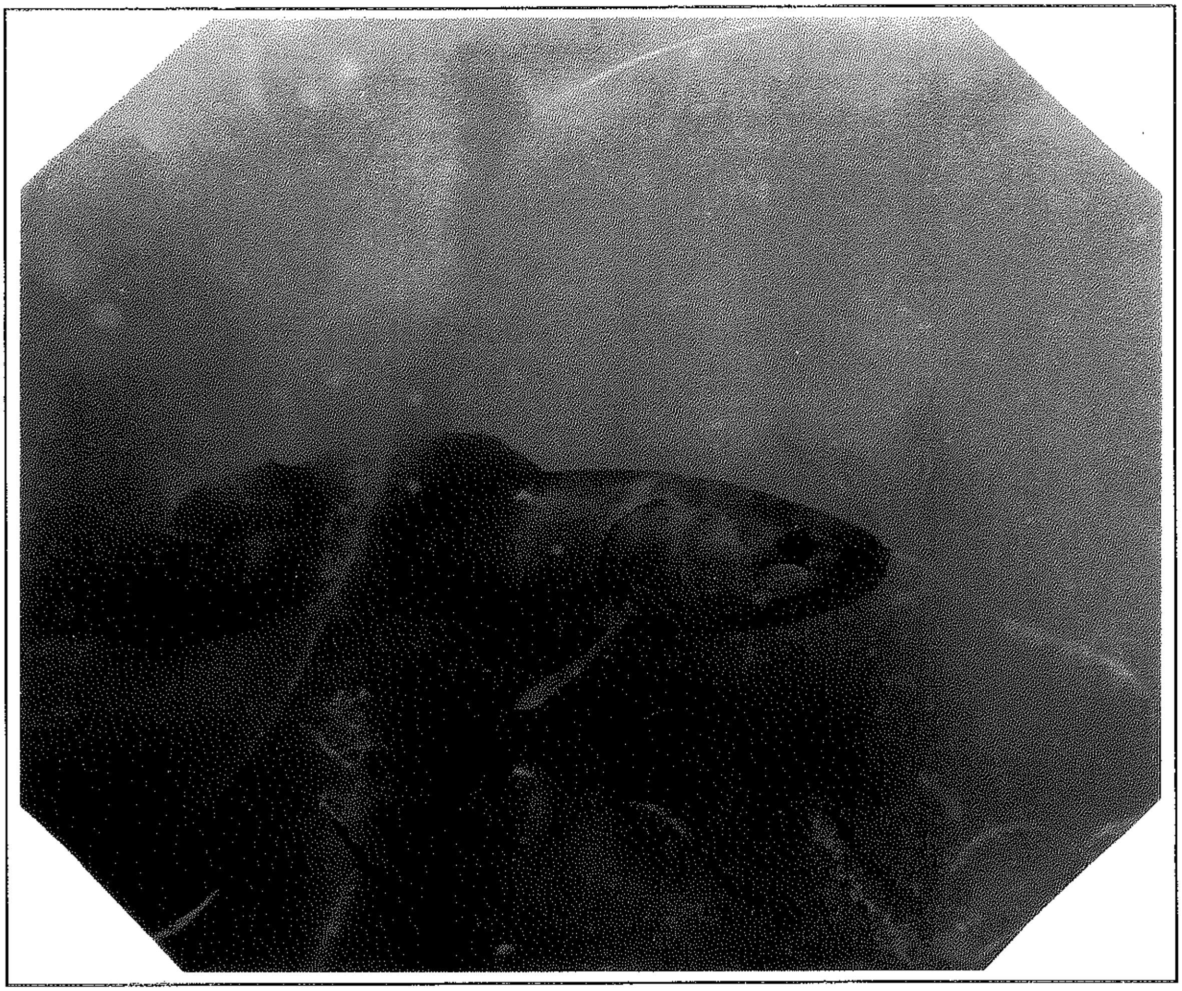
LPL-224

ROCK LAKE
JEFFERSON COUNTY



PRIORITY LAKE PROJECT
WATER RESOURCES APPRAISAL

Department of Natural Resources
Jefferson County Land Conservation
Rock Lake Improvement Association

July, 1997

Rock Lake - Priority Lake Project
Water Resources Appraisal

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Jefferson Land Conservation Department
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Cover photo: (Schultz's Bay, July, 1996) Bowfin or dogfish, mudfish, grindle, grinnel, lake lawyer, lawyer, cottonfish, blackfish, speckled cat, beaverfish, scaled ling, spot-tail. Bowfin or *Amia calva* is the sole species remaining from a family of fish that has not changed appreciably for over 200 million years. This "living fossil" is a fierce predator that lives within aquatic plant beds. Maligned as it is, bowfin are important members of the fish community. Bowfin add to the lake's biodiversity and function as predators controlling nuisance carp and over-populated small panfish. "This primitive fish is a relict, the lone survivor of a large family now found only as fossils in Europe and North America" (Becker, 1983).

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Introduction

In 1995, the Rock Lake watershed was selected as a Priority Lake Project under Wisconsin's Nonpoint Source Water Pollution Abatement Program. The lake was selected thanks to strong support from the Rock Lake Improvement Association, Jefferson County, and the Department of Natural Resources. The DNR has long recognized Rock Lake as one of the best lake resources in southcentral Wisconsin. DNR managers have ranked the lake and watershed "high priority" for protection efforts in numerous management planning documents over the years.

This report completes the first phase of the Priority Lake Project. The Water Resources Appraisal was designed to characterize existing water quality conditions and establish goals and objectives for protecting the resources within the Rock Lake watershed. The Water Resources Appraisal Committee selected the objectives based on achieving realistic expectations for protecting and improving water resources. The objectives are supported by intensive water quality monitoring and lake models. Data collection was a cooperative effort involving DNR staff, Jefferson County staff, and Rock Lake Improvement Association members. Reaching our lake protection goals will depend on the public's willingness to accept Rock Lake as more than an isolated feature of the landscape, but rather a living ecosystem that is closely linked with the entire watershed.

Water Resources Objectives

1. Reduce nonpoint source phosphorus loading from the Rock and Mud Lake subwatersheds by 30%.

2. Protect the Bean Lake Natural Area by reducing nonpoint source phosphorus loading from hydrologic unit 46 by 30%.

3. Protect the rural agricultural character of the watershed.

4. Preserve important habitats needed to sustain biodiversity, rare nongame species and sportfish production. Important habitats include lake "sensitive areas" and riparian wetlands.

5. Restore drained wetlands to improve water quality and fish and wildlife habitat.

6. Determine the carp population size and potential for removal to protect valuable native aquatic plants and "Sensitive Areas".

Summary of Water Resources Conditions

In 1986, the Department of Natural Resources selected Rock Lake as one of the 50 Long Term Trends Lakes statewide. Over the last ten years, the lake has generally displayed good water quality and is considered mesotrophic. The mesotrophic conditions are typical of marl lakes in southeast Wisconsin. In 1996, the worst water quality conditions in 10 years coincided with record high precipitation and runoff in June. Water clarity dropped to less than one meter compared to the 10 year mean which is greater than three meters (range 1.5 - 5.6 meters) during the growing season.

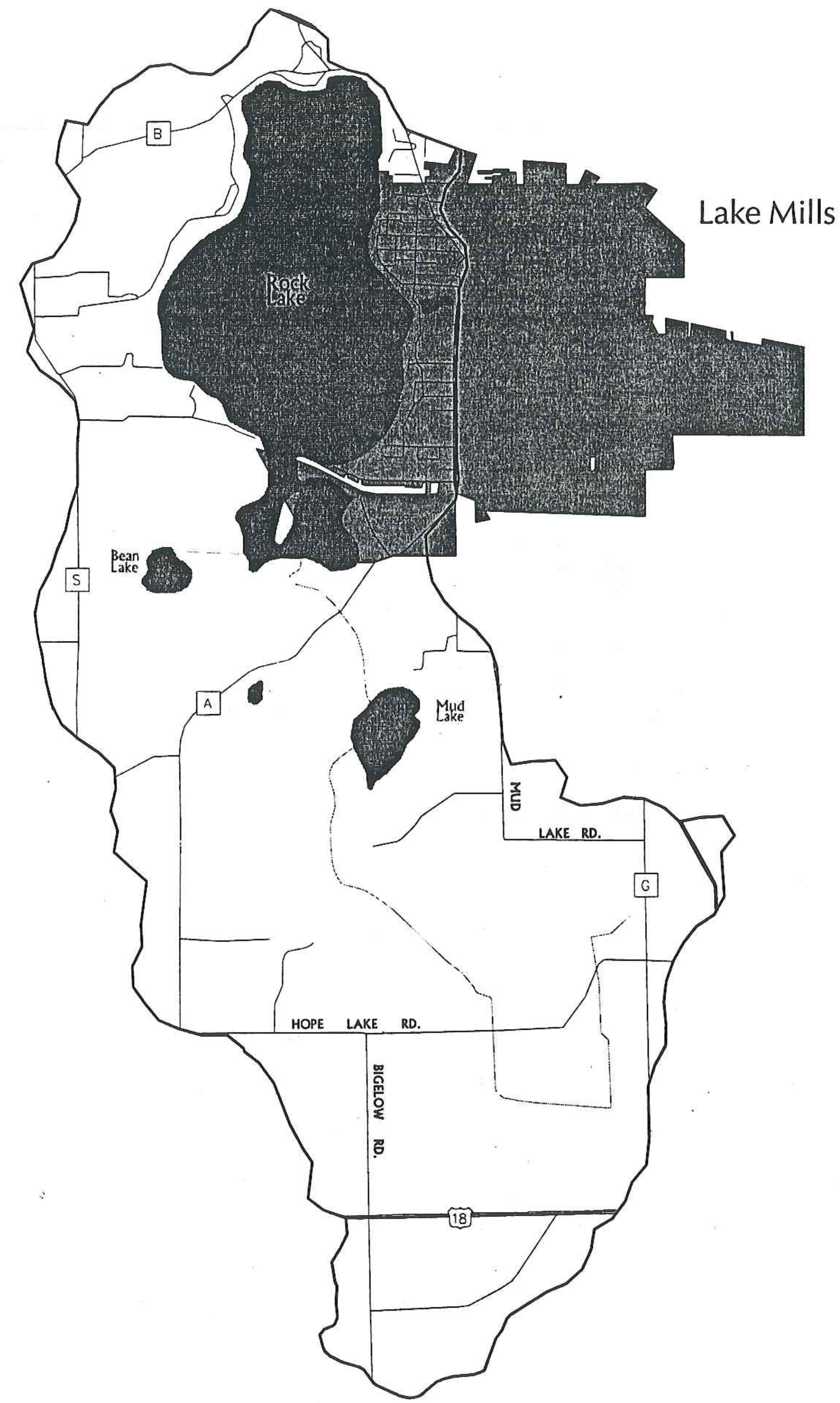
While marl lakes are usually somewhat less susceptible to nonpoint point source pollution compared to lakes with lower calcium levels, poor water quality in June of 1996 clearly indicates that external phosphorus sources are affecting the lake water quality. The lake response to nonpoint source pollution and external phosphorus was further confirmed by lake sediment core data (Paleoecology). Rock Lake had excellent water quality prior to European settlement but declined as the watershed became developed. Extensive wetlands and upstream basins have prevented more serious water quality decline in the lake.

Based on lake sediment cores, Rock Lake had excellent water quality prior to the arrival of European settlers in the mid-1800's. Most likely in the late 1800's, water quality began to decline as a result of agricultural activities in the watershed. Peak erosional rates probably occurred around 30 cm sediment depth. During this time period the lake's water quality was at its worse. The diatom inferred P level in the surface water was the highest (16 ug/l) and the greatest extent of anoxia occurred in the hypolimnion. In the last few decades, sedimentation rates likely have remained higher than presettlement levels but the lake's water quality has improved, both in the extent of anoxia as well as the P levels. There is some evidence that P levels in the lake have begun to increase again in the last few years but they are not as high as concentrations experienced earlier in the 20th century.

Even though Rock Lake's water quality is still considered "good", both conventional wisdom and lake water quality data indicate that phosphorus reduction is needed to protect the lake. Currently, Mud Lake receives most of the nonpoint source pollution from the watershed and is trapping much of the phosphorus before it reaches Rock Lake. While Rock Lake is partially protected, the water quality in Mud Lake is being compromised. In 1996, very poor water quality was observed in Mud Lake. Continued phosphorus loading to Mud Lake will not only degrade water quality even further, but the phosphorus trapping function (which has protected Rock Lake over the years) will decline as well. If Mud Lake's water quality continues to decline, important fish and wildlife functions will be lost.

While watershed drainage characteristics and lake chemistry have reduced nonpoint source pollution impacts on Rock Lake's water quality, nearshore habitat functions have been seriously compromised in recent years. Extensive piers, seawalls and

Figure 1:
Rock Lake Priority Watershed



motorboat traffic have destroyed valuable emergent, floating leaf and submersed aquatic plant beds around the lake. Cumulative effects of shoreline developments have reduced valuable fish spawning and nursery habitat. Numbers of piers increased from 96 in 1950, to 153 in 1963, to 276 in 1996.

Coinciding with increased piers was reduced fish diversity in the lake. Nearshore fish distribution surveys produced 17 species in 1974 and only 11 species in 1996. Loss of nearshore habitat has been the most obvious change and most serious threat to fish production and biodiversity in Rock Lake.

Only a few partially developed or undeveloped shorelines still persist around the lake today. In an effort to protect the fish and wildlife habitat functions found in these relatively intact nearshore areas, the Rock Lake Improvement Association recommended that the DNR identify these as "Sensitive Areas" under Wisconsin Administrative Code NR 107. Protecting nearshore habitat functions is a fundamental aspect of lake protection.

Even though Rock Lake is the primary focus of the Priority Lake Project, the wetlands and small basins within the upper watershed are very important for fish and wildlife habitat, recreation and buffering Rock Lake from pollution. Water quality modeling indicates that 30% phosphorus reduction from lands draining directly into Rock, Mud and Bean lakes will protect the water quality of these resources. Preventing further habitat loss is a concern for the entire watershed. Intensive shoreline development, and perhaps carp, threaten nearshore habitat and the "Sensitive Areas" in Rock Lake.

Description of Water Resources in the Rock Lake Watershed

Rock Lake is an 1160 acre dimictic mesotrophic lake with maximum and mean depths of 57' and 16' respectively. It is a natural glacial lake formed as a large compound depression in the ground moraine. Although mostly natural, the water level was altered by construction of a 10 foot dam in 1865, creating the Marsh Lake basin south of the Glacial Drumlin bike trail. The dam expanded recreational opportunities on the lake, however managing the water levels has been a challenge since the various user groups have different views regarding desirable lake levels and mother nature is usually difficult to predict.

Extensive wetlands adjoin the lake to the south but most of the lake's direct drainage area is in agricultural production. The most intensively developed area lies within the City of Lake Mills on the eastern shore. In recent years, housing development has expanded rapidly along the north, west and south shores and reduced agriculture within the watershed.

Rock is the largest lake within the Crawfish River Subbasin of the Upper Rock Basin and is considered one of the best quality

lakes in southern Wisconsin. Known for its clear water, the lake is intensively used for recreation including swimming, boating, and angling. Angling is popular because the lake supports walleye, smallmouth bass, largemouth bass, northern pike and panfish populations. Reports that Rock Lake contains submerged native American artifacts and structures is an additional attraction for divers and archeology enthusiasts who routinely survey the lake bed.

Over the past 30 years, Rock Lake has been the focus of numerous lake assessment or protection efforts due to the overall high popularity for the lake and a concern repeatedly voiced by local residents that "our lake is being loved to death". Figure 2 contains a chronological list of management activities beginning in 1971, on up to the Priority Lake Project start.

Already mentioned in this report are the extensive wetlands and small basins which are important natural features within the watershed. The small basins include Mud Lake, Bean Lake and Marsh Lake.

Mud Lake is a small drainage lake located within wetlands south of Rock Lake. The lake area is 93 acres and has maximum depth of 22 feet. The Lake Mills Wildlife Area encompasses the lake and access for non-motorized watercraft is provided. The lake is popular angling site in the spring and shortly after ice cover.

Marsh Lake is the shallow basin created by the 1865 dam. It supports excellent native aquatic plant beds and is a popular early season largemouth bass and panfish angling site.

Bean Lake is a small landlocked shallow lake that is one of the best examples of a wilderness experience in southern Wisconsin. The 33 acre lake is surrounded by over 280 acres of tamarack which is part of the Bean Lake Scientific Area. The lake supports native aquatic plants and stunted panfish. The combined wetlands and basins within the wildlife and scientific areas support rare herptiles, plants and habitats as well as abundant migrating waterfowl populations.

Data Collection and Analysis

Water Column Monitoring. Priority Lake Project appraisal monitoring began in May, 1996 and was completed by the middle of October. From June through October, Rock Lake was sampled weekly to measure water clarity (Secchi), epilimnetic total phosphorus and temperature/oxygen profiles. Epilimnetic phosphorus profiles were measured to determine if the north-south fetch of Rock Lake resulted in periodic phosphorus loading from the hypolimnion into the epilimnion. If storms or strong winds did not follow a sampling run, the phosphorus samples would be disposed of the

Figure 2: Recent Rock Lake Management and Planning Highlights

1971: DNR staff conducted bacteriology survey on Rock Lake
1974: USEPA evaluated Rock Lake as part of the National Eutrophication Survey and determined the lake was mesotrophic.
1974-75: DNR Fish Distribution Survey on Rock Lake
1975: Most of the Town of Lake Mills sewer system was completed.
1978: UW Madison Urban and Regional Planning Commission completed a land use plan for the watershed - recommended "protecting wetlands, lake resources, agriculture, and forming a Lake Management District"
1981: Jefferson County Soil and Water Conservation District identified Rock Lake as "high priority" for protection efforts
1981: DNR 208 Planning Task Force recommended Rock Lake for NPS controls
1986: DNR staff select Rock Lake for Long Term Trends monitoring
1986: DNR staff recommended Rock Lake for Key Lake Project
1988-89: UW Ext. facilitated citizen focus groups to identify lake issues
1990: DNR prohibited broad spectrum herbicides to protect native aquatic plants
1994: Rock Lake Improvement Association awarded Lake Planning Grant
1995: Rock Lake selected as Priority Lake Project under Wisconsin's Nonpoint Source Water Pollution Abatement Program
1996: First Rock Lake Fair was held
1997: Rock Lake Improvement Association recognized at Lakes Convention

following week to reduce analytical costs. Biweekly, additional water samples were collected along with field conductivity and oxygen/temperature profiles. Water samples were collected with a Kemmerer bottle from both the epilimnion and hypolimnion. The samples were submitted to the State Laboratory of Hygiene to measure chlorophyll a, ammonia and total phosphorus. Conductivity was measured with a YSI Model 3000 self-compensating meter. A YSI Model 58 Oxygen Meter was used for temperature and oxygen.

At the beginning of lake stratification in June, and again just prior to fall turnover in October, hypolimnetic total dissolved phosphorus profiles were collected to assess internal phosphorus loading. Water was pumped at one meter intervals from 8 to 15 m.

While the intensive monitoring effort was conducted in 1996, the DNR Long Term Trends monitoring continues on Rock Lake. Since 1986, the lake is sampled five times per year (March, April, June, July and August). The Long Term Trends Program provides an annual perspective for comparing Rock Lake's water quality.

Mud Lake was sampled five times and Bean Lake was sampled twice during the Appraisal. Standard procedures for lake sampling are described in the *WDNR Field Procedures Manual for Water Quality and Compliance Monitoring.*

Lake Water Quality Modeling. The modeling method used on Mud Lake and Bean lakes was the Walker 1987 model. The Wisconsin Lake Model Spreadsheet (WILMS) Version 2.0 was used to model Rock Lake and Bean Lake. WILMS is a lake modeling spreadsheet that contains 10 empirical lake response models coupled with a watershed loading and a lake response module.

The development of a phosphorus model included an estimated water budget. Lake volunteers, DNR staff and City of Lake Mills staff collected lake elevation and outlet structure data that were entered into an outflow spreadsheet. The spreadsheet data was used to estimate the mean daily outflow.

Jefferson County staff updated the land use inventory to correspond with specific hydrologic units. The overall watershed was divided into three subwatersheds to account for phosphorus trapping in the chain of lakes.

Paleoecology. A 169 cm core was extracted near the deep hole of the lake on February 20, 1996. The top 50 cm sections were sliced into 1 cm intervals, 50 to 100 cm into 2 cm intervals, and the remainder of the core into 4 cm intervals. Parameters measured in the core include bulk density, loss on ignition, geochemical elements (Ca, Mg, K, Al, Fe, Mn, P, TKN, Pb) and diatoms. ^{210}Pb dating, zooplankton and algal pigments were not been completed in time for this report.

Macrophytes, Zooplankton and Phytoplankton. Additional aspects of the Long Term Trends monitoring include macrophyte surveys and plankton sampling. Macrophyte surveys are conducted every three years and 1996 was part of the three year cycle. Aquatic plant species and relative densities are sampled along established transects around the lake. Along each transect, a weighted rake is tossed at four corners from the boat to sample plants at regular depth intervals: at 0.5 feet, three feet, six feet, nine feet, and twelve feet.

Phytoplankton and zooplankton are sampled five times each year along with the water chemistry sampling. Phytoplankton grabs are collected at 0.5 m and preserved in lugol's solution. Vertical net tows sampled the entire water column for zooplankton. The zooplankton samples are preserved in 5% buffered formalin.

Plankton identification and analysis is very time consuming and expensive. A plankton ecology section cannot be completed at this time since only a few samples have not been analyzed so far.

Fisheries. In 1974, Rock Lake was included in the Wisconsin Fish Distribution Study. As part of the Water Resources Appraisal, the Rock Lake fish sampling was duplicated. At numerous shoreline stations around the lake, a thirty foot bag seine was pulled to determine relative densities and species present within the littoral zone. The survey was not designed to study growth rates or size structure of sport fish, but was primarily designed to determine species diversity and community structure which can reflect health of the lake ecosystem. To compliment the fisheries surveys, piers were inventoried around the lake to evaluate relative changes in fish habitat since 1950.

Results

A. Water Quality

Dissolved oxygen and temperature. Rock Lake is dimictic since the lake undergoes complete water column mixing in the spring and fall. By April each year, the water column is nearly uniform with temperatures averaging 7° C and dissolved oxygen levels averaging 11.7 mg/l (based on 11 years of monitoring). In April 1996, the temperature and dissolved oxygen recordings were 4.9° C and 10.2-13 mg/l respectively. By June each year, the lake becomes thermally stratified and oxygen is rapidly depleted within the cold hypolimnion and thermocline. In most years, oxygen is depleted below 10 meters (33') and becomes unfavorable for fish growth below 7 meters (23'). In 1996, oxygen levels were exhausted below 7 meters and were unfavorable for fish below 5 m (about 16'). Hypolimnetic oxygen depletion is typical for mesotrophic and eutrophic lakes as bacteria decompose organic material at the lake bottom. Low oxygen levels found within the upper mixed epilimnion in 1996 indicated water quality less than

Figure 3A: Rock Lake - 10 Year Mean Dissolved Oxygen and Temperature Profiles

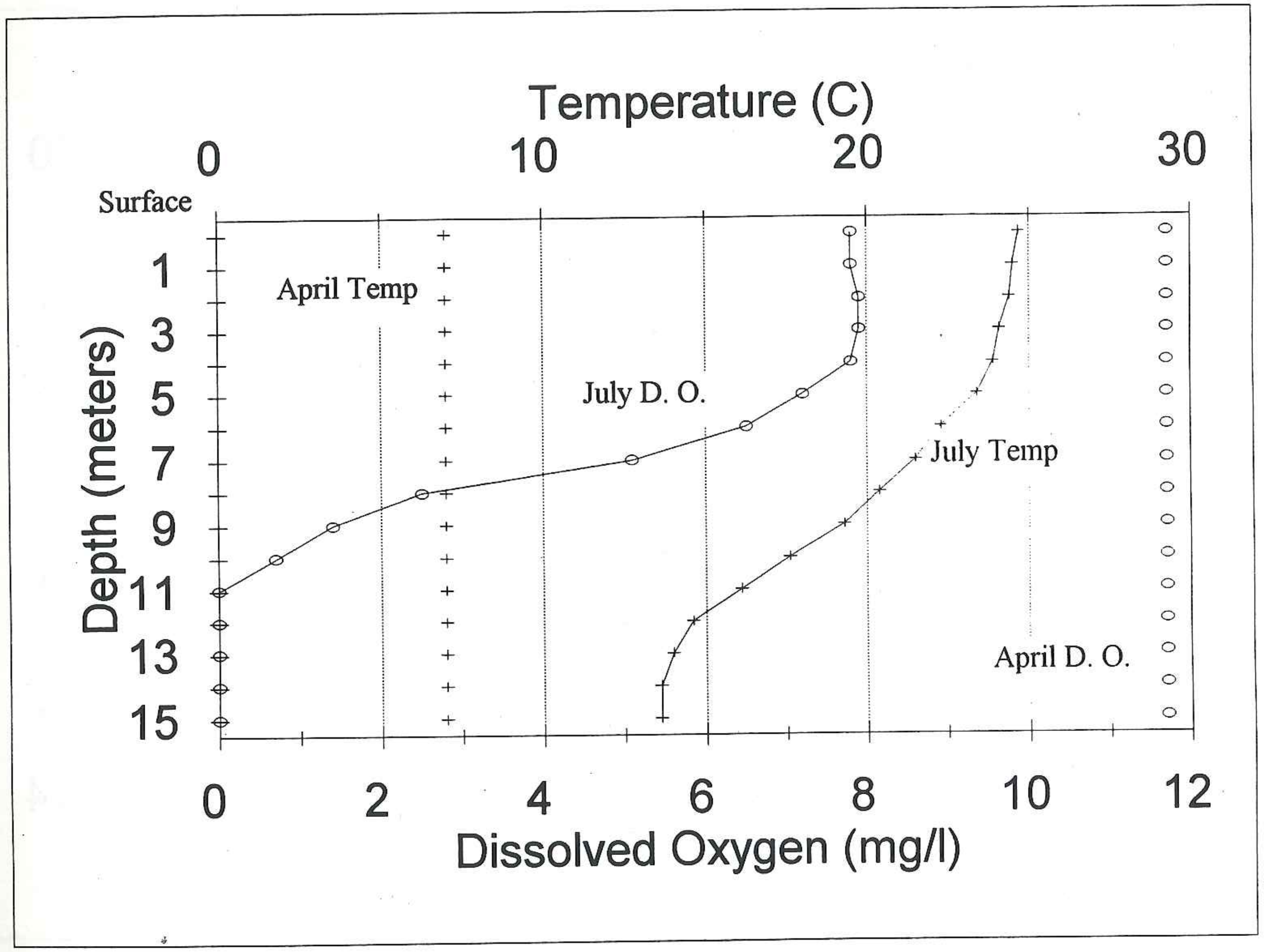
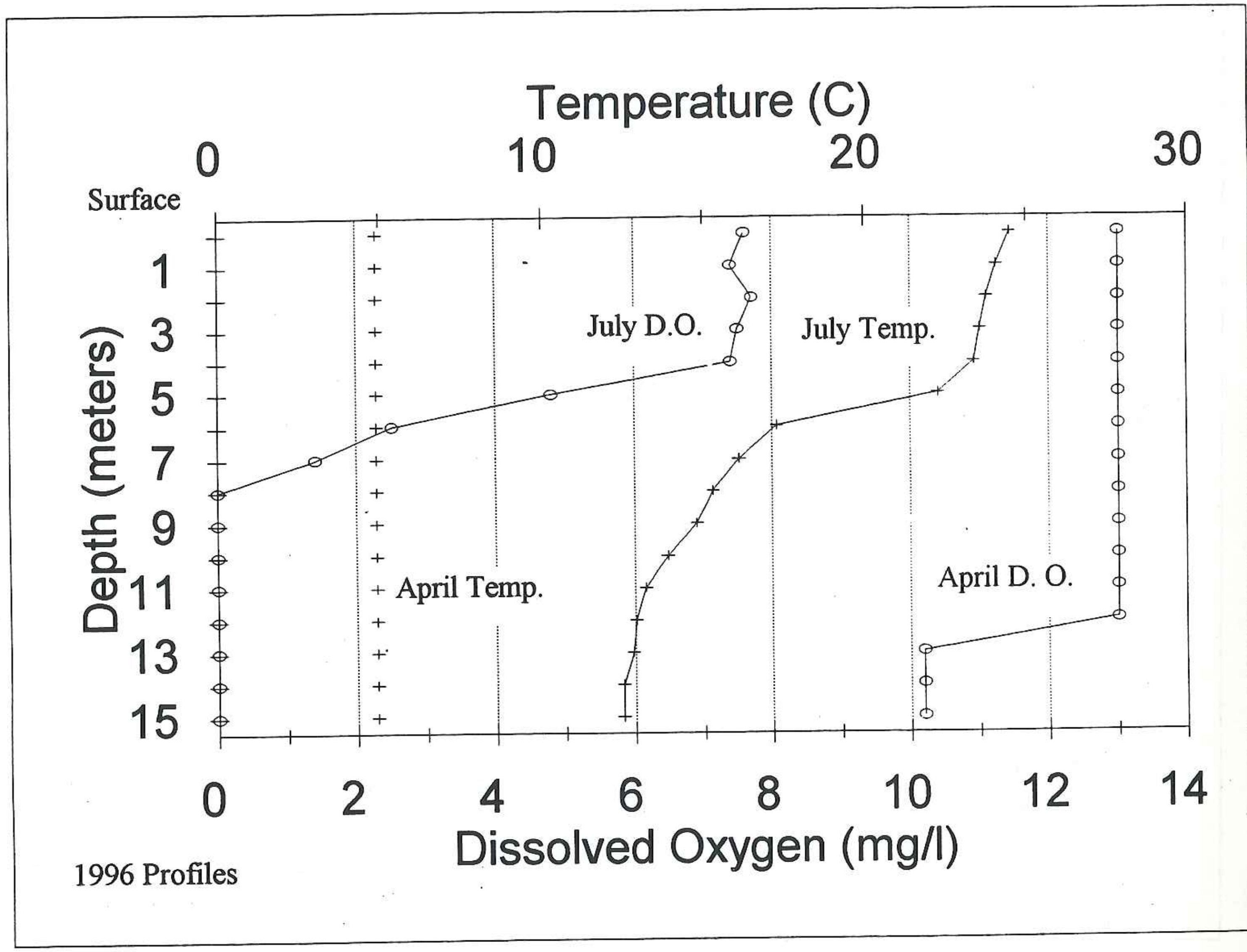


Figure 3B: Rock Lake - 1996 Dissolved Oxygen and Temperature Profiles



desirable for a typical mesotrophic lake. Fishing below 16 feet in the summer of 1996 guaranteed an empty creel. By October 8, 1996, cool temperatures and fall winds eroded the thermocline and again mixed the entire water column. Fall surface to bottom water temperatures and dissolved oxygen levels ranged from 13.8 to 13.2° C and from 8.5 to 5.6 mg/l respectively. Figures 3A and 3B contain average April and July temperature and dissolved oxygen profiles and 1996 profiles.

Water Clarity (Secchi). Good water clarity is one of Rock Lake's most popular features and is desirable for recreation and aesthetics. Water clarity is measured by lowering an eight inch diameter black and white disc from the side of a boat until it can no longer be seen. Secchi is one of three parameters (also total phosphorus and chlorophyll a) used to calculate the Trophic State Index. Lake volunteers routinely collect secchi data.

From 1986 to 1995, secchi measurements averaged 3.1 m with a range of 1.5 - 5.5 m. Secchi measurements greater than 2 m are considered good for most Wisconsin lakes. In 1996, record precipitation and runoff in June stimulated phytoplankton growth and reduced water clarity. Record low water clarity was recorded in June and July (0.8 - 1.0 m), but recovered later in the summer as below normal rainfall followed the June flood. Secchi measurements during the 1996 growing season averaged 2.4 m (range 0.8 - 4.4 m). Figure 4 contains water clarity and lake elevation data for 1996. Poor water clarity correlated well with high lake elevation, a result of high runoff and nonpoint source pollution.

Generally speaking, the best water clarity will be found during drought years when lake productivity is low. During the 1988-89 drought, for example, lower amounts of nonpoint source pollutants reached the lake and water clarity averaged 3.4 m (range 2 - 4.6 m). Figure 5 compares annual precipitation with water clarity measurements over the last 11 years.

Chlorophyll-a is another parameter used to calculate the Trophic State Index (TSI). It is the photosynthetic pigment found in all autotrophic plants. When filtered from lake water, chlorophyll-a concentrations will reflect lake productivity. Higher levels indicate algal blooms and inversely correlate with water clarity.

Consistent with Rock Lake water clarity data, chlorophyll a concentrations are generally low, indicating low productivity and good water quality. From 1986 - 1995, chlorophyll-a levels averaged 5 ug/l (range 1 - 11 ug/l) during the summer growing seasons. Concentrations less than 7 ug/l indicate good water quality for most Wisconsin lakes. Concentrations greater than 10 ug/l are routinely found during the spring when phosphorus is available for cold water algae growths. By May in most years, the spring algae blooms have diminished and the annual best water clarity follows.

Figure 4: Rock Lake - 1996 Water Clarity and Lake Elevation

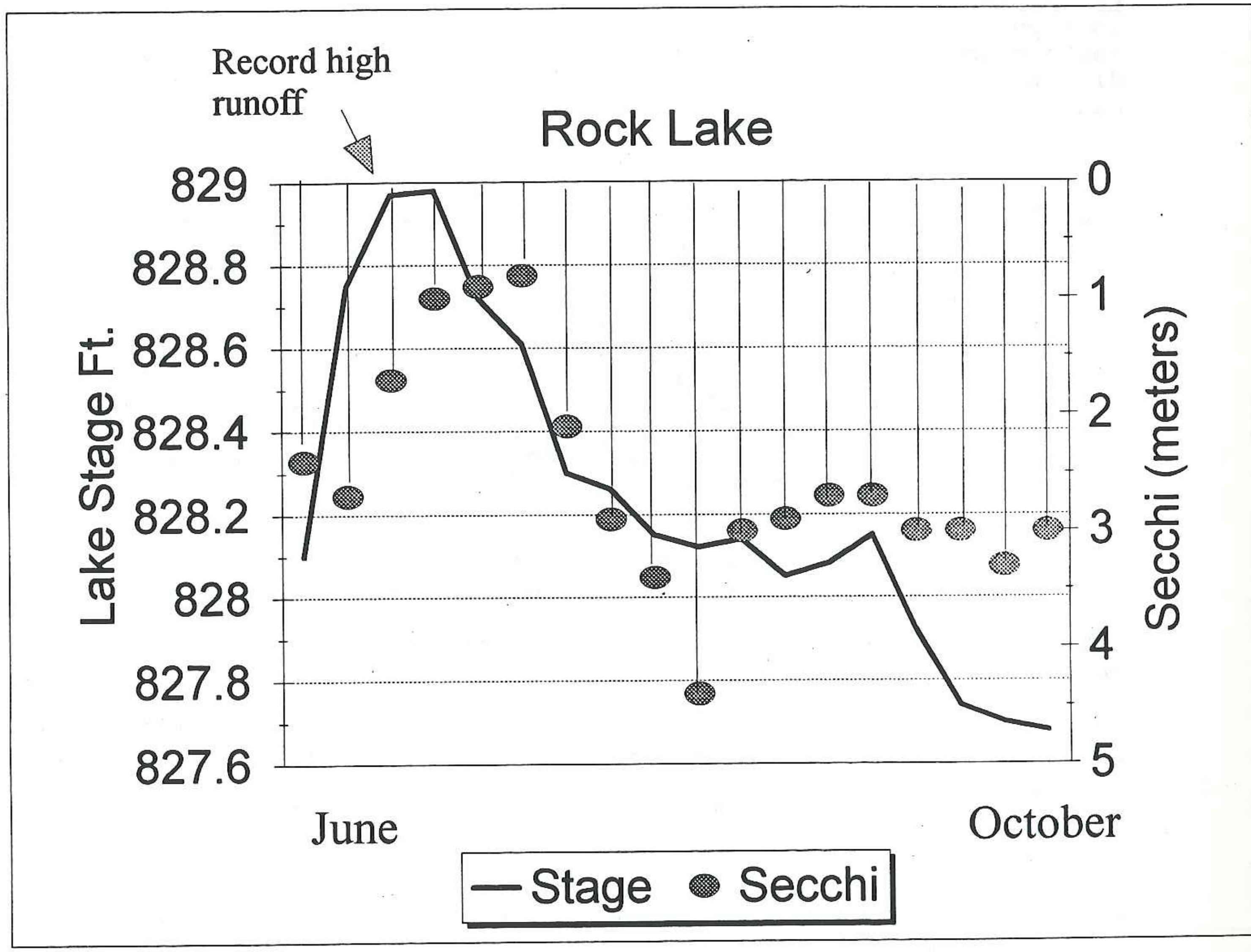
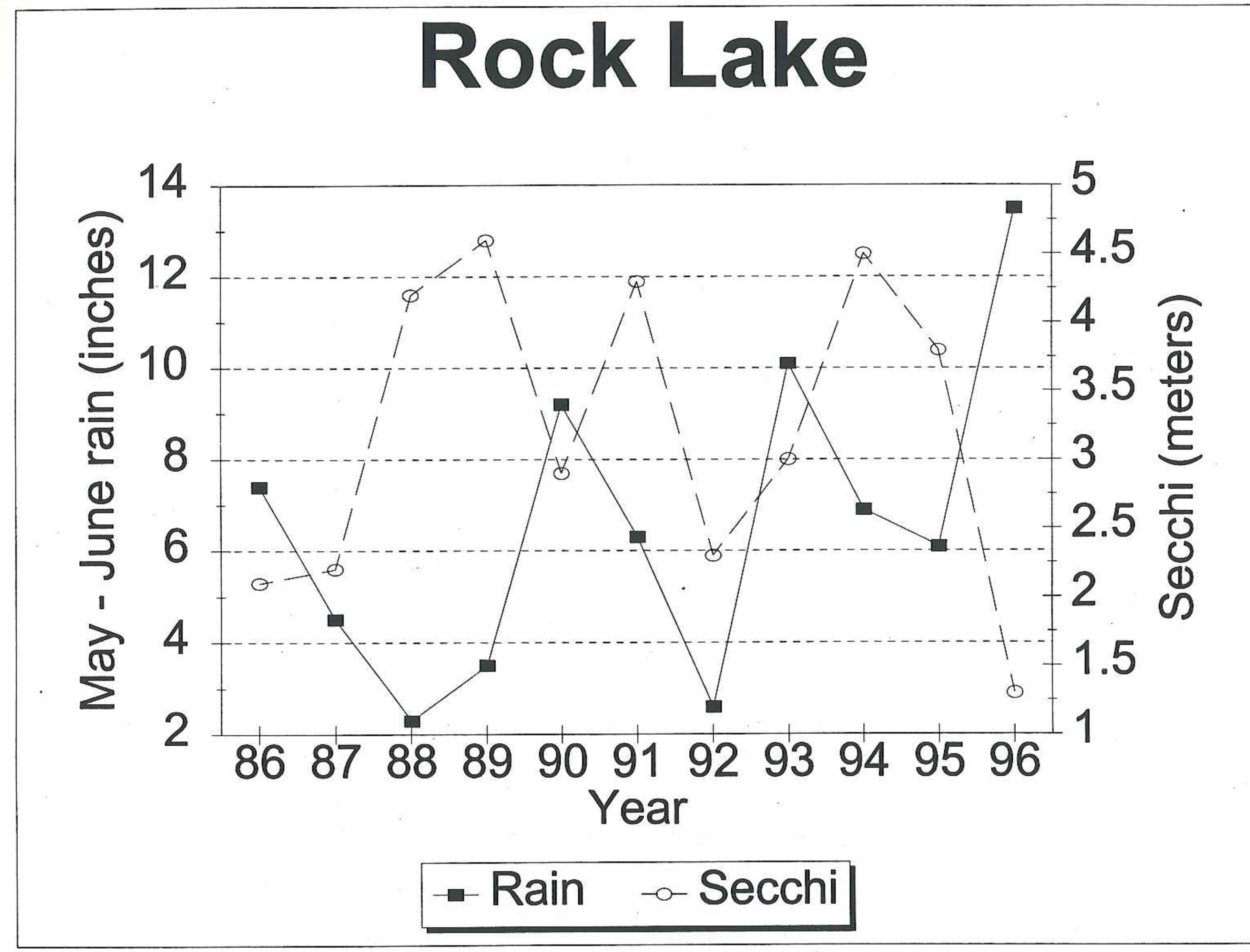


Figure 5: 11 Year May - June Rainfall versus Rock Lake Secchi



In 1996, low Spring chlorophyll-a levels (1 ug/l) increased to 9 ug/l as high runoff contributed to algal blooms and low water clarity. Following the June rains, algal blooms stabilized and chlorophyll-a concentrations ranged from 3 - 5 ug/l. After the fall turnover, chlorophyll-a increased to 8 ug/l as phytoplankton growths were stimulated by internal phosphorus loading from the hypolimnion.

Phosphorus is the third TSI parameter and is the primary driving force behind lake productivity and water quality. High phosphorus concentrations usually stimulate algae blooms (high chlorophyll-a) which reduce water clarity. From 1986-95, summer surface total phosphorus concentrations averaged 13 ug/l (range 6 - 26 ug/l). Less than 17 ug/l total phosphorus indicates good water quality. Mixed spring phosphorus levels averaged 16 ug/l (range 7 - 20 ug/l) during the 10 year period. Concentrations have fluctuated both annually and within single growing seasons. Phosphorus concentrations are likely to respond to variable runoff rates and internal loading.

In 1996, spring phosphorus was 18 ug/l and average surface phosphorus during the growing season was 11 ug/l (range 7 - 16 ug/l). The highest summer concentration (16 ug/l) coincided with high runoff and the lowest (7 ug/l) coincided with the late summer drought.

While reducing watershed sources of phosphorus is the primary focus of the Priority Lake Project, internal phosphorus loading from the hypolimnion is an additional consideration for managing the lake nutrient budget. Phosphorus from past years is recycled within the anaerobic hypolimnion and can be partially released during strong summer storms or more significantly at fall turnover. In 1996, hypolimnetic grab samples averaged 30 ug/l and ranged from 26 to 34 ug/l with no discernable trend of increasing levels. These levels are low compared with more fertile lakes where internal loading is more significant. For example, in Fish Lake, Dane County and Lake Ripley, Jefferson County, hypolimnetic phosphorus concentrations can exceed 300 and 200 ug/l respectively.

To better evaluate the potential for internal loading in Rock Lake, total dissolved phosphorus (TDP) samples were pumped and filtered at one meter intervals throughout the hypolimnion. Shortly after thermal stratification became established in June, 1996, TDP concentrations averaged 18 ug/l and ranged from 11 - 33 ug/l. By September 3, TDP averaged 48 ug/l and ranged from 14 - 198 ug/l. The TDP profiles suggested more significant internal loading than the biweekly hypolimnetic grab sampling indicated, but still not as serious as other lakes in the area. By September 25, mean TDP dropped to 20 ug/l and coincided with partial mixing and expansion of the epilimnion. On September 3, the maximum depth supporting dissolved oxygen was 7 meters. By

September 25, the maximum depth with oxygen was 10 meters. At the fall turnover, surface phosphorus concentrations increased from 11 ug/l on September 25 to 19 ug/l on October 8. Below normal rainfall during late summer and early fall indicated that internal loading was the primary source for the 8 ug/l increase.

Hypolimnetic water temperatures can affect biochemical processes within the profundal zone, with colder temperatures reducing rates of decomposition and oxygen depletion. In 1996, the hypolimnion was relatively cold at 12.8° C. Over the last 11 years, hypolimnetic temperatures averaged 14.4° C (range 12.6 - 16.4). Perhaps 1996 was not the best year to evaluate internal loading since hypolimnetic temperatures are warmer in most years and biochemical processes should occur more rapidly. Therefore, the 1996 study may have underestimated internal loading for an otherwise more typical year.

Another Rock Lake feature which may encourage internal loading is the north - south orientation and wind fetch. To determine if strong winds will erode part of the thermocline and release phosphorus into the epilimnion during the growing season, epilimnetic phosphorus profiles were sampled before and after three storm events. As a result, no significant phosphorus gain was observed based on the three 1996 surveys. Perhaps in other years, a warmer hypolimnion and weaker stratification may release more phosphorus during the growing season.

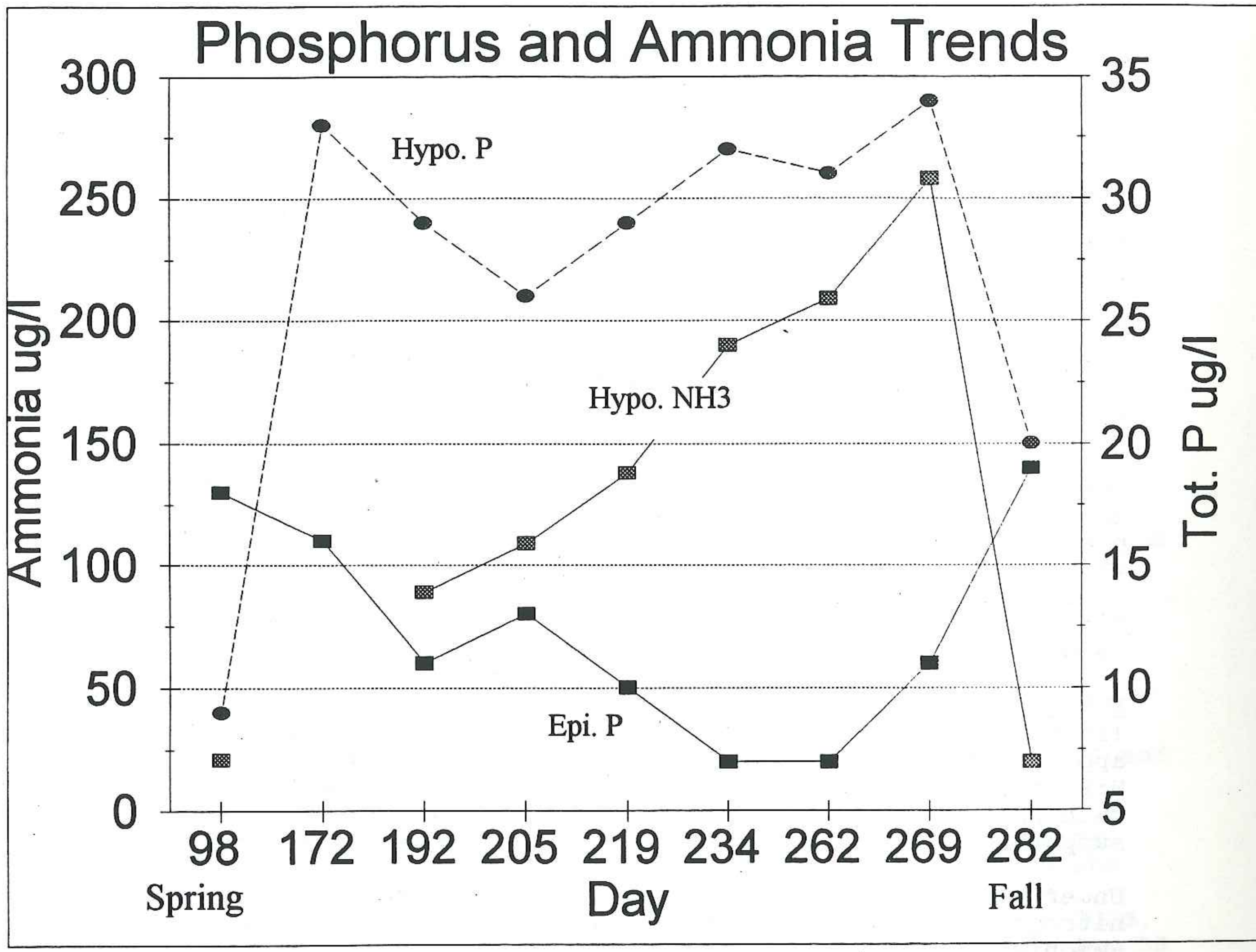
Currently, the coprecipitation of phosphorus with calcium carbonate appears to be sustaining mesotrophic conditions and prevents more serious internal loading within the lake. Over time, nonpoint source pollution and organic loading may reduce calcium inputs and the lake may shift to eutrophic conditions. Figure 9 displays average TSI values since 1986. Some of the values drift slightly into the eutrophic range (above 50).

Nitrogen. Typical for mesotrophic lakes, Rock Lake is phosphorus limited since the ratio of total nitrogen to total phosphorus is approximately 55:1. Lakes are phosphorus limited as long as the N:P ration exceeds 15:1 (Carlson, 1980). Hypereutrophic lakes such as Lake Koshkonong are frequently nitrogen limited and support excessive blooms of nitrogen fixing bluegreen algae.

Under aerobic conditions, organically bound and inorganic nitrogen forms (nitrate and nitrite) are much higher than ammonia. Following thermal stratification in a lake, ammonia concentrations are rapidly released from the sediments under anaerobic conditions. Figure 6 displays the following: hypolimnetic and mixed ammonia, hypolimnetic and mixed total phosphorus, and epilimnetic and mixed total phosphorus.

Specific Conductance, Alkalinity and pH. Conductivity measurements reflect total dissolved solids in water. Since 1986, spring mixed conductivity levels have averaged about 430

Figure 6: Rock Lake - 1996 Epilimnetic Phosphorus and Hypolimnetic Phosphorus and Ammonia Trends



umhos/cm. The Rock L. mean lies between levels found in two other southcentral Wisconsin Long Term Trends Lakes (Figure 7). In 1996, mid-summer concentrations averaged 403 in the epilimnion and 473 near the bottom of the hypolimnion. Higher concentrations in the hypolimnion reflect ion migration from the sediment during anoxia.

Alkalinity ($CaCO_3$) indicates the buffering or acid neutralizing capacity of water. The 11 year spring mixed mean for Rock Lake is 190 mg/l. This level is much higher than the statewide mean (52 mg/l) and reflects the substantial calcium loading to the lake.

Hydrogen ion concentrations are expressed in pH standard units (s.u.) and have a strong correlation with alkalinity. All pH measurements taken from Rock Lake over the years have been on the alkaline side of neutrality. In 1996, mixed spring pH in Rock Lake was 8.2 s.u., which is significantly higher than the state mean of 7.2 s.u. Highest measurements were found in the epilimnion during the summer and reflect a photosynthetic demand on CO_2. Lowest pH measurements occur in the hypolimnion because CO_2 is liberated initially from aerobic decomposition and ultimately from anaerobic decomposition of organic matter.

<u>Ionic Composition</u>. Figure 8 compares Rock Lake mean concentrations with two other southcentral Long Term Trend Lakes.

<u>Mud Lake Water Quality</u>. Mud Lake was sampled five times in 1996. Poor water quality was frequently observed and was seasonally variable. In February, very high phosphorus levels were found with 168 micrograms/liter at the surface and 84 micrograms at 2.5 meters. The lake approached winterkill conditions since surface dissolved oxygen levels reached only 3.6 mg/l. Only 0.9 mg/l occurred at 2.5 meters. These levels were well below the minimum state water quality standards (5 mg/l) established to protect fish and aquatic life.

By June 13, the secchi water clarity was measured at 1.7 meters. From surface to bottom, dissolved oxygen and temperature profiles ranged from 12.4 to 5.4 mg/l and 23 to 16° C respectively. High phosphorus (108 ug/l) and chlorophyll-a (43 ug/l) reflected poor water quality.

On June 26, no oxygen was found below 3.5 meters of water depth. All of the TSI parameters indicated poor water quality. The secchi measurement was only 0.9 meters. Total phosphorus and chlorophyll-a levels were 215 and 49 ug/l respectively.

On August 6, no oxygen was found below 3 meters and levels ranged from 6.9 - 6.3 mg/l within the top 3 meters. Again, all TSI parameters indicated poor water quality (secchi = 1.1m, total phosphorus = 104 ug/l, chlorophyll-a = 66 ug/l). The TSI values for these parameters were 59, 64 and 66 respectively.

Figure 7: Alkalinity and Conductivity in SCR Long Term Trends Lakes

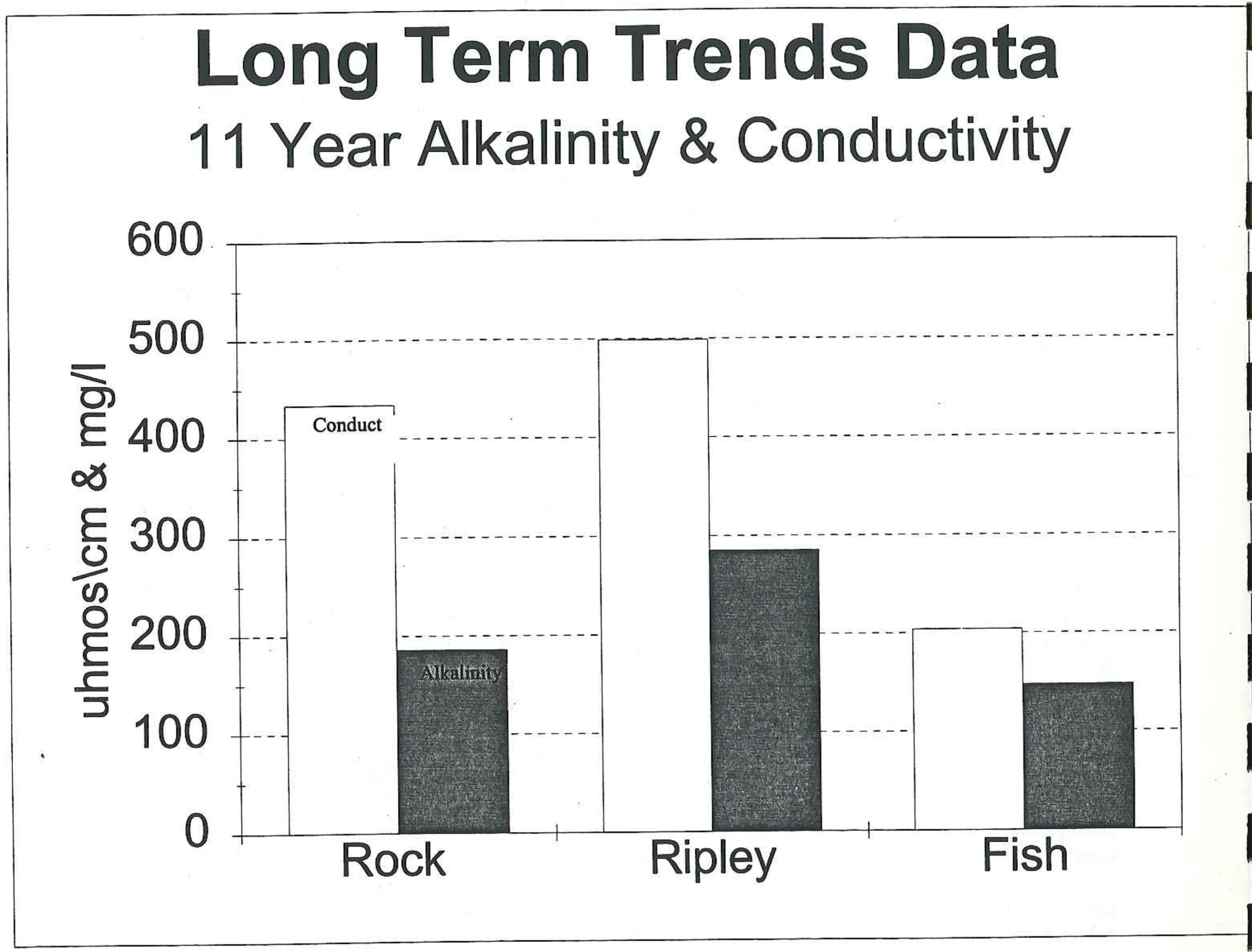
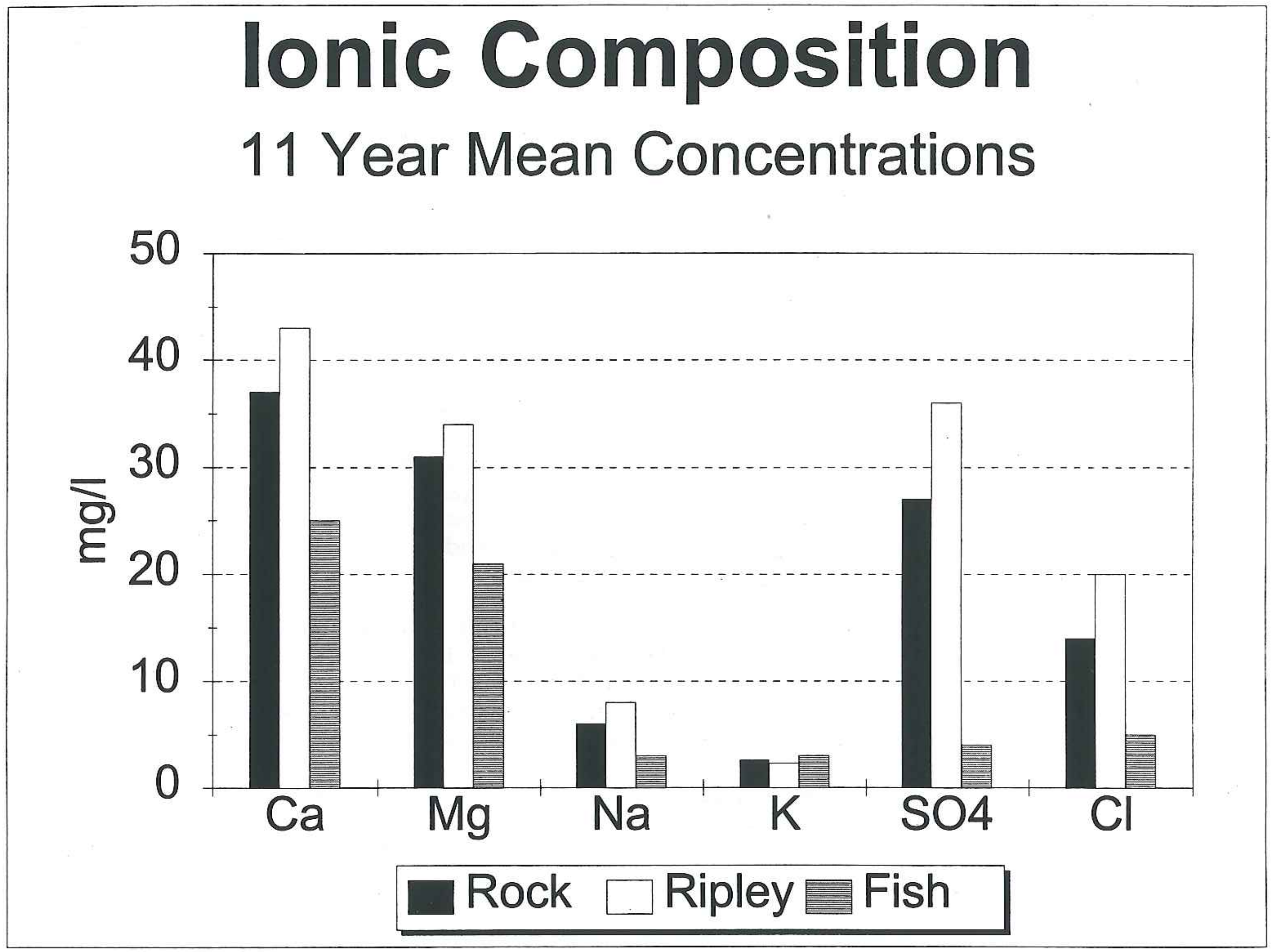


Figure 8: Ionic Composition of SCR Long Term Trends Lakes



By October 16, Mud Lake was mixed and well oxygenated throughout the water column (13.5-12 mg/l). Poor water quality conditions were still observed however, with 0.7m secchi depth, 83 ug/l total phosphorus and 59 ug/l chlorophyll-a.

Bean Lake Water Quality. Due to the remote site and time limitations of the Appraisal, Bean Lake was sampled only twice in 1996. In February, near winterkill conditions were observed since the maximum dissolved oxygen level was only 2.0 mg/l. A significant algal bloom was also observed under the ice and was reflected by both high chlorophyll-a (99 ug/l) and phosphorus (124 ug/l) levels.

By April 10, the presence of numerous small panfish indicated that a complete winterkill did not occur. Chlorophyll-a and total phosphorus concentrations were 20 and 29 ug/l respectively. A more thorough investigation is needed to characterize the limnology and ecology of this locally important resource. Cropland runoff from the south and west may be affecting the lake water quality.

B. Lake Response Modeling

Water quality goal setting requires an understanding of the relationship between watershed nutrient loading and in-lake phosphorus concentration. The lake-watershed relationship is best described using a phosphorus response model. The lake models that did the best job of predicting observed in-lake phosphorus was the Reckow Natural Lake Model (1979) in Rock Lake and the Walker Model (1987) in Mud Lake.

The development of the models included an estimated water budget. Lake volunteers collected rain gauge and lake elevation data. Combined with outlet structure data, monthly and seasonal water volumes were calculated. The Rock Lake outflow volume was about 2,683 acre/feet which translates into about 4.4 watershed inches.

The lake response modeling included Mud Lake, Marsh Lake and Rock Lake. The models were fit to the three lake system with minimal calibration. Bean Lake was modeled separately since it is not directly connected to the other lakes.

To model the chain of lakes effect on phosphorus trapping and transport, the Rock Lake watershed was broken down into three subwatersheds (Mud L., Marsh L. and Rock L.). The Mud Lake subwatershed has the largest drainage area, encompassing 4609 acres of mostly cropland and wetland (see Figure 10). The Walker Model predicts an annual phosphorus loading of 2309 lbs. The predicted outflow phosphorus load is 491 lbs/yr with a net gain of 1818 lbs/yr.

The Marsh Lake subwatershed has a drainage area of 1679 acres. Since most of it is buffered by the publicly owned wetlands,

Figure 9: Trends of Rock Lake Trophic State Index

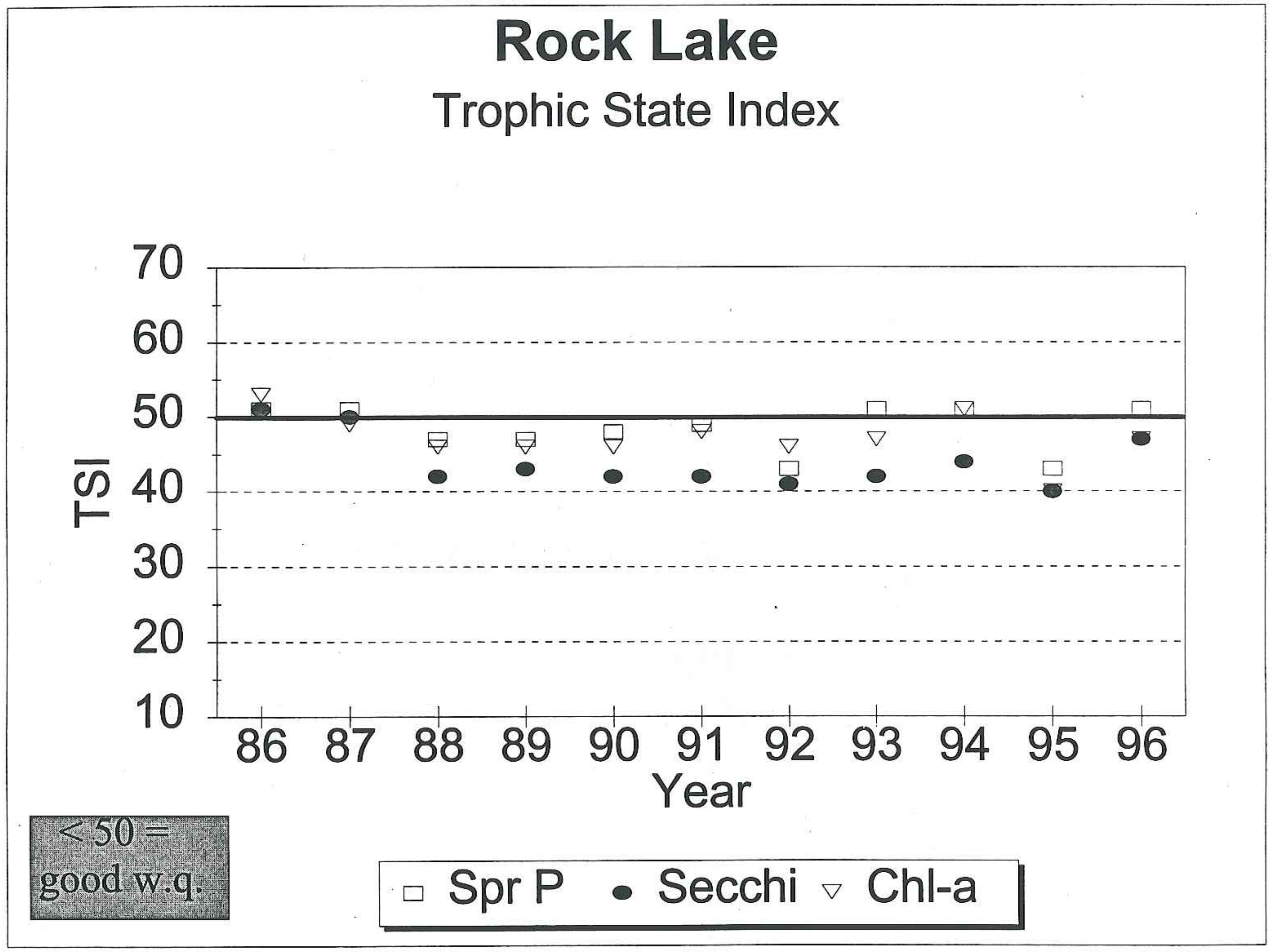
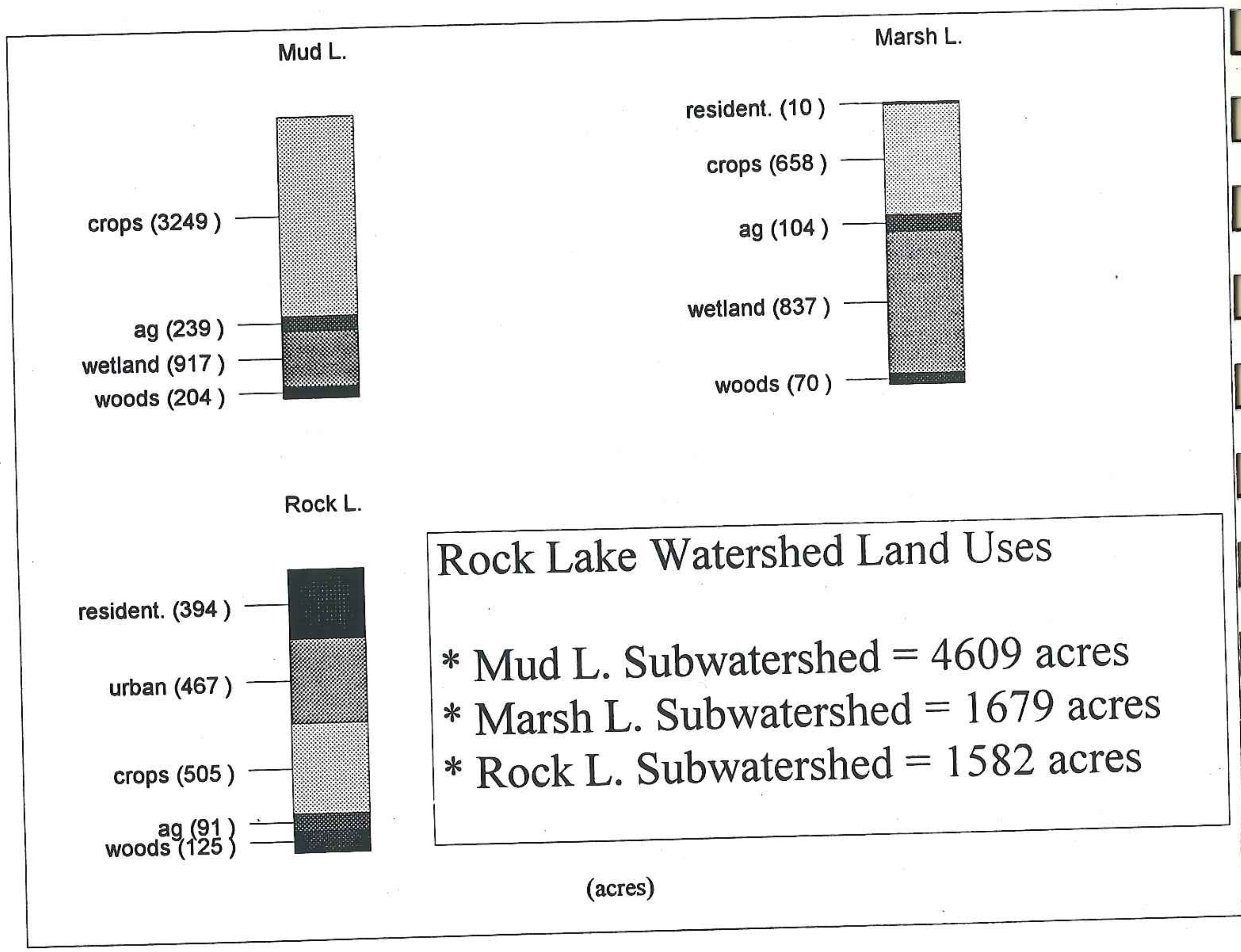


Figure 10: Principal Land Uses in the Rock Lake Watershed



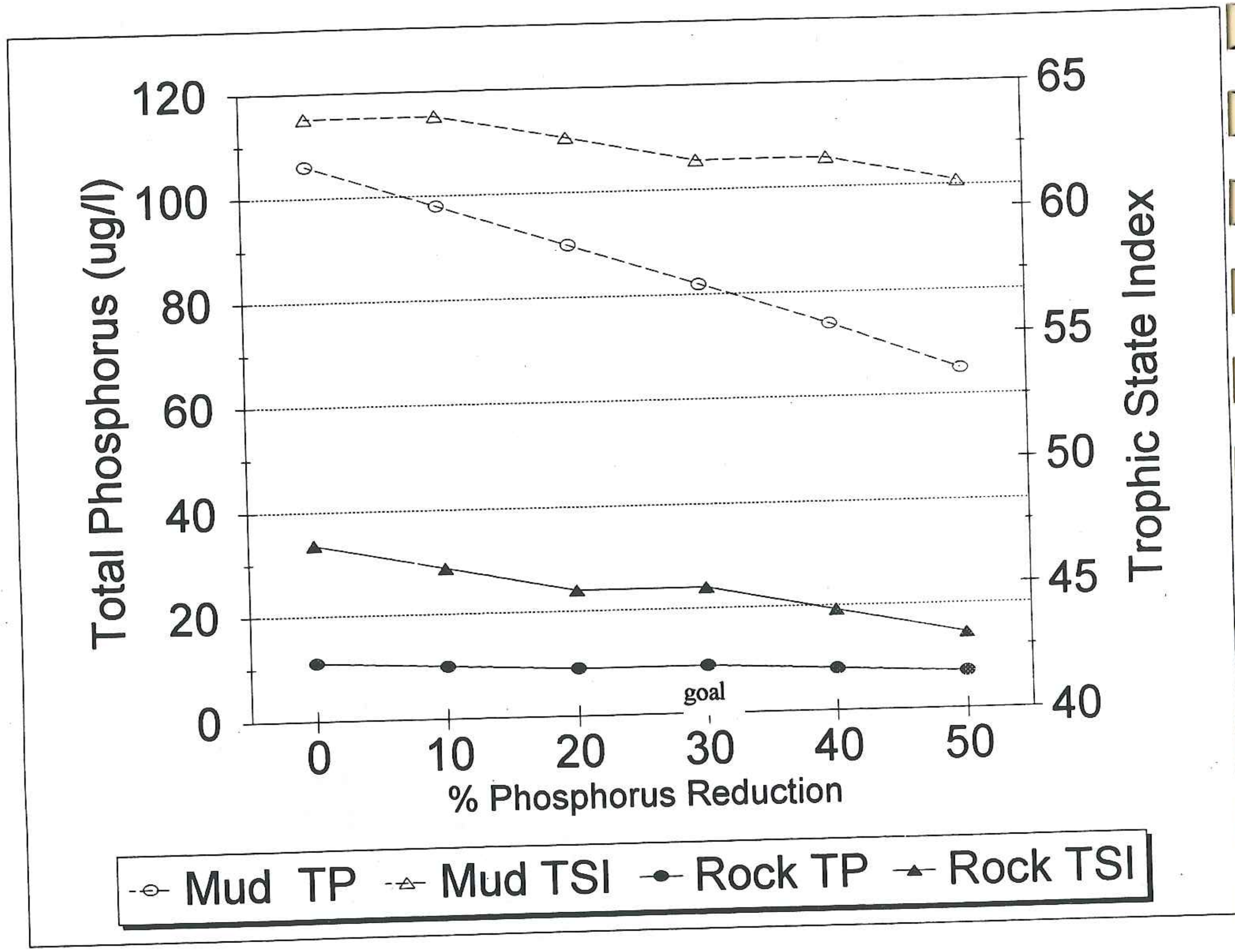
minimal phosphorus loading occurs within the subwatershed. The annual load is predicted at 581 lbs/yr. with an outflow load of 259 lbs. reaching Rock Lake. Eighty-five percent of the predicted Marsh Lake phosphorus load is transported from Mud Lake. This prediction is not based on water quality data. Marsh Lake and the creek were not sampled due to budget limitations. In 1994, DNR staff collected biweekly flow and phosphorus samples at the CTH A bridge in anticipation of the Priority Lake Project. Biweekly baseflow sampling does not replace expensive continuous flow monitoring but can provide a rough idea as to the amount of nutrient loading. Based on the 1994 data set, approximately 300 pounds of phosphorus passed into Marsh Lake that year compared to the predicted 581 pounds in 1996. Since the baseflow monitoring can not account for peak runoff loads, the phosphorus loading prediction appears to be reasonable.

The Reckow Model predicts the annual phosphorus loading to Rock Lake is 1430 lbs/yr. The subwatershed area is 1582 acres with 505 acres of cropland and 861 acres of housing and urban development.

Currently, the system functions as a chain with Mud and Marsh lakes trapping most of the phosphorus coming off the watershed from the south. Mud and Marsh lakes trap approximately 2400 lbs. of phosphorus per year or 63% of the annual load. If the Mud Lake water quality continues to be compromised, the trapping function will likely decline and more phosphorus will be transported downstream to Rock Lake. A phosphorus reduction goal of 30% for the Mud Lake subwatershed should reduce in-lake concentrations from 106 ug/l to 82 ug/l and protect this important function.

At the present time, upstream land uses contribute only 18% of the annual phosphorus load to Rock Lake due to the trapping functions mentioned above. Both urban and rural land uses surrounding Rock Lake are contributing the other 82% of the annual phosphorus load. To protect the mesotrophic conditions and reduce the frequency of eutrophic conditions in the lake, a phosphorus reduction goal of 30% is also recommended for the Rock Lake subwatershed. Of particular concern is phosphorus and sediment runoff associated with rapid development around the lake. Phosphorus and sediment runoff from construction sites will commonly exceed cropland runoff tenfold or greater. Construction site runoff within the Rock Lake subwatershed has been documented frequently over the last five years and constitutes the most serious watershed disturbance since early European settlement. Since the lake models are based on average phosphorus concentrations found near the middle of each lake, the model may not be reflecting recent construction site runoff due to temporary storage in the shallow inlets and bays around Rock Lake. The small tributary that drains into Korth Bay is the most obvious site where sediment has settled. Figure 11 summarizes

Figure 11: Lake Response Modeling



(Based on a 30% P reduction from the Mud and Rock L. subwatersheds)

the lake modeling and phosphorus reductions goals for Mud Lake and Rock Lake.

Even though minimal chain of lakes phosphorus loading occurs within the Marsh Lake subwatershed, Bean Lake displays eutrophic conditions due to runoff from agricultural lands to the south and west (hydrologic unit 46). A 30% phosphorus reduction goal for hydrologic unit 46 is recommended to protect biodiversity and wildlife habitat functions of this unique resource.

C. Paleoecology

This section details the work that has been completed for this study and some preliminary interpretation. Work that has been completed includes chemical and physical analysis as well as the diatoms. The work that has not been finished includes the dating, algal pigments, and zooplankton. The most important of these is the dating as this allows us to assign dates to the core segments. We hope that this work will be completed by the end of the summer along with the algal pigments and zooplankton identification.

European settlement around the lake began in the 1830's and the Village of Lake Mills was incorporated in 1856 (Table 1). Tourism increased in the 1880's following the completion of the rail line to the village. With arrival of Europeans, the watershed was converted from oak savanna to agriculture throughout the last half of the 1800's. This resulted in increased sediment and nutrient delivery to the lake. This should be reflected in the sediment core and the effect on the lake's water quality can be determined.

Profiles of selected chemical parameters are shown in Figure 12. Aluminum is primarily associated with soil particles and indicates erosion from the watershed. Aluminum concentrations began to increase above background levels at 45 cm and peaked at 30 cm. This likely indicates large scale land disturbance associated with agricultural activities. The Al concentrations declined after 30 cm. This is probably the result of two factors. The sedimentation rate likely has increased to some extent thus diluting Al in the sediments but the decline is probably also the result of a decline in the erosional rates.

Calcium concentration also peaks at 45 cm. Calcium enters from the watershed but is largely the result of $CaCO_3$ precipitation within the lake. Its decline below background levels is good evidence that the sedimentation rate in the last few decades is higher than presettlement rates. Further evidence of increased erosional rates in the last century is provided by the ratio of Ca:Al. Calcium deposition rates likely have not greatly increased since settlement. Therefore a decline in this ratio is indicative of increased erosion. Since the time period

Rock Lake Timeline

1836	Captain John Keyes staked out the village and built a mill at the outlet
1840	First cheese cooperative run by Anne Pickett
1843	The creek was deepened and dam was raised to improved water power for mills
1848	The Harvick brothers, stone and brick masons, set up shop using bricks made on the banks of Rock Creek
1856	Lake Mills incorporated as a village
1867	Stephen Faville began the towns first cheese factory
1881	Paul Gerike began an ice business using Rock Lake as a source
1882	The Northwestern rail line completed into Lake Mills
mid 1880's	Tourism begins to boom because of easier access to the town
1885	Rock Lake Hotel built
late 1880's	Residential houses start being built on the lakefront
1893	Royal Electric Water Company established by Creamery Package Company
1905	Lake Mills incorporated as a city
1906	Cottage Hotel built
early 1900's	Claude and Lee Wilson claimed they saw the top of a 'pyramid' 6 feet under the surface of the water. Brought back teacup - sized stones as proof
1911	The city purchased the power company
1931	The city purchased Keyes Mill. The mill, dam, and bounteous were demolished New 175 foot boathouse erected on the south shore of Mill Pond
during depression	A fish hatchery was established southeast of the central business district
1937	linked levee ponds were completed
1967	7 divers found a formation 20' across, 50-70' long and 10-15' tall due west of Bartell's Boat Rentals that was made up of grapefruit - sized lumps of rock

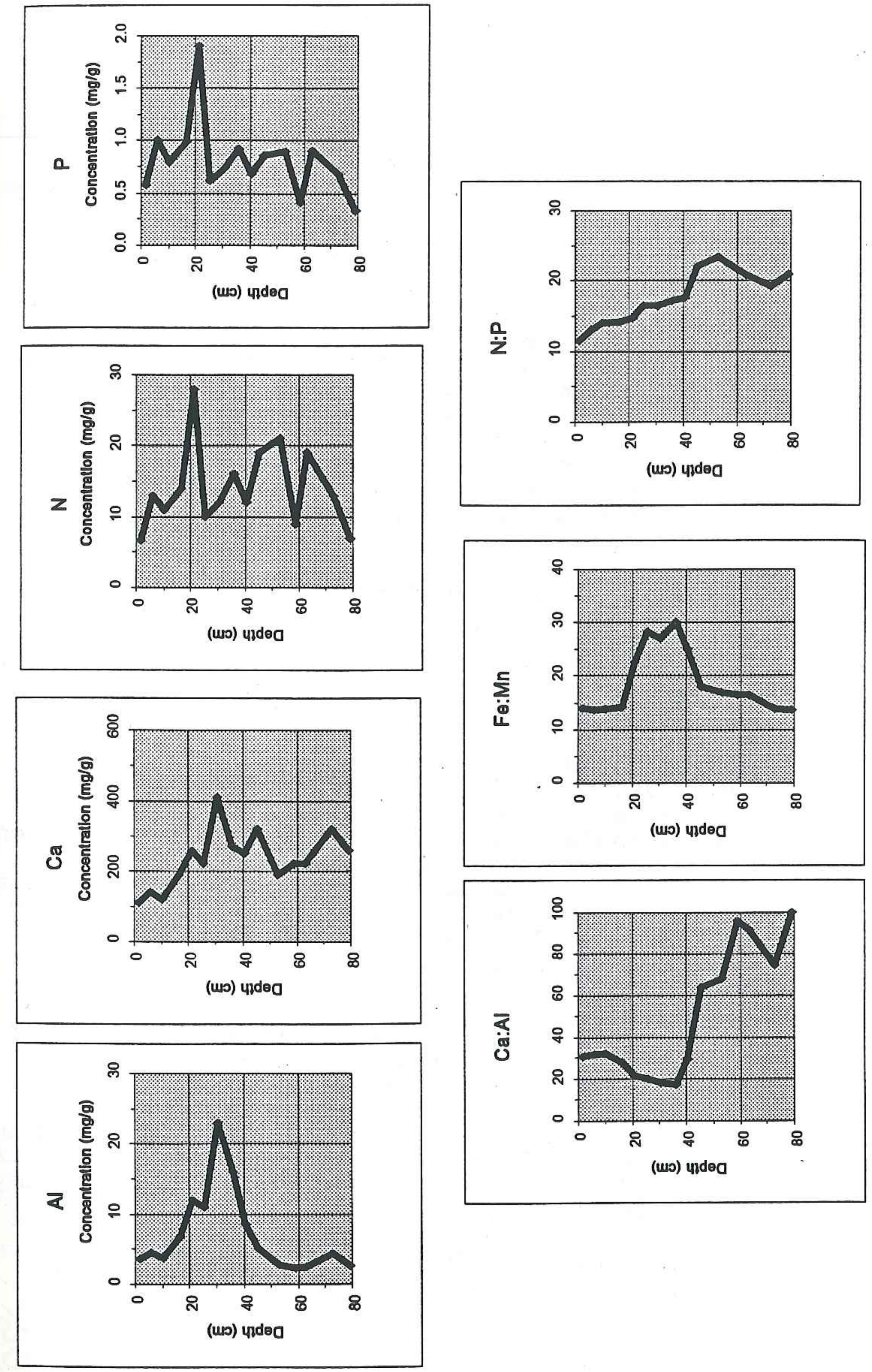


Figure 12. Profiles of selected chemical parameters. Aluminum is indicative of watershed erosion. Calcium is largely the result of $CaCO_3$ precipitation within the lake. The Fe:Mn ratio is indicative of the extent of anoxia in the hypolimnion. A decline in the N:P ratio results from a greater delivery of phosphorus than nitrogen to the sediments.

represented by 20 cm, the ratio has increased somewhat although it is much less than background levels. This indicates that the sedimentation rate may be lower in recent times compared with the turn of the century, but is still greater than pre-European settlement rates.

The ratio of Fe:Mn reflect changes in the anoxic conditions in the hypolimnion. An increase indicates an increase in the volume or duration of anoxia. It appears that at present time anoxic conditions are similar to pre-European settlement times but between the time period represented by 40 to 20 cm, anoxia was more extensive.

Peak concentrations of nitrogen and phosphorus occurred at 20 cm. Concentrations in the recent sediments are similar to background levels. Because other parameters, such as the Ca:Al ratio, indicate that recent sedimentation rate is greater than historical levels, the accumulation rate of both of these nutrients is actually much greater than historical levels. Phosphorus appears to be accumulating in the sediments at a greater rate than nitrogen based upon the decline in the N:P since the time period represented by 40 cm.

The diatom assemblage in the sediments were used to estimate changes in the nutrient conditions within the lake. They are particularly useful for this since some taxa are found in nutrient poor conditions while others are found at higher levels. The diatoms indicate that the historical water quality was very good in the lake. The dominant taxa was *Cyclotella michiganiana* which typically resides in the metalimnion. This indicates that water clarity was very good. This diatom, as well as an unidentified *Cyclotella*, dramatically declined at about 45 cm (Figure 13) indicating a decline in the water clarity. These taxa were replaced by those that typically grow in the epilimnion and are indicative of somewhat higher nutrient levels. This is particularly true of *Aulacoseira* spp. taxa and to a lesser extent *Asterionella formosa* and *Fragilaria crotonensis*. The decline in water quality conditions, indicated by the reduction in the abundance of *C. michiganiana*, occurred at the time when sediment aluminum concentrations began to increase, indicating increased erosion in the watershed. In nearby Lake Ripley, this occurred around 1870. The presence of *A. granulata,* another indicator of high nutrients, around 30 cm indicates the P levels in the lake were higher during this time period than elsewhere in the core. At this depth in the core the Al concentrations indicate that peak erosional rates were occurring and mostly likely discharging more nutrients into the lake. In the most recent sediments, this taxon has made a reappearance indicating that nutrient levels may be increasing in the last few years.

Weighted averaging regression and calibration is a robust and straightforward method for reconstructing environmental variables.

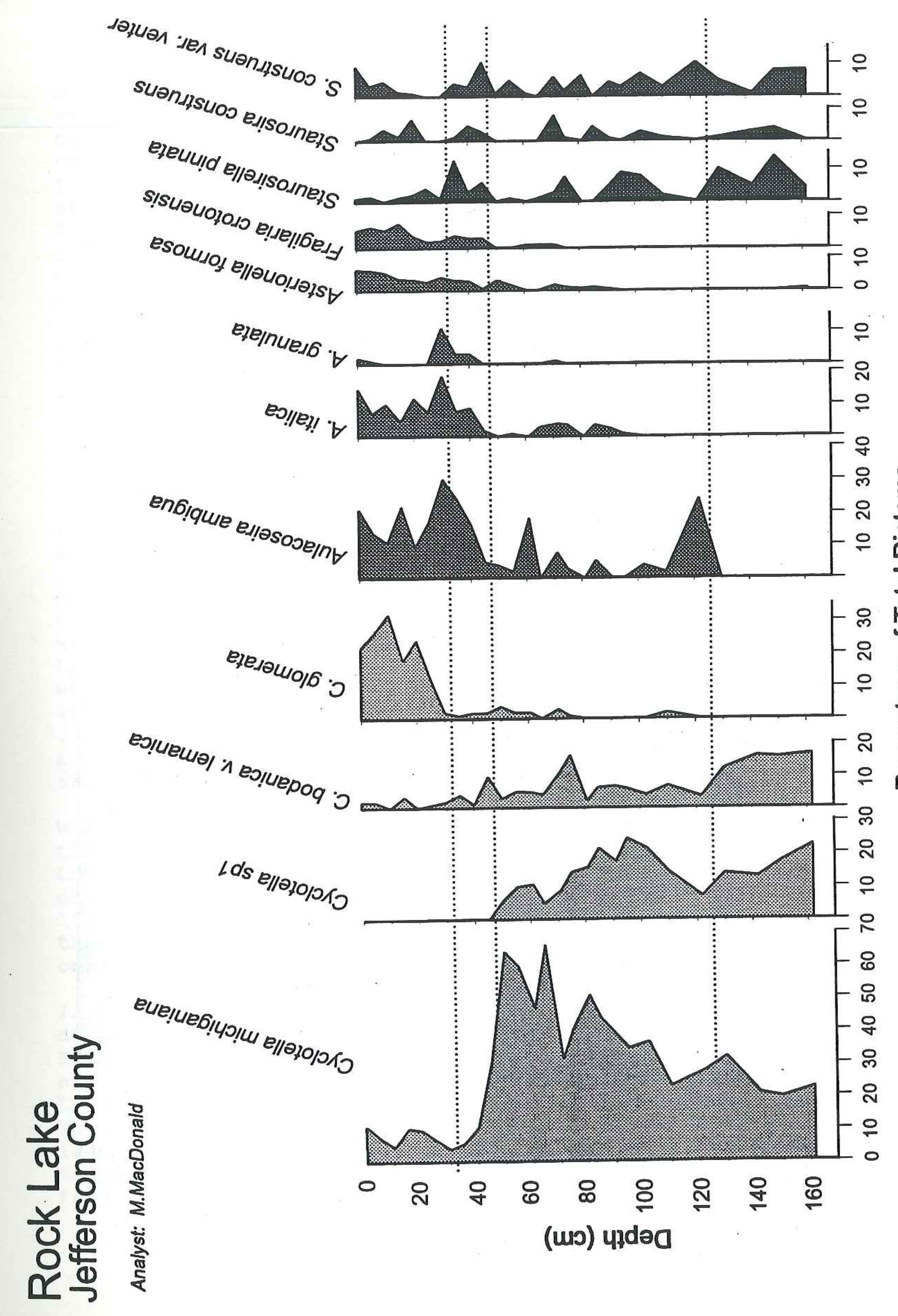


Figure 13. Diatom profiles from the Rock Lake core. *Cyclotella* spp. generally indicates better water quality while *Aulacoseira* indicates higher nutrient levels.

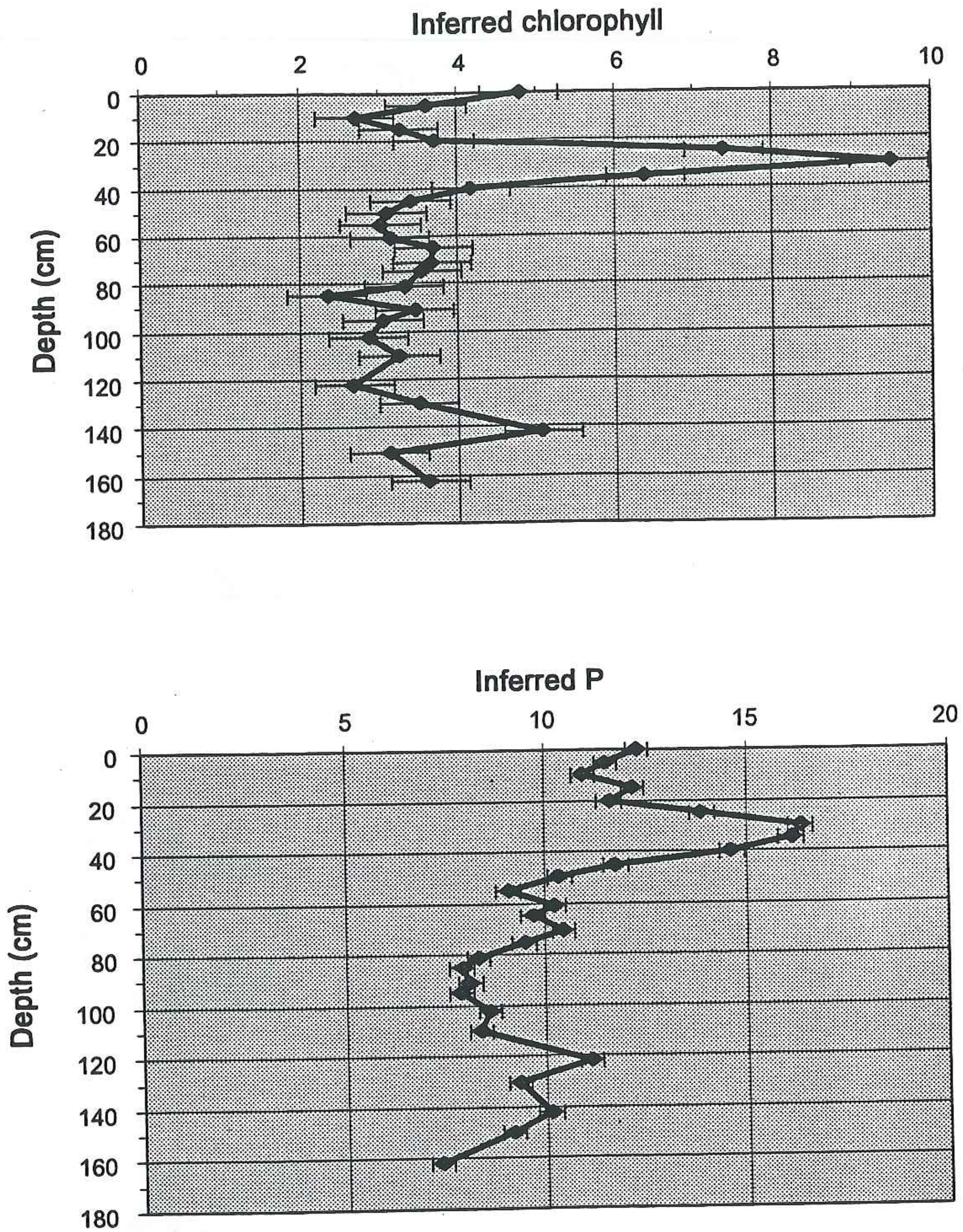


Figure 14. The diatom inferred mean summer chlorophyll (a) and phosphorus (b) concentration in the surface waters from the Rock Lake sediment core.

It provides an accurate and precise inference for historical water quality parameters. The fundamental assumption of this technique is that the weighted average of a taxon represents the conditions for which this taxon is most abundant. Once the weighted average values for an environmental variable have been calculated, the information can be used to infer historical concentrations throughout the sediment core. In the case of Rock Lake, this was done for mean summer concentration of the epilimnetic phosphorus. The inferred P concentration for the top 80 cm are shown in Figures 13 and 14. Historical P concentrations in the lake were about 10 ug/l. Beginning at about 50 cm, concentrations began to increase and reached a peak of 16 ug/l between 30 and 35 cm. Following this time the P levels declined to near background conditions. In the time period represented in the top 10 cm P levels begun to increase to the present level of 12 ug/l.

D. Fisheries

Rock Lake supports a diverse fisheries with 32 species identified in the lake over the years (Table 2). The lake supports popular panfish and gamefish species as well as diverse non-sport species. Primary gamefish include northern pike, largemouth bass, smallmouth bass and walleye. At present, the lake supports excellent populations of both largemouth and smallmouth bass, however the popularity of walleye has been reflected in both past and current fish management. From 1937 to 1946, 9,137,000 walleye fry and 5,000 walleye fingerlings were stocked in Rock Lake. From 1976 to 1996, 781,100 fry and 346,730 fingerlings were stocked in the lake. In addition to walleye stocking, 1650 largemouth bass fingerlings (1984&87), 206,000 white sucker fry (1990), 3100 smallmouth bass fingerlings (1990), 1495 yellow perch fingerlings (1993) and 20,000 northern pike fry were stocked in Rock Lake.

While walleye is often considered the prize Wisconsin fish, it is the only species in Rock Lake listed in the Wisconsin Fish Consumption Health Advisory for unsafe mercury levels. The advisory cautions that pregnant women and children younger than 15 should not eat more than one meal of Rock Lake walleye (less than 22 inches in length) per month. Pregnant women should not consume any Rock Lake walleye 22 inches or greater in length.

In 1987, DNR divers collected sediment cores from Rock Lake to determine possible trends of mercury deposition in the lake. Based on the laboratory detection limits at the time (0.1 mg/kg), no significant levels were found. In hard water lakes like Rock Lake, mercury contamination is usually not serious. Both the Rock Lake sediment samples and mercury research in Wisconsin, indicate that large walleyes have an affinity for accumulating mercury. The primary mercury sources have been atmospheric fallout due to coal and paint emissions in the 20th Century.

Table 2: FISHES OF ROCK LAKE, Jefferson County

COMMON NAME	SCIENTIFIC NAME	IMPORTANCE
1. bowfin	*Amia calva*	"living fossil", ecological balance
2. longnose gar	*Lepisosteus osseus*	"living fossil, ecological balance
3. central mudminnow	*Umbra limi*	gamefish food
4. grass pickerel	*Esox americanus*	biodiversity, ecological balance
5. northern pike	*Esox lucius*	popular gamefish
6. common carp*	*Cyprinus carpio*	destroys habitat, under-utilized food
7. goldfish*	*Carassius auratus*	escaped/released pet, destroys habitat
8. golden shiner	*Notemigonus crysoleucas*	gamefish food
9. emerald shiner	*Notropis atherinoides*	gamefish food
10. blacknose shiner	*Notropis heterolepis*	gamefish food
11. pugnose shiner	*Notropis anogenus*	Threatened species, biodiversity
12. minic shiner	*Notropis volucellus*	gamefish food
13. bluntnose minnow	*Pimephales notatus*	gamefish food
14. fathead minnow	*Pimephales promelas*	gamefish food, major bait species
15. lake chubsucker	*Erimyzon sucetta*	rare species, biodiversity
16. white sucker	*Catostomus commersoni*	gamefish food, major bait species
17. black bullhead	*Ictalurus melas*	common sport fish
18. yellow bullhead	*Ictalurus natalis*	common sport fish
19. banded killifish	*Fundulus diaphanus*	gamefish food, biodiversity
20. blackstripe topminnow	*Fundulus notatus*	gamefish food, biodiversity
21. brook silverside	*Labidesthes sicculus*	gamefish food
22. smallmouth bass	*Micropterus dolomieui*	popular gamefish
23. largemouth bass	*Micropterus salmoides*	popular gamefish
24. rock bass	*Ambloplites rupestris*	incidental panfish catch
25. bluegill	*Lepomis macrochirus*	popular panfish
26. pumkinseed sunfish	*Lepomis gibbosus*	popular panfish
27. green sunfish	*Lepomis cyanellus*	incidental panfish catch
28. black crappie	*Pomoxis nigromaculatus*	popular panfish
29. walleye	*Stizostedion vitreum*	popular gamefish, compete w/ bass
30. yellow perch	*Perca flavescens*	popular panfish
31. Iowa darter	*Etheostoma exile*	gamefish food, biodiversity
32. least darter	*Etheostoma microperca*	rare species, biodiversity

High diversity of native species = healthy lake.
* Non-native (exotic) species.

As part of the Wisconsin Fish Distribution Study, the Rock Lake shoreline was seined in 1974. Eleven stations were sampled around the entire lake to identify the types of fish that inhabit the nearshore littoral zone. This type of sampling does not assess gamefish size structure but identifies non-game species and juvenile sportfish that inhabit the shallow zones within the lake. The sampling effort was duplicated in 1996 to determine if changes in nearshore habitat over the last 22 years have affected fish diversity in the lake. As a result, the 1996 survey produced only 11 species compared to 17 species in 1974. While individual numbers would be expected to vary, total species numbers should not have decreased considering the expansive area sampled. In 1974, 6 cyprinid species, 2 darter species and 2 Cyprinodontid species were found compared to only one cyprinid and no darters or cyprinidontids in 1996. Also not found during the 1996 survey were three rare species previously found in the lake: the pugnose shiner (Threatened), least darter (Special Concern) and lake chubsucker (Special Concern). The decline of both rare and common nongame small forage species should be of concern. Their decline or disappearance indicates ecosystem simplication and unbalance, probably due to shoreline impacts since water quality has not changed significantly over the last 30 years or so.

To compliment the fish distribution surveys, pier inventories were taken to reflect habitat changes in the lake. While pier construction is just one form of shoreline and littoral zone disturbance (others being seawalls, riprap for aesthetic purposes and aquatic plant eradication due to herbicides and motorboat scouring, and exotic invasions), changes in total pier numbers will indicate the extent of shoreline development. In 1996, the total pier numbers and their dimensions were surveyed by DNR and Jefferson County staff. Compared to mid-summer aerial photographs taken from 1950 and 1963, changes in shoreline development were assessed. From 1950 to 1996, pier numbers increased from 96 to 276 or 65%. Impacts from pier development alone include aquatic plant community fragmentation due to shading and motorboat scouring. Considering the trends of increasing motorboat size, horsepower and shallow running jet skis, pier impacts are probably much greater than the 65% numerical increase would otherwise indicate. Figure 15 displays changes in both pier densities and fish diversity over the years.

Other interesting fish found in Rock Lake included two "living fossils", bowfin (dogfish) and longnose gar. Both species possess characteristics found in their 200 million year old relatives, which include functional lungs. These piscivores have been persecuted for many years by both anglers and former Conservation Department fish managers who believed that they were destructive. Only recently have fish biologist understood the value that these species offer for ecosystem stability by preying on exotic carp and over populated panfish. In some lakes,

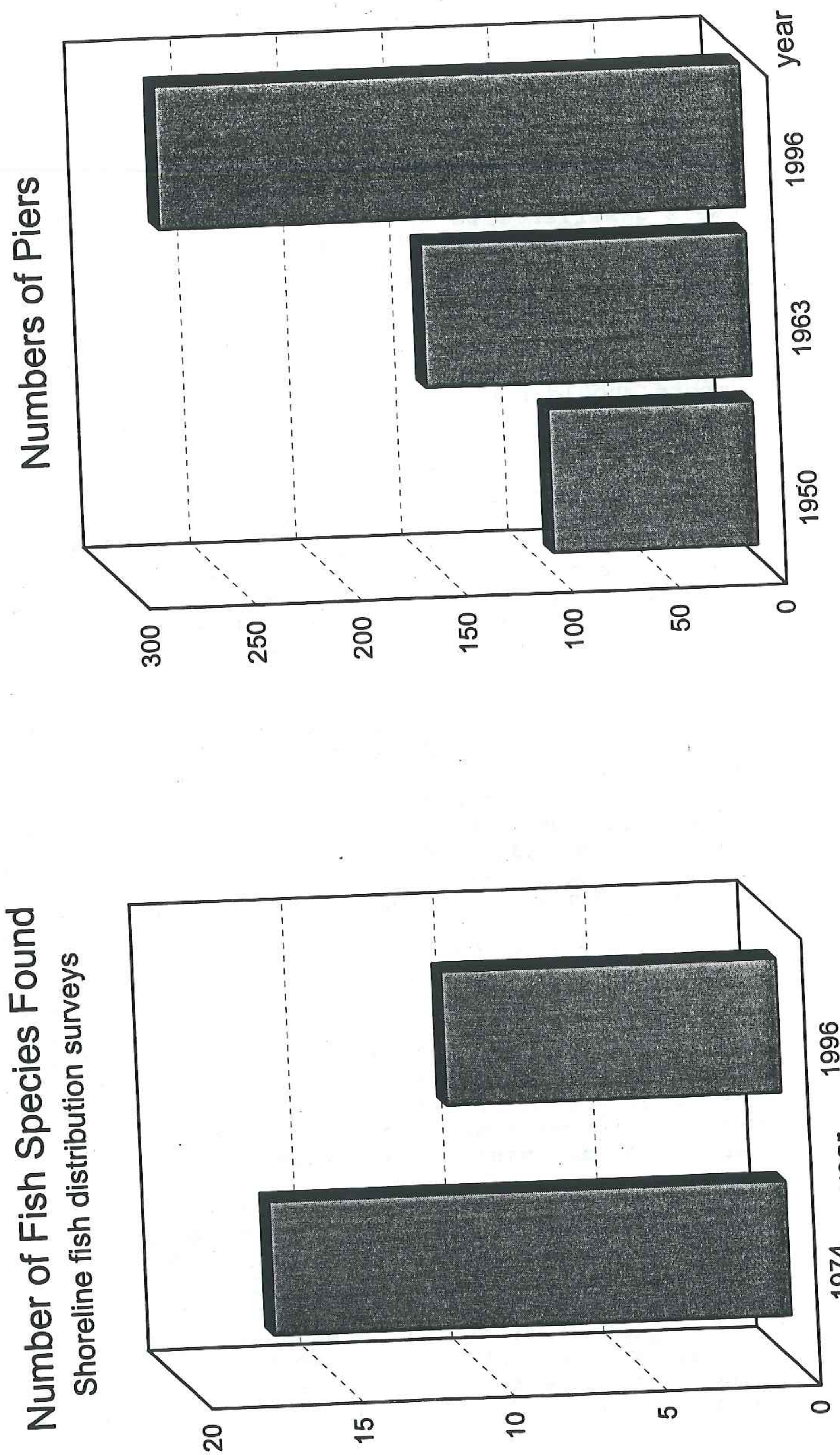


Fig. 15: Rock Lake, Jeff. Co.: fish diversity declines as shoreline development increa

Primary causes for diversity decline in Rock Lake have been loss of emergent, floating and submersed vegetation due to increased piers, motor boat traffic and seawall construction. Overall water quality did not change significantly over the years while riparian and near shore habitats clearly declined. Numbers of individuals are expected to fluctuate but not species numbers over a large lake shore area.

managers have stocked these species to control carp. Carp and goldfish are the only two exotic species in Rock Lake at this time.

E. Macrophytes

Table 3 lists aquatic plant species found in Rock Lake. Aquatic plant "rake" surveys are conducted on a three year cycle as part of the Long Term Trends Study. The triennial survey goal is to evaluate trends of dominant plant species. One hundred-ten sites are sampled along 22 established transects around the lake. Surveys have been conducted in 1990 and 1996 so far.

While at least 25 species have been recorded from the lake, the surveys indicate that four species have clearly dominated over the last six years; Eurasian watermilfoil, Chara, wild celery and spiny naiad. While these species dominated during each survey, their frequency of occurrence did vary somewhat. Eurasian watermilfoil increased from 27 sampling sites in 1990 to 35 in 1996. Chara increased from 57 to 68, wild celery increased from 15 to 30 and spiny naiad decreased from 22 to 21 (Figure 16).

While the four species dominated the plant community during both surveys, some clear growth patterns have emerged. Chara is the most common plant in the lake and was found at 52% (1990) and 62% (1996) of the sampling sites. The densest Chara stands can be found out to about 6 feet. Chara is an advanced type of algae and is indicative of hard-water lakes. It is tolerant of motorboat traffic at moderate levels, but has declined in areas of heavy motorboat traffic in Rock Lake and nearby Lake Ripley. Where Chara has declined due to motorboat scouring, a biological void exists exposing fine marl sediment to resuspension. Nearshore turbidity is common on windy days or following periods of heavy motorboat traffic as the fine white particles from these scoured areas cloud the water.

The second most common species found in Rock Lake is Eurasian watermilfoil. This exotic plant has caused nuisance conditions and ecological imbalances in hundreds of lakes throughout North America. In lakes with severe invasions, Eurasian watermilfoil will crowd out desirable native species and alter both the physical and chemical environment. Dense stands of the exotic "weed" can interrupt predator-prey interactions within a lake, resulting in over-populated slow growing panfish as well as slow growing gamefish. Dense milfoil beds can create an unnatural panfish refuge from gamefish. In Rock Lake, Eurasian watermilfoil is common lake-wide, but the greatest densities can be found at the depth range from 9-14'. Currently, this narrow band of Eurasian watermilfoil is not a serious management problem. It has created an outer "reef" habitat for piscivores such as largemouth bass and walleye. Cutting channels through this "barrier reef" will likely improve the habitat and

Figure 16: Dominant Plants found in Rock Lake

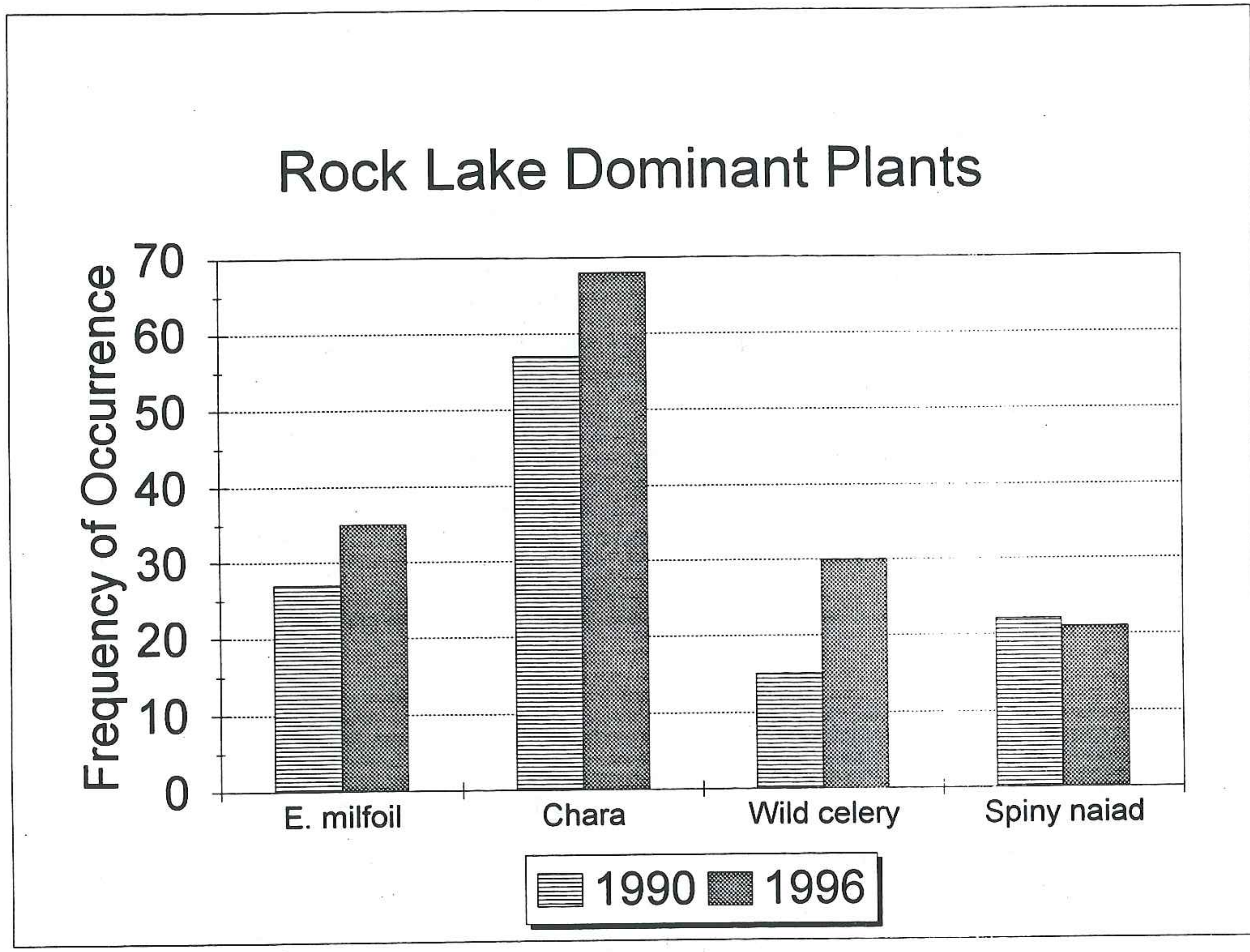


Table 3: Rock Lake Macrophytes

Common Name	Scientific Name	Habitat Values
Arrowhead	*Sagitaria latifolia*	(E) bank stabilization, fish, birds, reptiles
Bladderwort	*Utricularia vulgaris*	(S) biodiversity, fish
Bulrush	*Scirpus* spp.	(E) erosion control, fish, waterfowl, reptiles
Cattail, Broad leaf	*Typha latifolia*	(E) erosion control, fish, waterfowl, reptiles
Cattail, Narrow	*Typha augustifolia*	(E) erosion control, fish, waterfowl, reptiles
Coontail	*Ceratophyllum demersu*	(S) fish, waterfowl
Elodea	*Elodea canadensis*	(S) fish, waterfowl
Milfoil, Northern	*Myriophyllum sibericum*	(S) fish
* Milfoil, Eurasian	*Myriophyllum spicatum*	(S) fish at moderate levels
Muskgrass	*Chara vulgaris*	(S) fish, waterfowl
Naiad, Slender	*Najas flexilis*	(S) fish, waterfowl
Naiad, Spiny	*Najas marina*	(S) waterfowl, probably fish
Nitella	*Nitella flexilis*	(S- deep water stonewort)
Pondweed, Floating leaf	*Potamogeton natans*	(FL) fish, waterfowl, herptiles
Pondweed, Clasping	*P. richardsonii*	(S) fish, waterfowl
Pondweed, Flat stem	*P. zosteriformes*	(S) fish, waterfowl
Pondweed, illinois	*P. illinoensis*	(S) fish, waterfowl
* Pondweed, Curly leaf	*P. crispus*	(S) fish at moderate levels
Pondweed, Variable	*P. gramineus*	(S) fish, waterfowl
Pondweed, Small	*P. pucillus*	(S) fish, waterfowl
Pondweed, Sago	*P. pectinatus*	(S) fish, waterfowl
Water Buttercup	*Ranunculus aquatilis*	(S) fish
Water Buttercup	*R. flabellaris*	(S) fish
Spatterdock	*Nuphar variegata*	(FL) fish, waterfowl, herptiles
White water lily	*Nymphaea odorata*	(FL) fish, waterfowl, herptiles
Wild celery	*Vallisneria americana*	(S) fish, waterfowl

E=emergent, FL=floating leaf, S=submersed, *=exotic predator-prey interactions. Maintaining healthy and diverse native plant communities nearshore may prevent further expansion of the exotic milfoil.

Rock Lake supports numerous high value native plant species that provide important fish and wildlife habitat functions. Wild celery is an abundant species that provides food for migrating waterfowl as well as fish and invertebrate habitat. Both broad leaved and narrow leaved pondweeds provide a variety of fish and wildlife ecological functions. Broad leaved pondweeds, such as Illinois pondweed and Richardson's pondweed, are susceptible to motorboat traffic. Floating leaf pondweeds, white waterlilies and spatterdock provide shade and cover for numerous forms of aquatic life. Early in the season, largemouth bass often deposit eggs on waterlily rhizomes. Later, the lilypad shade canopy supports numerous developing sportfish and nongame species as the season progresses. Waterlilies and other floating leaf plants are also susceptible to motorboat traffic. Other valuable plants in Rock Lake include bulrushes in Korth Bay and bladderwort, a species adapted to feeding on minute crustaceans.

Over the years, the aquatic plant community has been altered by development, intensive motorboat traffic and the Eurasian watermilfoil invasion. A few parts of the lake still support diverse stands of native plants that provide important spawning and nursery habitat functions. These are located in Marsh Lake, Korth Bay, Schultz's Bay and the millpond. The Department of Natural Resources cooperated with the Rock Lake Improvement Association and a private consultant to identify these "Sensitive Areas" for plant protection. The Town of Lake Mills has already passed a no-wake ordinance to protect these areas. To further protect these plants and their ecological functions within the "Sensitive Areas", management activities such as dredging, sand blankets, seawalls and herbicides are prohibited. New piers will be scrutinized and constructions will be limited to the maximum allowed in the Pier Planner Guidance. In most cases, boat slips will be concentrated at a common access point to reduce further habitat fragmentation along the shoreline. To reduce further habitat disturbances throughout the lake, broad spectrum herbicides are prohibited to protect valuable native species and only chemicals that will selectively remove Eurasian watermilfoil are allowed.

Exotic species will often disturb balanced ecosystems since they are immune to the natural checks and balances that have evolved in native communities. Eurasian watermilfoil is one example of an exotic disturbance species, carp is another. In 1996, DNR and Jefferson County staff observed severe turbidity and uprooted native plants within Schultz's Bay due to carp spawning activities. Carp can act like an overgrazing cattle herd and destroy habitat. Along with destroying habitat, the exotic carp reduced water quality by increasing water column phosphorus

concentrations seven-fold and suspended solids sixteen-fold. Based on an established carp/phosphorus generation factor of 0.011 lb/lb carp/year, an estimated carp biomass of 30,000 lbs. could contribute 330 lbs. of phosphorus or 23% of the annual load in Rock Lake. Further evaluation is needed to determine the extent of carp damage and ecosystem disturbances. In the mean time, harvesting carp can be beneficial and enjoyable.

F. Biodiversity

The representative fish and aquatic plant species mentioned above comprise only a small fraction of the plant and animal communities that reside in the Rock Lake Watershed. The watershed includes a variety of aquatic and riparian habitats and species adapted to them. In Rock Lake alone, fish depend upon the complex food web including freshwater mussels, crustaceans, micro-crustaceans, aquatic insects, plants, waterfowl and herptiles.

To the scientist, biodiversity means the entire spectrum of life forms and the many ecological processes that support them. For many people, biodiversity is not a scientific concept but rather a part of the lake experience. Gazing at schools of minnows, basking turtles, leaping frogs or hovering dragonflies are examples of appreciating the rich diversity of healthy lakes.

Within both publicly owned lands and some relatively undisturbed privately owned parcels are some unique and scarce habitats that support Rock Lake Watershed's rich biodiversity. Within the wetland complex south of Rock Lake includes a calcareous seepage lake (Bean Lake), calcareous fen, tamarack swamp, shrub carr and sedge meadow. Some of the interesting plants that the complex wetlands support include grass-of-parnassus, Ohio goldenrod, lesser fringed gentian, small white lady's slipper, small yellow lady's slipper, showy lady's slipper and fen betony. Herptiles that can be found in the watershed include: (turtles) spiny softshell, painted, Blanding's, musk, snapping, (frogs-toad) northern leopard, green, bull, spring peeper, chorus, Blanchard's cricket, and Eastern American toad (salamanders) mudpuppy, central newt and tiger (snakes) Northern water, brown, garter, bull, Eastern milk, smooth green, queen, and Northern redbelly.

Public ownership of lands is one of the reasons that the watershed still supports diverse and rare species. However, rapid development of the Rock Lake shoreline and encroachment around the natural areas are stressing our ability to protect biodiversity. Many herptile species are dependent on undisturbed riparian areas. Extensive piers, seawalls and riprap destroy nearshore habitat and interrupt the links between terrestrial and aquatic ecosystems. Intensive development beyond the shores and wetlands will also affect migrating herptiles, such as the Threatened Blanding's Turtle.

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THE ROCK LAKE CHAIN OF LAKES - JEFFERSON
PHOSPHORUS MODEL

PREDICTED LAKE QUALITY		-----------	Lakes
		Mud	Marsh
Total Phosphorus (ppb)		106	40
Chlorophyll_a (ppb)		30	15
Secchi Depth (m)		1.2	1.6
INPUT VARIABLES	UNITS	-----------	Lakes
Lake Names	--	Mud	Marsh
lake area	acres	93	210
lake volume	acre-ft	558	1060
Mean Depth	Feet	6.0	5.0
dir tributary area	acres	4609	1679
dir area unit runoff	in/yr	4.43	4.43
DIR UNIT AREA EXPO	lbs/ac-yr	0.50	0.05
atmospher unit export	lbs/ac-yr	0.27	0.27
precip-evaporation	in/yr	1.4	1.4
groundwater p load	lbs/yr	0.0	0.0
groundwater flow	ac-ft/yr	0.0	0.0
OTHER TRIB P LOADI	lbs/yr	0.0	0.0
OTHER TRIB FLOW	ac-ft/yr	0.0	0.0
upstream pond p load	lbs/yr	0.0	491.9
upstream pond outflow	ac-ft/yr	0.0	1712.6
% REDUCT. DIR WTRSHD LOA		0.0	0.0
total annual load	lbs/yr	2304.5	580.9
total annual flow	ac-ft/yr	1712.6	2357.4
OUTPUT VARIABLES			
outflow p load	lbs/yr	491.9	258.5
outflow volume	ac-ft/yr	1712.6	2357.4
=> PRED. SUMMER T	ppb	106	40
=> OBS. SUMMER TP.	ppb	106	NA
p removal efficiency	%	78.7	75.9
POND WATER BUDGETS			
runoff + dir precip	ac-ft/yr	1712.6	644.9
upstream pond	ac-ft/yr	0.0	1712.6
groundwater inflow	ac-ft/yr	0.0	0.0
other trib inflow	ac-ft/yr	0.0	0.0
total inflow	ac-ft/yr	1712.6	2357.4
outflow	ac-ft/yr	1712.6	2357.4
POND PHOSPHORUS BUDGETS			
runoff + precip	lbs/yr	2304.5	580.9
upstream pond	lbs/yr	0.0	491.9
groundwater	lbs/yr	0.0	0.0
other tribs	lbs/yr	0.0	0.0
total inflow	lbs/yr	2304.5	1072.9

net sedimentation	lbs/yr	1812.6	814.3
outflow	lbs/yr	491.9	258.5
HYDRAULIC PARAMETERS			
pond mean depth	feet	6	5
residence time	years	0.33	0.45
residence time	days	119	164
overflow rate	ft/yr	18.4	11.2
inflow phos conc	mg/m^3	495.1	167.4
outflow phos conc	mg/m^3	105.6	40.3
p retention coef. <r>	-	0.79	0.76
1-r	-	0.21	0.24
Walker, 1987 Model <r	-	0.85	0.76
Calibration Factor	-	0.92	1.00
NR	-	40.62	13.07
K2	m^3/mgYr	0.25	0.17
Qs	m/Yr	5.61	3.42
Fo	-	0.066	0.066

WILMS 2.00 used to set Mud Lakes calibration factor.

WISCONSIN LAKE MODEL SPREADSHEET
VERSION 2.00 - AUGUST 1996
WISCONSIN DEPARTMENT OF NATURAL RESOURCES

Although this model has been tested by WDNR, no warranty is expressed or implied. See users manual prior model use.

LAKE ID Rock Lake Priority Lake Project
To auto load wtrshd data, enter county ID, hold CTRL and type L.
WATERSHED COUNTY IDENT. NUMBER = 28 CO. NAME: Jefferson

HYDROLOGIC AND MORPHOMETRIC MODULE

	ENGLISH		METRIC	
TRIB. DRAINAGE AREA =	1582.0	Ac.	6.40E+06	m^2
TOTAL UNIT RUNOFF =	4.4	In.	0.113	m
ANNUAL RUNOFF VOLUME =	584.0	Ac-Ft.	7.20E+05	m^3
LAKE SURFACE AREA <As> =	1160.0	Ac.	4.69E+06	m^2
LAKE VOLUME <V> =	18580.0	Ac-ft.	2.29E+07	m^3
LAKE MEAN DEPTH <z> =	16.02	Ft.	4.88	m
PRECIP. - EVAP. =	1.4	In.	0.04	m
HYDRAULIC LOADING =	3079.4	Ac-Ft/Yr	3.80E+06	m^3/Yr
AREAL WATER LOAD <qs> =	2.65E+00	Ft/Yr.	8.09E-01	m/Yr
LAKE FLUSHING RATE <p> =	0.17	/Yr Tw =	6.03	Yr

PHOSPHORUS LOADING MODULE

		--LOADING (Kg/Ha-Yr)--			
LAND USE	AREA (AC)	LOW	MOST LIKELY	HIGH	LOADING PERCENT
ROW CROP AG	505.0	0.50	1.14	3.00	36.7
MIXED AG	61.0	0.80	1.00	1.40	3.9
PASTURE/GRASS	30.0	0.10	0.30	0.50	0.6
HD URBAN	0.0	1.00	1.30	2.00	0.0
MD URBAN	467.0	0.40	0.50	0.80	14.9
RURAL RES.	394.0	0.05	0.10	0.25	2.5
WETLANDS	0.0	0.10	0.10	0.10	0.0
FOREST	125.0	0.05	0.09	0.18	0.7
OTHER LAND USE 1	0.0	0.00	0.00	0.00	0.0
OTHER LAND USE 2	0.0	0.00	0.00	0.00	0.0
LAKE SURFACE	1160.0	0.10	0.30	1.00	22.2
POINT SOURCE WATER LOADING (m^3/Yr) =				2.91E+06	---
POINT SOURCE PHOS.(Kg/Yr)		0.00	117.30	0.00	18.5
SEP.TANK OUTPUT(kg/cp-yr)		0.30	0.50	0.80	---
# capita-years =	0.00	----	----	----	---
% P. RETAINED BY SOIL =		98	90	80	---
SEP. TANK LOADING (Kg/Yr)		0.00	0.00	0.00	0.0
TOTAL LOADINGS (Lb) =		5.65E+02	1.40E+03	2.92E+03	100.0
TOTAL LOADINGS (Kg) =		2.56E+02	6.34E+02	1.32E+03	100.0

AREAL LOADING(Lb/Ac-Yr)=	4.87E-01	1.21E+00	2.52E+00
AREAL LOADING(mg/m^2-yr)=	5.46E+01	1.35E+02	2.82E+02
% TOTAL PHOSPHORUS REDUCTION =		0	

To view a graph of phosphorus inputs expressed as percentages of the total phosphorus load, hold CTRL and type G. When done viewing the graph, press any key to continue.

PHOSPHORUS PREDICTION MODULE

THE OBSERVED SPRING TOTAL PHOSPHORUS = 20 mg/m^3
THE OBSERVED GROWING SEASON PHOSPHORUS = 11 mg/m^3

Enter the spring and/or the growing season P concentration. The lake models predict either an SPO or a GSM P concentration. A predicted phosphorus concentration will appear only for those models where the observed value has been entered. An "NA" is returned if a model is not calculated.

Spring Overturn P conc = SPO ; Growing Season Mean P conc = GSM

LAKE PHOSPHORUS MODELS				PREDICTED TOTAL PHOSPHORUS (mg/m^3)
1. WALKER, 1987 RESERVOIR MODEL (GSM)				45
	18	45	95	
2. CANFIELD-BACHMANN, 1981, NATURAL LAKE MODEL (SPO)				40
3. CANFIELD-BACHMANN,1981,ARTIFICAL LAKE MODEL (SPO)				35
4. RECKHOW, 1979, NATURAL LAKE MODEL (GSM)				11
	4	11	22	
5. RECKHOW, 1977, ANOXIC LAKE MODEL (GSM)				77
	31	77	162	
6. RECKHOW, 1977 OXIC LAKES qs < 50 m/yr (GSM)				20
	8.0695908538148	19.98365	41.68321948	
7. RECKHOW, 1977 OXIC LAKES qs > 50 m/yr (GSM)				NA
	NA	NA	NA	
8. WALKER 1977, GENERAL LAKE MODEL (SPO)				58
	23.554307925886	58.33023	121.6690418	
9. VOLLENWEIDER, 1975 LAKE MODEL (SPO and GSM)				13
10. DILLON-RIGLER-KIRCHNER, 1975 LAKE MODEL (SPO)				39
P. RETENTION COEFF. <R> qs < 10 m/yr			0.76	
P. RETENTION COEFF. <R> qs >= 10 m/yr			NA	

UNCERTAINTY ANALYSIS MODULE

PREDICTED MINUS

70 PERCENT

LAKE RESPONSE MODEL	OBSERVED (mg/m^3)	PERCENT DIFF.	CONFIDENC INTERVAL		
1.WALKER, 1987 RESERVOIR	25	125	25	80	
2.CANFIELD-BACHMANN, 1981	20	100	13	116	<=
3.CANFIELD-BACHMANN, 1981	15	75	11	100	<=
4.RECKHOW, 1979 GENERAL	0	0	6	19	
5.RECKHOW, 1977 ANOXIC	66	600	43	135	
6.RECKHOW, 1977 qs<50m/yr	9	82	11	35	
7.RECKHOW, 1977 qs>50m/yr	NA	NA	NA	NA	
8.WALKER, 1977 GENERAL	38	190	27	110	
9.VOLLENWEIDER, 1975	-3	-19	--	--	
10.DILLON-RIGLER-KIRCHNER	19	95	--	--	

<= Range within which 95% of the observations should fall.
See users manual discussion on the use of these models.

PARAMETER RANGE MODULE

Model input values MUST be within the ranges listed below.
WILMS displays FIT if inputs satisfy conditions ; NO FIT if not.

PARAMETERS

AREAL WATER LOADING <qs=z/Tw> =	8.09E-01	m/yr
INFLOW PHOSPHORUS CONC.<LTw/z> =	0.167	mg/l
MEAN DEPTH <z> =	4.88	m
FLUSHING RATE <p> =	0.17	/yr
HYDRAULIC RETENTION TIME <Tw> =	6.03	yr
AREAL PHOSPHORUS LOADING <L> =	135.15	mg/m^2-yr

P = PREDICTED IN LAKE PHOS. CONCENTRATION mg/m^3

		Model data base size
1. WALKER, 1985 RESERVOIR MODEL		(41)
1.5 < z < 58 m 0.13 < Tw < 1.91 yr	<NO FIT>	
0.014 < LTw/z < 1.047 mg/l	P=	45
2. CANFIELD-BACHMANN, 1981 NATURAL LAKE MODEL		(290)
4< P < 2600 mg/m^3 30< L < 7600 mg/m^2-yr	<FIT>	
0.2< z <307 m 0.001< p <183/yr	P=	40
3. CANFIELD-BACHMANN, 1981 ARTIFICIAL LAKE MODEL		(433)
6< P <1500 mg/m^3 40< L <820,000 mg/m^2/yr	<FIT>	
0.6< z <59 m 0.019< p <1800/Yr	P=	35
4. RECKHOW, 1979 NATURAL LAKE MODEL		(47)
4< P <135 mg/m^3 70< L <31,400 mg/m^2-yr	<FIT>	
0.75< qs <187 m/yr	P=	11
5. RECKHOW,1977 ANOXIC LAKE MODEL	<FIT>	(21)
17< P < 610 mg/m^3 0.024< LTw/z< 0.621mg/l	P=	77
6. RECKHOW, 1977 OXIC LAKES qs < 50 m/yr	<FIT>	(33)

P < 60 mg/m^3 LTw/z < .298 mg/l	P=	20
7. RECKHOW, 1977 LAKES WITH qs > 50 m/yr P < 135 mg/m^3 LTw/z < 0.178 mg/l Tw < 0.25 yr z < 13 m	NA P=	(28) NA
8. WALKER, 1977 GENERAL LAKE MODEL P < 900 mg/m^3 LTw/z < 1.0 mg/l	<FIT> P=	(105) 58
9. VOLLENWEIDER, 1975 GENERAL LAKE MODEL NOT AVAILABLE	<FIT> P=	 13
10. DILLON, RIGLER, KIRCHNER, 1975 LAKE MODEL P < 15 mg/m^3 107 < L < 2210 mg/m^2-yr 1.5< qs <223 m/yr 0.21< p < 63/yr	<NO FIT> P=	(15) 39

WATERSHED LOAD BACK CALCULATION MODULE

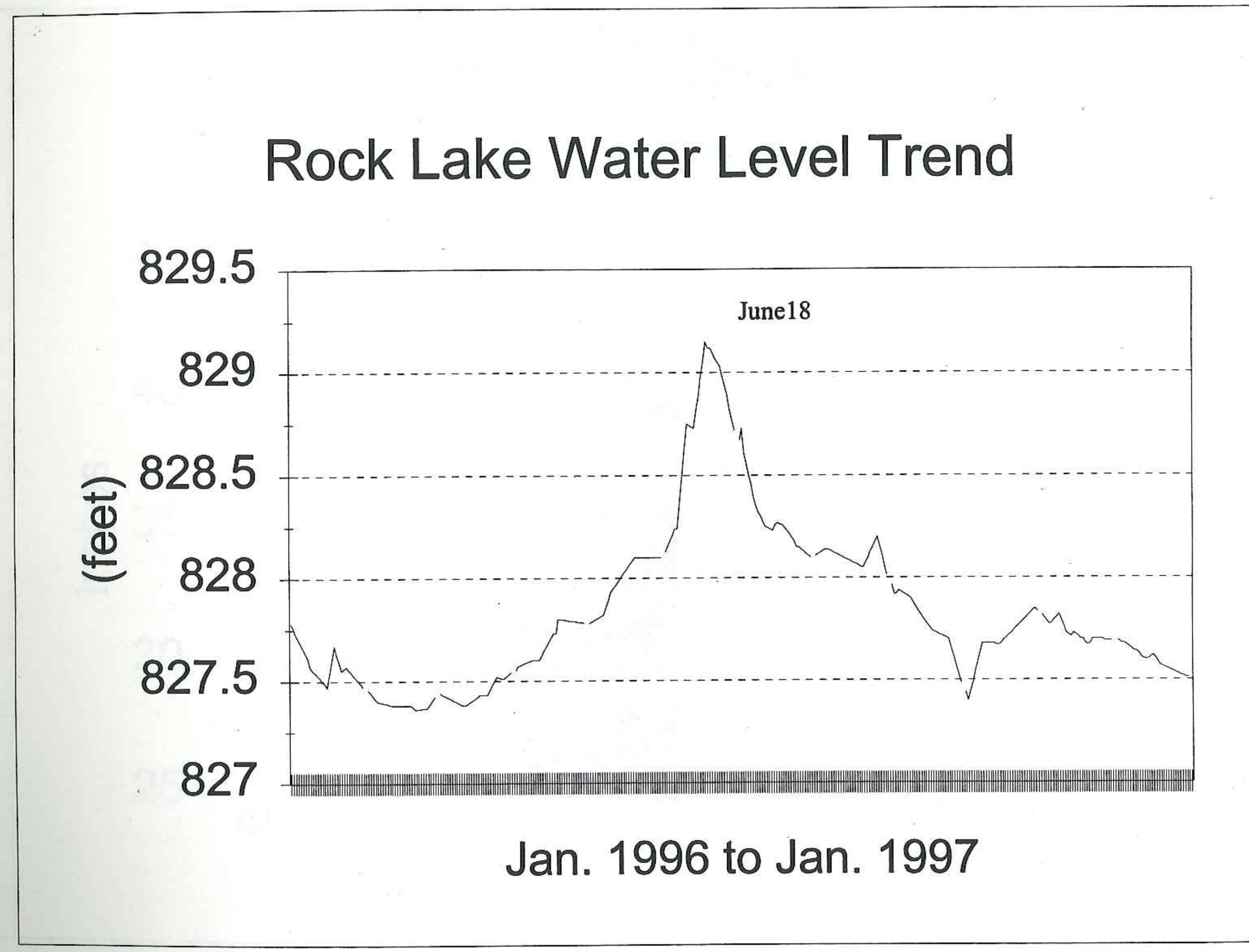
This section will calculate predicted phosphorus loads for each model given an in-lake phosphorus concentration.

Enter the spring and/or the growing season P concentration. WILMS will calculate a watershed load using the appropriate models. An "NA" is returned if a model requires either a spring overturn or growing season mean phosphorus concentration and one is not provided.

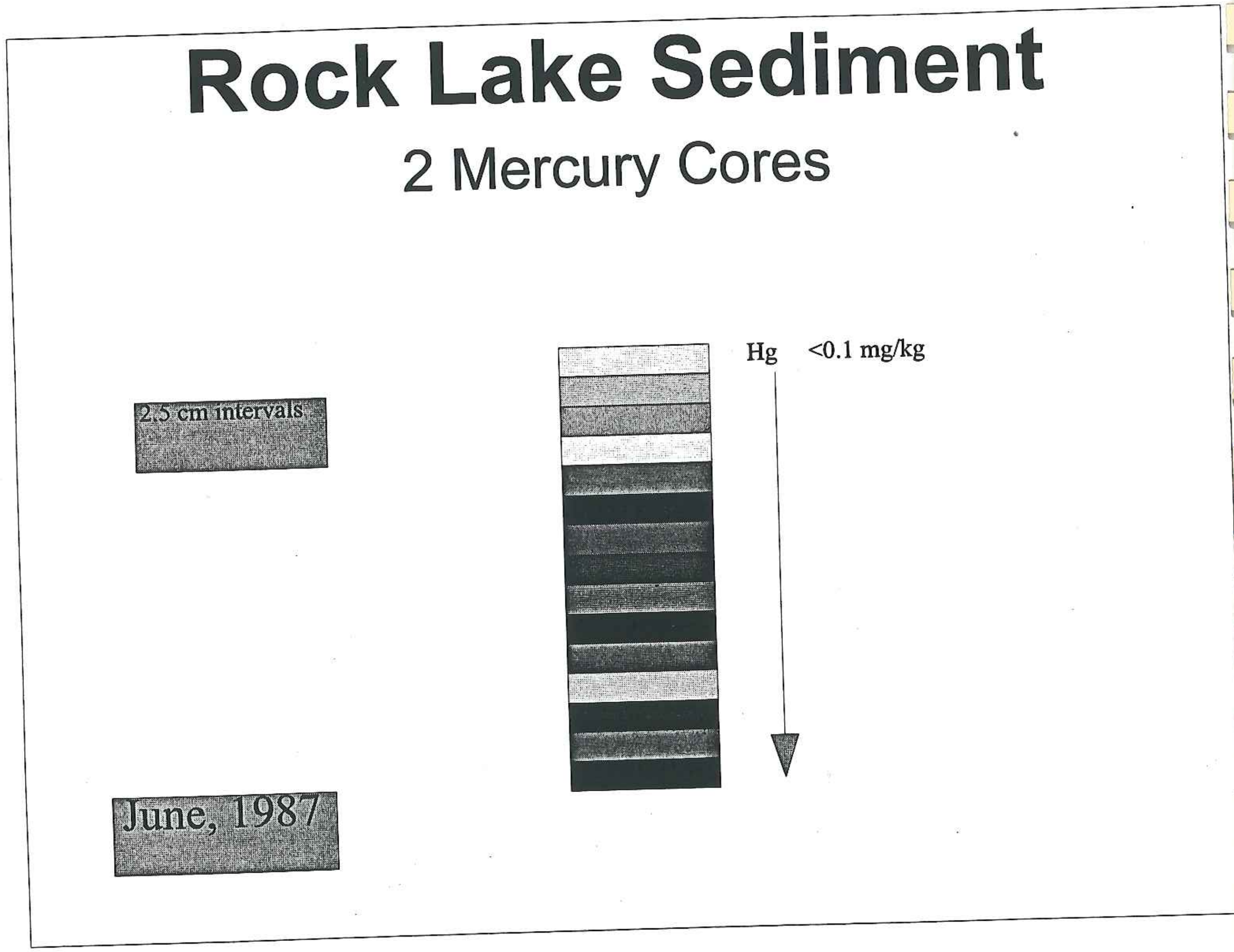
NOTE: To calculate the Canfield-Bachmann models, the user MUST enter the spring phosphorus concentration, hold CTRL and PRESS "C".

OBSERVED SPRING OVERTURN TOT. PHOS. (SPO) = 20 mg/m^3
OBSERVED GROWING SEASON MEAN PHOS. (GSM) = 11 mg/m^3

LAKE PHOSPHORUS MODELS	PREDICTED PHOSPHORUS LOAD (Kg/Yr)
1. WALKER, 1987, RESERVOIR MODEL (GSM)	154
2. CANFIELD-BACHMANN, 1981, NATURAL LAKE MODEL (SPO)	950
3. CANFIELD-BACHMANN,1981,ARTIFICAL LAKE MODEL (SPO)	4400
4. RECKHOW, 1979, NATURAL LAKE MODEL (GSM)	649
5. RECKHOW, 1977, ANOXIC LAKE MODEL (GSM)	90
6. RECKHOW, 1977 OXIC LAKES qs < 50 m/yr (GSM)	349
7. RECKHOW, 1977 OXIC LAKES qs > 50 m/yr (GSM)	NA

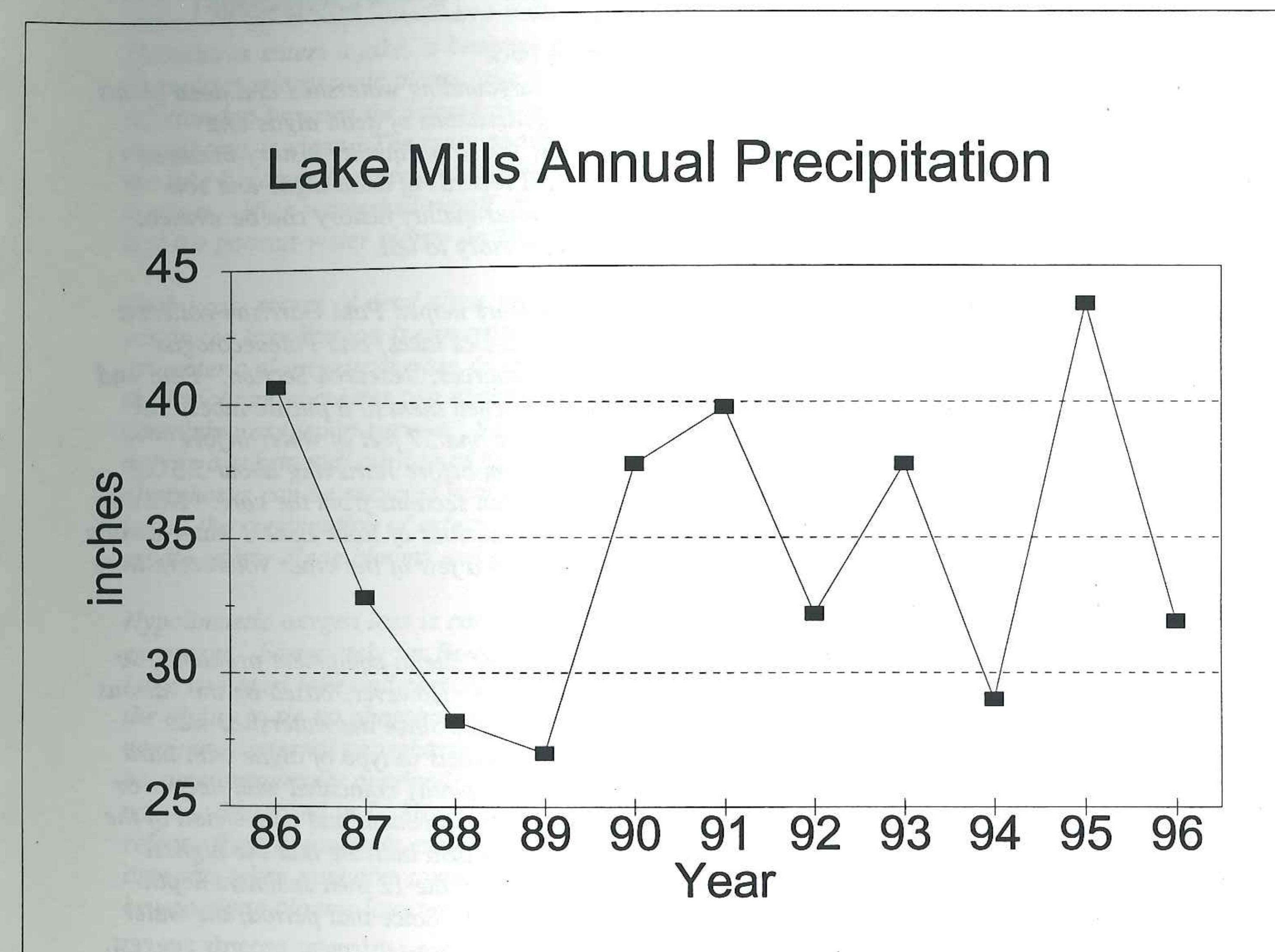


Appendix C: Rock Lake Mercury Deposition in Lake Sediment



2 cores collected by SCUBA divers at 50' water depth

Appendix D: Lake Mills Annual Precipitation



Source: Midwest Climate Center

MAKING WAVES

What do fossils in Rock Lake tell us?

Most natural lakes in the eastern and northern two-thirds of Wisconsin were formed nearly 10,000 years ago, when the last glacier - the Wisconsin Glacier, receded northward. As temporary features of the landscape, these glacial gifts began filling-in from day one. The lakes became part of an extremely slow process of reverting back to land. All lakes gradually fill in with soils from the surrounding watershed and dead plants and animals produced within the lake. As successive generations of dead algae and watershed runoff are deposited in lakes year after year, the water quality history becomes preserved within the bottom mud. By studying the fossil records of dead algae and soil particles (not dinosaurs!) at the bottom of a lake, the water quality history can be written. Since no two lakes are identical, each lake has a unique story to tell.

In February, 1996, Lake Mills students and other volunteers helped Paul Garrison collect a sediment core from Rock Lake. Paul is a Limnologist (studies lakes) and Paleoecologist (studies lake history) with the Department of Natural Resources, Research Section. Paul and the volunteers assembled numerous pipe sections and attached them to a plastic tube. The coring assembly was then guided through a hole in the ice and 57 feet of water before reaching the bottom. They pushed the core into the bottom before retrieving about 5.5' of mud. The messy part began when they helped Paul cut thin sections from the core. The thin sections were later tested separately to represent specific periods of Rock Lake's water quality history. By the time they were finished, Hope Oostdik and a few of the other volunteers were literally draped in Rock Lake history.

At the present time, sediment dating has not been completed due to equipment problems, so specific dates will not be known for the next 6 months or so. However, based on the various other tests, the top 20 inches of lake mud have been deposited since the watershed was cleared for agriculture, beginning around 1830. Fossil diatoms (a type of algae with hard silica shells) and mineral deposits indicated the best water quality coincided with deeper or older mud deposits. The older deposits preceded European settlement and conversion of the watershed from oak savanna to agriculture. Fossil records also indicate that the highest watershed erosion rate and poorest water quality occurred at the 12 inch sediment depth. This mud layer was deposited around the turn of the century. Since that period, the water quality has generally improved but is still not as good as the pre-settlement records suggest. The top or most recent mud layer indicates that the water quality is again declining slightly. When the mud dating is completed, Paul will be presenting the Rock Lake Paleoecology study in more detail, including how the information can be used for setting lake protection goals.

While Paul has given us a glimpse of Rock Lake's past, next time you can find out about technology that allows us to predict Rock Lake's water quality future.

(Prepared by Dave Marshall for the Rock Lake Improvement Association)

MAKING WAVES

What happens when Phosphorus reaches a lake?

As a lake watershed is altered for development and agriculture, the rate of phosphorus loading to a lake increases, particularly if no steps are taken to reduce runoff or nonpoint source pollution. Once phosphorus enters a lake, it becomes a fertilizer for myriads of microscopic plants (algae). The relationship between the minute plants and phosphorus is clear. The more phosphorus added, the lake becomes greener and the water clarity declines. High watershed runoff (containing phosphorus) in June of 1996 is why Rock Lake had the poorest water clarity on record. During that time, the algae were well fed!

Each year, scores of dead algae gradually sink to the bottom of a lake. All of the oxygen within the hypolimnion (summertime cold water layer, 25 to 57 ft. in Rock Lake) is consumed as bacteria slowly decompose dead algae produced from past years. Oxygen consumed within the hypolimnion creates two undesirable conditions: First, fish must seek shallow water containing oxygen to survive. Second, phosphorus is released from the organic ooze. Not only is a substantial portion of fish habitat lost from the lake water column each summer, but phosphorus can be recycled within the lake to produce even more algae growths. In some lakes, the combination of external phosphorus loading and internal phosphorus loading can create severe algae blooms and very poor water quality.

Hypolimnetic oxygen loss is common in most southern Wisconsin lakes and Rock Lake is no exception. Fortunately for Rock Lake, internal phosphorus loading is not excessive. Rock Lake is a marl lake and contains high calcium levels that bond with phosphorus. However, the ability to tie-up phosphorus can be overwhelmed over time. If nonpoint source pollution continues, internal phosphorus loading will result. Lake Mendota was once a marl lake that became organically overloaded due to nonpoint source pollution. The inorganic calcium content decreased in L. Mendota as dead algal remains increased. As a result, phosphorus release from organically enriched mud frequently cause severe algae blooms, even during droughts when nonpoint source pollution or external phosphorus loading is low. Not only do severe algae blooms lower water quality conditions, but some blooms can be toxic!

If Rock Lake became organically overloaded, internal phosphorus loading would be a serious problem due to the north-south orientation of the lake. Strong winds during the summer would bring phosphorus laden water from the deep to feed surface algae blooms. Fortunately, Rock L. is not organically overloaded now. If nonpoint source pollution can be controlled in the near future, serious water quality problems can be avoided down the road. Reducing nonpoint source pollution is the primary goal of the Rock L. Priority Lake Project.

Prepared by Dave Marshall, WDNR for the Rock Lake Improvement Association

MAKING WAVES

Rock Lake's Crystal Ball

Over the last 20 years or so, scientists have developed computer models that predict the water quality of lakes and streams. By plugging in data on watershed size, land uses, lake volume, and annual rainfall rates, models can accurately predict future water quality based on various land use changes. The models predict the effects of phosphorus and sediment runoff or pollutants that threaten the health of lakes.

The Department of Natural Resources (DNR) staff use a number of different water quality models to guide management of lakes. To predict phosphorus and sediment runoff from land uses, the DNR developed a rural model and an urban model. These models are based on large water quality data sets and have been tested statewide. The models are available locally and the Jefferson County staff are using them to predict Rock Lake pollution rates.

In addition to the phosphorus and sediment runoff models, a number of lake response models will predict the actual lake water quality at a given phosphorus pollution rate. John Panuska, an Environmental Engineer with the DNR Lakes Program, developed a soft-ware program that includes 10 empirical lake models. The model that most accurately reflects present water quality is the one that is chosen for the predictions.

Modeling Rock Lake required customizing several models to account for urban, rural and natural landscapes. The greatest challenge was to predict the effects of the extensive wetlands and small basins south of the lake. Generally speaking, the wetlands and upstream basins benefit Rock Lake since they trap sediment and nutrients. The challenge is predicting the amounts trapped versus amounts transported downstream. To accomplish this goal, the watershed was divided into three parts, the Mud Lake, Marsh Lake and Rock Lake drainage areas. The lakes were then modeled separately to predict the phosphorus imputs and exports. Since Mud Lake drains about 60% of the watershed, the Mud Lake response model predicted very poor water quality and most of the phosphorus would be trapped there. 1996 lake monitoring data confirmed the prediction. Mud Lake's water quality was very poor because of very high chlorophyll (indicates excessive algae) and high phosphorus levels. Mud Lake phosphorus levels were at least 10 times higher than levels found in Rock Lake.

Presently, Mud Lake removes more than half of the phosphorus runoff that would otherwise reach Rock Lake. While Rock Lake benefits at this time, the fisheries in Mud Lake are threatened. Already, we've measured extremely low oxygen levels in the lake. At some point in the future, Mud Lake will become overloaded and no longer protect Rock Lake from watershed pollutants. The Marsh Lake. drainage area contains mostly wetlands and doesn't contribute much phosphorus. The Rock Lake drainage area amounts to about 20% of the total watershed. Land use practices around Rock Lake, including lawn fertilizers, street runoff, and construction site runoff, directly affect the lake water quality.

(Prepared by Dave Marshall for the Rock Lake Improvement Association)