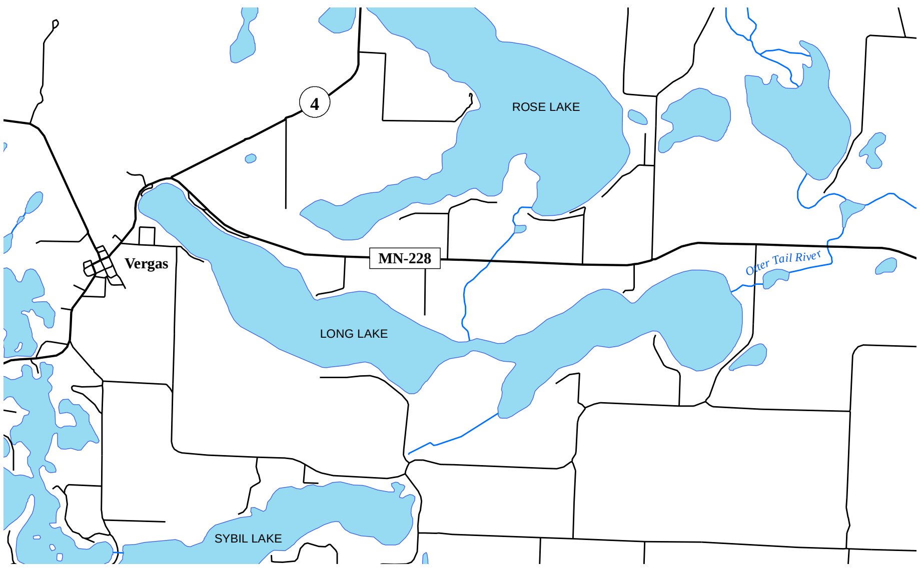
LAKE ASSESSMENT PROGRAM

Long Lake: #56-0388

1999

Otter Tail County, Minnesota



Minnesota Pollution Control Agency

Environmental Analysis and Outcomes Division

MAY 2005

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Long Lake (56-0388)

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May 2005

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TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

SUMMARY AND RECOMMENDATIONS

Long Lake is located in Otter Tail County near the town of Vergas. This lake has a surface area of 1,273 acres and a maximum depth of 128 feet. Mean depth of the lake is estimated at 28 feet. The immediate watershed of Long Lake is approximately 7,418 acres (including the lake surface area). Land use in the watershed is characterized by open water/marsh (21 percent), forested (19 percent), cultivated (45 percent), grassland/pasture (12 percent), and residential/urban areas (the remaining 3 percent). These land use percentages are typical of what would be expected for lake watersheds in the North Central Hardwood Forests (NCHF) Ecoregion of the state.

Long Lake was sampled during the summer of 1999 by Minnesota Pollution Control Agency (MPCA) staff. Water quality data collected during the study revealed a summer mean total phosphorus concentration of 20 µg/L, chlorophyll-*a* concentration of 6 µg/L, and a Secchi transparency of 8.8 feet. All three of these values are well within or below (better than) the typical range exhibited by reference lakes in the NCHF ecoregion. The parameters: total phosphorus, chlorophyll-*a*, and Secchi transparency help to characterize the trophic status of a lake. For Long Lake, these measures indicate *mesotrophic* conditions.

A good historical database is available for assessing trends in the transparency of Long Lake. Citizen Lake-Monitoring Program (CLMP) Secchi transparency data revealed some minor annual fluctuations in transparency from 1985 to 2004. During this period, the summer mean annual Secchi ranged from a low of 6.6 feet in 1991 to a high of 11.8 feet in 1986. Transparency varies from year to year but no long-term trend is evident based on analysis of Secchi transparency data.

Two water quality models were used to estimate the water quality of Long Lake based on morphometry and watershed characteristics. The MINLEAP water quality model and the Vighi and Chiaudani regression model both provide a means to compare the measured water quality of the lake relative to the predicted water quality.

MINLEAP predicted summer-mean total phosphorus (TP) concentration of 40 µg/l, which is quite high when compared to the 1999 observed summer-mean of 20 µg/l. This may be explained by the upstream lakes within the watershed which retain much of the phosphorus in the water traveling to Long Lake. Therefore, the average TP inflow was lowered to take this phenomenon into account in a calibrated model run. The calibrated run predicted a summer-mean TP concentration of 21 µg/l, which is much closer to the observed value.

The following recommendations are based on the 1999 Lake Assessment Program (LAP) study of Long Lake:

1. Long Lake is sensitive to a change in trophic status because it presently has relatively low total phosphorus and chlorophyll-a concentrations. Relatively minor increases in the nutrient loading rates from any watershed or in-lake sources which would increase the in-lake total phosphorus concentration could degrade the lake. It is essential, therefore, that lake protection efforts be conveyed to all local government groups with land use/zoning authorities for Otter Tail County.

   The Long Lake Association should be commended for their efforts to date, which include strong involvement with the Otter Tail County Coalition of Lake Associations (COLA), participation with the Otter Tail County COLA Lake Monitoring Program, and participation in the CLMP. To complement these efforts, the Association should develop a plan for protecting the water quality of the lake. This plan, referred to as a lake management plan, should incorporate a series of activities in a prioritized fashion which will aid in the long-term protection and improvement of the lake. The plan should be developed cooperatively by a committee consisting of representatives from state agencies (e.g., MDNR, BWSR, MPCA), local units of government, and lake association members. The reference document, Developing a Lake Management Plan, is available on the web at: http://www.shorelandmanagement.org/depth/plan.pdf. The following activities could be included in the plan:

a. The Association should continue to participate in the CLMP. Data from this program provides an excellent basis for assessing long-term and year-to-year variations in algal productivity, i.e., trophic status of the lake. At a minimum, measurements should be taken weekly during the summer at consistent sites.

b. The continued education of homeowners around the lake, with respect to septic system and lawn maintenance and shoreline protection may be beneficial. Staff from the MPCA and the Minnesota Department of Natural Resources (MDNR), along with the county officials, such as staff from Minnesota Extension Service, the East Otter Tail County Soil and Water Conservation District and the County Land and Resource Management Office could provide assistance in these areas.

c. Further development in the immediate watershed of the lake should occur in a manner that minimizes water quality impacts on the lake. Consideration to setback provisions, lot size, and septic systems will be important in providing water quality protection. The MDNR, City of Vergas, and county shoreland regulations will be important in these regards and should be strictly enforced. The Association should also explore additional safeguards in land-use, zoning, and shoreline protection that could be included in a long term plan to address future development activity within the immediate watershed.

d. Maintenance of shoreline vegetation (both upland and aquatic) is very important. Soil erosion from the construction of roads and homes should be minimized. The disturbance or the removal of vegetation on bluffs or slopes should be avoided.

e. The Association should continue to seek representation on boards or commissions that address land management activities so that their impact can be minimized. Safeguarding the Shoreland Ordinance from those who would choose to weaken it should be a priority for Long Lake as well as other lake associations in Otter Tail County. The pamphlet "Your Lake and You," available from the North American Lake Management Society (www.nalms.org), may be a useful educational tool in this area.

f. The Association is encouraged to be aware of the possible nutrient and sediment sources such as urban and agricultural runoff, septic systems, lawn fertilizer, and the effects of activities in the total watershed that change drainage patterns, such as wetland removal, creating new wetland discharges to the lake, or major alterations in lake use. As these activities occur within the watershed, the Association is encouraged to make sure that the water quality effects are minimized with the use of best management practices (BMPs) for water quality. Some of the county and state offices mentioned above may be of help in this regard.

2. The 1999 water quality of Long Lake was good relative to other lakes in the NCHF Ecoregion. It could, however, exhibit a measurable decline in transparency, increases in the amount of algae, and possible increases in the amount of rooted vegetation from a fairly small increase of in-lake total phosphorus. Changing land use practices, poor management of shorelands, failure to maintain (pump) septic tanks, and draining of wetlands in the watershed provide the greatest likelihood for changes in phosphorus loading.

   Conversely, a reduction of the amount of nutrients that enter the lake may result in improved transparency and a reduction in algal concentrations. One means of reducing nutrient input is by implementing BMPs in the watershed (land management activities used to control nonpoint source pollution). Technical assistance in BMP implementation may be available through local resource management agencies. The Association can work with the Otter Tail SWCD to examine land use practices in the watershed and develop strategies for reducing the transport of nutrients to the lake. It may be wise to first focus efforts on the area of the watershed near the lake. There may be few opportunities (or the need) to implement BMPs on existing land use. However, opportunities may arise during road building, construction or other activities which may result in increased sediment and phosphorus loading to the lake.

   Restoring or improving wetlands in the watershed may also be beneficial for reducing the amount of nutrients or sediments which reach Long Lake. The U.S. Fish and Wildlife Service may be able to provide technical and financial assistance for these activities.

   MPCA's Clean Water Partnership Program is also an option for further assessing and dealing with nonpoint sources of nutrients in the watershed. However, since there is extensive competition for CWP funding, it may be in the best interest of the Long Lake Association to continue to work with the Otter Tail SWCD, Otter Tail County Land and Resource Management staff, and the local townships to do as much as possible to protect the condition of the lake by means of local ordinances and education of shoreland and watershed residents. If these steps prove to be inadequate or the lake condition declines (as evidenced by a significant reduction in Secchi transparency), application to CWP may then be appropriate. A CWP may not be needed at that time but a repeat of a LAP level effort may be necessary to understand and document changes in total phosphorus, chlorophyll and Secchi within the lake.

3. Should a CWP application be deemed necessary, this LAP report serves as a foundation upon which further studies and assessments may be based. The next step would be to define water and nutrient sources to the lake in a much more detailed fashion. These detailed studies would allow the estimation of reasonably accurate total phosphorus (and ortho-phosphorus), total nitrogen (and inorganic nitrogen) and water in and out-flow summaries. This should be accomplished prior to implementation of any extensive in-lake restoration techniques.

LAKE ASSESSMENT PROGRAM: Long Lake 1999

INTRODUCTION

Long Lake was sampled by the Minnesota Pollution Control Agency (MPCA) during the summer of 1999 as a part of the Lake Assessment Program (LAP). This program is designed to assist lake associations or municipalities in the collection and analysis of baseline water quality data in order to assess the trophic status of their lakes. The general work plan for LAP includes Association participation in the Citizen Lake-Monitoring Program (CLMP), cooperative examination of land use and drainage patterns in the watershed of the lake, and an assessment of the data by MPCA staff.

Long Lake was sampled on four occasions during the summer and fall of 1999 by Mike Vavricka from the MPCA. Land-use information for the lake's watershed was assembled by the East Otter Tail Soil and Water Conservation District. The septic survey and follow up work was conducted by the Otter Tail County Land and Resource Management staff.

This study was conducted at the request of the Association, whose members are interested in identifying sources of pollution to the lake, characterizing the quality of the lake, and developing a program to assist in lake management. Several years of data were available for Long Lake from the CLMP and from Otter Tail County COLA monitoring. Historical data provides a basis for assessing year-to-year fluctuations in the quality of Long Lake.

BACKGROUND

Long Lake is located near Vergas, Minnesota in Otter Tail County. It has a surface area of 1,273 acres and a maximum depth of 128 feet. The immediate watershed of Long Lake is 7,418 acres, but when combined with the two contributing watersheds from Lake Sybil (13,267 acres) and Rose Lake (8,774 acres) the total watershed is 29,459 acres (Figure 1). In other words, two-thirds of the watershed to Long Lake drains through either Sybil or Rose Lake prior to reaching Long Lake.

Long Lake has two major inlets and one outlet. Sybil, a 706 acre lake, from the south, and Rose, a 1,190 acre lake, from the north, both drain into Long Lake. Long Lake flows into the Otter Tail River from the east end of the basin.

Long Lake was likely formed by an ice block basin in glacial till in the Keewatin Sheet of the lake Wisconsin Glaciation (Zumberge, 1952). Soils near the lake consist of the Nebish-Rockwood and Estherville-Wadena-Hubbard series. This area is generally hilly terrain with well to excessively drained soils. The Nebish-Rockwood soils are light in color and developed from calcareous glacial till. The Estherville-Wadena-Hubbard soils are dark in color and developed from calcareous gravel outwash (Arneman 1963).

Since land use affects water quality, it has proven helpful to divide the state into regions where land use and water resources are similar. Minnesota is divided into seven regions, referred to as ecoregions, as defined by soils, land surface form, natural vegetation and current land use. Data gathered from representative, minimally-impacted (reference) lakes within each ecoregion serve as a basis for comparing the water quality and characteristics of other lakes. Long Lake is located in the North Central Hardwood Forests (NCHF) ecoregion (Figure 2).

Land Use
The land uses observed in the watershed of Long Lake are similar to the typical range for the NCHF ecoregion (Table 1). Agricultural/cultivated has the largest percentage present in the watershed (approximately 45 percent of the watershed). Lakes/water/wetlands account for 21 percent of the land use. These wetlands provide an area where pollutants in snowmelt and stormwater runoff can settle out and serve to slow the flow of nutrients which enter Long Lake during periods of precipitation and runoff. Forested land accounts for about 19 percent of the land use in this watershed. The remainder of the watershed is a mix of grassland, pasture, and residential (Figure 4).

Precipitation
Based on State Climatology records, precipitation averages 24 inches (0.61 m) annually in this part of the state. Water-year precipitation near Long Lake was well above normal in 1999, with 32-34 inches of precipitation recorded (Appendix II). Site-specific data for this area noted several events in summer 1999 where one inch of rain or more fell in the area in one day – June 23 (1.3 in), July 5 (1.62 in), July 23 (1.58 in), and August 10 (1.24 in). There were also 2 multiple day events in 1999, August 12-13 (3.42 in) and September 2-5 (2.81 in). Evaporation typically exceeds precipitation in this region of the state and averages about 36 inches (0.91 m) per year. Runoff averages for this area are about 4 inches with 1 in 10 year low and high values (low and high runoff values which might occur once in ten years) of 0.8 inches and 6 inches respectively for this area (Gunard, 1985).

Fisheries
DNR fisheries managers utilize netting survey information to assess the well-being of fish communities and measure the efficacy of management programs. Presence, absence, abundance, physical condition of captured fishes and community relationships among fish species within survey catch information also provide good indicators of current habitat conditions and trophic state of a lake (Schupp and Wilson 1993). This long term fisheries survey database has also proven valuable in qualifying and quantifying changes in environmental and fisheries characteristics over time. This fishery of Long Lake is managed by the Minnesota Department of Natural Resources Fisheries Office located in Fergus Falls, Minnesota. A summary of Long Lake's fishery as surveyed by the MDNR on June 16, 2003 is available in Appendix III of this report or a current report can be found at www.dnr.state.mn.us.

History
The following is drawn from information provided by the Vergas-Long Lake Association:

Long Lake (56-0388) is located in Otter Tail County near the town of Vergas. Originally within Hobart Township, Long Lake is one of the largest in a group of many area lakes, all of which are a part of the Red River basin. It is the deepest of the Otter Tail County lakes with a maximum depth of 128 feet. Numerous natural springs feed into its basin.

Long Lake has been known for years as an excellent fishing lake, particularly for bass, northern pike, crappies and sunfish. Several drop-offs in the lake yield good fishing in both the summer and winter, though the rocky western edge of the lake's narrows make it difficult for fishermen when the lake level is low. At one point, the lake level was so low that people could easily ride their bicycles along the sandy beaches recently exposed.

Settlers have lived on Long Lake for well over a century. The area at the east end of the lake, now known as Hillcrest Beach, passed from hand to hand before being developed and divided into several lots. In 2000, the number of lakeshore residents had grown to one hundred. Vergas Park, in which the famous 20 foot loon statue sits, was founded in 1958 at the western edge of Long Lake. Upon completion of the noted tourist attraction, the park was dedicated on June 30th, 1963. Another change to the Long Lake area occurred in 1993 when a lateral gas line from a local transmission plant to Fergus Falls was built across the lake.

Long Lake historically had high total phosphorus and chlorophyll levels and low clarity readings when compared to area lakes. Thus, in 1996 the Vergas-Long Lake Association was formed with an emphasis upon environmental issues. Originally, the Lake Association comprised 60 family memberships. Officers and area captains provide lakeshore residents with information necessary to improve the water quality of the lake. The organization is also a member of the Minnesota Lakes Association as well as of the County Coalition of Lakes Association (COLA) which has monitored the water quality of the lake for several years.

Figure 1. Long Lake Watershed

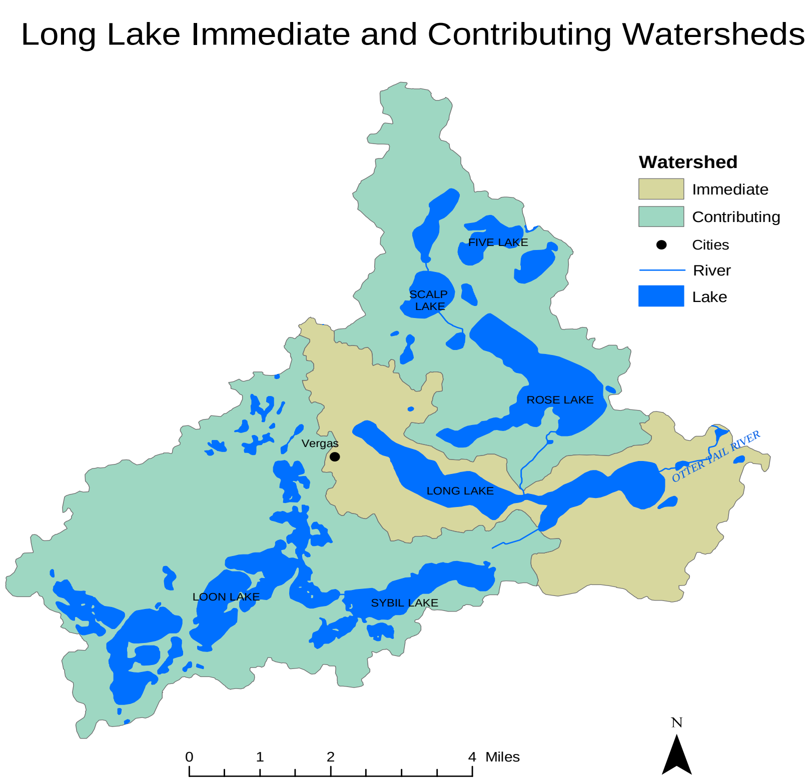


Figure 2. Long Lake Location Ecoregion Map

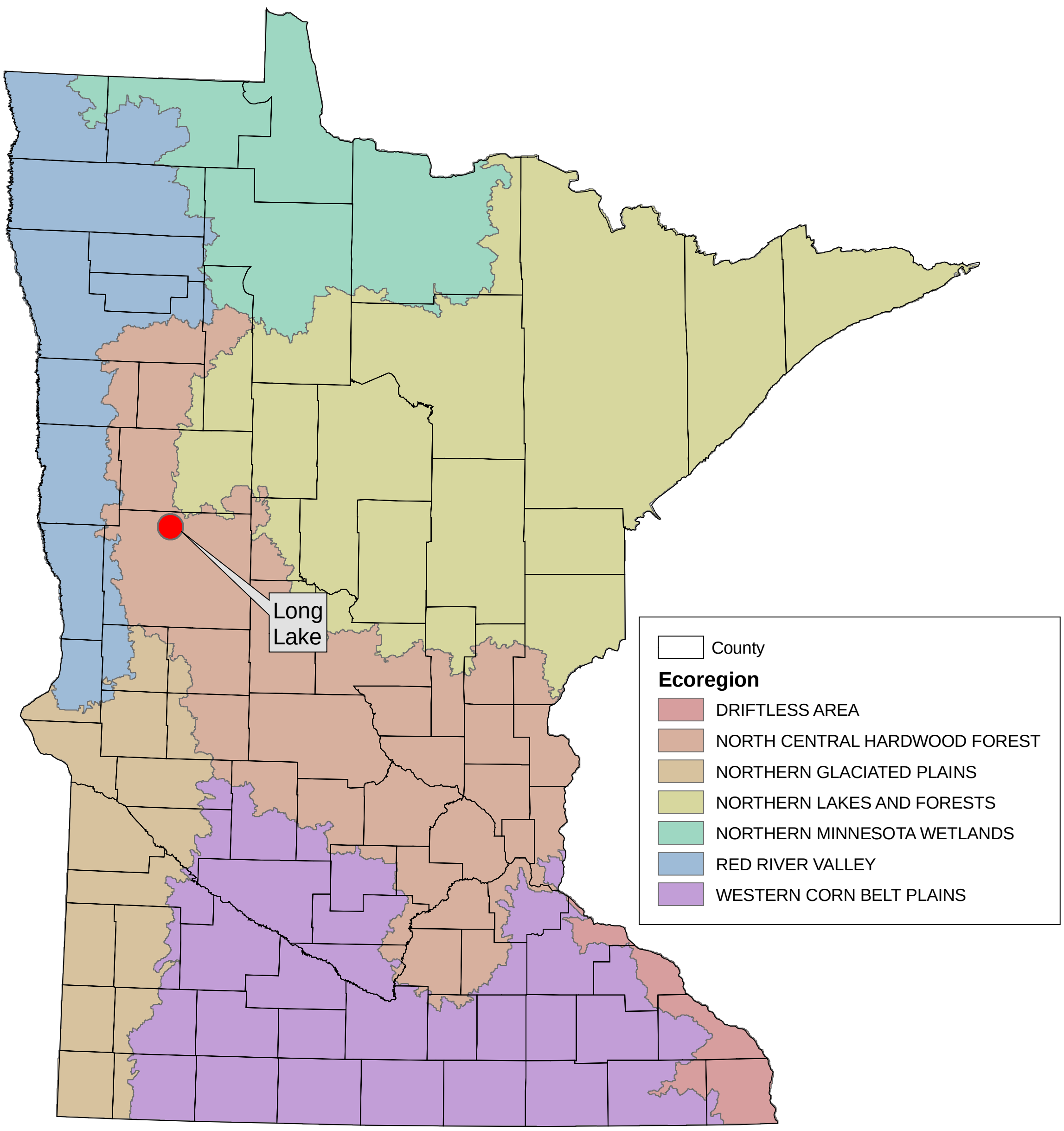


Figure 3. Long Lake Bathymetric Map and Monitoring Locations

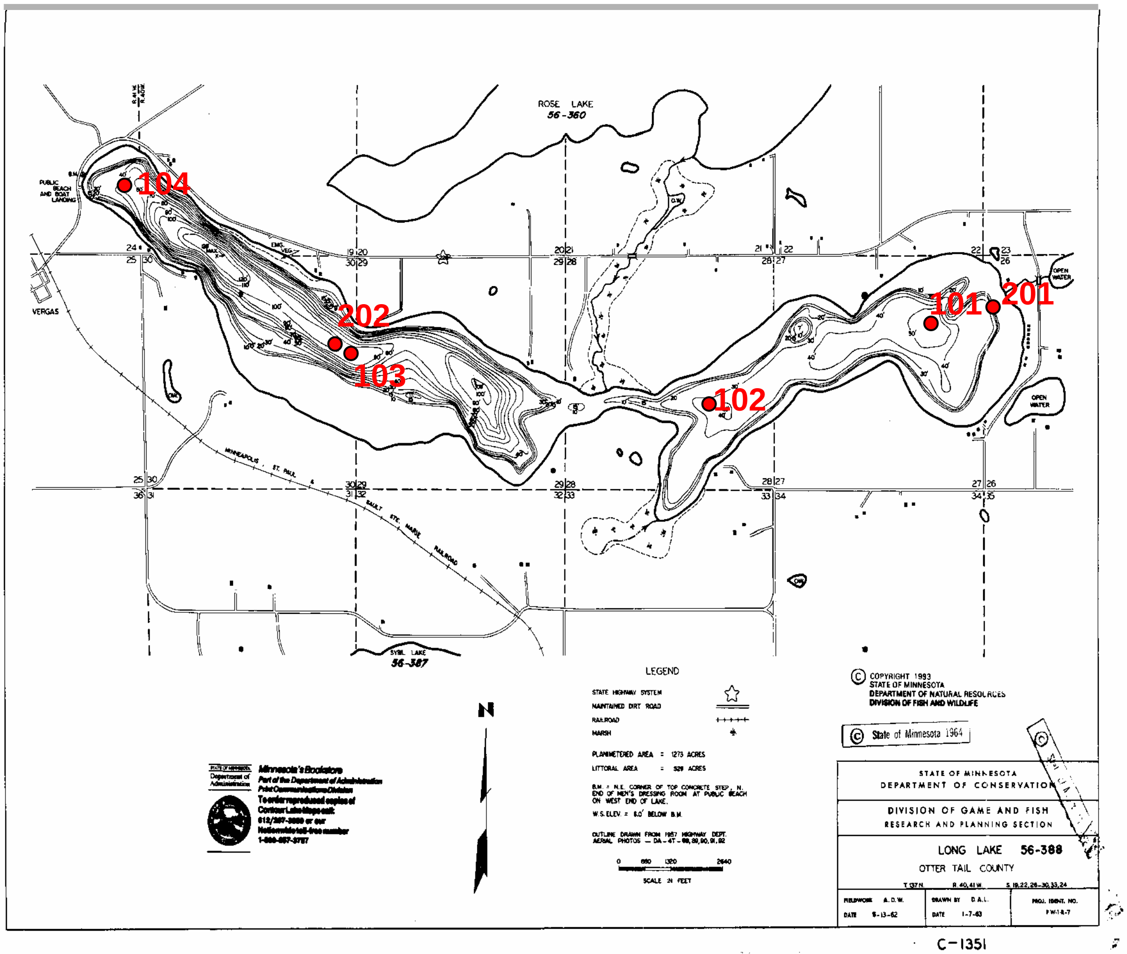


TABLE 1. Long Lake (56-0388): Morphometric, Watershed, and Fishery Characteristics

Area[1]: 1,273 acres (2mi^2) (515 ha)

Mean Depth[2]: 28 feet (8.5 m)

Maximum Depth: 128 feet (39 m)

Volume: 35,644 acre-feet (44 hm^3)

Littoral area[1]: 529 acres (42 %)

Watershed Area[3]: 7,418 acres (11.6 mi^2) (3,002 ha) immediate watershed, includes lake
6,145 acres (9.6 mi^2) (2,487 ha) immediate watershed, excludes lake
29,459 acres (46 mi^2) (11,922 ha) total watershed, includes lake
28,186 acres (44 mi^2) (11,407 ha) total watershed, excludes lake

Immediate Watershed Area : Lake Surface Ratio: ~ 5:1

Total Watershed Area : Lake Surface Ratio: ~ 22:1

Estimated Average Water Residence Time: 3 years

Fisheries[1] – Schupp's Lake class: 22

Public Access[1]: 1 **Inlets[2]:** 2 **Outlets[2]:** 1

Land Use	**Forest**	**Wetlands or water**	**Pasture or grassland**	**Cultivated**	**Urban**
Long Watershed (acres)	1375	1585	929	3251	279
Long Lake (%)	19	21	12	45	3
NCHF Ecoregion (%)	6 – 25	14 – 30	11 – 25	22 – 50	2 – 9

Source:
[1] MN Department of Natural Resources
[2] MN Pollution Control Agency
[3] Otter Tail County

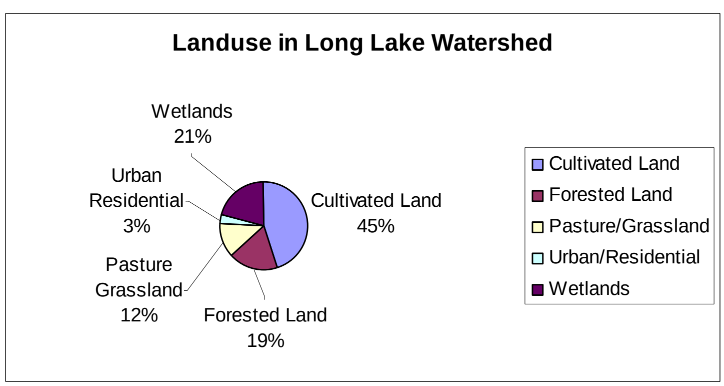
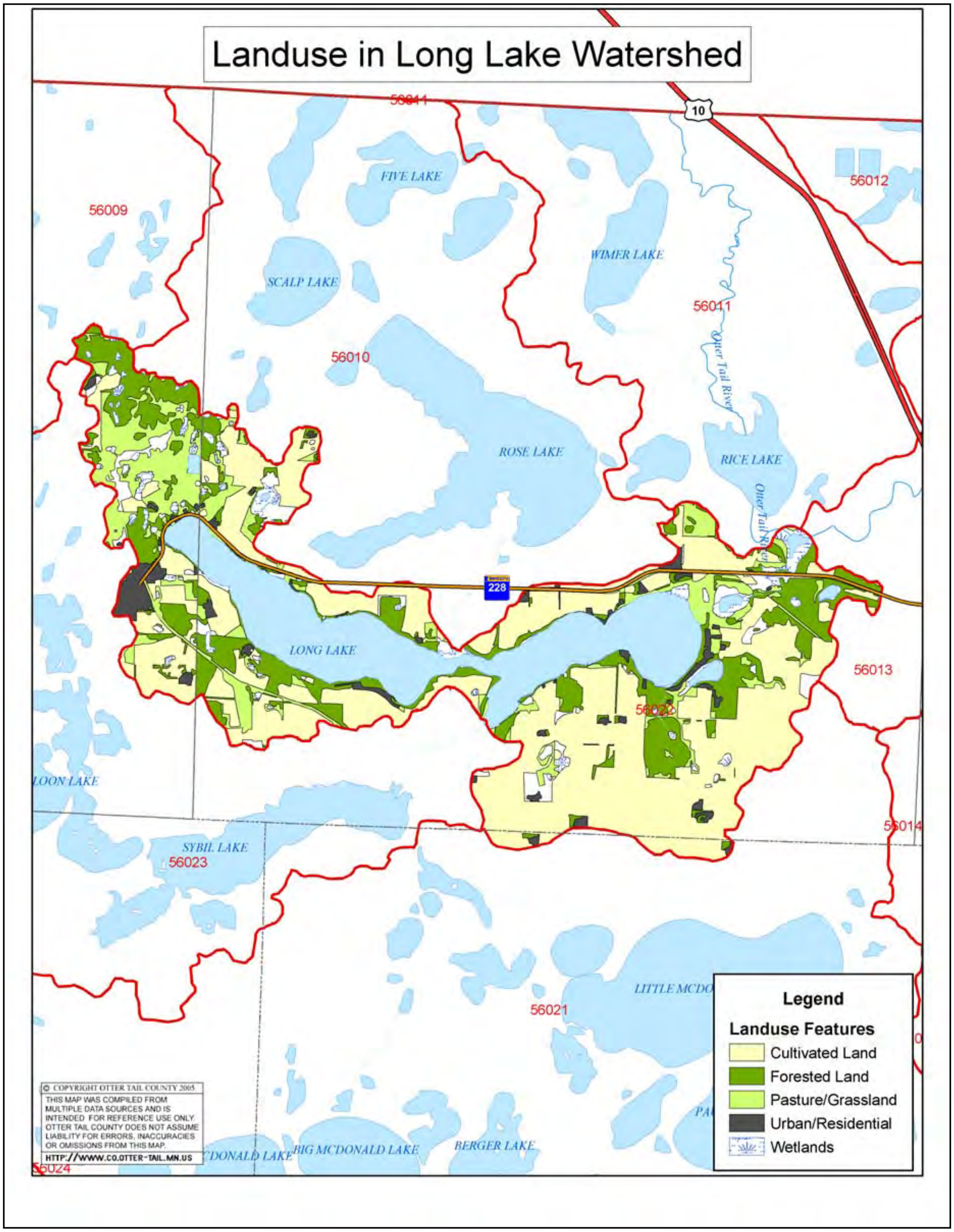


Figure 4. Long Lake Watershed Land Use



Septic System Survey
Minnesota Extension Service recommends pumping every one to three years for a 1,000 gallon tank serving a three-bedroom house and four occupants (assumes year-round use). The importance of septic system maintenance to Long Lake should be emphasized to all lake residents. The Association is encouraged to look into developing a program which encourages or arranges for the periodic pumping of septic tanks. The Association should inform its membership that poor septic system maintenance can lead to the contamination of shallow wells.

Lakeshore residents are encouraged to locate on their property an alternative drain field site. This site should be picked with the necessary setbacks in mind and should be protected for the time when it will be needed in the future when the existing drain field begins to fail. This is especially crucial for small lots where there may only be one good alternative drain field site available. Drain fields typically have a design lifetime of 20 to 30 years. Keep in mind that proper maintenance of the septic tank (regular pumping), protecting the drain field from compaction (keep vehicles and other heavy objects off), and water conservation in the home will all help to extend the useful lifetime of the drain field.

Lake Level
A summary of lake level information was drawn from the MDNR website: Long Lake levels have been monitored since August 4, 1970. The highest recorded level was 1348.8 ft on July 25, 1993; the lowest recorded level was 1346.72 ft on August 4, 1970. The average lake level for the period of record is 1347.9 ft with a range of 2.08 ft. Long Lake's Ordinary High Water (OHW) elevation is established at 1348.3 ft. A summary of records for the most recent ten years shows declining water levels from 1997 to 2003 with a sharper decrease in 1995 when water levels dropped to 1347.18 ft on August 7 (Appendix IV).

RESULTS AND DISCUSSION

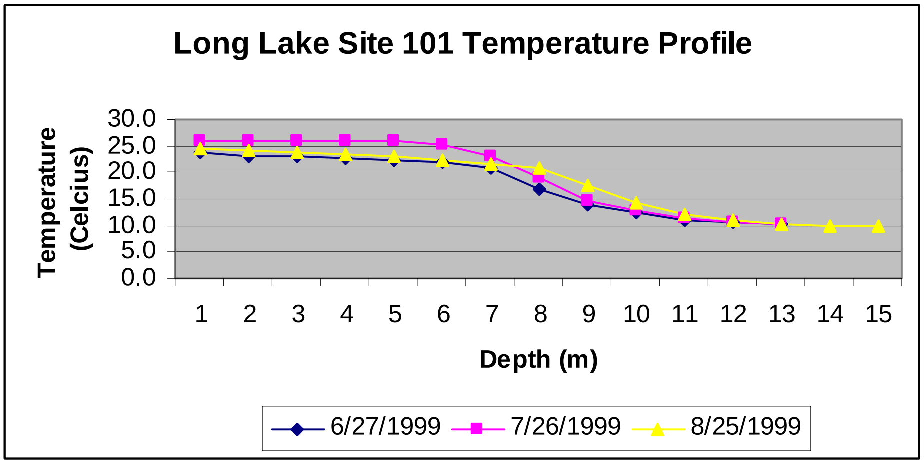
Water quality data was collected on June 27, July 26, August 25, and September 26, 1999. Four sites were used: Sites 101, 102, 103 and 104, orientated from east to west in (Figure 3). Lake surface samples were collected with an integrated sampler, which is a PVC tube 6.6 feet (2 meters) in length with an inside diameter of 1.24 inches (3.2 centimeters).

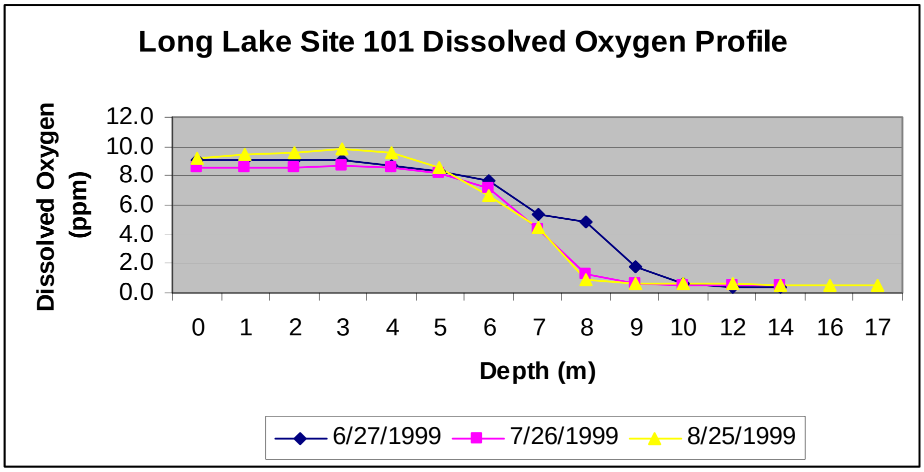
Sampling procedures were employed as described in the MPCA Quality Control Manual. Laboratory analyses were performed by the laboratory of the Minnesota Department of Health using U.S. Environmental Protection Agency (EPA) approved methods. Samples were analyzed for nutrients, color, solids, pH, alkalinity, conductivity, chloride and chlorophyll (Table 2). Temperature and dissolved oxygen profiles and Secchi transparency measurements were also taken. CLMP measurements from previous years were available for comparison. All data is stored in STORET, the EPA'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.

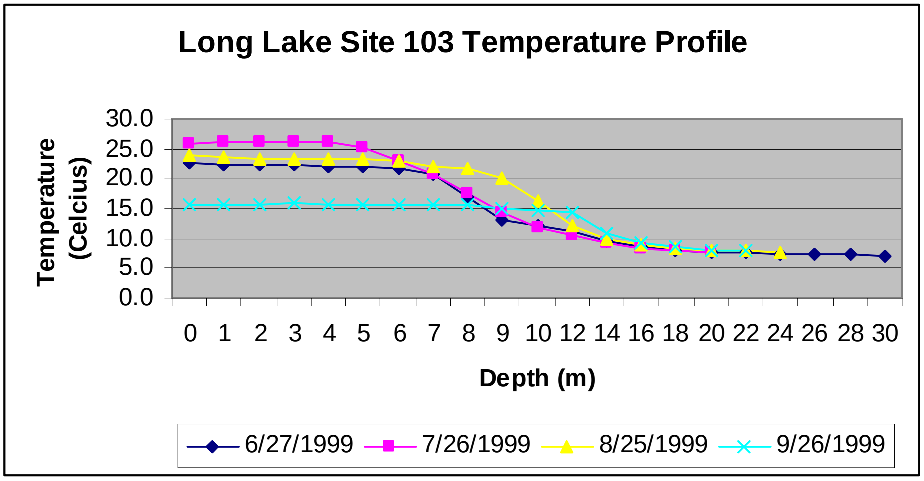
In-lake Conditions: 1999
Dissolved oxygen and temperature profiles were taken at a point near maximum depth at sites 101 and 103. Long Lake was stratified on the June sampling date with the thermocline (zone of greatest change in temperature over a small depth range) between about 8 – 12 meters. Long Lake remained

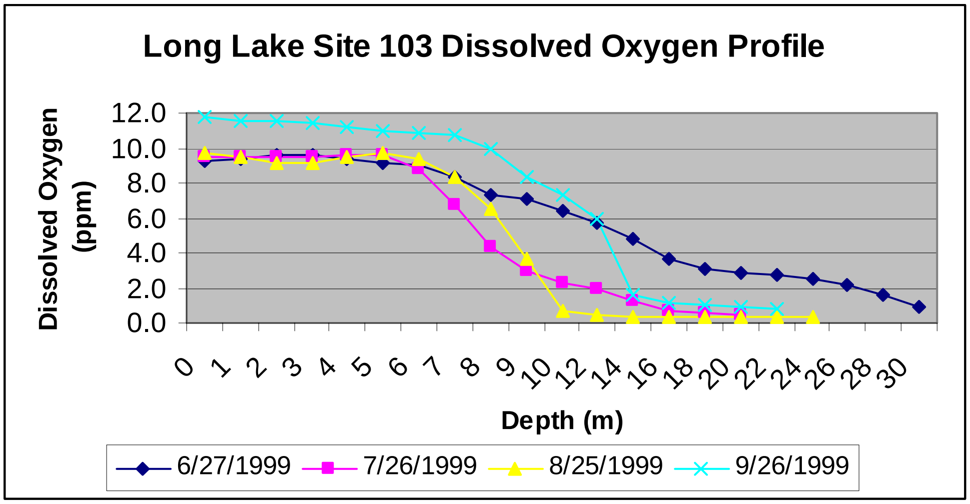
stratified through September. Based on the dissolved oxygen and temperature profiles, Long Lake would be considered dimictic (mixes once in spring and fall).

Figure 5. Long Lake Temperature and Dissolved Oxygen Profiles



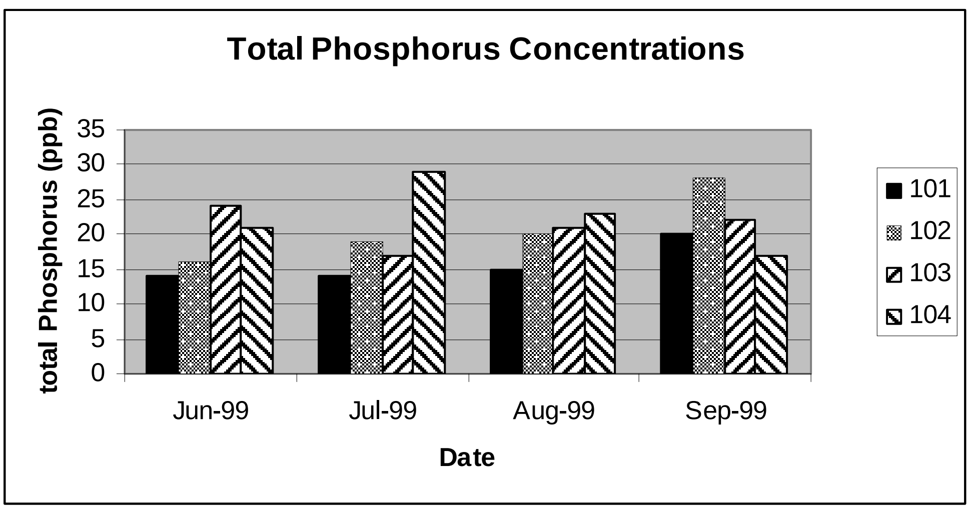






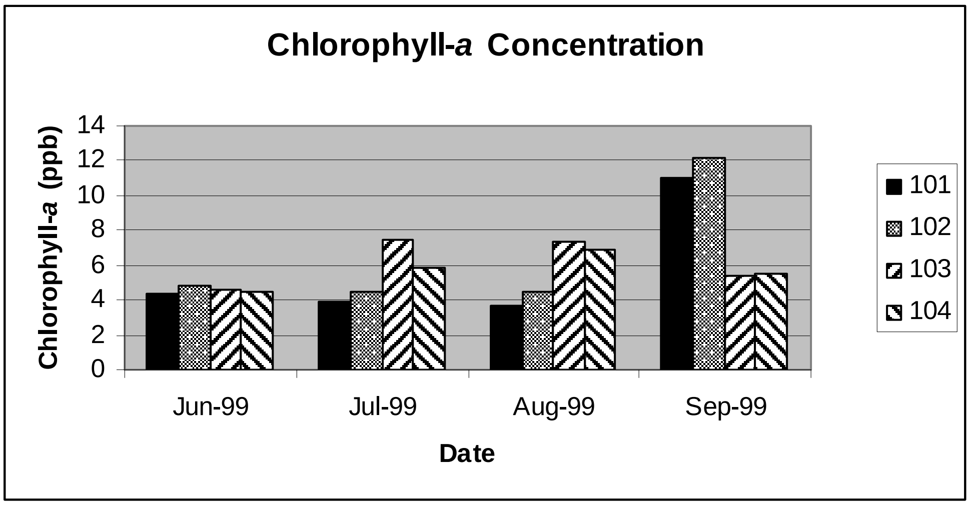
Total phosphorus (TP) concentrations (an important nutrient for plant growth) averaged 20 µg/L (micrograms per liter or parts per billion) in the epilimnion during the summer of 2000. This value is slightly better than the range of concentrations typically found in reference lakes in the North Central Hardwood Forests ecoregion (Figure 6 and Table 2).

Figure 6. Long Lake 1999 Total Phosphorus Concentrations



Chlorophyll-*a* concentrations provide an estimate of the amount of algal production in a lake. During the summer of 2000, chlorophyll-*a* concentrations ranged from 4.4 – 12.2 µg/L with an average of 6.5 µg/L. Concentrations from 10-20 µg/L are frequently perceived as a mild algal bloom, while concentrations greater than 30 µg/L may be perceived as a severe nuisance (Heiskary and Walker, 1988). Both the average and maximum chlorophyll-*a* concentrations for Long Lake are well within the range of values for reference lakes from this ecoregion. The only mild nuisance bloom noted in 1999 would have been in September at sites 101 and 102 (Figure 7).

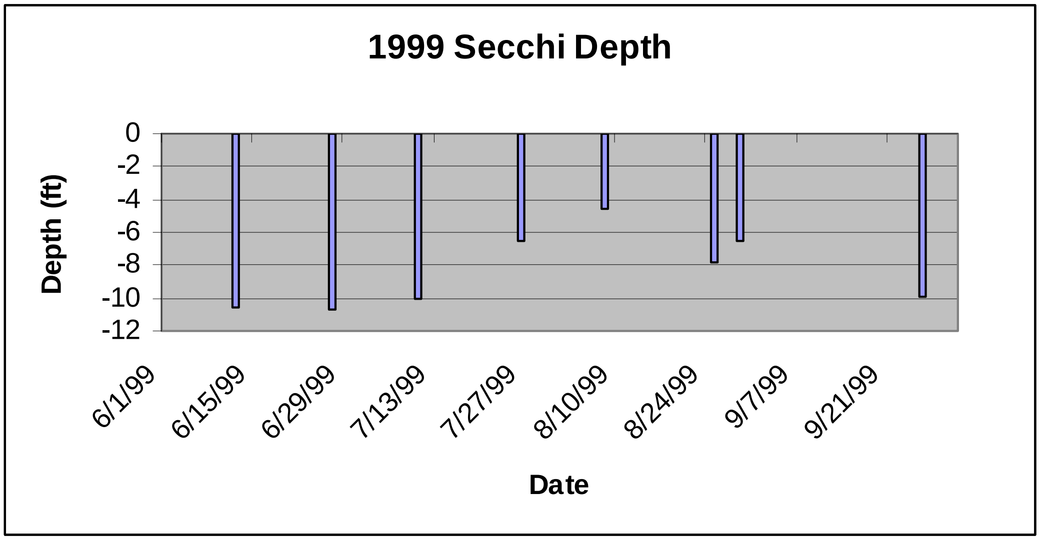
Figure 7. Long Lake 1999 Chlorophyll-*a* Concentrations



Secchi disk transparency is generally a function of the amount of algae in the water. Suspended sediments or color due to dissolved organics may also reduce water transparency. Color averaged 5 Pt-Co Units indicating a low coloration. Total suspended solids averaged 2.0 mg/L over the summer. The total suspended solids value is comparable to the reference lakes in this region. These levels of color and total suspended solids should not appreciably limit water transparency in Long Lake. Secchi transparency ranged from 5.5 – 10.5 feet and averaged 7.9 feet during the summer of 1999 (Figure 8). These transparency measures are well within the typical range of values for reference lakes in this ecoregion (Table 2). Long term monitoring of Secchi transparency at a consistent site will yield the best data for performing water quality trend analysis.

The change in the transparency of Long Lake over the course of the summer is fairly typical for mesotrophic lakes in Minnesota. Transparency is high in the spring when the water is cool and algae populations are low. Frequently, zooplankton (small crustaceans which feed on algae) populations are high at this time of year also, but decline later in the due to predation by young fish. As the summer goes on and the waters warm, the algae make use of available nutrients. As algae become more abundant, the transparency declines. The decrease in the abundance of zooplankton may allow for further increases in the amount of algae. Later in the summer, surface blooms of algae may also appear. On a day-to-day basis, transparency may differ between the sites, but the overall pattern was consistent among the four sites.

Figure 8. Long Lake 1999 Secchi Transparency



One means to evaluate the **trophic status** of a lake and to interpret the relationship between total phosphorus, chlorophyll-*a* and Secchi transparency is Carlson's Trophic State Index (TSI, Carlson 1977). This index was developed from the interrelationships of summer Secchi transparency and the concentrations of surface water chlorophyll a and total phosphorus. TSI values are calculated as follows:

Total phosphorus TSI (TSIP) = 14.42 1n (TP) + 4.15
Chlorophyll-*a* TSI (TSIC) = 9.91 1n (Chl-*a*) + 30.6
Secchi disk TSI (TSIS) = 60 - 14.41 1n (SD)

TP and chlorophyll-*a* are in µg/L and Secchi transparency is in meters. TSI values range from 0 (ultra-oligotrophic) to 100 (hypereutrophic). In this index, each increase of 10 units represents a doubling of algal biomass. Average values for the trophic variables in Long Lake and respective TSI's are presented in Table 2. Based on these values, Long Lake is considered mesotrophic in condition (Figure 12). The individual TSI values agree fairly well and therefore Secchi transparency should be a good predictor for overall water quality for Long Lake.

TABLE 2: Average Summer Water Quality and Trophic Status Indicators: Long Lake, based on 1999 Epilimnetic Data.

Parameter	Mean	Typical Range for NCHF Ecoregion[1]
Total Phosphorus µg/L	**20.0**	**23 – 50**
Chlorophyll-*a* (µg/L) Mean **Chlorophyll-*a* (µg/L) Maximum**	**6.0** **12.2**	**5 – 22** **7 – 37**
Secchi disk (feet)	**8.9**	**4.9 – 10.5**
Total Kjeldahl Nitrogen (mg/l)	**0.6**	**< 0.60 – 1.2**
Alkalinity (mg/ l)	**157**	**75 – 150**
Color (Pt-Co Units)	**5.0**	**10 – 20**
Chloride (mg/l)	**9.4**	**4 – 10**
Total Suspended Solids (mg/l)	**3.6**	**2 – 6**
Total Suspended Inorganic Solids	**2.4**	**1 – 2**
Conductivity (µmhos/cm)	**--**	**300 – 400**
TN:TP Ratio	**30:1**	**25:0 – 33 :1**

Carlson's Trophic Status Indicators: 1999

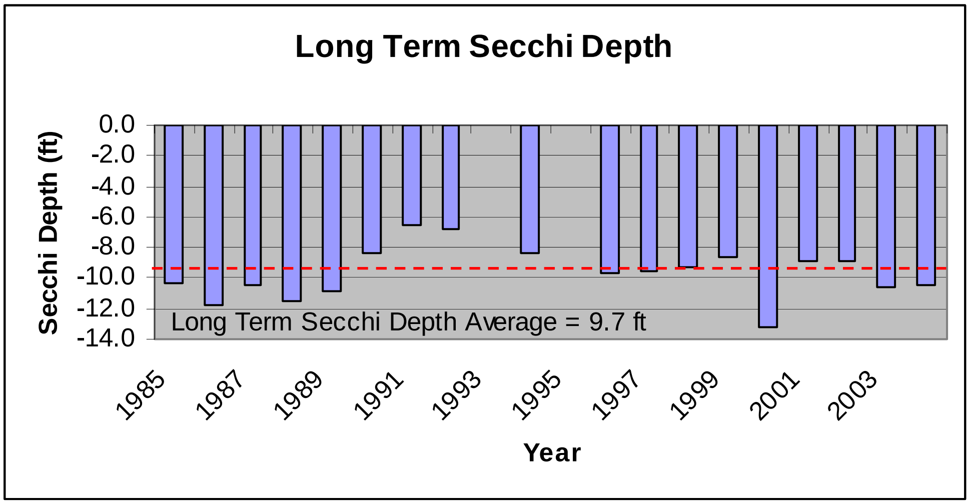
PARAMETER	***TSI LABEL***	***TSI VALUE***
Total Phosphorus	TSIP	47
Chlorophyll-*a*	TSIC	48
Secchi	TSIS	46
MEAN	***TSI***	***47***

[1]North Central Hardwood Forests as derived from Heiskary and Wilson (1990).
[2]Relative to assessed lakes in North Central Hardwood Forests Ecoregion, whereby the lower the trophic state (TSI), the higher the percentile ranking (100 percent level implies lowest TP or deepest Secchi disk for that ecoregion).

Water Quality Trends

Eighteen years of Secchi data are available for determining trends in the quality of Long Lake. The majority of the data available were collected as part of the Citizen Lake-Monitoring Program. These data do not reveal a significant trend but do indicate that summer-mean transparency varies between about 6.6 feet and 13.1 feet (Figure 9). The long-term mean transparency is 9.7 feet. The year-to-year fluctuations in transparency may be related to differences in the amount of precipitation, runoff, and groundwater which enter the lake. Due to the relatively low in-lake phosphorus levels, year to year variability can be caused by relatively small differences in annual nutrient loading and small increases in algal biomass.

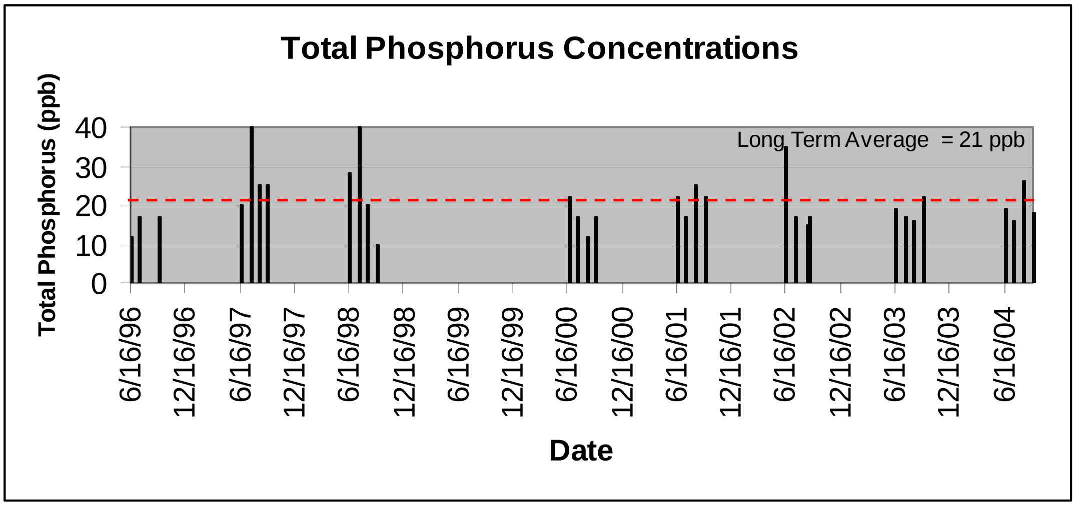
FIGURE 9. Long Lake Long-Term Secchi Transparency



As part of the larger Otter Tail County Coalition of Lake Association (COLA) monitoring, Long Lake was sampled from 1996 to 2004 (with no COLA data collected in 1999 when the LAP study was underway). Total phosphorus, chlorophyll-*a*, and Secchi transparency have been collected monthly from May to September for this period of record (data used for analysis includes June – September only). The following graphs depict the average annual concentrations of both phosphorus and chlorophyll-*a*, as well as the long term average over the period of record. Secchi data was incorporated into long term CLMP Secchi data in the previous graph.

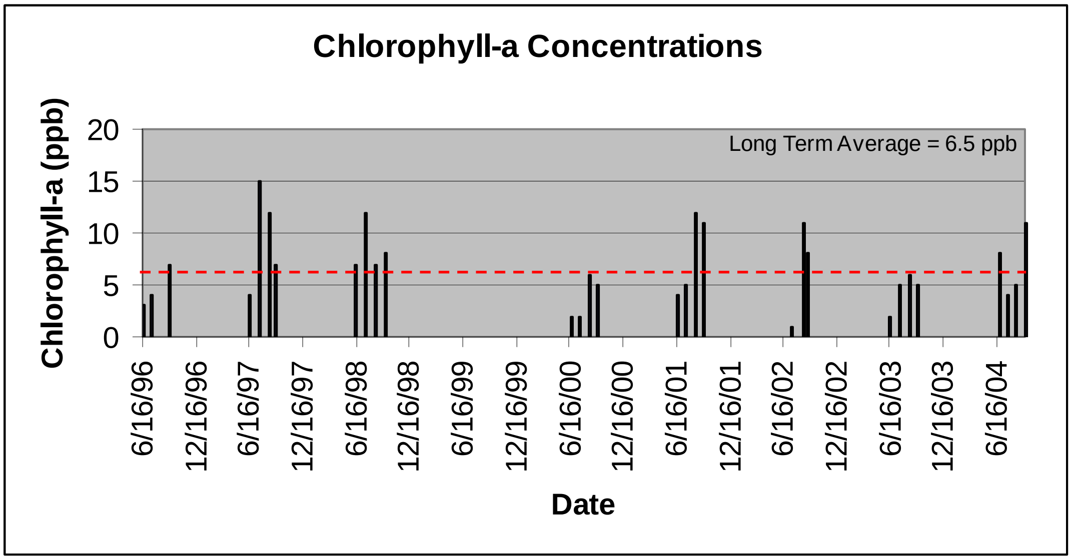
Total Phosphorus surface samples have been collected at site 202 for 8 years. Total phosphorus readings range from a low of 10 µg/L in September of 1998 to a high of 40 µg/L in July of 1997 and 1998. The long term average total phosphorus concentration, calculated over the period of record from samples collected between June and September, is 21 µg/L (Figure 10).

FIGURE 10. Long Lake Long-Term Total Phosphorus



Chlorophyll-*a* was also sampled by COLA monitoring from 1996 to 2004 at site 202. Concentrations ranged from a low of <1 µg/L in June of 2002 to a high of 15 µg/L in July of 1997. The long term average concentration was 6.5 µg/L (Figure 11).

FIGURE 11. Long Lake Long-Term Chlorophyll-*a*



Modeling Summary

Numerous complex mathematical 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 the lake. To analyze the 1999 quality of Long Lake, the model MINLEAP (Wilson 1988) was used. "Minnesota Lake Eutrophication Analysis Procedures" (MINLEAP) was developed by MPCA staff based on an analysis of data collected from the ecoregion reference lakes. It is intended to be used as a screening tool for estimating lake conditions with minimal input data including: lake area and mean depth, watershed area, and observed water quality data. The model is described in greater detail in Wilson and Walker (1988).

No actual measure of water flow into or out of the lake was made. Rather, ecoregion-specific runoff coefficients, precipitation and evaporation data, and nutrient export coefficients were used in this modeling.

Using the total watershed (minus lake area) as noted in Table 1, the **MINLEAP model** predicts a summer-mean total phosphorus (TP) concentration of 40 μg/L for Long Lake (Table 3). This value is significantly higher than the observed summer-mean TP concentration (20 μg/L) for 1999. However, MINLEAP does not take into account the large reduction in phosphorus loading that will result from tributaries first flowing through Rose and Sybil lakes in the watershed. Thus estimated P-loading rate is overestimated. Similar results are found with both Secchi depth and chlorophyll-*a* concentrations (1.6 meters and 14.3 μg/L, respectively). MINLEAP overestimated both parameters, with elevated chlorophyll-a levels and decreased Secchi depth.

Because of this, three alternate scenarios were run to try to “bracket” the actual P loading to the lake. In the first we used only the immediate watershed area. In the second, we used the total watershed area, which more accurately depicts the flow of water through Long Lake. In the third, we used the total watershed (as in the second case) but reduced the “stream inflow TP” to 50 μg/L, to account for the significant retention of phosphorus in Rose and Sybil Lakes (Table 3).

Based on the calibrated MINLEAP model scenario, Long Lake retains about 65 percent of the P which enters the lake. Water residence time (time it would take to fill the lake if it were empty) is on the order of three years. The model predicts a total phosphorus concentration of 21 μg/L, a chlorophyll-*a* concentration of 5.5 μg/L and a Secchi transparency of 2.8 meters. All of these values are very close to the observed values from the 1999 sampling season (Table 3).

TABLE 3. MINLEAP Model Results

Parameter	Observed 1999	Immediate Watershed MINLEAP	Total Watershed MINLEAP	Calibrated Total Watershed MINLEAP
TP (µg/L)	20 ± 1.1	23 ± 9	40 ± 14	21 ± 7
chl-*a* (µg/L)	6 ± 0.6	6.4 ± 4.5	14.3 ± 9.1	5.5 ± 3.3
% chl-*a* >20 µg/L	--	0	18	0
% chl-*a* >30 µg/L	--	0	4	0
Secchi (meters)	2.7 ± 0.1	2.6 ± 1.2	1.6 ± 0.7	2.8 ± 1.1
P-loading rate (kg/yr)	--	633	2349	896
% P retention	--	88	75	65
P inflow conc. (µg/L)	--	184	156	60
water load (m/yr)	--	.67	2.92	2.92
outflow volume (hm^3/yr)	--	3.44	15.04	15.04
"background P"	--	19.8	19.8	19.8
residence time (years)	--	12.7	2.9	2.9

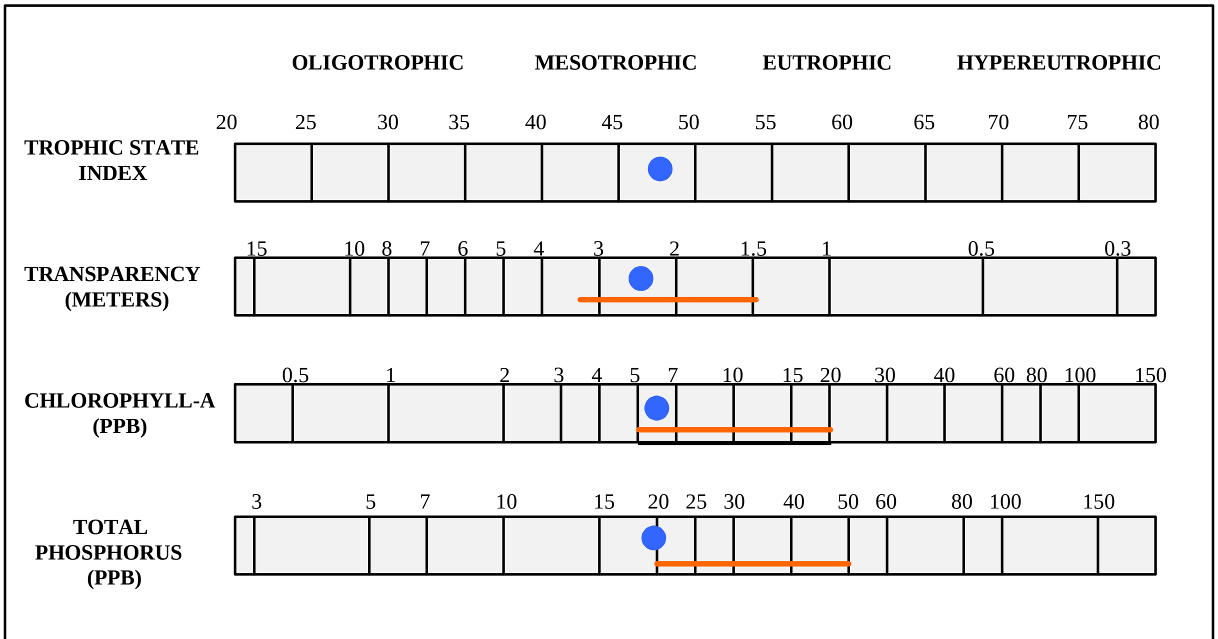
Goal Setting

The phosphorus criteria value for lakes in the North Central Hardwood Forests ecoregion is less than 40 µg/L for support of swimmable use. At or below 30 µg/L, "nuisance algal blooms" (chlorophyll-*a* > 20 µg/L) should occur less than 10 percent of the summer and transparency should remain at or above 3 meters over 85 percent of the summer.

For Long Lake, it would be desirable to keep in-lake P concentrations at or below levels observed in 1999. Based on data from 1996 – 2004, mean total phosphorus ranged from 15-28 µg/L and mean chlorophyll-*a* ranged from 4-10 µg/L, with the maximum chlorophyll-*a* remaining below 20 µg/L. However, were TP to increase to 40 µg/L, the frequency of nuisance blooms would go from 0% of the summer to about 20% (Table 3). Should in-lake P concentrations increase, it is likely that the frequency of nuisance algal blooms would increase and transparency would decrease. Maintaining a summer-mean P concentration of about 20 µg/L or lower over the long term may require that P-loading to the lake be reduced. Important considerations include land use practices in the shoreland and watershed area of the lake. A more comprehensive review of land use practices in the watershed may reveal opportunities for implementing BMPs in the watershed and reducing P-loading to the lake.

FIGURE 12. Carlson's Trophic State Index for Long Lake, Otter Tail County
R.E. Carlson

TSI < 30	Classical Oligotrophy: Clear water, oxygen throughout the year in the 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 hypereutrophic.
TSI > 80	Algal scums, summer fish kills, few macrophytes, dominance of rough fish.



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NCHF Ecoregion Range: Long Lake:

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Appendix

I. MPCA Water Quality Data
II. Precipitation Maps
III. Fisheries Status
IV. Lake Level
V. MPCA Secchi Depth and User Perceptions
VI. Water Quality Data from Otter Tail COLA

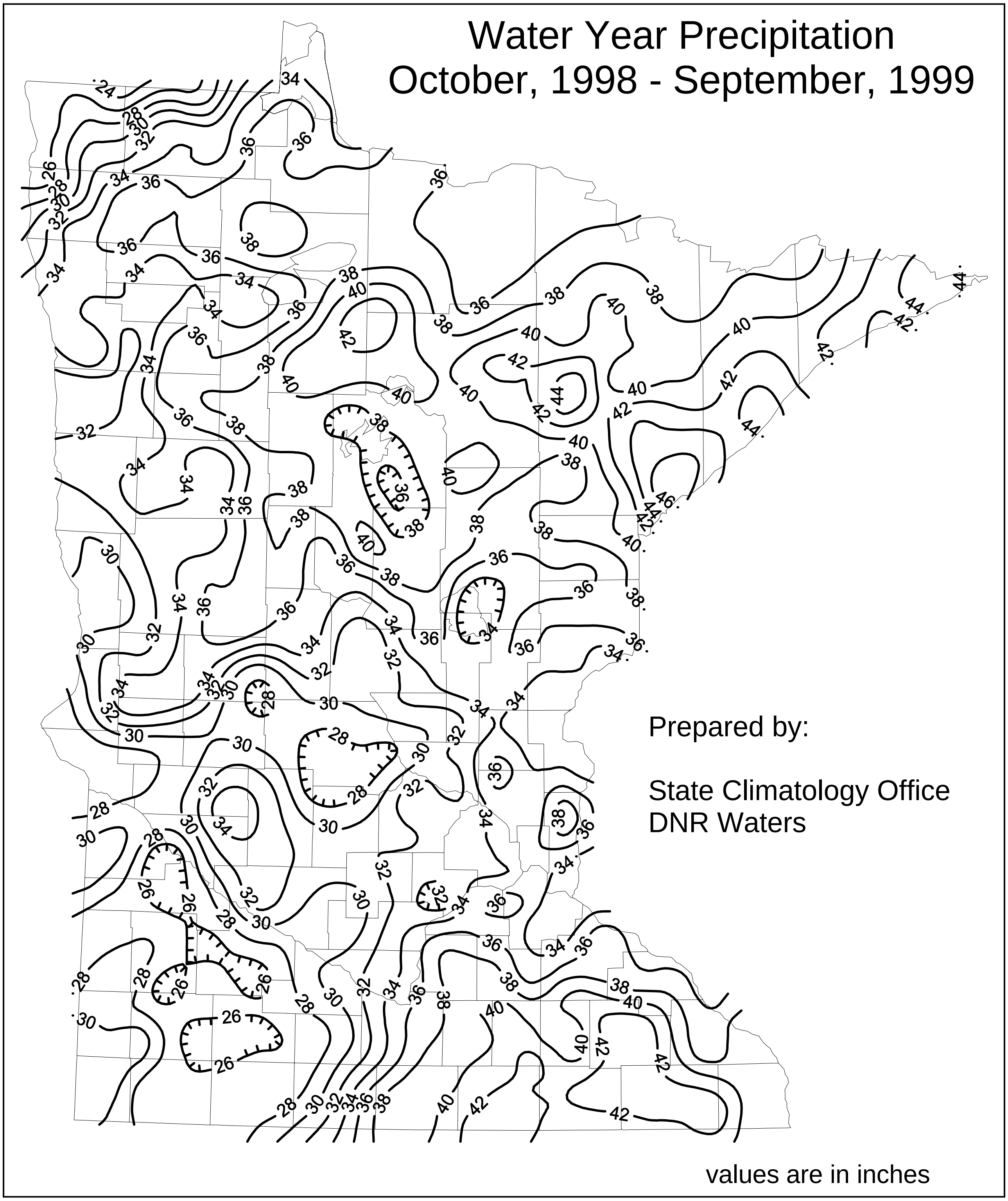
Appendix I. Water Quality Data

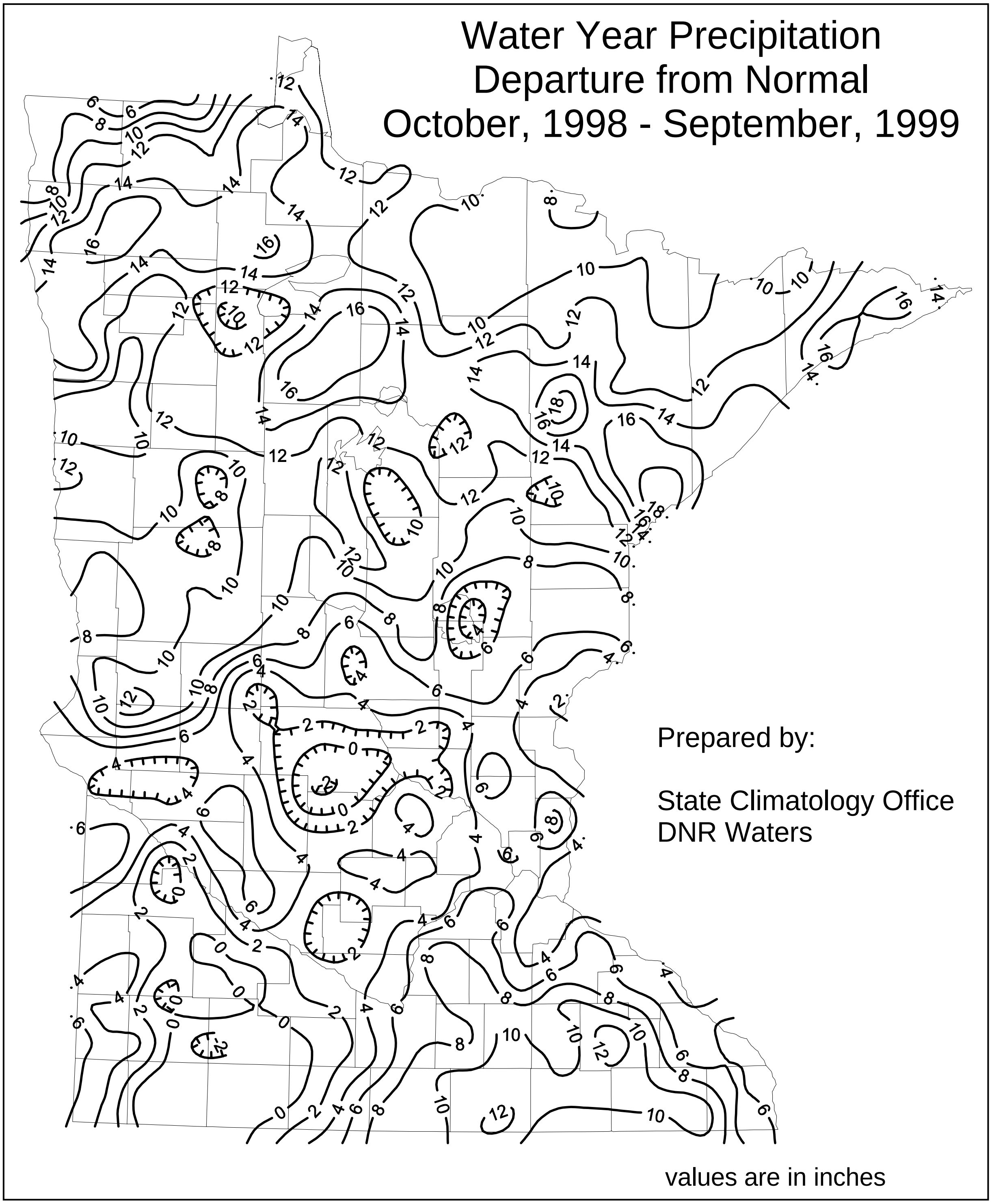
Date	Site	Color	Alkalinity	TSS	TKN	TP (ppb)	Chloride	Chl-a (ppb)	Pheo	Secchi (ft)	Secchi (m)
6/27/1999	101					14		4.37	0.41	10.5	3.2
6/27/1999	102					16		4.84	0.83	10	3.0
6/27/1999	103					24		4.63	0.21	11.5	3.5
6/27/1999	104					21		4.42	0.50	11	3.4
7/26/1999	101					14		3.89	0.21	7.5	2.3
7/26/1999	102					19		4.49	0.21	6.5	2.0
7/26/1999	103	5	150	5.2	0.590	17	17.0	7.48	0.21	6	1.8
7/26/1999	104					29		5.87	0.21	6	1.8
8/25/1999	101					15		3.68	0.32	8.5	2.6
8/25/1999	102					20		4.49	0.47	8.5	2.6
8/25/1999	103	5	150	3.6	0.680	21	6.0	7.31	0.32	7.5	2.3
8/25/1999	104					23		6.92	0.32	7	2.1
9/26/1999	101					20		11.00	0.84	9	2.7
9/26/1999	102					28		12.20	1.32	8.5	2.6
9/26/1999	103	5	170	2.0	0.530	22	5.2	5.43	0.75	11	3.4
9/26/1999	104					17		5.56	0.59	11	3.4
	Count	3	3	3	3	16	3	16	16	16	16
	Minimum	5	150	2	0.530	14	5.2	3.68	0.21	6	1.8
	Maximum	5	170	5.2	0.680	29	17	12.20	1.32	11.5	3.5
	Mean	5	157	3.6	0.600	20	9.4	6.04	0.48	8.75	2.7
	Standard Error	0	6.7	0.9	0.0	1.1	3.8	0.6	0.1	0.5	0.1
	Standard Deviation	0	11.5	1.6	0.1	4.5	6.6	2.5	0.3	1.9	0.6

STATION	DATETIME	COLLBY	TP (ppb)
Inlet/Outlet Sampling			
North Inlet	6/27/1999		17
Outlet	6/27/1999		24
North Inlet	7/26/1999		20
Outlet	7/26/1999		140
North Inlet	8/25/1999		39
South Inlet	8/25/1999		12
Outlet	8/25/1999		15
North Inlet	9/28/1999		14
South Inlet	9/28/1999		12
Outlet	9/28/1999		20

Year	TP mean	# TP	TP Min	TP Max	Std Error TP	Chl –*a* mean	# Chl-*a*	Chl-*a* Min	Chl-*a* Max	Std Error Chl-*a*	SDF Mean	# SDF	SDF Min	SDF Max	Std Error SDF
1985											3.1	9	2.0	4.1	0.3
1986											3.6	7	2.0	5.2	0.5
1987											3.2	3	2.1	4.0	0.5
1988											3.5	1	3.5	3.5	
1989											3.3	11	2.6	4.4	0.2
1990											2.6	9	2.0	3.2	0.2
1991											2.0	7	1.7	2.4	0.1
1992											2.1	3	1.7	2.6	0.3
1994											2.6	8	1.8	3.2	0.2
1996	15	3	12	17	2						2.9	3	2.4	3.7	0.4
1997	30	4	20	40	4						2.3	4	2.1	4.6	0.6
1998	25	4	10	40	6	8.5	4	7	12	1.2	2.8	9	1.4	4.6	0.4
1999	20	15	14	28	1	6.6	8	4.4	12.2	1	2.4	4	1.4	3.2	0.4
2000	17	4	12	22	2	3.8	4	2	6	1	4.0	9	2.0	4.9	0.5
2001											2.7	9	1.4	3.7	0.3
2002											2.5	7	2.0	3.5	0.2
2003											3.0	10	1.8	4.6	0.3

Appendix II. Precipitation Maps




Water Year Precipitation
Departure from Normal
October, 1998 - September, 1999
Prepared by:
State Climatology Office
DNR Waters
values are in inches

Appendix III. Fisheries Status

From http://www.dnr.state.mn.us/lakefind/showreport.html?downum=56038800

Status of the Fishery (as of 06/16/2003)

Long Lake is a 1,273 lake located in north-central Otter Tail County. The southwest shoreline of the lake abuts the city of Vergas, MN. Long Lake is composed of two distinct basins. The west basin is characteristic of an oligotrophic lake (i.e., deep and unfertile) while the east basin is characteristic of a mesotrophic lake (i.e., moderately deep and fertile). Several intermittent inlets are located along the north and south shorelines of the lake. An outlet to the Otter Tail River is located along the east shoreline of the lake. The inlets and outlet are not navigable by boat. The immediate watershed is composed primarily of agricultural land interspersed with hardwood woodlots. The maximum depth of Long Lake is 128 feet; however, 42% of the lake is less than 15 feet in depth. Secchi disk readings have ranged from 8.0 to 14.0 feet. Periodic plankton/algae blooms throughout the summer months can influence secchi disk readings. Long Lake is included in lake class 22 of the MNDNR lake classification scheme. Residential development is scattered around the entire shoreline of the lake and composes approximately 30% of the shoreline use. The development consists of homes, cottages, and resorts. In reference to the 1995 lake resurvey, there are approximately 96 homes/cottages and four resorts located on Long Lake. Approximately 40% of the shoreline remains undeveloped mixed hardwoods. A DNR owned concrete public water access is located off of Minnesota State Highway 228 along the northwest shoreline of the lake. A city park is located along the west shoreline of the lake. A disabled accessible fishing pier is located in the park and is available for public use. The shoal water substrates consist primarily of sand and gravel. Large stands of hardstem bulrush and common cattail are prevalent around the shoreline of the lake. Emergent aquatic plants such as bulrush and cattail provide valuable fish and wildlife habitat, and are critical for maintaining good water quality. They protect shorelines and lake bottoms, and can actually absorb and break down polluting chemicals. Emergent plants provide spawning areas for fish such as northern pike, largemouth bass, and panfish. They also serve as important nursery areas for all species of fish. Because of their ecological value, emergent plants may not be removed without a DNR permit. Long Lake can be ecologically classified as a bass-panfish-walleye type of lake and this is reflected in the assemblage of the fish community. Walleye, northern pike, largemouth bass, and bluegill are the dominant gamefish species in the fish community of Long Lake. The prolificacy of these species can be attributed to the abundance of suitable spawning habitat that is available. The northern pike test-net catch rate exceeded the upper limit of the normal range for class 22 lakes. Age data indicate that northern pike reproduction rates are consistently good. Northern pike ranged in length from 16.8 to 32.1 inches with an average length and weight of 21.6 inches and 2.3 pounds. Pike attain an average length of 20.3 inches at four years of age. Long Lake is a popular lake with largemouth bass anglers. Summer test-net indices are not reliable indicators of largemouth bass abundance or size structure; however, bass were sampled that ranged in length from 8.8 to 16.2 inches. Angler reports from largemouth bass anglers have been positive. The bluegill test-net catch rate exceeded the upper limit of the normal range for class 22 lakes which is consistent with previous surveys. Age data indicate that the 1997 year class is very strong. Eighteen percent of the bluegills were 7.0 inches or greater in length. Bluegills attain an average length of 6.7 inches at seven years of age. Walleye is a primary management specie in this lake.

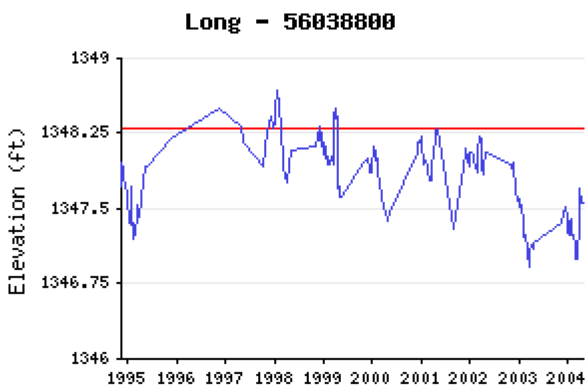
The walleye test-net catch rate declined after increasing in five successive surveys. Walleye in this assessment ranged in length from 9.5 to 27.6 inches with an average length and weight of 16.3 inches and 1.8 pounds. Data from recent test-netting assessments indicate that walleye natural reproduction can be substantial in some years. A biennial fingerling stocking plan was initiated in 2000 and will be evaluated in the future series of lake surveys to determine if this stocking sequence and natural reproduction can maintain the walleye population at or above management goals. Walleye reach an average length of 13.5 inches at four years of age. The DNR does not stock any fish species other than walleye in Long Lake. The other species present are able to sustain their levels at or above management goals without stocking. This is an indication of the excellent water quality and fish habitat that is available. To maintain the excellent fishing that this lake has to offer, it is imperative to preserve the water quality and fish habitat. Anglers can also maintain the quality of fishing by practicing selective harvest. Selective harvest encourages the release of medium to large-size fish while allowing the harvest of the more abundant smaller fish for table fare. Releasing the medium to large fish will ensure that the lake will have enough spawning age fish on an annual basis and will provide anglers with more opportunities to catch large fish in the future.

Appendix IV. Lake Level

Lake water level report

Lake Name: Long **County: Otter Tail**

Period of record: 08/04/1970 to 10/10/2004
# of readings: 275
Highest recorded: 1348.8 ft (07/25/1993)
Lowest recorded: 1346.72 ft (08/04/1970)
Recorded range: 2.08 ft
Average water level: 1347.86 ft
Last reading: 1347.56 ft (10/10/2004)
OHW elevation: 1348.3 ft
Datum: 1912 (ft)



Appendix V.
Secchi Depth and Physical Condition / Recreational Suitability Rankings

56-0388 Long Lake				
Date	**Site**	**Secchi (ft)**	**Physical Condition**	**Recreational Suitability**
6/27/99	**101**	**10.5**	**2**	**2**
6/27/99	**102**	**10**	**2**	**2**
6/27/99	**103**	**11.5**	**2**	**2**
6/27/99	**104**	**11**	**2**	**2**
7/26/99	**101**	**7.5**	**2**	**2**
7/26/99	**102**	**6.5**	**2**	**2**
7/26/99	**103**	**6**	**2**	**2**
7/26/99	**104**	**6**	**2**	**2**
8/25/99	**101**	**8.5**	**2**	**2**
8/25/99	**102**	**8.5**	**2**	**2**
8/25/99	**103**	**7.5**	**2**	**2**
8/25/99	**104**	**7**	**2**	**2**
9/26/99	**101**	**9**	**2**	**2**
9/26/99	**102**	**8.5**	**2**	**2**
9/26/99	**103**	**11**	**2**	**2**
9/26/99	**104**	**11**	**2**	**2**

Number	**Physical Condition**	**Recreational Suitability**
1	Crystal clear water	Beautiful, could NOT be better
2	Not quite crystal clear – a little algae present/visible	Very minor aesthetic problems; excellent for swimming, boating
3	Definite algae green, yellow, or brown color apparent	Swimming and aesthetic enjoyment slightly impaired because of algae levels
4	High algal levels with limited clarity and/or mild odor apparent	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	Severely high algae levels with one or more of the following: massive floating scums on the lake or washed up on shore, strong, foul odor, and/or fish kill	Swimming and aesthetic enjoyment of the lake nearly impossible because of algae levels

Appendix VI. Water Quality Data from Otter Tail COLA
RMB Environmental Laboratories, Inc
(http://www.rmbel.info)

Long Lake (56-0388)
Site 202

Date	T.P. (ug/l)	Chl – a (ug/l)	Secchi (feet)
06/16/96	12	3	12
07/14/96	17	4	9
09/15/96	17	7	8
06/16/97	20	4	15
07/20/97	40	15	8
08/18/97	25	12	7
09/14/97	25	7	8
06/14/98	28	7	14.5
07/19/98	40	12	5.5
08/16/98	20	7	5
09/20/98	10	8	12
06/18/00	22	2	20
07/16/00	17	2	20
08/20/00	12	6	10
09/18/00	17	5	16
06/17/01	22	4	15.1
07/14/01	17	5	10.5
08/19/01	25	12	5.5
09/16/01	22	11	7
06/16/02	35	< 1	15
07/14/02	17	1	8
08/23/02	15	11	8.5
09/2/02	17	8	8
06/16/03	19	2	19
07/20/03	17	5	10
08/17/03	16	6	6
09/15/03	22	5	12
06/20/04	19	8	13
07/18/04	16	4	9.5
08/15/04	26	5	12
09/19/04	18	11	10.5