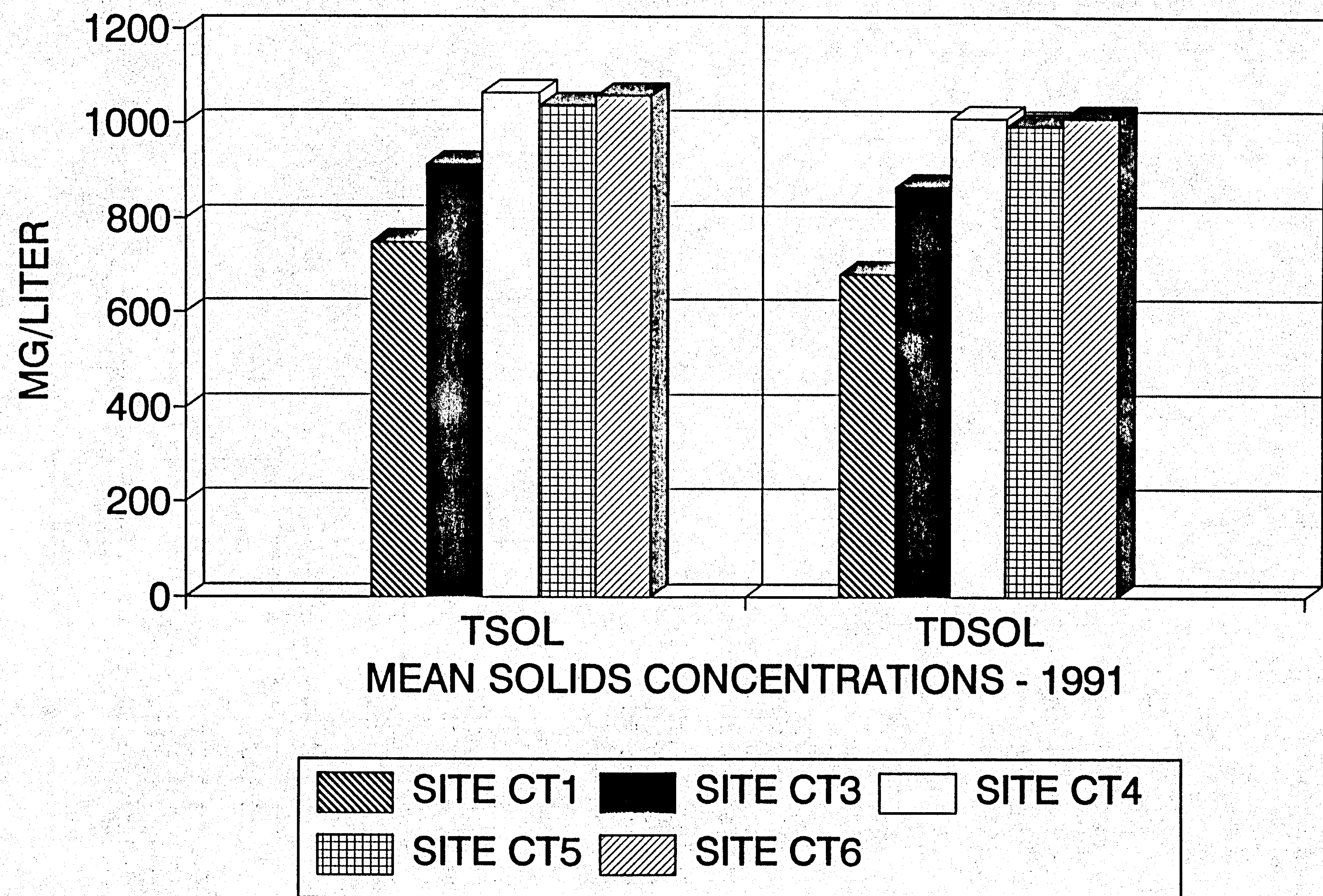


Figure 29

LAKE CAMPBELL D/F - TRIB SITE RESULTS
SUSPENDED, VOLATILE AND FIXED SOLIDS

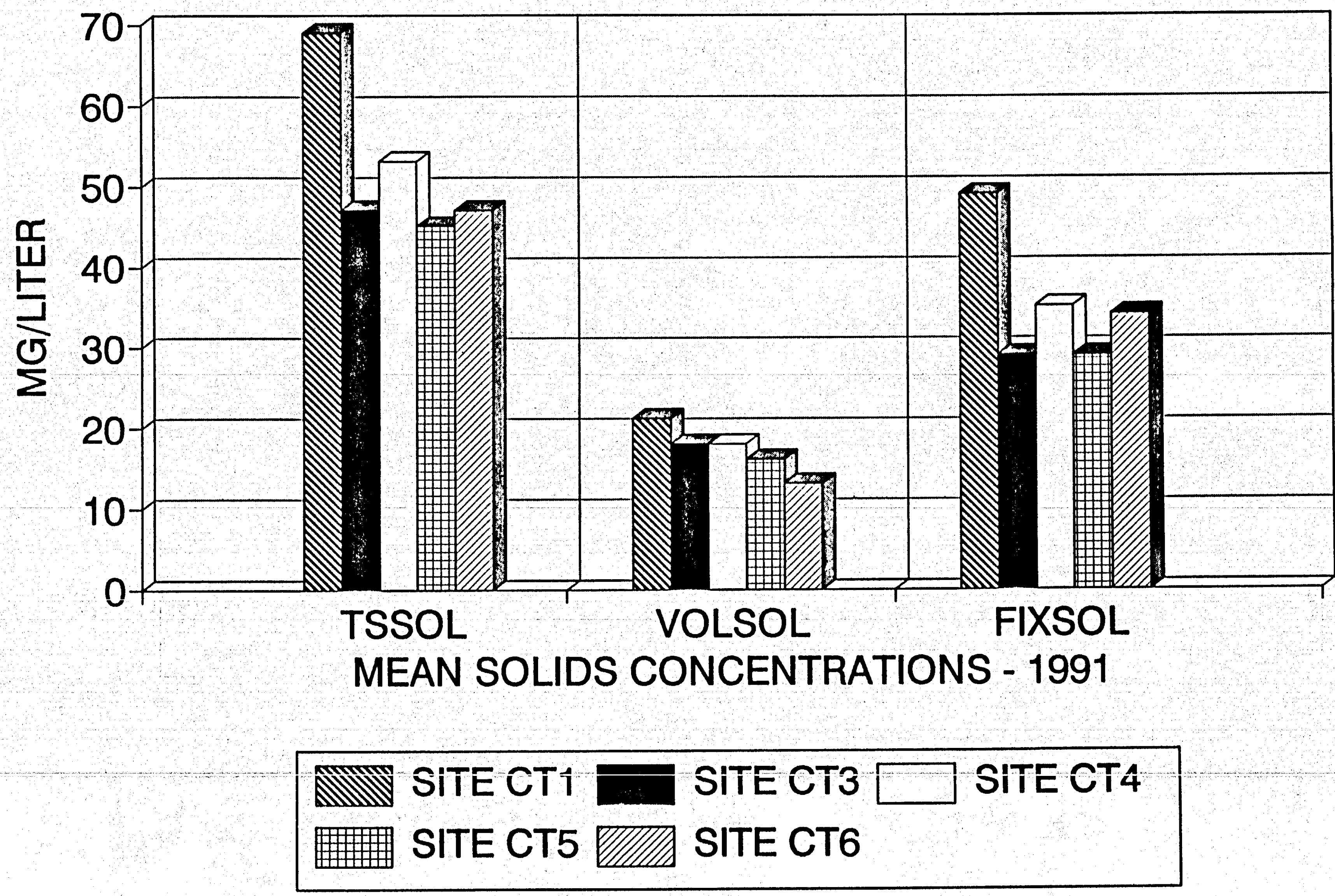


Figure 30

LAKE CAMPBELL D/F LOADS–TRIB SITES

EST. ANNUAL TOTAL NUTRIENT LOADS 1991

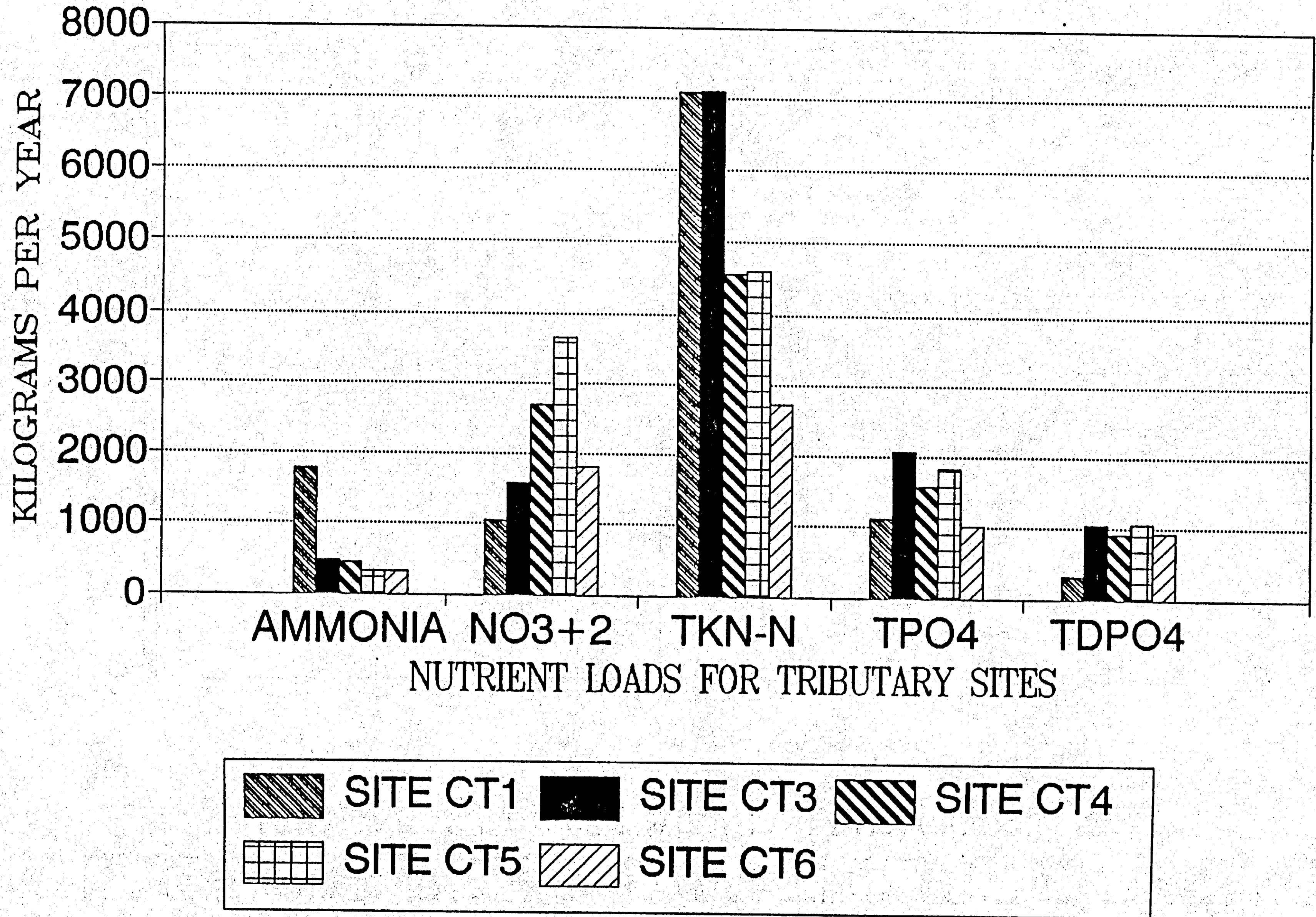
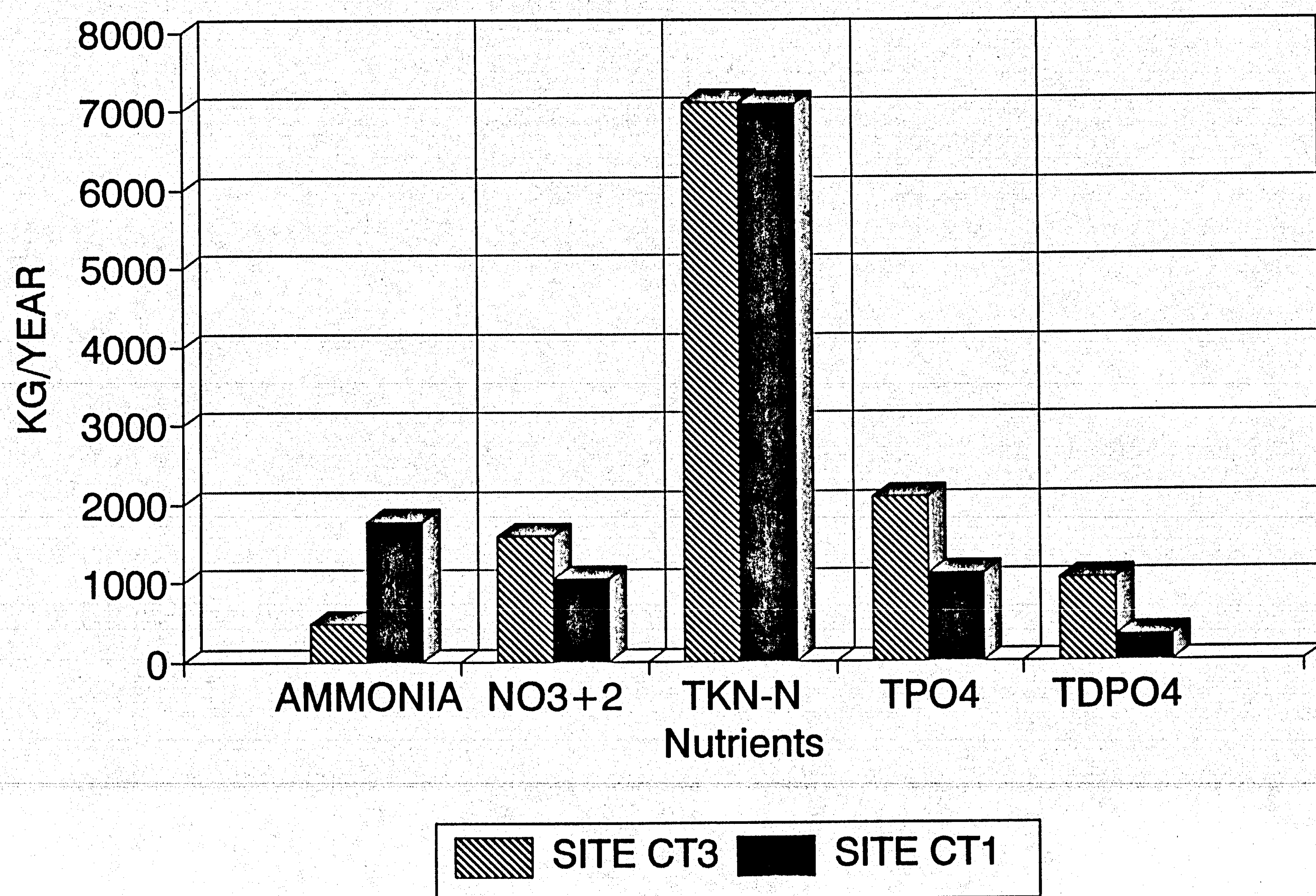


Figure 31

LAKE CAMPBELL NUTRIENT LOAD COMPARISON
INLET vs. OUTLET



before leaving through the outlet. The nitrogen parameters other than ammonia demonstrate relatively similar loads entering and exiting the lake.

Significantly higher loadings of total phosphorus and total dissolved phosphorus are entering the lake than are leaving the lake. The total phosphorus load at Site CT3 (inlet) is 2,073.5 kilograms (kg). The total load at Site CT1 (outlet) is 1,109.7 kg. The difference indicates that 963.8 kg of total phosphorus was retained in the lake during the study period. This represents a significant load of nutrients available for algae and plant growth. The difference in load between total dissolved phosphorus (1044.0 kg) entering the lake versus total dissolved phosphorus (320.1 kg) leaving the lake is 723.9 kg. This readily available form of phosphorus is probably either taken-up by vegetation or sorbed to sediment particles and becomes unavailable. Continued high loadings of phosphorus into Lake Campbell will result in an increased rate of eutrophication of the lake.

The graph for annual loads of total solids for 1991 (Figure 32) demonstrates that the highest annual loading of total solids occurred at Site CT-3. Samples indicate that total solids concentrations increase as water moves downstream. Unlike the total solids load, suspended solids loads do not increase as the water moved downstream (Figure 33). At Site CT-4 the total suspended solids load (231,101 kg/year) dropped below that of the previous Site CT-5 (287,154 kg/year). The suspended solids load at Site CT-3 increased (362,410 kg/year). The area of Battle Creek located between Sites CT-5 and CT-4 appears to have an area which settles out the suspended solids. There is a corresponding reduced load in nutrients in the above mentioned area.

The graph titled LAKE CAMPBELL ANNUAL LOAD COMPARISON FOR TOTAL SOLIDS AND TOTAL DISSOLVED SOLIDS (Figure 34) shows higher loads of solids flowing into the lake than leaving the lake. A comparison of loads entering the lake versus leaving the lake indicates that 1,989,893 kg of total solids were retained in the lake. Of the suspended solids entering the lake 72% is non-volatile solids or sediment (Figure 35). Of the suspended solids leaving the lake, 65% are non-volatile. This, along with the fact that approximately 20% more water is entering the lake than leaving through the outlet, indicates an allochthanous non-volatile suspended solid load of 97,800 kg (108 tons). The total load of all suspended solids retained by the lake is 109,235 kg (120 tons). A sediment survey of the lake has shown that a very large volume of silt already exists in the lake bottom. One-hundred and twenty tons of sediment is not considered a significant load to a lake the size of Lake Campbell.

Tributary samples were taken during spring runoff in 1992. The sampling period which lasted only five or six weeks, is more representative of a spring snow-melt event than any period of sampling in the 1991 sample season. Because of the short sampling period in 1992, loads are calculated for the sampling period only. This data seems to indicate that the majority of the loading occurs during spring runoff. Appendix B contains summaries of loading results for the 1991 and 1992 tributary data.

Spring flows during 1992 caused significant loads of nutrients and solids for the relatively short monitoring period. The loading of total phosphorus during the 1992 spring runoff period at Site CT-3 was approximately 5,000 kilograms. The loading of total phosphorus during the entire 1991 sampling period at Site CT-3 was just over 2,000 kilograms. The loading of total solids during the 1992 spring runoff period at Site CT-3 was just over 6 million kilograms, whereas the loading of total solids at the same site during the entire 1991 sampling period was approximately 5.5 million kilograms.

Figure 32

LAKE CAMPBELL ANNUAL LOADS - 1991

TOTAL SOLIDS AND TOTAL DISSOLVED SOLIDS

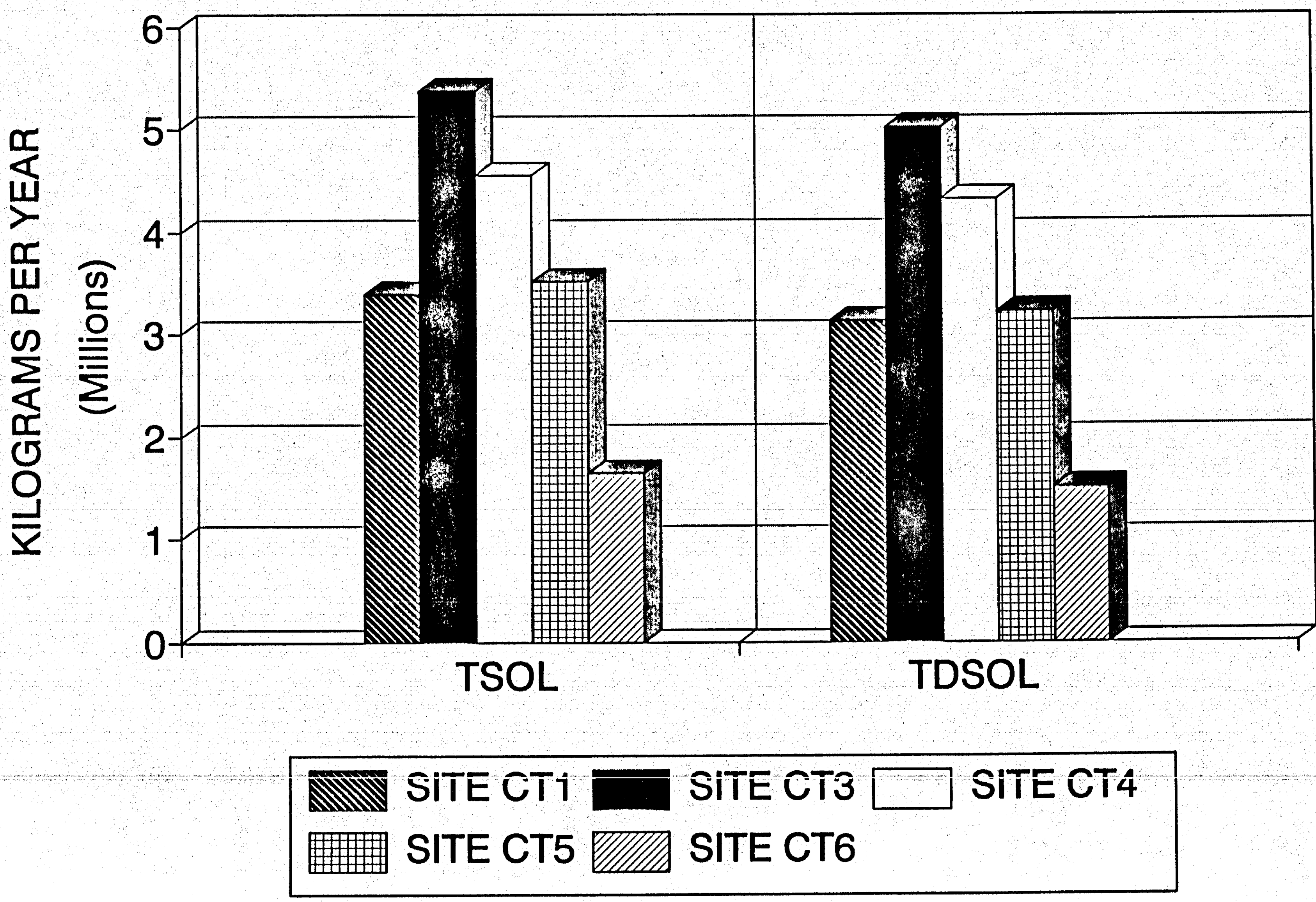


Figure 33

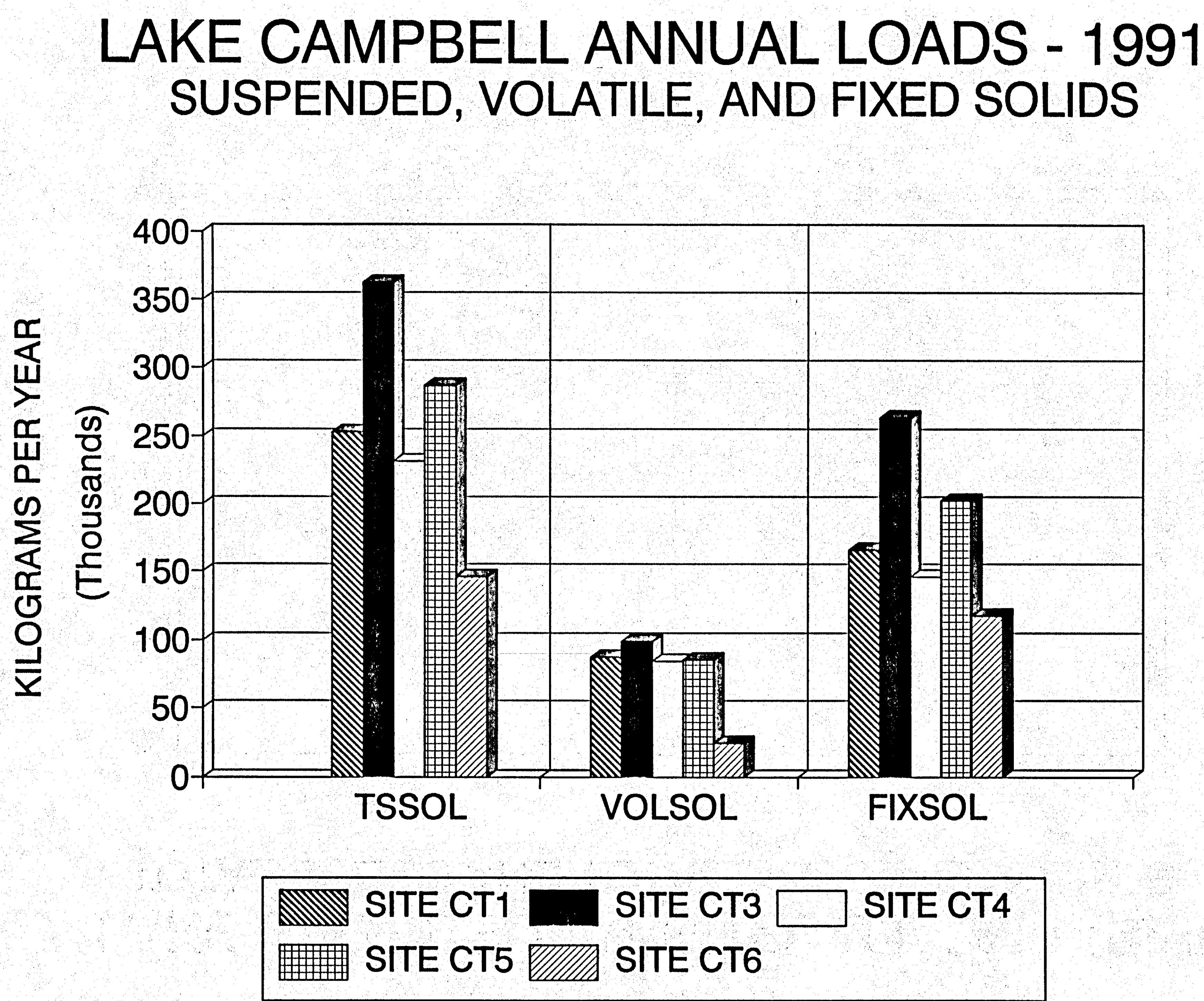

LAKE CAMPBELL ANNUAL LOADS - 1991
SUSPENDED, VOLATILE, AND FIXED SOLIDS
KILOGRAMS PER YEAR
(Thousands)
400
350
300
250
200
150
100
50
0
TSSOL
VOLSOL
FIXSOL
SITE CT1
SITE CT3
SITE CT4
SITE CT5
SITE CT6

Figure 34

LAKE CAMPBELL SOLIDS LOAD COMPARISON

TOTAL SOLIDS AND TOTAL DISSOLVED SOLIDS

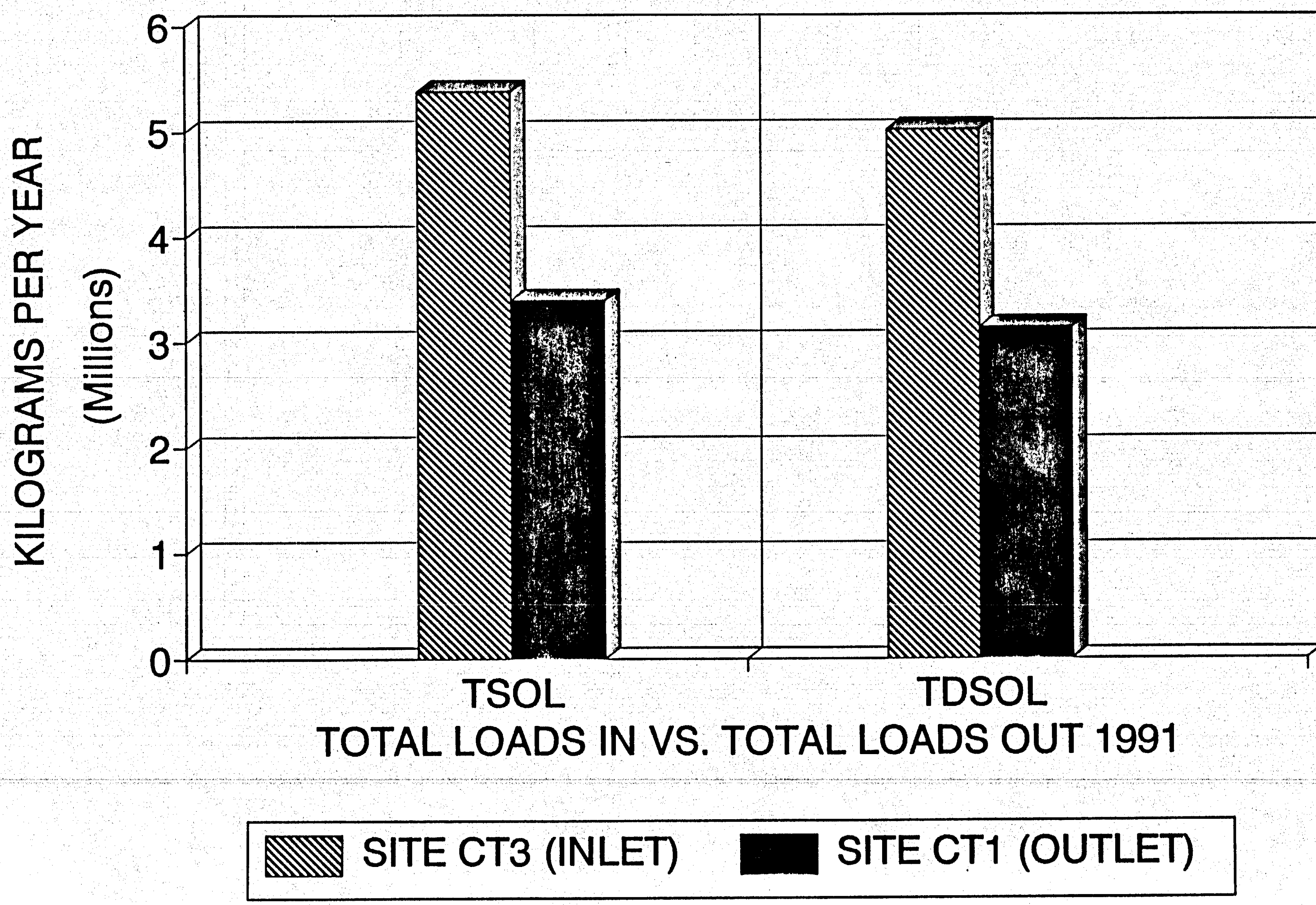
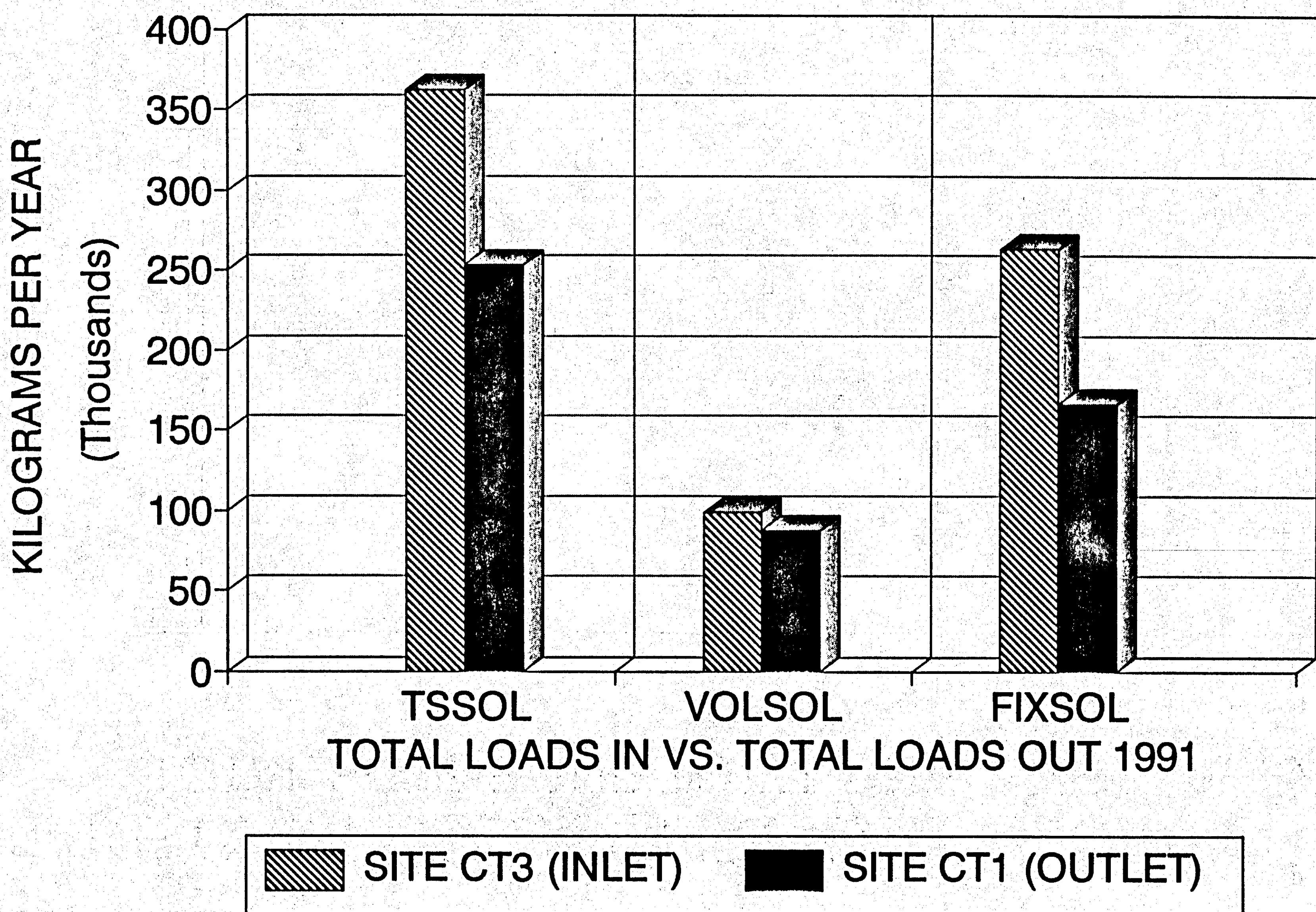


Figure 35

LAKE CAMPBELL SOLIDS LOAD COMPARISON
SUSPENDED, VOLATILE AND FIXED SOLIDS



The 1992 data indicated that 4899 kg of total phosphorus flowed into Lake Campbell from Site CT3, whereas only 2,907 kg of total phosphorus flowed out at Site CT1. The difference indicated that 1,992 kg of total phosphorus were retained in the lake. For total solids, 6,323,133 kg flowed into the lake, and only 4,019,670 kg flowed out of the lake. The difference here indicates that 2,303,463 kg of total solids were retained in Lake Campbell.

SEDIMENT SAMPLING AND SURVEY

A survey of the bottom sediments of Lake Campbell was conducted by a consulting engineering firm during the fall of 1990. The purpose of conducting the survey was to determine the volume of sediment in the lake bottom. The survey produced the following results:

Water Surface Area	321.9 ha (795.3 acres)
Average Water Column Depth	1.5 m (5 feet)
Average Sediment Column Depth	1.8 m (6 feet)
Estimated Sediment Volume	5,993,884 m^3 (4,860 acre feet)

Maps showing the elevations of water depths and sediment depths are included in APPENDIX D, LAKE CAMPBELL SEDIMENT SAMPLING AND SURVEY. The maps indicate that the sediment is relatively uniform throughout the lake at an average depth of 1.5 meters.

A sediment sample was also collected from Lake Campbell and submitted to the U.S. Army Corps of Engineers Laboratory in Omaha, Nebraska, for analysis of metals, pesticides, and other potentially toxic chemicals. The results of the analysis (Table 30) indicated no toxic levels of chemicals in the elutriate. Therefore, the analysis indicated that disturbance by dredging of the sediments sampled should not release excessive chemicals.

BIOLOGICAL RESOURCES

Lake Campbell and its watershed area are rich in biological resources. Lake Campbell drains into the Big Sioux River, which eventually flows into the Missouri River. The Lake Campbell area is also rich in plant diversity, both terrestrial and aquatic. There are a number of rare plants present in the watershed.

Littoral areas act as natural sanctuaries for many waterfowl types. Some waterfowl species, which utilize the back reaches of Lake Campbell for reproduction and brood rearing, need the deeper water of Lake Campbell for a food supply. These deeper waters also maintain an abundant aquatic fauna population for shore-feeding species of birds.

Lake Campbell supplies many of the essential elements for large and diverse populations of plants and animals. APPENDIX D, BIOLOGICAL RESOURCES OF LAKE CAMPBELL AND ITS WATERSHED, contains further information on the plant and animal species that inhabit the area. Some of the lists of species in APPENDIX D indicate that certain species may occur in the Lake Campbell area but are not common.

Table 23
LAKE CAMPBELL
Elutriate Sample Data

DEPARTMENT OF THE ARMY
Missouri River Division, Corps of Engineers
Division Laboratory
Omaha, Nebraska

Parameter	SITE #1		
	Receiving Water	Elutriate Water	Bulk
MRD No. 80/174	M 573	M 574	M 572
Ammonia NH_3 (as N)	0.32 ppm	9.13 ppm	
Chemical Oxygen Demand	<5 ppm	16.8 ppm	
Cyanide, Tot (as CN)	<0.01 ppm	<0.01 ppm	<1.25 mg/kg
Nitrate, Tot (as N)	0.02 ppm	0.02 ppm	
Phosphorus, Tot (as P)	0.10 ppm	2.52 ppm	
Phosphorus, Ortho, Tot (as P)	0.01 ppm	1.33 ppm	
Tot, Kjeldahl Nitrogen (as N)	0.4 ppm	8.1 ppm	
Oil and Grease	15.8 ppm	34.6 ppm	
Antimony Tot (as Sb)	<1.0 ppb	<1.0 ppb	<1.0 mg/kg
Arsenic, Tot (as As)	<1.0 ppb	4.8 ppb	10.5 mg/kg
Barium, Tot (as Ba)	27 ppb	267 ppb	167 mg/kg
Beryllium, Tot (as Be)	<2 ppb	<2 ppb	7 mg/kg
Cadmium, Tot (as Cd)	<3 ppb	<3 ppb	16 mg/kg
Chromium, Tot (as Cr)	<5 ppb	14 ppb	265 mg/kg
Copper, Tot (as Cu)	<5 ppb	6 ppb	224 mg/kg
Iron, Tot, (as Fe)	63 ppb	6430 ppb	24 g/kg
Lead, Tot (as Pb)	<5 ppb	12 ppb	107 mg/kg
Magnesium, Tot (as Mg)	<1.0 ppm	7.6 ppm	6.1 g/kg
Manganese, Tot (as Mn)	31 ppb	4.72 ppm	2.3 g/kg
Mercury, Tot (as Hg)	<.2 ppb	<.2 ppb	.03 mg/kg
Selenium, Tot (as Se)	<1.0 ppb	<1.0 ppb	0.8 mg/kg
Silver, Tot (as Ag)	<10 ppb	<10 ppb	<10 mg/kg
Thallium, Tot (as Tl)	<20 ppb	<20 ppb	<20 ppb
Zinc, Tot (as Zn)	17 ppb	75 ppb	900 mg/kg
Lithium, Tot (as Li)	<1.0 ppm	<1.0 ppm	100 mg/kg
Nickel, Tot (as Ni)	7 ppb	<5 ppb	182 mg/kg
Chlorinated Hydrocarbons PCB and Herbicides	None		None

SUMMARY AND CONCLUSION

In summary, many factors are influencing the water quality of Lake Campbell. According to the watershed analysis, two subwatershed areas (5 and 6) were found to be contributing greater loadings of sediment and nutrients. It should be noted, however, that the analysis was conducted several years ago.

The survey of shoreline erosion determined that 4,155 feet of shoreline are in erodible conditions ranging from minor to moderate/severe. These areas represent direct loadings of sediment into Lake Campbell.

The survey of septic wastewater systems around the lake found that at least 10% of the systems are out of compliance with current construction requirements. Because of their age and location, many more septic systems may be failing and contributing to the degradation of water quality in Lake Campbell.

The survey of the bottom sediment in Lake Campbell determined a total sediment volume of 7,840,000 cubic yards. An elutriate analysis of the sediment determined that there were not significant toxic levels of contaminants in the sample.

The in-lake water quality monitoring program determined that Lake Campbell is in a hypereutrophic condition. The watershed monitoring program showed cumulative loads of sediment and nutrient from Battle Creek to Lake Campbell. Upstream sites CT-5 and CT-6 showed higher concentrations of loadings. Based on the data from this study, the upper watershed is in need of implementation measures to control soil erosion and the entire watershed is in need of animal waste management.

RESTORATION ALTERNATIVES AND RECOMMENDATIONS

The diagnostic portion of the Lake Campbell Phase 1 Study has shown that the lake is in a hypereutrophic condition, and in need of a reduction of sediments and nutrients. The following restoration alternatives are recommended, based on their effectiveness and economic feasibility:

<u>Information/Education Program to Promote Best Management Practices</u>

An information and education program should be established to promote the implementation of best management practices in the Lake Campbell watershed. Although traditional best management practices such as conservation tillage, waterways, terraces, crop rotation, and filter strips have been extensively applied in the Lake Campbell watershed, there are additional areas in the watershed needing Best Management Practices.

In order to reduce loadings of sediment and nutrients, the implementation of best management practices should be promoted in areas of the watershed found to have the greatest loadings. The analysis of the watershed determined that two areas, referred to as Areas 5 and 6 contribute greater loadings of sediment and nutrients. Area 6, is located immediately adjacent to the lake, and has the potential to contribute significant loadings of sediment and nutrients. For this reason, Area 6 is one of the subwatershed areas that should be targeted for promotion of best management practices.

Other subwatershed areas where best management practices should be promoted extensively are the areas that drain to the tributary monitoring sites CT-5 and CT-6 on Battle Creek. The results of the Phase 1 Study monitoring program indicated that the runoff from these areas contained significant loadings of nutrients and solids.

In addition to traditional best management practices which are already extensively applied in the Lake Campbell watershed, it is recommended that Integrated Crop Management practices be promoted through a program of information and education. Integrated Crop Management practices would include components such as soil testing to determine proper fertilization rates, and scouting of cropland to determine optimum application of pesticides. Cost-sharing should be considered for Integrated Crop Management practices. This would help to promote these practices, and gain wider acceptance among landowners in the watershed. As with the traditional best management practices, Integrated Crop Management Practices should be promoted most extensively in the critical subwatershed areas. These would include Area 6, as identified in the watershed analysis, and the areas that drain to Sites CT-5 and CT-6 on Battle Creek.

The estimated costs to carry out an effective Information/Education Program are as follows, on an annual basis:

Item	Cost per Year
Promotional materials	2,500 to 3,000
Travel within watershed	3,000 to 4,000
Total Cost Per Year	$5,500 to $7,000

Animal Waste Management

There are ten to twelve livestock operations in the Lake Campbell watershed which may be contributing runoff to Battle Creek and Lake Campbell. It is recommended that these livestock operations be rated by means of a feedlot runoff model, to determine which facilities are contributing the highest loads of sediment and nutrients.

The average cost to control runoff from a feedlot is estimated to be $27,000 to $30,000 for the construction of an Animal Waste Management System. It is recommended that animal waste management systems be constructed. Animal Waste Management Systems should be constructed as resources permit. The annual cost to construct two systems each year is estimated to be $54,000 to $60,000.

Low-cost alternatives to control feedlot runoff, such as diversion of clean water around lot areas or establishment of vegetative buffer strips, should be implemented wherever possible.

Shoreline Erosion Control

A shoreline erosion survey was conducted at Lake Campbell as part of the Phase 1 Diagnostic/Feasibility Study. Areas of shoreline erosion were rated as minor, minor/moderate, moderate, and moderate/severe.

Because areas of shoreline erosion contribute direct loads of sediment to the lake, it is recommended that they be corrected as soon as possible. Areas of moderate to moderate/severe erosion should be repaired first. The estimated cost of such repairs, including backsloping, rip-rapping, and seeding to vegetation is $20 per lineal foot for moderate erosion, and $25 per lineal foot for moderate/severe erosion.

A total of 785 feet of shoreline was found to have moderate erosion, and 580 feet was found to have moderate/severe erosion. The estimated costs to repair these areas are as follows:

Erosion Category	Length (ft.)	Cost per ft.	Total
Moderate	785	$20	$15,700
Moderate/Severe	580	25	14,500
Total Cost			$30,200

It is recommended that shoreline erosion repairs be undertaken over a two-year period. The estimated cost per year is $15,000.

Sanitary District Establishment

The survey of septic systems around Lake Campbell found that at least 10% of the systems are out of compliance with current construction standards. In addition, many more systems may be directly contributing contaminants to Lake Campbell because of their age and location. It is recommended that a sanitary district be established to address the problem of failing septic wastewater systems.

The costs to establish a sanitary district would be minimal. However, some costs would be associated with the required circulation of petitions, publication of notices, and an election.

Once a sanitary district was formed, taxes would be assessed to cover annual expenses. If it was determined that a central sewer and wastewater system should be constructed, the district may be able to qualify for a loan from the South Dakota State Revolving Fund (SRF) for construction of wastewater treatment systems.

It is recommended that a sanitary district be established as soon as possible in order to fully assess the potential need for a central wastewater treatment system. The South Dakota Department of Environment and Natural Resources may be contacted for assistance in the formation of a sanitary district.

Wetlands Evaluation, Restoration, and Establishment

The potential exists for the enhancement, restoration, and establishment of wetlands throughout much of the Lake Campbell watershed. It is recommended that a cooperative effort be undertaken to evaluate the potential for wetland enhancement and establishment throughout the Lake Campbell watershed. Agencies and local entities that should be involved in this effort include the U. S. Fish and Wildlife Service, the Soil Conservation Service, local conservation districts, and the Lake Campbell Association. A particular effort should be made to investigate the critical watershed areas that were identified in the Phase 1 Diagnostic/Feasibility Study.

Restoration or establishment of wetlands through the construction of low-head dams in the watershed should be evaluated. Such structures would help to retain sediment and nutrients. Cost-sharing for such structures may be available through a number of different entities including the Soil Conservation Service, the U. S. Fish and Wildlife Service, Ducks Unlimited, and private foundations.

The wetland area at the south end of Lake Campbell should be evaluated. Flows from Battle Creek pass through this wetland before reaching Lake Campbell. Enhancement of the wetland, if possible, could potentially improve water quality in Lake Campbell.

Dredging

The sediment survey of Lake Campbell completed by a consultant engineering firm indicated a total sediment volume of 7,840,000 cubic yards. The removal of sediment by dredging would improve the fisheries habitat of the lake, and help to control the growth of rooted aquatic vegetation.

It is recommended that approximately one million cubic yards of sediment be removed by dredging. By dredging an average sediment column depth of six feet, about 100 surface acres of the lake would be provided with a water column depth of ten to eleven feet.

The estimated cost and length of time required to dredge one million cubic yards of silt from Lake Campbell is shown below:

Dredge Size	Length of Time	Total Cost
8-inch intake	10 years	$2,000,000
14-inch intake	2 years	$1,000,000

Use of a 14-inch intake dredge is recommended, based on the reduced time and cost. However, it is recommended that dredging not be undertaken right away. This will provide an opportunity to reduce sediment loadings into the lake through shoreline and watershed work. It will also provide the Lake Campbell Association and other local entities the time required to secure the resources necessary for a major dredging project.

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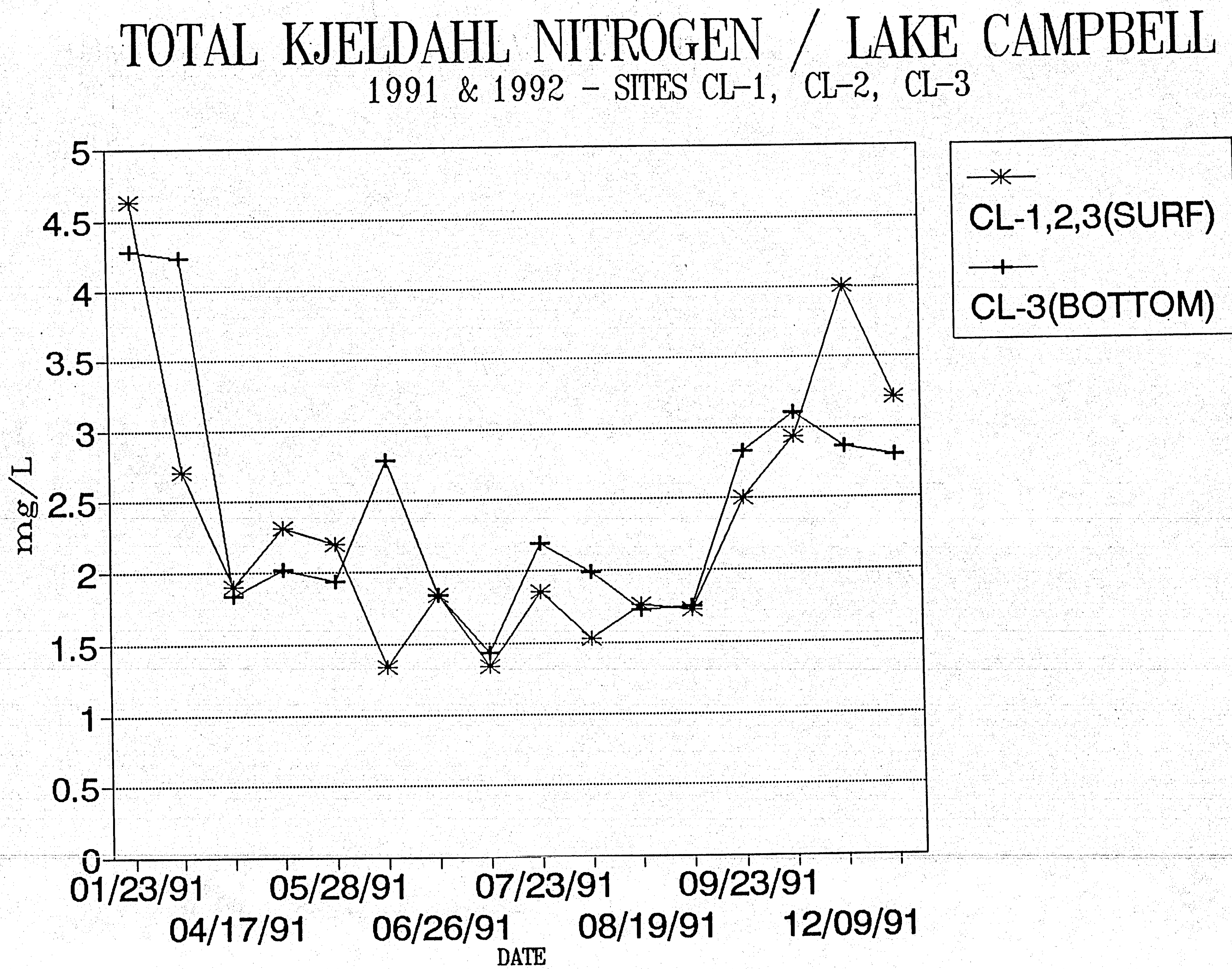
APPENDIX A. LAKE CAMPBELL IN-LAKE WATER QUALITY DATA

Figure A-1



TOTAL KJELDAHL NITROGEN / LAKE CAMPBELL
1991 & 1992 - SITES CL-1, CL-2, CL-3
CL-1,2,3(SURF)
CL-3(BOTTOM)
mg/L
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
01/23/91
04/17/91
05/28/91
06/26/91
07/23/91
08/19/91
09/23/91
12/09/91
DATE

Figure A-2

TOTAL NITROGEN / LAKE CAMPBELL

1991 & 1992 - SITES CL-1, CL-2, CL-3

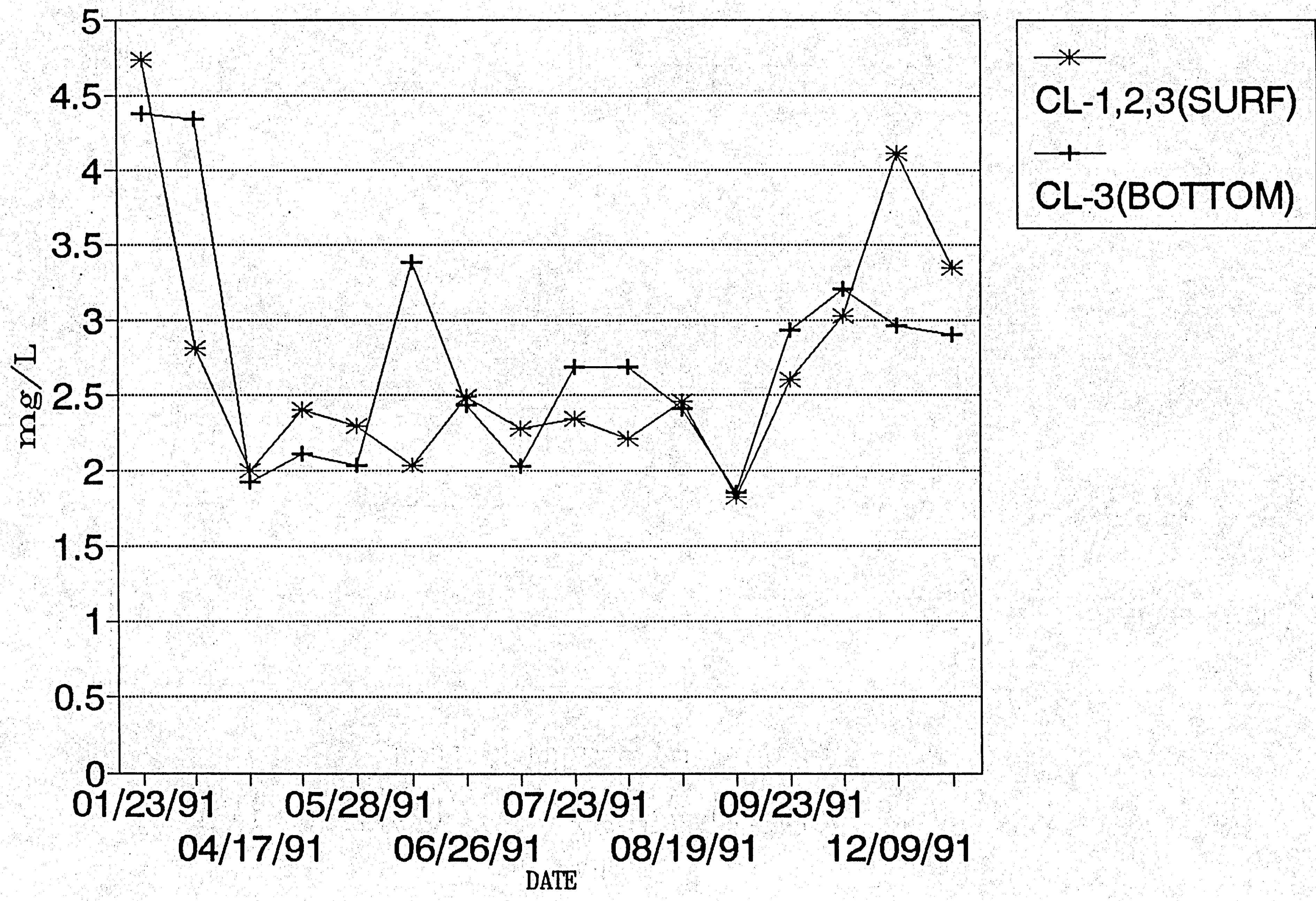
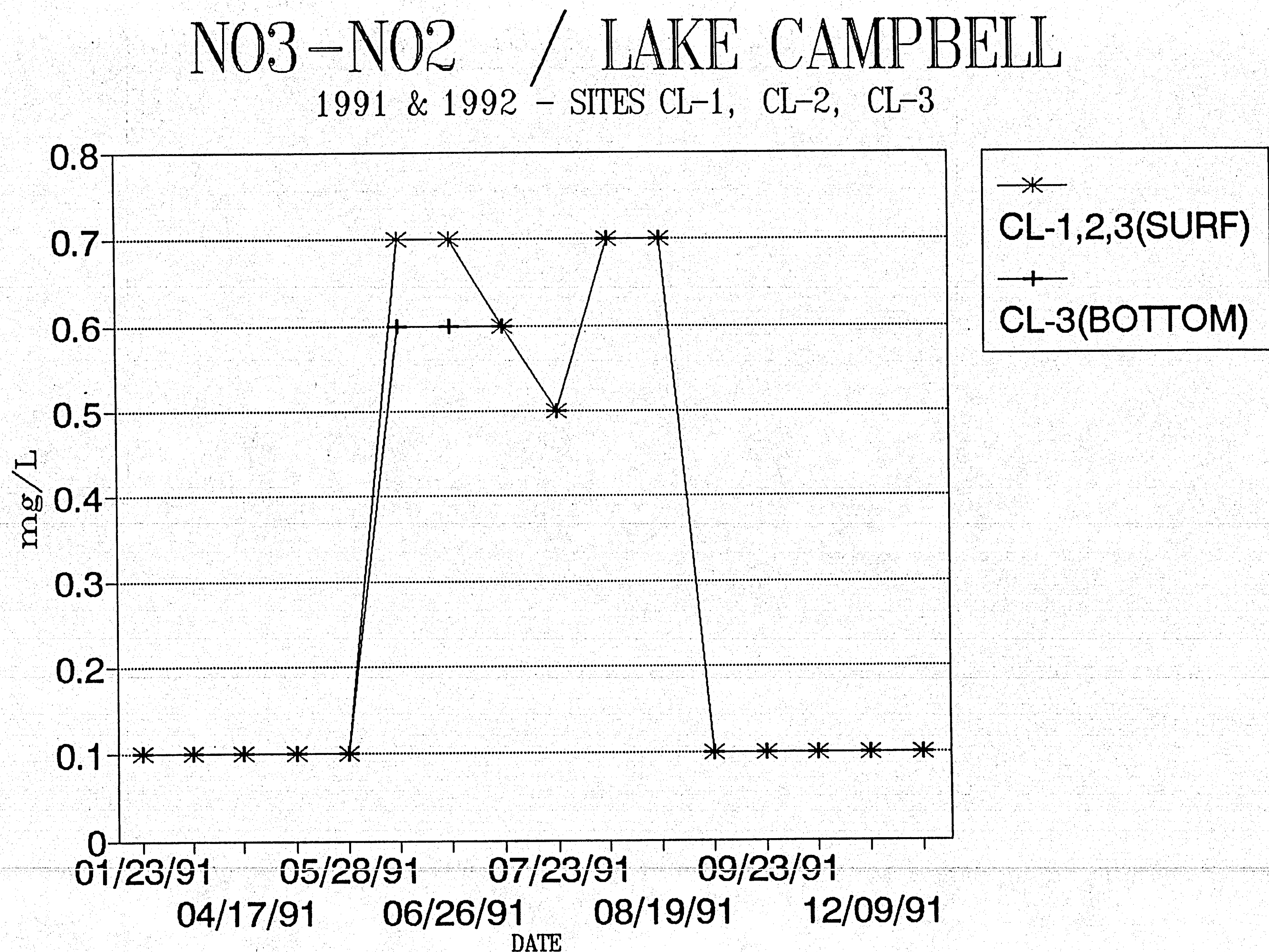


Figure A-3



NO3-NO2 / LAKE CAMPBELL
1991 & 1992 - SITES CL-1, CL-2, CL-3
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
mg/L
01/23/91
04/17/91
05/28/91
06/26/91
07/23/91
08/19/91
09/23/91
12/09/91
DATE
CL-1,2,3(SURF)
CL-3(BOTTOM)

Figure A-4

WATER TEMPERATURE / LAKE CAMPBELL

1991 & 1992 - SITES CL-1, CL-2, CL-3

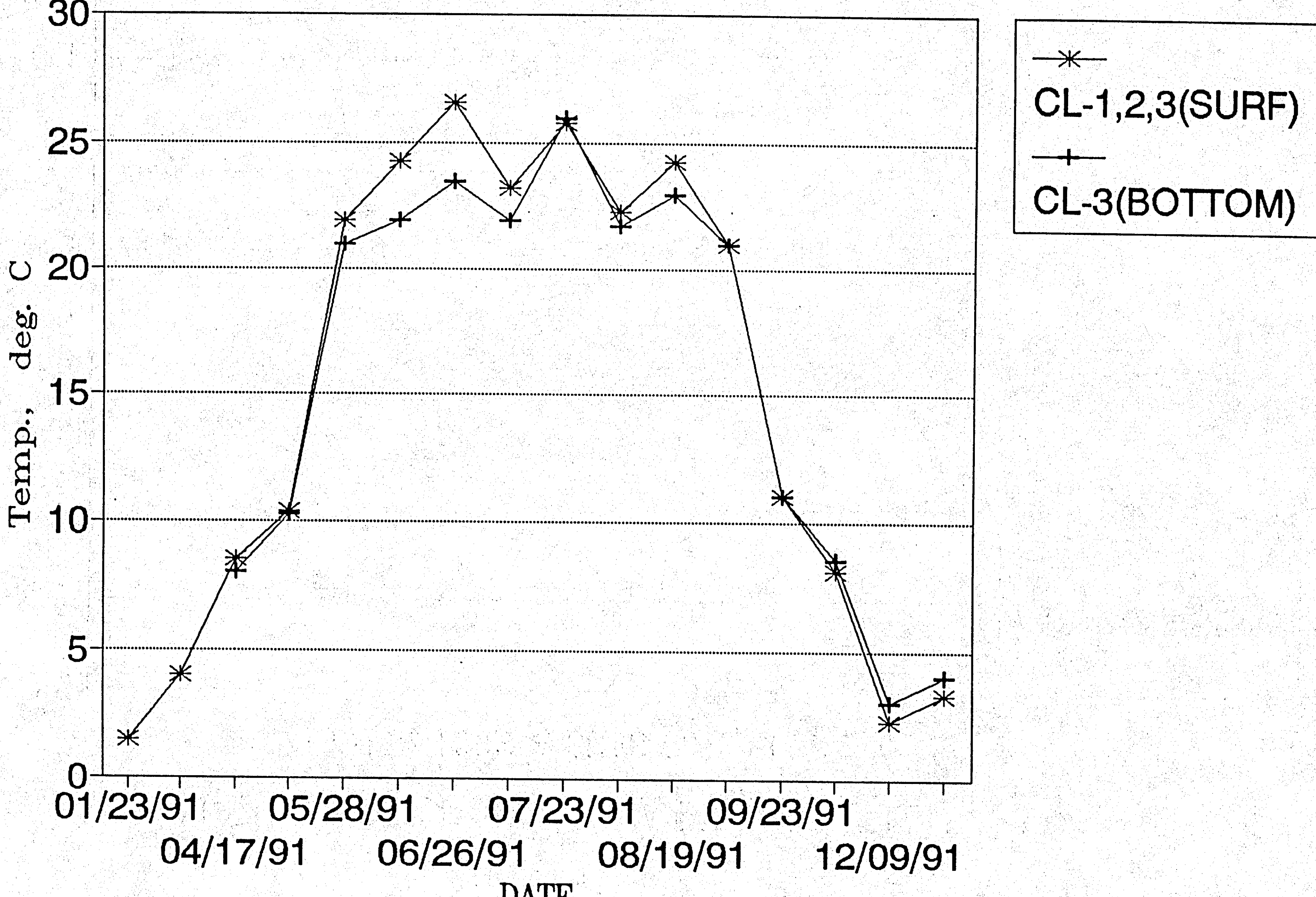
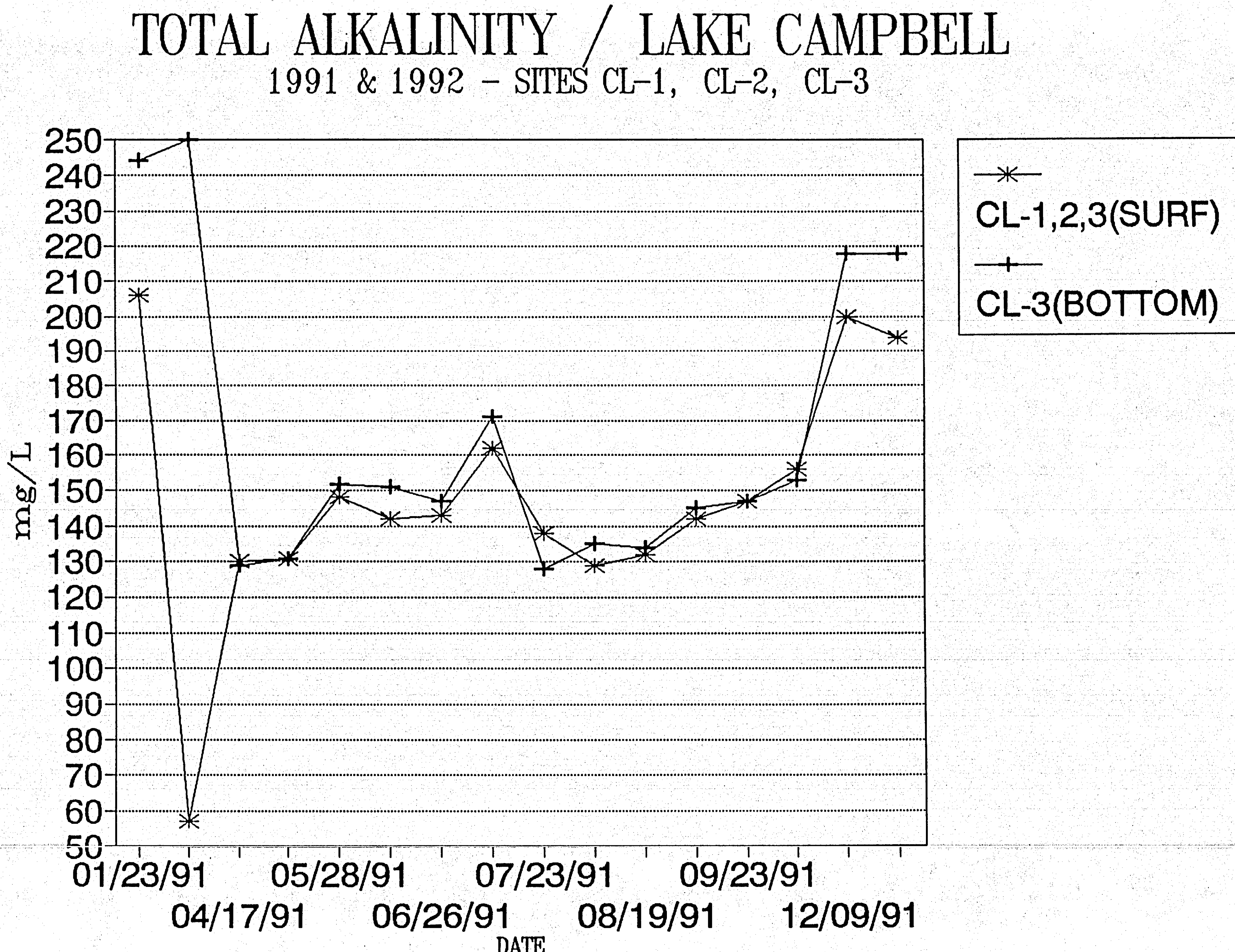


Figure A-5



TOTAL ALKALINITY / LAKE CAMPBELL
1991 & 1992 - SITES CL-1, CL-2, CL-3
mg/L
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
01/23/91
04/17/91
05/28/91
06/26/91
07/23/91
08/19/91
09/23/91
12/09/91
DATE
CL-1,2,3(SURF)
CL-3(BOTTOM)

APPENDIX B. TRIBUTARY LOADINGS

Table B-1. 1991 TRIBUTARY LOADS CT1, CT3

SUMMARY OF RESULTS LAKE CAMPBELL PROJECT
ESTIMATED DAILY TRIBUTARY LOADS
ALL LOADS IN KILOGRAMS PER DAY-DISCHARGE IN LITERS PER DAY

SAMPLE DATA FOR LAKE CAMPBELL OUTLET (CT1), 1991
12 SAMPLES

DATE	SAMP	FLOW L/DAY	TALKAL KG/DAY	TSOL KG/DAY	TDSOL KG/DAY	TSSOL KG/DAY	VOLSOL KG/DAY	FIXSOL KG/DAY	AMMONIA KG/DAY	NO3+2 KG/DAY	TKN-N KG/DAY	TPO4 KG/DAY	TDPO4 KG/DAY
18-Mar-91	GRAB	11256.13	1.53	6.74	6.67	0.17	0.07	0.101	0.007	0.001	0.016	0.001	0.000
20-Mar-91	GRAB	104157.06	13.02	60.83	57.91	2.92	1.46	1.458	0.059	0.010	0.186	0.014	0.006
03-Apr-91	GRAB	317429.24	39.68	237.44	176.49	60.95	17.78	43.170	0.006	0.032	0.597	0.114	0.027
16-Apr-91	GRAB	874514.95	113.69	648.89	578.93	69.96	17.49	52.471	0.642	0.087	1.819	0.314	0.213
30-Apr-91	GRAB	1250422.98	187.56	1016.59	841.53	175.06	47.52	127.543	0.563	0.625	1.913	0.488	0.064
17-May-91	GRAB	3596373.75	489.11	2934.64	2747.63	187.01	35.96	151.048	1.403	0.360	6.653	1.036	0.306
29-May-91	GRAB	21289889.61	3001.87	16414.50	14924.21	1490.29	681.28	809.016	15.329	2.129	33.638	5.855	1.512
04-Jun-91	GRAB	11343962.31	1633.53	8337.81	7543.73	794.08	22.69	771.389	8.395	1.134	16.562	2.995	1.078
21-Jun-91	GRAB	18939688.20	2537.92	14129.01	13447.18	681.83	151.52	530.311	1.326	11.364	33.713	3.788	1.023
24-Jun-91	GRAB	57404579.40	8036.64	49540.15	46784.73	2755.42	1492.52	1262.901	2.296	40.183	90.125	12.457	2.124
31-Jul-91	GRAB	130509.10	17.49	107.80	100.49	7.31	2.87	4.437	0.003	0.065	0.210	0.026	0.014
08-Aug-91	GRAB	22712.63	3.04	16.92	15.92	1.00	0.27	0.727	0.000	0.016	0.031	0.001	0.001
KG/YEAR OR L/YR		4222985649.81	584599.21	3382846.86	3129671.74	253175.11	87455.21	165719.907	1772.731	1037.116	7075.937	1109.680	320.091
DAILY MIN		11256.13	1.53	6.74	6.57	0.17	0.07	0.101	0.000	0.001	0.016	0.001	0.000
DAILY MAX		57404579.40	8036.64	49540.15	46784.73	2755.42	1492.52	1262.901	15.329	40.183	90.125	12.457	2.124
DAILY MEAN		19108531.90	2645.26	15307.00	14161.41	1145.69	395.72	749.864	8.021	4.693	32.018	5.021	1.448

SAMPLE DATA FOR BATTLE CREEK (CT3), 1991
15 SAMPLES

DATE	SAMP	FLOW L/DAY	TALKAL KG/DAY	TSOL KG/DAY	TDSOL KG/DAY	TSSOL KG/DAY	VOLSOL KG/DAY	FIXSOL KG/DAY	AMMONIA KG/DAY	NO3+2 KG/DAY	TKN-N KG/DAY	TPO4 KG/DAY	TDPO4 KG/DAY
06-Mar-91	GRAB	1223208.10	244.66	1056.70	1036.12	19.67	14.68	4.893	0.037	0.122	1.089	0.290	0.257
18-Mar-91	GRAB	1610877.20	123.17	521.81	503.60	18.20	6.07	12.135	0.030	0.152	1.107	0.186	0.103
20-Mar-91	GRAB	1690274.50	241.72	1068.66	1003.46	65.20	47.71	17.493	0.032	0.159	0.843	0.226	0.075
25-Mar-91	GRAB	1345616.90	212.61	881.38	849.08	32.29	24.22	8.074	0.027	0.135	0.807	0.237	0.073
01-Apr-91	GRAB	5137809.90	1032.70	4418.52	4213.00	205.51	128.45	77.067	0.103	0.514	4.881	1.116	0.226
09-Apr-91	GRAB	4403837.00	1122.98	4289.34	4157.22	132.12	114.50	17.616	0.088	0.440	3.787	0.881	0.238
15-Apr-91	GRAB	13700826.00	3521.11	14413.27	13755.63	667.64	219.21	438.426	0.274	1.370	10.961	3.302	1.206
30-Apr-91	GRAB	24465761.00	6483.43	29701.43	29065.32	636.11	489.32	146.795	0.734	2.447	16.881	5.798	2.985
29-May-91	GRAB	53824675.00	13940.59	69272.36	64535.78	4736.57	1291.79	3444.779	1.076	5.382	96.808	19.162	7.320
04-Jun-91	GRAB	34252066.00	9213.81	44253.67	41719.02	2534.65	274.02	2260.636	7.635	3.425	51.036	13.701	6.963
21-Jun-91	GRAB	70950708.00	14544.90	59527.64	54986.80	4540.85	1560.92	2979.930	12.771	70.951	104.298	29.586	15.183
24-Jun-91	GRAB	227531579.00	29124.04	141069.58	119226.65	21843.03	5460.76	16382.274	22.753	22.753	284.414	144.255	69.397
31-Jul-91	GRAB	7584386.00	2017.45	8600.69	8221.47	379.22	91.01	288.207	0.152	3.792	10.163	2.366	2.002
09-Aug-91	GRAB	9296989.30	2361.44	9166.83	8720.58	446.26	74.38	371.880	0.372	7.438	9.483	2.612	1.673
24-Aug-91	GRAB	48931.62	12.43	48.25	45.90	2.35	0.39	1.957	0.002	0.039	0.050	0.014	0.009
KG/YEAR OR L/YEAR		5147106847.57	1165859.31	6372739.79	5010329.61	362410.17	98889.70	263520.470	480.346	1577.452	7098.921	2073.606	1043.995
DAILY MIN		48931.52	12.43	48.25	45.90	2.35	0.39	1.957	0.002	0.039	0.050	0.014	0.009
DAILY MAX		227531579.00	29124.04	141069.58	119226.55	21843.03	5460.76	16382.274	22.753	70.951	284.414	144.255	69.397
DAILY MEAN		29925039.81	6778.25	31236.86	29129.82	2107.04	574.94	1632.096	2.793	9.171	41.273	12.056	6.070

Table B-2

1991 TRIBUTARY LOADS CT4, CT5

SUMMARY OF RESULTS LAKE CAMPBELL PROJECT
ESTIMATED TRIBUTARY LOADS
ALL LOADS IN KILOGRAMS PER DAY - DISCHARGE IN LITERS PER DAY

SAMPLE DATA FOR BATTLE CREEK (CT4), 1991
6 SAMPLES

DATE	SAMP	FLOW L/DAY	TALKAL KG/DAY	TSOL KG/DAY	TDSOL KG/DAY	TSSOL KG/DAY	VOLSOL KG/DAY	FIXSOL KG/DAY	AMMONIA KG/DAY	NO3+2 KG/DAY	TKN-N KG/DAY	TPO4 KG/DAY	TDPO4 KG/DAY
16-Apr-91	GRAB	11106930.43	3031.92	12138.78	11516.85	621.93	177.69	444.237	0.222	1.111	10.662	2.632	0.977
30-Apr-91	GRAB	18107267.10	6233.00	22263.83	21927.90	325.93	217.29	108.644	0.362	1.811	11.589	4.237	2.644
29-May-91	GRAB	47529787.01	12647.86	69174.68	66417.86	2766.73	1520.95	1235.774	1.901	4.763	43.252	12.548	6.607
21-Jun-91	GRAB	65402767.37	13930.79	54088.08	50163.91	3924.17	1177.26	2746.916	9.156	71.943	88.294	29.235	17.070
24-Jun-91	GRAB	207268643.48	25908.68	121666.69	111303.26	10363.43	4145.37	6218.059	14.609	248.722	186.542	84.358	58.242
08-Aug-91	GRAB	8430899.41	2293.20	9376.16	8953.62	421.64	84.31	337.236	1.180	6.745	8.431	3.229	1.627
KG/YEAR OR L/YEAR		4468472479.68	1040816.46	4556488.85	4325387.38	231101.47	84630.06	146571.416	449.369	2687.982	4557.916	1581.386	919.427
DAILY MIN		8430899.41	2293.20	9376.16	8953.62	325.93	84.31	108.644	0.222	1.111	8.431	2.632	0.977
DAILY MAX		207268643.48	25908.68	121666.69	111303.26	10363.43	4145.37	6218.059	14.609	248.722	186.542	84.358	58.242
DAILY MEAN		31917660.67	7434.40	32546.36	30895.62	1650.72	603.79	1046.939	3.210	19.200	32.557	11.296	6.567

SAMPLE DATA FOR BATTLE CREEK (CT5), 1991
9 SAMPLES

DATE	SAMP	FLOW L/DAY	TALKAL KG/DAY	TSOL KG/DAY	TDSOL KG/DAY	TSSOL KG/DAY	VOLSOL KG/DAY	FIXSOL KG/DAY	AMMONIA KG/DAY	NO3+2 KG/DAY	TKN-N KG/DAY	TPO4 KG/DAY	TDPO4 KG/DAY
04-Apr-91	GRAB	357708.04	121.62	363.43	356.56	7.87	0.72	7.16	0.007	0.036	0.490	0.153	0.064
09-Apr-91	GRAB	663863.43	219.74	628.68	618.06	10.62	9.29	1.33	0.013	0.066	0.817	0.178	0.090
16-Apr-91	GRAB	4649771.40	1282.44	5333.99	5182.00	151.99	76.00	76.00	0.237	0.475	4.417	0.917	0.666
30-Apr-91	GRAB	4879447.31	1296.49	5669.92	5464.98	204.94	121.99	82.95	0.244	0.488	4.953	1.274	0.896
29-May-91	GRAB	22767562.87	5939.72	27331.82	26148.43	1183.39	773.76	409.64	1.138	2.276	25.033	7.487	5.553
04-Jun-91	GRAB	17881266.61	5042.61	21207.17	20563.44	643.73	107.29	536.44	1.609	3.576	33.259	6.187	5.579
21-Jun-91	GRAB	113639921.77	14078.96	66863.16	53363.76	12489.39	2724.96	9764.43	13.625	204.372	107.863	63.128	36.219
08-Aug-91	GRAB	1031636.63	259.97	948.07	877.92	70.15	16.51	53.66	0.072	1.032	1.382	0.622	0.269
24-Aug-91	GRAB	16506.47	4.16	15.17	14.05	1.12	0.26	0.86	0.001	0.017	0.022	0.010	0.004
KG/YEAR OR L/YR		3888716579.38	824686.07	3509122.27	3221655.79	287164.11	84998.77	202144.68	329.750	3660.247	4594.690	1828.651	1074.502
DAILY MIN		16506.47	4.16	15.17	14.05	1.12	0.26	0.86	0.001	0.017	0.022	0.010	0.004
DAILY MAX		113639921.77	14078.96	66853.16	53363.76	12489.39	2724.96	9764.43	13.625	204.372	107.863	63.128	36.219
DAILY MEAN		27004976.25	5726.98	24368.90	22372.61	1994.13	590.27	1403.78	2.290	25.418	31.907	12.699	7.462

Table B-3

1991 TRIBUTARY LOADS CT-6

SUMMARY OF RESULTS LAKE CAMPBELL PROJECT
ESTIMATED DAILY TRIBUTARY LOADS
ALL LOADS IN KILOGRAMS PER DAY-DISCHARGE IN LITERS PER DAY

SAMPLE DATA FOR BATTLE CREEK (CT6), 1991
8 SAMPLES

DATE	SAMP	FLOW L/DAY	TALKAL KG/DAY	TSOL KG/DAY	TDSOL KG/DAY	TSSOL KG/DAY	VOLSOL KG/DAY	FIXSOL KG/DAY	AMMONIA KG/DAY	NO3+2 KG/DAY	TKN-N KG/DAY	TPO4 KG/DAY	TDPO4 KG/DAY
08-Apr-91	GRAB	417165.67	287.84	267.81	241.12	16.69	9.18	7.509	1.3016	1.210	2.746	0.638	0.617
15-Apr-91	GRAB	1278669.87	200.75	1777.34	1746.65	30.69	12.79	17.901	0.0268	0.128	1.906	0.286	0.182
30-Apr-91	GRAB	1284128.09	236.00	1784.94	1774.67	10.27	7.70	2.568	0.0267	0.128	1.181	0.248	0.175
29-May-91	GRAB	11106360.87	2665.63	13038.87	12816.74	222.13	80.00	142.127	0.2221	1.111	22.213	6.009	4.365
04-Jun-91	GRAB	12097374.79	3024.34	14335.39	13875.69	459.70	169.36	290.337	0.6049	1.210	15.969	6.315	5.662
21-Jun-91	GRAB	94876214.78	11764.65	70872.63	56071.84	14800.69	2277.03	12523.660	37.9505	189.762	177.419	71.442	68.216
08-Aug-91	GRAB	1488062.53	436.18	1326.40	1257.92	68.48	8.93	59.547	0.0595	1.191	1.563	0.813	0.682
23-Aug-91	GRAB	4806.47	1.41	4.28	4.06	0.22	0.03	0.192	0.0002	0.004	0.005	0.003	0.002
KG/YEAR OR LITERS/YR		1730336963.27	350442.64	1641409.36	1495581.06	145828.30	24131.96	116988.864	333.7637	1815.308	2711.306	1027.695	933.773
DAILY MIN		4806.47	1.41	4.28	4.06	0.22	0.03	0.192	0.0002	0.004	0.005	0.003	0.002
DAILY MAX		94876214.78	11764.65	70872.63	56071.84	14800.69	2277.03	12523.660	37.9505	189.762	177.419	71.442	68.216
DAILY MEAN		12016228.91	2433.63	11398.68	10385.98	1012.70	167.58	812.423	2.3178	12.606	18.829	7.136	6.485

Table B-4

1992 Tributary Loads - CT1, CT3

1992 SUMMARY OF RESULTS LAKE CAMPBELL PROJECT
ESTIMATED TRIBUTARY LOADS
ALL LOADS IN KILOGRAM S PER DAY-DISCHARGE IN LITERS PER DAY

SAMPLE DATA FOR LAKE CAMPBELL OUTLET (CT1), 1992
9 SAMPLES

DATE	SAMP	FLOW L/DAY	TALKAL KG/DAY	TSOL KG/DAY	TDSOL KG/DAY	TSSOL KG/DAY	AMMONIA KG/DAY	UNIONIZED AMMONIA KG/DAY	NO3+2 KG/DAY	TKN-N KG/DAY	TPO4 KG/DAY
04-Feb-92	GRAB	296035.71	34.64	175.65	172.69	2.96	0.047	0.002	0.059	0.332	0.036
19-Feb-92	GRAB	80247696.83	14605.08	73667.39	68050.05	5617.34	35.309	1.344	8.025	316.978	36.272
26-Feb-92	GRAB	24294500.90	4300.13	20213.02	19824.31	388.71	19.193	0.407	4.859	77.986	10.082
02-Mar-92	GRAB	366986418.45	38166.59	163675.94	157804.16	5871.78	300.929	1.913	220.192	928.476	175.420
04-Mar-92	GRAB	319302649.81	28034.77	110159.41	106966.39	3193.03	146.879	2.635	159.651	712.046	125.167
11-Mar-92	GRAB	319302649.81	38954.92	160609.23	149752.94	10856.29	284.179	1.014	127.721	549.201	122.932
16-Mar-92	GRAB	271618881.18	34767.22	140970.20	134451.35	6518.85	244.457	2.820	135.809	668.182	100.227
24-Mar-92	GRAB	36615458.26	5016.32	21310.20	20724.35	585.85	12.816	0.747	18.308	64.809	8.275
30-Mar-92	GRAB	24465761.23	3498.60	16025.07	14899.65	1125.43	0.489	0.063	17.126	60.155	7.633
TOTAL KG. OR L.		7609474398.15	941052.88	4019670.09	3836494.32	183175.77	5340.646	69.139	3344.275	17457.873	2906.619
DAILY MIN		296035.71	34.64	175.55	172.69	2.96	0.047	0.002	0.059	0.332	0.036
DAILY MAX		366986418.45	39912.83	163675.94	157804.16	10856.29	300.929	2.820	220.192	928.476	175.420
DAILY MEAN		135883471.36	16804.52	71779.82	68508.83	3271.00	95.367	1.235	59.719	311.748	51.904

SAMPLE DATA FOR BATTLE CREEK (CT3), 1992
8 SAMPLES

DATE	SAMP	FLOW L/DAY	TALKAL KG/DAY	TSOL KG/DAY	TDSOL KG/DAY	TSSOL KG/DAY	AMMONIA KG/DAY	UNIONIZED AMMONIA KG/DAY	NO3+2 KG/DAY	TKN-N KG/DAY	TPO4 KG/DAY
19-Feb-92	GRAB	342520667.22	22674.87	109606.61	87685.29	21921.32	243.190	1.779	342.621	816.199	284.292
26-Feb-92	GRAB	395122043.86	39907.33	162790.28	137502.47	25287.81	233.122	1.434	276.686	972.000	233.517
02-Mar-92	GRAB	339829423.48	30176.85	119619.96	103987.80	15632.16	163.118	0.762	339.829	676.261	172.633
04-Mar-92	GRAB	231935416.46	26904.51	116431.58	106226.42	10205.16	76.639	0.547	185.548	463.871	97.877
11-Mar-92	GRAB	183493209.23	30459.87	165510.87	154134.30	11376.58	44.038	0.262	201.843	177.988	66.975
16-Mar-92	GRAB	171260328.61	31683.16	168006.38	162526.05	5480.33	17.126	0.172	154.134	227.776	51.721
24-Mar-92	GRAB	146794567.38	30973.65	165584.27	153253.53	12330.74	2.936	0.066	58.718	113.032	39.047
30-Mar-92	GRAB	127221958.40	29133.83	150376.35	139180.82	11195.53	2.544	0.059	12.722	199.738	36.767
TOTAL KG. OR L.		9963436603.31	1301863.89	6323132.69	5733763.26	589369.42	3820.857	25.092	7987.105	18096.820	4899.325
DAILY MIN		127221958.40	22674.87	109606.61	87685.29	5480.33	2.544	0.059	12.722	113.032	36.767
DAILY MAX		447723430.61	42488.95	180594.02	170660.92	25287.81	256.829	1.779	380.565	996.185	284.292
DAILY MEAN		243010348.86	31752.78	154222.75	139847.88	14374.86	93.192	0.612	194.807	441.386	119.496

Table B-5

1992 Tributary Loads - CT4, CT5

1992 SUMMARY OF RESULTS LAKE CAMPBELL PROJECT
ESTIMATED DAILY TRIBUTARY LOADS
ALL LOADS IN KILOGRAMS PER DAY-DISCHARGE IN LITERS PER DAY

SAMPLE DATA FOR BATTLE CREEK (CT4), 1992
5 SAMPLES

DATE	SAMP	FLOW L/DAY	TALKAL KG/DAY	TSOL KG/DAY	TDSOL KG/DAY	TSSOL KG/DAY	AMMONIA KG/DAY	UNIONIZED AMMONIA KG/DAY	NO3+2 KG/DAY	TKN-N KG/DAY	TPO4 KG/DAY
02-Mar-92	GRAB	353995099.24	30868.37	120712.33	110092.48	10619.85	169.918	0.758	353.995	761.089	162.130
04-Mar-92	GRAB	246150023.74	29291.85	124551.91	119136.61	5415.30	76.307	0.519	172.305	425.840	100.429
11-Mar-92	GRAB	153485953.08	24711.24	130309.57	126932.88	3376.69	28.093	0.139	168.835	584.781	46.353
24-Mar-92	GRAB	134940906.06	28337.59	145871.12	141553.01	4318.11	2.699	0.078	26.988	148.435	30.901
30-Mar-92	GRAB	97863044.92	22508.50	113619.00	110095.93	3523.07	1.957	0.059	9.786	132.115	20.160
TOTAL KG. OR L.		4612664526.38	764190.10	3807052.08	3682165.18	124886.90	797.102	5.276	3046.480	10266.153	1424.693
DAILY MIN		97863044.92	21488.03	103986.73	100610.04	3376.69	1.957	0.059	9.786	132.115	20.160
DAILY MAX		353995099.24	30937.48	151268.76	146680.76	10619.85	169.918	0.758	353.995	761.089	162.130
DAILY MEAN		159057397.46	26351.38	131277.66	126971.21	4306.44	27.486	0.182	105.051	354.005	49.127

SAMPLE DATA FOR BATTLE CREEK, RUTLAND, (CT5), 1992
6 SAMPLES

DATE	SAMP	FLOW L/DAY	TALKAL KG/DAY	TSOL KG/DAY	TDSOL KG/DAY	TSSOL KG/DAY	AMMONIA KG/DAY	UNIONIZED AMMONIA KG/DAY	NO3+2 KG/DAY	TKN-N KG/DAY	TPO4 KG/DAY
02-Mar-92	GRAB	489315224.60	47561.44	204533.76	204533.76	9786.30	220.192	220.192	440.384	963.951	224.106
04-Mar-92	GRAB	195726089.84	22899.95	101190.39	101190.39	1957.26	60.675	0.000	137.008	444.298	75.355
11-Mar-92	GRAB	165143888.30	27744.17	146847.77	146847.77	2642.30	21.469	21.469	181.658	208.081	46.075
16-Mar-92	GRAB	134561686.77	24759.35	129582.90	129582.90	807.37	2.691	2.691	94.193	113.032	27.720
24-Mar-92	GRAB	110095925.54	22679.76	120114.65	120114.65	3082.69	2.202	2.202	11.010	75.966	18.606
30-Mar-92	GRAB	97863044.92	21529.87	112248.91	112248.91	1370.08	1.957	1.957	9.786	111.564	12.037
TOTAL KG. OR L.		4507816506.63	728850.93	3689357.28	3689357.28	69592.86	733.300	460.568	2997.667	6178.767	1262.299
DAILY MIN		97863044.92	21468.71	101190.39	101190.39	807.37	1.957	0.000	9.786	75.966	12.037
DAILY MAX		489315224.60	47561.44	204533.76	204533.76	9786.30	220.192	220.192	440.384	963.951	224.106
DAILY MEAN		155441948.50	25132.79	127219.22	127219.22	2399.75	25.286	15.882	103.368	213.061	43.528

Table B-6

1992 Tributary Loads - CT6

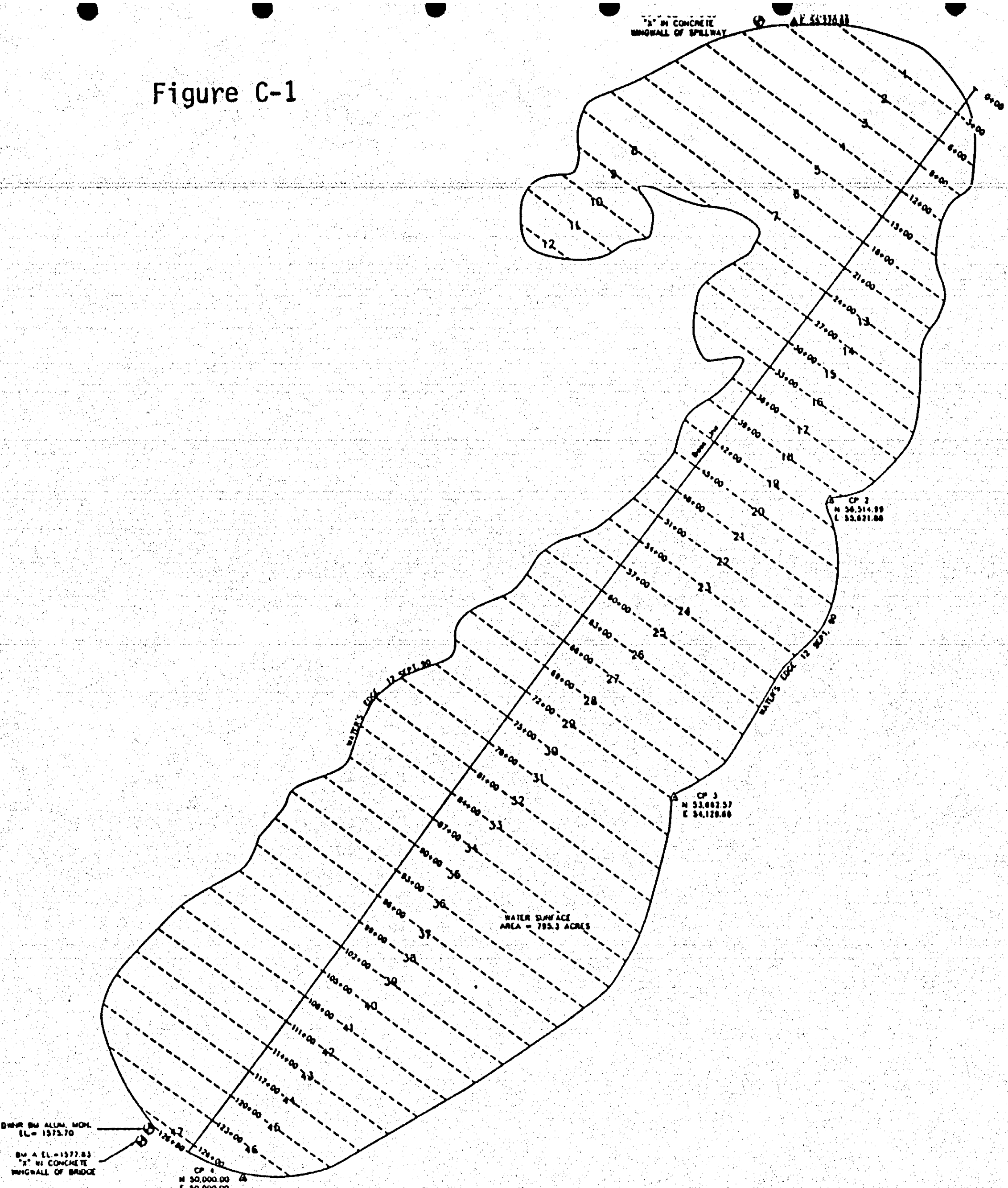
1992 SUMMARY OF RESULTS LAKE CAMPBELL PROJECT
ESTIMATED DAILY TRIBUTARY LOADS
ALL LOADS IN KILOGRAMS PER DAY-DISCHARGE IN LITERS PER DAY

SAMPLE DATA FOR BATTLE CREEK (CT6), 1992
6 SAMPLES

DATE	SAMP	FLOW L/DAY	TALKAL KG/DAY	TSOL KG/DAY	TDSOL KG/DAY	TSSOL KG/DAY	AMMONIA KG/DAY	UNIONIZED AMMONIA KG/DAY	NO3+2 KG/DAY	TKN-N KG/DAY	TPO4 KG/DAY
02-Mar-92	GRAB	209133326.99	23213.80	112932.00	106658.00	6274.00	81.562	0.320	125.480	439.180	104.776
04-Mar-92	GRAB	137815633.01	14332.83	63395.19	59811.98	3583.21	49.614	0.243	82.689	322.489	64.498
11-Mar-92	GRAB	86217342.57	12415.30	70439.57	69577.40	862.17	8.622	0.037	60.352	112.945	28.021
16-Mar-92	GRAB	34619052.14	5331.33	30845.58	30499.38	346.19	0.692	0.005	17.310	34.273	8.378
24-Mar-92	GRAB	22019185.11	4007.49	23098.13	22789.86	308.27	0.440	0.018	2.202	29.286	4.382
30-Mar-92	GRAB	17126032.86	3373.83	18821.51	18616.00	205.51	0.343	0.007	1.713	20.894	2.963
TOTAL KG. OR L.		1833721037.07	248133.33	1324944.55	1292143.94	32800.61	351.821	1.708	1002.323	3035.245	660.345
DAILY MIN		17126032.86	3373.83	18821.51	18616.00	205.51	0.343	0.005	1.713	20.894	2.963
DAILY MAX		209133326.99	23213.80	112932.00	106658.00	6274.00	81.562	0.320	125.480	439.180	104.776
DAILY MEAN		84488428.78	10445.76	53255.33	51325.44	1929.89	23.55	0.11	48.29	159.84	36.50

APPENDIX C. LAKE CAMPBELL SEDIMENT SAMPLING AND SURVEY

Figure C-1



LAKE CAMPBELL
SEDIMENTATION RANGE MAP

GRAPHIC SCALE

(IN FEET)

LEGEND

▲	Control Point (5/8" Rebar /w Steel Fence Post)
⊕	Benchmark
- - 17 - -	Range Line and Range Number
12+00	Stationing in Feet

NOTES: Assumed Coordinates. Elevations based on SD DWNR benchmark elevation. Range lines surveyed at 300' intervals with data captured at a 50 foot 8± mark spacing on-line.

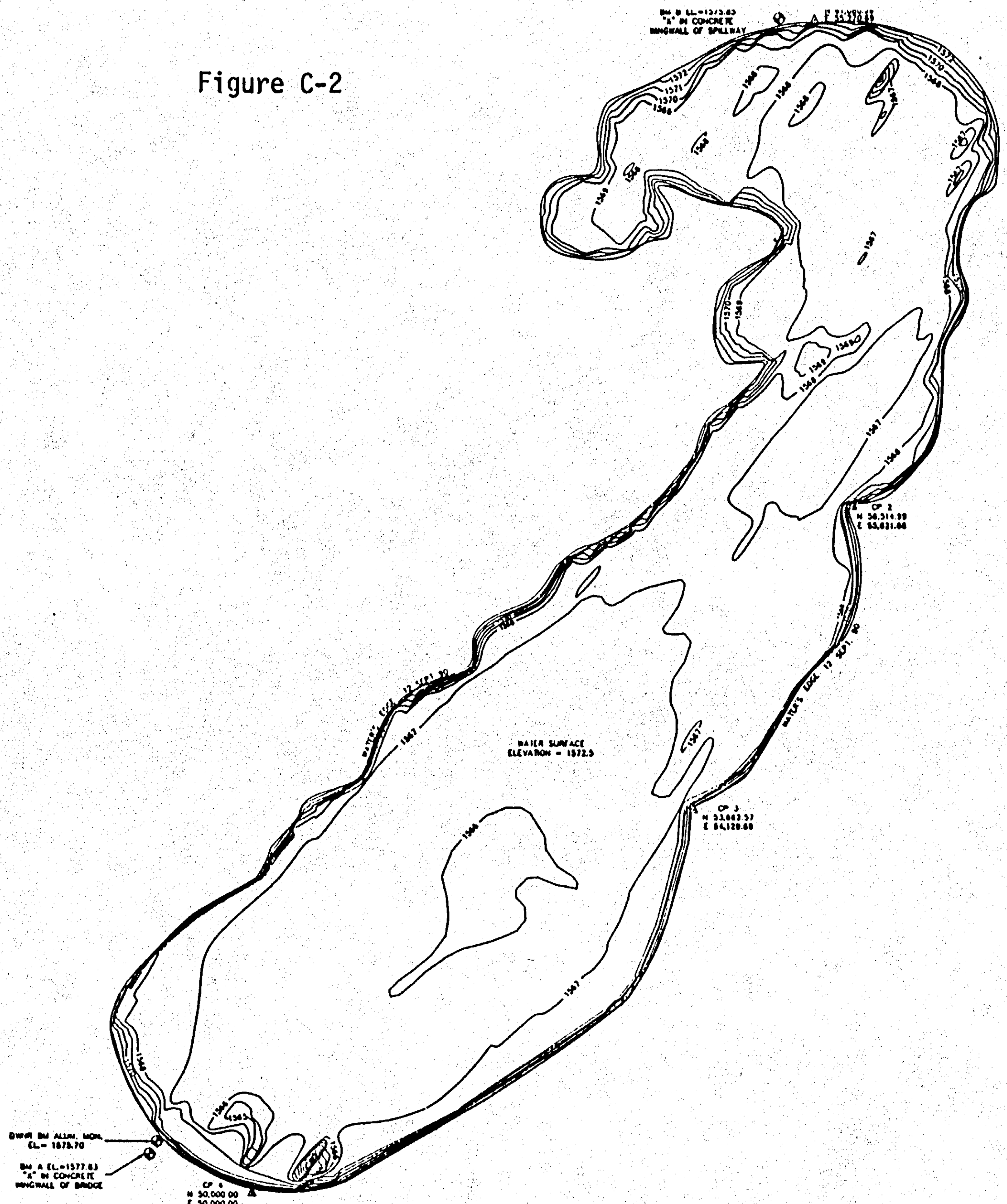
Dates of Survey: Sept. 12 and Oct. 23-30, 1990.

LAKE CAMPBELL SEDIMENTATION SURVEY		
SEDIMENTATION RANGE MAP		
90-058	90058-1	1 of 1
B. KENNEDY	D. EISENBRAUN	9/20/90

Bernhard, Eisenbraun and Associates
134 Walnut • Suite 101
Yankton, South Dakota

Figure C-2

LAKE CAMPBELL
TOPOGRAPHIC MAP DEPICTING TOP OF SEDIMENT LAYER



GRAPHIC SCALE

(IN FEET)

LEGEND

▲ Control Point (36" Rebar /o Steel Fence Post)

Benchmark

—1570— Contour Line

NOTES: Assumed Coordinates. Elevations based on SD DWNR benchmark elevation. Range lines surveyed at 300' intervals with data captured at a 50 foot fix mark spacing on-line.

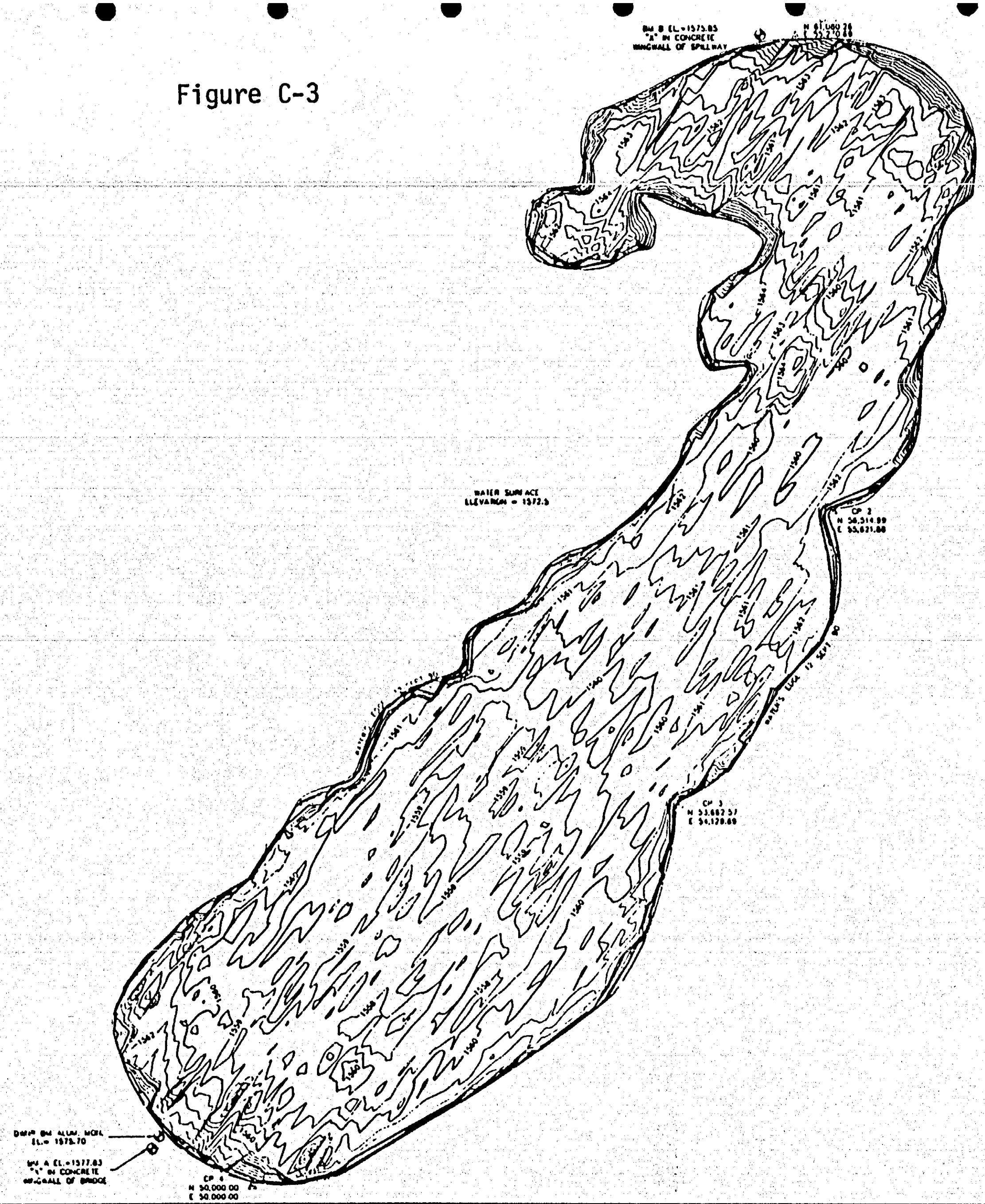
Contour Interval = 1 foot.

Dates of Survey: Sept. 12 and Oct. 23-30, 1990.

LAKE CAMPBELL SEDIMENTATION SURVEY		
TOP OF SEDIMENTATION TOPOGRAPHY		
90-038	90038-2	2 of 7
B. KENNEDY	D. EISENBRAUN	11/07/90

Bernhard, Eisenbra[illegible]
and Associates
124 Walnut - Suite 101
Yankton, South Dakota 57078

Figure C-3



LAKE CAMPBELL
TOPOGRAPHIC MAP DEPICTING BOTTOM OF SEDIMENT LAYER

GRAPHIC SCALE

(IN FEET)

LEGEND

Control Point (58" Rebar /o Steel Fence Post)

Benchmark

Contour Line

NOTES: Assumed Coordinates. Elevations based on SD DM&R benchmark elevation. Range lines surveyed at 300' intervals with data captured at a 50 foot & mark spacing on-line

Contour Interval = 1 foot.

Dates of Survey: Sept. 12 and Oct. 23-30, 1990.

LAKE CAMPBELL SEDIMENTATION SURVEY		
BOTTOM OF SEDIMENTATION TOPOGRAPHY		
90-038	9CO58-3	3 of 7
B KENNEDY	D. EISENBRAUN	11/07/90

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Yankton, South Dakota 57078

APPENDIX D. BIOLOGICAL RESOURCES OF LAKE CAMPBELL AND ITS WATERSHED

Fish Species Known to Inhabit Lake Hendricks

Common Name	Scientific Name
Black Bullhead	Ictolurus melas
Yellow Perch	Perca flavescens
White Sucker	Catostomus commerson
Northern Pike	Esox lucius
White bass	Morone chrysops
Carp	Cyprinus carpio
Large Buffalo	Ictiobus cyprinellus
Walleye	Stizostedion vitreum
Blue Gill	Lepomis chrysops
Black Crappie	Pomoxis nigromaculatus
White Crappie	Pomoxis annularis
Fathead Minnow	Pimephales promelas
Orange Spotted Sunfish	Lepomis humilis
Channel Catfish	Ictalurus punctatus
Sand Shiner	Notropis stramineus
Threespined Stickleback	Gasterosteus aculeatus

Harper & Row, 1981

Aquatic/Emergent Plants Possibly Occurring in Lake Hendricks and Watershed

Common Name	Scientific Name
Common Cattail	Typia latifolia
Leafy Pondweed	Potamogeton foliosus
Sago Pondweed	Potamogeton pectinatus
Richardson Pondweed	Potamogeton richardsonii
Flatstem Pondweed	Potamogeton zosteriformis
Wigeon Grass	Ruppia occidentalis
Horned Pondweed	Zannichella palustris
Slender Naiad	Najas flexilis
Broadleaf Waterplankton	Najas marina
Northern Arrowhead	Alisma plantago-aquatica
Waterweed	Sagittaria cuneata
Eel Grass	Anacharis occidentalis
Reed Grass	Vallisneria americana
Wild Rice	Phragmites communis
Slender Spikerush	Zizania aquatica
Common Soikerush	Eleocharis acicularis
Hardstem Bulrush	Eleocharis palustris
Three Square	Scirpus acutus
River Bulrush	Scirpus americanus
Slender Bulrush	Scirpus fluviatilis
Alkali Bulrush	Scirpus heterochaetus
Sweet Flag	Acorus calamus
Star Duckweed	Lemma trisulca
Giant Duckweed	Spirodela polyrhiza
Water Stargrass	Ceratopphyllum demersum
Coontail	Heteranthera dubia
Northern Water Milfoil	Myriophyllum exalbescens
Common Bladderwort	Utricularia vulgaris

Harlow, William M. and Ellwood S. Harrar, Textbook of Dendrology, McGraw-Hill Book Co., New York, 1950

Native Trees of Lake Hendricks Watershed

Common Name	Scientific Name
Black Willow	Salix niger
Quaking Aspen	Populus tremuloides
Bigtooth Cottonwood	Populus tacamadaca
Eastern Cottonwood	Populus deltoides
Butternut	Juglans cineria
Paper Birch	Betula paprifera
American Elm	Quercus macrocarpa
Slippery Elm	Ulmus americana
Rock Elm	Ulmus fulva
Hackberry	Ulmus thomasi
Red Maple	Celtis occidentalis
Boxelder	Acer rubrum
Basswood	Acer negundo
Green Ash	Fraxinus pennsyvanica

Harlow, William M. and Ellwood S. Harrar, Textbook of Dendrology, McGraw-Hill Book Co., New York, 1950

Migrational Waterfowl Possible In The Lake Hendricks Area

Common Name	Scientific Name
Common Loon	Gavia immer
Red-Necked Grebe	Podiceps grisegena
Green Heron	Butorides striatus
Trumpeter Swan	Olar buccinator
Brant	Branta bernicla
White Fronted Goose	Anser albifrons
Snow Goose	Chen caerulescens
Ross' Goose	Chen rossii
Red-Breasted Merganser	Mergus serrater
Common Merganser	Mergus merganser
Whooping Crane	Grus americana

Harper and Row, 1981

Raptors Possible In The Lake Hendricks Region

Common Name	Scientific name
Permanent or Breeding Species	
Great Horned Owl	Bubo virginianus
Barred Owl	Strix varia
Short-Eared Owl	Asio flammeus
Long-Eared Owl	Asio otus
Coopers Hawk	Acciper cooperii
Red-Tailed Hawk	Buteo jamaicensis
Swainsons Hawk	Buteo swainsoni
Rough-Legged Hawk	Buteo lagopus
Ferruginous Hawk	Buteo regalis
Northern Harrier	Circus cynaneus
Prairie Falcon	Falco mexicanus
Merlin	Falco columbarius
Kestrel	Falco sparverius
Migrational Species	
Turkey Vulture	Cathartes aura
Northern Goshawk	Accipiter gentilis
Sharpshinned Hawk	Accipiter striatus
Golden Eagle	Aquila chrysaetos
Bald Eagle	Haliaeetus leucocephlalus
Osprey	Pandion haliaetus
Gyrfalcon	Falco rusticolus
Peregrine Falcon	Falco peregrinus

Harper and Row, 1981

Mammals Of The Lake Hendricks Region

Common Name	Scientific Name
Water Shrew	Sorex palustris
Pygmy Shrew	Microsorex hoyi
Short-Tailed Shrew	Blarina brevicauda
Least Shrew	Crypotis parva
Eastern Mole	Scalopus aquaticus
Keens Bat	Myotis keenii
Big Brown Bat	Eptesicus fuscus
Red Bat	Lasiurus borealis
Eastern Cottontail	Sylvilagus floridanus
Black-Tailed Jackrabbit	Lepus california
Eastern Chipmunk	Tamias striatus
Richardsons Ground Squirrel	Spermophilus richardsonii
Thirteen-Lined Ground Squirrel	Spermophilus tridecemineatus
Franklin's Ground Squirrel	Spermophilus franklinii
Fox Squirrel	Sciurus niger
Grey Squirrel	Sciurus carolinensis
Plains Pocket Gopher	Geomys bursarius
Plains Pocket Mouse	Perognathus flavescens
Beaver	Caster canadensis
Deer Mouse	Peromyscus maniculatus
White-Footed Deer Mouse	Peromyscus leucopus
Red-Backed Vole	Clethrionomys gapperi
Meadow Vole	Microtus pennsylvanicus
Muskrat	Ondatra zibethcus
Porcupine	Erethizon dorsatum
Coyote	Canis lantrans
Red Fox	Vulpes vulpes
Racoon	Procyon lotor
Long-tailed Weasel	Mustela frenata
Mink	Mustela vision
Badgers	Taxidea taxus
Striped Skunk	Mephitis mephitis
White-Tail Deer	Odocoilus virginianus

Harper & Row, 1981

Reptile Species Found In The Lake Hendricks Region

Common Name	Scientific Name
Painted Turtle	Chrysemys picta
Snapping Turtle	Chelydra serpentina
Common Garter Snake	Thamnophis sirtalis
Smooth Green Snake	Opheodrys vernalis
Bullsnake	Pituophis melanoleucus

Harper & Row, 1981

Rare Plants in the Lake Hendricks Region

Common Name	Scientific Name
Sugar Maple	*Acer saccharum*
Sweetflag	*Acorus americanus*
Wood Anemone	*Anemone quinquefolia*
Spikenard	*Aralla racemosa*
Wild Ginger	*Asarum canadense*
Rush Aster	*Aster borealis*
Flattop Aster	*Aster umbellatus*
Indian Plantain	*Cacalla plantaginea*
Hair Sedge	*Carex capillaris*
Lake Sedge	*Carex lacustris*
Penuncled Sedge	*Carex pedunclata*
Blue Cohosh	*Caulophyllum thalictroides*
Pale Coral-Root	*Corallorhiza trifida*
White Lady Slipper	*Cypripedium candidum*
Toothwort	*Dentaria laciniata*
Downy Gentian	*Gentiana puberulenta*
Small Fringed Gentian	*Gentianopsis procera*
Wild Cranesbill	*Geranium maculatum*
Bottlebrush Grass	*Hystrix patula*
Jointed Rush	*Juncus articulatus*
Florida Lettuce	*Lactuca floridana*
Virginia Cutgrass	*Leersia virginica*
Water Nymph	*Najas marina*
Balsam Poplar	*Populus balsamifera*
Largeleaf Pondweed	*Potamogetan amplifolia*
White Rattlesnake Root	*Prenanthes alba*
Green-fruited Bur Reed	*Sparganium chlorocarporum*
Meadowsweet	*Spiraea alba*
Nodding Trillium	*Trillium cernum*
Declining Trillium	*Trillium flexipes*
Large-flowered Bellwart	*Uvularia grandiflora*
Wildrice	*Zizania aquatica*

Moyle, John B., 1954

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