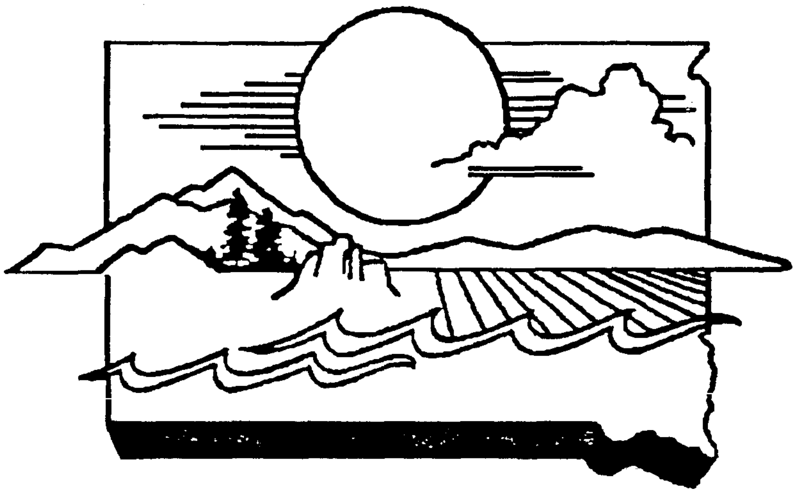
DIAGNOSTIC/FEASIBILITY STUDY REPORT
LAKE HENDRICKS / DEER CREEK WATERSHED
BROOKINGS COUNTY, SOUTH DAKOTA;
LINCOLN COUNTY, MINNESOTA



SOUTH DAKOTA CLEAN LAKES PROGRAM
DIVISION OF WATER RESOURCES MANAGEMENT
SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
EAST DAKOTA WATER DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION VIII

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KEN MADISON
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LAKE HENDRICKS / DEER CREEK WATERSHED

EXECUTIVE SUMMARY

Lake Hendricks is a glacial lake located on the South Dakota-Minnesota border, approximately 20 miles northeast of Brookings, South Dakota. The surface area of the lake is 1,534 acres. The contributing watershed area is 31,693 acres. Approximately 80% of the watershed area is in South Dakota, and 20% of the watershed area is in Minnesota. Upper Deer Creek drains the major subwatershed, and flows into the southwest end of the lake. Minnesota County Ditch 11 drains the other major subwatershed area, and flows into the southeast side of the lake. An un-named tributary drains a smaller subwatershed to the northwest, and enters at the southwest side of the lake.

During recent years, lake property owners and recreational users of the lake have expressed concern about the declining quality of the lake. The main concerns are degradation of water quality, excessive algae and weed growth, and decreasing depth of the lake caused by sedimentation.

At the request of the Lake Hendricks Improvement Association, the South Dakota Department of Environment and Natural Resources submitted an application to the U. S. Environmental Protection Agency to conduct a Diagnostic/Feasibility Study of Lake Hendricks. The application and funding for a Phase I Diagnostic/Feasibility Study grant was approved by the U.S. Environmental Protection Agency on June 5, 1990. The study period for the Phase I grant was from July 1, 1990 to May 30, 1992.

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

Based on the results of the study, the following conclusions have been drawn:

1. Water Quality The water quality in Lake Hendricks and its watershed is in need of improvement. In-lake monitoring results indicated that the lake is in a hypereutrophic condition, resulting in excessive algae blooms and weed growth. The tributary monitoring results showed that excessive loads of nutrients are being added to the lake. The Upper Deer Creek subwatershed was found to be the largest source of the sediment and nutrient loadings to the lake.

2. Watershed Analysis The Lake Hendricks watershed was also analyzed by interpretation of U. S. Geological Survey maps and aerial photos. This watershed analysis revealed that the greatest potential sources of sediment and nutrients to Lake Hendricks are the Upper Deer Creek subwatershed, and the subwatershed drained by Minnesota County Ditch #11.

3. Shoreline Erosion A survey of shoreline erosion around Lake Hendricks indicated approximately 4,040 feet of active erosion. Of this total, about 2,045 feet were considered to be moderate or moderate/severe erosion.

4. Septic Systems A survey of the septic systems around the lake indicated that many of the systems are ten to fifteen years old or older, making them subject to failure. In addition, about 10% of the systems have drainfields within 100 feet of the lake.

5. <u>Sediment Analysis and Survey</u> A sediment survey completed by a consulting engineering firm found a total sediment volume in the lake of 22,594,000 cubic yards. An elutriate analysis of the sediment indicated no excessive concentrations of toxic substances were present in the sample.

In order to address the water quality problems in Lake Hendricks and its watershed area, the following restoration activities are recommended:

1. Information/Education Program to Promote Best Management Practices

2. Feedlot Runoff Control

3. Shoreline Erosion Control

4. Wastewater System Improvements

5. Lac Qui Parle River Channel Cleanout

6. Dredging

7. Cooperative Lake Restoration Project

Further information on these recommendations is included in the RESTORATION ALTERNATIVES AND RECOMMENDATIONS section of the report.

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INTRODUCTION

The Phase I Diagnostic/Feasibility Study of Lake Hendricks was initiated at the request of the Lake Hendricks Association. The purpose of conducting the Phase I Study was to determine the sources of water quality problems in Lake Hendricks 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, Environmental Protection Agency (Region VIII), the East Dakota Water Development District, and the Lake Hendricks 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 Phase I Diagnostic/Feasibility 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 Hendricks, and discuss the rationale for selection of recommended restoration alternatives.

LAKE IDENTIFICATION AND LOCATION

Lake Name: Lake Hendricks

States: Minnesota and South Dakota

Counties: Brookings and Deuel Counties, SD; Lincoln County, MN

Nearest Municipality: Hendricks, MN

Latitude: 44 deg. 29 min. 54 sec. N.

Longitude: 96 deg. 27 min. 12 sec. E.

EPA Region: VIII

Major Tributaries: Deer Creek, Minnesota County Ditch #11, and un-named tributary

Receiving Body of Water: Lac Qui Parle River

Maps showing the location of Lake Hendricks and the Deer Creek watershed are found in Figures 1 and 2.

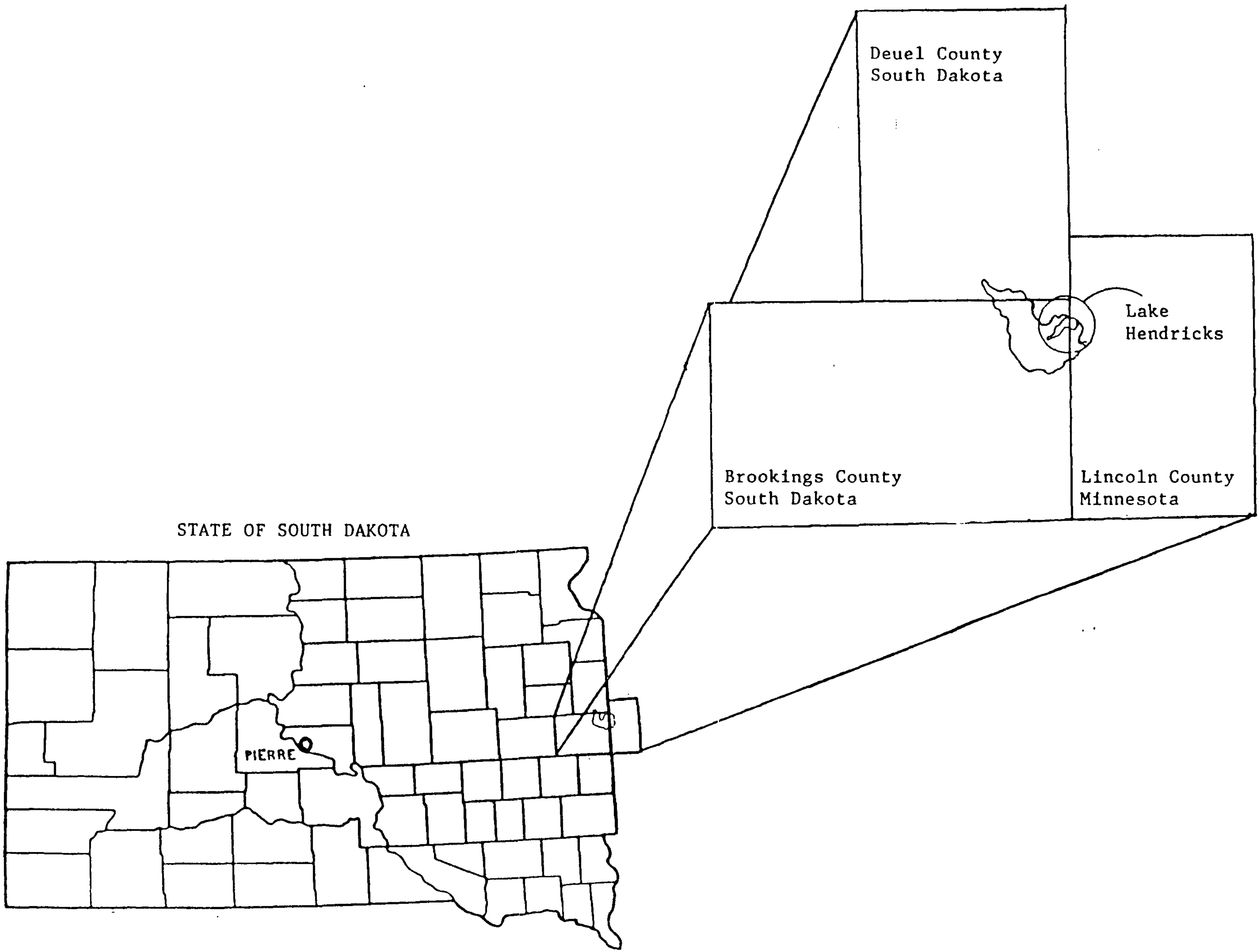


Figure 1. Lake Hendricks Location Map

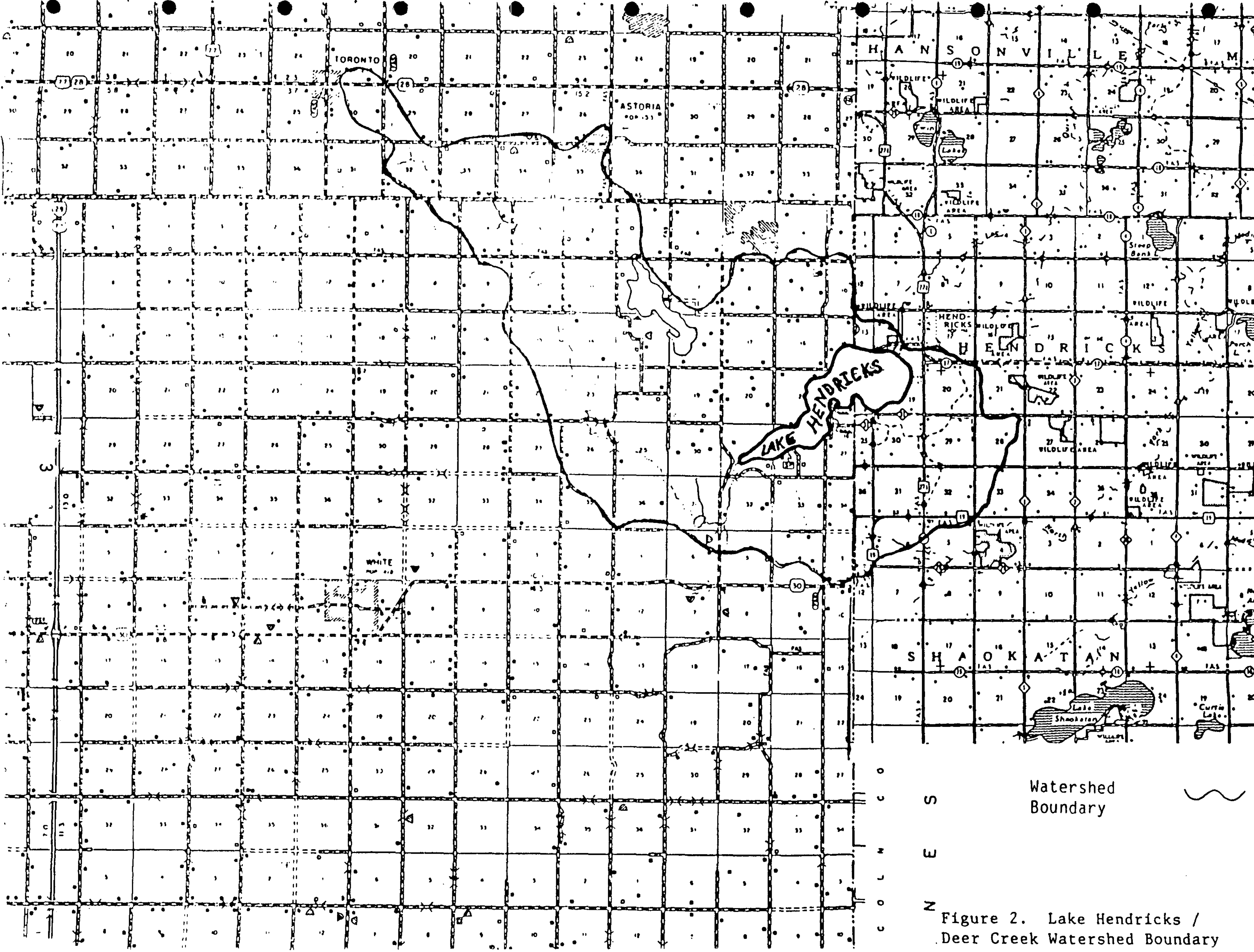


Figure 2. Lake Hendricks / Deer Creek Watershed Boundary

Water Quality Standards

The South Dakota beneficial use classifications for Lake Hendricks are as follows:

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 may be 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 of 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 Hendricks Water Quality Standards.

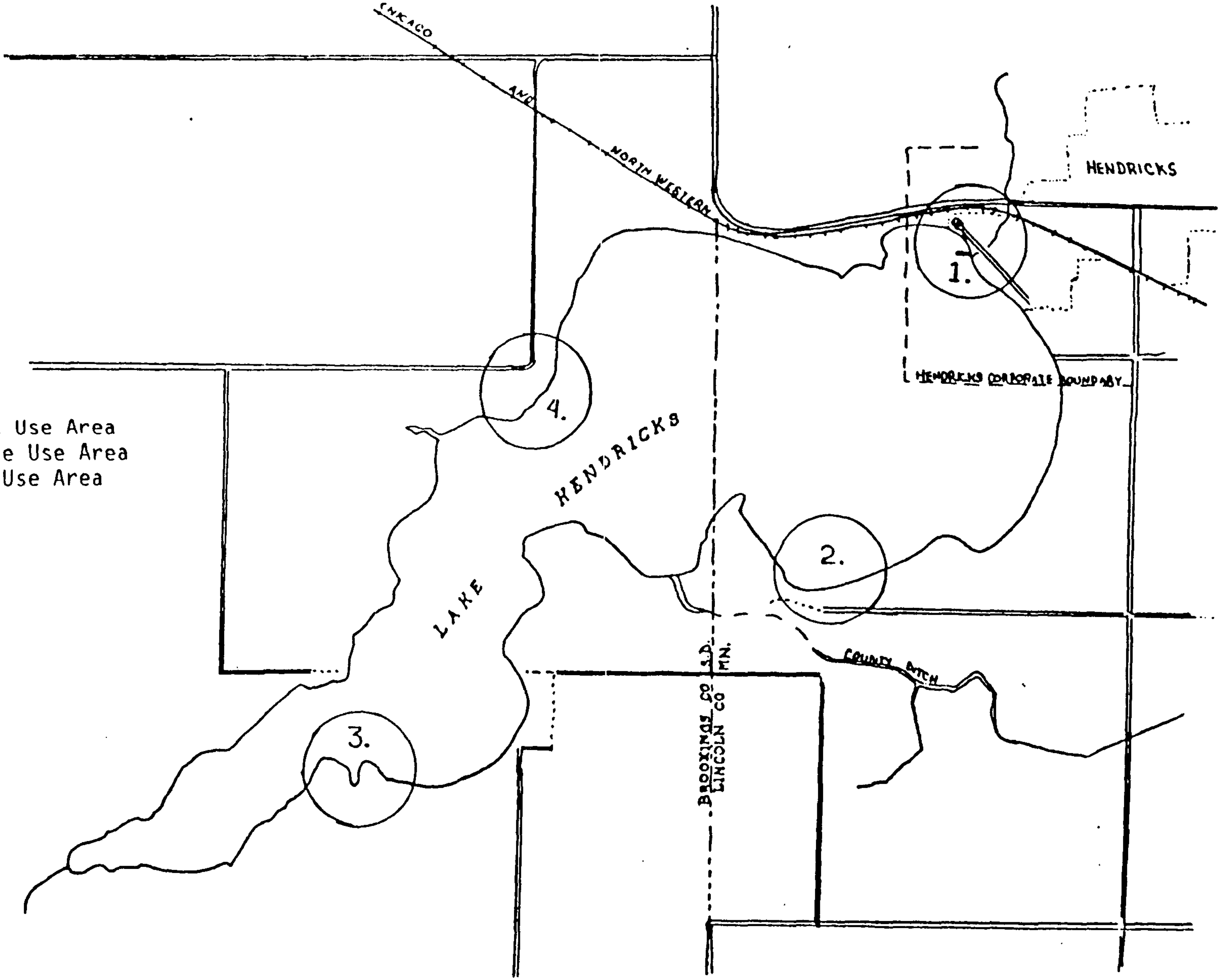
DESCRIPTION OF PUBLIC ACCESS

Lake Hendricks has four public access areas evenly divided between South Dakota and Minnesota (Figure 3, Accesses to Lake Hendricks). Facilities provided in the public access area include shore fishing, boat ramps, campgrounds, and picnic areas. Additional information is contained in Table 2, Public Accesses.

There are no public transportation facilities to Lake Hendricks. Private transportation is the only means of transportation due to a small population base. Population centers, and routes to Lake Hendricks are shown in Figure 4.

Table 1.
Lake Hendricks 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



1) Hendricks City Park
2) Minnesota DNR Public Use Area
3) South Dakota Lakeside Use Area
4) South Dakota Public Use Area

Figure 3

Accesses to Lake Hendricks

Table 2.
Public Accesses

Name:	Hendricks City Park	DNR South Side Mgt. Area
Responsible Agency:	City of Hendricks	Minnesota DNR
Type:	City Park	Boat Launch
Land Area (ha):	11	0.12
Lake Frontage (m)	361	39
Facilities:	Boat ramps 2, 20' Boat docks 2 Fishing pier 1 Picnic shelters 2 Picnic tables 70 Parking for 60 Camping 32 sites Wet bathroom 1 Electric hookups 32 Dump station 1 Concession May - Sept.	Boat ramp 20' Parking for 10
Fees:	Camping $ 7.00/night $ 35.00/week Campground is on bid system. All money is returned to general city fund or water fund.	No fee area

Name:	Lake Hendricks Lakeside Use Area	South Dakota North Access
Responsible Agency:	South Dakota Game, Fish, and Parks	South Dakota Game, Fish, and Parks
Type:	State Park	Boat Launch, Public Use area
Land Area (ha):	4.7	0.6
Lake Frontage (m):	800	540
Facilities:	Boat ramp 16' Parking 25 Picnic grills 10 Camping allowed, assigned sites Water pump Pit toilet	Boat ramp 16' Parking 10 Primitive area No facilities
Fees:	No fee area	No fee area

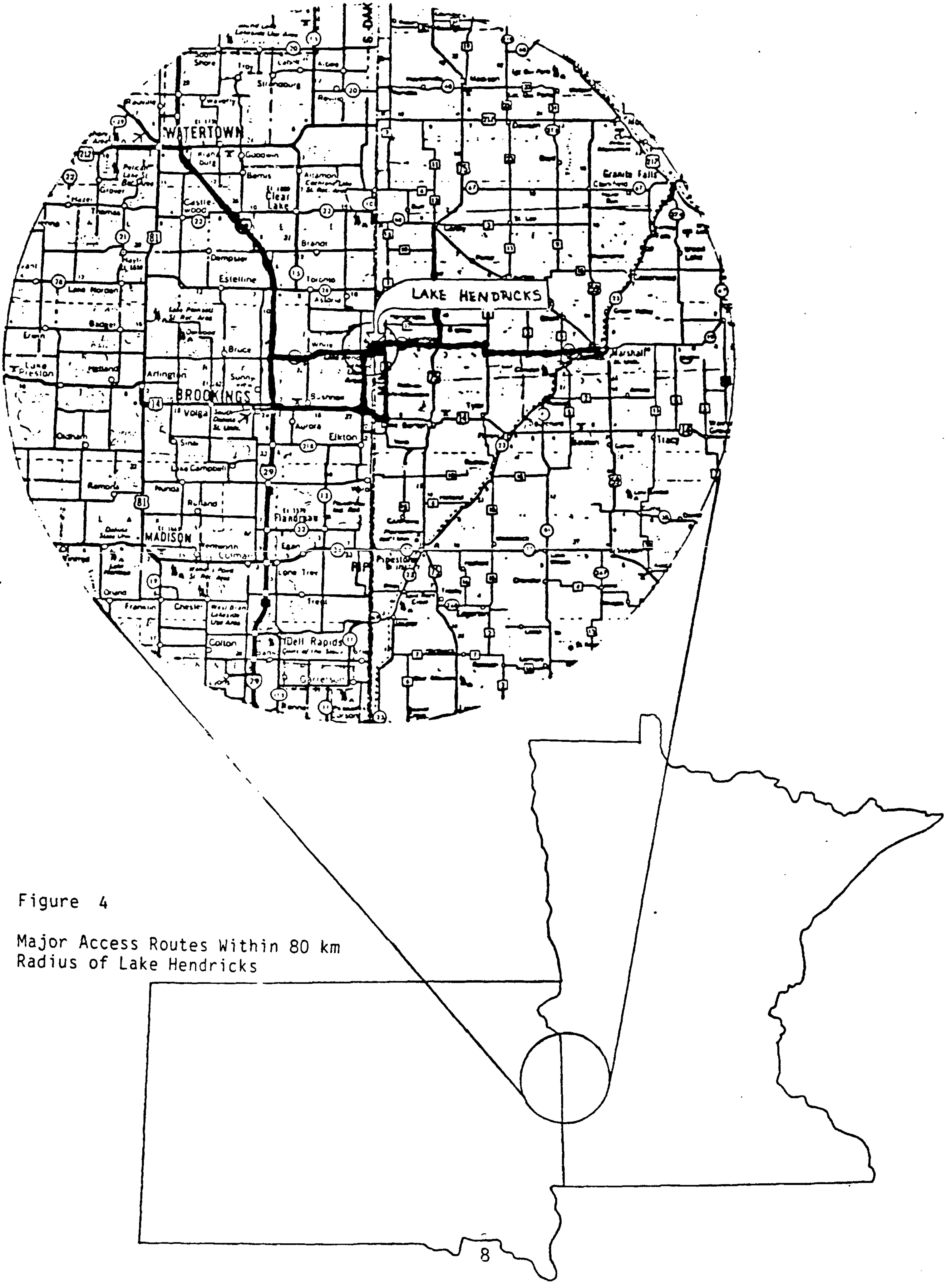


Figure 4

Major Access Routes Within 80 km
Radius of Lake Hendricks

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 Hendricks 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 Hendricks. 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 Hendricks is 332,500 persons. Sixty-four percent of this population resides in South Dakota, with the remaining 36% residing in Minnesota.

The total population residing within a 20 mile radius of Lake Hendricks is 35,440 persons. A very high proportion of this population is young adults. The reason for this is that South Dakota State University at Brookings is within the 20 mile radius. South Dakota State University is the State's largest university with an enrollment of 7,500 students. The large number of young adults in the immediate area places a high demand on Lake Hendricks for summer water sports such as swimming and boating. The young adults also place a high demand on the lake for winter recreational activities such as cross-country skiing, snowmobiling, and ice-fishing.

Southwest State University at Marshall, Minnesota, is located just outside the 20 mile radius. This additional population of young adults places an even higher demand on the lake for summer and winter recreational activities.

In examining the economic status of the potential user population, it was found that the per capita income within the 50 mile radius of Lake Hendricks was $8,678. This is substantially lower than the averages for Minnesota and South Dakota.

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

SUMMARY OF HISTORICAL LAKE USES

Lakeshore Development

Lakeshore development includes 102 lakeside residences, numerous farms, and the City of Hendricks, Minnesota. Other developments include a city park, four public access areas, and a golf course. Lake Hendricks experiences extensive public use because of the recreational facilities that have been developed over the years.

Fisheries

Historically, Lake Hendricks has been an active fishery. Its connection to the Minnesota River, via the Lac Qui Parle River, allows for natural restocking by migration of spawning fish. Lake Hendricks has also been managed as a fishery by the Minnesota Department of Natural Resources and the South Dakota Department of Game, Fish and Parks.

Table 3 lists fish stocking records from 1958 to 1989. Naturally occurring species are the principal types of fish stocked.

Table 3.
Fish Stocking Records For Lake Hendricks

Year	Species	Size	Amount
1958	Northern Pike	Adult	16
	Walleye	Fry	500,000
1959	White Crappie	Adult	448
1960	Walleye	Fry	400,000
1967	Northern Pike	Fry	120,000
1969	Walleye	Fry	301,000
1975	Walleye	Fry	255,360
1976	Walleye	Fry	201,600
1977	Black Crappie	Adult	850
	Blue Gill	Adult	3,400
	Walleye	Fingerling	35,000
1978	Walleye	Fry	702,400
	Northern Pike	Fingerling	608
	White Crappie	Adult	2,000
	Black Crappie	Adult	2,000
1979	Walleye	Fry	400,000
1980	Walleye	Fry	778,000
	Northern Pike	Fry	300,000
1982	Walleye	Fry	797,000
1983	Walleye	Fingerling	3,000
	Blue Gill	Adult	2,010
1984	Walleye	Fry	2,804,700
1985	Blue Gill	Adult	2,562
1986	Blue Gill	Adult	2,562
1987	Yellow perch	Adult	18,240
	Walleye	Fry	384,720
1989	Walleye	Fry	398,200

Minnesota Department of Natural Resources
South Department of Game, Fish and Parks

Wildlife Propagation

A sheltered bay extends from the mouth of Deer Creek to approximately three-fourths of a mile into Lake Hendricks (Figure 5). This area is about 250 acres in size, and is too shallow for motor boats. It provides excellent breeding habitat for waterfowl and other species of birds.

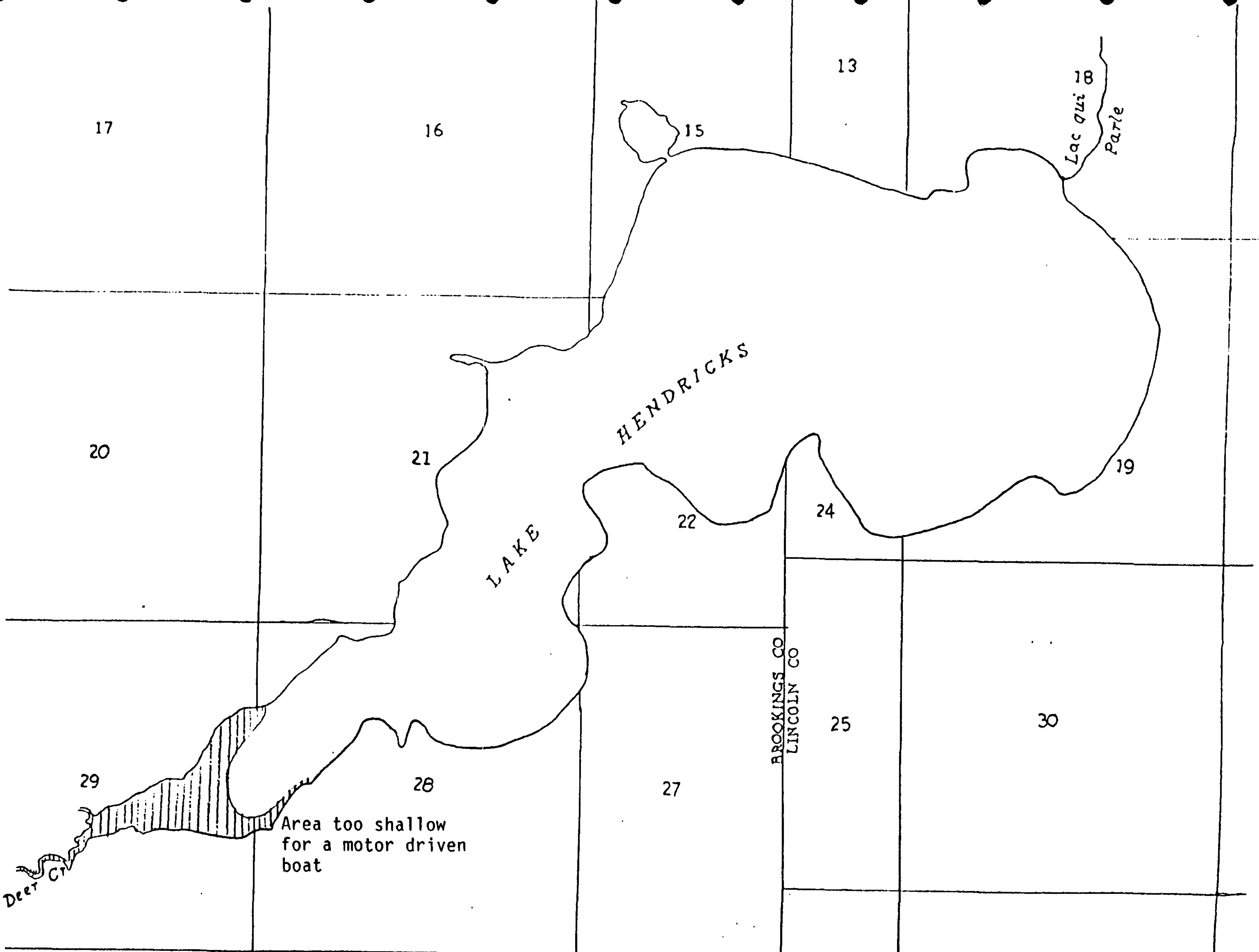


Figure 5. Natural Waterfowl Area on Lake Hendricks

Swimming and Boating

The Minnesota Pollution Control Agency started a Citizen Lake-Monitoring Program at Lake Hendricks in 1988. Some of the most useful information obtained from this program are Secchi disc measurements, and corresponding rankings of water conditions. Water conditions are ranked for recreational use and aesthetic quality.

Suitability rankings for recreational use are as follows:

1 = Beautiful, could not be better.
2 = Very minor aesthetic problems: excellent for swimming, boating.
3 = Swimming and aesthetic enjoyment slightly impaired because of algae levels.
4 = Desire to swim and level of enjoyment of the lake substantially reduced because of algae levels (i.e., would not swim but boating is okay).
5 = Swimming and aesthetic enjoyment of the lake nearly impossible because of algae levels.

The ranking system for the physical condition of the lake is similar to the suitability ranking. Lake condition rankings are as follows:

1 = Crystal clear water.
2 = Not quite crystal clear - a little algae present/visible.
3 = Definite algal green, yellow, or brown color apparent.
4 = High algal levels with limited clarity and/or mild odor present.
5 = Severely high algae levels with one or more of the following:
- massive floating scum on lake or shore
- strong, foul odor
- fish kill

Figures 6 through 9 show that water quality in Lake Hendricks is much better in the spring than in mid- to late-summer. The data also shows that swimming is impaired throughout large portions of the summer. The water quality has even degraded to the point where boating and limited contact recreation are affected during the worst algae blooms.

Watershed Development

Flood Control: In 1966 the Soil Conservation Service, in cooperation with the Upper Deer Creek Watershed Board and Lincoln County Board of Commissioners, developed a watershed plan for Lake Hendricks. As a result of this plan, a flood control dam was built on Upper Deer Creek. The dam and associated channelization were completed to provide flood control for municipalities downstream (Figure 10).

As part of the watershed plan, the main outlet from the dam was constructed to divert 100 percent of the flow from Upper Deer Creek to Lake Hendricks. Previously, the flow in Upper Deer Creek split below the dam. Part of the flow went south and crossed Highway 14 about one mile east of Brookings, South Dakota. The remainder of the flow went to Lake Hendricks.

The overall SCS watershed plan included improvement of 1.5 miles of the Lake Hendricks outlet channel to handle the increased outflow from Lake Hendricks to the Lac Qui Parle River. All the project features were completed except for the 1.5 miles of channel improvement at the outlet from Lake Hendricks. During

Figure 6.

COMPARISON OF SECCHI DISC READINGS AND PHYSICAL LAKE CONDITION DURING THE SUMMER OF 1988
(Citizen Lake-Monitoring Program)

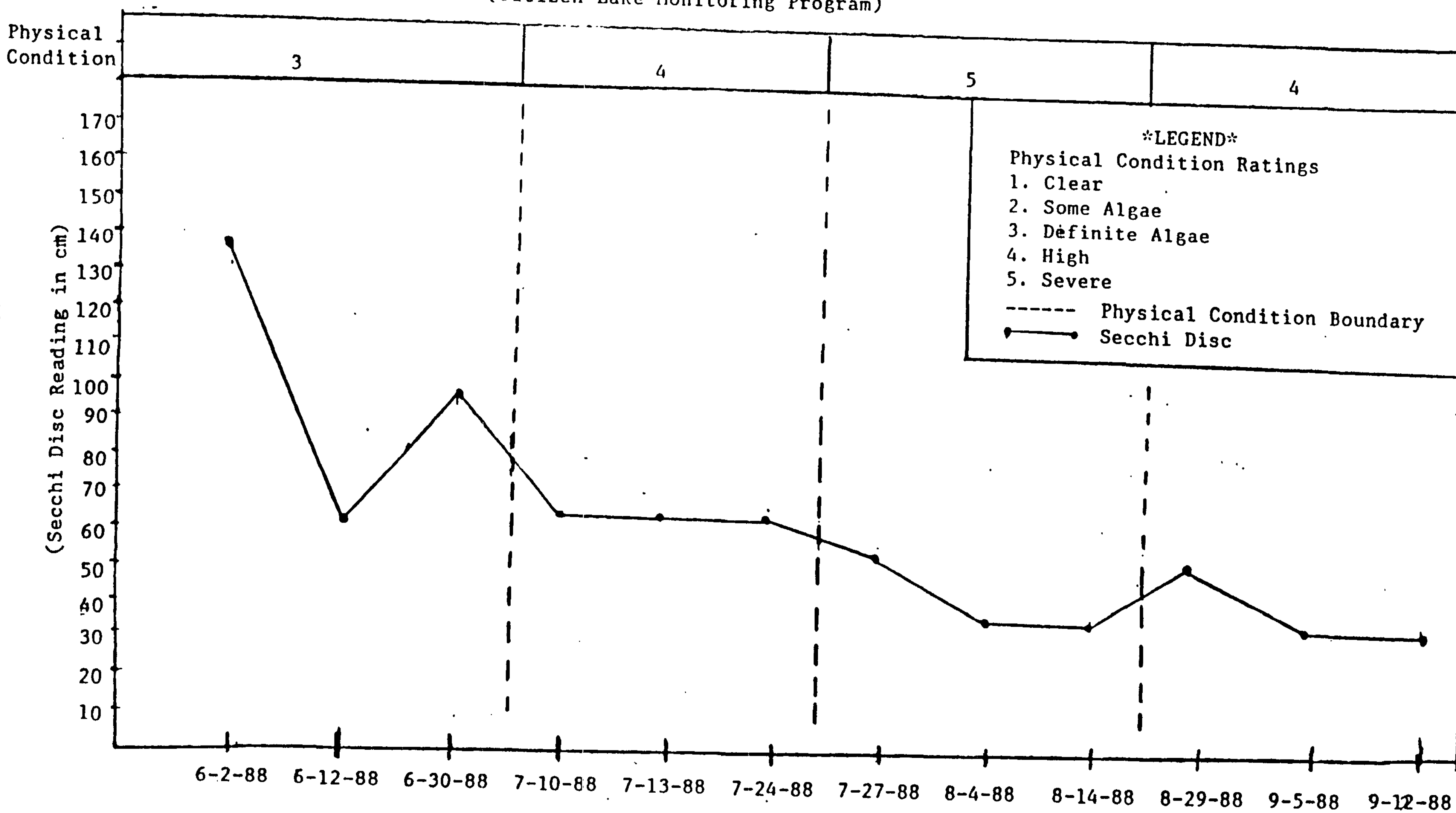


Figure 7.

COMPARISON OF SECCHI DISC READINDS AND RECREATIONAL SUITIBILITY DURING SUMMER OF 1988
(Citizen Lake-Monitoring Program)

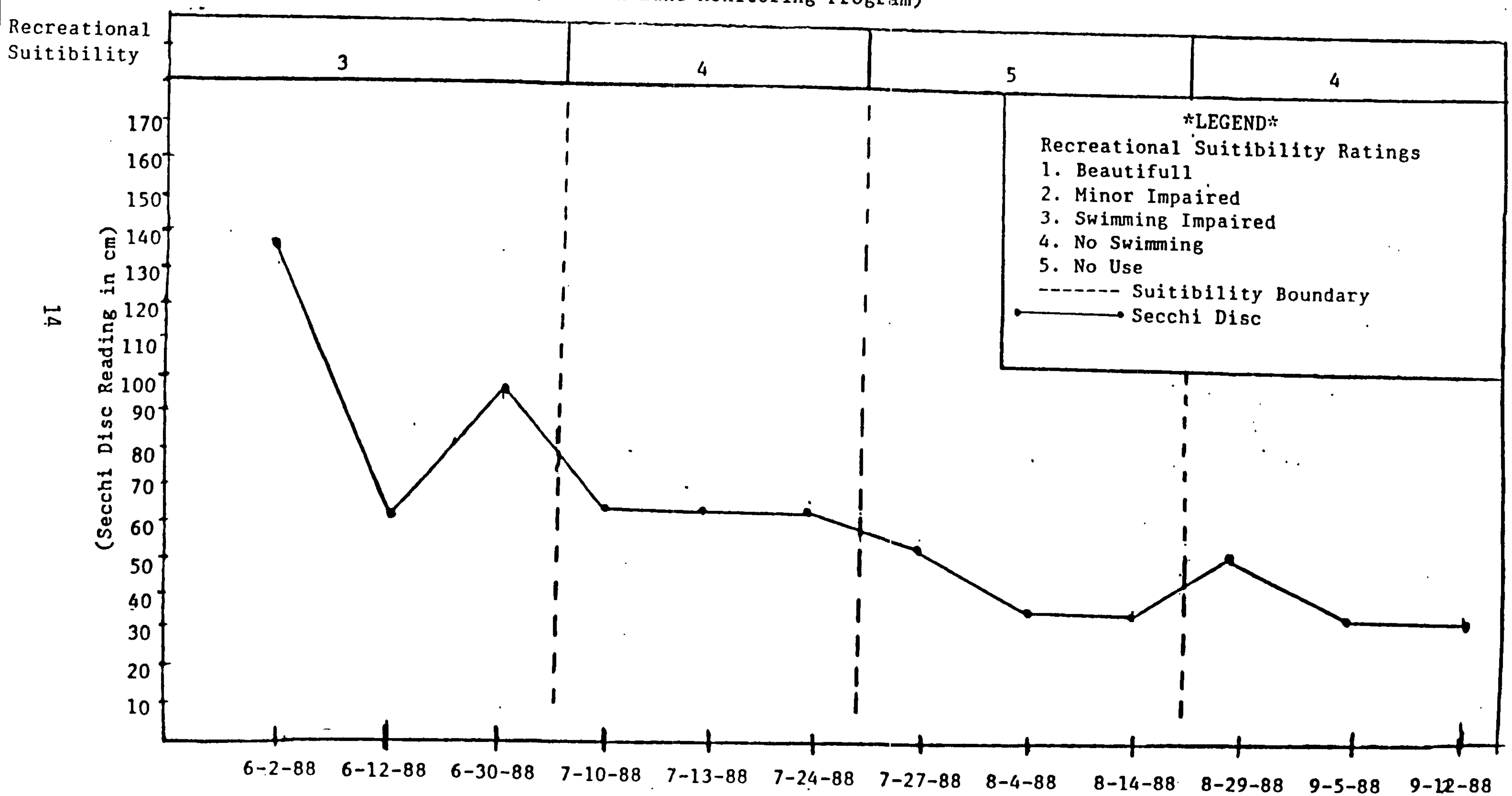


Figure 8.

COMPARISON OF SECCHI DISC READINGS AND PHYSICAL LAKE CONDITIONS DURING THE SUMMER OF 1989
(Citizens Lake-Monitoring Program)

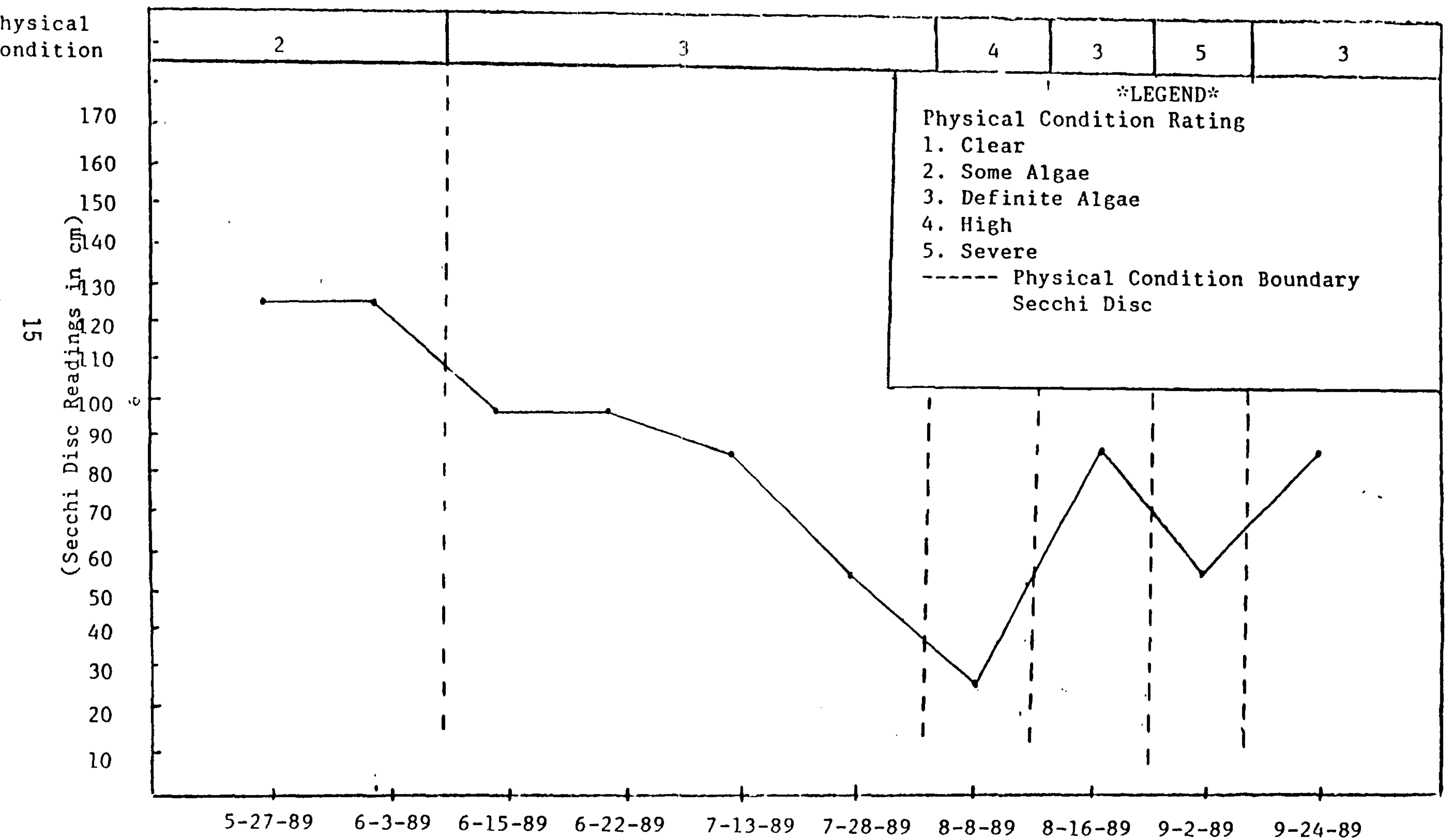
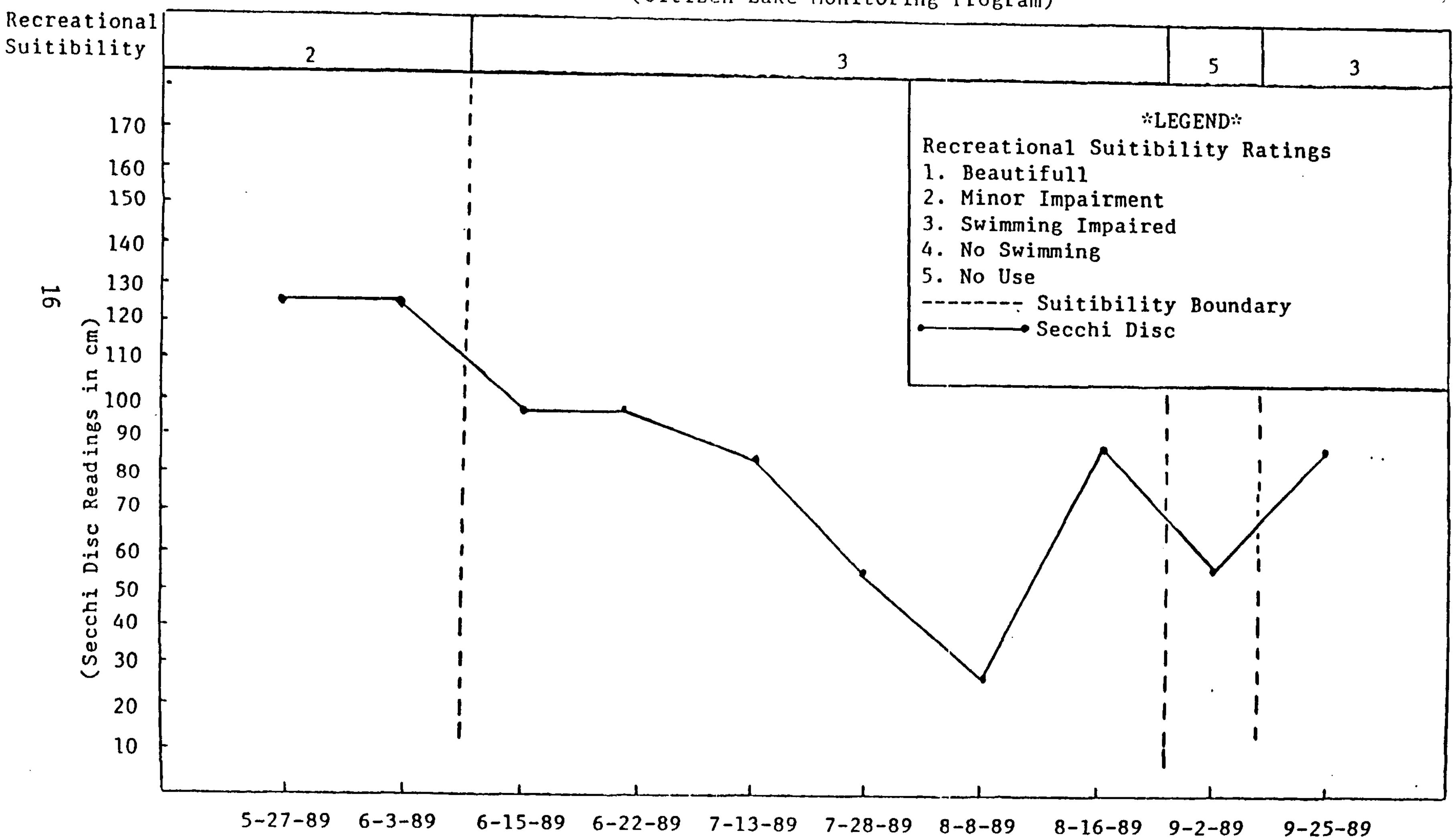


Figure 9.

COMPARISON OF SECCHI DISC READINGS AND RECREATIONAL SUITIBILITY DURING THE SUMMER OF1989
(Citizen Lake-Monitoring Program)



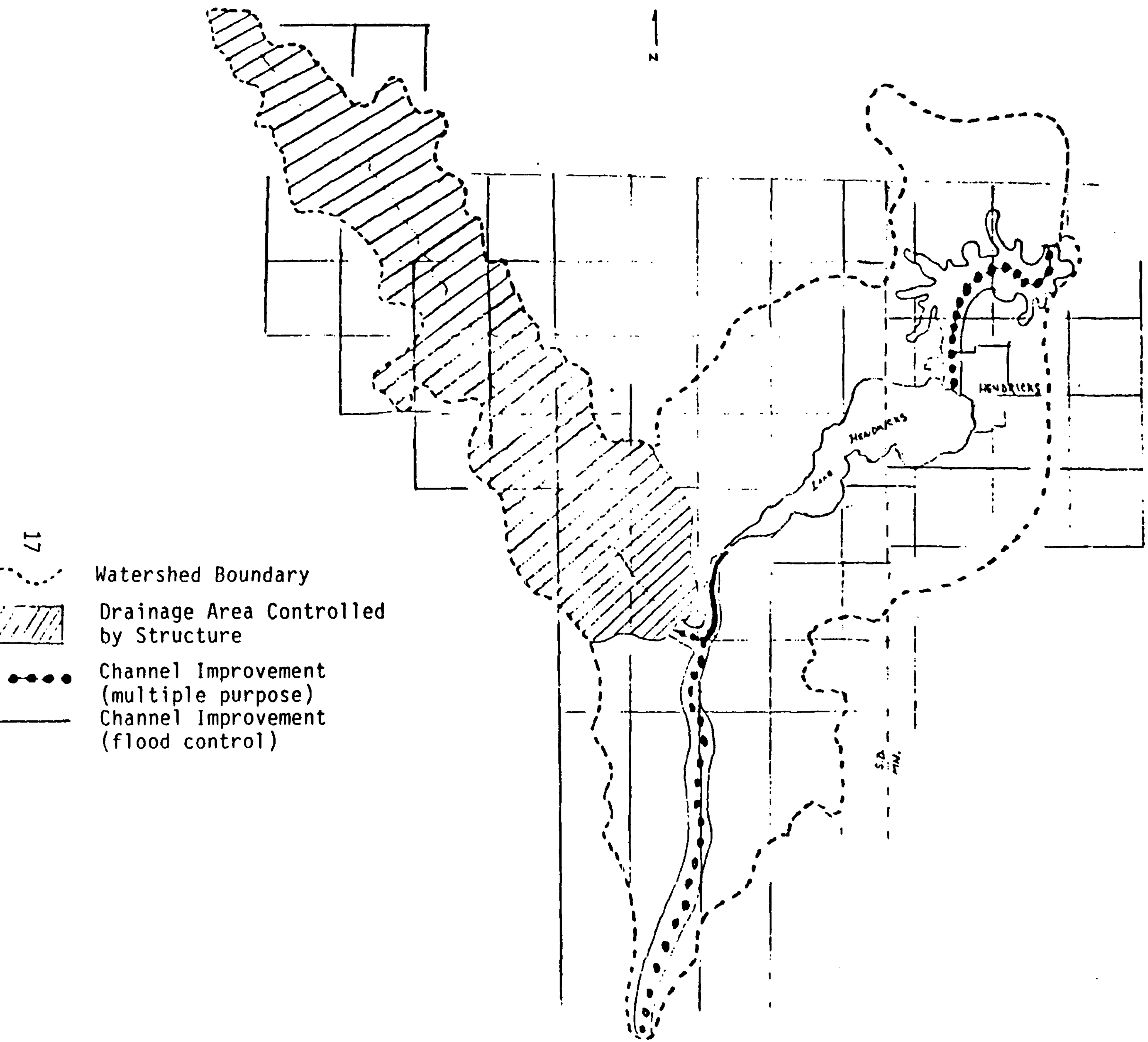


Figure 10.
FLOOD CONTROL

recent years, lake levels have increased due to the inflows being greater than the outlet structure can handle. The resulting higher water elevations have caused severe bank erosion and increased sedimentation into the lake.

County Ditch: Minnesota County Ditch #11 was constructed to drain much of the area immediately surrounding Lake Hendricks (Figure 11). It flows from Minnesota, through a small area of South Dakota, and then into Lake Hendricks.

POPULATION SEGMENTS ADVERSELY AFFECTED BY LAKE DEGRADATION

The population segment most directly affected by the degradation of Lake Hendricks is the City of Hendricks, Minnesota (population 580). Retail establishments within the City of Hendricks such as boat dealers, gas stations, grocery stores, and bait vendors rely heavily on business from residents and recreational users of the lake.

Other population segments affected by the degradation of Lake Hendricks would include those within a 50 mile radius of the lake (total population 332,500). (See previous section of the report titled DESCRIPTION OF THE SIZE AND ECONOMIC STRUCTURE OF POTENTIAL USER POPULATION.) Within the 50 mile radius of the lake are two cities (Brookings, South Dakota and Marshall, Minnesota), and two universities (South Dakota State University and Southwest State University). The population segments of these cities and universities place an increased demand on Lake Hendricks for recreational activities.

In summary, there is a significant population base within a 50 mile radius of Lake Hendricks that relies heavily on the lake for economic support and recreational activities. The degradation of Lake Hendricks will adversely affect this population.

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

Lake Hendricks lies on the eastern edge of the Coteau des Prairie, an area abundant in freshwater lakes. Lake Lac Qui Parle, located 50 miles to the northeast is a much larger lake, and contains more species of fish.

Of the other lakes identified within the 50 mile radius of Lake Hendricks, many have very marginal fisheries, and several have only small gravel boat ramps or no boat ramps. Other lakes in the region have parks and recreational facilities that are suited primarily for tourists (Table 4).

Lake Shaokatan and Lake Benton, both in Minnesota, are within easy traveling distance of Lake Hendricks. These lakes are the most similar in use, size, and quality. Because of the need for out-of-state licenses, many South Dakota residents do not utilize these lakes.

Table 5 provides a summary list of the parks and public facilities located at the 22 lakes within a 50 mile radius of Lake Hendricks. As can be seen from Tables 4 and 5, there are numerous and diverse recreational facilities in the vicinity of Lake Hendricks which attract people to the area. Lake Hendricks serves an important role in providing many of the public and recreational facilities used by these people.

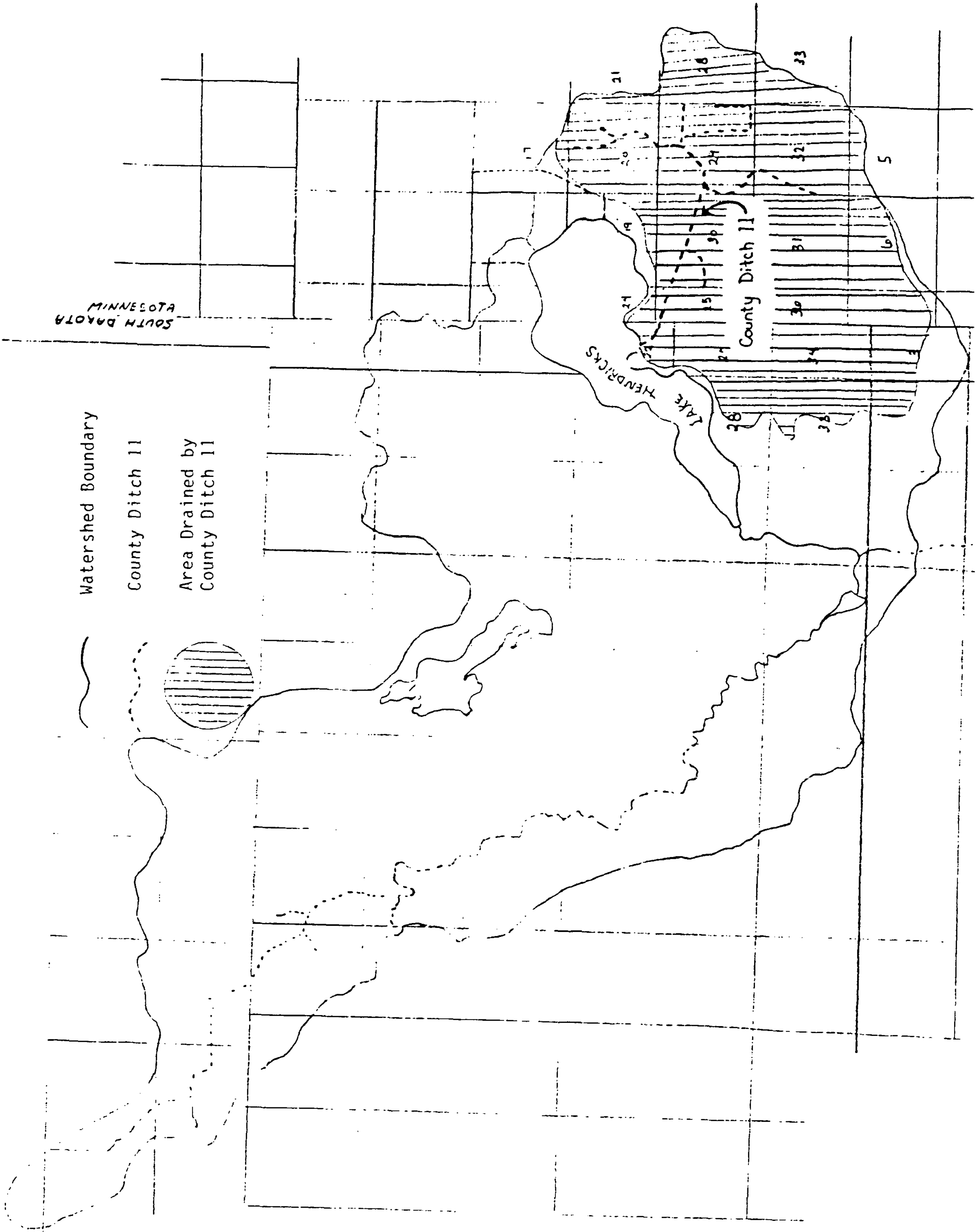


Figure 11. Minnesota County Ditch 11

Table 4.
Lakes Within a 50 Mile Radius of Lake Hendricks

Body of Water	Parks	Ramps	Uses	Nearest Municipality
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
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

Table 4. (continued)
Lakes Within a 50 Mile Radius of Lake Hendricks

Body of Water	Parks	Ramps	Uses	Nearest Municipality
Lake Carthage	1	2	Boating	Carthage, SD
Lake Cochrane	1	1	Boating Fishing Swimming Camping Picnicking	Brandt, SD
Goldsmith Lake*		1	Fishing Boating Swimming	Volga, SD
Camden	1	2	Boating Fishing Swimming Camping Picnicking	Lynd, MN
Lake Sarah		1	Boating Fishing Swimming Picnicking	Garvin, MN
Lake Shetek	1	2	Boating Fishing Swimming Camping Picnicking	Currie, MN
Long Lake*		1	Boating Fishing Swimming Picnicking	Garvin, MN

*Gravel boat launch or no boat launch.

Table 5.
Summary of Parks and Facilities Within 50 Mile Radius of Lake Hendricks

Total of 22 lakes:

Description of Public Accesses		Uses Available to the Public
County/City Parks	2	Swimming, Fishing, Camping, Picnicking
State Parks and Recreation Areas	10	Swimming, Fishing, Camping, Picnicking,
Public Landings	41	Boat Launching

INVENTORY OF POINT SOURCE POLLUTION DISCHARGES

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

GEOLOGICAL AND SOILS DESCRIPTION OF DRAINAGE BASIN

Geology

Lake Hendricks is a glacial outwash lake, located on an erosion remnant that extends north and south. All of the basins within this erosion remnant drain either to the Big Sioux River or the Minnesota River. Lake Hendricks drains to the Minnesota River by way of the Lac Qui Parle River. The Lake Hendricks area was glaciated at least four times during the Pleistocene epoch. Deposits left by these four ice sheets are from youngest to oldest the Wisconsin, Illinoian, Kansan, and Nebraskan.

The Wisconsin stage has been sub-divided into four sub-stages, the Iowan, Tazewell, Cary, and Mankato (Figure 12). Of the four sub-stages of glaciation in eastern South Dakota, the predominant remnants on the surface in the Lake Hendricks area are of the Tazewell, Cary, and Iowan age.

Tazewell glacial deposits are till and outwash gravels. The till is typically a mixture of boulders and clay. The soil that developed on the till ranges from several inches to three feet in thickness. Tazewell outwash deposits are found in terraced areas along the Big Sioux River and its tributaries, such as Deer Creek. The terraces are generally small, covering less than a square mile in area (Steece, 1958).

Iowan deposits are generally referred to as any till or boulder clays that are older than Tazewell deposits. These deposits are characterized by level to slightly sloping topography. Cary deposits are comprised of till, outwash, and glacial lake sediments. Soils in these areas are usually poorly developed, and are often only six inches thick.

Topography

The Lake Hendricks watershed (31,693 acres) can be divided into three main areas. The first area is a well-defined subwatershed known as Upper Deer Creek. Upper Deer Creek covers approximately 12,677 acres, and makes up about 40 percent of the entire watershed. This drainage area extends southeast for approximately 10 miles. It has gently sloping hills and valleys in the upland area, but severely steep slopes at the sides of the creek. This area drains to a flood control structure just before it enters Deer Creek proper. All of the water that discharges out of the flood control structure has been diverted to flow directly to Lake Hendricks. Slopes in this drainage area range from 0.07 percent to 33.01 percent, with an average of 3.75 percent (Figure 13).

The second area is also well-defined with a combination of gentle slopes, moderately severe slopes, and severe slopes. It covers approximately 3,803 acres, and makes up about 12 percent of the watershed. It extends from the flood control dam to Lake Hendricks, a distance of about 1 1/2 miles. Slopes in this drainage area range from 0.55 percent to 35 percent, with an average of 1.19 percent.

The third area of the Lake Hendricks watershed is comprised of the land immediately surrounding the lake. It covers 15,213 acres, and makes up approximately 48 percent of the watershed. This land consists primarily of low rolling hills and valleys. A series of drainage ditches have been constructed on the south side of this area to increase the productivity of the surrounding farm land. The average slope of these ditches ranges from 0.25 to 0.50 percent. Slopes in the rest of this area range between 0.00 to 6.89 percent, and average 0.80 percent.

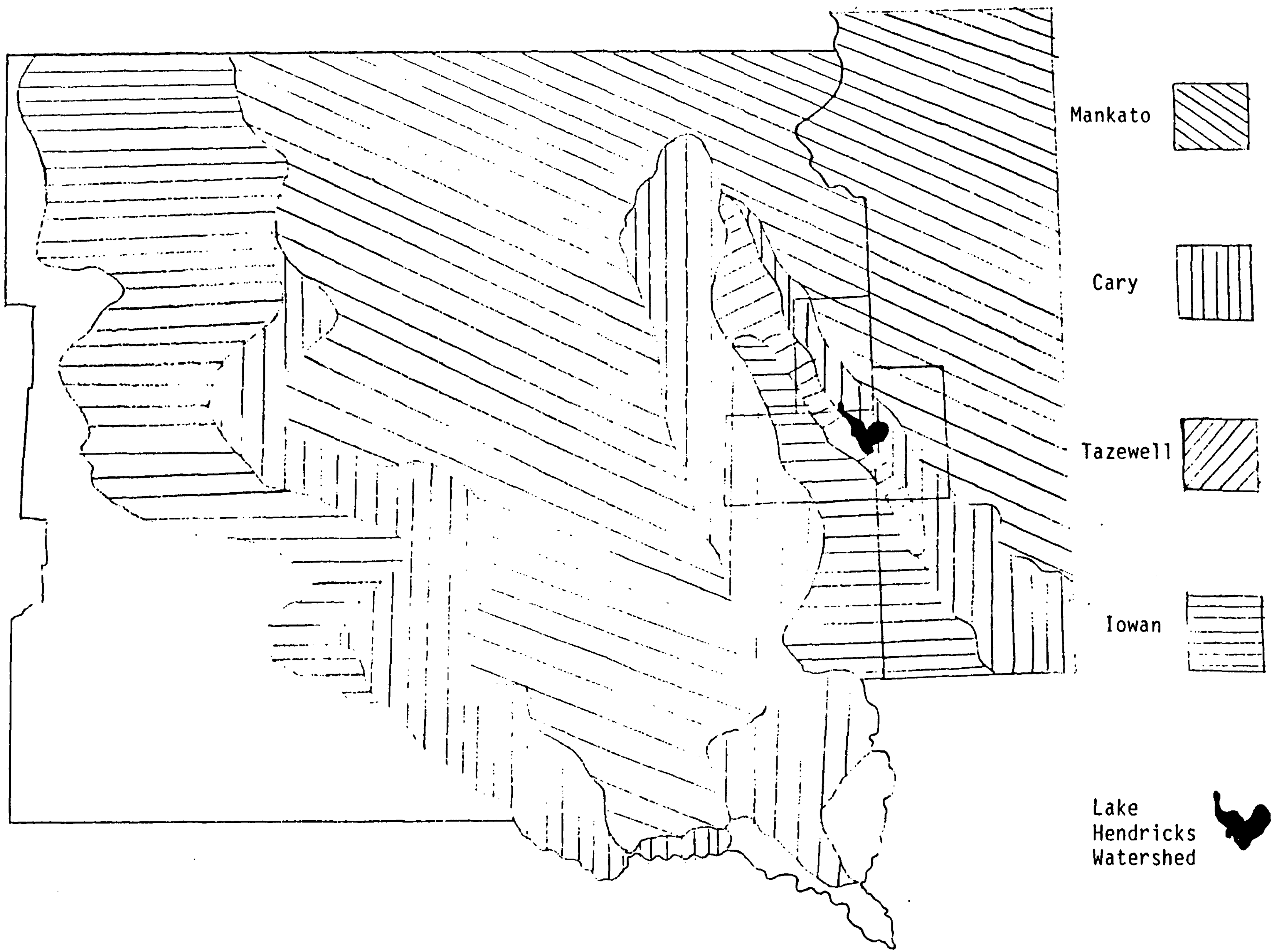
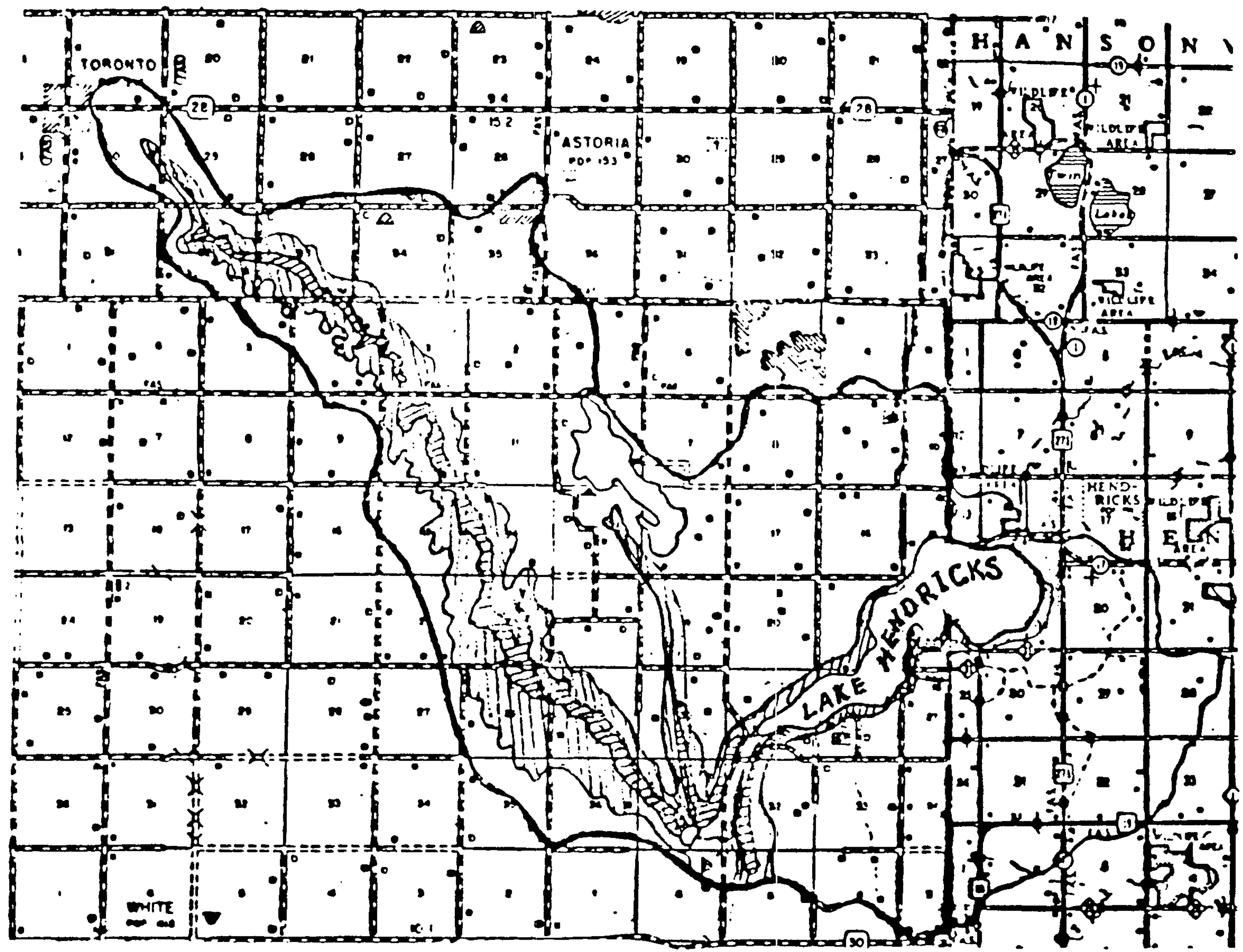


Figure 12. Glaciation of the Lake Hendricks Watershed


TORONTO
ASTORIA
POP 153
HANSON
HENDRICKS
LAKE HENDRICKS
WHITE

Watershed Boundary
Slopes Greater than 20%
Slopes Greater than 10%
and less than 20%
Slopes Less than 10%

Soils

According to the soil surveys of Brookings and Lincoln Counties, the major soil types in the Lake Hendricks watershed are Singrass-Oak Lake, Forman-Bruse, and Lamour (Figure 14). The following is a description of the three major soil types.

1. Singrass-Oak Lake

   Singrass-Oak Lake soils are the principal soils in the Lake Hendricks watershed. They are silty soils composed of glacial till. These types of soil are found in the north, west, and southwest sides of the watershed. They are deep, well-drained soils covering the greatest amount of acreage in the watershed. The surface layer is composed of a silty clay loam about 10 inches thick. The subsoil is about seven inches thick.

   The permeability of these soils is moderately rapid, and the moisture-holding capacity is high. Soils of this type are usually found on slopes of 0 to 6 percent (Soil Survey, Lincoln County, 1970).

2. Forman-Bruse

   Forman-Bruse soils are found along the steep hillsides of the Upper Deer Creek and Deer Creek drainage areas. These soils have developed from a glacial till that is composed of loam, or a clay-loam mixture. Forman-Bruse soils are generally found on slopes that range from 10 to 25 percent. Severe erosion can be a problem on these soils.

3. Lamour

   Lamour soils are found on the western edge of the Upper Deer Creek and Deer Creek drainage areas. They have developed in glacial till that is of a loam or clay-loam texture. These soils occur on gently sloping ridge tops, and on gentle slopes at the head of drainage areas. In profile, Lamour soils are predominantly loam. The top soil is 13 to 18 inches thick. These soils have moderate, to moderately rapid, permeability. They are found in areas with slopes of 3 to 4 percent (Brookings County Soil Survey, 1955).

Groundwater Hydrology

Lake Hendricks and part of its watershed lie over the Big Sioux Aquifer. This is the only unconfined shallow aquifer within the drainage area. The Big Sioux Aquifer is a shallow glacial aquifer composed of outwash sand and gravel. Recharge to the aquifer is by infiltration of rain water and snowmelt through the overlying 0.3 to 6.0 meters of top soil.

The Big Sioux Aquifer has a ground water divide that lies at the headwaters of Deer Creek. At this point, water in the aquifer and on the surface flows east towards Lake Hendricks and the Lac Qui Parle River and also west towards the Big Sioux River. Because of the close proximity of the aquifer to Lake Hendricks there is a hydrologic connection.

In theory, Lake Hendricks receives ground water recharge during high water periods in the spring and also in the fall when groundwater levels increase. Conversely, during periods of low groundwater levels, Lake Hendricks may actually recharge the aquifer (Siegel, 1990).

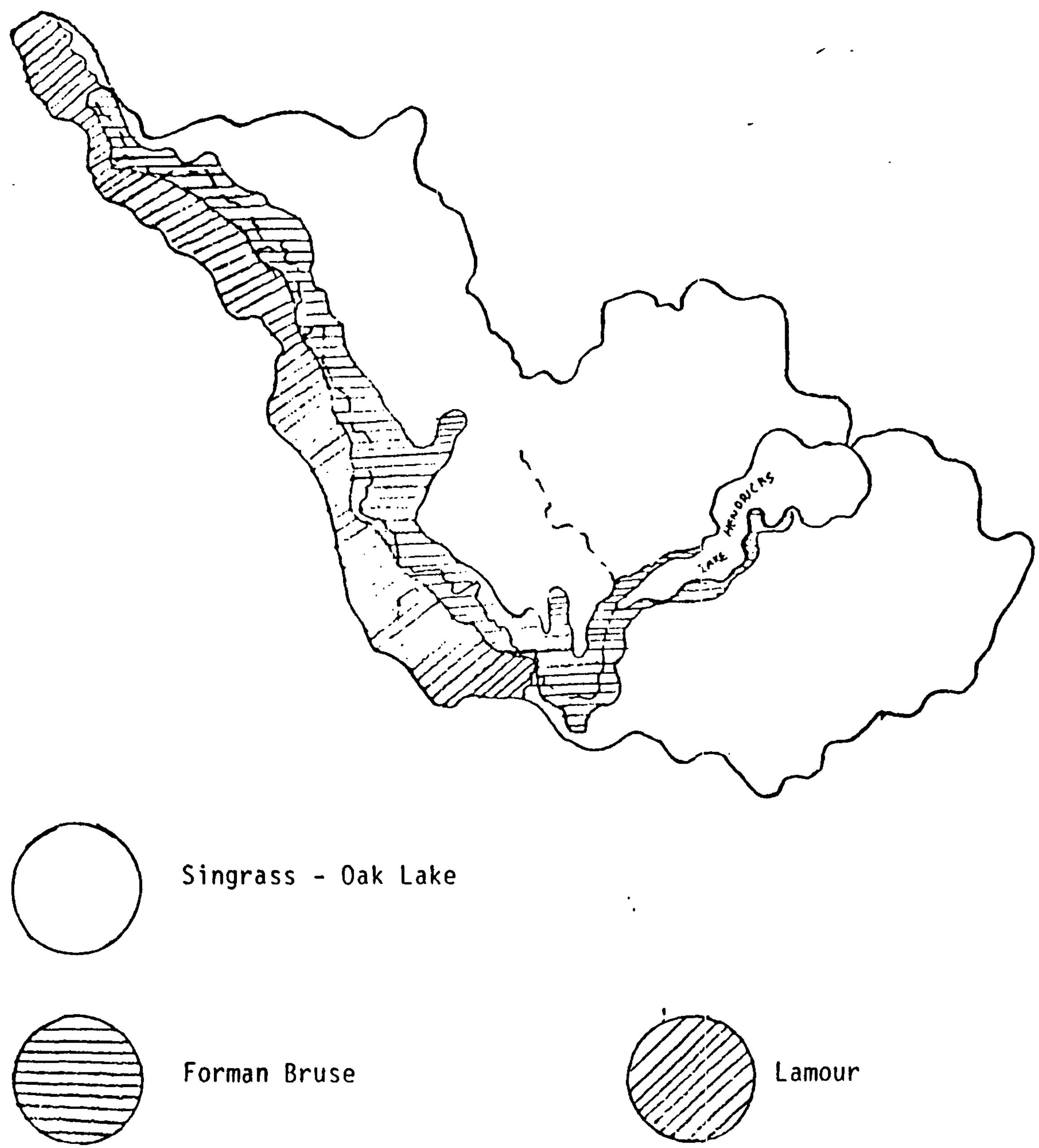


Figure 14.

Soils of Lake Hendricks Watershed

LAND USES AND NONPOINT POLLUTANT LOADINGS

Watershed Analysis

The Lake Hendricks watershed is located on the Prairie Coteau in the northeast corner of Brookings County, South Dakota, and extends into Lincoln County, Minnesota. The size of the watershed area is 12,836 hectares, or 31,693 acres.

The Lake Hendricks watershed was analyzed by use of U. S. Geological Survey topographic maps and Soil Conservation Service aerial photos. The analysis indicated that land use in the watershed is 89.6% agricultural, involving either livestock or crop production. The Land Use and Nonpoint Pollutant Loading Analysis is available upon request to the South Dakota Department of Environment and Natural Resources, Division of Water Resources Management. The table below provides a summary of land uses and percentages for the entire watershed.

Table 6.
1992 Land Use Percentages for Lake Hendricks Watershed

Land Use	Hectares	Acres	%Watershed
Agricultural Cultivated	6,705	16,555	52.13
Agricultural Non-cultivated	3,662	9,042	28.47
Conservation Reserve Program	815	2,012	6.34
Water	800	1,975	6.22
Farmsteads	343	847	2.67
Transportation	246	607	1.91
Forest	103	254	0.80
High Density Residential	90	222	0.70
Low Density Residential	61	151	0.47
Other	11	28	0.29
Total	12,836	31,693	100.00

Sediment and nutrient loading estimates to Lake Hendricks were calculated using the Universal Soil Loss Equation. Loading estimates for the entire watershed are as follows:

Sediment:	5,166,000 kg/year
Nitrogen:	31,009 kg/year
Phosphorus:	2,584 kg/year

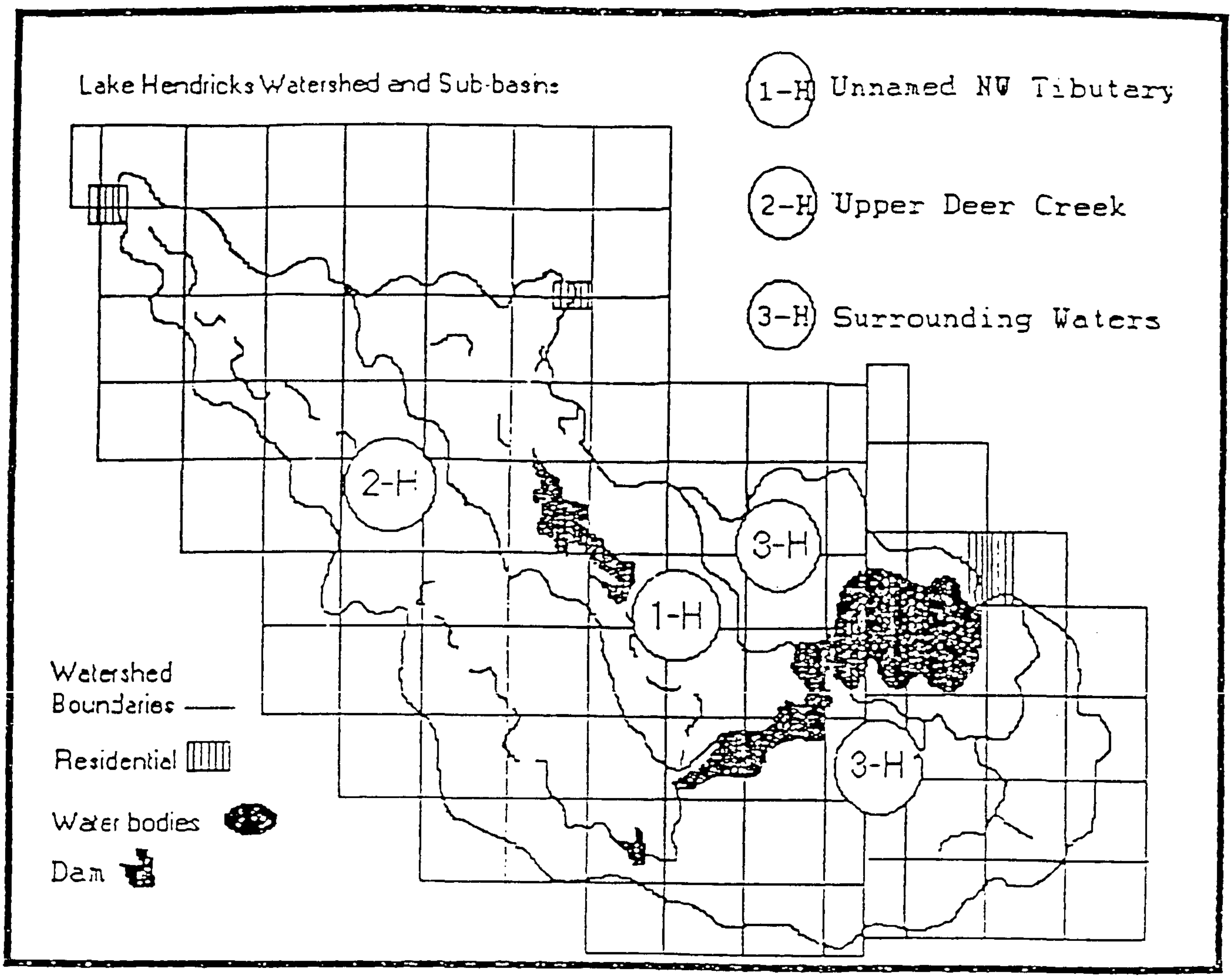
Loadings were also estimated for sub-basins within the watershed (Figure 15.) The sub-basins analyzed were as follows:

1) Sub-basin 1-H: Area drained by un-named northwest tributary
2) Sub-basin 2-H: Area drained by Deer Creek
3) Sub-basin 3-H: Area drained by Minnesota County Ditch 11

Analysis of the Sub-basins provided estimated loading results as follows:

Sub-basin Name	Sediment	Nitrogen	Phosphorus
1-H (N. W. trib.)	1,002,000 kg/yr	6,011 kg/yr	503 kg/yr
2-H (Deer Creek)	1,991,000 kg/yr	11,898 kg/yr	989 kg/yr
3-H (MN Co. Ditch)	2,173,000 kg/yr	13,100 kg/yr	1,092 kg/yr
Total	5,166,000 kg/yr	31,009 kg/yr	2,584 kg/yr

Figure 15.



Lake Hendricks Watershed and Sub-basins
1-H Unnamed NW Tibutary
2-H Upper Deer Creek
3-H Surrounding Waters
2-H
3-H
1-H
3-H
Watershed Boundaries
Residential
Water bodies
Dam

From the above loading estimates, it can be seen that the sub-basins drained by Deer Creek and Minnesota County Ditch #11 carry the greatest load of sediment and nutrients. Since the construction of the soil retention dam on Deer Creek a significant reduction in loads has occurred. The trapping efficiency of this structure is believed to be greater than 85%. It is recommended that best management conservation practices such as conservation tillage, grassed waterways, and filter strips be implemented where needed in the watershed.

Shoreline Erosion Survey

A survey of the Lake Hendricks shoreline was conducted on September 27, 1990. The shoreline around the entire lake was surveyed by pontoon with the help of a number of people familiar with the lake. Areas of erosion were recorded on videotape. In addition, the areas of erosion were documented 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 minor, minor/moderate, moderate, moderate/severe, and severe.

The results of the shoreline erosion survey are as follows:

Erosion Category	Length of Erosion
Minor	1,475 ft.
Minor/Moderate	520 ft.
Moderate	1,195 ft.
Moderate/Severe	850 ft.
----------------	-----------------
Total Eroding Shoreline:	4,040 ft.

The overall shoreline of Lake Hendricks was found to be in good condition, as no areas of severe erosion were observed. However, a total of 2,045 feet of shoreline were found to be Moderate and Moderate/Severe in erosion (Figure 16, Lake Hendricks Shoreline Erosion). Erosion around Lake Hendricks appears to be caused by a combination of high water levels and livestock grazing. The areas of erosion in these two categories should be corrected as soon as possible, as they represent significant direct loadings of sediment to Lake Hendricks.

Septic System Survey

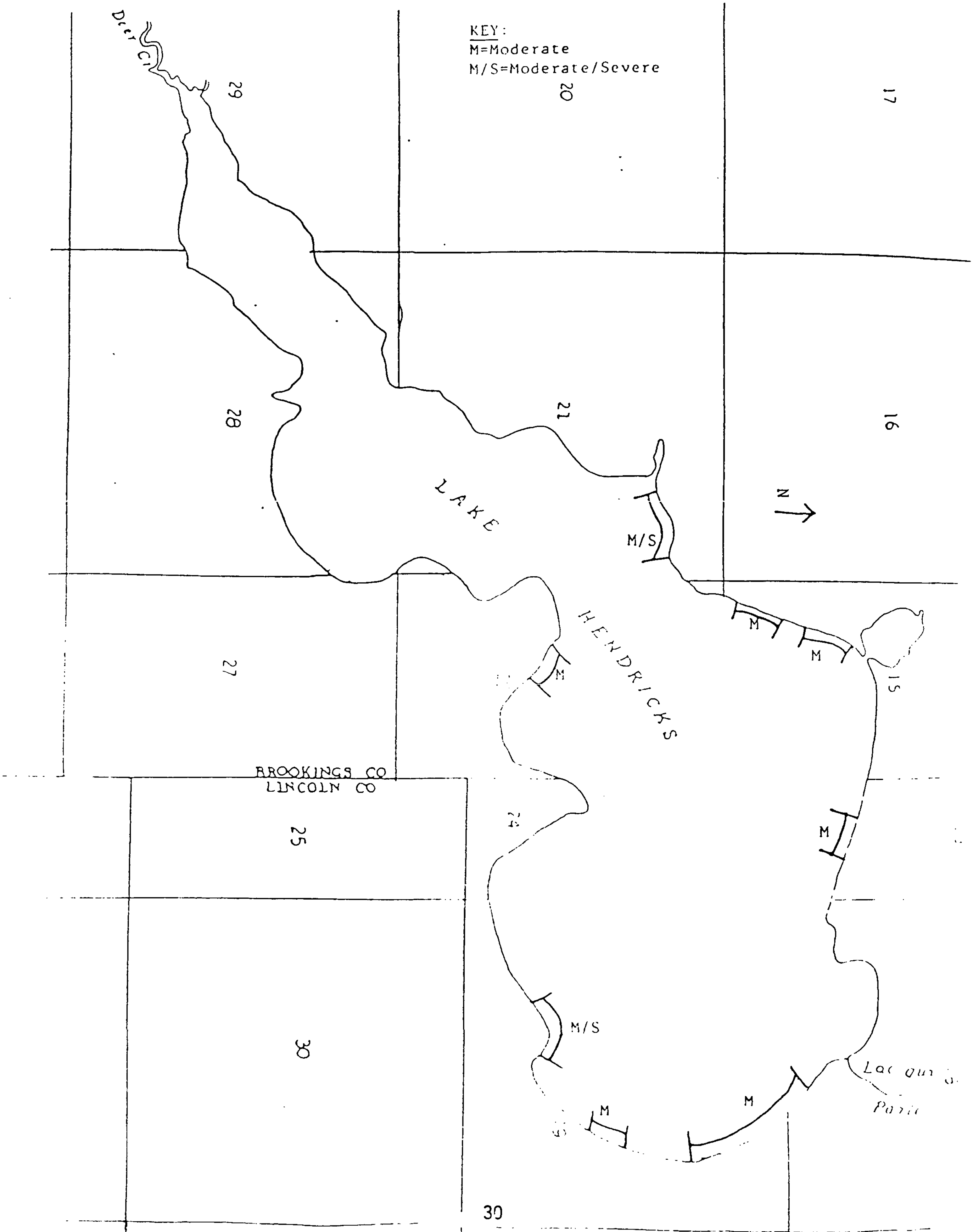
A survey of septic wastewater disposal systems was conducted at Lake Hendricks on June 1, 1991. Members of the Lake Hendricks Association and Phase I Project staff conducted the survey. Residents not found at home that day were contacted later to obtain the necessary information concerning their wastewater disposal systems.

A total of 111 survey reports were obtained for Lake Hendricks. Of the 111 reports, 74 (67%) had documented dates for construction of the septic systems. In checking the construction dates, it was found that 22% of the systems were 15 years old, or older. A total of 66% of the 74 reported dates were ten years old, or older. The increasing age of septic systems can make them more subject to failure.

It was found that 68% of the septic systems had the distance from the drainfield to the lake documented. Eight indicated a distance of less than 100 feet from the drainfield to the lake. This would indicate that approximately 11% of the systems are out of compliance with South Dakota regulations for septic system drainfields. The minimum distance required between a drainfield and a lake, under current South Dakota state rules, is 100 feet.

Figure 16.

Lake Hendricks Shoreline Erosion



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 Lake Hendricks is in a hypereutrophic condition, measures should be taken to eliminate these nonpoint sources of contamination to the lake.

BASELINE LIMNOLOGICAL DATA

Baseline Water Quality Data

Table 7 is a composite of water quality monitoring results for Lake Hendricks over the past twenty-five years. Intervals between samples and laboratory procedures were not always consistent. Interpretations can only be general due to these inconsistencies.

Figure 17, is a graph of chloride concentrations using available data. Chloride was sampled and can be a good indicator of trends in man-made pollution. Metabolic utilization does not cause significant variation in the spatial and seasonal distribution of chlorides within a lake. It has been shown that pollution sources can modify natural concentrations of chlorides greatly (Wetzel, 1975). Lake Hendricks concentrations are variable, but tend toward higher concentrations. This may be an indication of external pollution sources such as watershed runoff and failing septic systems.

Ortho phosphorus concentrations, as well as total phosphorus concentrations, can be significantly affected by the amount of runoff entering from the watershed at the time of sampling. This may account for the variable concentrations shown in Figure 18. Concentrations of ortho phosphorus show a gradual increase over the years. This is another indication of external sources of pollution to Lake Hendricks.

Table 7.
Water Quality Data for Lake Hendricks
(All chemical parameters in mg/L unless otherwise stated)

Date	pH	(M) SD	DO	Na	K	Mg	Ca	SO4	Cl	REF.
7/65	8.5		7.2	11	16	26	32	325	4	A
12/65			8.6	5	13	19	42	142	4	A
1970			7.6	6	12	55	99	161	5	B
1971			8.9	30	11	33	221	165	12	B
1972			7.7	10	12	45	142	156	6	B
9/76		0.5	11.3	13	18	56	91	261	14	C
2/77	8.3		8.6	17	21	76	111	378	16	C
6/79	8.4	1.0	5.7					181	6.7	D
8/81	7.8		9.5					306	13	E
7/84	7.6							74	9	E
7/89	8.4	0.3								F
8/89	8.3	0.4							12	F

Table 7 (cont).
Water Quality Data on Lake Hendricks

Date	Tot Alk.	Umhos Cond.	TDS	Tot P	Ortho P	NO2-N NO3-N	NH3-N	(C) Temp.	REF
7/65	147	520			.24		.83	26	A
12/65	206	850			.80	.70	.35		A
1970	163				.13	.22	.18		B
1971	171				.21	.05	.03		B
1972	186				.18	.13	.05		B
9/76	260			.33	.25	.30	.21	17	C
2/77	245	1080	971	.36	.26	.85	1.53	4	C
6/79	160	645	568	.13	.08	.10	.08	24.7	D
8/81	302	777	533	.47	.28	.28	1.06	8	E
7/84			417	.38	.28	.50	.29	3	E
7/89	158	750	724	.25	.11	.10	.12	22	F
8/89	180			.25		.13			F

A. Schmidt, 1967.
B. Haertel, 1972.
C. East Dakota Conservancy Sub-District, 1976. (Unpublished).
D. DWNR, 85. Lake Hendricks Water Quality Study Area Report.
E. Hieskary, S.A. & Wilson, B.C. 1990.
F. Stewart, 1989. (Unpublished).

Lake Hendricks Chlorides

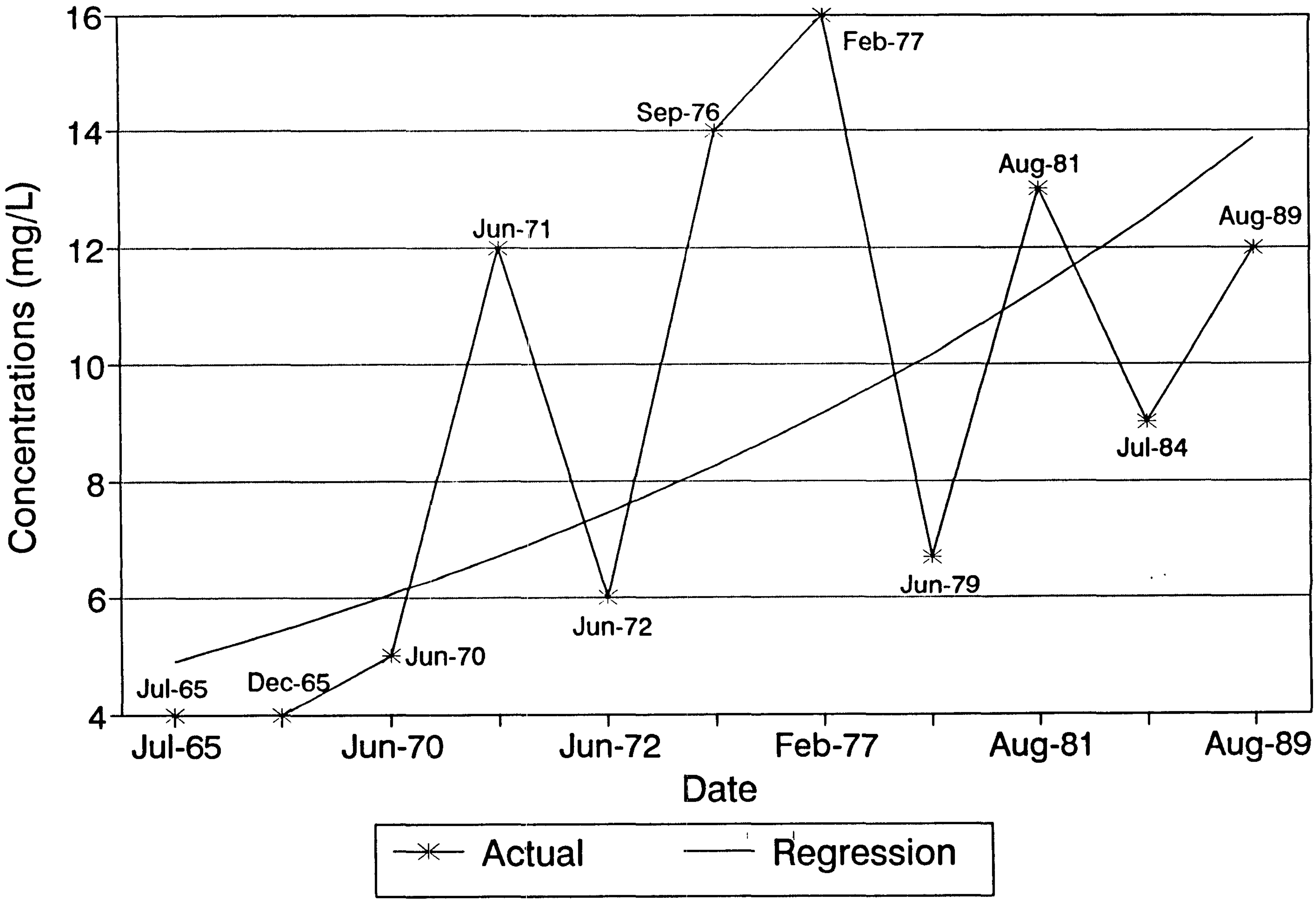


Figure 17.

Lake Hendricks Ortho Phosphorus

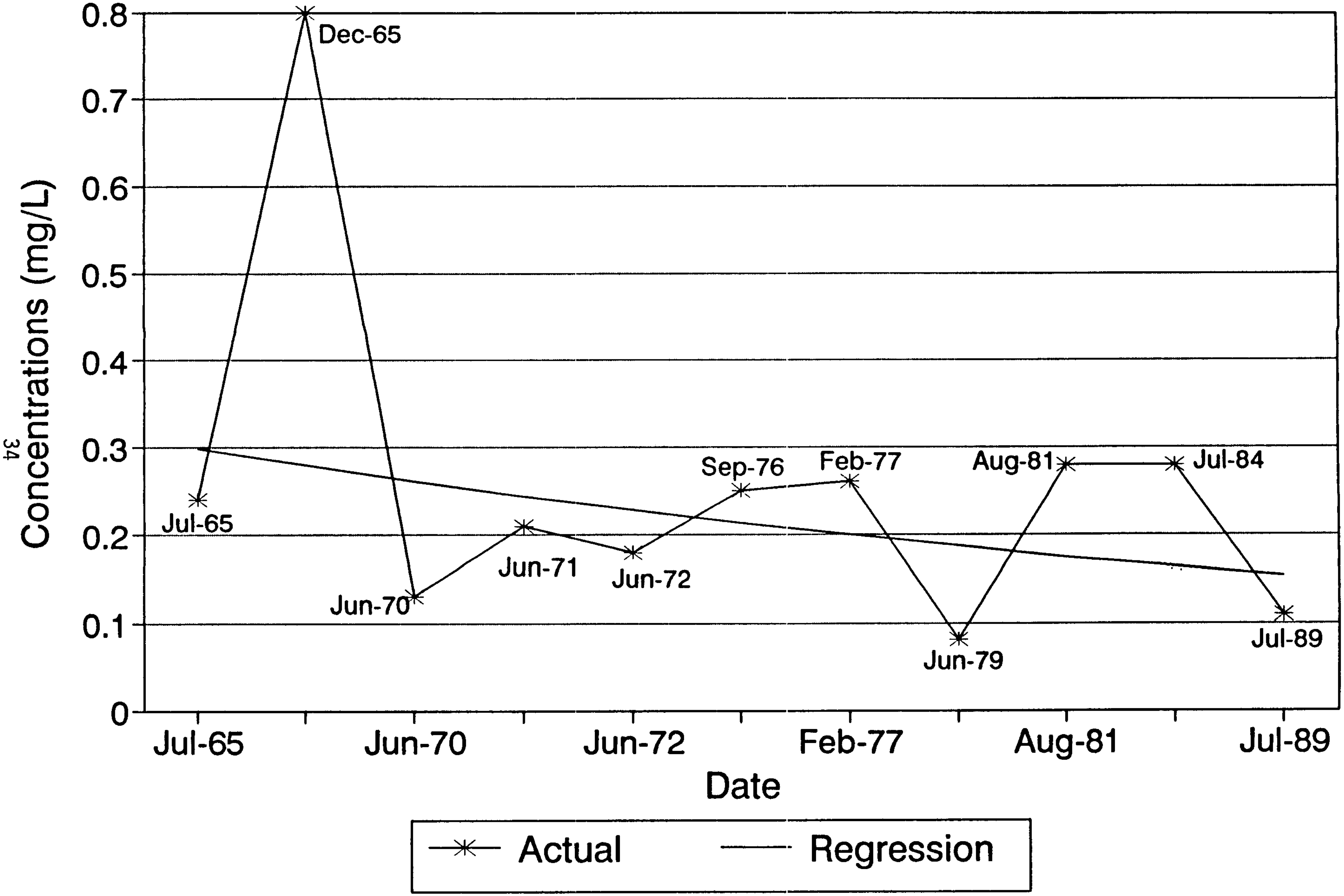


Figure 18.

CURRENT IN-LAKE DATA

In-lake samples were collected from Lake Hendricks at three sites (Figure 19, Lake Hendricks Monitoring Sites).

Site HL-1 was located in the middle of the northeast end of the lake, approximately 1/4 mile southwest of the outlet. The average depth at this site over the sampling period was 8.8 feet.
Lat 44 deg, 27 min, 45 sec N   Long 96 deg, 26 min, and 52 sec W

Site HL-2 was located in the middle of the lake, approximately 1/2 mile north of the inlet from Minnesota County Ditch 11. The average depth at Site HL-2 was 9.8 feet.
Lat 44 deg, 29 min, 41 sec N   Long 96 deg, 27 min, 48 sec W

Site HL-3 was located in the middle of the lake at the southwest end, about 1/2 mile northeast of the Deer Creek inlet. The average depth at Site HL-3 over the sampling period was 9.2 feet.
Lat 44 deg, 28 min, 56 sec N   Long 96 deg, 28 min, 33 sec W

Summaries of the results from the in-lake monitoring program are included in Table 8 (Sites HL-1 and HL-2) and Table 9 (Site HL-3). Generally, the concentrations of the in-lake parameters tested were within the limits of the South Dakota water quality standards. It should be noted, however, that the state standards do not include parameters such as total phosphorus and total nitrogen. These parameters need to be considered when assessing the water quality condition of Lake Hendricks.

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 Hendricks. Summaries and graphs of other Lake Hendricks in-lake data can be found in APPENDIX A, LAKE HENDRICKS IN-LAKE WATER QUALITY DATA.

Trophic Status Index

Carlson (1977) proposed a Trophic State Index (TSI) 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. The state of South Dakota considers a trophic index of greater than 65 to be a hypereutrophic condition.

TSI's 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. Upon completion of the analyses, chlorophyll TSI results and concentrations will be available from the South Dakota Department of Environment and Natural Resources.

The mean Secchi disk TSI from all three in-lake monitoring sites is 66. The mean total phosphorus TSI from all three sites is 74. Both of these values are near the top of Carlson's scale, which would place Lake Hendricks in a hypereutrophic classification.

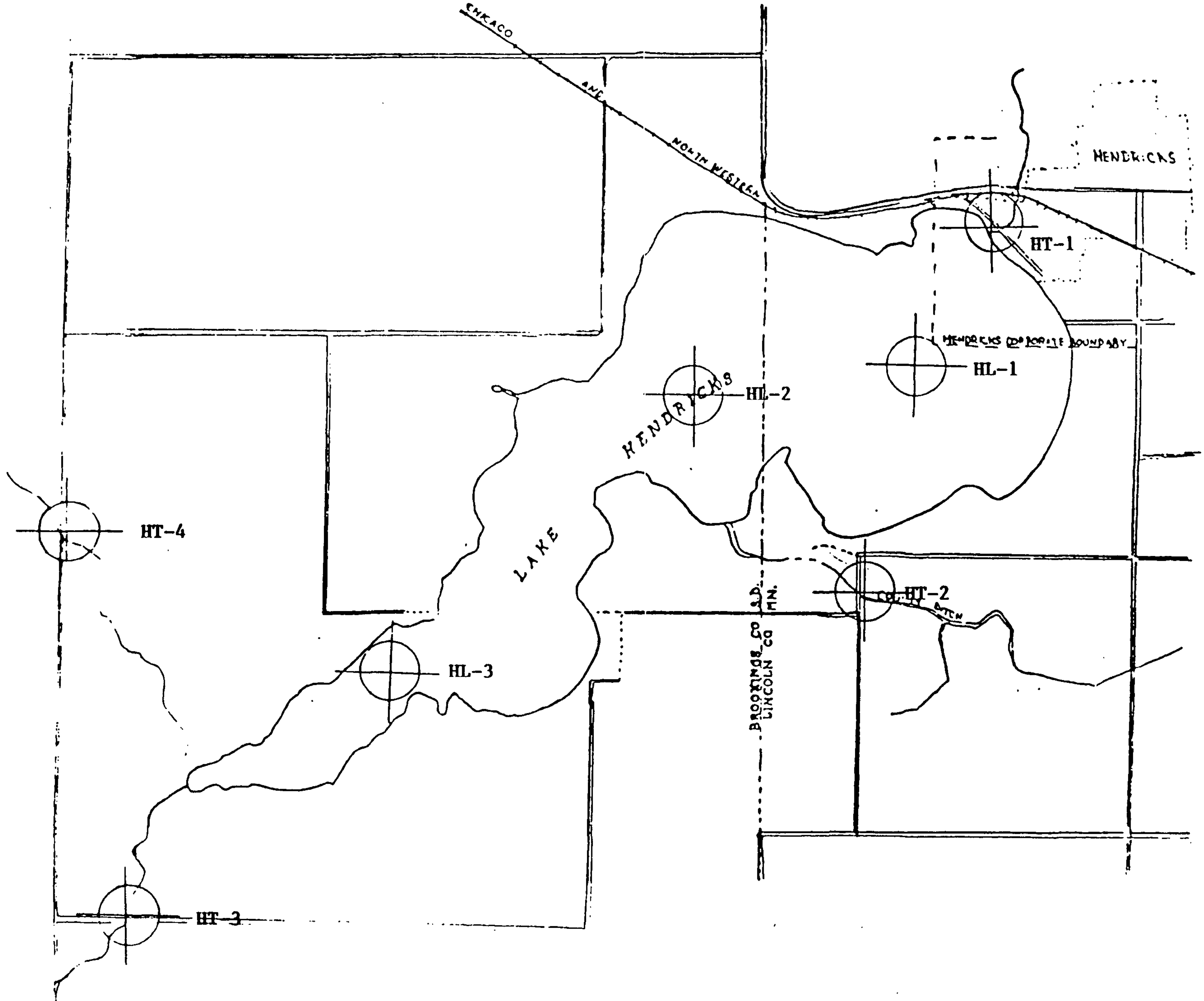


FIGURE 19. LAKE HENDRICKS MONITORING SITES

SAMPLE DATA FOR LAKE HENDRICKS FOR 1991-1992, SITE HL1

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	TALKAL mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	VOLSOL 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	NITR. PHOS. RATIO
01/22/91	1000	GRAB	9.8	1.0		0.0	2.8	46	8.6		10	7.20	157	698	696	2	2	0	0.72	0.0010	0.6	2.58	3.18	0.173	78	0.166	18.38
02/13/91	915	GRAB	10.0	4.0		-2.0	2.5	47	7.8		2	7.60	152	678	670	6	4	2	0.67	0.0031	0.4	2.23	2.63	0.142	76	0.139	18.52
04/18/91	1345	GRAB	8.0	6.0		14.0	0.6	67	12.2	12.2	2	8.26	109	555	529	26	24	2	0.02	0.0005	0.1	1.27	1.37	0.122	73	0.047	11.23
04/22/91	1215	GRAB	9.0	10.0	10.0	17.0	0.5	70	11.2	11.2	2	8.48	111	567	553	14	4	10	0.02	0.0011	0.1	1.24	1.34	0.119	73	0.034	11.26
05/30/91	930	GRAB	8.5	22.0	22.0	25.0	1.1	59	8.2	8.2	6	8.12	131	668	638	28	26	2	0.25	0.0143	0.3	1.16	1.46	0.102	71	0.108	14.31
06/10/91	1000	GRAB	9.5	22.0	21.8	30.0	0.8	63	7.2	6.2	30	8.14	136	618	612	6	4	2	0.37	0.0221	0.7	1.54	2.24	0.119	73	0.102	18.82
06/26/91	1100	GRAB	8.0	23.5	23.0	29.0	0.5	70	8.4	8.0	140	8.23	147	633	585	48	4	44	0.32	0.0256	0.8	1.54	2.34	0.254	84	0.136	9.21
07/09/91	930	GRAB	10.0	22.5	22.3	22.0	0.5	70	7.9	7.7	10	8.48	151	618	592	24	18	6	0.10	0.0121	0.8	1.73	2.53	0.144	76	0.217	17.57
07/22/91	1030	GRAB	9.0	26.0	26.0	27.0	0.6	67	8.0	7.8	2	8.67	152	564	550	14	6	8	0.04	0.0089	0.6	1.14	1.74	0.142	76	0.112	12.25
08/05/91	930	GRAB	9.0	21.0	21.0	20.0	0.4	73	6.5	6.4	10	8.43	160	569	535	34	18	18	0.02	0.0021	0.5	0.96	1.46	0.183	79	0.170	7.98
08/19/91	930	GRAB	8.0	22.3	2.3	19.0	0.3	77	7.7	7.7	10	8.65	162	545	509	36	4	32	0.10	0.0173	0.6	1.03	1.63	0.170	78	0.098	9.59
09/23/91	930	GRAB	7.5	11.5	11.5	15.5	0.5	69	9.4	8.9	10	8.65	127	515	473	42	20	22	0.14	0.0120	0.1	1.21	1.31	0.125	74	0.064	10.48
10/15/91	1000	GRAB	7.5	8.0	8.0	9.0	0.5	70	10.4	10.2	10	8.55	134	525	481	44	16	28	0.02	0.0011	0.1	1.09	1.19	0.115	73	0.136	10.35
12/16/91	930	GRAB	8.0	3.0		0.0	0.5	69	14.0	11.2	2	8.47	161	608	607	1	0	1	0.02	0.0008	0.1	1.10	1.20	0.043	58	0.030	27.91
01/22/92	900	GRAB	8.0	1.0		10.0			12.4	12.2	2	8.21	164	652	644	6	11	6	0.02	0.0200	0.1	1.37	1.47	0.063	64	0.155	23.33
HL1 - 14 SAMPLES		MIN	7.5	1.0	2.3	0.0	0.3	46	6.6	6.2	2	7.20	109	515	473	1	0	1	0.02	0.0005	0.1	0.96	1.19	0.043	58	0.034	7.98
		MAX	10.0	26.0	26.0	30.0	2.6	70	14.0	12.2	140	8.67	162	698	696	48	26	22	0.72	0.0256	0.8	2.58	3.18	0.254	84	0.217	27.91
		MEAN	8.8	14.5	16.8	18.1	0.9	66	9.1	8.8	16	8.28	142	597	574	23	11	13	0.20	0.0087	0.4	1.42	1.83	0.140	74	0.114	14.13
		MEDIAN	9.0	16.3	21.4	18.0	0.5	70	8.3	8.0	10	8.60	149	589	549	25	5	20	0.10	0.0060	0.5	1.23	1.55	0.134	74	0.124	11.76

SAMPLE DATA FOR LAKE HENDRICKS FOR 1991-1992, SITE HL2

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	TALKAL mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	VOLSOL 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	NITR. PHOS. RATIO
01/22/91	1030	GRAB	10.0	1.0		0.0	3.0	44	7.1		10	7.60	159	688	685	3	1	2	0.77	0.0027	0.6	2.55	3.15	0.156	77	0.160	20.19
02/13/91	1000	GRAB	10.0	4.0		0.0	3.0	44	4.0		2	7.70	150	649	637	12	6	6	0.76	0.0044	0.5	2.30	2.80	0.159	77	0.106	17.61
04/16/91	1415	GRAB	9.5	6.0		14.0	0.7	65	12.2	12.2	2	8.31	106	549	521	28	12	16	0.02	0.0005	0.1	1.02	1.12	0.068	65	0.056	18.47
04/22/91	1315	GRAB	9.0	9.0	9.0	17.0	0.7	65	11.8	12.0	2	8.50	111	548	530	16	14	4	0.02	0.0010	0.1	1.20	1.30	0.078	67	0.078	16.67
05/30/91	1000	GRAB	9.5	22.0	22.0	25.0	1.0	60	8.2	7.2	6	8.02	130	671	655	16	14	2	0.26	0.0119	0.1	1.20	1.30	0.100	71	0.137	13.00
06/10/91	1015	GRAB	11.0	22.5	22.0	22.0	0.5	70	8.4	8.2	10	8.22	146	595	555	40	6	34	0.36	0.0264	0.7	1.55	2.25	0.129	74	0.095	17.44
06/26/91	1015	GRAB	10.0	23.0	22.5	28.0	0.5	70	8.4	8.2	10	8.22	146	595	555	40	12	28	0.35	0.0265	0.9	1.60	2.50	0.173	76	0.112	14.45
07/09/91	1000	GRAB	10.0	22.5	22.5	22.0	0.5	70	8.7	8.2	10	8.47	149	614	598	16	14	2	0.07	0.0066	1.0	1.14	2.14	0.129	74	0.125	16.59
07/22/91	1000	GRAB	11.0	27.0	26.5	26.0	0.3	77	9.2	8.2	2	8.75	152	592	574	18	4	14	0.02	0.0054	0.5	2.95	3.45	0.247	84	0.125	13.97
08/05/91	1000	GRAB	9.0	21.0	21.0	20.0	0.4	73	6.3	6.1	10	8.46	159	576	542	34	10	24	0.02	0.0022	0.5	0.87	1.37	0.180	80	0.166	7.21
08/19/91	1000	GRAB	9.0	22.3	21.8	19.0	0.4	73	7.2	7.2	10	8.57	162	626	592	36	2	34	0.16	0.0238	0.6	0.98	1.58	0.159	77	0.092	8.84
09/23/91	1015	GRAB	8.5	11.0	11.0	15.5	0.5	71	10.2	9.8	20	8.56	133	513	473	40	24	16	0.17	0.0116	0.1	1.14	1.24	0.152	77	0.095	8.16
10/15/91	1030	GRAB	9.0	8.0	8.0	9.0	0.5	70	10.4	10.2	10	8.57	134	521	481	40	12	28	0.02	0.0011	0.1	1.04	1.14	0.112	72	0.105	10.18
12/16/91	1100	GRAB	10.0	3.0		0.0	0.5	69	13.6	11.9	2	8.51	159	590	589	1	0	1	0.02	0.0007	0.1	1.35	1.45	0.066	65	0.066	21.97
01/22/92	1030	GRAB	8.6	2		9.0			13.8	13.6	2	8.28	164	640	634	6	5	1	0.02	0.0004	0.1	1.26	1.36	0.043	58	0.112	31.63
HL2 - 14 SAMPLES		MIN.	9.0	1.0	6.0	0.0	0.3	44	4.0	7.2	2	7.60	106	513	473	1	0	1	0.02	0.0005	0.1	0.87	1.12	0.066	58	0.058	7.17
		MAX.	11.0	27.0	26.5	28.0	3.0	73	13.6	12.2	20	8.75	162	688	685	40	24	34	0.77	0.0265	1.0	2.95	3.45	0.247	84	0.186	52.27
		MEAN	9.8	14.5	18.6	15.5	0.9	66	9.1	9.0	8	8.32	143	595	571	24	9	15	0.22	0.0091	0.4	1.49	1.91	0.137	73	0.112	14.56
		MEDIAN	9.8	16.5	21.8	18.0	0.5	70	8.6	8.2	10	8.47	148	594	565	23	11	15	0.12	0.0049	0.5	1.20	1.52	0.141	74	0.107	12.63

Table 8. Lake Hendricks In-Lake Data, Sites HL1 and HL2

SAMPLE DATA FOR LAKE HENDRICKS FOR 1991-1992, SITE HL3

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	TALKAL mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	VOLSOL 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	NITR. PHOS. RATIO
01/22/91	1100	GRAB	9.8	1.0		2.0	2.8	45	6.6		30	7.40	163	704	702	2	1	1	0.62	0.0014	0.7	2.59	3.29	0.163	78	0.153	20.18
02/13/91	1030	GRAB	10.0	7.0		2.0	2.4	47	5.4		2	7.80	111	472	462	10	5	5	0.52	0.0048	0.3	1.59	1.89	0.102	71	0.088	18.53
04/16/91	1440	GRAB	8.5	6.0	6.0	14.0	0.7	65	12.2	12.8	24	8.37	112	549	529	20	12	8	0.02	0.0006	0.1	1.18	1.28	0.054	62	0.041	23.70
04/22/91	1350	GRAB	8.5	9.5	9.0	17.0	0.8	63	11.5	11.8	2	8.49	114	553	539	14	8	6	0.02	0.0010	0.1	1.50	1.60	0.081	68	0.037	19.75
05/30/91	1015	GRAB	9.0	22.3	21.6	25.0	0.8	63	7.8	7.2	12	7.94	134	681	669	12	10	2	0.28	0.0110	0.3	1.24	1.54	0.125	74	0.095	12.32
06/10/91	1030	GRAB	10.0	22.5	22.0	22.0	0.5	70	6.8	6.6	1300	7.90	149	642	630	12	10	2	0.34	0.0124	0.7	1.26	1.96	0.142	76	0.092	13.80
06/26/91	930	GRAB	9.0	24.0	23.0	29.0	0.5	70	7.6	7.8	40	8.20	152	589	551	38	6	32	0.33	0.0256	0.9	1.51	2.41	0.186	80	0.186	12.96
07/09/91	1030	GRAB	9.5	22.3	23.0	22.0	0.4	73	8.4	7.9	10	8.48	158	624	608	18	12	6	0.04	0.0048	1.0	1.66	2.66	0.159	77	0.105	16.73
07/22/91	930	GRAB	10.0	27.0	26.5	25.0	0.3	77	7.6	7.3	20	8.56	160	593	567	26	6	20	0.02	0.0040	0.6	1.61	2.21	0.295	86	0.112	7.49
08/05/91	1030	GRAB	9.0	21.0	21.5	20.0	0.4	73	8.5	8.2	10	8.40	164	583	557	26	2	24	0.05	0.0048	0.5	1.13	1.63	0.217	82	0.149	7.51
08/19/91	1030	GRAB	9.0	22.3	22.3	20.0	0.4	73	7.2	7.0	20	8.49	166	638	600	38	2	36	0.24	0.0304	0.7	1.24	1.94	0.180	79	0.092	10.78
09/23/91	930	GRAB	9.0	11.0	11.0	15.0	0.4	73	9.4	9.2	10	8.69	140	522	478	44	20	24	0.22	0.0198	0.1	1.33	1.43	0.146	76	0.054	9.79
10/15/91	1100	GRAB	9.0	8.0	8.0	9.0	0.5	70	10.2	10.2	10	8.51	136	537	519	18	14	4	0.02	0.0010	0.1	0.95	1.05	0.129	74	0.054	8.14
12/16/91	1015	GRAB	8.0	3.0		0.0	0.5	69	13.6	11.2	2	8.49	278	604	602	2	0	2	0.02	0.0006	0.1	0.88	0.98	0.050	61	0.163	19.60
01/22/92	1000	GRAB	8.0	1.0	2.0	10.0			13.2	12.2	2	8.52	164	659	655	4	3	1	0.02	0.0006	0.1	1.11	1.21	0.056	62	0.102	21.61
HL3 - 14 SAMPLES		MIN.	8.0	1.0	6.0	0.0	0.3	45	5.4	6.6	2	7.40	111	472	462	2	0	1	0.02	0.0006	0.1	0.88	0.98	0.050	61	0.037	7.49
		MAX.	10.0	27.0	26.5	29.0	2.8	77	13.6	12.8	1300	8.69	278	704	702	44	20	36	0.62	0.0304	1.0	2.59	3.29	0.295	86	0.186	23.7
		MEAN	9.2	14.8	17.6	15.9	0.8	67	8.8	8.7	107	8.27	153	592	572	20	8	12	0.20	0.0087	0.4	1.40	1.85	0.1449	74	0.102	14.38
		MEDIAN	9.0	16.0	21.8	19.0	0.5	70	8.1	7.9	11	8.43	151	591	582	18	7	6	0.14	0.0048	0.4	1.30	1.76	0.144	75	0.094	13.38

Table 9. Lake Hendricks In-Lake Data, Site HL3

Dissolved Oxygen

The results of the in-lake sampling in Table 8 indicate that the dissolved oxygen concentration fell below the state standard of 5.0 mg/L on one occasion during the sampling period. On February 13, 1991, the dissolved oxygen concentration at the surface at site HL-2 (middle site) was found to be 4.0 mg/L. There was two feet of ice cover at the time the sample was taken. The thickness of the ice and snow cover, may have caused a decrease in light penetration into the water, killing many photosynthetic organisms. Decomposition of the organic material may have resulted in a slight oxygen depletion.

Figure 20 shows the average results for surface oxygen at the three in-lake sites as compared to the average results for the bottom measurements. None of the average results fell below the state standard.

Dissolved oxygen concentrations below 3.5 mg/L may be fatal to certain species of game fish (Cole, 1983). The concentration of 4.0 mg/L at Site HL-2 on February 13, 1991, was above the 3.5 mg/L needed by certain fish. In addition, the concentrations of dissolved oxygen at Sites HL-1 and HL-3 ranged between 7.5 mg/L and 5.4 mg/L respectively. Therefore, fish could migrate to other areas of the lake with higher oxygen levels, negating any adverse impact on the fisheries.

Concentrations of dissolved oxygen were adequate for the beneficial use of warmwater marginal fish life propagation for the sampling period.

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.

The state standards were exceeded on one occasion during the sampling period (Figure 21). On June 10, 1991, a count of 1300 fecal coliform organisms per 100 milliliters (1300/100 mL) was found in the sample from Site HL-3. This result exceeds the state standard for a 24-hour period (200/100 mL), and the state standard for a single sample (400/100 mL). Site HL-3 was located at the southwest end of the lake, approximately 1/2 mile northeast of the Deer Creek inlet. This single exceedence coincides with a runoff event in the watershed. No definitive interpretation can be made based on a single exceedence. High levels of fecal coliform bacteria were found in samples from each of the tributary sites in early June. Because there was no exceedence at the other in-lake sites, the extent of the fecal coliform contamination is unknown.

Sources of fecal coliform bacteria include human and animal wastes. Discharges from failing septic systems, and runoff from livestock operations, may have caused the high levels of fecal coliform bacteria found in the samples from the tributaries and at in-lake Site HL-3. The possibility of a sampling artifact or human error can not be discounted since only one sample exhibited an exceedence.

An effort should be made to determine sources of the fecal coliform bacteria which were found in Lake Hendricks and its tributaries. However, because the results for fecal coliform bacteria exceeded state standards on only one occasion, it can be assumed that Lake Hendricks is generally safe from a health standpoint for recreational activities such as swimming and skiing.

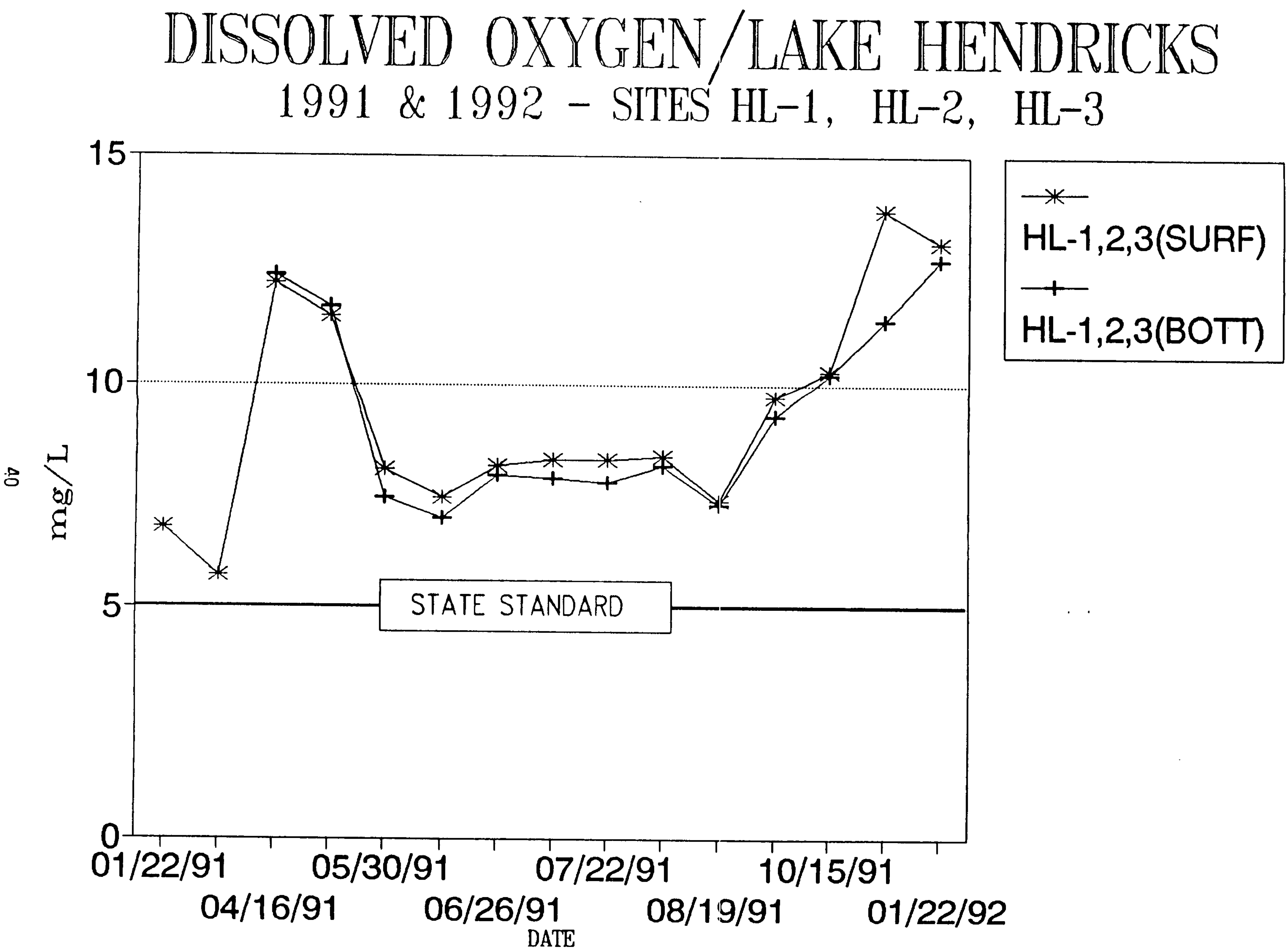

DISSOLVED OXYGEN/LAKE HENDRICKS
1991 & 1992 - SITES HL-1, HL-2, HL-3
mg/L
15
10
5
0
STATE STANDARD
HL-1,2,3(SURF)
HL-1,2,3(BOTT)
01/22/91
04/16/91
05/30/91
06/26/91
07/22/91
08/19/91
10/15/91
01/22/92
DATE

Figure 20.

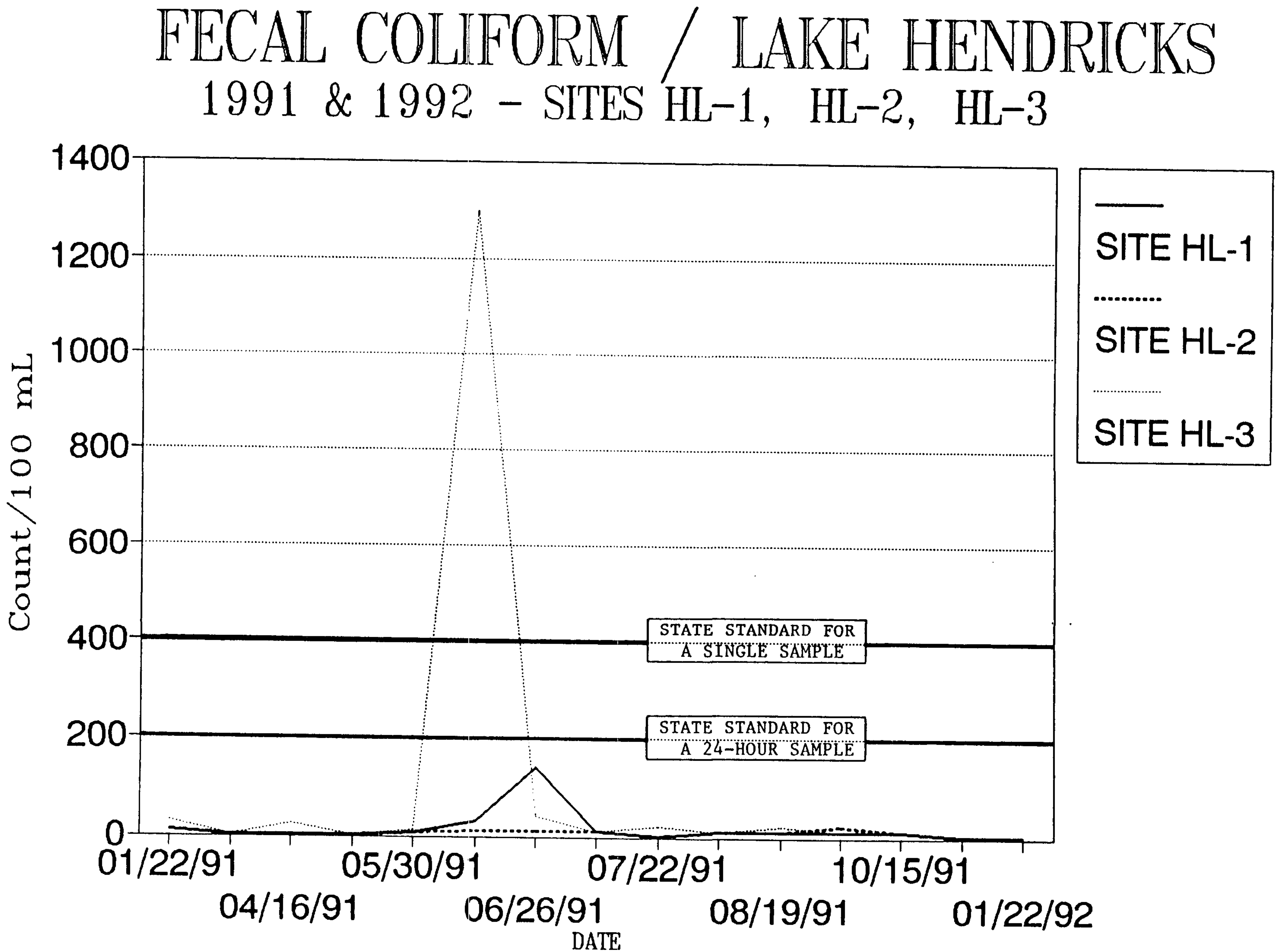

FECAL COLIFORM / LAKE HENDRICKS
1991 & 1992 - SITES HL-1, HL-2, HL-3
Count/100 mL
1400
1200
1000
800
600
400
200
0
STATE STANDARD FOR A SINGLE SAMPLE
STATE STANDARD FOR A 24-HOUR SAMPLE
01/22/91
04/16/91
05/30/91
06/26/91
07/22/91
08/19/91
10/15/91
01/22/92
DATE
SITE HL-1
SITE HL-2
SITE HL-3

Figure 21.

pH

The pH standard for Lake Hendricks is between the range of 6.5 and 9.0 units. All samples were within the acceptable range set by the state standards for water quality (Figure 22). The highest pH reading (8.75 su) occurred at Site HL-2 on July 22, 1991.

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).

Ammonia

Elevated concentrations of ammonia occurred during the period from May 30 to July 9, 1991, and from August 19 to September 23, 1991. However, the highest levels of ammonia resulted from samples collected on January 22 and February 13, 1991. These samples were collected during a period of ice cover on the lake when there was very little flow of water into the lake. Therefore, these high levels of ammonia represent the decomposition of organic matter in the lake. Increases and decreases in ammonia concentrations (Figure 24) coincide with the empirical results for un-ionized ammonia.

Un-ionized Ammonia

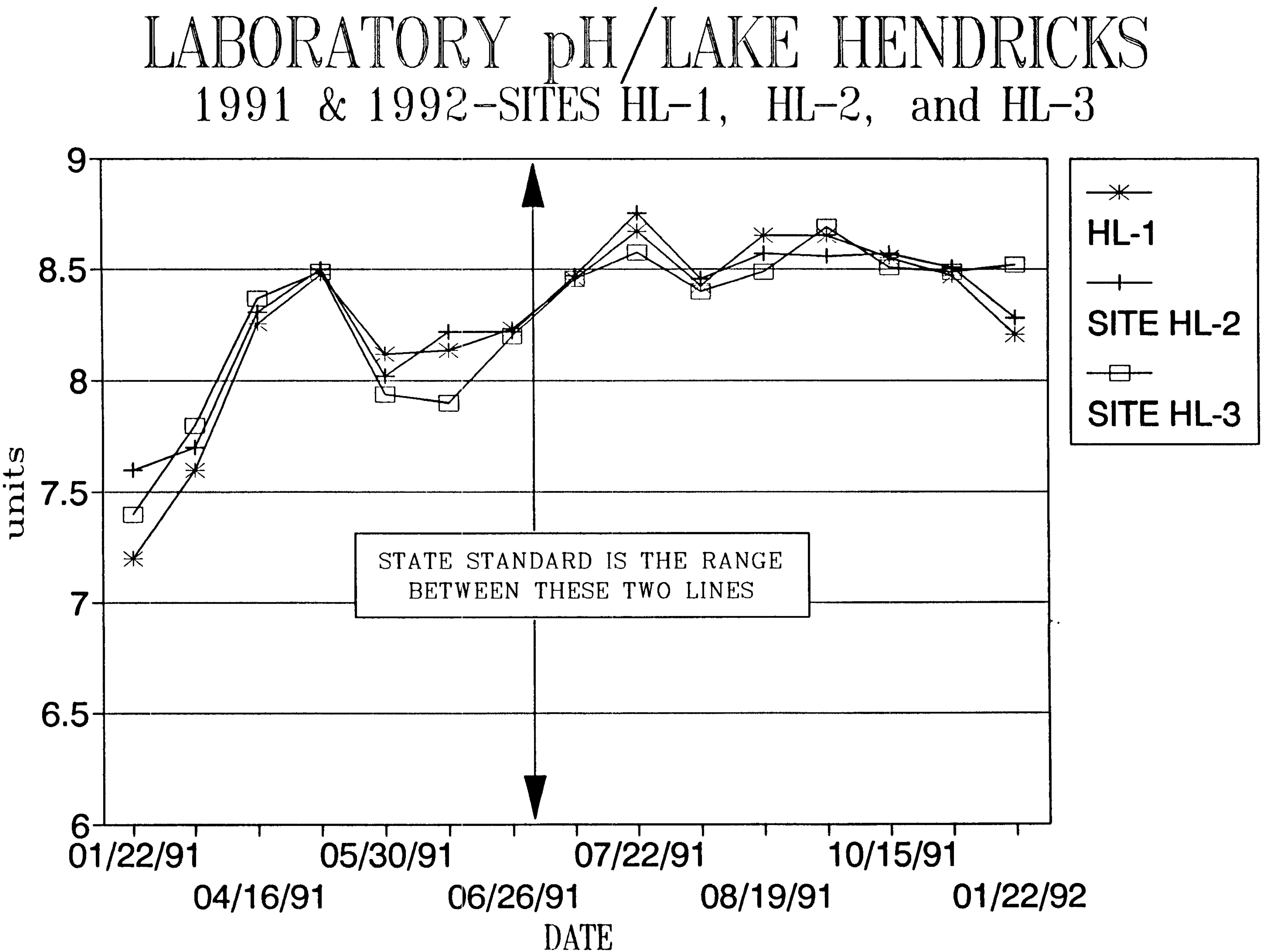
Un-ionized ammonia is the toxic fraction of ammonia. High levels of un-ionized ammonia are toxic to fish and cause fish-kills. The state standards for un-ionized ammonia were not exceeded during the sampling period. Elevated levels of un-ionized ammonia were observed during the sampling period from May 30, 1991 to July 9, 1991, and again during the sampling period from August 19, 1991 to September 23, 1991 (Figure 23). The higher levels of un-ionized ammonia from May to July correspond with higher flows into Lake Hendricks from the tributaries during that period. These increases in concentrations of un-ionized ammonia are due to the increased nutrient loads and organic material entering the lake from runoff events.

Higher levels of un-ionized ammonia during August and September are during a period of low flow from the tributaries into Lake Hendricks. The increased concentrations during these months are most likely due to decomposition of organic matter in the lake.

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

Phosphorus

The State of South Dakota does not include phosphorus in its state water quality standards. However, levels of phosphorus were found in Lake Hendricks that may be leading to impairment of the beneficial uses of the lake (Figure 25, Total Phosphate). For example, the minimum concentration of phosphorus found during the sampling period (0.043 mg/L) was from the sample at Site HL-1 on December 16, 1991. Even at this minimum level, the amount of phosphorus is over two times the 0.02 mg/L level needed for optimum growth of many algae species (Wetzel, 1983).



LABORATORY pH/LAKE HENDRICKS
1991 & 1992-SITES HL-1, HL-2, and HL-3
9
8.5
8
7.5
7
6.5
6
units
STATE STANDARD IS THE RANGE
BETWEEN THESE TWO LINES
HL-1
SITE HL-2
SITE HL-3
01/22/91
04/16/91
05/30/91
06/26/91
07/22/91
08/19/91
10/15/91
01/22/92
DATE

Figure 22.

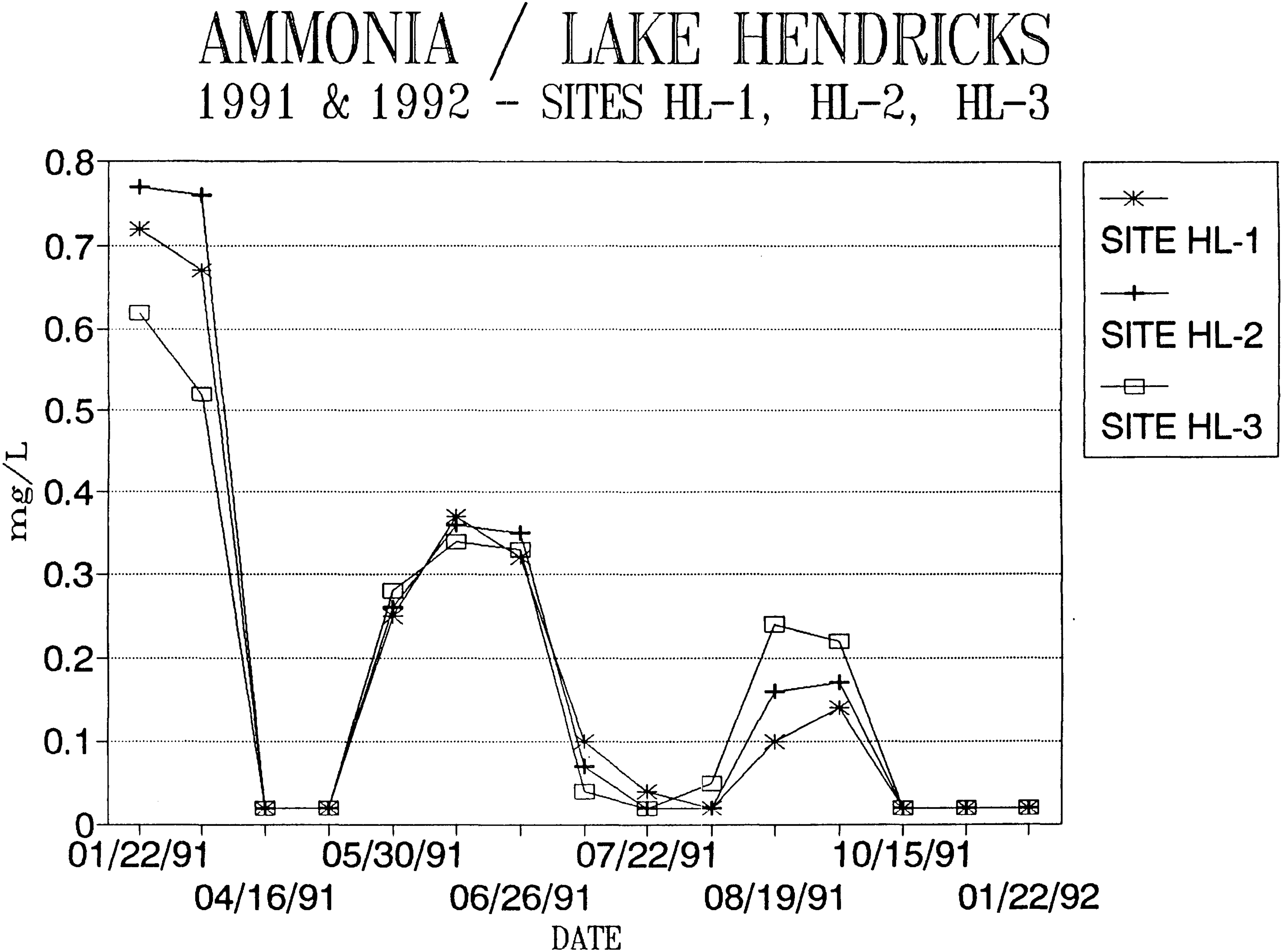

AMMONIA / LAKE HENDRICKS
1991 & 1992 - SITES HL-1, HL-2, HL-3
mg/L
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
01/22/91
04/16/91
05/30/91
06/26/91
07/22/91
08/19/91
10/15/91
01/22/92
DATE
SITE HL-1
SITE HL-2
SITE HL-3

Figure 23

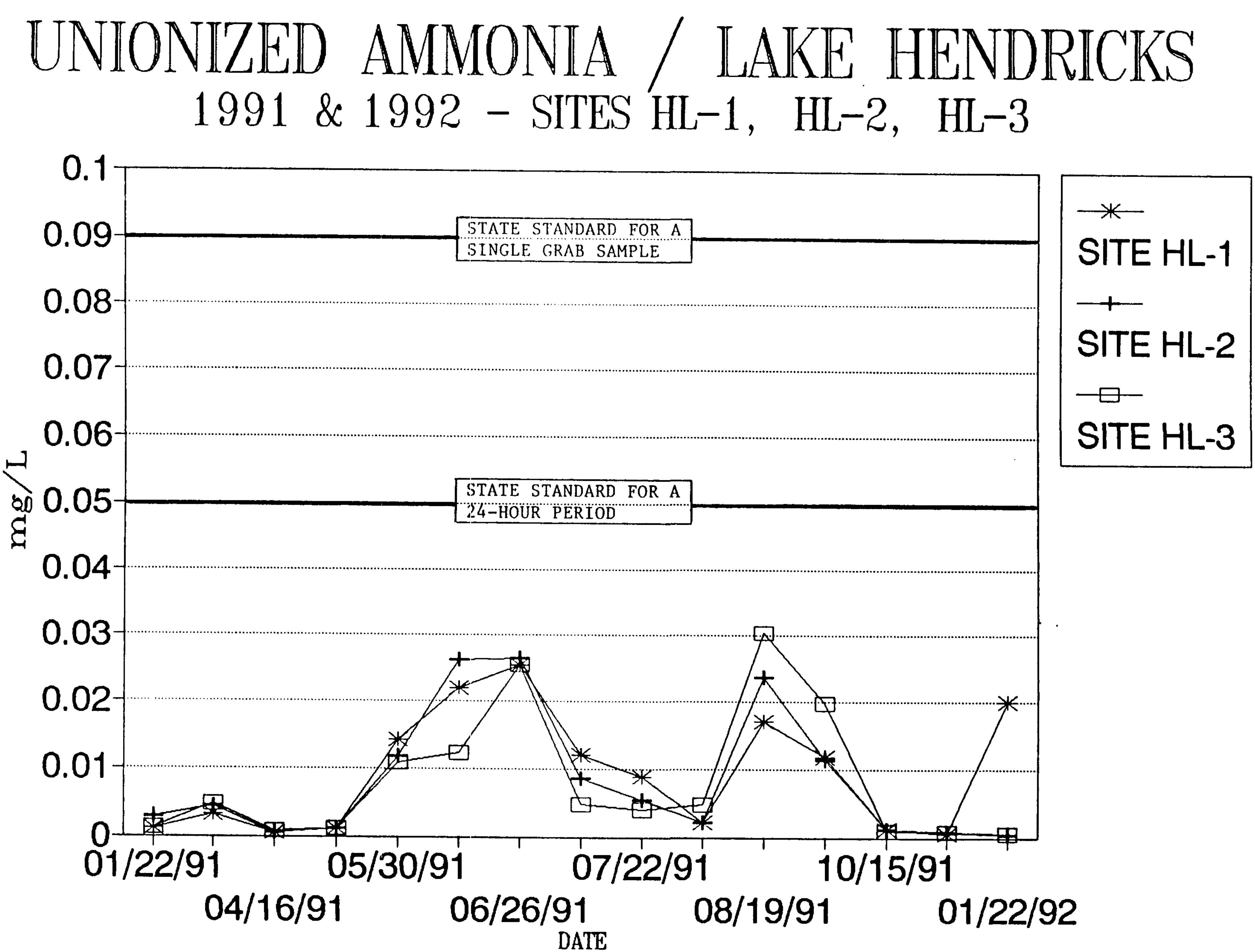

UNIONIZED AMMONIA / LAKE HENDRICKS
1991 & 1992 - SITES HL-1, HL-2, HL-3
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
mg/L
STATE STANDARD FOR A SINGLE GRAB SAMPLE
STATE STANDARD FOR A 24-HOUR PERIOD
SITE HL-1
SITE HL-2
SITE HL-3
01/22/91
04/16/91
05/30/91
06/26/91
07/22/91
08/19/91
10/15/91
01/22/92
DATE

Figure 24

TOTAL PHOSPHATE / LAKE HENDRICKS
1991 & 1992-SITES HL-1, HL-2, and HL-3

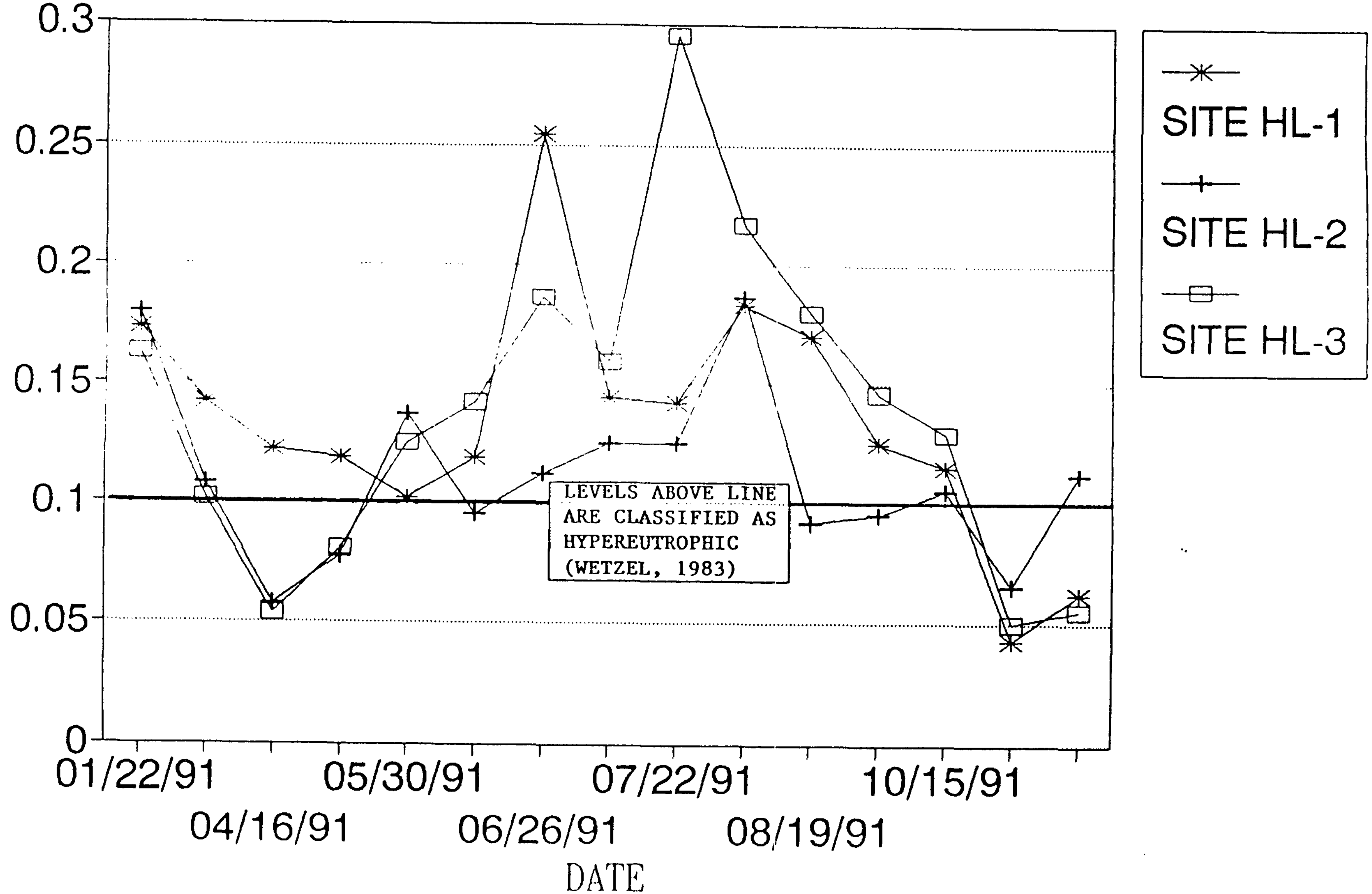


Figure 25.

The maximum concentration of phosphorus (0.295 mg/L) was found in the sample taken at Site HL-3 on July 22, 1991. At this high concentration, the phosphorus level is about fifteen times the level needed by many species of algae for optimum growth.

Total dissolved phosphorus was also analyzed (Figure 26). Total dissolved phosphorus is the form of phosphorus most readily available for algae and plant growth (as compared to the particulate phosphorus fraction). When phosphorus is sorbed to particulate matter it is not available for use by aquatic plants. Seventy-eight percent of the mean total phosphorus was total dissolved phosphorus.

The concentrations of phosphorus in Lake Hendricks would classify it as being in a hypereutrophic condition. Hypereutrophic lakes have an over-abundance of nutrients which can result in nuisance algae blooms, and extensive weed growth. Due to the shallow depth of Lake Hendricks, the water column does not stratify and remain mixed throughout the year with the exception of short periods under the ice. Because of the mixing it is unlikely that anoxic conditions occur at the water/sediment interface. For this reason, internal loading of phosphorus from the sediment is unlikely. Phosphorus can be recyled in the water column by decomposition of aquatic vegetation such as algae. Sources of phosphorus to Lake Hendricks include lawn and crop fertilizers, failing septic systems, feedlot runoff, and decaying aquatic vegetation. Because high levels of phosphorus contribute to nuisance algae and weed growth, efforts should be taken to control phosphorus loads to the lake.

Limiting Nutrient

Phosphorus is believed to be the limiting nutrient to algal growth if the ratio of total nitrogen to total phosphorus is greater than 10:1. The graph of the nitrogen to phosphorus (N:P) ratio (Figure 27) demonstrates that the ratio in Lake Hendricks during the sampling period was generally greater than 10:1. This indicates that phosphorus is the limiting nutrient for algae growth. During late summer the ratio became less than 10:1, indicating nitrogen as the limiting nutrient. This was particularly true for the sampling period from August 5, 1991 to October 15, 1991.

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 phosphorus spike solution arrived near the end of the sampling period, only two spiked samples were analyzed. A total of 115 water samples were taken during 1991 and 1992, along with 12 QA/QC sample sets (Tables 10 and 11).

Large concentrations of dissolved phosphorus were found in the first samples for the blank QA/QC sample sets. To correct the problem the State Health Lab stopped adding acid (preservative) to the bottles. Apparently the liner in the dissolved phosphorus bottle cap was contributing to the dissolved phosphorus concentration. Also the distilled water on certain occasions became contaminated such as the blank sample taken on June 10, 1991.

TOT DISSOLVED PHOSPHORUS/LAKE HENDRICKS
1991 & 1992 - SITES HL-1, HL-2, HL-3

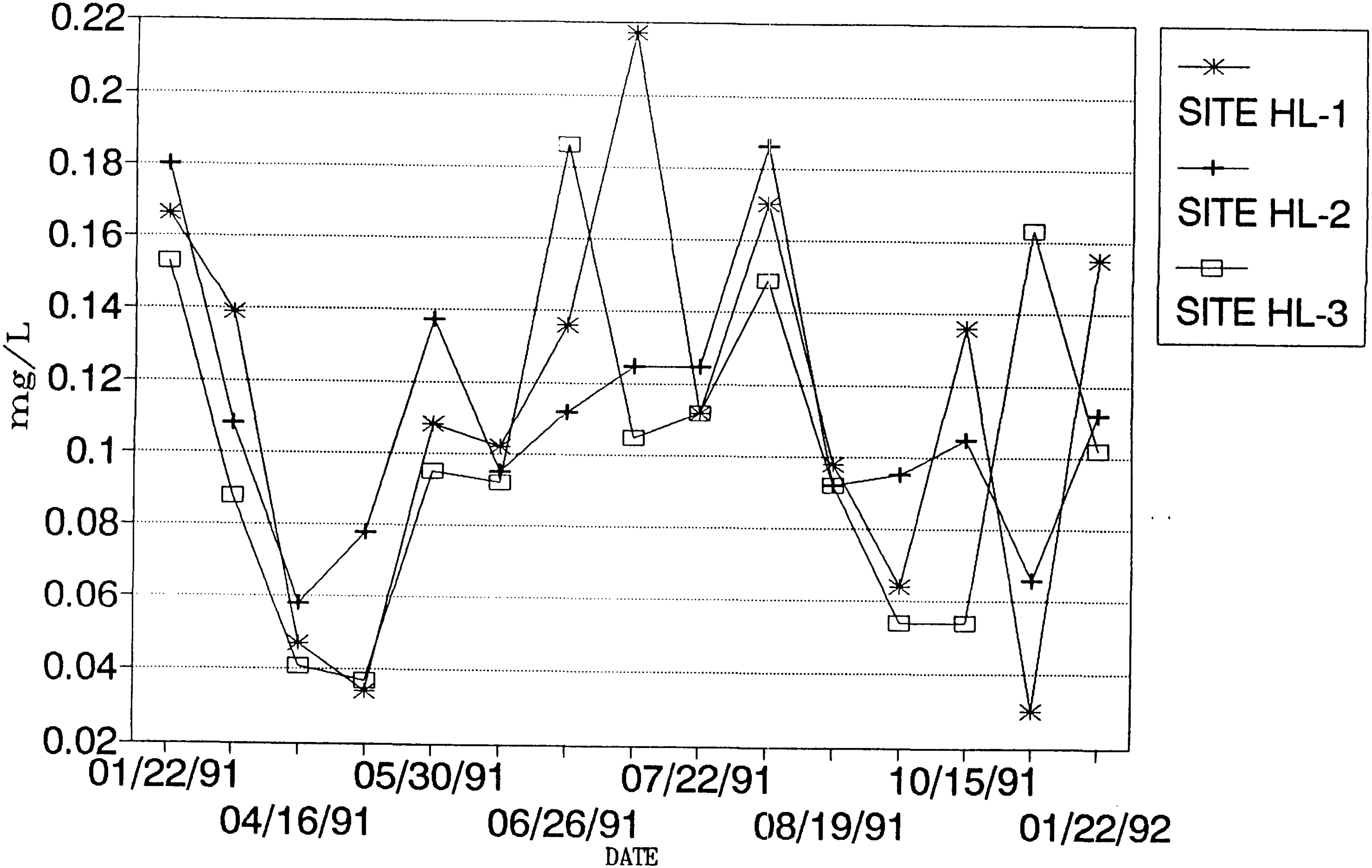


Figure 26

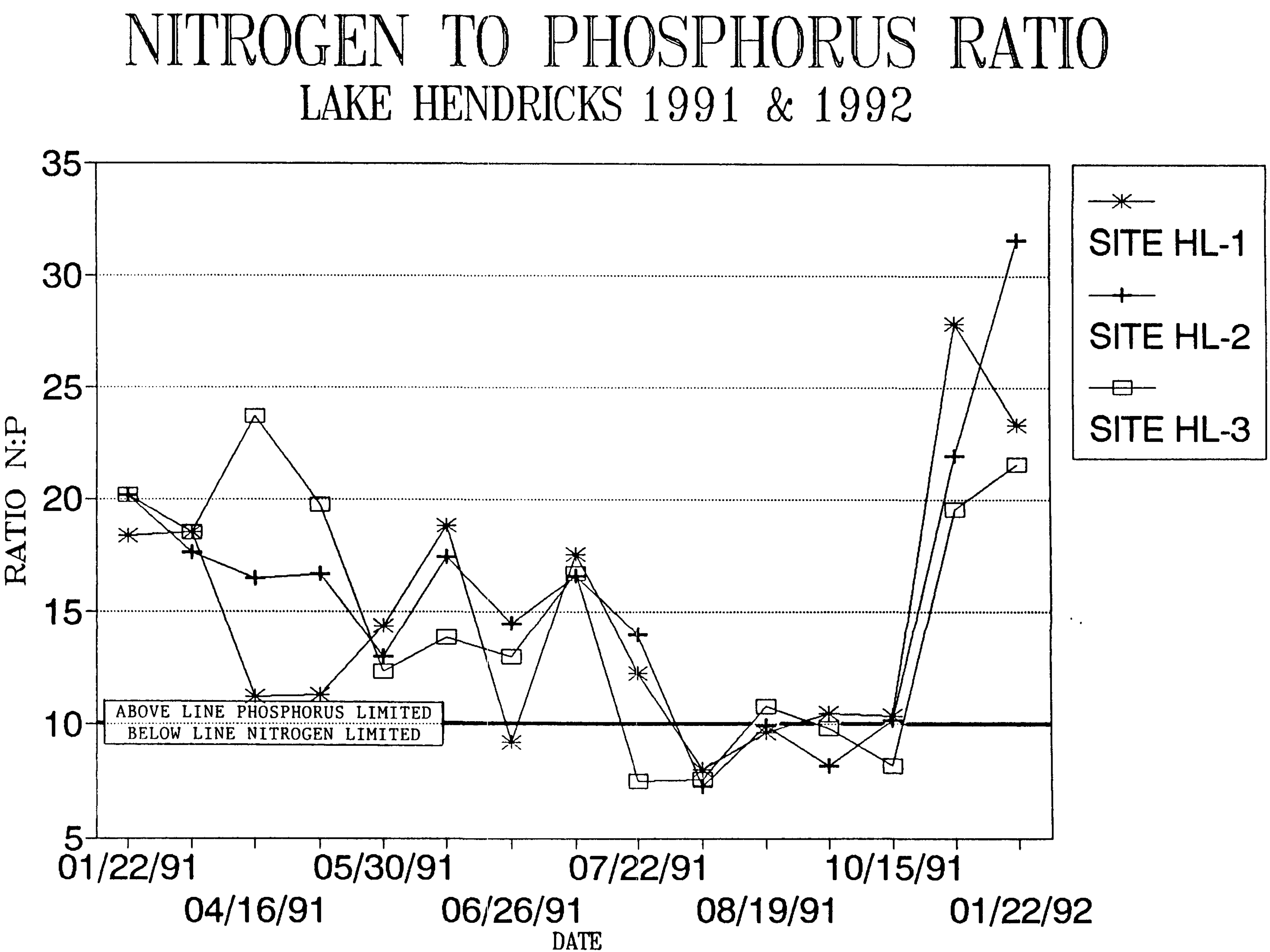

NITROGEN TO PHOSPHORUS RATIO
LAKE HENDRICKS 1991 & 1992
SITE HL-1
SITE HL-2
SITE HL-3
ABOVE LINE PHOSPHORUS LIMITED
BELOW LINE NITROGEN LIMITED
RATIO N:P
35
30
25
20
15
10
5
01/22/91
04/16/91
05/30/91
06/26/91
07/22/91
08/19/91
10/15/91
01/22/92
DATE

Figure 27.

-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	945	HT-3B	GRAB	SURFACE	6	15	8.21	2	2.4	5	3	2	2	0	0.03	0.00065	0.1	0.10	0.020	0.020
04/03/91	930	HT-1B	GRAB	SURFACE	7	19	8.13	2	1.4	4	3	1	1	0	0.02	0.00039	0.1	0.10	0.010	0.047
04/22/91	1215	HL-1B	GRAB	SURFACE	10	17	8.21	2	2.4	10	6	4	2	2	0.02	0.00059	0.1	0.10	0.010	0.010
04/30/91	1430	HT-1B	GRAB	SURFACE	9	13	8.72	2	2.6	5	3	2	0	2	0.05	0.00414	0.1	0.10	0.000	0.007
05/29/91	945	HT-1B	GRAB	SURFACE	20.8	23	8.20	22	2.0	4	0	6	4	2	0.02	0.00125	0.1	0.13	0.014	0.020
06/10/91	1100	HL-3B	GRAB	SURFACE	22.5	22	8.22		5.4	85	83	2	0	2	0.03	0.00220	0.6	0.18	0.003	0.024
06/21/91	900	HT-3B	GRAB	SURFACE	20	21	7.65		3.2	11	9	2	2	0	0.02	0.00055	0.6	0.10	0.005	0.056
07/22/91	1030	HL-1B	GRAB	SURFACE	26	27	7.00	2	2.8	5	3	2	0	2	0.02	0.00012	0.5	0.11	0.005	0.027
09/12/91	930	HT-1B	GRAB	SURFACE	19.5	22	8.58		2.8	4	0	4	2	2	0.02	0.00254	0.1	0.10	0.005	0.005
09/23/91	930	HL-1B	GRAB	SURFACE	11.5	15.5	8.66	10	2.8	2	0	12	10	2	0.02	0.00175	0.1	0.31	0.005	0.005
01/22/92	900	HT-1B	GRAB	SURFACE	1	10	6.81	2	3.0	7	4	3	2	1	0.02	0.00001	0.1	0.10	0.005	
03/11/92	1400	HT-1B	GRAB	SURFACE	0.5	-1	7.59	2	1.6	13	11	2			0.02	0.00007	0.1	0.34	0.005	0.005
03/16/92	1500	HT-1B	GRAB	SURFACE	2	16	8.30	2	2.8	8	6	2			0.02	0.00038	0.1	0.10	0.005	0.005

-PHOSPHORUS SPIKE-

DATE	TIME	SITE	SAMP	DEPTH	TPO4 mg/L	DIFFERENCE mg/L
03/11/92	1400	HT-1S	GRAB	SURFACE	0.292	0.206
03/11/92	1400	HT-1	GRAB	SURFACE	0.086	
03/16/92	1500	HT-1S	GRAB	SURFACE	0.005	0.061
03/16/92	1500	HT-1	GRAB	SURFACE	0.066	

Underlined concentrations have exceeded the EPA holding time.

Table 10. Quality Assurance/Quality Control for Lake Hendricks: Blanks and Phosphorus

-FIELD DUPLICATES-

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	945	HT-3D	GRAB	SURFACE	6	15	7.69	2	127	349	347	2	2	0	0.02	0.00013	0.1	0.99	0.220	0.170
03/25/91	945	HT-3	GRAB	SURFACE	6	15	7.90	2	129	354	352	2	2	0	0.02	0.00021	0.1	0.96	0.220	0.203
04/03/91	930	HT-1D	GRAB	SURFACE	7	19	8.72	2	108	559	533	26	5	21	0.02	0.00143	0.1	1.60	0.136	0.061
04/03/91	930	HT-1	GRAB	SURFACE	7	19	8.69	2	109	555	530	25	8	17	0.02	0.00134	0.1	1.55	0.136	0.068
04/22/91	1215	HL-1D	GRAB	SURFACE	10	17	8.43	2	113	562	544	18	2	16	0.02	0.00096	0.1	1.26	0.105	0.034
04/22/91	1215	HL-1	GRAB	SURFACE	10	17	8.46	2	111	567	553	14	4	10	0.02	0.00107	0.1	1.24	0.119	0.034
04/30/91	1430	HT-1D	GRAB	SURFACE	9	13	7.96	28	125	596	550	48	24	22	0.04	0.00062	0.2	1.00	0.271	0.058
04/30/91	1430	HT-1	GRAB	SURFACE	9	13	8.05	18	122	573	521	52	24	28	0.05	0.00095	0.1	0.92	0.197	0.064
05/29/91	930	HT-1D	GRAB	SURFACE	20.8	23	7.89	420	131	636	612	24	12	12	0.28	0.00686	0.1	1.67	0.148	0.078
05/29/91	930	HT-1	GRAB	SURFACE	20.8	23	7.93	440	130	621	595	26	20	6	0.28	0.00969	0.1	1.33	0.136	0.071
06/10/91	1030	HL-3D	GRAB	SURFACE	22.5	22.5	8.16	4800	149	640	628	12	10	2	0.36	0.02318	0.7	1.31	0.142	0.112
06/10/91	1030	HL-3	GRAB	SURFACE	22.5	22	7.90	1300	149	642	630	12	10	2	0.34	0.01239	0.7	1.26	0.142	0.092
08/21/91	900	HT-3D	GRAB	SURFACE	20	21	8.06		254	708	680	28	10	18	0.03	0.00131	0.6	0.86	0.268	0.186
08/21/91	900	HT-3	GRAB	SURFACE	20	21	8.02		259	705	679	26	8	18	0.04	0.00160	0.6	0.82	0.261	0.186
07/22/91	1030	HL-1D	GRAB	SURFACE	26	27	8.64	4	153	564	550	14	6	8	0.04	0.00842	0.6	1.16	0.142	0.102
07/22/91	1030	HL-1	GRAB	SURFACE	26	27	8.67	2	152	564	550	14	6	8	0.04	0.00889	0.6	1.14	0.142	0.112
09/12/91	1030	HT-4D	GRAB	SURFACE	17.5	22	7.55		325	1405	1393	12	0	12	0.09	0.00104	0.1	1.35	0.292	0.178
09/12/91	1030	HT-4	GRAB	SURFACE	17.5	22	7.46		322	1496	1486	10	0	10	0.11	0.00104	0.1	1.19	0.278	0.180
09/23/91	930	HL-1D	GRAB	SURFACE	11.5	13.5	8.64	10	129	517	477	40	12	28	0.17	0.01424	0.1	1.19	0.136	0.084
09/23/91	930	HL-1	GRAB	SURFACE	11.5	15.5	8.65	10	127	515	473	42	20	22	0.14	0.01198	0.1	1.21	0.125	0.084
03/11/92	1400	HT-1D	GRAB	SURFACE	0.5	-1	8.32	2	143	535	531	4			0.02	0.00035	0.1	0.70	0.080	0.023
03/11/92	1400	HT-1	GRAB	SURFACE	0.5	-1	8.29	4	144	545	541	4			0.18	0.00265	0.1	0.58	0.086	0.020
03/16/92	1500	HT-1D	GRAB	SURFACE	2	18		2							0.21		0.1	0.82	0.060	0.027
03/16/92	1500	HT-1	GRAB	SURFACE	2	18	8.38	2	144	525	517	8			0.22	0.00482	0.1	0.82	0.066	0.033

Underlined concentrations have exceeded the EPA holding times.

Table 11. Quality Assurance/Quality Control for Lake Hendricks: Field Duplicates

TRIBUTARY DATA

Tributary samples were collected at four sites in the Lake Hendricks watershed (Figure 19, Lake Hendricks Monitoring Sites). A description of the sites is as follows:

<u>Site HT-1</u> Lake Hendricks outlet, located at the northeast end of the lake.
Lat 44 deg, 30 min, 17 sec N - Long 96 deg, 23 min, 35 sec W

<u>Site HT-2</u> Minnesota County Ditch, located on the south side of Lake Hendricks.
Lat 44 deg, 29 min, 01 sec N - Long 96 deg, 26 min, 45 sec W

<u>Site HT-3</u> Deer Creek, located approximately 1/4 mile from the entrance to Lake Hendricks.
Lat 44 deg, 27 min, 55 sec N - Long 96 deg, 29 min, 58 sec W

<u>Site HT-4</u> Un-named tributary to Lake Hendricks entering from the northwest.
Lat 44 deg, 28 min, 53 sec N - Long 96 deg, 30 min, 00 sec W

The beneficial uses designated for Deer Creek, the main tributary to Lake Hendricks, 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 12, Deer Creek Water Quality Standards.

Samples from the tributaries were analyzed for the same parameters as the in-lake samples from Lake Hendricks.

<u>Field Parameters</u>

Air Temperature	Water Temperature	Dissolved Oxygen

<u>Chemical Parameters</u>

Laboratory pH	Fecal Coliform	Total Alkalinity
Total Solids	Total Dissolved Solids	Total Suspended Solids
Volatile Solids	Non-volatile Solids	Un-ionized Ammonia
Ammonia	Nitrate+Nitrite	Total Kjeldahl Nitrogen
Total Phosphorus	Total Dissolved Phosphorus	

The following discussion will summarize the results of the tributary monitoring. Summaries of 1991 and 1992 tributary concentrations are contained in Tables 13, 14, 15, and 16.

Table 12.
Deer 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 absorption ratio	<10:1

Table 13. 1991 - 1992 Tributary Concentrations, Site HT1.

SAMPLE DATA FOR LAKE HENDRICKS OUTLET (HT1),1991
11 SAMPLES

DATE	SAMP	W TEMP C	DISOX mg/L	FECAL COLIFORM PER 100ML	LABPH UNITS	TALKAL mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	VOLSOL mg/L	FIXSOL mg/L	AMMONIA mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TPO4 mg/L	TDPO4 mg/L
27-Mar-91	GRAB	2.0	14.2	2	8.61	118	538	509	29	29	0	0.23	0.0088	0.10	2.08	0.197	0.095
01-Apr-91	GRAB	6.0	14.1	2	8.89	106	548	526	22	9	13	0.02	0.0019	0.10	2.06	0.136	0.058
03-Apr-91	GRAB	7.0	11.6	2	8.69	109	555	530	25	8	17	0.02	0.0013	0.01	1.55	0.136	0.068
09-Apr-91	GRAB	11.0	9.8	14	8.67	112	555	537	18	16	2	0.23	0.0198	0.10	1.34	0.102	
15-Apr-91	GRAB	4.0	11.1	2	8.25	108	547	523	24	8	16	0.03	0.0006	0.10	1.21	0.119	0.061
30-Apr-91	GRAB	9.0	9.8	18	8.05	122	573	521	52	24	28	0.05	0.0009	0.10	0.92	0.197	0.064
03-May-91	GRAB	8.0	11.2	229	7.85	118	559	545	14	12	2	0.02	0.0002	0.10	1.01	0.081	0.041
29-May-91	GRAB	20.8	7.0	440	7.93	130	621	595	26	20	6	0.28	0.0097	0.10	1.33	0.136	0.071
06-Jun-91	GRAB	22.8	7.0	100	7.90	131	621	613	8	6	2	0.36	0.0133	0.10	1.43	0.129	0.078
31-Jul-91	GRAB	21.5	7.3	40	8.66	156	660	628	32	12	20	0.02	0.0034	0.50	1.16	0.217	0.095
08-Aug-91	GRAB	19.0	8.1	25	8.38	155	555	525	30	2	28	0.06	0.0049	0.80	0.93	0.374	0.149
MIN		2.0	7.0	2	7.85	106	538	509	8	2	0	0.02	0.0002	0.01	0.92	0.081	0.041
MAX		22.8	14.2	440	8.89	156	660	628	52	29	28	0.36	0.0198	0.80	2.08	0.374	0.149
MEAN		11.9	10.1	79	8.35	124	576	550	25	13	12	0.12	0.0059	0.19	1.37	0.166	0.078

SAMPLE DATA FOR LAKE HENDRICKS OUTLET (HT1), 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	3.0	12.8	2	8.19	150	604	600	4	0.18	0.0001	0.10	0.96	0.066
04-Mar-92	GRAB	3.5	12.8	2	8.26	143	530	516	14	0.16	0.0032	0.10	1.28	0.046
11-Mar-92	GRAB	5.0	13.8	4	8.29	144	545	541	4	0.16	0.0038	0.10	0.58	0.086
16-Mar-92	GRAB	2.0	13.5	2	8.36	14	525	517	8	0.22	0.0048	0.10	0.82	0.066
23-Mar-92	GRAB	6.0	12.8	2	8.30	143	520	518	2	0.02	0.0005	0.10	0.86	0.070
30-Mar-92	GRAB	7.0	11.2	2	8.31	189	531	513	18	0.02	0.0006	0.10	1.06	0.110
MIN		2.0	11.2	2	8.19	14	520	513	2	0.02	0.0001	0.10	0.58	0.046
MAX		7.0	13.8	4	8.36	189	604	600	18	0.22	0.0048	0.10	1.28	0.110
MEAN		4.4	12.8	2	8.29	131	543	534	8	0.13	0.0022	0.10	0.93	0.074

Table 14. 1991 - 1992 Tributary Concentrations, Site HT2.

SAMPLE DATA FOR MINNESOTA COUNTY DITCH (HT2), 1991
12 SAMPLES

DATE	SAMP	W TEMP C	DISOX mg/L	FECAL COLIFORM PER 100ML	LABPH UNITS	TALKAL mg/L	TSOL mg/L	TDSOL mg/L	TSSOL mg/L	VOLSOL mg/L	FIXSOL mg/L	AMMONIA mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TPO4 mg/L	TDPO4 mg/L
18-Mar-91	GRAB	3.0	12.8	12	7.46	130	457	438	19	7	12	0.09	0.0003	0.20	1.60	0.312	0.217
20-Mar-91	GRAB	1.0	13.1	8	7.46	193	564	549	15	10	5	0.10	0.0003	0.10	1.84	0.373	0.237
25-Mar-91	GRAB	1.0	12.4	48	7.46	119	700	680	20	20	0	0.10	0.0003	0.50	1.37	0.322	0.220
01-Apr-91	GRAB	8.0	11.8	2	8.16	175	614	587	27	10	17	0.02	0.0004	0.10	0.87	0.119	0.153
09-Apr-91	GRAB	12.1	9.4	14	7.99	196	864	838	4	2	2	0.02	0.0004	0.10	0.97	0.085	0.054
15-Apr-91	GRAB	6.0	9.8	32	7.82	216	1,114	1,088	26	20	6	0.02	0.0002	0.10	1.08	0.088	0.102
30-Apr-91	GRAB	8.3	11.2	190	7.88	185	1,298	1,296	2	0	2	0.02	0.0002	0.10	1.01	0.119	0.078
03-May-91	GRAB	7.0	12.0	2,395	7.92	221	1,073	1,069	4	2	2	0.02	0.0002	0.80	0.94	0.047	0.044
29-May-91	GRAB	20.0	4.8	4,600	7.60	99	551	469	82	28	54	0.05	0.0008	2.60	1.54	0.373	0.210
06-Jun-91	GRAB	19.0	6.0	7,200	7.58	96	407	303	104	58	46	0.10	0.0014	2.00	1.37	0.454	0.176
21-Jun-91	GRAB	17.0	7.8		7.64	75	573	293	280	80	200	0.10	0.0014	2.10	1.33	0.454	0.224
08-Aug-91	GRAB	17.5	5.7		7.96	100	448	405	43	4	39	0.04	0.0012	1.60	1.09	0.515	0.449
MIN		1.0	4.8	2	7.46	75	407	293	2	0	0	0.02	0.0002	0.10	0.87	0.047	0.044
MAX		20.0	13.1	7,200	8.16	221	1,298	1,296	280	80	200	0.10	0.0014	2.60	1.84	0.515	0.449
MEAN		10.0	9.7	1,450	7.74	163	764	732	30	16	15	0.06	0.0006	0.86	1.25	0.272	0.180

SAMPLE DATA FOR MINNESOTA COUNTY DITCH (HT2), 1992
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	AMMONIA mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TPO4 mg/L
27-Feb-92	GRAB	3.0	6.8	2	7.58	97	241	233	8	0.85	0.0034	0.60	2.73	0.568
02-Mar-92	GRAB	8.5	5.8	2	7.45	105	354	346	8	1.47	0.0068	1.20	4.32	0.518
04-Mar-92	GRAB	4.0	11.4	4	7.64	168	493	491	2	1.01	0.0051	1.30	2.87	0.305
11-Mar-92	GRAB	0.0	11.8	10	7.57	244	1037	1033	4	0.29	0.0009	4.00	1.26	0.199
16-Mar-92	GRAB	8.0	11.8	2	7.73	226	927	925	2	0.10	0.0008	2.20	0.98	0.129
23-Mar-92	GRAB	9.0	14.4	10	8.04	263	1012	962	50	0.02	0.0004	1.50	1.06	0.216
30-Mar-92	GRAB	10.0	17.6	2	8.45	239	1023	1017	6	0.02	0.0010	0.70	0.83	0.043
MIN		0.0	5.8	2	7.45	97	241	233	2	0.02	0.0004	0.60	0.83	0.043
MAX		10.0	17.6	10	8.45	263	1037	1033	50	1.47	0.0068	4.00	4.32	0.568
MEAN		6.1	11.4	5	7.78	192	727	715	11	0.54	0.0026	1.64	2.01	0.283

Table 15. 1991 - 1992 Tributary Concentrations, Site HT3.

SAMPLE DATA FOR DEER CREEK (HT3), 1991
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	VOLSOL mg/L	FIXSOL mg/L	AMMONIA mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TPO4 mg/L	TDPO4 mg/L
05-Mar-91	GRAB	1.0	13.8	100	7.50	95	317	315	2	2	0	0.20	0.0006	0.40	1.94	0.542	0.475
18-Mar-91	GRAB	2.0	12.2	2	7.80	100	328	314	14	2	12	0.02	0.0001	0.30	1.51	0.319	0.122
20-Mar-91	GRAB	2.0	12.8	6	7.80	112	338	330	8	4	4	0.03	0.0002	0.20	1.24	0.288	0.203
25-Mar-91	GRAB	6.0	13.2	2	7.90	129	354	352	2	2	0	0.02	0.0002	0.10	0.96	0.220	0.203
01-Apr-91	GRAB	9.0	13.2	2	8.07	176	523	515	8	3	5	0.02	0.0004	0.10	0.92	0.119	0.051
09-Apr-91	GRAB	10.0	10.8	2	8.20	221	626	618	8	6	2	0.02	0.0006	0.10	0.78	0.078	0.058
15-Apr-91	GRAB	7.0	11.4	18	8.00	232	682	660	22	10	12	0.02	0.0003	0.10	0.74	0.081	0.047
30-Apr-91	GRAB	11.0	10.4	12	8.10	239	783	781	2	0	2	0.02	0.0005	0.10	0.57	0.071	0.041
03-May-91	GRAB	10.0	9.6	256	8.10	238	785	771	14	12	2	0.02	0.0005	0.10	3.00	0.058	0.041
29-May-91	GRAB	23.5	8.6	500	8.00	251	788	770	18	16	2	0.02	0.0010	0.10	0.47	0.153	0.129
06-Jun-91	GRAB	21.0	8.0	360	8.00	238	553	523	30	12	18	0.09	0.0037	0.30	0.75	0.220	0.170
12-Jun-91	GRAB	20.0	7.4	360	8.02	259	705	679	26	8	18	0.04	0.0016	0.60	0.82	0.261	0.186
31-Jul-91	GRAB	19.0	6.3	220	7.97	298	783	753	30	10	20	0.02	0.0007	0.50	0.94	0.298	0.095
08-Aug-91	GRAB	19.0	6.9		7.86	276	688	646	42	8	34	0.05	0.0013	0.70	0.66	0.212	0.110
MIN		1.0	6.3	2	7.50	95	317	314	2	0	0	0.02	0.0001	0.10	0.47	0.058	0.041
MAX		23.5	13.8	500	8.20	298	788	781	42	16	34	0.20	0.0037	0.70	3.00	0.542	0.475
MEAN		11.5	10.3	142	7.95	205	590	573	16	7	9	0.04	0.0008	0.26	1.09	0.209	0.138

SAMPLE DATA FOR DEER CREEK (HT3), 1992
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	AMMONIA mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TPO4 mg/L
27-Feb-92	GRAB	2.5	12.4		7.54	92	297	283	14	0.53	0.0019	0.80	2.55	0.302
02-Mar-92	GRAB	6.3	10.2	14	7.53	91	250	242	8	0.48	0.0022	0.60	2.18	0.329
04-Mar-92	GRAB	3.5	11.2	16	7.68	104	229	221	8	0.39	0.0021	0.40	1.71	0.286
11-Mar-92	GRAB	1.5	9.8	2	7.90	203	597	589	8	0.16	0.0012	2.10	0.95	0.156
16-Mar-92	GRAB	7.8	14.2	2	8.04	240	633	631	2	0.02	0.0003	1.50	1.06	0.093
23-Mar-92	GRAB	8.4	11.4	2	8.34	228	622	608	14	0.02	0.0007	0.70	0.69	0.090
30-Mar-92	GRAB	8.0	18.4	2	8.40	231	638	628	10	0.02	0.0008	0.20	0.78	0.070
MIN		1.5	9.8	2	7.53	91	229	221	2	0.02	0.0003	0.20	0.69	0.070
MAX		8.4	18.4	16	8.40	240	638	631	14	0.53	0.0022	2.10	2.55	0.329
MEAN		5.4	12.5	6	7.92	170	467	457	9	0.23	0.0013	0.90	1.42	0.189

Table 16. 1991 - 1992 Tributary Concentrations, Site HT4.

SAMPLE DATA FOR UNNAMED NORTHWEST TRIBUTARY (HT4), 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	VOLSOL mg/L	FIXSOL mg/L	AMMONIA mg/L	UNIONIZED AMMONIA mg/L	NO3+2 mg/L	TKN-N mg/L	TPO4 mg/L	TDPO4 mg/L
06-Mar-91	GRAB	2.0	11.6	58	7.40	127	366	358	8	2	6	0.53	0.0013	1.00	2.65	0.475	0.373
25-Mar-91	GRAB	6.0	12.8	6	7.67	186	561	559	2	2	0	0.06	0.0004	0.60	2.17	0.237	0.136
26-Mar-91	GRAB	1.0	13.8	2	7.51	292	744	743	1	1	0	0.05	0.0001	0.30	1.60	0.129	0.088
03-Apr-91	GRAB	12.0	10.6	2	7.48	301	643	642	1	1	0	0.02	0.0001	0.10	0.76	0.061	0.037
09-Apr-91	GRAB	11.2	9.6	2	8.14	378	1,047	1,015	32	24	8	0.02	0.0005	0.10	1.16	0.068	0.081
15-Apr-91	GRAB	5.0	11.5	2	7.94	337	867	847	20	18	2	0.02	0.0002	0.10	0.98	0.061	0.061
30-Apr-91	GRAB	10.0	11.4	28	7.96	274	783	779	4	2	2	0.02	0.0003	0.10	0.72	0.064	0.064
03-May-91	GRAB	7.0	11.8	134	7.93	309	709	703	6	4	2	0.03	0.0004	0.10	0.45	0.051	0.051
29-May-91	GRAB	23.0	8.2	240	7.88	347	639	631	8	6	2	0.02	0.0007	0.10	1.30	0.298	0.278
02-Jun-91	GRAB	20.5	6.2	820	7.76	145	377	317	60	16	44	0.07	0.0016	1.20	1.22	0.336	0.163
06-Jun-91	GRAB	24.0	7.8	1,400	7.88	295	515	505	10	8	2	0.07	0.0027	0.10	1.00	0.200	0.200
08-Aug-91	GRAB	17.0	7.9		7.72	238	560	550	10	2	8	0.02	0.0003	0.80	1.00	0.266	0.242
MIN		1.0	6.2	2	7.40	127	366	317	1	1	0	0.02	0.0001	0.10	0.45	0.051	0.037
MAX		24.0	13.8	1,400	8.14	378	1,047	1,015	60	24	44	0.53	0.0027	1.20	2.65	0.475	0.373
MEAN		11.6	10.3	245	7.77	269	651	637	14	7	6	0.08	0.0007	0.38	1.25	0.187	0.148

SAMPLE DATA FOR UNNAMED NORTHWEST TRIBUTARY (HT4), 1992
4 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
27-Feb-92	GRAB	1.0	12.8	2	7.78	91	319	307	12	0.79	0.0043	2.00	3.44	0.438
02-Mar-92	GRAB	7.0	9.8	18	7.71	208	390	386	4	0.66	0.0049	0.60	1.93	0.212
04-Mar-92	GRAB	4.0	9.9	2	7.67	249	535	529	6	0.24	0.0013	0.50	1.79	0.179
16-Mar-92	GRAB	1.0	15.2	2	7.74	382	796	792	4	0.02	0.0001	0.10	0.99	0.066
MIN		1.0	9.8	2	7.67	91	319	307	4	0.02	0.0001	0.10	0.99	0.066
MAX		7.0	15.2	18	7.78	382	796	792	12	0.79	0.0049	2.00	3.44	0.438
MEAN		3.3	11.9	6	7.73	232	510	504	7	0.43	0.0026	0.80	2.04	0.224

Dissolved Oxygen

The water quality standards for Deer 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 Deer Creek.

The dissolved oxygen level of one sample from the Minnesota County Ditch monitoring site (HT-2) fell slightly below a level of 5.0 mg/L. The sample collected on May 29, 1991, had a dissolved oxygen reading of 4.8 mg/L (Table 14).

Fecal Coliform Bacteria

The water quality standard for fecal coliform bacteria on Deer Creek is a count of 1,000 organisms per 100 milliliters (1000/100 mL). Fecal coliform results for Deer Creek (Site HT-3) did not exceed the water quality standard during the sampling period. On five occasions significantly high fecal coliform counts were recorded on Deer Creek with a maximum of 500/100 mL were found during the sampling period from May 3, 1991 to July 31, 1991 (Table 15). These results correspond to a runoff events during the sampling period.

The highest concentrations of fecal coliform bacteria were found at the monitoring site on the Minnesota County Ditch (Site HT-2). Significant fecal coliform counts (>100 colonies/100 mL) were detected on four occasions during the monitoring period. A maximum of 7,200/100 mL was found on June 6, 1991 (Table 14). These fecal coliform results also correspond to runoff events in Minnesota County Ditch #11.

Fecal coliform bacteria are indicators of animal and/or human waste. Sources may include failing septic systems, and runoff from livestock feedlots. These sources need to be addressed, particularly in the subwatershed that is drained by Minnesota County Ditch #11.

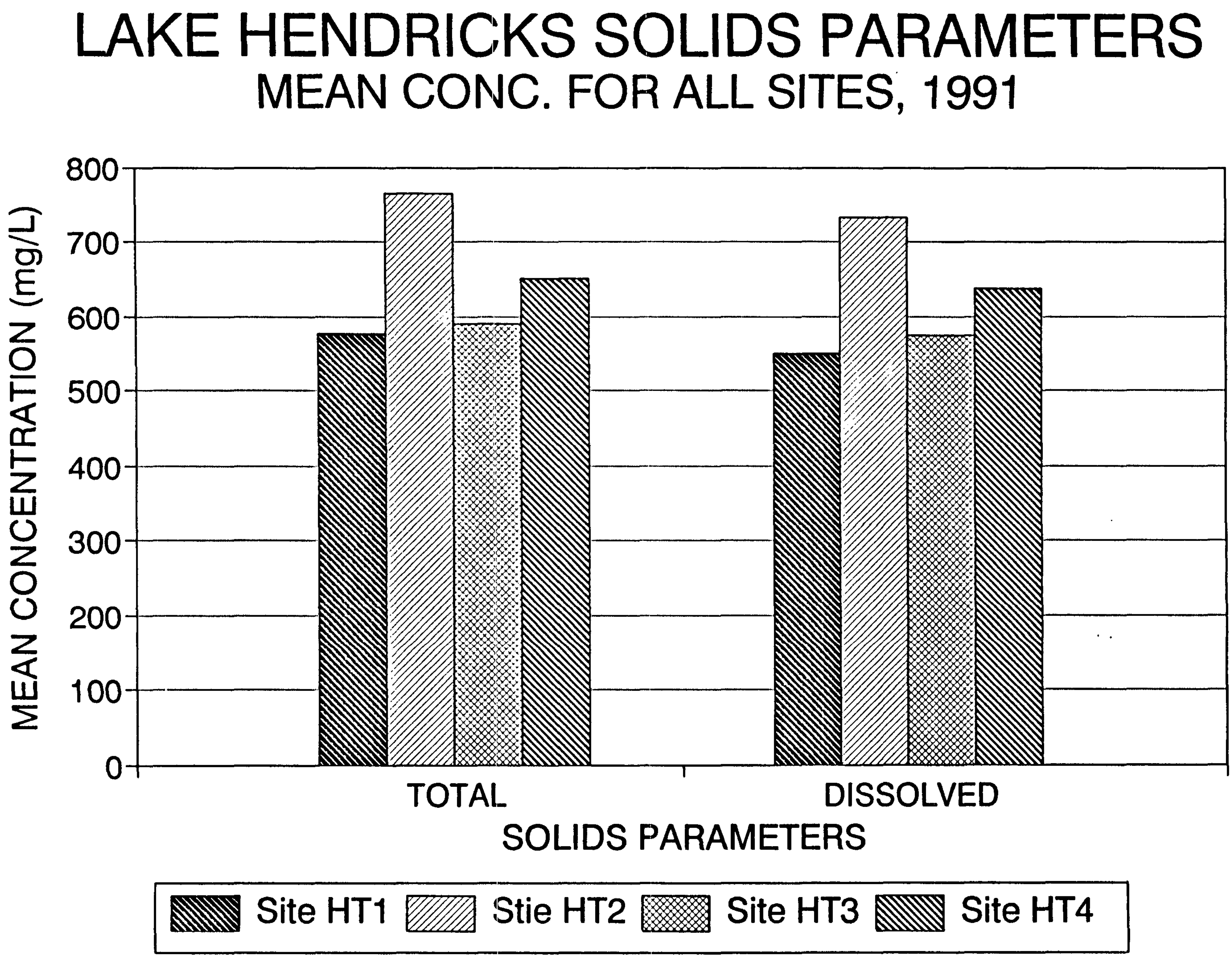
pH

The water quality standards for Deer Creek state that the pH level shall be greater than 6.0 su, and less than 9.0 su. The results of all the tributary samples were within this range of pH units.

Solids

Figures 28 and 29 depict the mean solids concentrations for Lake Hendricks. Figures 30 and 31 show the loads of solids to Lake Hendricks from the three inlets. The maximum average concentration of suspended solids was found at Site HT-2 (Minnesota County Ditch #11). The maximum concentration at this site was 280 mg/L and the mean concentration of 30 mg/L (Table 14). The maximum and mean concentrations at HT-3 (Deer Creek) were 42 mg/L and 16 mg/L respectively (Table 15). The maximum and mean concentrations at site HT-4 (un-named tributary) were 60 mg/L and 14 mg/L respectively (Table 16). There were no exceedences for the South Dakota Water Quality Standards for suspended solids 90 mg/L) during the sampling period.

The 1991 annual loads for suspended solids at Sites HT-2, HT-3, and HT-4 were 31,101 kg/year (34.3 tons), 173,531 kg/year (191.3 tons), and 2,449 kg/year (2.7 tons) respectively. The 1991 annual load from Site HT-3 has the largest contribution of sediment on a per acre basis compared to the rest of the



LAKE HENDRICKS SOLIDS PARAMETERS
MEAN CONC. FOR ALL SITES, 1991
MEAN CONCENTRATION (mg/L)
800
700
600
500
400
300
200
100
0
TOTAL
DISSOLVED
SOLIDS PARAMETERS
Site HT1
Stie HT2
Site HT3
Site HT4

Figure 28

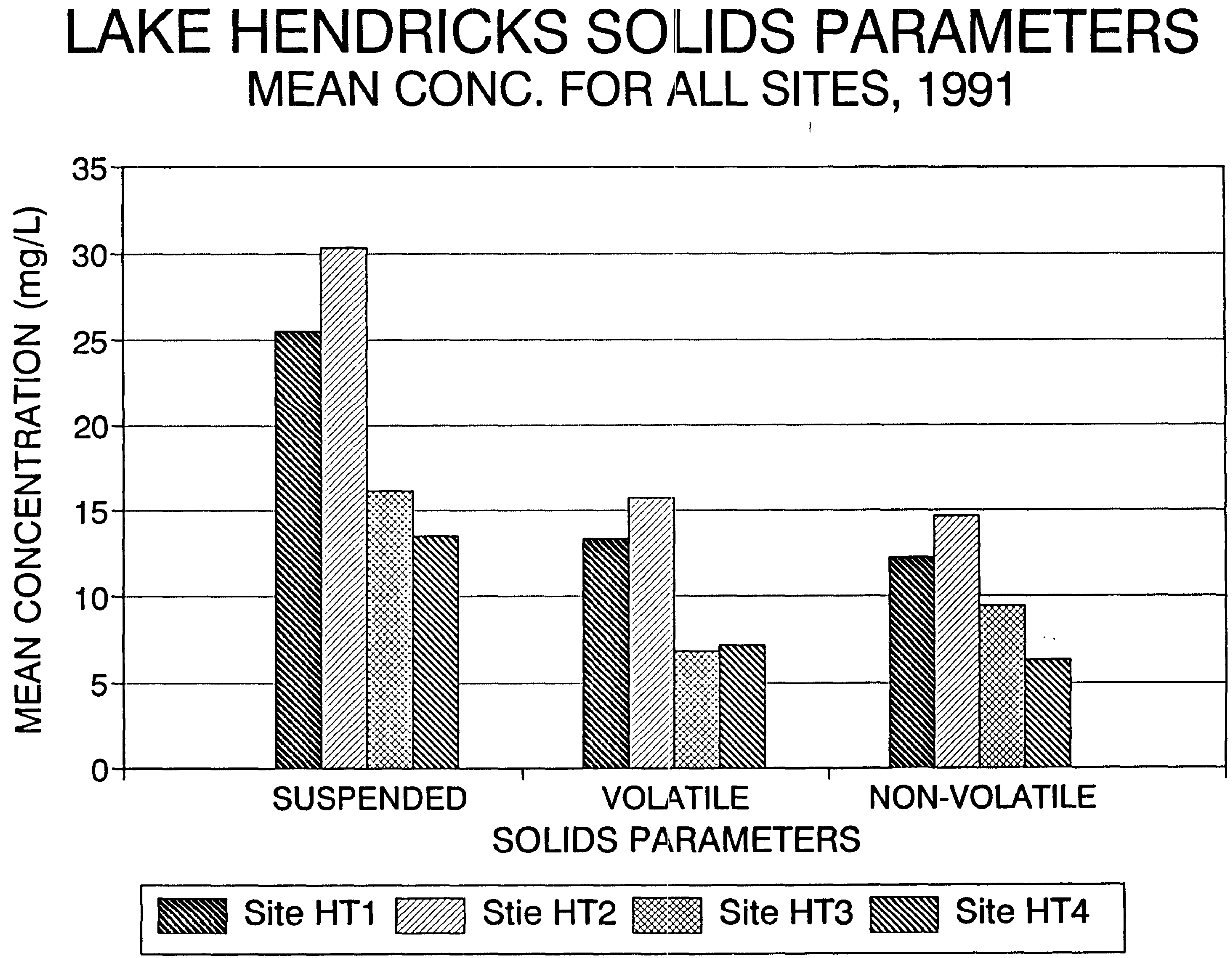

LAKE HENDRICKS SOLIDS PARAMETERS
MEAN CONC. FOR ALL SITES, 1991
MEAN CONCENTRATION (mg/L)
35
30
25
20
15
10
5
0
SUSPENDED
VOLATILE
NON-VOLATILE
SOLIDS PARAMETERS
Site HT1
Stie HT2
Site HT3
Site HT4

Figure 29

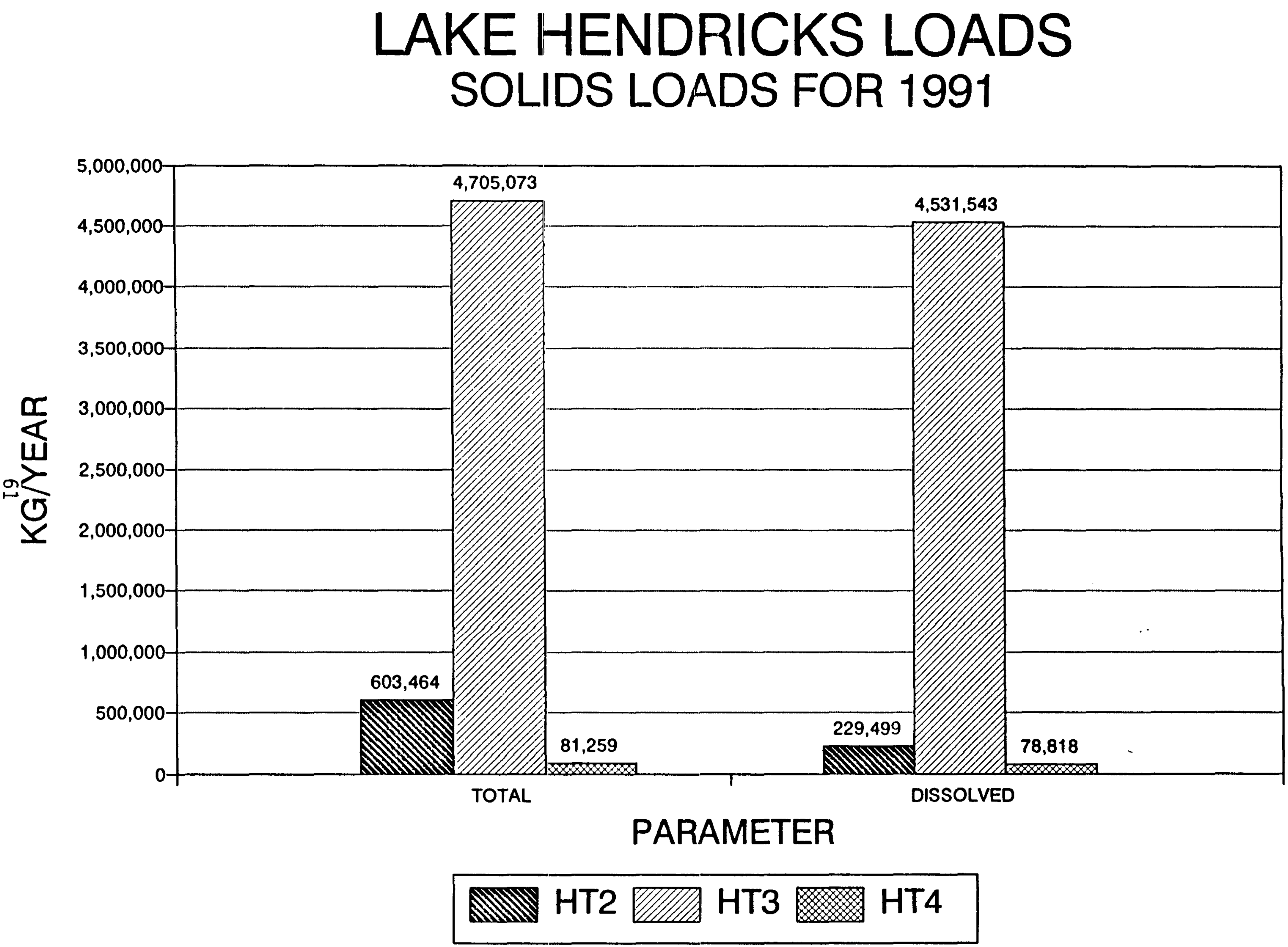

LAKE HENDRICKS LOADS
SOLIDS LOADS FOR 1991
KG/YEAR
5,000,000
4,500,000
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
4,705,073
4,531,543
603,464
81,259
229,499
78,818
TOTAL
DISSOLVED
PARAMETER
HT2
HT3
HT4

Figure 30

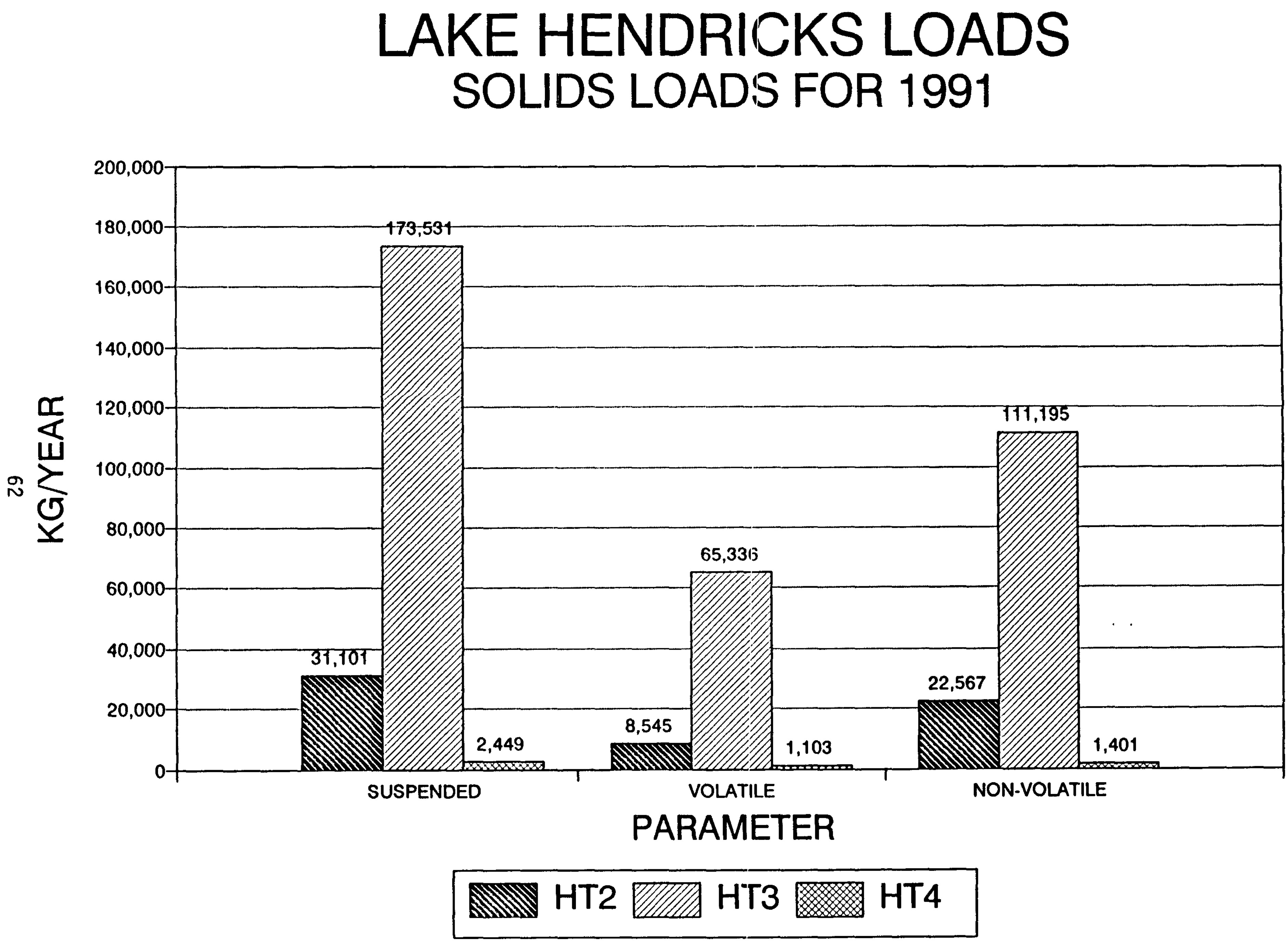

LAKE HENDRICKS LOADS
SOLIDS LOADS FOR 1991
KG/YEAR
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
31,101
173,531
2,449
8,545
65,336
1,103
22,567
111,195
1,401
SUSPENDED
VOLATILE
NON-VOLATILE
PARAMETER
HT2
HT3
HT4

Figure 31

watershed. The tributary monitoring did not indicate any excessive loads of sediment from the subwatersheds.

Nitrogen

Site HT-2 had the highest mean nitrogen concentrations of all the inlet sites to the lake (Figure 32). The highest mean concentrations for total Kjeldahl nitrogen (TKN) and nitrate+nitrite nitrogen (NO_3+NO_2) were 1.37 mg/L and 0.19 mg/L respectively. Site HT-3 (Deer Creek) had the largest annual load of both NO_3+NO_2 and TKN in 1991 (Figure 33).

The majority of the higher concentrations were found during spring runoff. Sources for these concentrations may have been animal and domestic waste, decaying vegetation, or runoff from nutrient rich agricultural land. High concentrations were also found in early June of 1991. Since much of the land is cropped, fertilizer runoff from recently planted crops was the most probable source.

The water quality standard for un-ionized ammonia on Deer Creek is 0.05 mg/L. No exceedences were found at Site HT-3 during the sampling period. The maximum concentration (0.02 mg/L) found was located at the outlet (Site HT-1) on April 9, 1992 (Table 13). This high concentration is more of a direct result from in-lake biological factors than tributary sources. Many prairie lakes stratify in the winter. During this stratified period, the profundal zone may become anoxic causing chemical reactions which release ammonia from the decaying organic matter. The profundal zone is the very bottom of the hypolimnetic layer of the lake near the sediment/water interface. In this zone oxygen may be depleted and the zone is characterized by decay rather than production of organic matter. When the ice breaks up on the lake the stratified layers become mixed throughout the lake. This mixing is accompanied by increases in pH and temperature which increases the un-ionized fraction of ammonia (Cole, 1963).

The inlet monitoring sites all reached a maximum concentration on the same date, March 2, 1992 (Tables 14, 15, and 16). The concentrations reached at Sites HT-2, HT-3, and HT-4 on this date were 0.007 mg/L, 0.002 mg/L, and 0.005 mg/L respectively. Because un-ionized ammonia is a fraction of ammonia the increase on that date coincides with increased ammonia concentration from snow-melt runoff in the watersheds.

A greater reduction in nitrogen may be realized by implementing Best Management Practices (BMP's) on Minnesota County Ditch #11 than on Deer Creek. This is due to the fact that a sediment control structure and BMP's have already been extensively implemented on the Deer Creek watershed.

Phosphorus

As shown on Figure 32, the mean total phosphorus concentrations for all inlet sites were relatively similar (range - 0.187 mg/L to 0.272 mg/L). The maximum concentration was found at site HT-2 (0.568 mg/L) on February 27, 1992 (Table 14). In general the largest concentrations were found in the spring runoff events in both 1991 and 1992. As with nitrogen, the sources of phosphorus during spring runoff are from animal and domestic waste and nutrient rich agricultural land.

Because of the large water volume through Deer Creek, Site HT-3 has the largest phosphorus load to Lake Hendricks. The load of total phosphorus through Site HT-3 is estimated at 3,127 kg (.71 tons). Since phosphorus sorbs to sediment

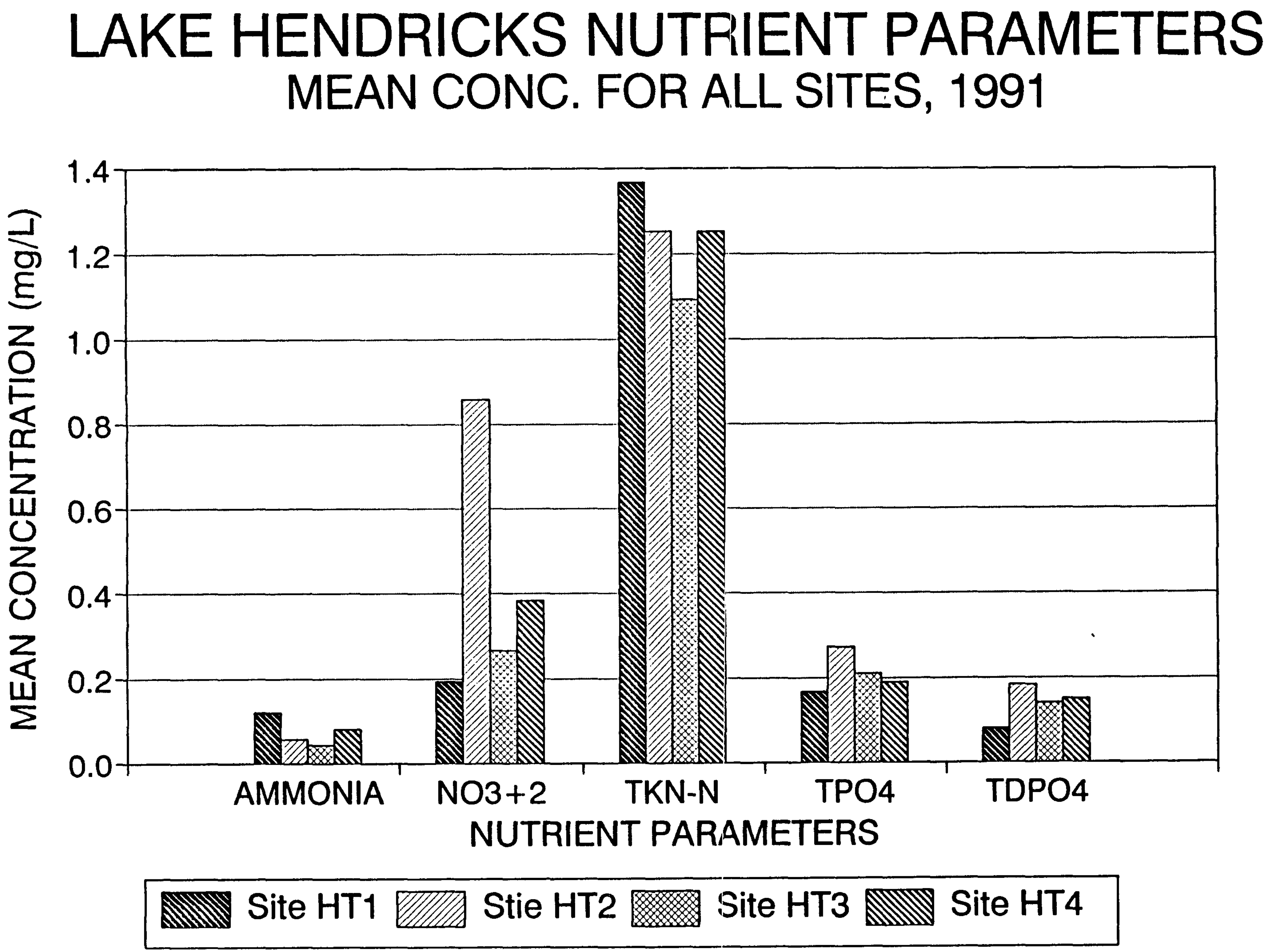

LAKE HENDRICKS NUTRIENT PARAMETERS
MEAN CONC. FOR ALL SITES, 1991
MEAN CONCENTRATION (mg/L)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
AMMONIA
NO3+2
TKN-N
TPO4
TDPO4
NUTRIENT PARAMETERS
Site HT1
Stie HT2
Site HT3
Site HT4

Figure 32

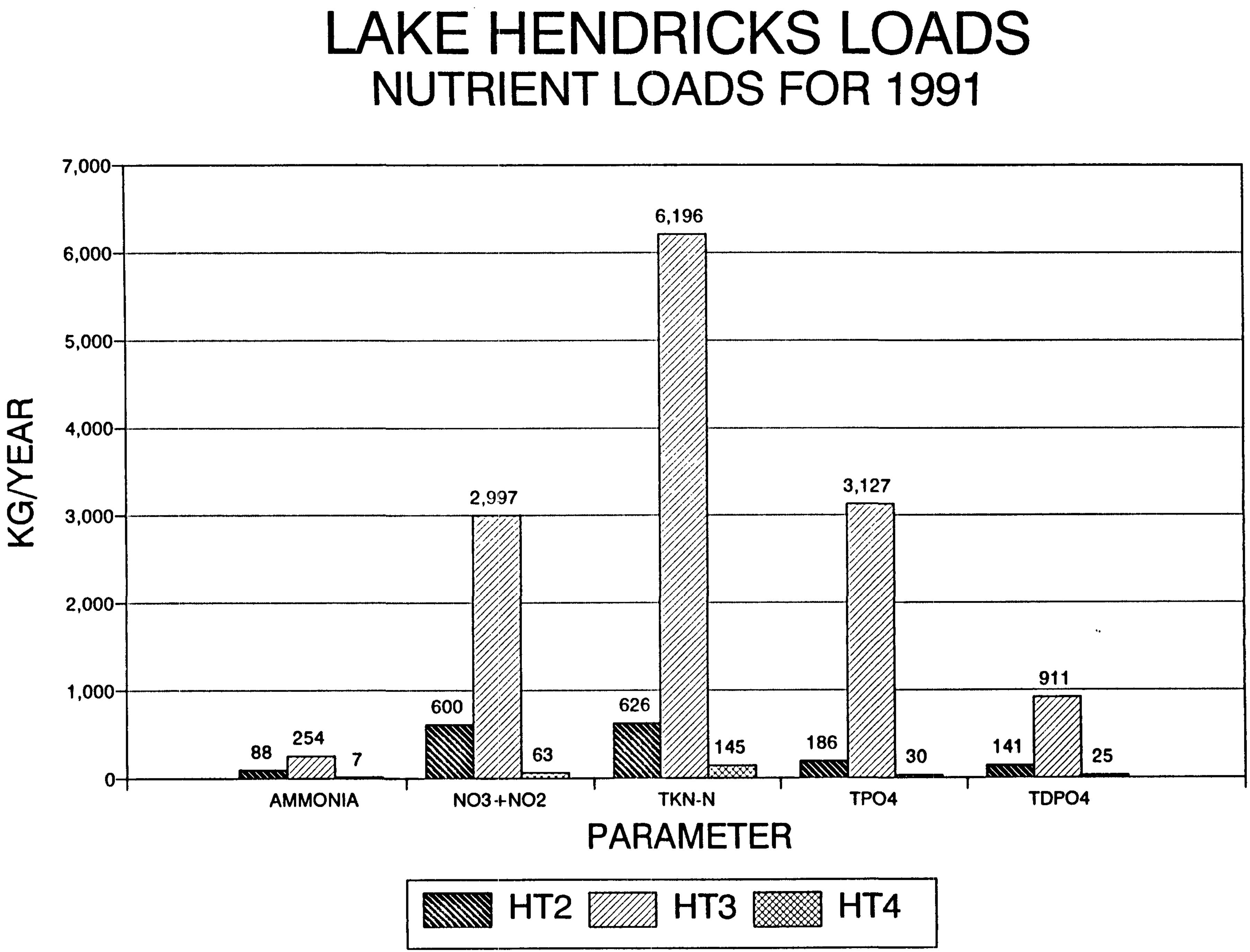

LAKE HENDRICKS LOADS
NUTRIENT LOADS FOR 1991
KG/YEAR
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
88
254
7
600
2,997
63
626
6,196
145
186
3,127
30
141
911
25
AMMONIA
NO3+NO2
TKN-N
TPO4
TDPO4
PARAMETER
HT2
HT3
HT4

Figure 33

the increased sediment loads are probably responsible for increasing the particulate portion of the total phosphorus. The total dissolved phosphorus loads to Lake Hendricks are also greatest at Site HT-3. While the loads were higher at the monitoring site on Deer Creek, concentrations of dissolved phosphorus were higher at Site HT-2 on Minnesota County Ditch #11. Sources of phosphorus from the Lake Hendricks watershed include animal waste, runoff from agricultural land, decaying organic matter, and failing septic systems.

<u>In-lake Sediment/Nutrient Budget</u>

The total measured load of suspended solids into Lake Hendricks in 1991 was 207,080 kg (228.3 tons) the suspended solids load which left through the outlet was 130,207 kg (143.6 tons) (Figure 34). The sediment retained in the lake was 76,873 kg (84.8 tons). Although the lake has a large amount of sediment, the sediment retained in 1991 is not a significant amount. It is believed that the majority of the sedimentation occurred prior to implementation of modern conservation practices and the construction of the sediment control structure on Deer Creek.

Figure 35 shows the nutrient budget for Lake Hendricks during 1991. The graph shows that greater loadings of nitrate-nitrite nitrogen, total phosphorus, and total dissolved phosphorus entered Lake Hendricks than discharged through the outlet. The load of total phosphorus from the tributaries into the lake was 3,343 kg, whereas the total load from the lake through the outlet (HT1) was 1,058 kg. The total load of dissolved phosphorus into the lake was 1,078 kg, and the total load of dissolved phosphorus discharged from the lake through the outlet was 546 kg. The loads of total nitrogen and phosphorus retained in Lake Hendricks during 1991 were 912 kg (1 ton) and 2,285 kg (2.5 tons) respectively.

One nutrient parameter which was analyzed had a larger total outflow than inflow, TKN. TKN is used to measure organic nitrogen. Lake Hendricks appears to be creating a large amount of organic material which is discharged through the outlet. The total input of organic nitrogen was 6,618 kg and the discharge through the outlet was 6,830 kg. Although the difference is small (212 kg or 0.2 tons), it is still uncharacteristic when compared to the other nutrients tested. The retention of nutrients in the lake will contribute to algae and weed growth. Loadings of nutrients into the lake will contribute to increased eutrophication of Lake Hendricks.

SEDIMENT SAMPLING AND SURVEY

A survey of the bottom sediments of Lake Hendricks was conducted by a consulting engineering firm during the fall of 1990. The survey produced the following results:

Water Surface Area	1,534.2	acres
Average Water Column Depth	10	feet
Average Sediment Column Depth	9	feet
Estimated Sediment Volume	22,594,000 or 14,000	cubic yards acre feet

Maps showing the elevations of water depths and sediment depths are included in APPENDIX B, LAKE HENDRICKS SEDIMENT SURVEY. The maps indicate that the sediment is distributed quite evenly throughout the lake at an average depth of nine feet.

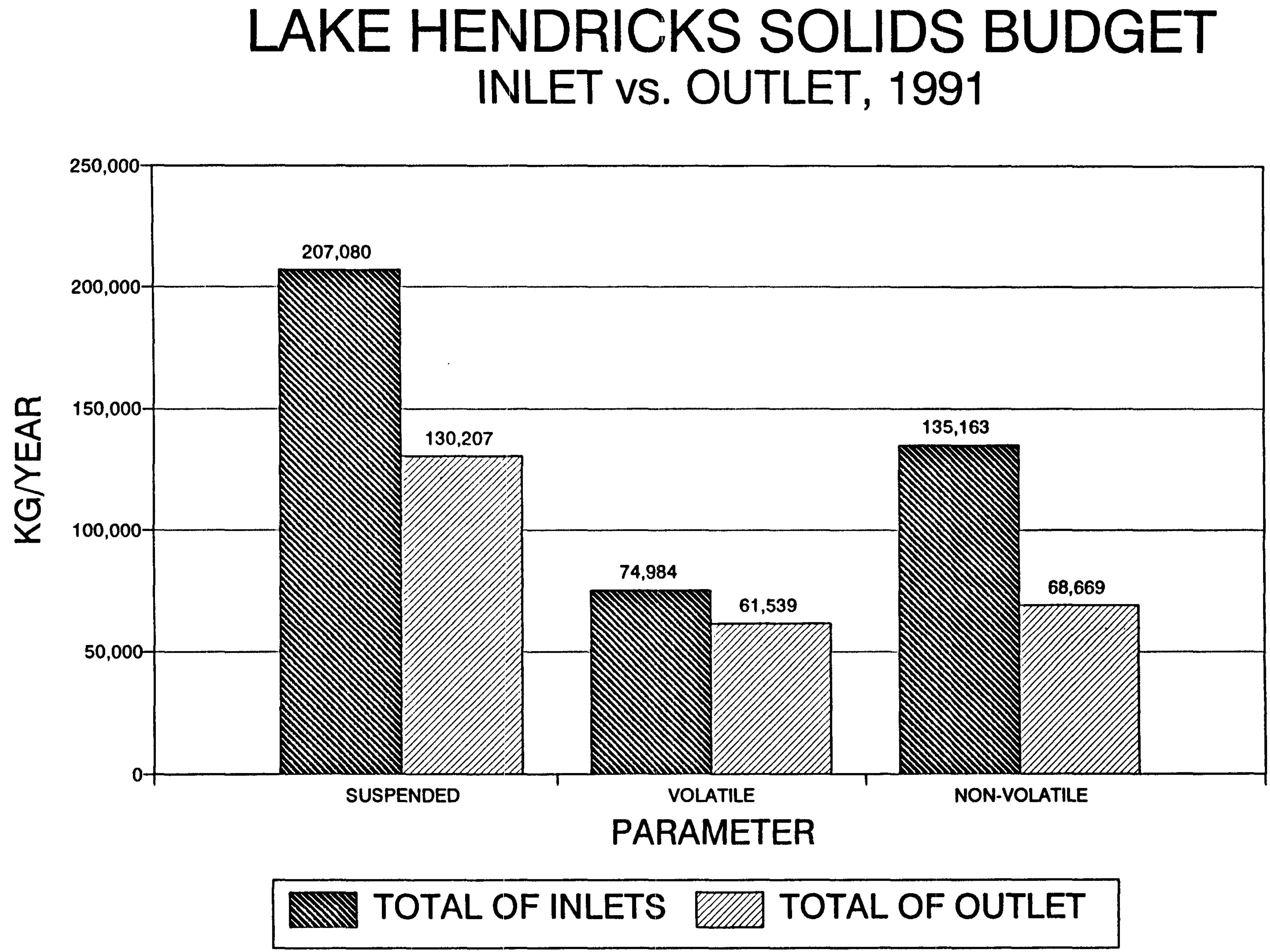

LAKE HENDRICKS SOLIDS BUDGET
INLET vs. OUTLET, 1991
KG/YEAR
250,000
200,000
150,000
100,000
50,000
0
207,080
130,207
74,984
61,539
135,163
68,669
SUSPENDED
VOLATILE
NON-VOLATILE
PARAMETER
TOTAL OF INLETS
TOTAL OF OUTLET

Figure 34

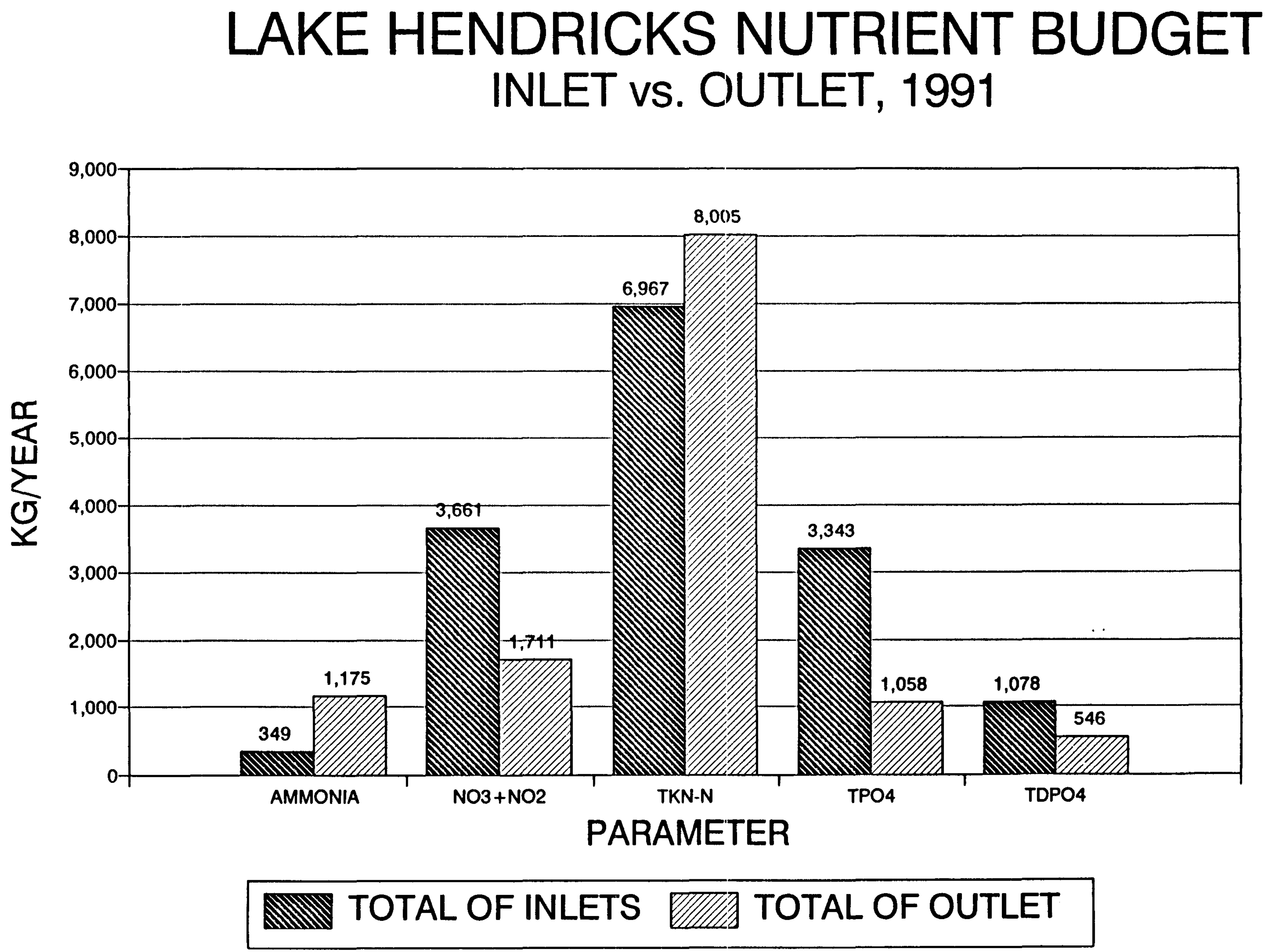

LAKE HENDRICKS NUTRIENT BUDGET
INLET vs. OUTLET, 1991
KG/YEAR
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
349
1,175
3,661
1,711
6,967
8,005
3,343
1,058
1,078
546
AMMONIA
NO3+NO2
TKN-N
TPO4
TDPO4
PARAMETER
TOTAL OF INLETS
TOTAL OF OUTLET

Figure 35.

An elutriate sample was collected from Lake Hendricks on March 13, 1990, and submitted to the U.S. Army Corps of Engineers Laboratory in Omaha, Nebraska. The sample was analyzed for metals, nutrients, pesticides, and other toxic substances. The results of the analysis indicated no excessive levels of toxic substances in the sediments (Table 17).

BIOLOGICAL RESOURCES

Lake Hendricks and its watershed have many diverse biological resources. Lake Hendricks discharges to the Lac Qui Parle River, a tributary of the Minnesota River. The aquatic life of Lake Hendricks is replenished and supplied with diversity by this connection to the Lac Qui Parle River.

Due to the large concentrations of nutrients in Lake Hendricks dense blue-green algae "blooms" are present during the summer months. These algal blooms serve to inhibit light penetration to the bottom sediments and this in turn, inhibits the growth of aquatic macrophytes.

The small shallow bays on Lake Hendricks act as nesting areas for many species of waterfowl. Waterfowl species utilize the back reaches of Lake Hendricks for reproduction and brood rearing. The deeper waters maintain an abundant food supply for shore-feeding species of birds. The lake is surrounded by numerous species of hardwood trees and deciduous shrubs which provide habitat for a variety of bird and mammal species.

Lake Hendricks supplies many of the essential elements for large and diverse population of plants and animals. APPENDIX C, BIOLOGICAL RESOURCES OF LAKE HENDRICKS AND ITS WATERSHED, contains further information on the plant and animal species that inhabit the area. Some of the lists of species in APPENDIX C show that certain species may "possibly" occur in the Lake Hendricks area. This indicates that some of the species may occur in the area, but are not common. APPENDIX C also has a list of rare plants that may be found in the Lake Hendricks watershed.

SUMMARY AND CONCLUSIONS

In summary, many factors are influencing the water quality of Lake Hendricks. According to the watershed analysis, two areas (the Upper Deer Creek subwatershed and the Minnesota County Ditch #11 subwatershed) were found to be contributing significant loads of nutrients. The sediment load to the lake from the tributaries does not appear to be significant, however the volume of sediment in the lake basin indicates that historically sedimentation was a problem.

The survey of shoreline erosion determined that 4,040 feet of shoreline are in erodible conditions ranging from minor to moderate/severe. These areas represent direct loadings of sediment into Lake Hendricks.

The survey of septic wastewater systems around the lake found that about 11% 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 Hendricks.

The survey of the bottom sediment in Lake Hendricks found a total sediment volume of 22,594,000 cubic yards. An elutriate analysis of the sediment

Table 17. Lake Hendricks Elutriate Sample Data

MRD LAB No.90/236
sheet 3 of 4

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

Project: South Dakota Department of Water and Natural Resource
Date Sample Taken: 13 Mar 90 Customer Sample Id: Lake Hendricks
Date Sample Received: 17 Mar 90 MRD Lab Sample No: M-1179
Sample Description: Water and Sediment Sample Container: 3-1gal glass (water) and 1-1gal glass (sediment)
Time Sample Taken: 11:15 AM
Comments: Lake Hendricks (Brookings Co.) South Dakota

Analysis	Sediment Result	Units	Receiving Water Result	Units	Elutriate Water Result	Units
Ammonia Nitrogen			0.89	mg/L	2.3	mg/L
Chemical Oxygen Demand			33	mg/L	49	mg/L
Total Cyanide			<0.02	mg/L	<0.02	mg/L
Nitrate-Nitrite Nitrogen			0.15	mg/L	0.16	mg/L
Total Phosphorus			0.22	mg/L	0.15	mg/L
Total Kjeldahl Nitrogen			1.9	mg/L	2.4	mg/L
Oil and Grease			<5	mg/L	<5	mg/L
Antimony	<10	mg/Kg	<1	ug/L	3	ug/L
Arsenic	4.0	mg/Kg	4	ug/L	6	ug/L
Barium	130	mg/Kg	90	ug/L	250	ug/L
Beryllium	0.4	mg/Kg	<1	ug/L	<1	ug/L
Cadmium	<0.1	mg/Kg	<0.1	ug/L	<0.1	ug/L
Chromium	20	mg/Kg	<1	ug/L	<1	ug/L
Copper	7	mg/Kg	<10	ug/L	<10	ug/L
Iron	13000	mg/Kg	70	ug/L	40	ug/L
Lead	<5	mg/Kg	<1	ug/L	<1	ug/L
Magnesium	9500	mg/Kg	33	mg/L	30	mg/L
Manganese	380	mg/Kg	63	ug/L	630	ug/L
Mercury	<0.1	mg/Kg	<0.2	ug/L	<0.2	ug/L
Selenium	0.25	mg/Kg	1.0	ug/L	<1.0	ug/L
Zinc	36	mg/Kg	<10	ug/L	<10	ug/L
Nickel	15	mg/Kg	1	ug/L	2	ug/L
Aluminum	13000	mg/Kg	<50	ug/L	<50	ug/L
Calcium	58000	mg/Kg	71	mg/L	80	mg/L
Sodium	120	mg/Kg	7.0	mg/L	9.0	mg/L
Potassium	1800	mg/Kg	7.2	mg/L	10	mg/L
Silver	<1	mg/Kg	<10	ug/L	<10	ug/L
Simazine (Princep)	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L
Metribuzin (Lexone)	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L
Atrazine (Aatrex)	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L
Aldrin	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
alpha-BHC	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
beta-BHC	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
gamma-BHC (Lindane)	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
Mirex	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
Chlordane	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
P'P"DDD	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
P'P"DDE	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
P'P"DDT	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
Dieldrin	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
Endosulfan I	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
Propachlor (Ramrod)	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L
Metolachlor (Dual)	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L
Alachlor (Lasso)	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L
Diazinon	<100	ug/Kg	<0.1	ug/L	<0.1	ug/L
Endrin	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
Heptachlor	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
Heptachlor epoxide	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
Methoxychlor	<10	ug/Kg	<0.01	ug/L	<0.01	ug/L
Toxaphene	<500	ug/Kg	<0.50	ug/L	<0.50	ug/L
PCB-1016	<100	ug/Kg	<0.10	ug/L	<0.10	ug/L
PCB-1221	<100	ug/Kg	<0.10	ug/L	<0.10	ug/L
PCB-1232	<100	ug/Kg	<0.10	ug/L	<0.10	ug/L
PCB-1242	<100	ug/Kg	<0.10	ug/L	<0.10	ug/L
PCB-1248	<100	ug/Kg	<0.10	ug/L	<0.10	ug/L
PCB-1254	<100	ug/Kg	<0.10	ug/L	<0.10	ug/L
PCB-1260	<100	ug/Kg	<0.10	ug/L	<0.10	ug/L

indicated that there were not excessive concentrations of toxic substances in the sediment.

The in-lake water quality monitoring program determined that Lake Hendricks is in a hypereutrophic condition. The watershed monitoring program showed that the greatest loads of sediment and nutrients are contributed from the Upper Deer Creek subwatershed. The subwatershed drained by Minnesota County Ditch #11 contributes significant loads of sediment and nutrients on a per acre basis.

RESTORATION ALTERNATIVES AND RECOMMENDATIONS

Many alternatives are possible for restoration of lakes and their watersheds. Water quality monitoring of the Lake Hendricks has shown that the lake is in a hypereutrophic condition, and the lake is in need of a reduction of sediments and nutrients. Based on these findings, the following restoration alternatives are recommended based on their effectiveness and economic possibility.

Information/Education Program to Promote Best Management Practices

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

In order to reduce loadings of sediment and nutrients to the greatest extent possible, the implementation of best management practices should be promoted in the areas of the watershed found to be contributing the highest loads. In the Lake Hendricks watershed, the Deer Creek sub-basin is contributing the greatest total loads of sediment and nutrients. However, information from the Soil Conservation Service indicates that traditional best management practices are already extensively applied in this area. Therefore, best management practices need to be promoted extensively in the Minnesota County Ditch #11 subwatershed which contributes higher loadings of sediment and nutrients on a per acre basis.

Because traditional best management practices are already extensively applied in the Lake Hendricks watershed, it is recommended that Integrated Crop Management practices should also 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 such as soil testing. This would help to promote these practices, and gain wider acceptance among landowners in the watershed.

The estimated costs to carry out an effective Information/Education Program for promotion of best management practices in the Lake Hendricks watershed are as follows:

Item	Cost per Year
Promotional materials	$1,500 to $2,000
Training workshops	1,500 to 2,000
Travel within watershed	2,500 to 3,000
Total Cost Per Year	$5,500 to $7,000

Feedlot Runoff Control

There are six to eight livestock operations in the subwatershed drained by Minnesota County Ditch 11 which may be contributing runoff to Lake Hendricks. 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 at $27,000 to $30,000 for the construction of an Animal Waste Management System. A total cost of constructing animal waste systems on Minnesota County Ditch #11 is estimated at $240,000. Fecal coliform counts from Site HT-2 (Deer Creek) indicate the presence of animal waste contamination in the watershed. An inventory of the feedlots in the Deer Creek watershed needs to be completed. The results of this inventory will be used to develop project needs for future implementation.

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 to the greatest extent possible.

Shoreline Erosion Control

A shoreline erosion survey was conducted at Lake Hendricks as part of the 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 repairs, including backsloping, rip-rapping, and seeding is $20 per lineal foot for moderate erosion, and $25 per lineal foot for moderate/severe erosion.

A total of 1,195 feet of shoreline was found to have moderate erosion, and a total of 850 feet was found to have moderate/severe erosion. The estimated cost to repair these areas is as follows:

Erosion Category	Length(ft.)	Cost per ft.	Total
Moderate	1,195	$20	$23,900
Moderate/Severe	850	25	$21,250
Total Cost			$45,150

It is recommended that shoreline repairs for areas of moderate and moderate/severe erosion be undertaken over a two-year period. The estimated cost per year is $22,575. Areas of minor and minor/moderate erosion should be repaired as time and resources permit.

Sanitary District Establishment

The survey of septic systems around Lake Hendricks found that about 11% of the systems may be out of compliance with current construction standards. It is recommended that an effort be made to address the problem of potentially failing septic wastewater systems. The majority of the cabin development on the lakeshore is located in Lincoln County, Minnesota.

The possibility of extending the wastewater line from the city of Hendricks, Minnesota should be explored. Assistance in dealing with sanitary system issues may be obtained from the Minnesota Pollution Control Agency. Assistance may be available from other agencies such as county governments, watershed districts, or the city of Hendricks.

Lac Qui Parle River Channel Cleanout

In 1970 a sediment control structure was constructed on Deer Creek by the U.S. Soil Conservation Service. As a part of the project, the flow from the discharge pipe of the dam was diverted into the lake and the stream bed was channelized. Only the flow from the emergency spillway was directed down the south channel, away from the lake. Virtually all of the flow from the creek enters Lake Hendricks. One of the results of this project was increased volume of water to Lake Hendricks.

The aggradation of the outlet channel due to sediment, cattails, and debris restricts the discharge of the water at the outlet of Lake Hendricks. The retarded flow causes higher water levels in the lake which leads to shoreline erosion and a longer hydrologic retention time. These problems could be reduced by a cleanout of the outlet channel. If the outlet channel was restored, an improved flushing rate would be achieved and the shoreline erosion problems would be alleviated.

The City of Hendricks has obtained a permit from the Minnesota Department of Natural Resources for cleanout of the Lac Qui Parle River channel downstream from the Lake Hendricks outlet. A copy of the permit and other information concerning the channel cleanout are included as APPENDIX D, LAC QUI PARLE RIVER CHANNEL CLEANOUT.

Dredging

The sediment survey of Lake Hendricks completed by a consultant engineering firm indicated a total sediment volume of 22,594,000 cubic yards. Due to the inordinate volume of sediment in Lake Hendricks, whole lake dredging is not feasible. The capability of the equipment, volume of sediment, and cost of removing the sediment combine to make whole lake dredging infeasible.

The removal of sediment by selective dredging would improve the fisheries habitat of the lake, and enhance recreational opportunities. It is recommended that one million cubic yards of sediment be removed. 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 approximately fifteen to sixteen feet.

A comparison of the estimated costs and length of time required to dredge one million cubic yards of silt by use of two different sized dredges is shown below:

Dredge Size	Length of Time	Total Cost
8-inch	10 years	$2,000,000
10-inch	4 years	$1,200,000
14-inch	2 years	$1,000,000

Use of the 10-inch or 14-inch dredge is recommended, based on the reduced time and cost. However, it is also recommended that dredging not be implemented right away. This will provide an opportunity to reduce sediment loadings into the lake through shoreline and watershed restoration. It will also provide the

Lake Hendricks Association and other local entities the time required to secure the resources necessary for a major dredging project.

Cooperative Lake Restoration Project

Because Lake Hendricks is located on the border between South Dakota and Minnesota, it is recommended that a cooperative project be initiated to implement restoration alternatives. The implementation project will require the cooperation of the two states and their respective U.S. Environmental Protection Agency regional offices.

As part of the cooperative project, implementation of the following restoration activities is recommended:

1. Development of an information/education program to promote best management practices, including Integrated Crop Management, in the Lake Hendricks watershed.

2. Evaluation of feedlots in the Lake Hendricks watershed by use of a feedlot runoff model to determine feedlots which require assistance in the development of runoff control. A cost-sharing program should be established to assist in the construction of animal waste management systems.

3. Areas of the lake shoreline with moderate and moderate/severe erosion should be surveyed, and plans developed for reconstruction and repair.

4. Coordination of local efforts to control disposal of wastewater from failing septic systems.

5. Coordination of local efforts to secure funding for dredging of Lake Hendricks.

6. Coordination of cleanout of the Lac Qui Parle River channel.

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APPENDIX A. LAKE HENDRICKS IN-LAKE WATER QUALITY

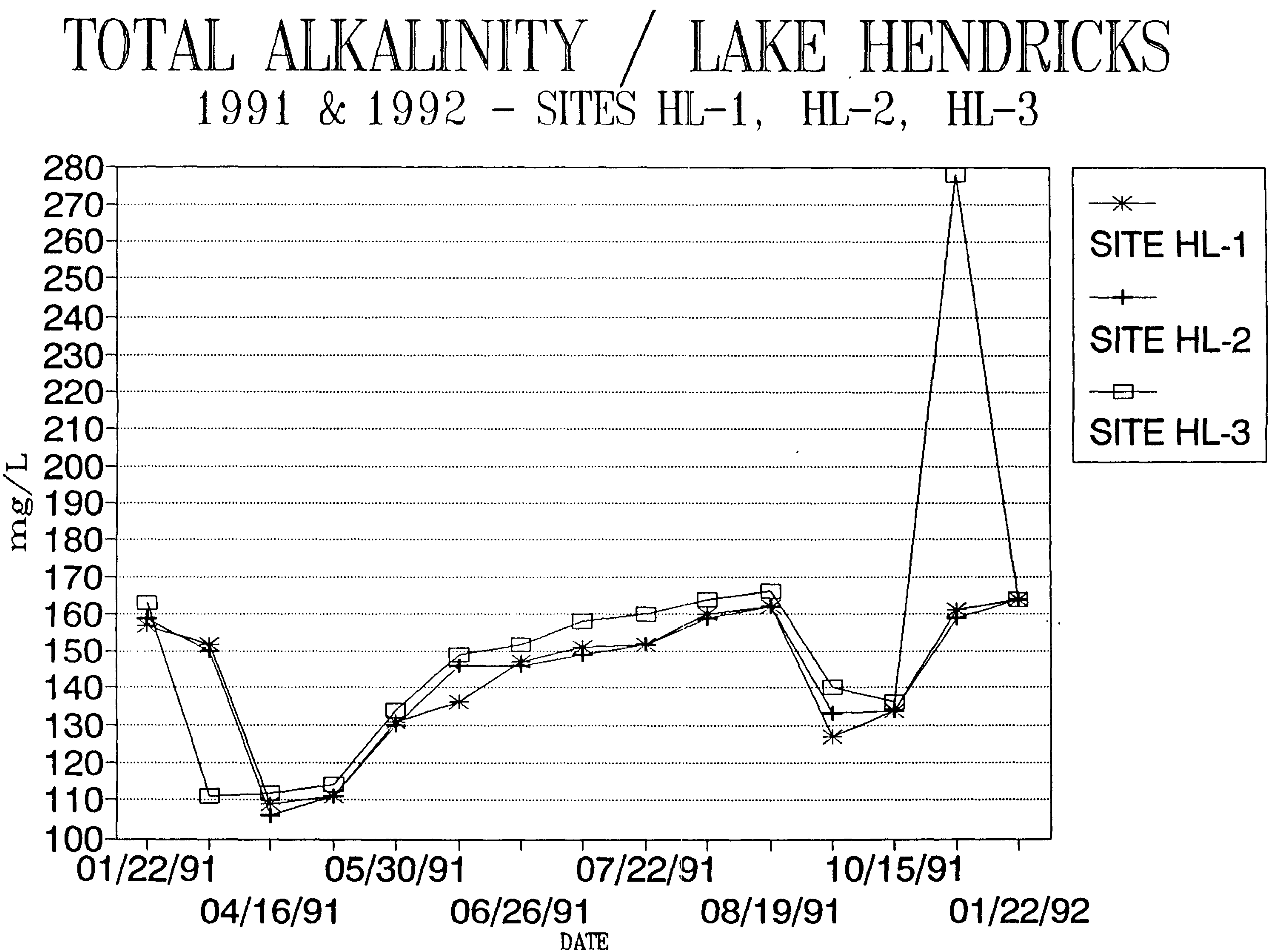

TOTAL ALKALINITY / LAKE HENDRICKS
1991 & 1992 - SITES HL-1, HL-2, HL-3
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
mg/L
01/22/91
04/16/91
05/30/91
06/26/91
07/22/91
08/19/91
10/15/91
01/22/92
DATE
SITE HL-1
SITE HL-2
SITE HL-3

Figure A-1.

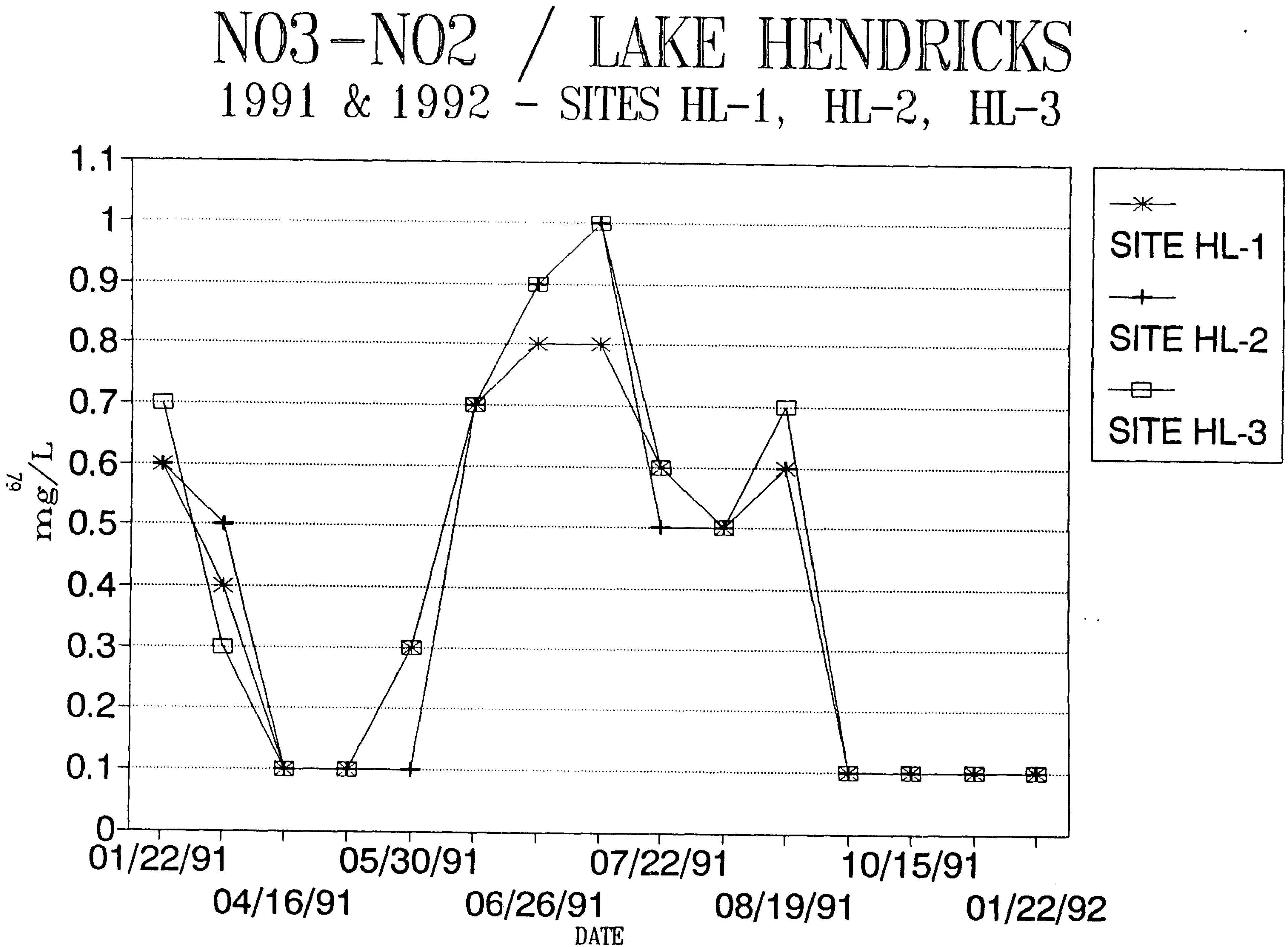

NO3-NO2 / LAKE HENDRICKS
1991 & 1992 - SITES HL-1, HL-2, HL-3
mg/L
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
01/22/91
04/16/91
05/30/91
06/26/91
07/22/91
08/19/91
10/15/91
01/22/92
DATE
SITE HL-1
SITE HL-2
SITE HL-3

Figure A-2.

TOTAL KJELDAHL NITROGEN/LAKE HENDRICKS
1991 & 1992 - SITES HL-1, HL-2, HL-3

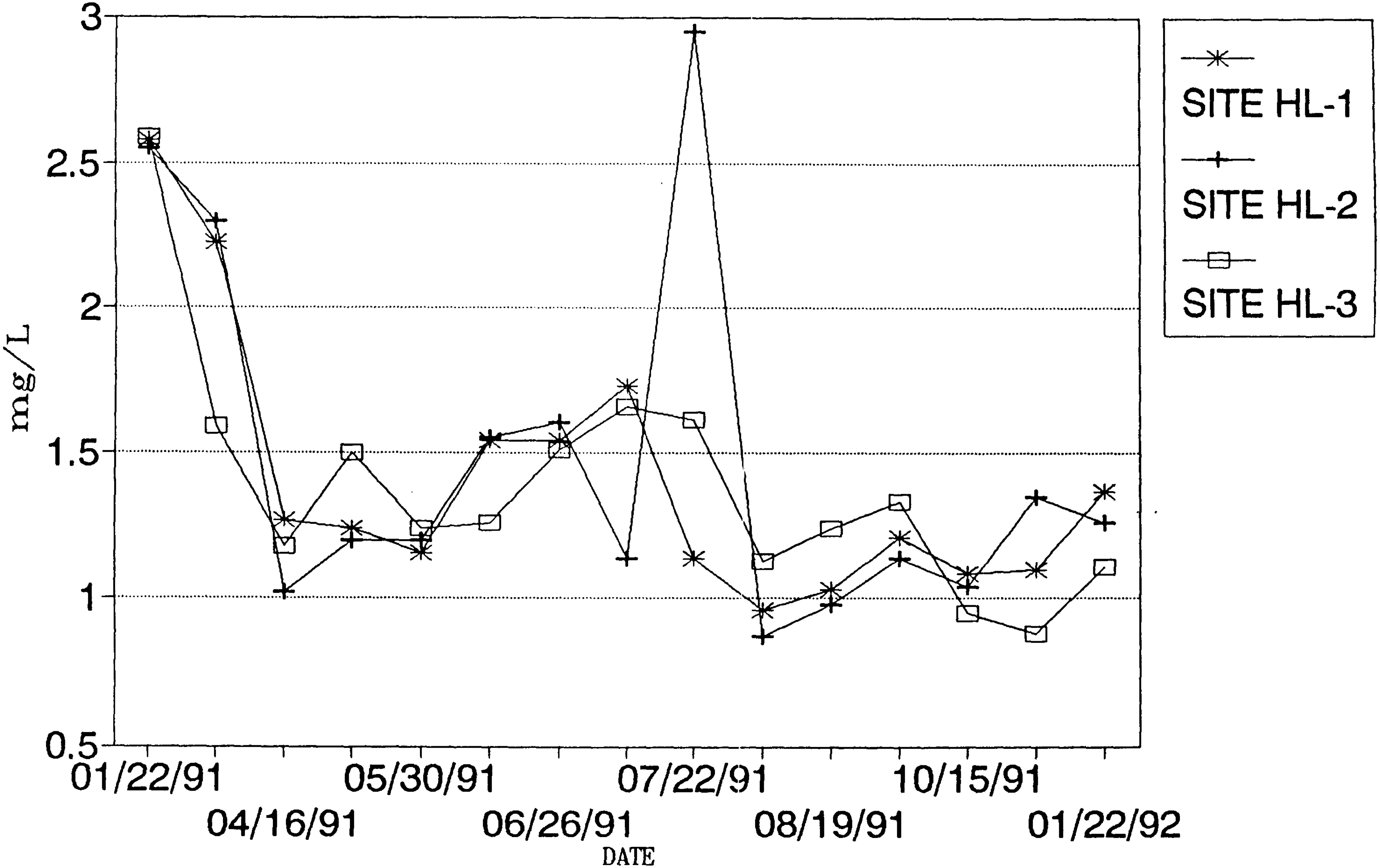


Figure A-3.

TOTAL NITROGEN / LAKE HENDRICKS
1991 & 1992 - SITES HL-1, HL-2, HL-3

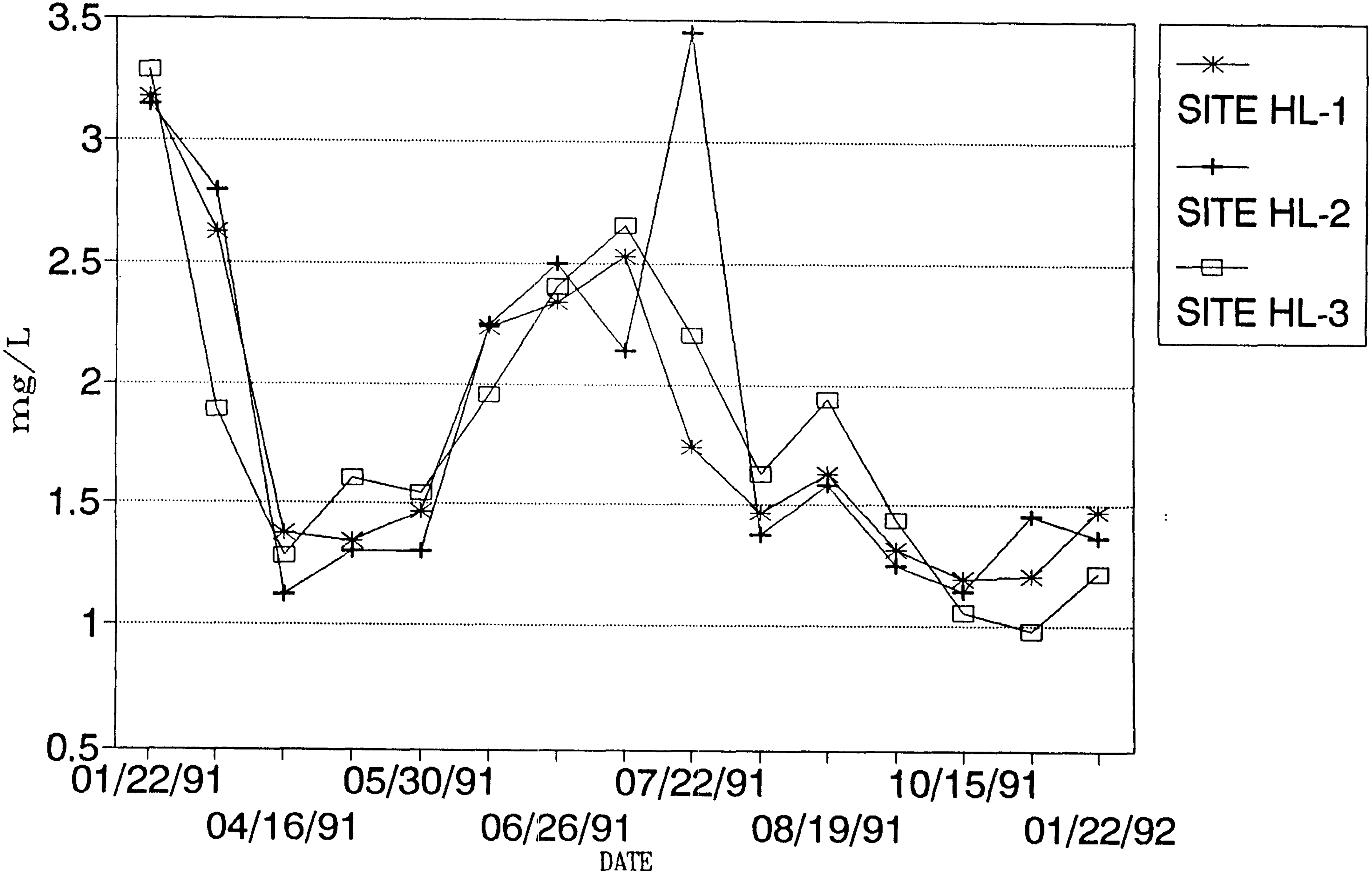
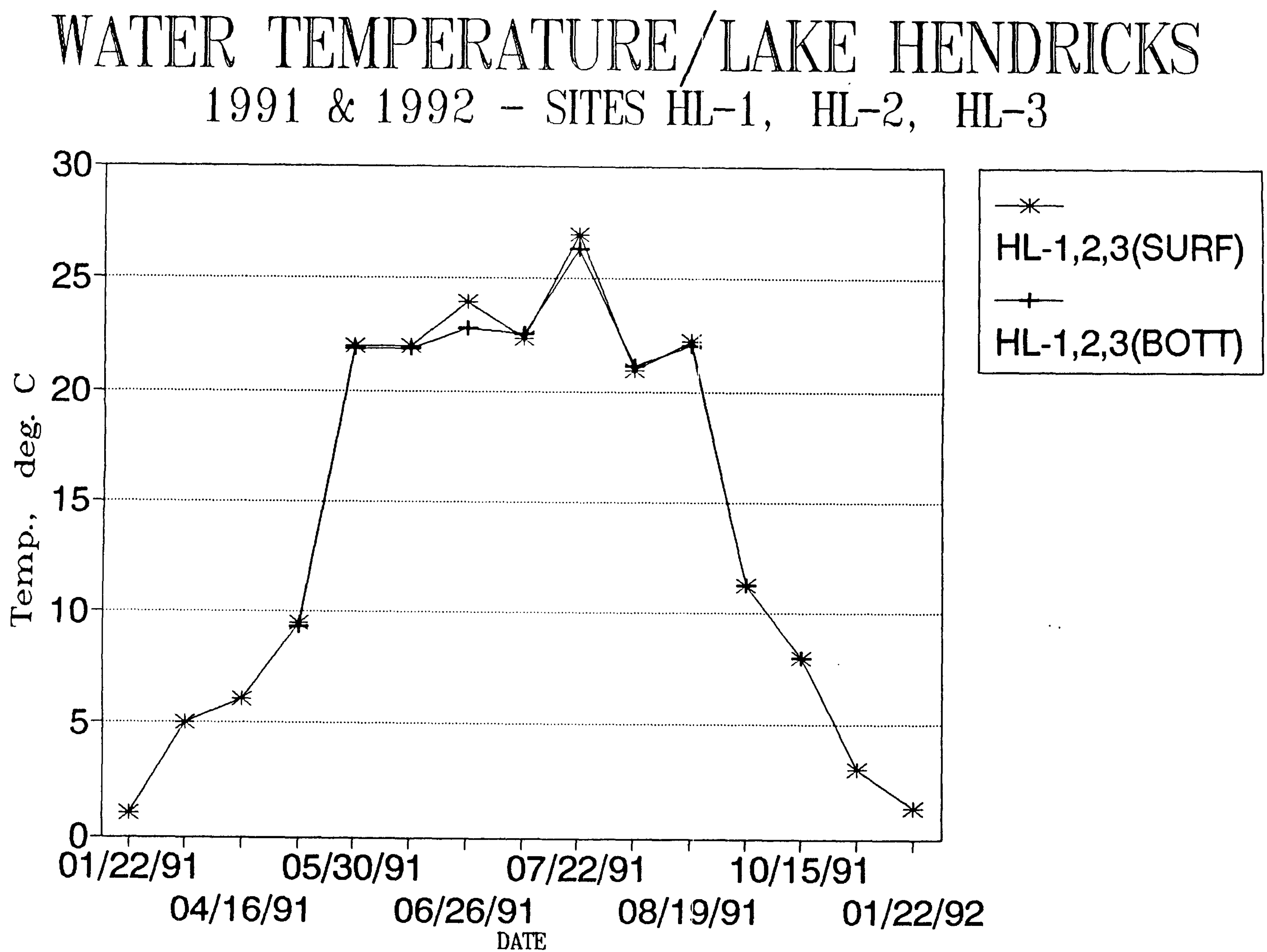


Figure A-4.



WATER TEMPERATURE/LAKE HENDRICKS
1991 & 1992 - SITES HL-1, HL-2, HL-3
30
25
20
15
10
5
0
Temp., deg. C
01/22/91
04/16/91
05/30/91
06/26/91
07/22/91
08/19/91
10/15/91
01/22/92
DATE
HL-1,2,3(SURF)
HL-1,2,3(BOTT)

Figure A-5.

VOLATILE SUSPEND. SOLIDS/LAKE HENDRICKS

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

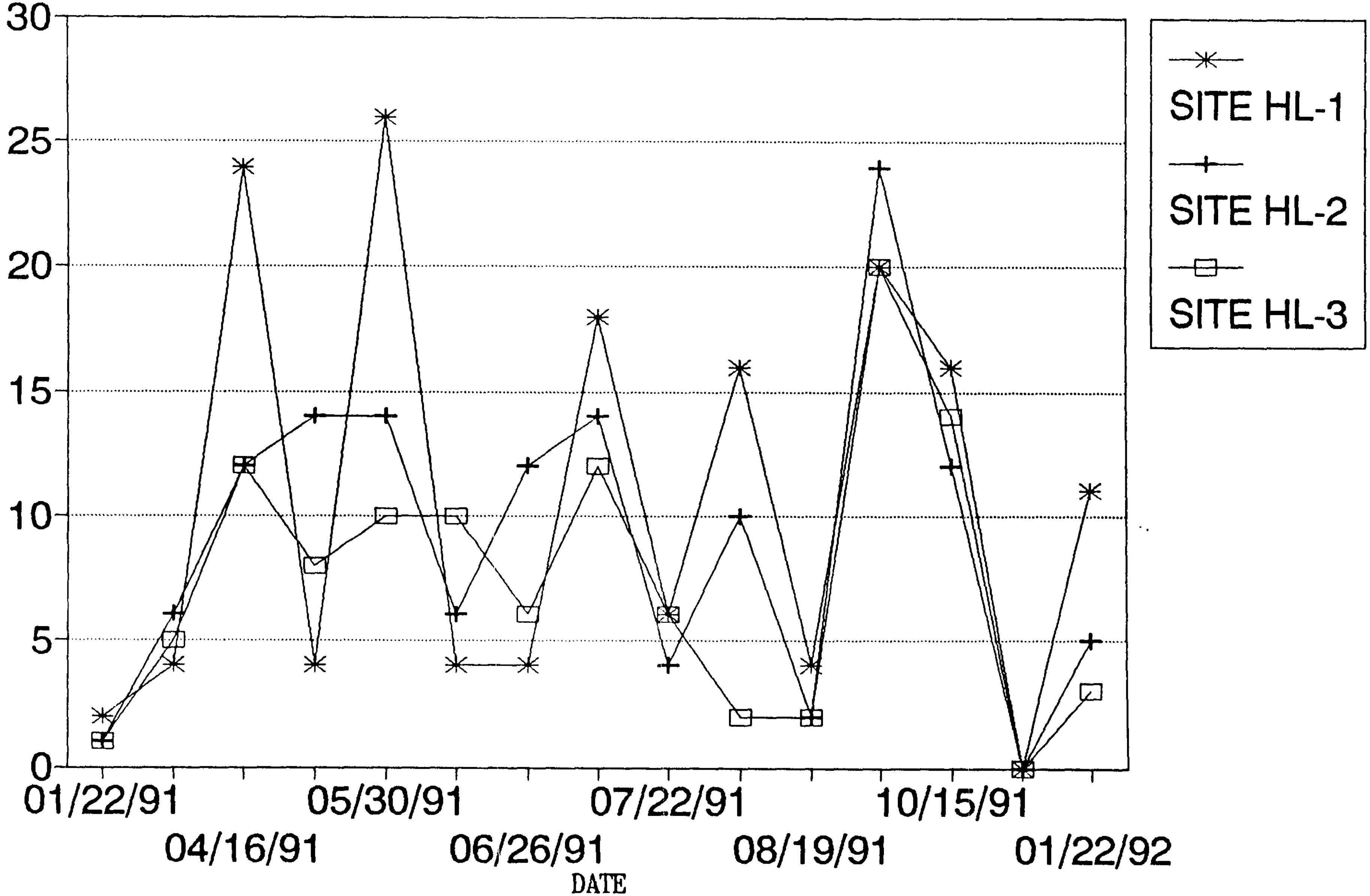


Figure A-6.

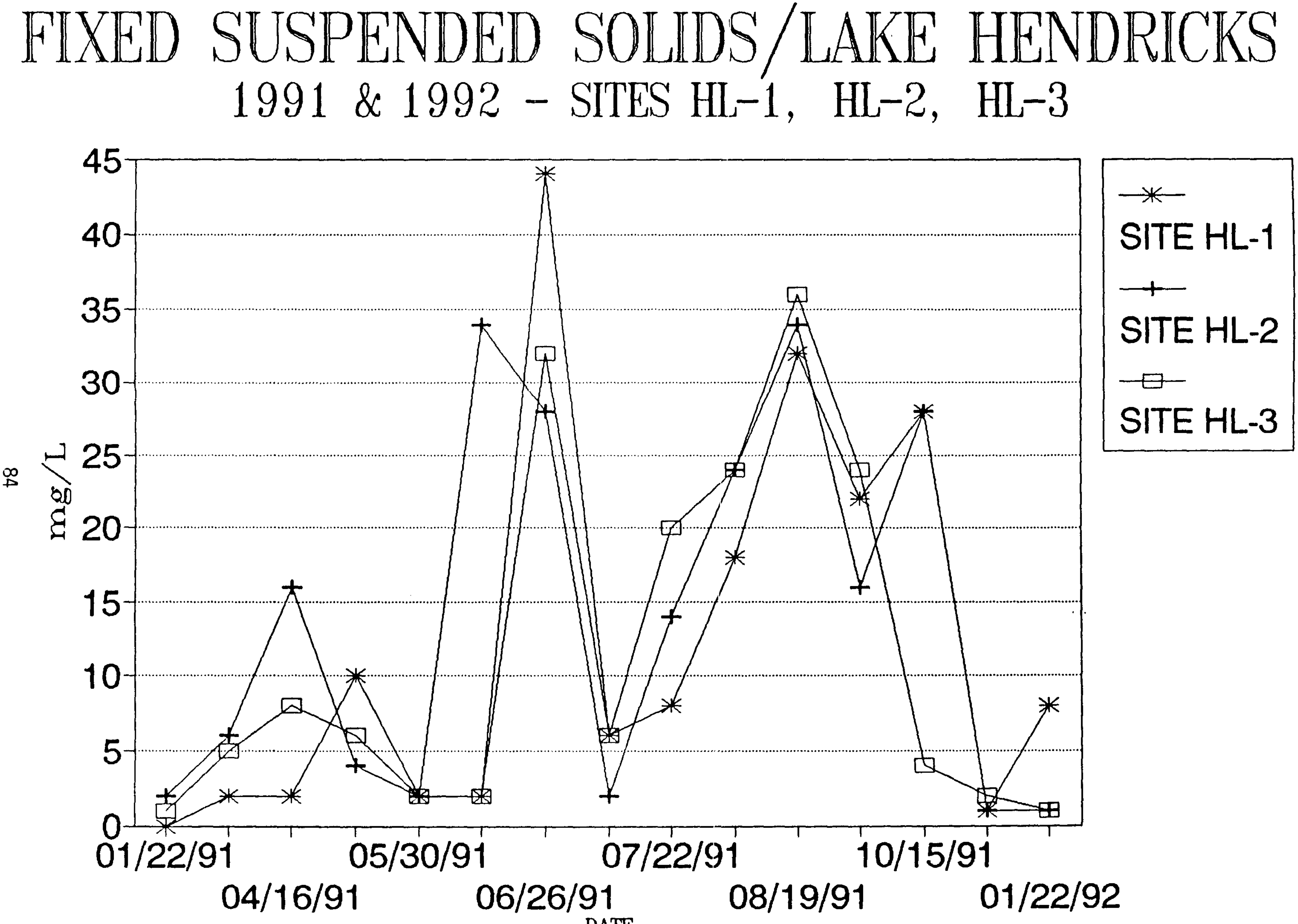

FIXED SUSPENDED SOLIDS/LAKE HENDRICKS
1991 & 1992 - SITES HL-1, HL-2, HL-3
mg/L
45
40
35
30
25
20
15
10
5
0
01/22/91
04/16/91
05/30/91
06/26/91
07/22/91
08/19/91
10/15/91
01/22/92
DATE
SITE HL-1
SITE HL-2
SITE HL-3

Figure A-7.

TOTAL SOLIDS / LAKE HENDRICKS

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

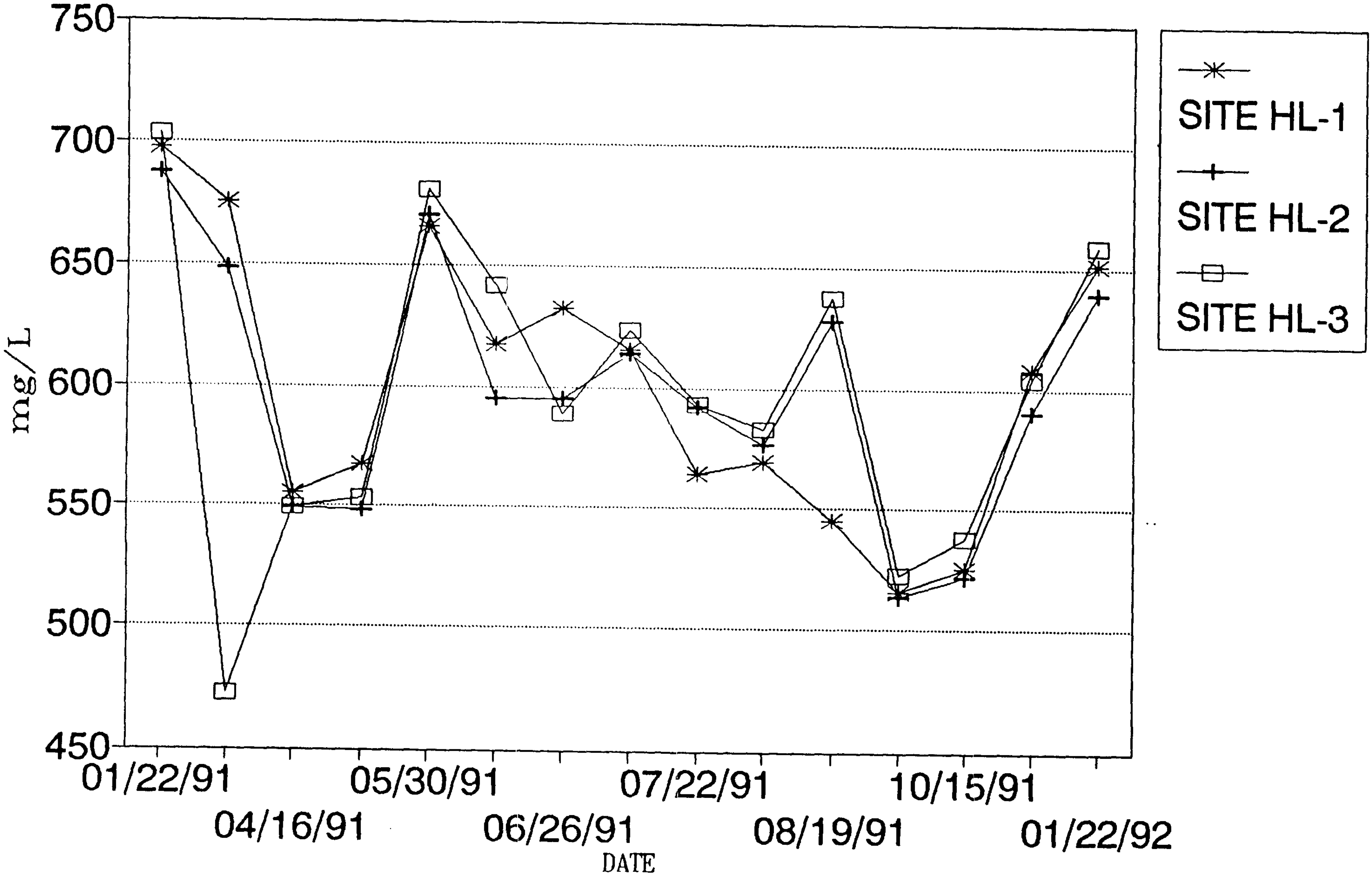
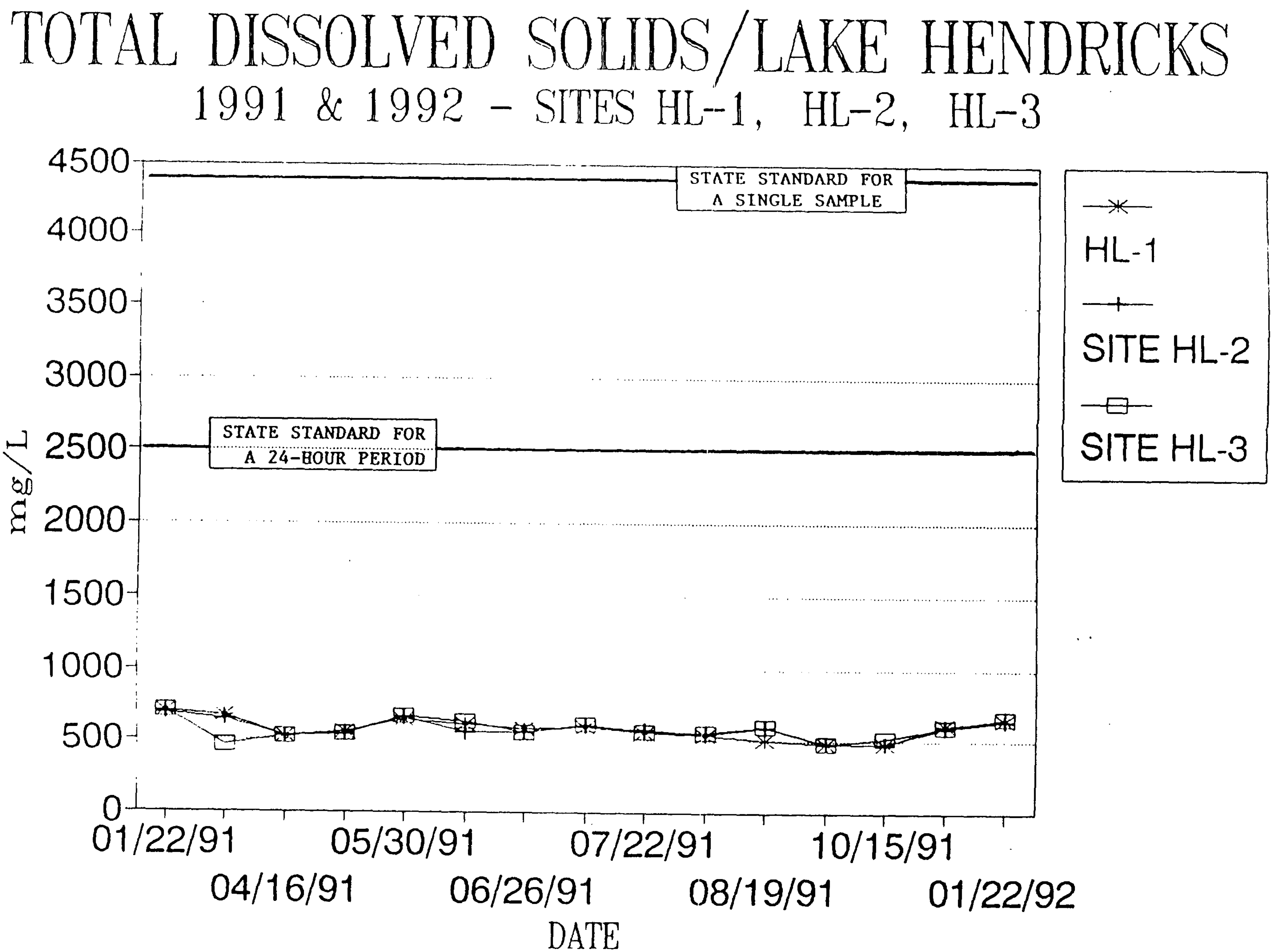


Figure A-8.



TOTAL DISSOLVED SOLIDS/LAKE HENDRICKS
1991 & 1992 - SITES HL--1, HL-2, HL-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
HL-1
SITE HL-2
SITE HL-3
01/22/91
04/16/91
05/30/91
06/26/91
07/22/91
08/19/91
10/15/91
01/22/92
DATE

Figure A-9

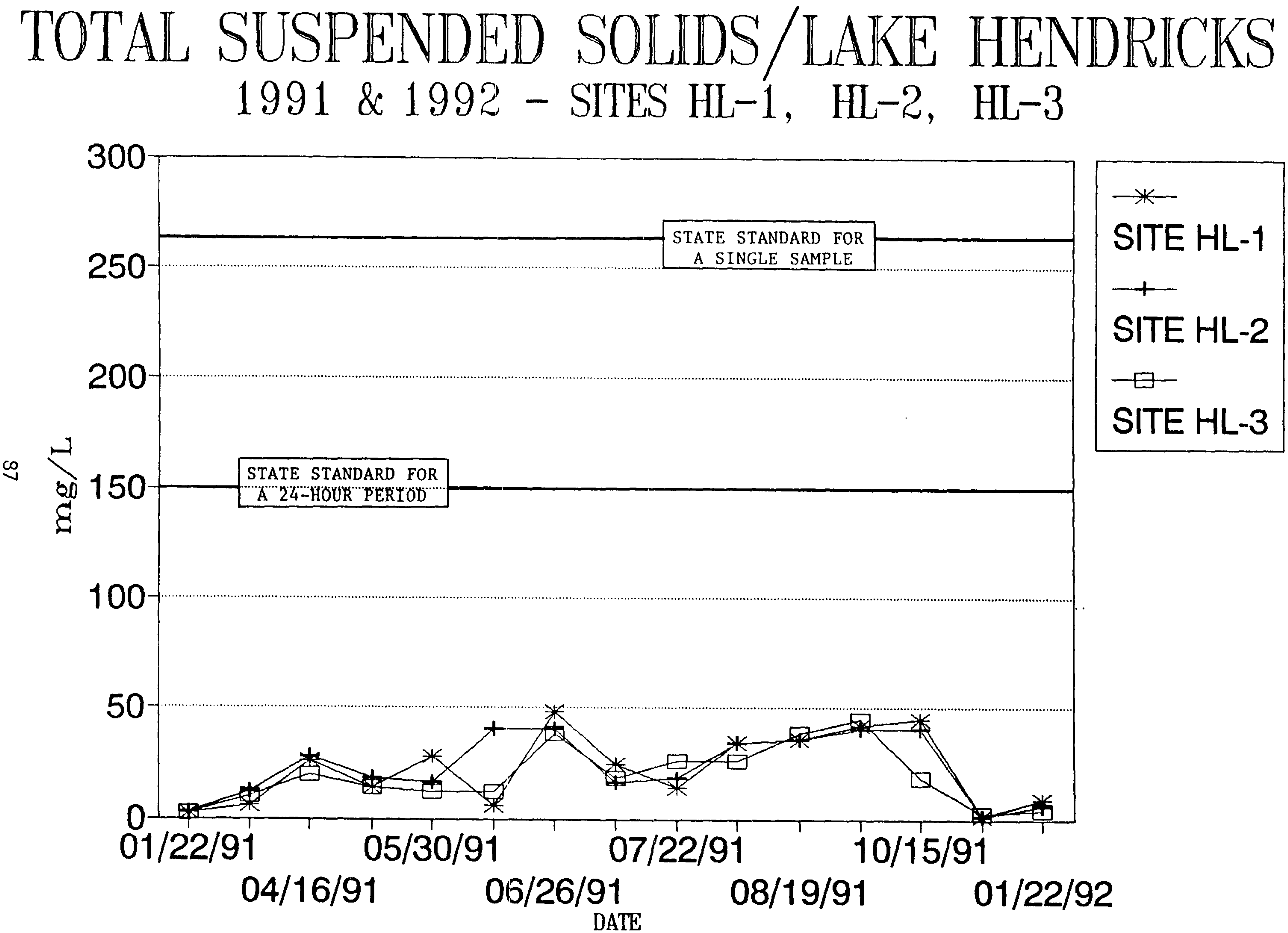

TOTAL SUSPENDED SOLIDS/LAKE HENDRICKS
1991 & 1992 - SITES HL-1, HL-2, HL-3
300
250
200
150
100
50
0
mg/L
STATE STANDARD FOR A SINGLE SAMPLE
STATE STANDARD FOR A 24-HOUR PERIOD
SITE HL-1
SITE HL-2
SITE HL-3
01/22/91
04/16/91
05/30/91
06/26/91
07/22/91
08/19/91
10/15/91
01/22/92
DATE

Figure A-10.

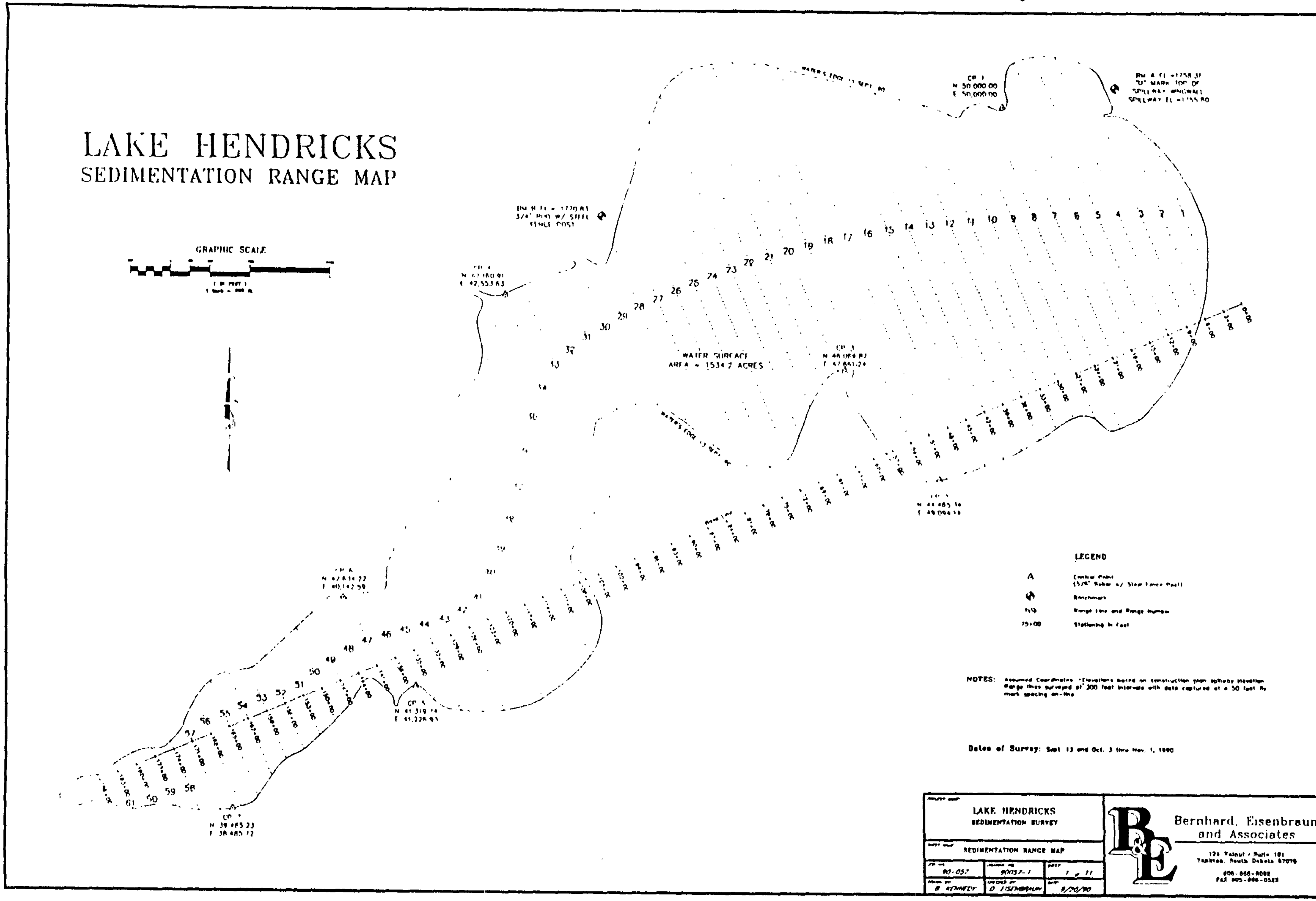

LAKE HENDRICKS
SEDIMENTATION RANGE MAP
GRAPHIC SCALE
WATER SURFACE
AREA = 1534.2 ACRES
LEGEND
NOTES:
Dates of Survey: Sept 13 and Oct. 3 thru Nov. 1, 1990
LAKE HENDRICKS
SEDIMENTATION SURVEY
SEDIMENTATION RANGE MAP
Bernhard, Eisenbraun
and Associates

Figure B-1.

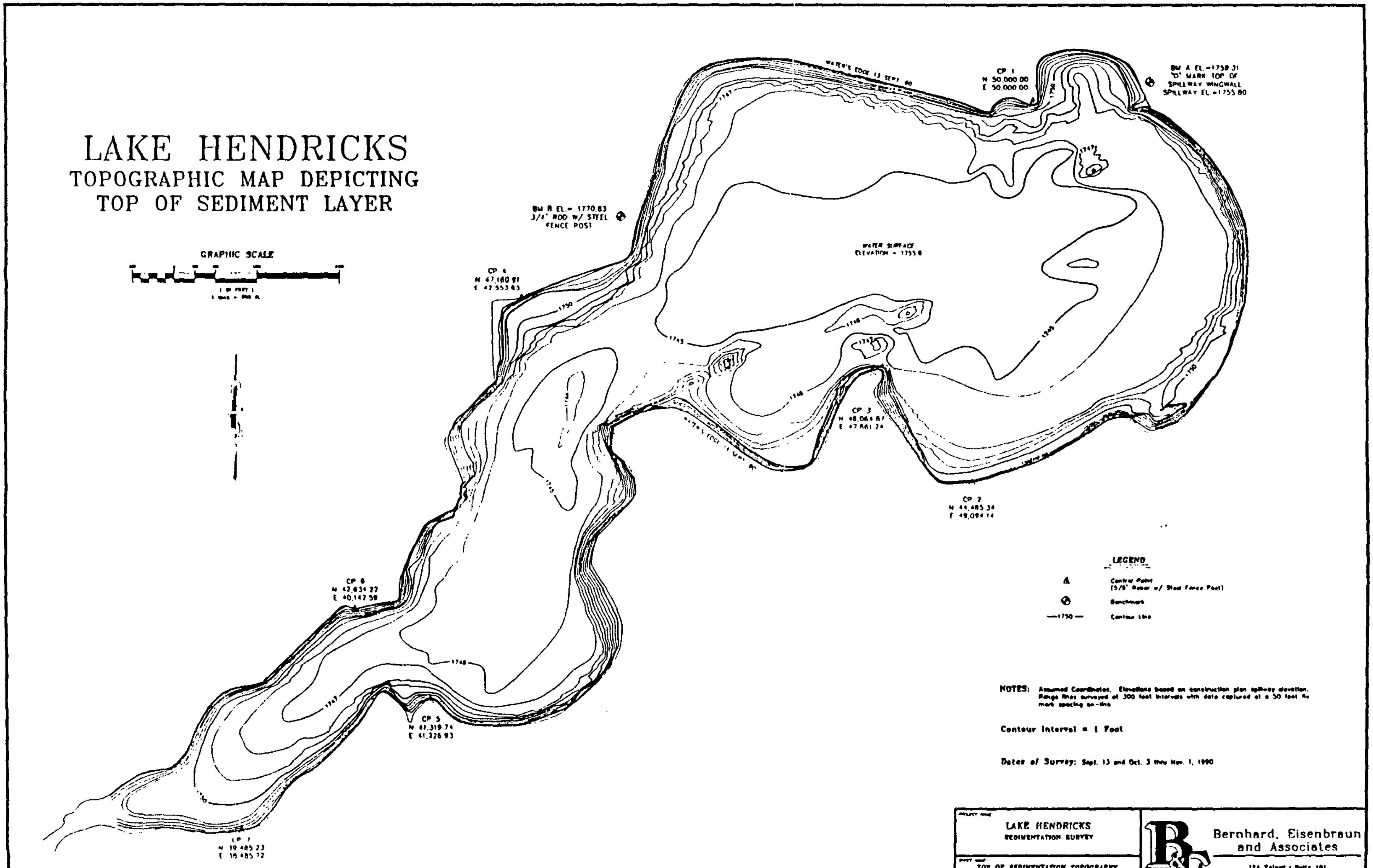

LAKE HENDRICKS
TOPOGRAPHIC MAP DEPICTING
TOP OF SEDIMENT LAYER
GRAPHIC SCALE
BM B EL.= 1770.83
3/4" ROD W/ STEEL
FENCE POST
CP 4
N 47,160.91
E 42,553.83
CP 1
N 50,000.00
E 50,000.00
BM A EL.=1758.31
"O" MARK TOP OF
SPILLWAY WINGWALL
SPILLWAY EL.=1755.80
WATER SURFACE
ELEVATION = 1755.8
CP 3
N 48,064.87
E 47,861.24
CP 2
N 44,485.34
E 49,094.14
CP 6
N 42,634.22
E 40,142.59
CP 5
N 41,319.74
E 41,226.93
CP 7
N 39,485.23
E 39,485.72
LEGEND
Control Point
(5/8" Rebar w/ Steel Fence Post)
Benchmark
—1750— Contour Line
NOTES: Assumed Coordinates. Elevations based on construction plan spillway elevation. Range lines surveyed at 300 foot intervals with data captured at a 50 foot fix mark spacing on-line
Contour Interval = 1 Foot
Dates of Survey: Sept. 13 and Oct. 3 thru Nov. 1, 1990
LAKE HENDRICKS
SEDIMENTATION SURVEY
TOP OF SEDIMENTATION TOPOGRAPHY
90-037
90037-2
2 of 11
J. ARENS
D. EISENBRAUN
12/06/90
Bernhard, Eisenbraun
and Associates

Figure B-2.

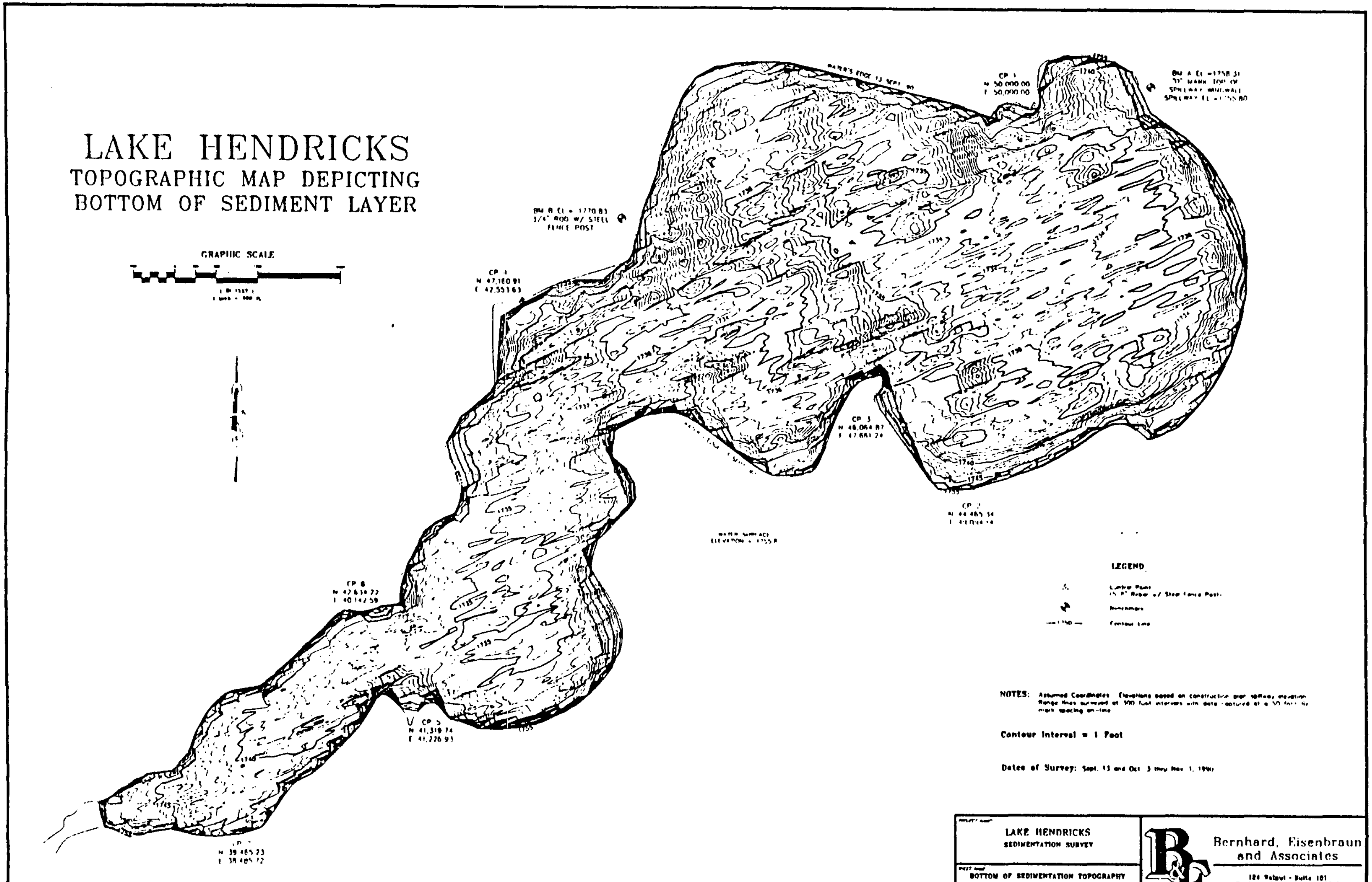

LAKE HENDRICKS
TOPOGRAPHIC MAP DEPICTING
BOTTOM OF SEDIMENT LAYER
GRAPHIC SCALE
CP 1
N 50,000.00
E 50,000.00
CP 3
N 46,064.87
E 47,881.24
CP 5
N 41,319.74
E 41,276.93
CP 8
N 42,634.22
E 40,142.59
LEGEND
Benchmark
Contour Line
NOTES:
Contour Interval = 1 Foot
LAKE HENDRICKS
SEDIMENTATION SURVEY
BOTTOM OF SEDIMENTATION TOPOGRAPHY
90-057
12/10/90
Bernhard, Eisenbraun
and Associates

Figure B-3.

Table C-1.

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

Table C-2.

Aquatic/Emergent Plants Possibly Occurring in Lake Hendricks and Watershed

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

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

Table C-3.

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

Table C-4.

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

Table C-5.

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

Table C-6.

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
Eastren 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

Table C-7.

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

Table C-8.

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

APPENDIX D. LAC QUI PARLE RIVER CHANNEL CLEANOUT

SOUTH DAKOTA MINNESOTA

LHIA

Lake Hendricks Improvement Association, Inc.

MAILING ADDRESS: P.O. BOX 161, HENDRICKS, MINNESOTA 56136

June 25, 1992

Mr. Ken Madison, Natural Resources Scientist
State of South Dakota Dept of Environment
and Natural Resources
913 5th Street S.E.
Watertown, SD 57201-3641

Re: Phase One Diagnostic/Feasability Study, Lake Hendricks

Dear Ken:

We thank you for your preliminary review of the Phase One Study at our Lake Hendricks Improvement Association annual meeting June 13, 1992. One point however that did not get covered is the proposal to evacuate approximately one mile of the Lac Qui Parle River bottom to improve the outflow of Lake Hendricks that would result in much less erosion that is taking place along the shore lines.

This subject is covered in considerable detail in correspondence between the City of Hendricks and the Department of Natural Resources in Minnesota. As noted, no action has been taking because the parties involved have been waiting for the Phase One Study. The main point is that Minnesota DNR has given permission for evacuation and financial resources must be obtained before work can begin. We look for such support and recommendations in your Phase One Report to the South Dakota Department of Environment and Natural Resources and to the Federal Enviromental Protection Agency in Denver.

Please refer to attached correspondence:

May 24, 1990	Lake Hendricks Outlet Study, MN Ditch #55 by LHIA
Oct 3, 1990	T.W. Reeves to J.R. Lewis, Re: Application of the City of Hendricks App # 89-3028
Oct 11, 1990	J.R.Lewis to T.W.Reeves, Re: Compromise Proposal of Oct. 3, 1990
Oct 27, 1990	T.W.Reeves to A.W.Clapp III, Re: In the Matter of City Of Hendricks Application...etc.
Nov 14, 1990	T.W.Reeves to A.W.Clapp III Re: In the Matter of City of Hendricks Application..etc. Addressed also to J.R.Lewis

Nov 30, 1990 R.Nyberg to H. Buchholz, Re: Limited Permit #89-4028, Lac Qui Parle River

Please keep in mind the permit for evacuation work expires Sept 1, 1995.

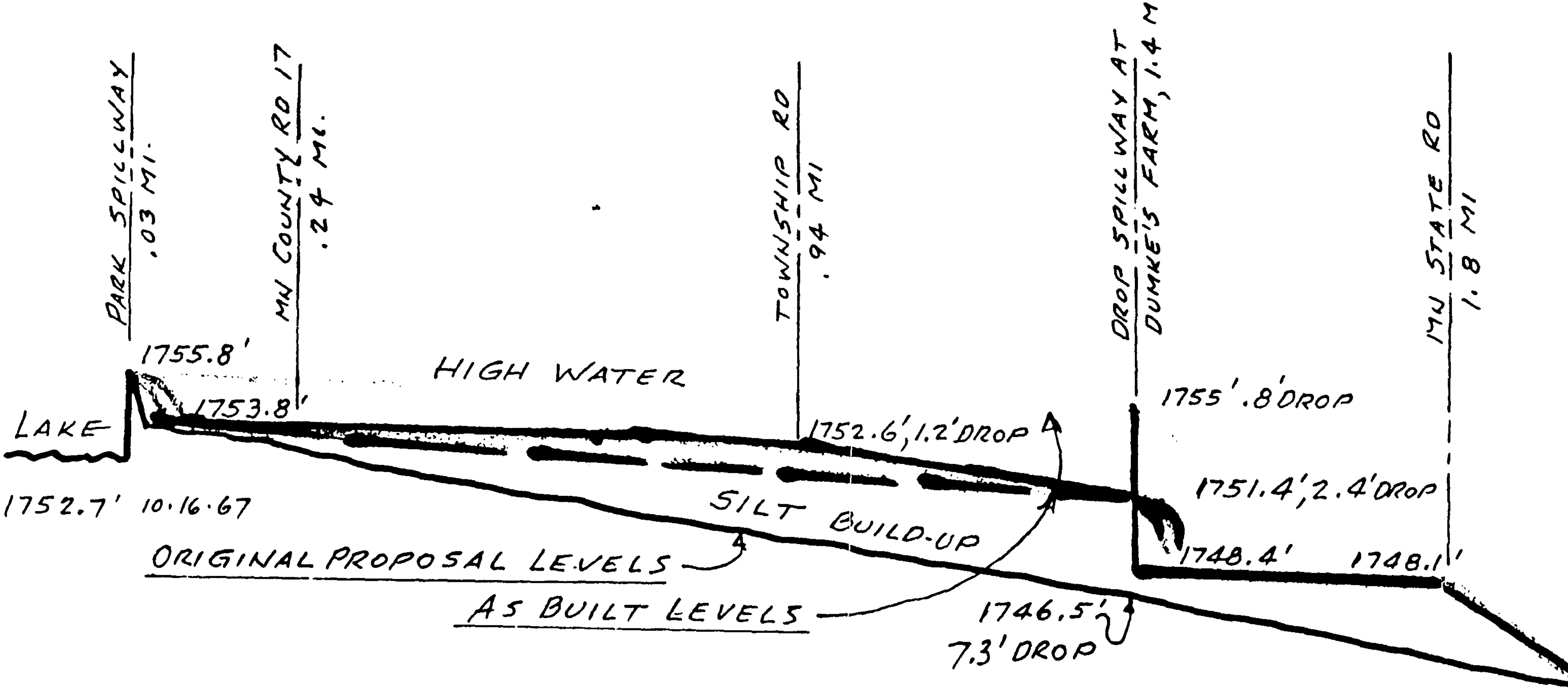
Your attention to this matter will be appreciated. Remember too permission has finally been obtained to evacuate silt only after many years of concern by the City of Hendricks and Lake land owners in addition to all those in the area involved with the future of the Lake.

Very truly yours,

J. Walter Dawson

J. Walter Dawson, LHIA Board

cc:S. Hemmingsen, Pres
A. Graslie, Secty
H. Buchholz, Mayor
T.W.Reeves, Atty



LAKE HENDRICKS OUTLET STUDY

MN DITCH # 55

BASED ON U.S. DEPT. OF AGRICULTURE
SOIL CONSERVATION SERVICE PLANS
AND MDNR READINGS.
LHIA – J.W. DAWSON. MAY 2[illegible] 199[illegible]

Figure D-1

THOMAS W. REEVES
ATTORNEY AT LAW
BOX 6
HENDRICKS, MINNESOTA 56136
TELEPHONE 507-275-3105

October 3, 1990

Mr. Jeffrey R. Lewis
Area Hydrologist
Minnesota Department of Natural Resources
P.O. Box 111
1400 East Lyon
Marshall, MN 56258

Re: Application of the City of Hendricks
App #89-3028

Dear Mr. Lewis:

Monday night I met with the City Council for Hendricks to discuss the hearing on October 30, 1990. A compromise was discussed to try and resolve the issue over the City's Permit Application dated 7/14/88 and revision dated 9/25/89 to excavate a channel for the outlet of Lac Qui parle and install a variable control structure on the completed Upper Deer Creek-Lake Hendricks Watershed Protection and Flood Prevention project.

The City has authorized me to propose this as a compromise:

1. Instead of the deepening and widening of the channel and a variable control structure as proposed by the City, the City be permitted to excavate this channel 18 feet wide at bottom to the original grade as shown in the project detail plans "as built" and completed August 15, 1975.

2. The City be permitted to lower the elevation of the wier crest of the drop structure at station 73 + 50 from 1,751.40 feet to 1,750.8 feet or to original grade whichever is lowest.

3. That DNR not be required to pay the cost of the permitted work.

4. That both parties recognize a comprehensive study of Lake Hendricks is ongoing and this study will consider and make recommendations about the outlet of Lake Hendricks to the Lac Qui Parle River which may be part of the basis for a later application of the City.

5. That the City have 5 years until October 30, 1995 to complete the permitted work.

This proposal is a compromise and recognizes the interests of both parties. The project "as built" left the original channel in place through DNR's property and part of the channel on land to the north. This channel is filling with silt which does obstruct the flow of water as observed by both parties. All that is intended is to clear the channel and take out the silt.

The City realizes it may have to get permission of other agencies and land owners not parties to this agreement, too.

Provision #1 about the profile of the channel is consistent with the profile of typical ditch section in the "as built" plans. Since there must be some definition of how wide the channel work can be this seems reasonable because it matches the work done downstream.

We are assuming the excavation would remove approximately 1 foot of sediment or slightly less based upon measurements by DNR in 1988.

Please review this and advise as to DNR's position as the City wants to resolve this at a pre-hearing conference without the time and expense of a hearing, if possible.

Very truly yours,

Thomas W. Reeves.
City Attorney
City of Hendricks, MN

cf: Mr. A.W. Clapp III
Special Assistant Attorney General
State of Minnesota
Office of the Attorney General
102 State Capitol
St. Paul, MN 55155

STATE OF
MINNESOTA
DEPARTMENT OF NATURAL RESOURCES
PO BOX 111, 1400 EAST LYON ST., MARSHALL, MN 56258
PHONE NO.
(507) 537-7258

Celebrate MINNESOTA 1990

FILE NO.

October 11, 1990

Mr. Thomas W. Reeves
City Attorney
PO Box 6
Hendricks, MN 56136

Dear Mr. Reeves:

SUBJECT: COMPROMISE PROPOSAL OF OCTOBER 3, 1990

We appreciate your willingness to attempt to come to some type of agreement regarding the outlet of Lake Hendricks. We agree with most of the items you proposed in your letter of October 3, 1990. The only item we do not agree with is Number 2. We are opposed to the lowering of the crest of the weir at Station 73+50. This elevation was chosen to preserve the wetlands that existed prior to the project and still do exist between this drop structure and the lake.

We would agree to widening of the weir at the crest elevation of 1751.40 so that the drop structure is wider at this elevation. At the present time, the drop structure is only 3'3" wide at elevation 1751.40, and steps up in 0.5' elevation increments as you go laterally along this structure. We would recommend cutting off the next four sheet pile panels on each side of the center notch. This would give you a weir crest length of approximately 16 feet at elevation 1751.4. This would greatly increase the capacity of this structure to discharge water without water impounding behind it.

The existing channel grade does go up and down quite a bit. We would suggest that the channel from the drop structure at Station 73+50 to the bottom of the culverts at Station 49+50 be dug slightly undercut. We would recommend the channel be dug about one foot below a grade line from the drop structure to the township road culverts. The channel should probably be wider than the 18' you suggest because this channel will not have much slope. The new channel should follow the existing alignment. We would suggest that the channel be about 24 feet wide. The next section of channel from this road crossing upstream to CSAH 17 crossing will have even less slope to it. This section of channel should also be about 24 feet wide. We would again recommend that this reach be undercut about one foot. The last section, from CSAH 17 upstream to the apron on the downstream side of the Lake Hendricks dam can be slightly narrower. This part of the channel has more slope to it. We would suggest this part of the channel have about an 18' foot bottom width.

We believe that cleaning this channel as we propose will significantly lessen the water impounded between CSAH 17 and the dam on Lake Hendricks. This channel will not

Mr. Thomas W. Reeves
October 11, 1990
Page 2

significantly harm the wetland areas between CSAH 17 and the drop structure at Station 73+50. The area upstream of CSAH 17 appeared to be the area of most concern to the city. [illegible] upstream [illegible] 73+50

We also will require that the material excavated from this channel cleaning be hauled away and deposited in upland areas. We do not want this material to be sidecast and left in the wetland areas. Removal of the accumulated materials to upland areas will also allow your organization to avoid the need to obtain a permit from the U.S. Army Corps of Engineers.

We feel that this approach will improve flow characteristics through this area. This channel has never been maintained and with the placement of additional obstructions, such as the rock crossing that was located at Station 64, flow conditions definitely have degraded since 1967. We hope that this approach could be tried and if, in the future, conditions do not improve we could then re-evaluate our decisions.

Sincerely,

DIVISION OF WATERS

Jeffrey R. Lewis

Jeffrey R. Lewis
Area Hydrologist

jgl

c: Bill Clapp
Ray Nyberg
Bob Meyer
Ken Varland

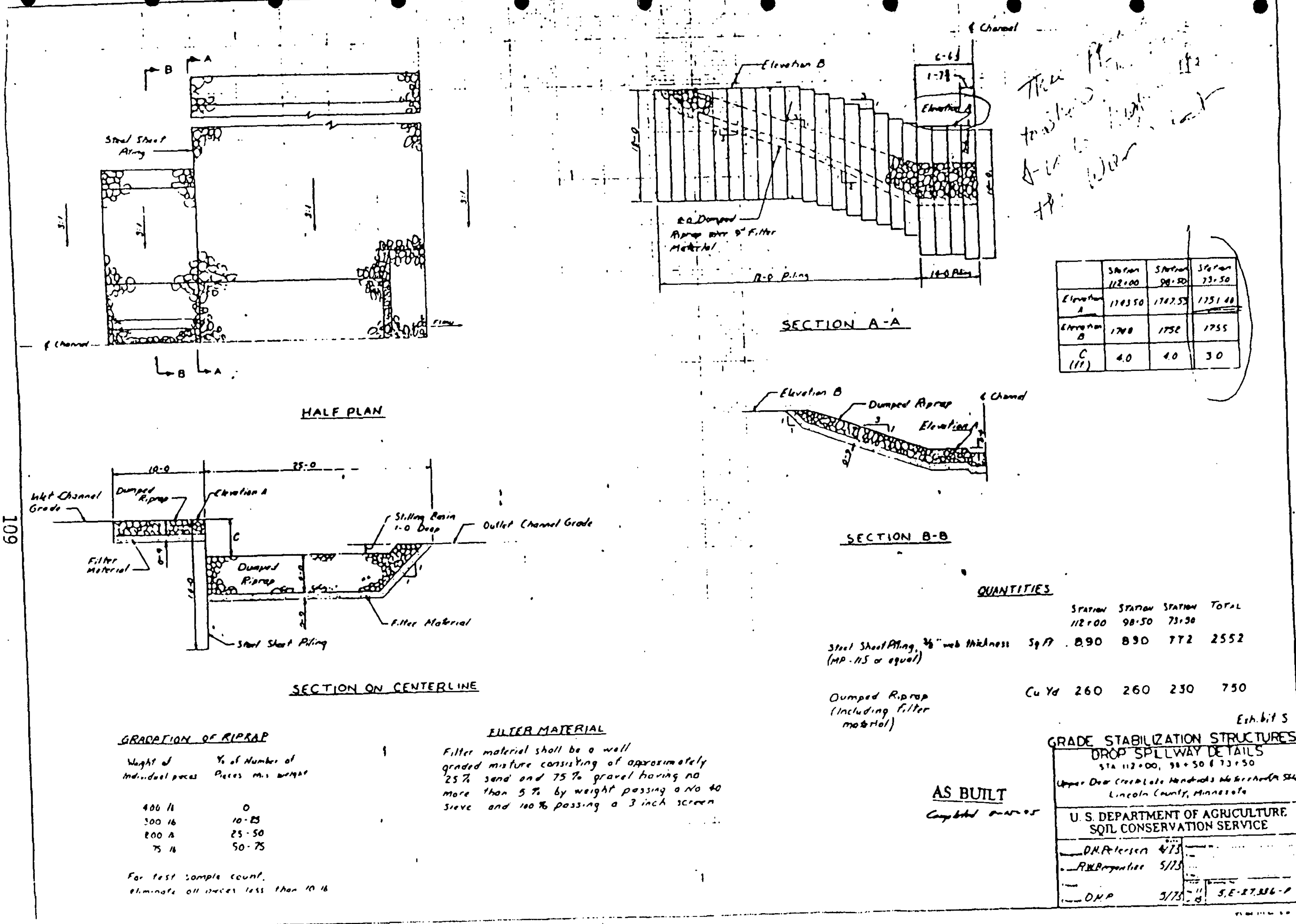

HALF PLAN
Steel Sheet Piling
℄ Channel
Flow
3:1
SECTION ON CENTERLINE
Inlet Channel Grade
Dumped Riprap
Elevation A
Filter Material
Dumped Riprap
Stilling Basin 1-0 Deep
Outlet Channel Grade
Filter Material
Steel Sheet Piling
10-0
25-0
C
SECTION A-A
℄ Channel
Elevation B
Elevation A
R-0 Dumped Riprap over 9" Filter Material
R-0 Piling
14-0 Piling
SECTION B-B
Elevation B
Dumped Riprap
℄ Channel
Elevation A
Station 112+00 | Station 98+50 | Station 73+50
Elevation A | 1183.50 | 1747.55 | 1751.40
Elevation B | 1748 | 1752 | 1755
C (ft) | 4.0 | 4.0 | 3.0
QUANTITIES
Station 112+00 | Station 98+50 | Station 73+50 | Total
Steel Sheet Piling, 3/8" web thickness (MP-115 or equal) | Sq Ft | 890 | 890 | 772 | 2552
Dumped Riprap (Including filter material) | Cu Yd | 260 | 260 | 230 | 750
GRADATION OF RIPRAP
Weight of individual pieces | % of Number of Pieces min weight
400 lb | 0
300 lb | 10-25
200 lb | 25-50
75 lb | 50-75
For test sample count, eliminate all pieces less than 10 lb
FILTER MATERIAL
Filter material shall be a well graded mixture consisting of approximately 25% sand and 75% gravel having no more than 5% by weight passing a No 40 sieve and 100% passing a 3 inch screen
AS BUILT
Exhibit 5
GRADE STABILIZATION STRUCTURES
DROP SPILLWAY DETAILS
STA 112+00, 98+50 & 73+50
Lincoln County, Minnesota
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
D.H. Petersen 4/75
5/75
D.H.P. 5/75
5-E-27,386-P

Figure D-2.

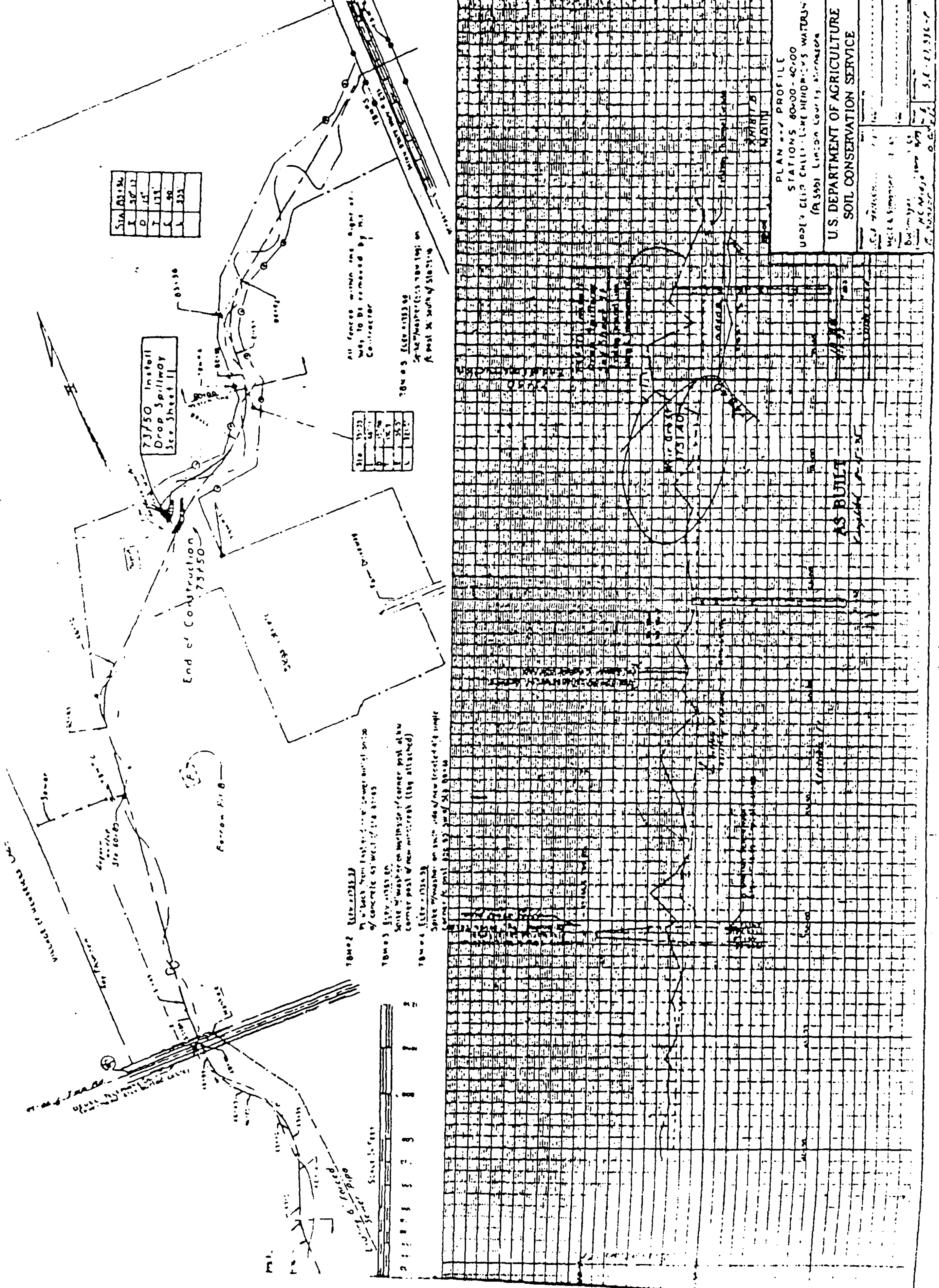

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
AS BUILT
End of Construction 73+50
73+50 Install Drop Spillway See Sheet 11

Figure D-3.

THOMAS W. REEVES
ATTORNEY AT LAW
BOX 6
HENDRICKS, MINNESOTA 56136
TELEPHONE 507-275-3105

October 27, 1990

A.W. Clapp III
Special Assistant Attorney General
102 State Capitol
St. Paul, MN 55155

Re: In the Matter of the Application of the City of Hendricks, Lincoln County, to Excavate one Mile Of the Lac Qui Parle River

Dear Mr. Clapp:

This is to confirm our phone conversation of October 26, 1990. We agreed to continue indefinitely the hearing scheduled October 30, 1990, at Hendricks.

I believe we have a mutual agreement on terms of a permit which will settle the matter. The terms of such agreement are contained in the letter of Jeffrey R. Lewis dated October 11, 1990. I reviewed this letter with my expert last week.

We are concerned about two points.

First, at paragraph two, Lewis proposes to allow widening of the wier at the crest elevation of 1751.40'. As I read this paragraph, Lewis means DNR would permit my client to cut off four sheet pile panels on both sides of the center notch so that the center notch would be approximately 16' wide instead of 3'3" as it now is. However the center notch is at elevation 1750.8', not 1751.40'. For that conclusion I refer you to sheet 11 of the "as built" Detail Plans for the project completed August 15, 1975. Lewis's proposal only makes sense if the lowest point of the structure as build is widened from 3'3" to approximately 16'. I will recommend my client accept this and I believe it will. Please make sure this is what Lewis meant.

Second, under the proposal in Lewis's letter, DNR would permit channeling more extensive than the City requests. At the least, DNR is either suggesting or recommending more channeling than the Citi requested in its compromise. The City does not want to be in a position where, in some future, permit application, DNR raises an issue about the City failing to follow its recommendations about the channeling. We may never be able to complete this channeling unless there is another dry period where it is possible to get the work done with locally available construction equipment. Before that happens it is possible the City could get funded to do channel improvement from another source.

Right now there is a joint study of Lake Hendricks which addresses, in part, the question of Lake level and the outlet into the Lac Qui Parle River. The results and recommendations are more than one year off. If channel work is recommended, it may be easier to fund the work. Also, I assume the study and recommendations would take the interests of DNR into account. Jeff Lewis is aware of this study.

It is unlikely the City will undertake any channel work other than to clean out sediment until it knows the recommendation of the study.

Accordingly, the channeling proposed by DNR may not be feasible or may not be the best solution. The City would like any agreement to give it enough time to wait for the study results or favorable weather.

Further, if the City has another proposal, different than the compromise proposal for channeling, it wants to be certain under its agreement with DNR, that failure to install the channel as agreed is not an issue in a future hearing.

To summarize, the City wants, first, to be certain DNR and the City are talking about the same wier crest elevation at the drop structure to be modified and, second, to be certain if any channeling is done this agreement does not interfere with recommendations of the lake study now underway.

Thank you.

COPY

Very truly yours,

Thomas W. Reeves.

City Attorney, Hendricks, MN

THOMAS W. REEVES
ATTORNEY AT LAW
BOX 6
HENDRICKS, MINNESOTA 56136
TELEPHONE 507-275-3105

November 14, 1990

A.W. Clapp III
Special Assistant Attorney General
102 State Capitol
St. Paul, MN 55155

Mr. Jeffrey R. Lewis
Area Hydrologist
Minnesota Department of Natural Resources
P.O. Box 111
1400 East Lyon
Marshall, MN 56258

Re: In the Matter of the Application of the City of Hendricks, Lincoln County, to excavate one mile of the Lac Qui Parle River

Dear Sirs:

Please be advised the City of Hendricks has accepted DNR's proposal in Jeffrey Lewis's letter of October 11, 1990. This is with the express understanding the two questions raised in my letter of October 27, 1990, were satisfactorily resolved.

First, the City is permitted to cut the structure at station 73 + 50 to elevation 1750.8' and 16' wide.

Second, if the City does not complete the channeling as recommended by DNR, this will not be an issue in any future permit application of the City.

According to Mr. Lewis, an amended permit incorporating the compromise settlement will be issued to the City. Please send a copy for the City's review at the earliest time.

Thank you for your cooperation.

Very truly yours,

TW Reeves

Thomas W. Reeves.
City Attorney
City of Hendricks, MN

STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES
PO BOX 756 - HIGHWAY 15 SOUTH, NEW ULM, MN 56073
PHONE NO.
(507) 359-6050

Celebrate MINNESOTA 1990

FILE NO.

RECEIVED 12-4-90
CF Arlen J Randall 12/6/90

November 30, 1990

Mr. Harvey Buchholz, Mayor
City of Hendricks
409 South Brook
Hendricks, MN 56136

Dear Mr. Buchholz:

SUBJECT: LIMITED PERMIT, 89-4028, LAC QUI PARLE RIVER

Attached please find Limited Permit 89-4028. This permit authorizes the City of Hendricks to remove accumulated silt along approximately 7200 feet of the existing alignment of the Lac Qui Parle River. This permit will replace the Order of the Commissioner issued November 3, 1989, and resolve the demand for hearing filed by the City of Hendricks. The permit authorizes the City to widen the existing lowest notch on the steel sheetpile structure at SCS Station 73+50. The elevation of this notch has been discussed and mistakenly reported at different elevations. We believe the correct elevation of the lowest notch is approximately 1750.90 feet above mean sea level. The intent of the permit is to allow the widening at its existing lowest elevation to a width of 16 feet as agreed to by all parties involved.

The drop structure at SCS Station 73+50 is a part of Lincoln CD 55. We would recommend that you contact Dan Girard, Lincoln County Ditch Inspector, or one of the Lincoln County Commissioners to discuss the alteration to this drop structure prior to any work being done. The intent of the permit is also to remove accumulated material along the Lac Qui Parle River. The actual depth of cuts along the watercourse will vary. The finished channel shall parallel a line from the drop structure at Station 73+50 to the downstream sill of the dam at Lake Hendricks. The channel can be slightly undercut to allow for the settling of materials without blocking the channel. We would recommend that the channel be cut no more than one foot below the grade line established from the drop structure upstream to the sill. All material excavated from the channel must be hauled off site and deposited on upland areas. The placement of excavated material along the channel would only lead to accelerated filling in of the channel during high water periods.

The permit has an expiration date of September 1, 1995. Prior to the excavation

33-04
(3/90)
DEPARTMENT OF MINNESOTA NATURAL RESOURCES
DIVISION OF WATERS

PROTECTED WATERS LIMITED PERMIT

P.A. Number
89-4028

Pursuant to Minnesota Statutes, Chapter 105, and on the basis of statements and information contained in the permit application, letters, maps, and plans submitted by the applicant and others supporting data, all of which are made a part herec by reference. PERMISSION IS HEREBY GRANTED to the applicant named below to change the course, current or cross section of the following:

Protected Water	County
Lac Qui Parle River	Lincoln (41)
Name of Applicant	**Telephone Number (include Area Code)**
City of Hendricks c/o Harvey Buchholz, Mayor	(507) 275-3521

Address (No. & Street, RFD, Box No., City, State, Zip Code)
409 South Brook, Hendricks, MN 56136

Authorized to clean approximately 7200 feet of the existing alignment of the Lac Qui Parle River from the Lake Hendricks outlet dam downstream to the sheetpile drop structure at SCS Station 73+50. The bottom width shall be approximately 18 feet wide for the reach from the lake to County Road 17; then 24 feet wide from CR 17 to the drop structure at Station 73+50. Finished sideslopes shall be no steeper than 2 feet horizontal to 1 foot vertical. Also authorized to widen the sheetpile drop structure at its existing center elevation so that the lowest notch is 16 feet wide. The bottom elevation of the channel shall basically be on a grade line from the drop structure upstream to the sill on the downstream side of the Lake Hendricks dam.

Purpose of Permit	Expiration Date of Permit
Improve Drainage	September 1, 1995
Property Described as:	**County**
Sections 7 and 18; Hendricks Twp. T112N, R46W	Lincoln (41)
As Indicated: (8)	**As Indicated: (11)**
Does Not Apply	Ordinary Highwater Mark (Edge of Aquatic Vegetation)

This permit is granted subject to the following GENERAL and SPECIAL PROVISIONS:

GENERAL PROVISIONS

1. This permit is permissive only and shall not release the permittee from any liability or obligation imposed by Minnesota Statutes, Federal Law or local ordinances relating thereto and shall remain in force subject to all conditions and limitations now or hereafter imposed by law.
2. This permit is not assignable except with the written consent of the Commissioner of Natural Resources.
3. The Regional Hydrologist shall be notified at least five days in advance of the commencement of the work authorized hereunder and shall be notified of its completion within five days thereafter. The Notice of Permit issued by the Commissioner shall be kept securely posted in a conspicuous place at the site of operations.
4. No change shall be made, without written permission previously obtained from the Commissioner of Natural Resources, in the dimensions, capacity or location of any items of work authorized hereunder.
5. The permittee shall grant access to the site at all reasonable times during and after construction to authorized representatives of the Commissioner of Natural Resources for inspection of the work authorized hereunder.
6. This Permit may be terminated by the Commissioner of Natural Resources at any time he deems it necessary for the conservation of water resources of the state, or in the interest of public health and welfare, or for violation of any of the provisions of this permit, unless otherwise provided in the Special Provisions.
7. Construction work authorized under this permit shall be completed on or before date specified above. Upon written request to the Commissioner by the Permittee, stating the reason therefore, an extension of time may be obtained.
8. The excavation of soil authorized herein shall not be construed to include the removal of organic matter (as indicated above) unless the area from which such organic matter is removed, is impervious, or is sealed by the application of bentonite after excavation.
9. In all cases where the doing by the permittee of anything authorized by this permit shall involve the taking, using, or damaging of any property rights or interests of any other person or persons, or of any publicly owned lands or improvements thereon or interests therein, the permittee, before proceeding therewith, shall obtain the written consent of all persons, agencies, or authorities concerned, and shall acquire all property, rights and interests necessary therefore.

SPECIAL PROVISIONS
LIMITED PERMIT 89-4028

1. EXCAVATED MATERIAL: No material excavated from the channel shall be deposited in wetland areas. All material shall be deposited on upland areas approved by the Department of Natural Resources.

2. EROSION CONTROL: The permittee shall cover or protect all exposed soil resulting from the construction authorized by placing riprap, sod, and/or seed on banks and slopes of said construction for the prevention of soil erosion, sedimentation and lake/stream discoloration.

3. MAINTENANCE: The permittee is authorized to maintain the approved work to the dimensions herein described. Prior to commencing any maintenance work, permittee shall advise the Department of Natural Resources of the extent and method of maintenance. Maintenance work shall not be commenced until permittee's receipt of the Department's approval.

4. RIGHT TO REVIEW: The Division of Waters reserves the right to review this permit as additional hydrologic data become available and to issue any further order as may become necessary to protect public interest.

5. SPOIL: Excavated materials shall not be deposited or stored alongside the protected water in a manner where the materials can be redeposited into the protected water by reasonably expected high water or storm runoff.

Ray Nyberg
RAY NYBERG, Regional Hydrologist

11-30-90
Date

This document was prepared by the South Dakota State Department of Environment and Natural Resources. Thirty-five copies of this document were printed at a cost of $3.68 each for a total of $128.87.