

**LAKE ASSESSMENT PROGRAM**

**1992**

**Mazaska Lake**

**MDNR ID Number 66-0039**

**MINNESOTA POLLUTION CONTROL AGENCY**

**Division of Water Quality**

**Nonpoint Source Section**

**and**

**Ed Weir**

**Southeast Regional Office**

**and**

**James Ziachke**

**and Mark Vlasak**

**Department of Biology**

**St. Olaf College**

**Northfield, Minnesota**

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## SUMMARY AND CONCLUSIONS

Mazaska Lake was sampled during the summer of 1992 as part of the Minnesota Pollution Control Agency's (MPCA) Lake Assessment Program. Data collected during the study showed that in terms of total phosphorus, chlorophyll and Secchi disk transparency, the water quality of Mazaska Lake is about the average of similar lakes in the North Central Hardwood Forest ecoregion of Minnesota. The mean summer concentrations of total phosphorus and chlorophyll were 55 and 25  $\mu\text{g/l}$ , respectively, and the mean Secchi disk transparency was 5.8 feet. Based on these water quality values Mazaska Lake would be considered eutrophic.

Phosphorus and chlorophyll data fit Carlson's model for trophic status indicators reasonably well (Carlson 1977). The Secchi disk transparency values were somewhat higher than expected based on the observed phosphorus and chlorophyll concentrations. Transparency readings can still provide good long-term estimates of phosphorus and chlorophyll and can be a useful tool for tracking future trends. An empirical computer lake model was used to predict 1992 water quality and the results were compared to observed conditions. The model predictions and observed conditions did not agree well. The model estimated total phosphorus concentrations which were lower than those observed in the lake. The contribution of nutrients from the sediments during the summer may provide some explanation for this discrepancy.

The water quality of Mazaska Lake compares well with other lakes in this ecoregion. Based on total phosphorus measurements made over the past 12 years, the lake would be classified as eutrophic (very productive). Further changes in land use in the immediate watershed, such as increased development and

draining or filling of wetlands, could result in a continual increase in phosphorus loading and a resulting decrease in water quality.

The following recommendations are based on the 1992 assessment of Mazaska Lake:

1. Participation in the Citizens Lake Monitoring Program should continue since it is an effective way to assess long-term and year-to-year variations in algal productivity (lake trophic status). Monitoring should be conducted over the site of maximum depth near MPCA site 101.
2. The Shieldsville Sportsmen Club should attempt to provide educational materials to homeowners with respect to lawn maintenance and shoreline protection. Protection of the existing vegetation along the shore will minimize erosion and preserve the aesthetic value of the lake. A lake lot with a diverse community of native vegetation will also provide habitat for songbirds and other small animals. The MPCA, MDNR, and county offices may be able to provide assistance in this area. The book Landscaping for Wildlife and the booklet A Citizens Guide to Lake Protection may also be useful educational tools for the Club.
3. Any development in the immediate watershed should be completed so that the impacts to lake water quality are minimized. Setback provisions and natural buffer strips should be strictly adhered to. Soil loss can be reduced by utilizing best management practices during construction or road building. Rice County's shoreland regulations will be important in this regard.
4. Activities in the Mazaska Lake watershed, such as wetland removal or major land use alterations that change the drainage or flow patterns, should be discouraged. Establishment and maintenance of effective buffers between agricultural areas and ditches, streams, and the lake will help to minimize nutrient-rich runoff and provide wildlife habitat.

5. The members of the Shieldsville Sportsmen Club should keep up-to-date on the progress of the French Lake Clean Water Project. Some of the projects management techniques may be applicable at Mazaska Lake. Those efforts which address shoreline management, and aquatic plant control will be of special interest to club members.
6. Although it can be difficult to assess how much impact individual watershed projects will have on the lake, the cumulative effect of several projects can be significant. In addition to the positive effects on water quality, watershed projects such as restoration of wetlands, protection of natural areas, and creation of buffer strips will improve the wildlife habitat, plant diversity and aesthetics of the watershed.

## LAKE ASSESSMENT PROGRAM - 1992

Mazaska Lake

(ID No. 66-0039)

Rice County, Minnesota

The Shieldsville Sportsmen Club applied for inclusion in the Lake Assessment Program in 1992 and listed in their application the following water quality concerns for Mazaska Lake.

1. An increase in the frequency of the toxic blue-green algae blooms in the last 10 years.
2. A dramatic increase in the growth of aquatic vegetation.
3. The potential for increased pressure on the lake resource as demographics change.

The group attributed the water quality problems to nutrient-rich agricultural runoff which reaches the lake through the extensive drainage system in the watershed. Improperly-maintained septic systems, extensive use of lawn fertilizers and the removal of natural lake-shore vegetation were also cited as contributors to the water quality problems. A report prepared by Rice County in 1986 stated that one water quality problem of Mazaska Lake was the presence of fecal coliform bacterial contamination. The presence of fecal coliform bacteria indicates that the lake has been impacted by untreated animal and/or human waste.

The Lake Assessment Program (LAP) was designed to assist lake associations or municipalities in the collection and analysis of baseline water quality data for the purpose of assessing the current trophic status of their lake. The work plan for participants in the Lake Assessment Program includes collection of lake transparency data through the Citizens Lake Monitoring Program (CLMP) and examination of the land-use and drainage patterns in the watershed. During the

summer of 1992 staff of the Minnesota Pollution Control Agency (MPCA) and St. Olaf College collected baseline water quality data as a part of the LAP for Mazaska Lake. Conclusions and recommendations based on water quality and watershed data are included in the report.

## BACKGROUND

Mazaska Lake was sampled five times during the summer of 1992 by Ed Weir of the MPCA Rochester regional office and Mark Vlasak and Al Akins of St. Olaf College. Orlien Halverson, Dennis Johnson and Bulrush Bay Resort provided the boat and motor for the sampling crew. The Citizens Lake Monitoring Program volunteers were Rachel Fischer and Duellloyd Casperson.

Mazaska Lake is four miles northwest of the city of Faribault in central Rice County (Fig. 1). Surface area of the lake is 687 acres and the shore length is 4.8 miles. It is one of seven lakes in Rice County larger than 600 acres. The maximum depth of the lake is 46 feet (14 meters) and the mean depth is 15 feet (4.6 meters). The littoral zone or that part of the bottom that supports rooted plants covers approximately 49% of the lake (Table 1).

Mazaska Lake was formed by an ice-block in glacial till (Zumberge, 1952). When the ice melted a pit was left which collected water to become a lake. Lakes in the area that were formed in a similar manner include Cedar and Roberds. Typically lakes of this type are steep-sided and the lake depth is determined by the maximum relief of the local topography. If the water and accumulated sediment were removed from the lake basin, the lake bed would occupy a natural position in the local topography.

Soils in the Mazaska Lake watershed belong to the Lester-Heyden associations which are moderately steep loams that were formed in upland glacial till.

Permeability of the soil is moderate and the water table is below 10 feet. The soils are suited for use as septic tank drain fields except in areas of high slope. Runoff is moderate to rapid and potential for erosion can be severe. Native vegetation in this area was prairie grass and deciduous trees. Some areas remain as forest or wooded pasture but most soils are presently used for crops.

Because conditions in the surrounding watershed affect the water quality in a lake, it is helpful to divide the state into areas, called ecoregions, where climate, native vegetation and land characteristics are similar. Minnesota can be divided into seven ecoregions based on soils, land surface form, natural vegetation, and current land use (Fig. 1). Mazaska Lake is located in the southern lobe of the North Central Hardwood Forest ecoregion near the border of the Western Corn Belt Plains ecoregion. Land use composition in the watersheds of the North Central Hardwood Forest ecoregion is typically 22-50% cultivated, 11-25% pastured and open, 14-30% water or marsh, 6-25% forested and 2-9% developed. The land use in the 2200-acre Mazaska Lake watershed is more similar to the land use in the North Central Hardwood Forest ecoregion than the typical land use in the Western Corn Belt Plain ecoregion (Table 1). See Appendix for map of Mazaska Lake watershed.

Water quality information was collected on May 13, June 10, July 7, August 8 and September 1, 1992 at two sites on Mazaska Lake (Fig. 2). Site 101 in the south central portion of the lake was chosen because it is the location of maximum depth (46 feet, 14 meters). The second site, 102, was chosen to gain an understanding of the water quality variability within the lake. The depth at site 102 was approximately 36 feet (11 meters). Lake surface water samples were collected with an integrated sampler, which is a PVC tube 6.6 feet (2 meters) long with an inside diameter of 1.4 inches (3.5 centimeters). Samples from near the bottom were collected with a 2-liter Kemmerer sampler, a water trap that closes at a desired depth. Plankton samples were collected with a Wisconsin plankton net which was

towed vertically from the bottom to the surface. A qualitative evaluation of the zooplankton was made in the field. Sampling procedures were followed as described in the MPCA Quality Control Manual and analyzed by the Minnesota Department of Health for total phosphorus, total Kjeldahl nitrogen, nitrate-nitrite nitrogen, suspended solids, alkalinity, chloride, color, turbidity, and chlorophyll-a. Measurements for pH, conductivity, Secchi disk transparency, and temperature and dissolved oxygen profiles were made in the field. Algal composition was determined by means of a rapid assessment method. Nearly two decades of Citizen Lake Monitoring Program transparency measurements along with water quality data collected in 1980, 1981, and 1989 are available for comparison (Table 3). All data with the exception of algal composition was stored in STORET, the U.S. Environmental Protection Agency's national water quality data bank. The following discussion assumes that the reader is familiar with basic water quality terminology as used in the Citizens Guide to Lake Protection.

## RESULTS AND DISCUSSION

### In-Lake Conditions 1992

#### Temperature

Lakes in temperate climates tend to stratify or separate into three layers in the summer due to differences in density caused by differences in temperature. The metalimnion or thermocline is the middle zone where the water temperature drops rapidly with small increases in depth. This zone separates the epilimnion above from the hypolimnion below. The epilimnion contains warmer water of similar density. This layer is mixed by the wind and is where most algae growth occurs. The hypolimnion contains much colder water, that does not mix, and is the zone where dead plant material accumulates and decomposes.

The temperature profiles measured at the deepest site (101) show that the lake was weakly stratified on some dates (e.g., June 10), but did not firmly stratify during the summer of 1992 (Figs. 3a-e). Surface water temperature ranged from 16.7° to 23.8° C (62° to 75° F) and bottom temperatures from 11.8° to 19.2° C (53° to 67° F). The greatest difference between the surface and bottom was 22.8° to 12.2° C (73° to 54° F) recorded on June 10. There are probably two major reasons that the lake did not firmly stratify. The summer of 1992 was relatively cool and atmospheric temperatures clearly affect water temperatures. Also the lake has a maximum depth of 46 feet and a relatively large surface area of 687 acres. A majority of the lake is less than 30 feet in depth. That is, Mazaska is not extremely deep but has a large wind fetch, which means that the lake may tend to mix easily.

#### Dissolved Oxygen

Dissolved oxygen concentrations decreased rapidly with increasing water depth during the summer at site 101 (Figs. 3a-e). Concentrations in the epilimnion remained above 7 mg/l throughout the summer. Near the bottom oxygen concentrations were near 0 mg/l in June, July and August. Very low concentrations were common at depths below 8 meters (26 feet).

The oxygen levels in different areas of a lake will determine where fish and other organisms are found. Concentrations greater than 5 mg/l are considered necessary for long-term survival of game fish. Below 5 mg/l fish will occupy the warmer more oxygenated waters in the epilimnion. Low oxygen can also affect the amounts of other chemicals present. For example, the amount of phosphorus in lower levels of a lake tends to increase as oxygen concentrations fall.

## Total Phosphorus

Phosphorus is an important nutrient for plant growth, and in most lakes it is the nutrient that limits the amount of algae and weed growth. Total phosphorus (TP) in the epilimnion decreased between the May and July samplings and then increased until September (Fig. 4). The mean (average) TP concentration in the epilimnion was 55  $\mu\text{g/l}$  and ranged from 33 to 86  $\mu\text{g/l}$ . TP concentrations in the epilimnion at sampling site 102 were similar to those at site 101 (Table 3). The mean TP value is slightly higher than concentrations in a set of minimally impacted reference lakes in the North Central Hardwood Forest ecoregion of Minnesota which ranged from 23 to 50  $\mu\text{g/l}$  (Table 2); 47% of the 436 assessed lakes in this ecoregion had phosphorus levels less than 55  $\mu\text{g/l}$ . TP concentrations in the hypolimnion were only determined on the June, August and September sampling dates. Hypolimnion concentrations ranged from 82 (September) to 653  $\mu\text{g/l}$  (August) and the mean was 294  $\mu\text{g/l}$ .

An increase in phosphorus in the hypolimnion during the summer is characteristic of productive, stratified lakes and is largely the result of two processes. First, periods of low oxygen levels in the hypolimnion will stimulate the release of phosphorus from the sediments into the lake. Second, algae in the epilimnion assimilate phosphorus as they grow. When algae die, they settle out of the epilimnion and into the hypolimnion where the phosphorus is released into the water during decomposition. This results in a decline in TP in the epilimnion from spring to fall. While phosphorus concentrations will likely increase in hypolimnetic waters under stratified conditions, much of the phosphorus will remain unavailable for the production of algae in the epilimnion. However, when stratification breaks down after the growing season (in this case early September), phosphorus is mixed throughout the lake and may be available for phytoplankton growth the next spring.

In the North Central Hardwood Forest ecoregion, distinct differences exist between lakes which maintain a stable stratification (referred to as dimictic lakes) and those which only stratify intermittently or do not stratify at all. In general, the phosphorus concentration of dimictic lakes tend to be two to three times lower than those lakes which do not remain stratified throughout the summer.

TP concentrations in Mazaska Lake were more characteristic of an unstratified lake. The lake did not undergo stable temperature stratification during the summer of 1992. Phosphorus levels in the epilimnion increased from July to September rather than declining as is typical in a stratified lake. This is probably unusual for Mazaska Lake.

#### Total Nitrogen

Total nitrogen (TN) which is defined as the sum of the total Kjeldahl nitrogen and nitrate-nitrite nitrogen averaged 1.5 mg/l during the summer of 1992. This is higher than the typical TN value for the ecoregion reference lakes which ranges between 0.6 to 1.2 mg/l. Both the average total Kjeldahl nitrogen and the nitrate-nitrite concentrations measured in Mazaska Lake (1.5 and 0.04 mg/l, respectively) are higher than those measured in minimally impacted lakes in the region (Table 2). Values this high indicate that nitrogen sources which include nitrogen fertilizer, septic system effluent, and animal waste are influencing the concentrations in Mazaska Lake.

#### Total Nitrogen to Total Phosphorus Ratio (TN:TP)

Nitrogen and phosphorus are nutrients required for growth of aquatic plants and algae. Although phosphorus is usually the nutrient limiting the productivity in most Minnesota lakes, nitrogen may be the limiting nutrient in some situations. The ratio of TN:TP can indicate which nutrient is limiting. For Mazaska Lake the

TN:TP ratio is 28:1. The TN:TP ratio measured for Mazaska Lake is within the range of ratios for other lakes in the ecoregion, which is 25:1 to 35:1 (Table 2). This suggests that increases in the in-lake phosphorus concentration may increase the production of algae and large aquatic plants.

### Chlorophyll-n

Chlorophyll concentrations provide a measure of the amount of algae in a lake. During the summer, Mazaska Lake chlorophyll concentrations ranged from 5.45 to 45  $\mu\text{g/l}$  with a mean concentration of 25  $\mu\text{g/l}$  (Table 2, Fig. 5). The high concentration observed in May corresponded with the lowest Secchi disk transparency measurement. Based on surveys of CLMP volunteers, concentrations from 10 to 20  $\mu\text{g/l}$  would be perceived as a mild algal bloom, and concentrations greater than 30  $\mu\text{g/l}$  would be perceived as severe nuisance conditions (Heiskary and Walker, 1988). The chlorophyll values reported for Mazaska Lake exceeded the nuisance conditions level in May, August and September and were slightly higher on these dates than typical values determined for the ecoregion which range between 5 and 22  $\mu\text{g/l}$  (Table 2, Fig. 5).

### Transparency (Secchi disk)

The Secchi disk transparency is an indirect measurement of the amount of algae and other suspended material in the lake. Transparency values can often be accurately correlated to the chlorophyll and the total phosphorus concentrations. The average transparency (Table 2) measured during the lake assessment sampling was 5.8 feet (1.8 meters). The average transparency based on the values determined by volunteer measurements was equal to 4.6 feet (1.4 meters) for the entire summer and 2.6 feet (0.8 meters) for July and August (Fig. 6). The difference between the two averages is due to natural variability and the number of

measurements. The transparency measured for Mazaska Lake is slightly lower than typical values for the ecoregion reference lakes.

#### Other Physical and Chemical Parameters

Other water quality parameters measured for Mazaska Lake in the summer of 1992 including color, pH, total suspended solids, total suspended inorganic solids, and alkalinity were similar to values typical for the ecoregion. Chloride, turbidity and conductivity values were higher than those for the ecoregion (Table 2).

#### Phytoplankton (Algae)

Phytoplankton samples taken in May, June and July from site number 101 were analyzed. Several species of green algae were abundant in the May and June samples. In addition, the blue-green alga *Aphanizomenon flos-aquae* was common. *Aphanizomenon* grows in bunches which resemble small grass clippings. This species tends to increase in abundance in area lakes during the summer. In July *Aphanizomenon* accounted for 90% of the volume in the algae samples.

#### Zooplankton

Zooplankton (microscopic animals) was collected and analyzed at each sampling date. Many small-bodied forms were observed in May, but fewer animals were observed in June and July. In July about 25% of the entire plankton sample was zooplankton, approximately half of which were water fleas and half copepods. Few large-bodied zooplankton were observed in any of the samples. Large-bodied forms can be beneficial for lakes because they can consume large quantities of algae.

## Aquatic Plants (Macrophytes)

The Shieldsville Sportsmen Club expressed concern about the increased growth of pondweed along the lake shore of Mazaska Lake. In a plant survey conducted in the summer of 1992, the most abundant species were the large-leaved pondweed (*Potamogeton amplifolius*) and sago pondweed (*P. pectinatus*). Curly-leaf pondweed (*P. crispus*) was present but not abundant. This plant is an introduced, or exotic species, that out-competes and replaces more desirable native species. Curly-leaf pondweed was probably introduced during the late 1960's and is of concern because it has gradually increased in density and areal extent.

Only areas of lake bottom shallow enough to receive adequate light will support the growth of macrophytes. There is a direct relationship between Secchi disk transparency and the maximum depth of colonization (MDC) by aquatic plants (Canfield *et al.*, 1985).

$$\log \text{MDC} = 0.79 \log \text{SD (meters)} + 0.25$$

Over the monitoring period the average Secchi disk transparency was 5.8 feet (1.8 meters). Using this value, the maximum depth of colonization for Mazaska Lake would be 9.2 feet. At 9 feet plant growth will be sparse and more plants will grow in progressively shallower water. About 35% of the lake is less than 10 feet deep. Most plant growth is in this area and forms a ring of weeds around the lake that may be a nuisance for boating or swimming.

A number of techniques may be used to control nuisance macrophytes in small areas. Manual or mechanical harvesting can be an effective, short-term control technique for small swimming areas or boat paths. This also has a small additional benefit of removing nutrients from the lake. In some cases permits from the DNR are required for weed control.

Sediment covers or surface shading are experimental techniques which may effectively control weed growth by controlling light in small areas. See the Lake

and Reservoir Restoration Guidance Manual (USEPA 1990) for more information. When deciding on an appropriate control technique, remember that many aquatic plants play an essential role in the health of the lake community. Although curly-leaf pondweed is an exotic species, removal of large areas of this weed without a reestablishment of native perennial species may result in an increase in the severity and frequency of algal blooms.

### Trophic Status

One means of evaluating the trophic status or productivity of a lake and interpreting the relationship between total phosphorus, chlorophyll, and Secchi disk transparency is Carlson's Trophic State Index (Carlson, 1977). This index was developed from the relationships of summer Secchi disk transparency and the surface water concentrations of total phosphorus and chlorophyll. Trophic State Index (TSI) values are calculated as follows:

$$\text{Total phosphorus TSI (TSIP)} = 14.42 \ln(\text{TP}) + 4.15$$

$$\text{Chlorophyll TSI (TSIC)} = 9.81 \ln(\text{Chl } a) + 30.6$$

$$\text{Secchi disk TSI (TSIS)} = 60 - 14.41 \ln(\text{SD})$$

Note units: TP in  $\mu\text{g/l}$ , Chlorophyll in  $\mu\text{g/l}$ , Secchi disk transparency in meters

Possible values for TSI range from 0 (ultra-oligotrophic) to 100 (hypereutrophic). With this index each increase of 10 units represents a doubling of algal biomass (Fig. 7).

The TSI values of total phosphorus, chlorophyll, and Secchi disk transparency for Mazaska Lake are between 52 and 62 with an average of 59 (Table 2). Based on these values the lake would be considered eutrophic. Usually the three TSI values are more similar than those determined for Mazaska Lake. The correspondence between TP and chlorophyll is perfect, but the Secchi TSI is lower. This discrepancy

may be due to the dominance of the blue-green algae *Aphanizomenon*. Under these conditions, Secchi disk transparencies tend to be higher than would be expected based on the TP and chlorophyll concentrations. However, Secchi disk monitoring of Mazaska Lake can still provide a reliable indication of the algal and phosphorus trends in the lake.

Comparison of TSI values for Mazaska Lake to those of other lakes in the North Central Hardwood Forest ecoregion can provide a basis for evaluating the water quality of the lake. A TSI value of 59 ranks in the 50th percentile for the ecoregion. In other words 50 percent of the lakes assessed in the region have TSI values less (are less eutrophic) than Mazaska Lake.

Another way to compare the trophic status variables is on scatterplots. Figure 8 illustrates the general relationships between total phosphorus, chlorophyll, and Secchi disk transparency and where the Mazaska Lake data plot on the graphs. The three parameters generally are closely correlated since phosphorus is often the nutrient limiting algal production, and Secchi disk transparency is dependent upon the algal levels in the lake. The plots show that increases in phosphorus will result in an increase in chlorophyll and a decrease in Secchi disk transparency depth. Alternately, a decrease in phosphorus will result in an increase in water quality as measured by chlorophyll concentrations and transparency readings.

### Trend Analysis and Historical Data

Historical data is available for Mazaska Lake and other lakes in Rice County. National Biocentric completed a water quality evaluation of lakes and streams in the county in 1972. Secchi disk measurements taken by the CLMP volunteers are available from 1974 to the present (Fig. 9). Water quality data from county and state sampling efforts are available for 1955, 1980, 1981, 1989 and 1992. Although

other water quality information is available, only years with two or more measurements for any parameter will be considered in this discussion. Mean summer total phosphorus, chlorophyll-a and Secchi disk measurements from previous years are shown below.

<u>Year</u>	TP (# of obs.) ( <u>µg/l</u> )	Chl a (# of obs.) ( <u>µg/l</u> )	Secchi (# of obs.) ( <u>feet</u> )
1974			3.4 (4)
1975			2.1 (4)
1980	78 (5)		4.1 (5)
1981	56 (4)		4.2 (7)
1982			2.9 (5)
1984			2.7 (2)
1989	62 (4)	26.2 (4)	3.6 (4)
1992	55 (4)	25.2 (4)	5.8 (4)

Based on the data available it does not appear that the water quality of Mazaska Lake has changed greatly over the past 12 years. In measurements taken between 1980 and 1992, mean epilimnion total phosphorus ranged from 55 to 78 µg/l. The mean trophic status index (TSIP) for the years 1980, 1981, 1989 and 1992 was 64. This value categorizes the lake as eutrophic. Mean chlorophyll-a values decreased from 26.2 to 25.2 µg/l between 1989 and 1992.

National Biocentrics assigned water quality indexes to nine lakes in Rice County in 1972. Each index was based on Secchi disk transparency, biochemical oxygen demand (BOD), available phosphate, ammonia, pH and total coliform bacteria. Direct comparison of the 1972 Biocentric data with the LAP data collected in 1992 is not meaningful, but the 1972 study does provide an indication of the relative water quality of lakes in Rice County at that time. Mazaska Lake was rated below Fox, but above French, Shields, Roberds, Cedar, Circle, Union and Cannon Lakes. In 1986 Rice County compiled a water quality evaluation of lakes and streams in the county which compared historical data and data the county

collected in 1984. Agricultural runoff, lakeshore development and nutrient-rich sediment were considered to be the major sources of nutrient input.

Mean summer Secchi disk transparencies have been collected for Mazaska Lake on an irregular basis since 1974. Secchi disk values have varied considerably over the period. In six of the eight years studied, mean transparency in July and August was near or over three feet. In 1989 and 1992 mean Secchi disk values for July and August exceeded four feet.

In the summer of 1993 perceptions of Mazaska Lake water quality were collected from people fishing the lake, as part of MDNR creel surveys. The surveys were conducted from 10 June to 16 October. Ratings (daily averages) of the lake's "physical condition" ranged from 1.5 (crystal clear water to not quite crystal clear -- a little algae present/visible) to 3 (definite algal green, yellow or brown color apparent). "Recreational suitability" ratings ranged from 1 (beautiful, could not be better) to 3 (swimming and aesthetic enjoyment slightly impaired because of algae levels). See Appendix for complete survey results. Perceptions of the lake's water quality did not vary greatly during the course of the survey.

### Nutrient Sources

There are three inflow streams to Mazaska Lake and one large outflow, Wolf Creek, to the east (Fig. 2). The inflow streams have intermittent flow and carry water from subwatersheds of the lake's entire watershed. The size and amount of agricultural activity in these subwatersheds differs. Nutrient input from the streams draining these areas varies because of these differences. There are marsh areas to the west, northwest and southeast of the lake.

It is likely that nonpoint source pollution accounts for much of the nutrient input to Mazaska Lake. Nonpoint source pollution includes: agricultural runoff

from croplands and pastures, pesticide and fertilizer use, feedlot runoff, urban runoff from streets, yards and construction sites, leachate from septic systems, dredging and draining activities, and the impacts from the loss of wetlands. Although it is unrealistic to expect that all nonpoint pollution sources can be eliminated, the implementation of Best Management Practices (BMP's) and other land use changes can minimize human impacts on water quality.

To control soil erosion, reduce the use of fertilizers and pesticides, and improve manure management, best management practices for agriculture should be selected that meet water quality goals as well as the individual farm operation. Refer to the MPCA's Agriculture and Water Quality publication for more information on agricultural BMP's.

Several direct discharges to Mazaska Lake from drain tiles were identified in the study. Runoff from the immediate watershed also contributes a significant amount of nutrients to the lake. Three sources of nutrients were identified as potential problems in the immediate watershed of Mazaska Lake: livestock feedlots and a pasture near the lake shore, failing on-site sewage treatment systems, and lawn fertilizers which contain phosphorus.

### **Livestock**

Feedlots and near-shore pasture can contribute large amounts of nutrients to a lake. Cattle allowed to wade in a lake tend to increase erosion along the shoreline and degrade water quality in the lake. Animal manure deposited directly into a lake adds not only nutrients but oxygen-demanding material and bacteria. A buffer of vegetation between permanent pasture and the lake with an alternate water source will effectively reduce the pollution load from the area. Agricultural BMPs include suggestions for the management of animal wastes.

## **In-Lake**

A portion of the nutrients that enter a lake from the watershed become bound to the bottom sediment. These nutrients are released under certain conditions. Phosphorus, for example, is released from the sediment when the bottom contains no oxygen. This was the case at site 101 in Mazaska Lake in 1992 on the June, July and August sampling dates. The contribution of phosphorus from the sediment can represent a significant part of the phosphorus load to a lake and, in some cases, may be the major source of phosphorus.

Estimates of the sediment contribution can be made from lake volume and phosphorus data (Appendix). Estimates of the internal phosphorus loading for Mazaska Lake based on 1992 data show sediment phosphorus contributions are approximately 2000 kilograms for the summer. Although calculations of sediment contributions on an annual basis would likely yield a lower value because phosphorus is lost to the sediments at other times of the year, the sediment-loading estimate is useful for making qualitative comparisons. The sediment contribution was compared to the watershed-loading estimates from the water quality models. The comparison suggests that the sediment contribution is greater than the contribution from the watershed area surrounding Mazaska Lake.

## **MODELING SUMMARY**

Numerous models are available for estimating nutrient and water budgets for lakes. These models can be used to relate the flow of water and nutrients from a lake's watershed to observed conditions in a lake. Alternately, they may be used for estimating changes in the quality of a lake as a result of altering nutrient inputs to the lake (e.g., changing land uses in the watershed) or altering the flow or amount of water entering the lake. The "Minnesota Eutrophication Analysis Procedure"

(MINLEAP) model and the Reckhow and Simpson (1980) model were used to assess the current water quality of Mazaska Lake. MINLEAP was developed by MPCA staff based on an analysis of data collected from a set of representative minimally-impacted lakes for each ecoregion. Total phosphorus, chlorophyll, and transparency values calculated by MINLEAP should reflect the values found in a minimally-impacted lake with the watershed size, lake morphometry, and geographic location of Mazaska Lake. It is intended to be used as a screening tool for estimating lake conditions with minimal data input and is described in greater detail in Heiskary and Wilson (1990).

Published runoff coefficients, precipitation and evaporation data, and nutrient export coefficients were used in this modeling effort. Precipitation and evaporation data were derived from Gunnard (1985) and data from the State Climatology Office (1989). Inputs to the models are noted in Tables 4 and 5.

The TP and chlorophyll concentrations for Mazaska Lake predicted by MINLEAP were 27 and 8  $\mu\text{g/l}$  respectively which is between two and three times lower than the values determined in the 1992 sampling (Table 2). The observed Secchi disk depth was approximately 2 feet lower than the predicted value. The estimated phosphorus loading, corresponding to an in-lake phosphorus concentration of 27  $\mu\text{g/l}$ , is 251 kg/yr. However, given the difference between the predicted versus observed in-lake phosphorus concentration, it is likely the actual phosphorus loading is much higher. MINLEAP estimated phosphorus retention at 86 percent and water residence time at approximately 10 years.

The second model used was Reckhow and Simpson (1980) which predicts the impact of watershed characteristics and management on lake phosphorus concentrations. The uncertainty associated with this simplified assessment requires that the model output be expressed as a range of values. The Reckhow-Simpson model (using the Canfield/Bachman equation) predicts an in-lake

phosphorus concentration ranging from 42 to 67  $\mu\text{g/l}$  for Mazaska Lake. The "average" concentration value of 52  $\mu\text{g/l}$  is most comparable to the 1992 summer mean (55  $\mu\text{g/l}$ ). The phosphorus flux (load) corresponding to a concentration of 52  $\mu\text{g/l}$  is 722 kg/yr. Thus, the difference in phosphorus flux predicted by Reckhow-Simpson (using "average" export coefficients) versus MINLEAP (251 kg/yr) suggests that the phosphorus loading is approximately 3 times that expected based on Mazaska Lake's morphometry, watershed size, and ecoregion. Neither model indicates how much of the "excess" nutrient loading is from the watershed and how much is recycled from lake sediments (internal loading).

Typical phosphorus export values for the area, based on "average" export coefficients, are used in the Reckhow-Simpson model. Based on these estimates, agricultural lands potentially contribute about 65 percent of the phosphorus from the watershed. Urban areas and septic tanks may contribute about 15 percent, while the other land uses contribute the remaining 20 percent. However, these are just estimates, and the actual contributions may vary significantly from the percentages above.

## GOAL SETTING

The historical data and model predictions indicate that attaining an average epilimnion phosphorus concentration of 40 to 45  $\mu\text{g/l}$  is a reasonable goal for Mazaska Lake. To maintain fisheries, aesthetics and full recreational usage, phosphorus levels of about 40  $\mu\text{g/l}$  are desirable for a majority of the lakes in Minnesota. If levels are maintained at 40 to 45  $\mu\text{g/l}$ , the lake will support fishing and swimming most of the time. Some algae would be present most of the summer but the periods of severe algal blooms (chlorophyll concentrations greater than 30

$\mu\text{g/l}$ ) would exist only about 20% of the summer. In 1992, chlorophyll concentrations exceeded 30  $\mu\text{g/l}$  over 60% of the summer.

Reduction in the phosphorus loading will be required to reach the goals stated above. Loading from the watershed should be controlled before in-lake treatments are attempted. If present conditions and inputs continue, a gradual worsening of the lake's condition and suitability for recreation will result.

The lake is a reflection of its watershed. The quality of the lake water is determined by not only the lake's shape and ecology, but also the activities that occur in the watershed. The results of this study suggest that excessive phosphorus is reaching the lake from the watershed and the lake sediments. Implementation of best management practices on cultivated land, feedlots, and the immediate watershed (lawns and septic systems) should help to reduce the phosphorus loading. Once watershed contributions are adequately controlled, some in-lake treatment which addresses the sediment contributions may be appropriate. A more detailed study would be necessary to predict the lake's response to watershed and in-lake treatment methods.

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**Table 1. Mazaska Lake morphometric, watershed and fishery characteristics.**

MDNR I.D. 66-0039

Area: 687 acres (278.1 ha)

Mean Depth: 15 feet (4.6 meters)

Maximum Depth: 46 feet (14.0 meters)

Volume: 10300 acre-feet (12.7 HM<sup>3</sup>)

Littoral Area: 49%

Shoreline Length: 4.8 miles

Watershed Area: 2200 acres (890 hectares)

Watershed Area: Lake Surface Area Ratio: 3.2:1

Estimated Average Water Residence Time: 10 years

Fisheries - Ecological Classification: Roughfish-Gamefish  
 Management Classification: Warmwater gamefish

	Land Use (percentage):				
	<u>Forests</u>	<u>Water/Marsh</u>	<u>Pasture/CRP</u>	<u>Cultivated</u>	<u>Urban</u>
Mazaska Lake	9	10	20	56	5
North Central Hardwood Forest	6-25	14-30	11-25	22-50	2-9

Public Accesses: 2

Inlets/Outlets: 3 inlets (unnamed) 1 outlet (Wolf Creek)

Shoreland Zoning: Recreational Development

<u>Year</u>	Development (Homes)		<u>Total</u>
	<u>Seasonal</u>	<u>Permanent</u>	
1967	15	30	45
1982	110	65	175

**Table 2. Mazaska Lake average summer water quality characteristics and trophic status indicators (based on epilimnion 1992) compared with other lakes in the North Central Hardwood Forest ecoregion.**

	<u>Mean</u>	<u>Typical Range for Ecoregion<sup>1</sup></u>
Total Phosphorus ( $\mu\text{g/l}$ )	5.5	2.3-5.0
Chlorophyll-a ( $\mu\text{g/l}$ ) mean	25.2	5-22
Chlorophyll-a ( $\mu\text{g/l}$ ) maximum	45.3	7-32
Secchi disk (meters)	1.8	1.5-3.2
Secchi disk (feet)	5.8	4.9-10.5
Total Kjeldahl Nitrogen (mg/l)	1.5	0.6-1.2
Nitrite & Nitrate-N (mg/l)	0.04	< 0.01
Alkalinity (mg/l)	137.5	75-150
Color (Pt-Co Units)	17.5	10-20
pH (SU)	8.8	6.6-8.9
Chloride (mg/l)	18.0	4-10
Total Suspended Solids (mg/l)	5.6	2-6
Total Suspended Inorganic Solids (mg/l)	1.4	1-2
Turbidity (NTU)	4.2	1-2
Conductivity (unhos/cm)	324	200-300
TN:TP ratio	28:1	25:1-35:1

Trophic Status Indicators: 1992

<u>Carlson Trophic Status Index Values</u>		<u>Percentile<sup>2</sup></u>
TP TSIP	62	53
Chl-a TSIC	62	54
Secchi TSIS	52	62
Mean TSI	59	50

<sup>1</sup> - 25-75th percentile for representative - minimally impacted lakes in the North Central Hardwood Forest Ecoregion (Heiskary & Wilson, 1990)

<sup>2</sup> - Relative to approximately 700 lakes in the NCHF ecoregion. One hundred percent level implies lowest TP and chlorophyll concentration or deepest Secchi disk measurement for that ecoregion.

Table 3. Mazaska Lake water quality data collected by MPCA ecoregion monitoring program and 1992 Lake Assessment Program study.

DATE	SITE	D	TP	RTP	TOM	MCN3	MC2M3	TSS	TSIN	ALK	PHF	CL	CONF	TURB	COLOR	CMLA	PNEO	SOF	
550718	300	0	.026		1.17	.	.	.	.	104	.	.	.	.	10	.	.	7.0	
800716	201	0	.049		1.68	.	.	.	.	120	.	.	.	6.8	20	102.00	.	6.0	
800729	101	0	.072		1.70	0.01	K	.	.	.	.	.	.	.	20	.	.	3.3	
800801	201	0	.103		1.17	.	.	.	.	.	.	.	.	.	10	.	.	3.0	
800814	201	0	.107		1.20	.	.	.	.	.	.	.	.	.	10	.	.	4.0	
800829	201	0	.060		1.21	.	.	.	.	.	.	.	.	.	10	.	.	4.0	
810626	201	0	.041		1.50	.	.	.	.	.	.	.	.	.	15	.	.	3.0	
810728	201	0	.058		1.36	.	.	.	.	.	.	.	.	.	20	.	.	4.0	
810820	201	0	.036		1.90	.	.	.	.	.	.	.	.	.	20	.	.	6.0	
811002	201	0	.089		1.55	0.01	K	6.4	1.6	130	.	16	285	3.3	20	22.40	2.14	2.6	
890518	101	0	.094		1.49	0.01	K	10.0	3.0	120	.	15	270	4.8	10	31.00	3.74	3.3	
890518	101	42	.177		1.88	0.01	K	.	.	.	.	.	.	.	.	.	.	3.0	
890627	101	37	.216		2.90	.	.	.	.	.	.	.	.	.	.	.	.	3.0	
890627	102	0	.057		1.36	0.01	K	6.0	2.4	120	.	15	260	3.5	10	35.20	1.60	4.9	
890726	101	16	.058		1.10	.	.	.	.	.	.	.	.	.	.	.	.	.	.
890726	101	39	.427		3.75	.	.	.	.	.	.	.	.	.	.	.	.	.	.
890726	102	0	.048		1.67	0.01	K	9.2	2.2	120	.	16	260	6.4	10	12.80	0.80	5.6	
890829	101	0	.041		1.49	0.01	K	.	.	.	.	.	.	.	.	.	.	3.3	
890829	101	39	.967		5.98	.	.	9.2	3.2	140	8.9	17	320	8.0	20	80.10	0.64	2.6	
920511	101	0	.112		2.23	0.01	K	9.2	3.2	140	9.1	17	320	8.0	20	85.90	0.64	2.6	
920513	102	0	.136		2.24	.	.	2.2	1.0	140	8.6	17	328	1.0	10	5.45	1.28	10.2	
920510	101	0	.055		1.35	0.01	K	.	.	.	.	.	.	.	.	.	.	.	.
920610	101	39	.148		3.27	0.01	K	.	.	.	8.7	.	325	.	.	6.09	0.32	10.5	
920610	101	0	.033		1.54	0.02	K	5.2	1.4	140	8.6	15	330	4.0	20	18.60	0.64	5.6	
920610	102	0	.046		1.79	0.10	K	7.6	1.4	130	8.7	15	330	5.0	20	20.50	1.28	5.6	
920707	102	0	.039		1.60	0.12	K	.	.	.	8.6	.	320	.	.	36.50	0.32	3.3	
920707	101	0	.055		1.50	0.01	K	.	.	.	.	.	.	.	.	.	.	.	.
920803	101	0	.065		5.97	0.01	K	.	.	.	8.7	.	320	.	.	35.60	0.32	3.3	
920803	101	39	.653		1.08	0.01	K	8.2	1.6	140	8.3	17	320	7.0	20	45.30	0.43	3.9	
920901	102	0	.046		1.82	0.01	K	.	.	.	.	.	.	.	.	.	.	.	.
920901	101	38	.082		1.75	0.01	K	.	.	.	8.3	.	320	.	.	33.70	0.85	3.9	
920901	102	0	.088		1.70	0.03	K	.	.	.	.	.	.	.	.	.	.	.	.

Table 4. MINLEAP modeling summary for Mazaska Lake 1992

Minnesota Lake Eutrophication Analysis Procedure

Input Variables

Lake Name:	Mazaska Lake
Ecoregion Number:	2=CHF
Watershed Area (HA)	878
Lake Surface Area (HA)	275
Lake Mean Depth (M)	4.8
Observed Mean Lake TP ( $\mu\text{g/l}$ )	55
Observed Mean Chl-a ( $\mu\text{g/l}$ )	25.2
Observed Mean Secchi (M)	1.8

Input Data

Lake Name:	Mazaska Lake
Ecoregion:	CHF
Lake Area:	275 HA
Watershed Area (excluding lake)	878 HA
Mean Depth	12.5 Meters
Observed Mean TP	55 $\mu\text{g/l}$
Observed Mean Chl-a	25.2 $\mu\text{g/l}$
Observed Mean Secchi	1.8 Meters

RESULTS

Lake:	Mazaska Lake	Ecoregion:	CHF
Average Inflow TP:	200.9168 $\mu\text{g/l}$	Total P Load:	251.4272 kg/yr
Lake Outflow:	1.2514 HM3/yr	Areal Water Load:	.4550545 M/yr
Residence Time:	10.1 yrs	P Retention Coef:	.8855

<u>Variable</u>	<u>Units</u>	<u>Observed</u>	<u>Predicted Std</u>	<u>Error</u>	<u>Residual</u>	<u>T-Test</u>
Total P	( $\mu\text{g/l}$ )	55.00	27.01	11.05	0.31	1.81
Chl-a	( $\text{mg/l}$ )	25.20	8.13	5.65	0.49	1.52
Secchi	(meters)	1.80	2.35	1.02	0.10	0.47

**NOTE:** Residual = LOG10 (observed/predicted)  
T-Test for significant difference between observed and predicted

Chlorophyll-a Interval Frequencies (%)

<u>Chl-a</u>		<u>Predicted</u>	<u>Predicted</u>	<u>Predicted</u>
<u>PPB</u>	<u>Observed</u>	<u>Case A</u>	<u>Case B</u>	<u>Case C</u>
10	95.41	25.08	26.75	35.48
20	59.60	1.72	2.54	12.09
30	27.28	0.15	0.32	5.08
80	2.03	0.00	0.00	0.74

**NOTE:** Case A: within-year variation considered  
Case B: within-year + year-to-year variation considered  
Case C: Case B + model error considered  
Ok







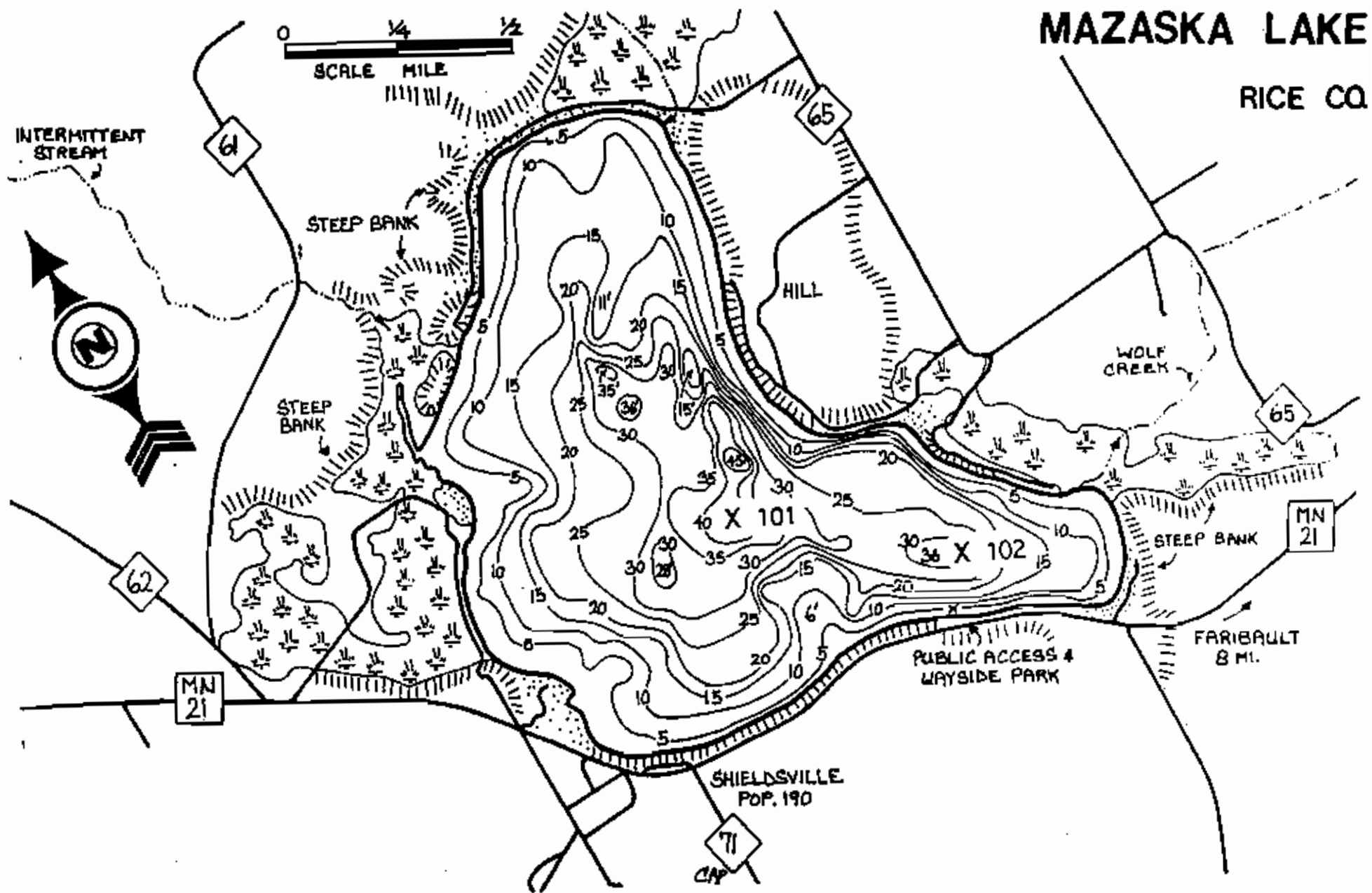


Figure 2. Mazaska Lake sampling sites 101 and 102. (map by D. D. I.)

Figure 3a. Dissolved Oxygen and temperature profiles for sampling site 101 on Mazaska Lake - May 13, 1992.

<u>SITE</u>	<u>DEPTH (m)</u>	<u>D.O. (mg/l)</u>	<u>TEMP (°C)</u>
101	0	12.2	16.7
	1	12.4	16.3
	2	11.7	15.6
	3	10.7	15.6
	4	10.7	15.5
	5	10.8	15.5
	6	9.9	15.4
	7	10.3	15.3
	8	8.9	14.6
	9	6.7	13.8
	10	6	13.2
	12	2.3	11.8

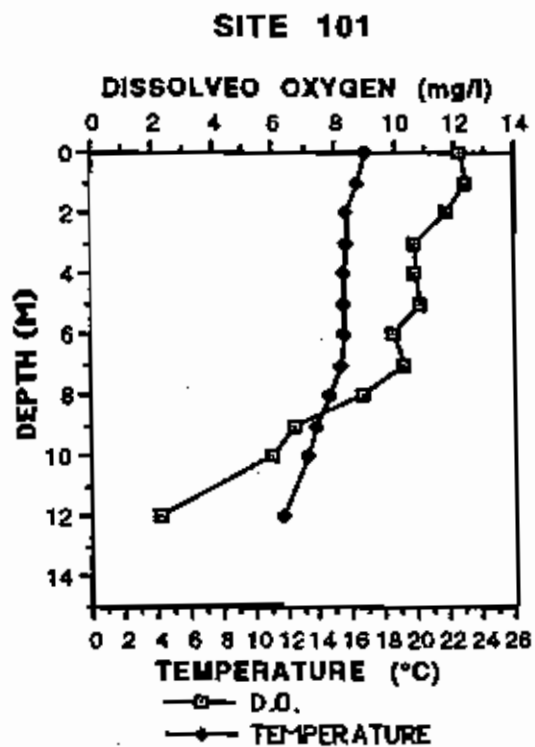


Figure 3b. Dissolved oxygen and temperature profiles for sampling sites 101 and 102 on Mazaska Lake - June 10, 1992.

SITE	DEPTH (m)	D.O. (mg/l)	TEMP (°C)
101	0	7.6	22.8
	1	7.6	21.5
	2	7.6	20.9
	3	7	20
	4	5.95	19.7
	5	2.2	18
	6	0.6	17.1
	7	0.3	16.2
	8	0.2	15.8
	9	0.2	15.7
	10	0.1	15.3
	12	0	13.7
	13	0	12.2
102	0	7.7	21.9
	1	7.7	21.2
	2	7.65	20.7
	3	7.2	20.3
	4	6.1	19.8
	5	2.3	18.2
	6	0.4	17
	7	0.3	16.4
	8	0.2	15.9
9	0.2	15.5	

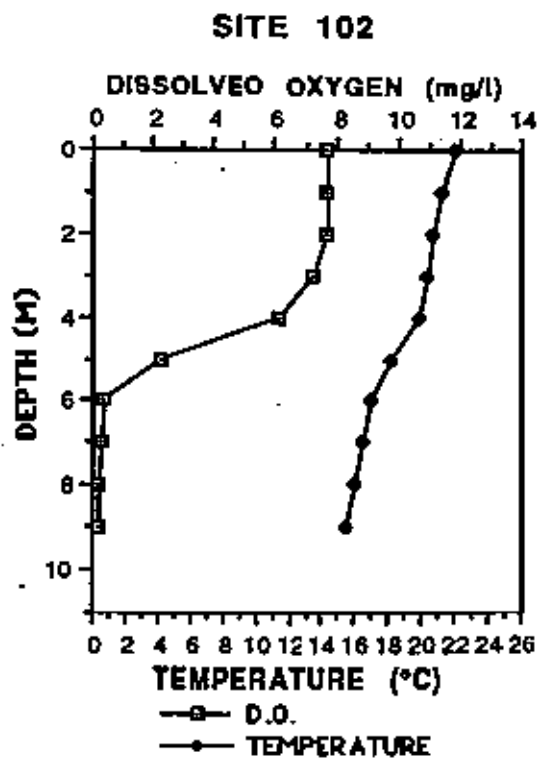
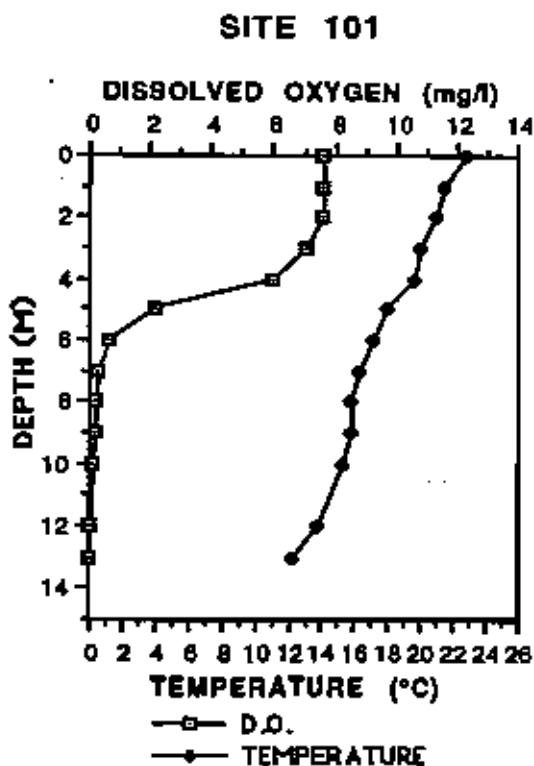


Figure 3c. Dissolved oxygen and temperature profiles for sampling sites 101 and 102 on Mazaska Lake - July 7, 1992.

SITE	DEPTH (m)	D.O. (mg/l)	TEMP (°C)
101	0	8.4	22
	1	8.4	22
	2	8.3	22
	3	8	21.5
	4	6.9	21.2
	5	5.6	20.8
	6	4.2	20.9
	7	3.9	20.3
	8	3.1	20.1
	9	0.8	19.9
	10	0.1	17.4
	12	0.1	15
102	0	8.2	21.7
	1	8.1	21.7
	2	8	21.3
	3	6.7	21
	4	5.6	20.8
	5	4.6	20.7
	6	4.3	20.5
	7	3	20.3
	8	0.8	20
	9	0.1	20

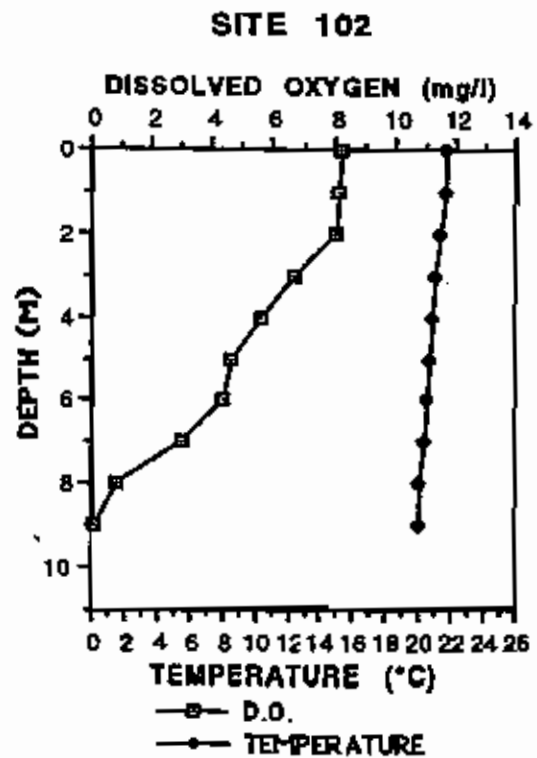
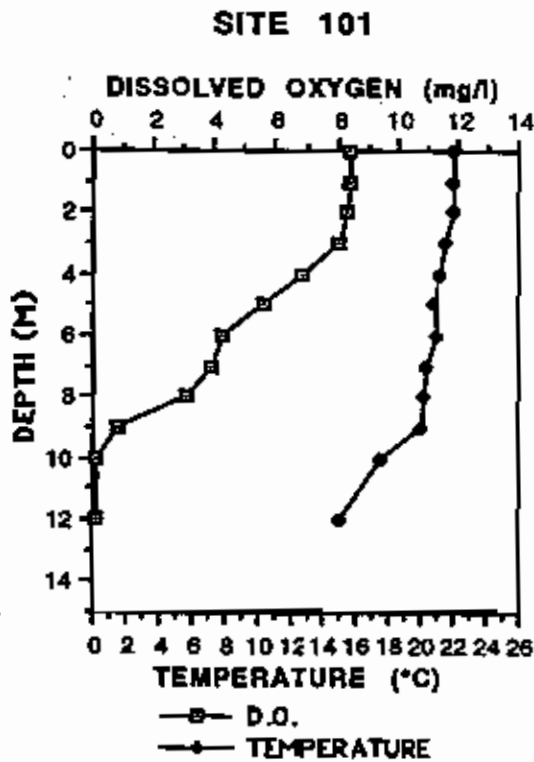


Figure 3d. Dissolved oxygen and temperature profiles for sampling sites 101 and 102 on Mazaska Lake - August 3, 1992.

SITE	DEPTH (m)	D.O. (mg/l)	TEMP (°C)
101	0	9.4	23.8
	1	9.4	23.5
	2	9.4	23.5
	3	9.3	23.5
	4	9.2	23.5
	5	6	22.8
	6	3.9	22.2
	7	2.45	22
	8	0.3	21.5
	9	0.25	21.1
	10	0.25	20.9
	11	0.24	18.3
	12	0.24	16.3
	13	0.24	15.8
102	0	9.7	23.9
	1	9.7	23.9
	2	9.7	23.9
	3	9.4	23.8
	4	9.2	23.8
	5	8.9	23.8
	6	4.25	22.7

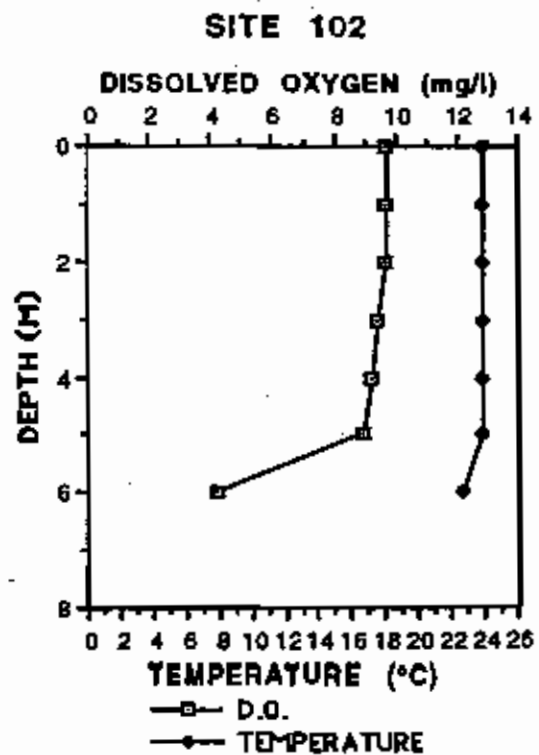
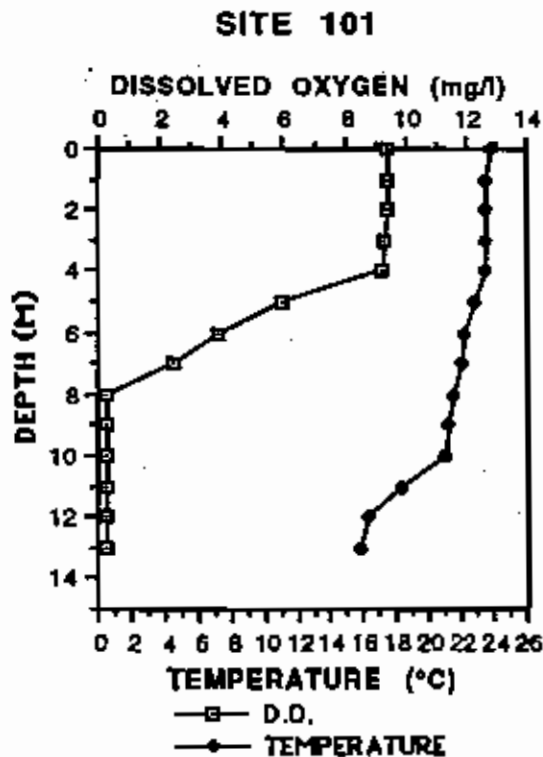


Figure 3e. Dissolved oxygen and temperature profiles for sampling sites 101 and 102 on Mazaska Lake - September 1, 1992.

SITE	DEPTH (m)	D.O. (mg/l)	TEMP (°C)
101	0	8.6	19.9
	1	8.4	19.9
	2	8.3	19.9
	3	8.3	19.9
	4	8.4	19.9
	5	8.2	19.8
	6	7.9	19.7
	7	7.8	19.7
	8	7.3	19.6
	9	6.8	19.6
	10	6.2	19.4
	11	4	19.2
102	0	8	19.9
	1	8	19.8
	2	7.8	19.8
	3	7.8	19.7
	4	5.8	19.6
	5	5.6	19.5
	6	5.5	19.5
	7	5.3	19.4
	8	4.8	19.3
	9	5.3	19.1
	10	1.5	19

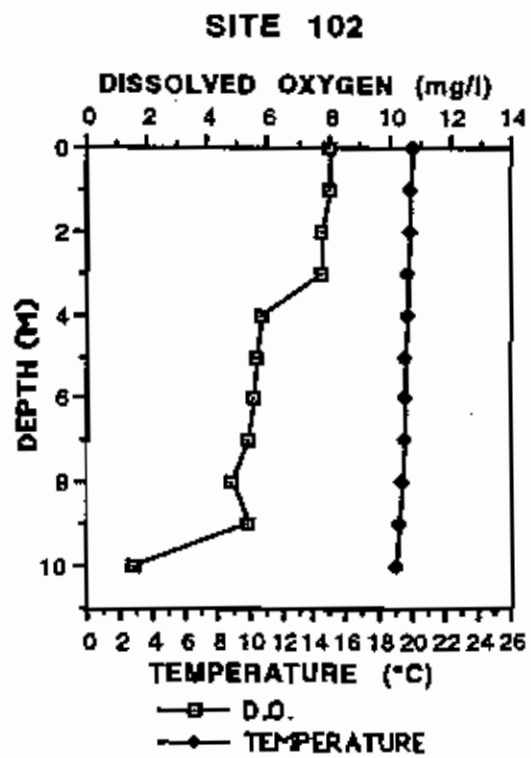
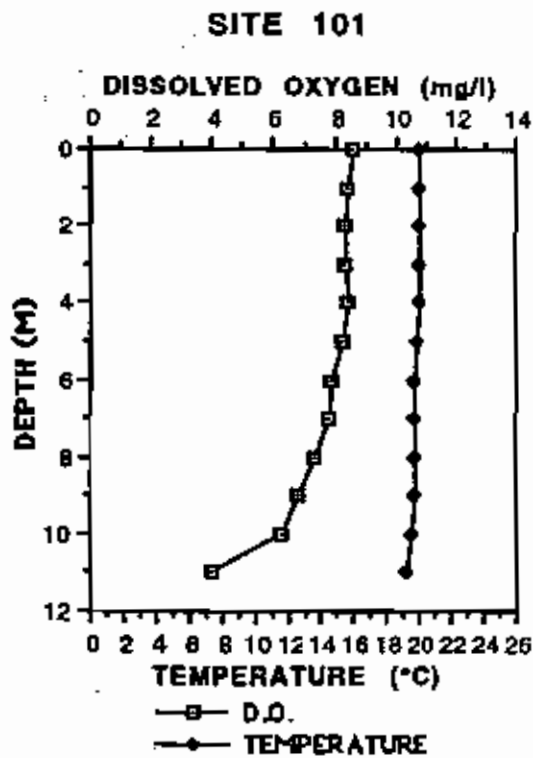


Figure 4. Surface (epilimnion) and bottom (hypolimnion) water total phosphorus (TP) concentrations at sampling site 101 on Mazaska Lake in 1992.

<u>Date</u>	<u>Depth (ft)</u>	<u>TP (<math>\mu\text{g/l}</math>)</u>
05/13/92	0	112
06/10/92	0	55
07/07/92	0	46
08/03/92	0	66
09/01/92	0	86
06/10/92	39	148
08/03/92	39	653
09/01/92	38	82

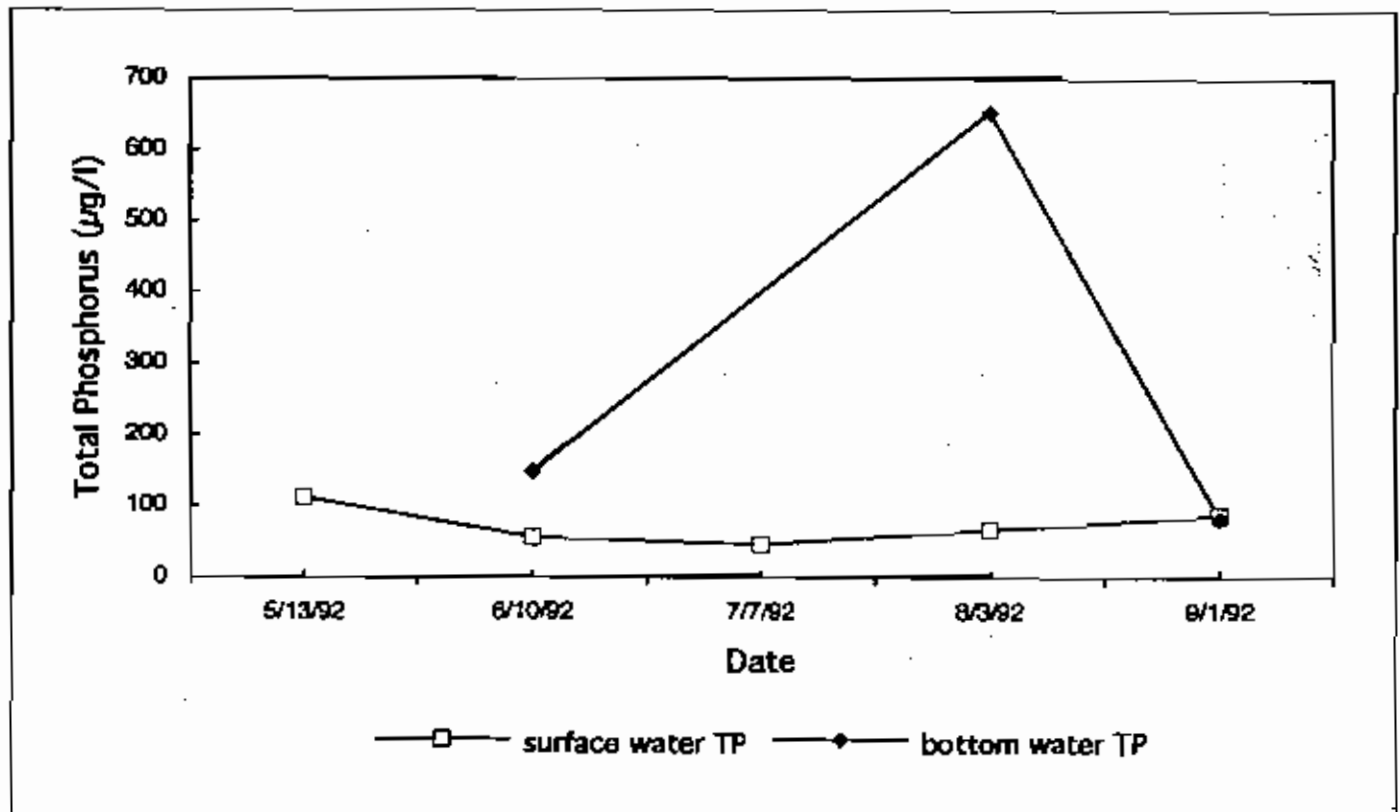


Figure 5. Chlorophyll-a concentrations in surface (epilimnion) water at sampling site 101 on Mazaska Lake in 1992.

<u>Date</u>	<u>Chl-a (<math>\mu\text{g/l}</math>)</u>
05/13/92	80.1
06/10/92	5.45
07/07/92	18.6
08/03/92	36.5
09/01/92	45.3

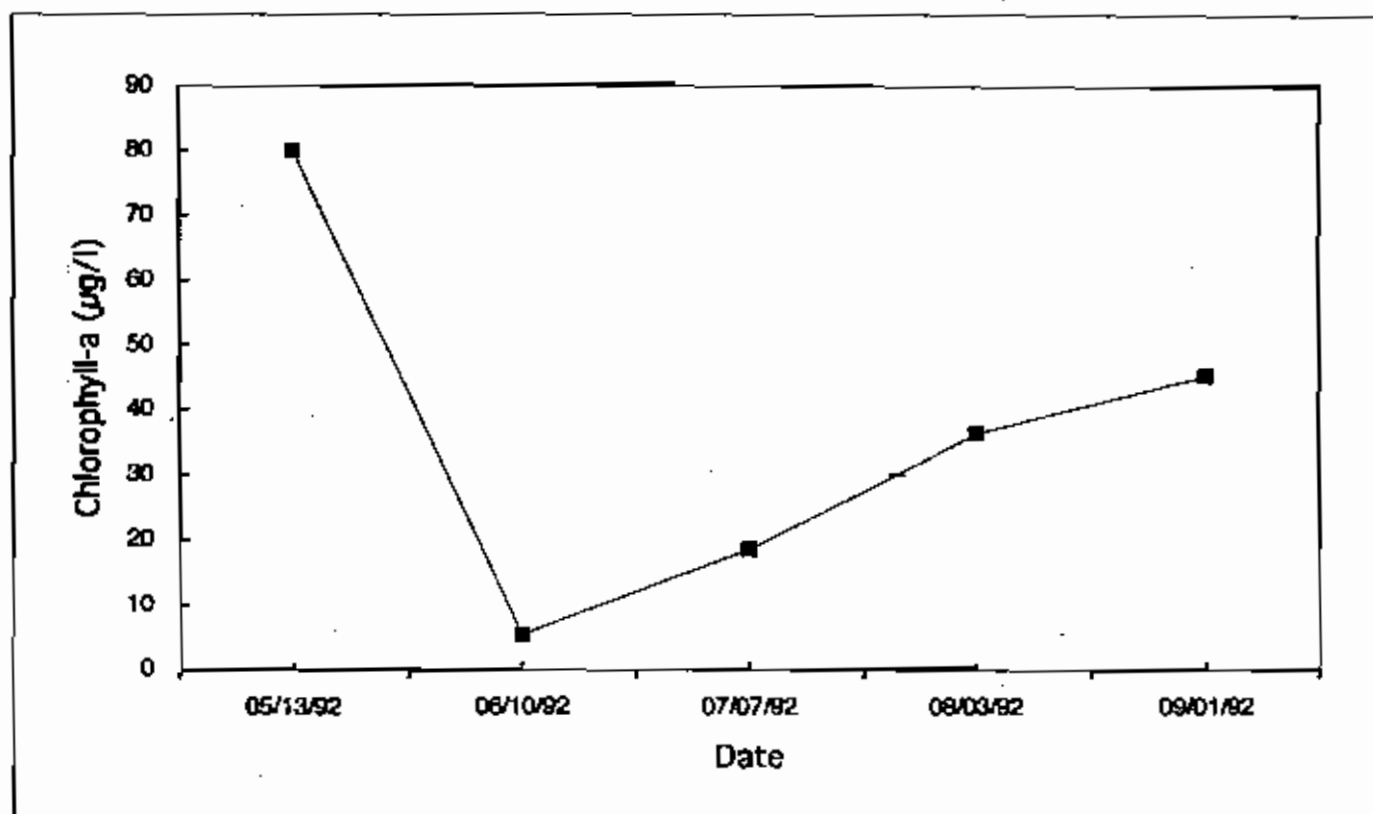


Figure 6. Secchi disk transparencies for Mazaska Lake in 1992, from measurements by the Citizen Lake Monitoring Program and the Lake Assessment Program.

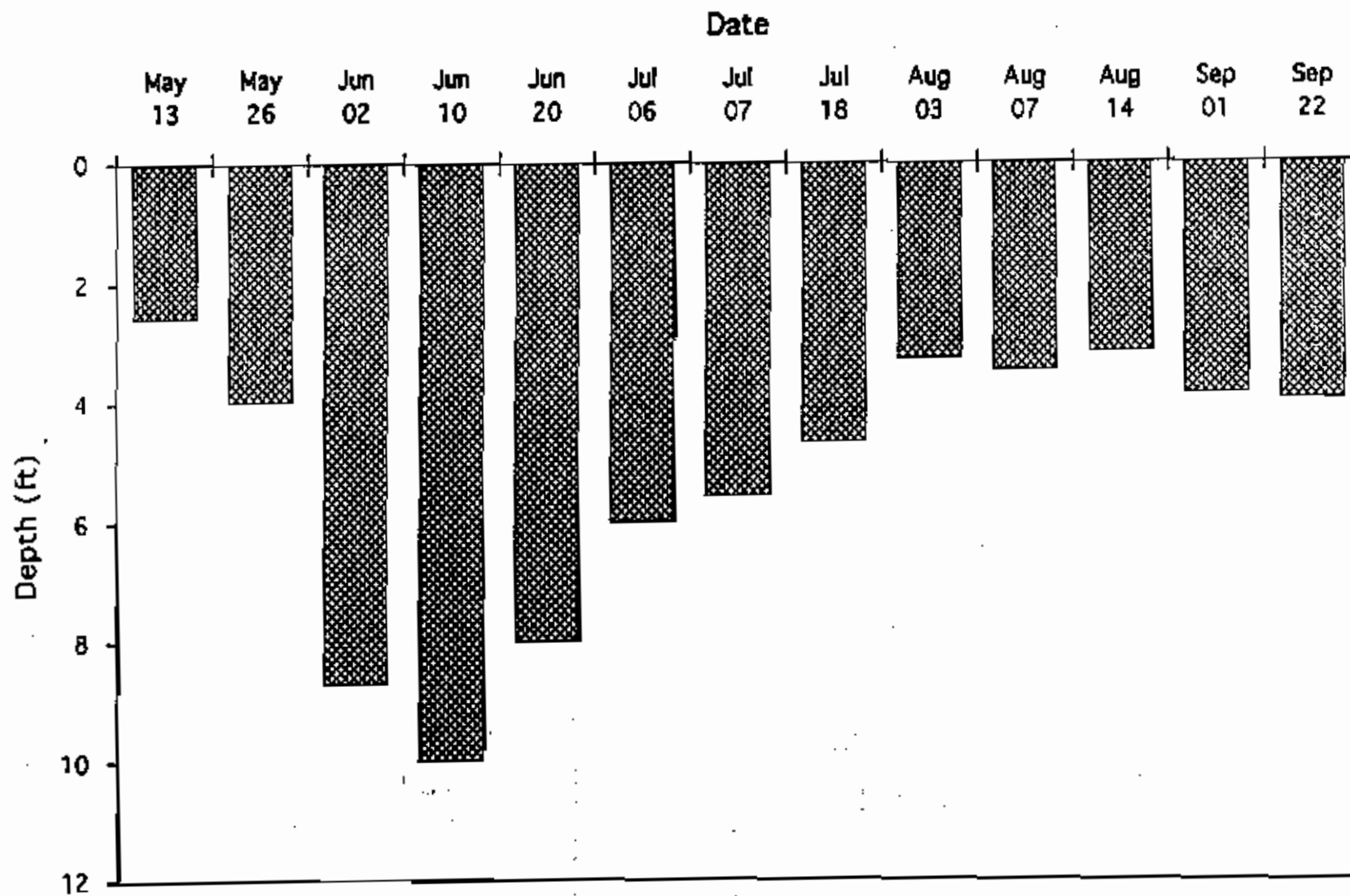
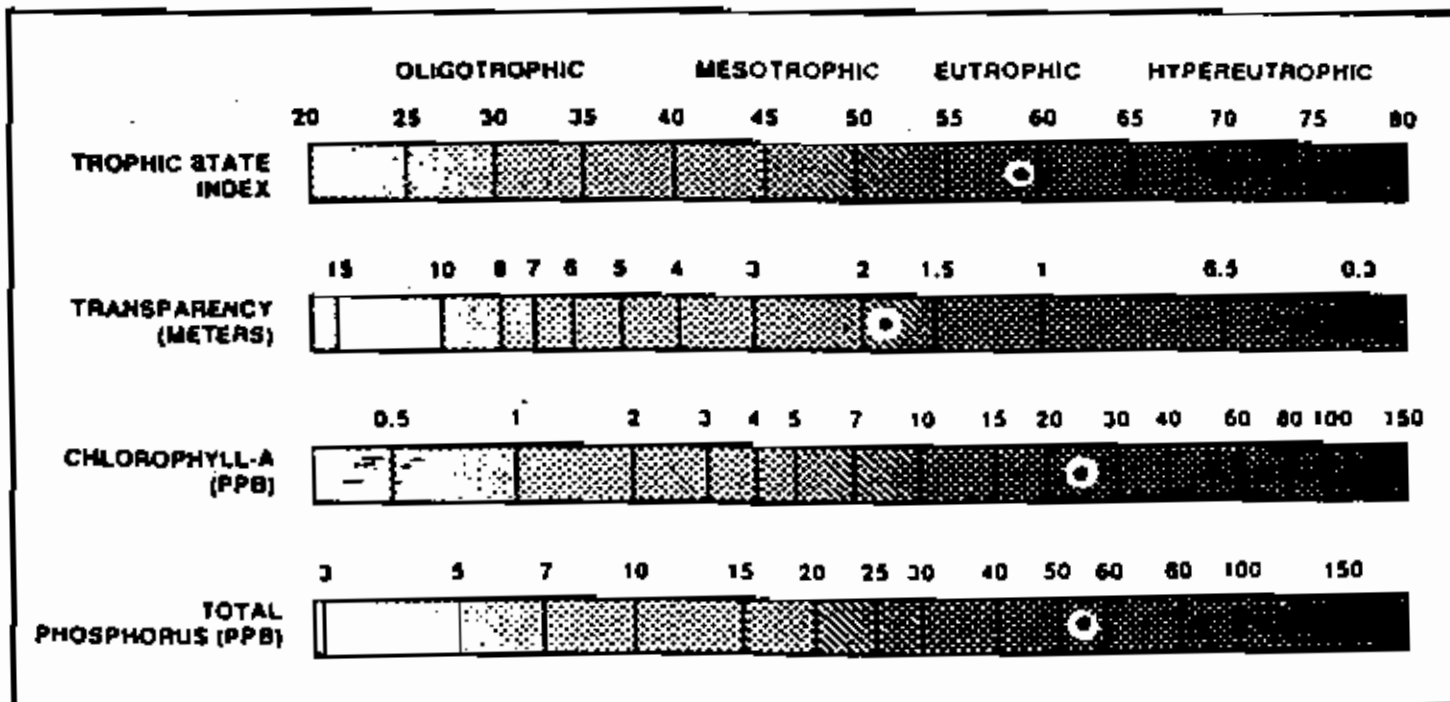


Figure 7. Carlson Trophic Status Index values (TSI) and relationships to Mazaska Lake data for 1992.

- TSI < 30** Classical oligotrophy: Clear water, oxygen throughout the year in hypolimnion, salmonid fisheries in deep lakes.
- TSI 30 - 40** Deeper lakes still exhibit classical oligotrophy, but some shallower lakes will become anoxic in the hypolimnion during the summer.
- TSI 40 - 50** Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.
- TSI 50 - 60** Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimnia during the summer, macrophyte problems evident, warm-water fisheries only.
- TSI 60 - 70** Dominance of blue-green algae, algal scums probable, extensive macrophyte problems.
- TSI 70 - 80** Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypertrophic.
- TSI > 80** Algal scums, summerfish kills, few macrophytes, dominance of rough fish.

• = Mazaska Lake values



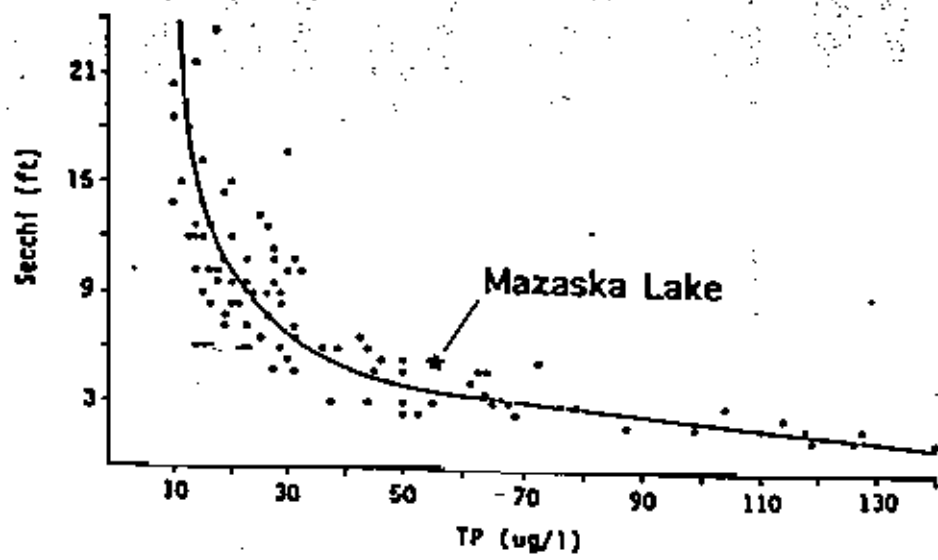
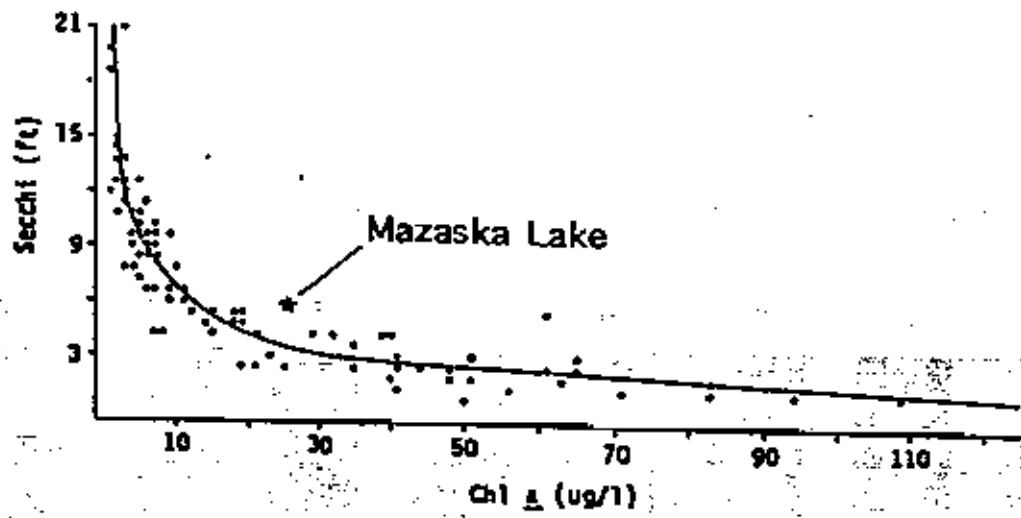
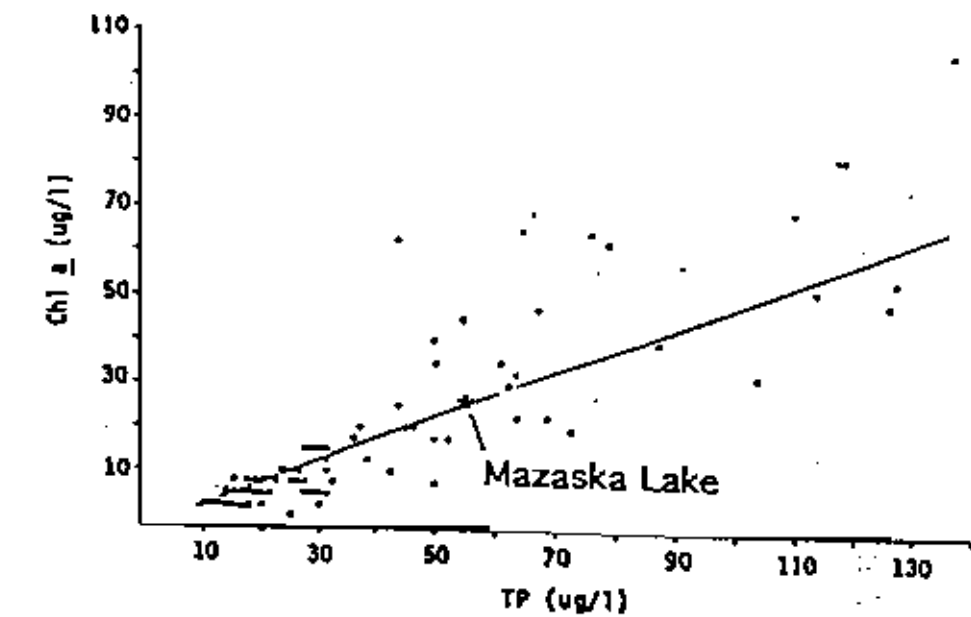
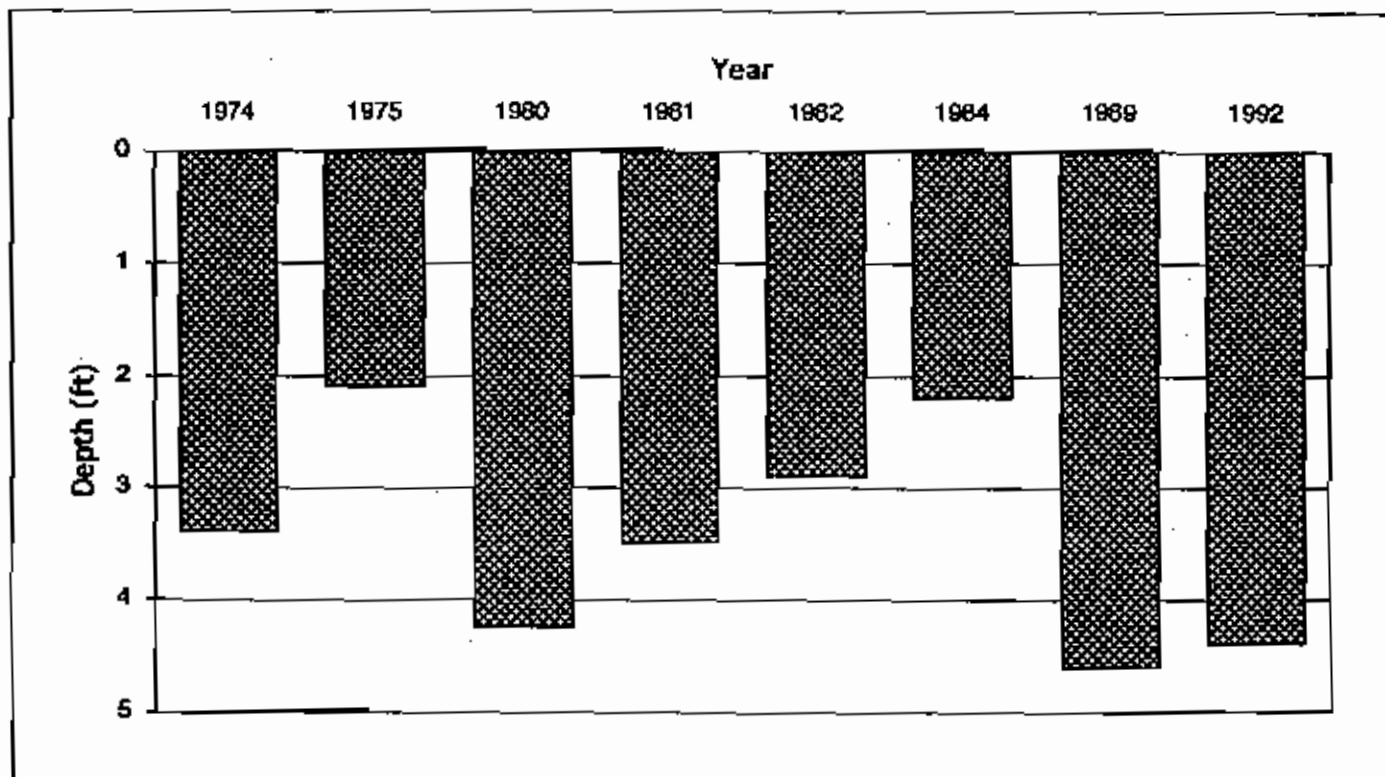


Figure 8. Scatterplots of chlorophyll-a, total phosphorus and Secchi disk transparencies based on summer data from a set of representative lakes from four ecoregions in Minnesota with values for Mazaska Lake in 1992.

Figure 9. Mean Secchi disk transparencies in July and August for Mazaska Lake since 1974.

CLMP data for Mazaska Lake

<u>Date</u>	<u>Feet</u>	<u># of obs</u>
1974	3.4	4
1975	2.1	4
1980	4.25	4
1981	3.5	2
1982	2.9	4
1984	2.2	3
1989	4.6	3
1992	4.4	16



# APPENDIX

## Estimate of sediment phosphorus contribution based on 1992 summer data.

This estimate is based on the following assumptions:

1. The increase of phosphorus in the hypolimnion is the result of the sedimentation and decay of algae from the epilimnion and flux of phosphorus from the sediments.
2. The hypolimnetic phosphorus concentration measured at site 101 in August was representative of the whole hypolimnion.
3. The decrease in epilimnetic phosphorus is due to the uptake and subsequent sedimentation of phosphorus by algae.
4. Other inputs and outputs of phosphorus to the lake over this period are negligible.

Lake Volume =  $V_L = 1.35 \times 10^{10}$  Liters  
Epilimnetic Volume =  $V_E = 8.80 \times 10^9$  Liters  
Hypolimnetic Volume =  $V_H = 4.74 \times 10^9$  Liters

Total Phosphorus; Spring Epilimnion =  $TP_{SPR} = 112 \mu\text{g/L}$   
Aug. Epilimnion =  $TP_{AUG} = 66 \mu\text{g/L}$   
Hypolimnion =  $TP_H = 653 \mu\text{g/L}$

1. The difference between the epilimnetic concentration in the spring and in August is considered the amount of phosphorus which entered the hypolimnion from the sedimentation of algae.

$$TP_{SPR} - TP_{AUG} = 112 \mu\text{g/L} - 66 \mu\text{g/L} = 46 \mu\text{g/L}$$

$$46 \mu\text{g/L} \times V_E (8.80 \times 10^9 \text{ L}) = 4.05 \times 10^{11} \mu\text{g phosphorus}$$

2. Assuming all of this phosphorus stays in the hypolimnetic water this would result in an increase equal the mass divided by the volume of the hypolimnion:

$$4.05 \times 10^{11} \mu\text{g P} \div 4.74 \times 10^9 \text{ L} = 85 \mu\text{g/L}$$

3. Add this to the spring hypolimnetic phosphorus concentration to get an estimate of the expected phosphorus concentration given no other inputs:

$$85 \mu\text{g/L} + 112 \mu\text{g/L} = 197 \mu\text{g/L}$$

4. Subtract this concentration from the observed concentration ( $V_H$ ) to obtain an estimate of the phosphorus increase due to sediment contributions:

$$(TP_H) 653 \mu\text{g/L} - 197 \mu\text{g/L} = 456 \mu\text{g/L}$$

multiply by ( $V_H$ ) to obtain mass:

$$456 \mu\text{g/L} \times 4.74 \times 10^9 \text{ L} = 2.16 \times 10^{12} \mu\text{g P}$$

or 2160 Kg P

This mass would result in a whole lake increase of 160  $\mu\text{g/L}$  if it were available to the whole lake.

Summary of responses to lake water quality questions collected during 1993 creel surveys on Mazaska Lake.

<u>Date</u>	<u>n</u>	<u>Physical Condition</u>	<u>Recreational Suitability</u>
6-10	6	2	2
6-12	4	1.5	2
6-20	1	3	2
6-23	1	2	2.5
6-27	7	2	2
6-28	1	2	2
7-2	2	1.5	2
7-3	1	2	2
7-28	1	2	2
8-2	2	2	2
8-6	4	2	2
8-8	4	2	1
8-13	1	3	3
8-14	5	2	2
8-15	3	3	2
8-17	3	2	2
8-21	1	2	2
8-23	2	2.5	1.5
8-29	3	2	2
9-4	4	2	2
9-6	3	2	2
9-12	2	1.5	2
10-16	1	2	2

Physical Condition

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 apparent
5. Sever high algae levels with one or more of the following:
  - massive floating scums on lake or washed up on shore
  - strong, foul odor
  - fish kill

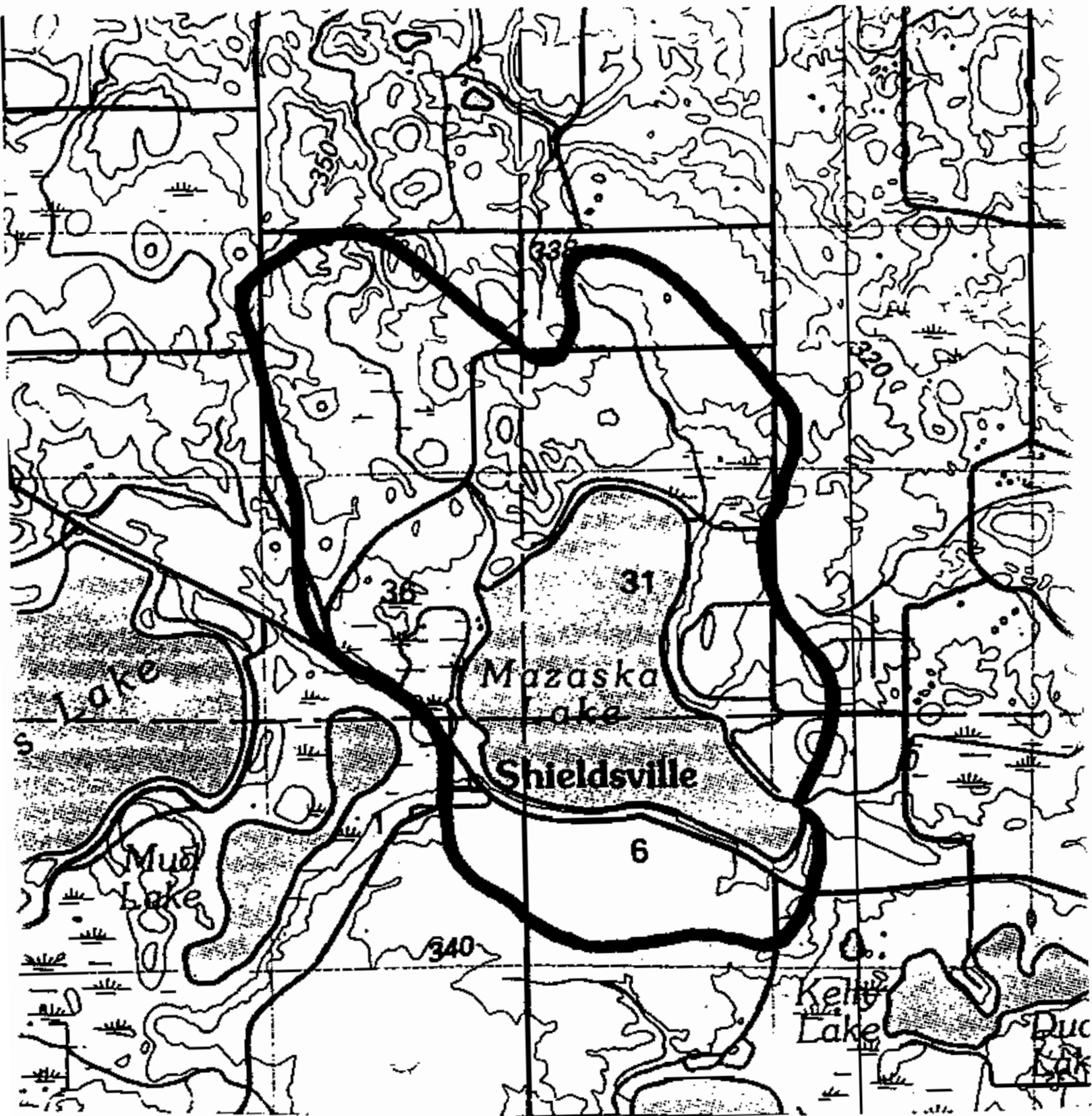
Suitability for Recreation

1. Beautiful, could not be better
2. Very minor aesthetic problems; excellent for swimming, boating, etc.
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

Water Clarity and Aquatic Plants

Of 61 responses:

- 14 (23%) prefer turbid water and few aquatic plants
- 47 (77%) prefer clear water and many aquatic plants



Approximate watershed area of Mazaska Lake.

