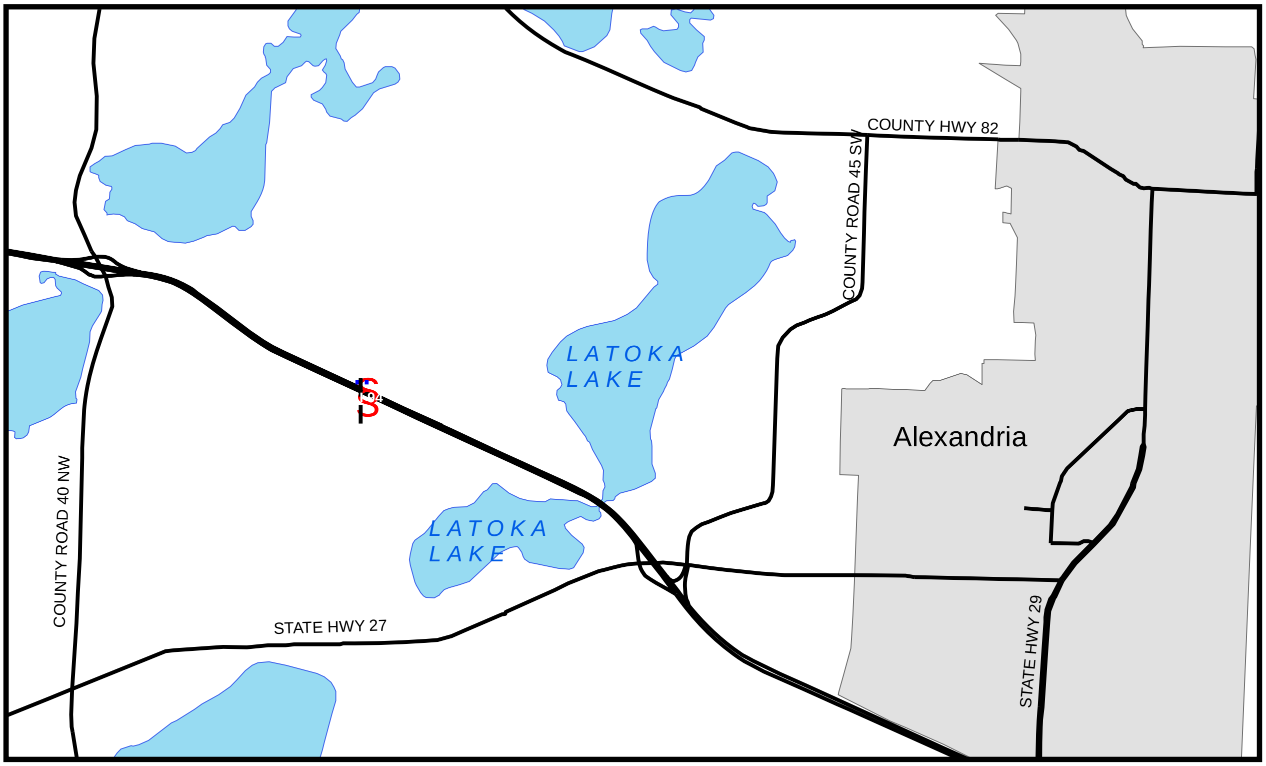
Lake Latoka Status and Trend Update Through the Citizen Lake-Monitoring Program (CLMP+):

Advanced Volunteer Lake Monitoring

Douglas County



Minnesota Pollution Control Agency

January 2006

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Lake Latoka Status and Trend Update Through the Citizen Lake-Monitoring Program (CLMP+):
Advanced Volunteer Lake Monitoring
Douglas County

Lake Latoka (North Bay) (21-0106-01)
Lake Latoka (South Bay) (21-0106-01)

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Lake Latoka Status and Trend Update Through the Citizen Lake-Monitoring Program (CLMP+): Advanced Volunteer Lake Monitoring Douglas County

Part 1: Program History and Background Information on Minnesota Lakes

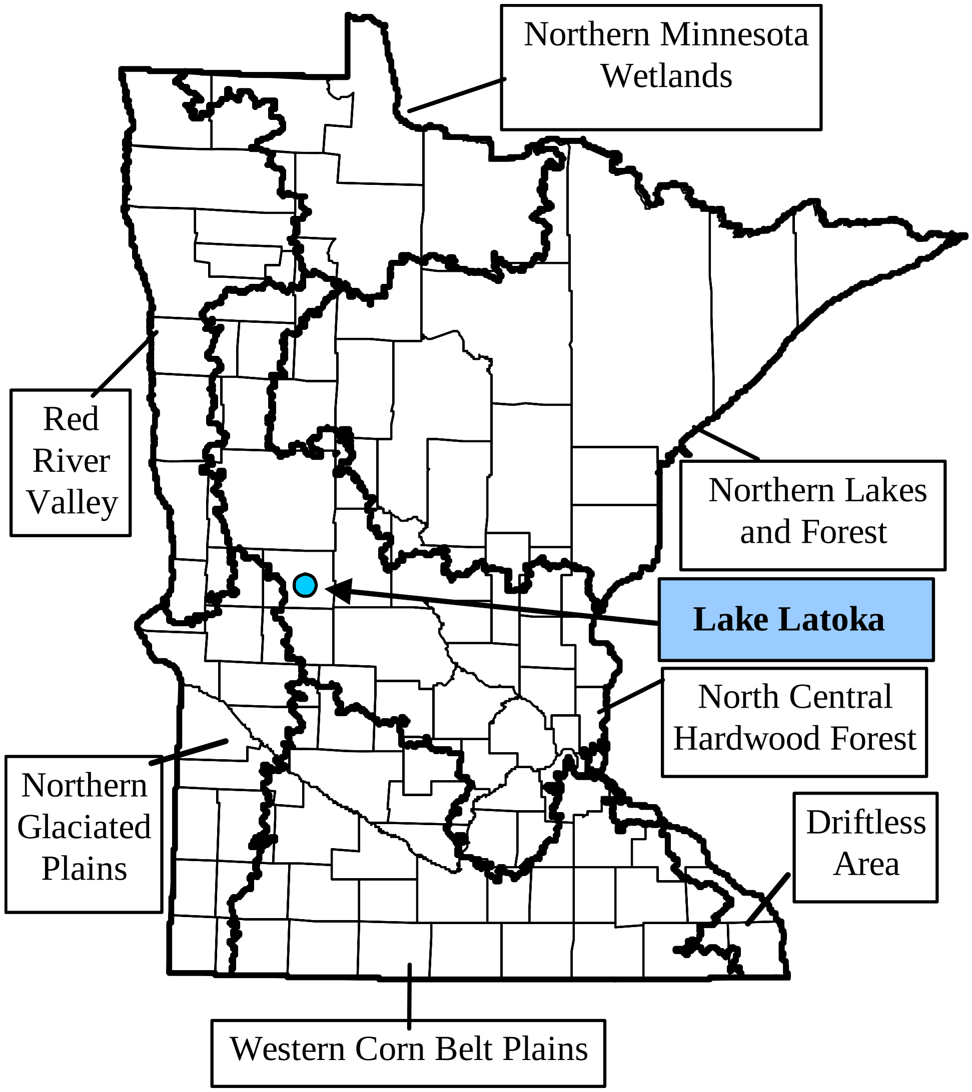
Minnesota's Citizen Lake-Monitoring Program (CLMP) is the largest and oldest volunteer lake-monitoring program in the country. Volunteers in the CLMP currently use a Secchi disk to measure the clarity on hundreds of Minnesota's lakes. The expanded program, including the collection of water chemistry samples for analysis along with Secchi transparency collection, was conducted in several counties. A total of sixteen lakes were selected for monitoring in 2005 by volunteer lake monitors. These lakes were: Latoka, Lobster and Mary Lakes (Douglas County); Big Kandiyohi, Diamond, Long, and Wakanda Lakes (Kandiyohi County); Blueberry, Duck, Jim-Cook, Lower Twin, Morgan, Upper Twin Lakes (Hubbard/Wadena Counties); Bass, Howard, and Pleasant Lakes (Wright County). Spirit and Stocking Lakes (Wadena County) were also sampled by volunteer lake monitors through the County. The data from these two additional lakes was incorporated in the 2005 Wadena County CLMP+ report. All equipment and analytical costs for the samples were provided for and paid by the Minnesota Pollution Control Agency (MPCA). *Note: Only data from Lake Latoka will be discussed in this update report.*

Volunteers on these lakes collected water chemistry samples and temperature profiles twice per month along with their weekly Secchi transparency readings. After sampling, the volunteers dropped off their samples at a predetermined location within their county. Jerry Haggenmiller and Kory Kosek, Douglas County Soil and Water Conservation District (SWCD), helped plan and coordinate the sample drop-off/pick up schedule for the samples in Douglas County. Special thanks to the volunteers on Lake Latoka who helped make this project a success: Rich & Marlene Braun and Rich Lorsung. MPCA staff and volunteer monitors collected quality assurance and quality control (QA/QC) samples for this project.

The MPCA core lake-monitoring programs include the CLMP, the Lake Assessment Program (LAP), and the Clean Water Partnership (CWP) Program. In addition to these programs, the MPCA annually monitors numerous lakes to provide baseline water quality data, provide data for potential LAP and CWP lakes, and characterize lake conditions in different regions of the state. MPCA also examines year-to-year variability in ecoregion reference lakes and provides additional trophic status data for lakes exhibiting trends in Secchi transparency. Lake Latoka was included in the MPCA's LAP program in 1993 with the help of Rich Braun and Charles Anderson from the lake association.

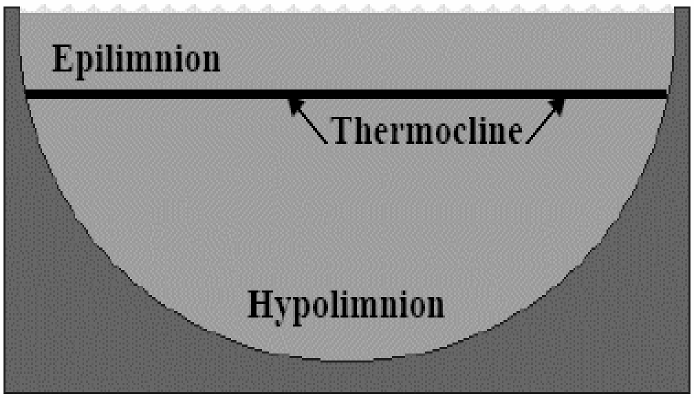
The state of Minnesota is divided into seven ecoregions (Figure 1), based on soils, landform, potential natural vegetation, and land use. Lake Latoka is located within the North Central Hardwood Forest (NCHF) ecoregion. Comparing a lake's water quality to that of reference lakes in the same ecoregion provided one basis for characterizing the condition of the lake.

Figure 1. Minnesota's Ecoregions and Counties

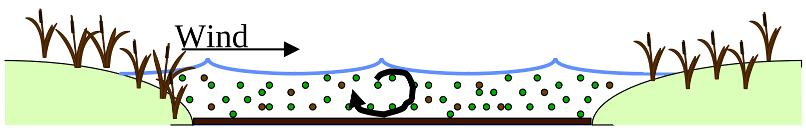


Lake depth can have a significant influence on lake processes and water quality. One such process is *thermal stratification* (formation of distinct temperature layers), in which deep lakes (maximum depths of 30 - 40 feet or more) often stratify (form layers) during the summer months and are referred to as *dimictic*. These lakes full-mix or turn-over twice per year; typically in spring and fall. Shallow lakes (maximum depths of 20 feet or less) in contrast, typically do not stratify and are often referred to as *polymictic*. Some lakes, intermediate between these two, may stratify intermittently during calm periods. Measurement of temperature throughout the water column (surface to bottom) at selected intervals (e.g. every meter) can be used to determine whether the lake is well-mixed or stratified. It can also identify the depth of the thermocline (zone of maximum change in temperature over the depth interval). In general, the upper, well-mixed layer (epilimnion) is warm and has high oxygen concentrations. In contrast, the lower layer (hypolimnion) is much cooler and often has little or no oxygen. Most of the fish in the lake will be found in the epilimnion or near the thermocline. The combined effect of depth and stratification can influence overall water quality.

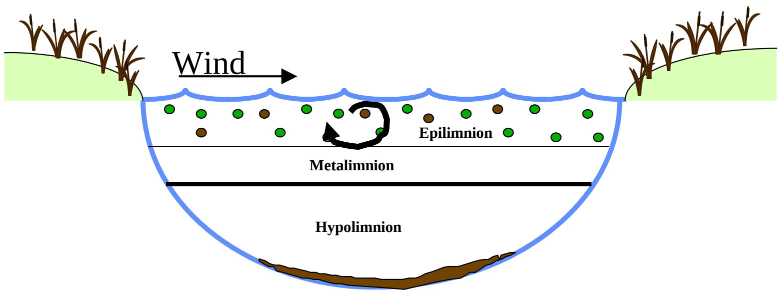
Diagram of Lake Layers for Deep and Shallow Lakes



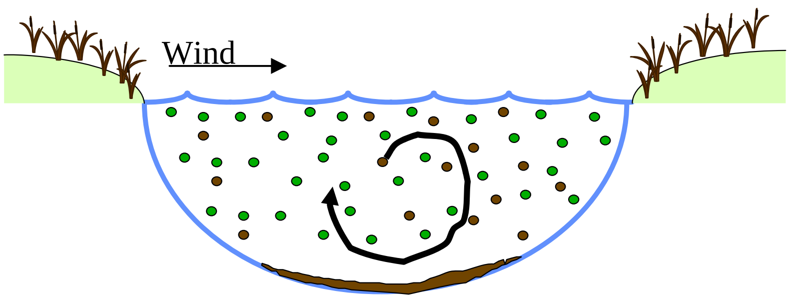
Polymictic Lake
Shallow, No Layers,
Mixes Continuously
Spring, Summer & Fall



Dimictic Lake
Deep, Form Layers,
Mixes Few Times
Summer



Dimictic Lake
Deep, Form Layers,
Mixes Few Times
Spring/Fall



Part 2: 2005 Lake Surveys

Methods

This report includes data from 2005 as well as previously collected data available in STORET, U.S. Environmental Protection Agency's (EPA) national water quality data bank (Appendix). The following discussion assumes familiarity with basic limnology terms as used in a "Citizens Guide to Lake Protection" and as commonly used in LAP reports. A glossary of terms is included in the appendix and can also be accessed at http://www.pca.state.mn.us/water/lakeacro.html .

One site in each bay of the lake was monitored twice per month, from June through September. Lake surface samples were collected with an integrated sampler, constructed from a PVC tube 6.6 feet (2 meters) in length with an inside diameter of 1.24 inches (3.2 centimeters). Lake-bottom samples were collected 1 meter off the bottom of the lake by MPCA staff using a Kemmerer sampler. Seasonal averages were calculated using June – September data. Sampling procedures were employed as described in the MPCA Quality Control Manual and Citizen Lake-Monitoring Program "Plus" Manual. Laboratory analyses were performed at the Minnesota Department of Health using EPA-approved methods. Surface samples from volunteers were analyzed for: total phosphorus (TP), chlorophyll-*a*, and pheophytin. Secchi disk transparency and user perception information was recorded at all sites. Volunteers also collected temperature profiles for each site using a FishHawk Model 520 digital depth and temperature meter. Algae samples were collected from the chlorophyll-*a* sample bottles and preserved with Lugol's solution.

MPCA staff collected surface samples and bottom samples for each site on three occasions. These data serve to augment the volunteer collection and provide an opportunity for comparison of results. MPCA collected surface samples were analyzed for the following parameters: TP, chlorophyll-*a*, pheophytin, total Kjeldahl nitrogen (TKN), total suspended solids (TSS), suspended volatile solids (SVS), total chloride, alkalinity and color. Conductivity, pH, and dissolved oxygen and temperature profiles were collected using a Hydrolab multi-probe unit. Lake-bottom samples were analyzed for TP. Secchi disk transparency and user perception information was recorded for each site. Qualitative analysis of zooplankton collected using a zooplankton net was also recorded for each site.

Additional information, such as bathymetric (contour) and location maps, was obtained from the DNR's lakefinder Web site (http://www.dnr.state.mn.us/lakefind/index.html) and the MPCA Web site (http://www.pca.state.mn.us) and from U.S. Geological Survey quad maps. Watershed area information for the lake was provided from the 1993 LAP report.

Data Analysis

A series of graphs are presented for each bay including: TP, chlorophyll-*a*, Secchi disk transparency, and temperature profiles. Sample dates with a single asterisk indicate data collected by the MPCA. Dates with no asterisk were collected by CLMP volunteer lake monitors. All raw data for each lake and site are available in the appendix.

Quality Assurance/Quality Control (QA/QC) samples are taken routinely throughout the sampling season for CLMP+. In 2005, thirteen field duplicate TP samples were taken. A field duplicate is a second sample taken right after an initial sample in the exact same location. Field duplicates assess the sampler's precision, laboratory precision (i.e. reproducibility of results), and possible temporal variability. The duplicate sample should be collected in the exact same manner as the first sample, including the normal sampling equipment cleaning procedures. Of these 13 samples, the percent difference ranged from 0 – 33 percent of the original sample, with the majority (77 %) falling within the 0 – 15 percent range. Of the 12 paired chlorophyll-*a* samples, the percent difference range was 2 – 16 percent, with the majority (83 %) falling within the 0 – 15 percent range. These results are very good considering the difference in quality of the participating lakes and varying concentration levels of these parameters. Four TP sample results from the following lakes were omitted due to sample contamination from adding Lugol's solution instead of sulfuric acid preservative: Duck Lake (Hubbard County), Upper Twin Lake (Hubbard County), Lower Twin Lake (Wadena County), and Pleasant Lake (Wright County). One chlorophyll-*a* sample from Duck Lake (Hubbard County) was also omitted due to sample contamination from Lugol's.

Several TP samples from early June, for the CLMP+ lakes, were held for one week longer than the recommended holding time due to the 2005 government shutdown. However, given that the samples were properly preserved with acid, kept cool and in a dark place, we do not feel these samples were compromised. Several samples for color analysis were held over the recommended holding time by one day. As with the TP samples, the integrity of these samples should also still be acceptable.

The Minnesota Lake Eutrophication Analysis Procedure (MINLEAP) computer model was used to predict the TP concentration, chlorophyll-*a* concentration, and Secchi disk transparency of the lake based on the lake area, lake depth, and the area of the lake's watershed. Additional information about this model can be found in the modeling section of this report or a complete explanation of this model may be found in Wilson and Walker (1989).

Table 1. Lake Latoka Morphometric and Watershed Characteristics

Morphometry	21-0106-01 North Basin	21-0106-02 South Basin	Whole Lake
Area[1]	**564 acres 228 ha 0.9 mi^2**	**199 acres 80.6 ha 0.3 mi^2**	**763 acres 309 ha 1.2 mi^2**
Mean Depth[1]	**36.4 feet 11.1 meters**	**31.7 feet 9.7 meters**	**35.1 feet 10.7 meters**
Maximum Depth[1]	**108 feet 25.3 meters**	**80 feet 24.3 meters**	**108 feet 25.3 meters**
Volume[1]	**19,796 acre-feet 24.4 hm^3**	**6,985 acre-feet 8.6 hm^3**	**26,781 acre-feet 33 hm^3**
Littoral Area[2]	**-**	**-**	**~ 20 %**
Watershed area[1] ***(excludes the lake)***	**-**	**-**	**1,565 acres 634 ha 2.4 mi^2**
Watershed:Lake[1]	**-**	**-**	**2:1**

Table 2: 1993 & 2005 Average Summer Water Quality Parameters: Lake Latoka.
(Based on 1993 and 2005 epilimnetic data.)

Parameters	North Latoka 1993	South Latoka 1993	North Latoka 2005	South Latoka 2005	Typical Range for NCHF Ecoregion[3]
Total Phosphorus (µg/L)	20.0	17.0	19.8	20.6	23 – 50
Chlorophyll-*a* (µg/L)[4] **Mean**	5.0	4.7	3.3	3.4	5 – 22
Chlorophyll-*a*(µg/L)[4] **Maximum**	7.7	8.0	4.7	4.2	7 – 37
Secchi disk (m)	3.6	3.7	4.0	4.1	1.5 – 3.2
Secchi disk (feet)	12.0	12.3	13.2	13.3	4.9 – 10.5
Total Kjeldahl Nitrogen (mg/L)	0.9	0.7	0.6	0.7	0.62 – 1.2
Alkalinity (mg/L)	183	178	177	177	75 – 150
Color (Pt-Co Units)	11	11	7	7	10 – 20
pH (SU)	--	--	8.2	8.1	8.6 – 8.8
Chloride (mg/L)	11	11.5	18	19	4 – 10
Total Suspended Solids (mg/L)	2.6	2.0	2.0	2.7	2 – 6
Total Suspended Inorganic Solids	0.9	0.6	1.6	1.5	1 – 2
Conductivity (µmhos/cm)	341	351	307	319	300 – 400
TN:TP Ratio	46:1	18:1	30:1	34:1	25:1 – 35:1

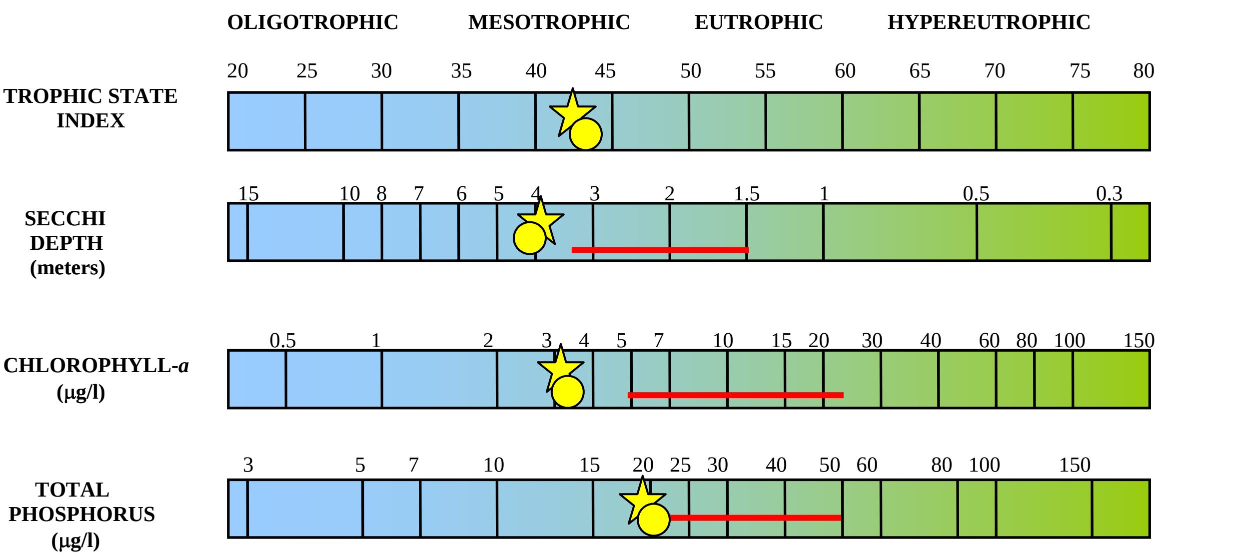
Table 3. Lake Latoka Trophic Status Indicators: 1993 and 2005

TSI Parameter	Latoka North 1993	Latoka South 1993	Latoka North 2005	Latoka South 2005
TP TSIP =	**47**	**47**	**47**	**48**
Chl-*a* TSIC =	**46**	**45**	**42**	**43**
Secchi TSIS =	**42**	**41**	**40**	**40**
Mean (All) TSI =	**45**	**44**	**43**	**44**

[1]1993 MPCA Lake Assessment Report (MPCA, 1994)
[2]DNR Web Site (www.dnr.state.mn.us)
[3] Based on approximately 700 assessed lakes in the North Central Hardwood Forests Ecoregion
[4] Chlorophyll-*a* measurements have been corrected for pheophytin.

Figure 2. Carlson's Trophic State Index (Carlson, 1977)
(Based on a scale of 0 – 100.)

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 bluegreen 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.



After Moore, L. and K. Thornton, [Ed.]1988. Lake and Reservoir Restoration Guidance Manual. USEPA>EPA 440/5-88-002.

NCHF Ecoregion Range, 25th – 75th percentile:

North Latoka (2005):

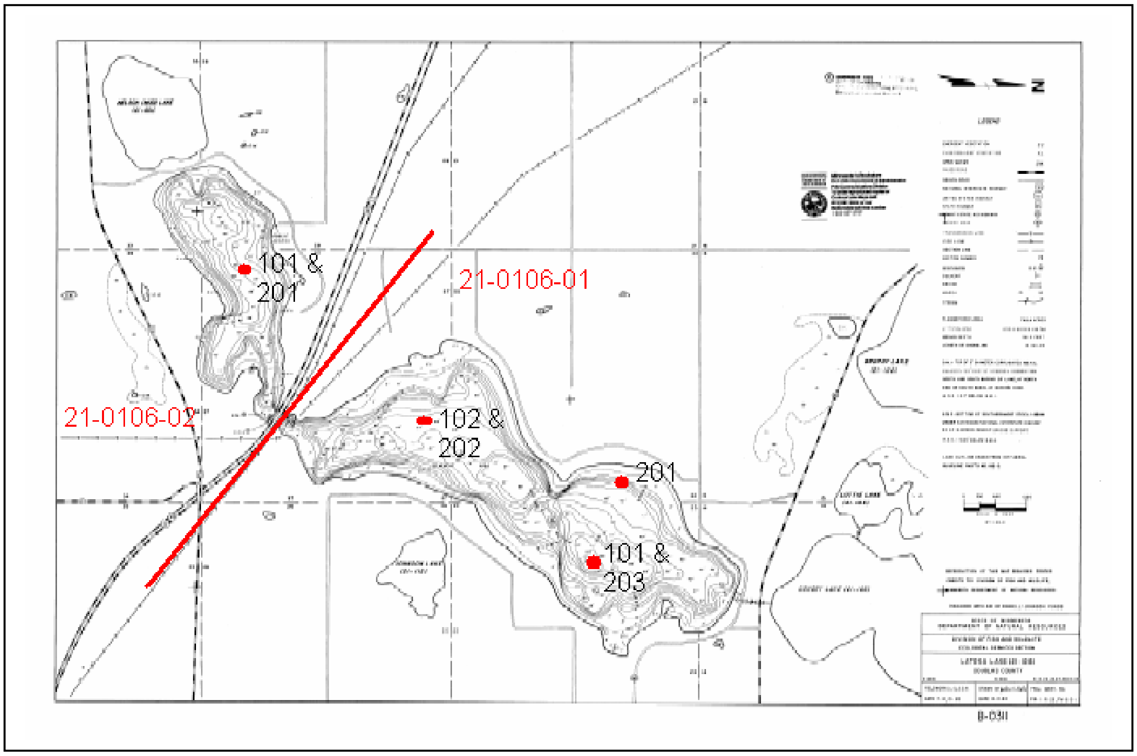
South Latoka (2005):

Lake Latoka (21-0106-01 and 21-0106-02)

Lake Latoka is located approximately one mile west of Alexandria, Minnesota. It is a large lake with two distinct basins that lie in a north-south orientation. The whole lake covers 763 acres with maximum depth of 108 feet (north basin) and mean depth of 31.1 feet (Table 1). It is in the upper five percent of lakes in terms of its size. Approximately 20 percent of the lake is littoral and there are two public accesses for the lake. It has a very small watershed, 2.4 mi^2; and as such, the watershed to lake ratio is also small at 2:1 (Table 1). The lake drains from south to north and the watershed area is evenly distributed around the lake (Appendix). Its water residence time is on the order of thirty-five years.

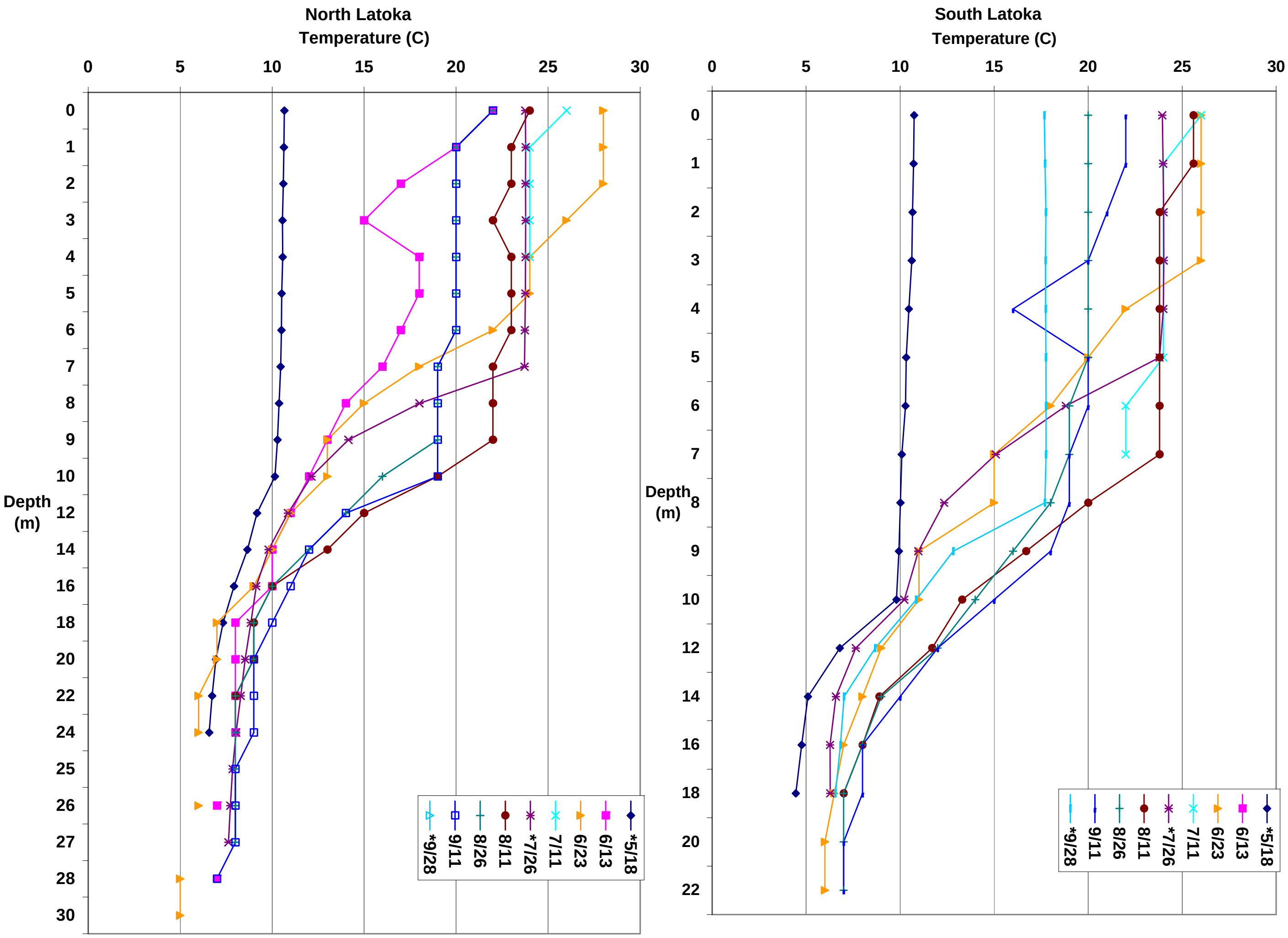
Water quality data was collected in June, July, August, and September, 2005 by volunteer lake monitors: Rich & Marlene Braun and Rich Lorsung . Two sites were used on Lake Latoka: Site 101– located in the northern basin (21-0106-01) of the lake and Site 101 – located in the south basin (21-0106-02) (Figure 3).

Figure 3. Lake Latoka Bathymetric Map and Monitoring Location



Temperature data indicated that the lake was well-mixed at the May and late September sampling events. Surface temperatures ranged from 10.7 °C in May to 28 °C in late-June for the north basin (Figure 4). Temperatures ranged from 10.7 °C in May to 26 °C late-June and early-July for the south basin. Based on these profiles, the lake was thermally stratified from June – September with a thermocline between about 8 – 10 meters. Declines in temperature in the upper waters; at three meters in June in the north basin and at four meters in September for the south basin are likely due to drifting of the boat (probe was not vertical in the water column). Some of the other profiles were incomplete; also due to drifting effects. The lake is very large and was wind-swept on most of the sampling occasions, making it difficult to anchor and collect consistent profile readings, particularly in the north basin.

Figure 4. Latoka Lake Temperature Profiles for 2005



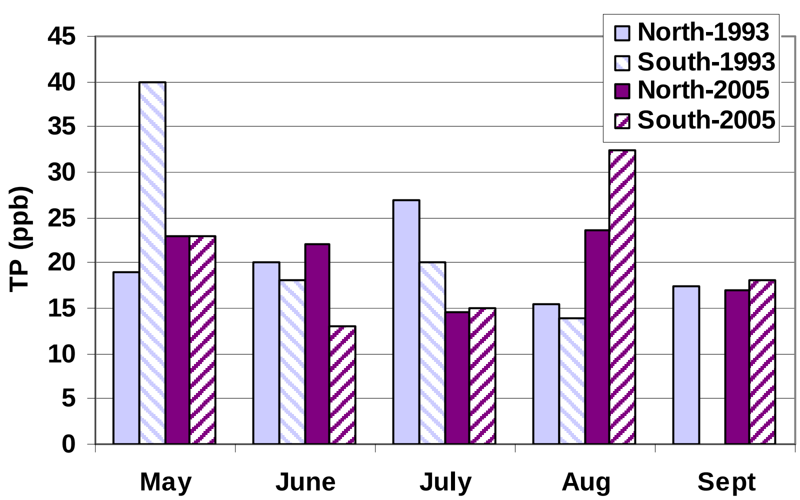
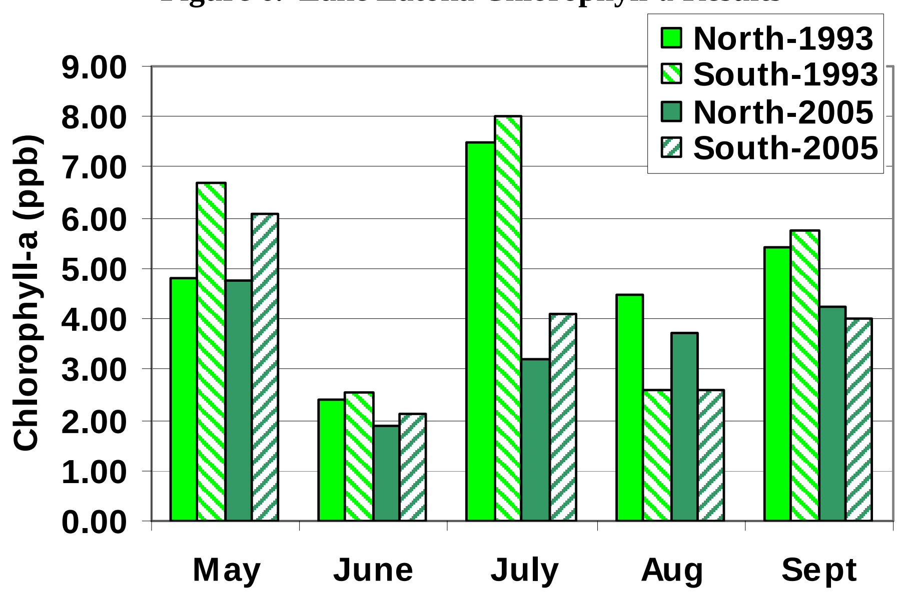


Figure 5. Lake Latoka Total Phosphorus Results

Total phosphorus (TP) concentrations averaged 19.8 and 20.6 µg/L (micrograms per liter or parts per billion) in North Latoka and South Latoka Lakes, respectively, during the summer of 2005. These values are better than the range of concentrations for reference lakes in this ecoregion (Table 2). TP concentrations observed in 2005 ranged from 12 – 31 µg/L for North Latoka and from 13 – 33 µg/L for South Latoka. With the exception of May, concentrations in 1993 were higher in the north basin than the south basin. In contrast, concentrations in the south basin were higher in 2005 with the exception of June. On average, concentrations in the north basin were not significantly different between 1993 and 2005; while concentrations in the south basin were slightly higher in 2005.

Chlorophyll-*a* concentrations averaged 3.3 and 3.4 µg/L, respectively, for North and South Latoka Lakes in 2005 and were well below the ecoregion range (Table 2). Concentrations in the north basin ranged from 1.4 – 4.7 µg/L; while concentrations in the south basin ranged from 2.1 – 4.2 µg/L (Figure 6) for 2005. Overall, chlorophyll-*a* values in 2005 were lower than those observed in 1993. Also, chlorophyll-*a* values were consistently lower in the north basin, with the exception of August, where concentrations in both 1993 and 2005 were actually higher in the northern basin**.**

Figure 6. Lake Latoka Chlorophyll-*a* Results



The compositions of the phytoplankton (algae) populations for Lake Latoka are presented in Figures 7a and 7b. Data are presented in terms of algal type. Samples were collected at Site 101 for each bay. Three algal samples were missing from the dataset due to labeling problems where the labels came off the bottles. The diatoms and yellow-browns were well represented in May in each bay. In July, bluegreens dominated the populations and were well represented throughout the remaining summer with the forms, *Anabaena* and *Anacystis* being most common. A seasonal transition in algal types from diatoms to greens to bluegreen is more typical for mesotrophic and eutrophic lakes in Minnesota.

Figure 7a. North Lake Latoka Algal Populations for 2005

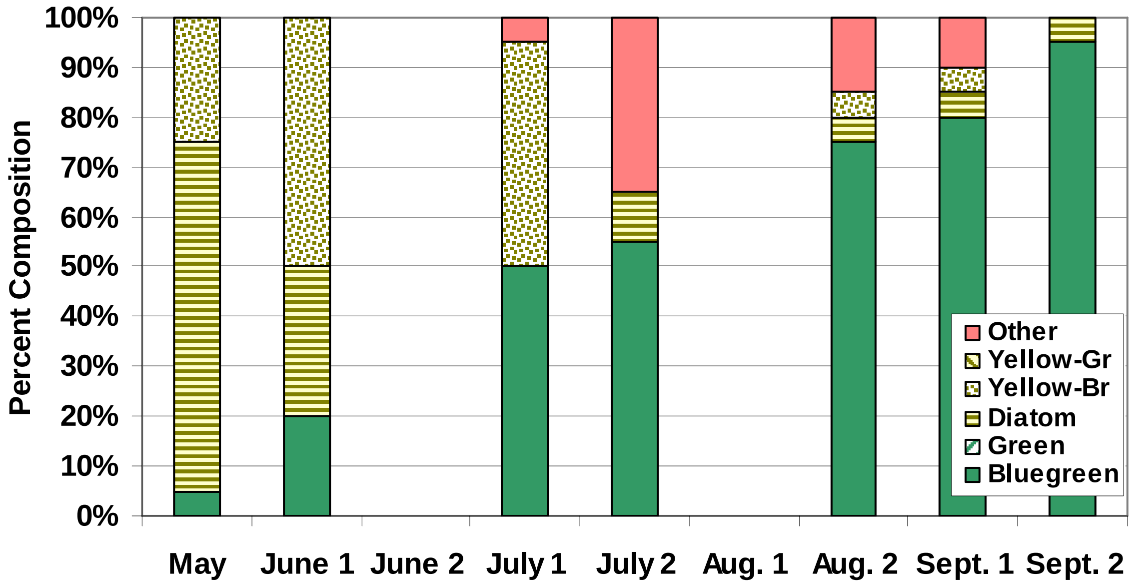
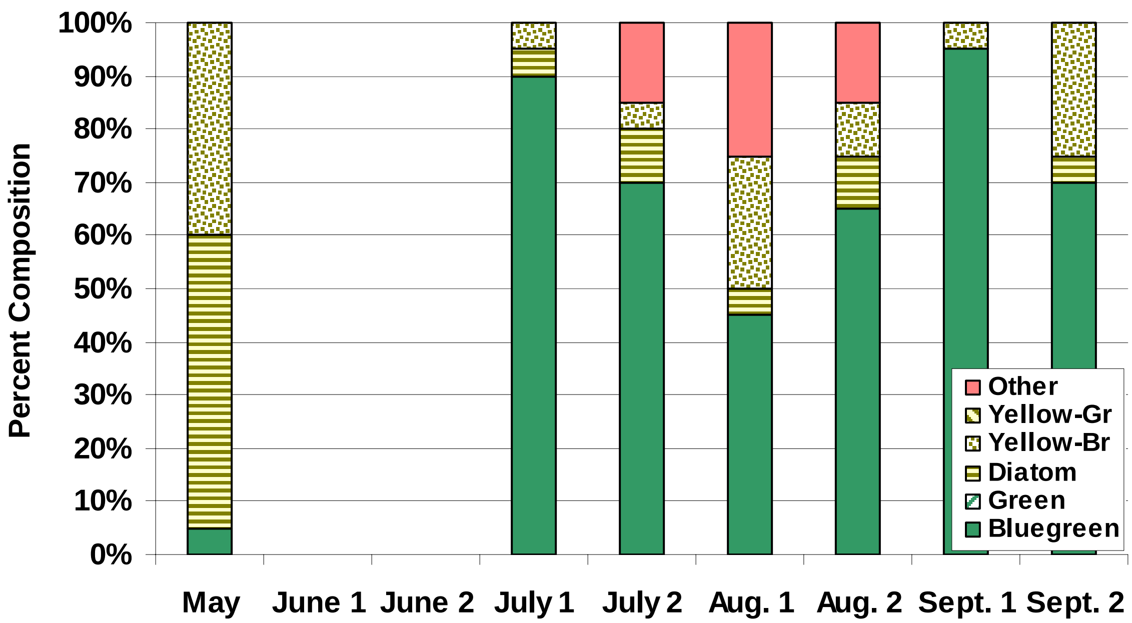


Figure 7b. South Lake Latoka Algal Populations for 2005

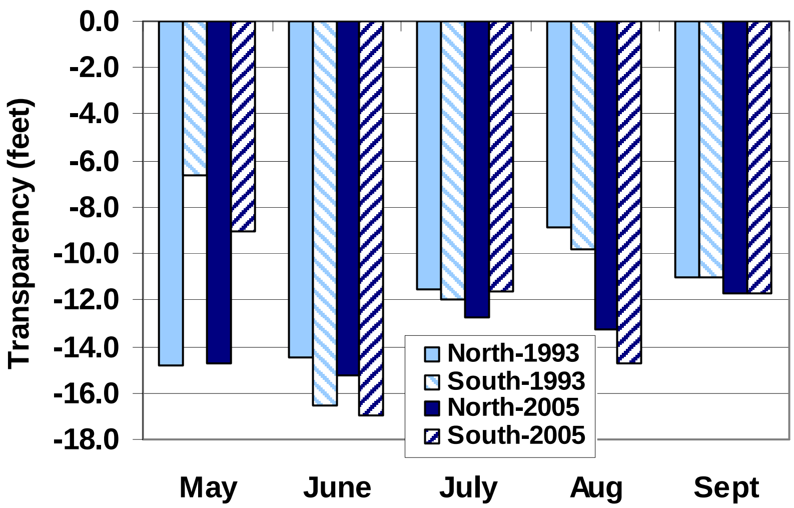


Secchi disk transparency on North Latoka Lake ranged from 11.5 feet in late-September to 16 feet in late-June and averaged 13.2 feet for 2005 (Figure 8). Transparency on South Latoka Lake ranged from 9 feet in May to 17 feet in late-June and average 13.3 feet for 2005 (Figure 8). These transparency measures are better than the typical range for ecoregion reference lakes (Table 2). Transparency in the north basin was significantly better than the south basin in May 1993 and 2005, but no significant difference between the two basins was noted for the remaining

2005 sampling season. Overall, transparency was better in 2005 at both basins as compared to the transparency in 1993 (Figure 8).

Along with transparency measurements, subjective measures of Lake Latoka's "physical appearance" and "recreational suitability" were made. Physical condition in 2005 was characterized as "crystal clear" and "not quite crystal clear" (Classes 1 and 2); while recreational suitability was characterized as "beautiful" and "minor problems" (Classes 1 and 2).

Figure 8. Lake Latoka Secchi Transparency Results



Other parameters, such as total Kjeldahl nitrogen, total suspended solids and conductivity, analyzed for Lake Latoka were all near or well within the typical range of values for ecoregion reference lakes (Table 2) for both basins. Lake Latoka is quite clear (lacks bog stain) based on the color measurements (Table 2). The pH is slightly below the ecoregion reference range; presumably because of the algal productivity. In contrast, alkalinity and chloride were slightly above the ecoregion reference range. A distinctive increase in chloride concentration between 1993 and 2005 is evident. This may reflect an increase in the road network, amount of impervious surface area and/or increased road salt use between these two time periods.

Trophic State Index (TSI) values for each basin of Lake Latoka compare very favorably to each other (Table 3); indicating *mesotrophic* conditions for both basins. Based on TSI values, it appears that overall water quality in the north basin in 2005 (Mean TSI = 43) was slightly improved over 1993 water quality (Mean TSI = 45). TSI values for the south basin were the same (Mean TSI = 44). As such, Secchi transparency should continue to be a good estimator for TP and chlorophyll-*a* values as well as an indicator of overall water quality for both basins of Lake Latoka.

Part 3. Water Quality Trends

All available Secchi transparency data from STORET (U.S. EPA's national water quality database) were used for these assessments. The majority of the data collected is from volunteer lake monitors in the MPCA's Citizen Lake-Monitoring Program. For our trend analysis, we ran Kendall statistical test using WQ Stat Plus™ software on the CLMP+ lakes with 4 or more transparency readings per summer (June – September) and eight or more years of data. We used a probability (p) level of $p \leq 0.1$ as the basis for identifying significant trends. At this p-level, there is a 10 percent chance of identifying a trend when it does not exist. Simply stated, the smaller the p-value, the stronger the trend (i.e. more likely a trend occurred). Summer-mean transparency in a lake varies from year to year due to climatic changes (precipitation, runoff, and temperature), nutrient and sediment loading, and biological factors. Understanding and quantifying the relative magnitude of this variability is essential to assessing trends. Based on a previous study (Heiskary and Lindbloom 1993), typical year-to-year Secchi transparency variability was found to be on the order of 1 – 2 feet. In general, annual transparency in Minnesota lakes fluctuates within about 20 percent of the long-term mean. Lakes with larger fluctuations or non-random fluctuations, relative to the long-term mean, often exhibit a trend. Both basins of Lake Latoka were included for Secchi transparency, total phosphorus and chlorophyll-*a* trend analysis. The figures of this section (Figures 9 – 11) contain a factor called standard error (Std. Error). Standard error is defined as the standard deviation of a dataset divided by the square root of the number of samples from that dataset. Standard error is a measure of variability within a dataset and provides a simple basis for comparing means. The closer the values are to each other, the smaller this line will be in following figures. Small standard error means minimal variability in the measurements during a given summer, whereas a large standard error implies a high degree of variability.

North Lake Latoka (21-0106-01)

Based on 20 years of Secchi data, there has been some fluctuation in transparency, but no statistically significant trend is noted ($p>0.2$) at this time. Secchi transparency has ranged from a low of 9.7 feet in 1998 to a maximum of 15.2 feet in 2005 with a long-term average of 12.6 feet (Figure 9). This is a very extensive and complete dataset (no significant breaks in the records).

North Lake Latoka was sampled as part of the MPCA's Lake Assessment Program (LAP) in 1993, along with South Lake Latoka. Both lakes have also been monitored in more recent years by the lake association. A comparison of historical TP and chlorophyll-*a* data are presented in Figure 10 and Figure 11, respectively. Based on 13 years of data, there is a slight, statistically significant ($p = 0.1$), decline in TP concentrations. Much of this decline has occurred between 1995 (when peak levels were measured) and 2005. TP ranged from a low of 12.9 μg/L in 2000 to a high of 56.7 μg/L in 1995 (Figure 10). Based on 13 years of chlorophyll-*a* data, there is a slight, but not statistically significant ($p>0.1$), increase in concentrations. Chlorophyll-*a* concentrations ranged from a low of 2.0 μg/L in 1990, 1994, & 1997 to a high of 4.7 μg/L in 1989 (Figure 11).

It should be noted, however, that there is a small break in the dataset from 2002 – 2004 for both parameters. Data from this time period would have helped strengthen our trend analysis for TP and chlorophyll-*a* in North Lake Latoka.

South Lake Latoka (21-0106-02)

Based on 16 years of data, there has been a statistically significant improvement in Secchi transparency ($p<0.05$). Secchi transparency has ranged from a low of 10.8 feet in 1995 to a maximum of 15.5 feet in 1990, with a long-term average of 12.8 feet (Figure 9). This is a very extensive and complete dataset (no significant breaks in the records).

Based on 10 years of TP data, there have been fluctuations in TP concentrations, but no statistically significant ($p > 0.2$) trend is noted. A more marked reduction in TP has occurred since 1995, where concentrations reached their peak levels. TP ranged from a low of 12 μg/L in

1998 to a high of 50 µg/L in 1995 (Figure 10). Based only eight years of chlorophyll-*a* data, there have been fluctuations in chlorophyll-*a* levels, but no significant ($p>0.2$) trend is noted. Chlorophyll-*a* concentrations ranged from a low of 2.0 µg/L in 1994 & 1997, to a high of 4.2 µg/L in 1993 (Figure 11).

It should be noted, however, that there is a significant break in the dataset from 1998 – 2004 for both parameters. Data from this time period would have helped strengthen our trend analysis for TP and chlorophyll-*a* in South Lake Latoka. Given the dramatic change in TP for the period from 1994 – 1998 (Figure 10), it might be interesting for the lake association or the county to review precipitation records and any changes in watershed development or land uses that might explain this change.

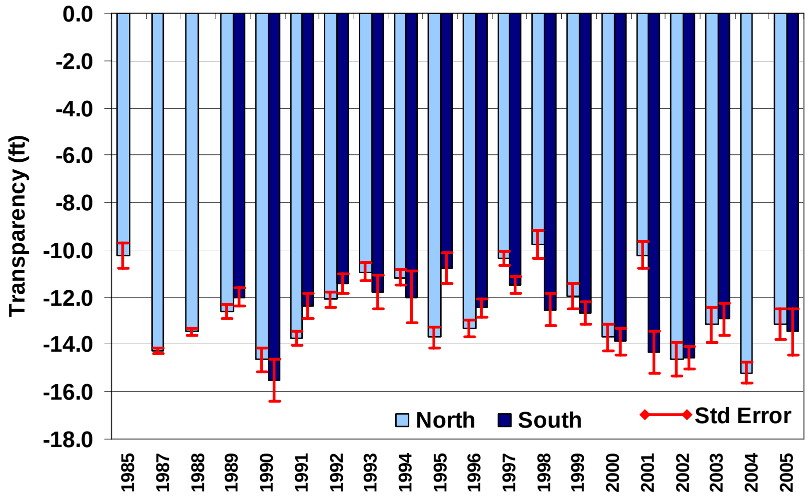
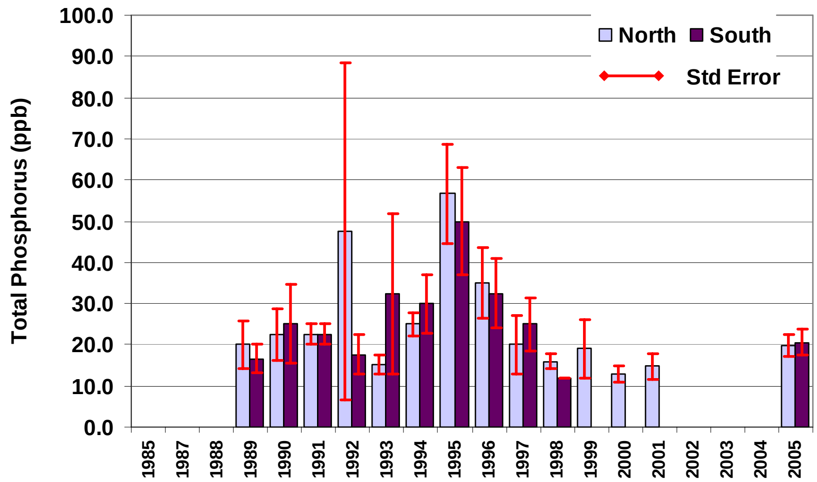


Figure 9. Lake Latoka Summer-Mean Secchi Transparency

Figure 10. Lake Latoka Summer-Mean Total Phosphorus



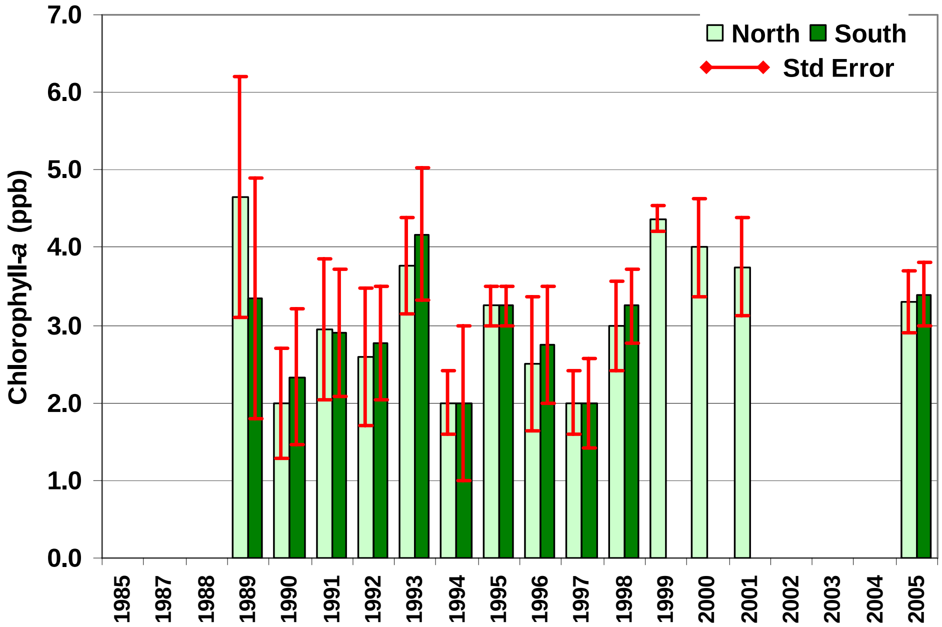


Figure 11. Lake Latoka Summer-Mean Chlorophyll-*a*

Part 4. Water Quality Modeling

The Minnesota Lake Eutrophication Analysis Procedure (MINLEAP) computer model was used to predict the TP concentration of each lake. These predictions are based on: lake area, mean depth, watershed area, and ecoregion in which the lake is located. Known information such as lake and watershed areas, and mean depth are inputs to the model; which in turn, computes a "predicted" TP value. The predicted TP value is used to predict a chlorophyll value, which in turn, is used to predict a Secchi value. The predicted values can then compared to the observed values (summer means) for each lake to determine if the lake's condition is what would be expected – based on its size, depth and watershed area. The model has some limitations in that it cannot take into account groundwater influence and cannot account for TP-trapping or settling in large lakes that may be upstream of the lake being modeled.

A subroutine in the MINLEAP model provides an estimate of background TP concentration for each lake based on its mean depth and alkalinity. This estimate was derived from an equation developed by Vighi and Chiaudani (1985) and is based on the morphoedaphic index commonly used in fisheries science. This equation assumes that most of the phosphorus entering the lake arises from soil erosion in the watershed, and that phosphorus and other minerals, which contribute to alkalinity, are delivered in relatively constant proportions. In turn, the mean depth of the lake will moderate the in-lake phosphorus concentration (e.g. deep lakes settle material readily, which contributes to low phosphorus concentrations). This estimated "background" concentration helps place modern-day results and goal setting in perspective. Mean depth, watershed area and volumes were known for each lake from previous studies and reports.

<u>Lake Latoka</u>
Modeling for the lake used "whole lake" information from Table 1. In addition, North and South Lake Latoka data were averaged for a "whole lake" concentration for TP, chlorophyll-*a* and

Secchi transparency for both 1993 and 2005. There was no distinct difference between the calculated 1993 and 2005 observed values for TP and chlorophyll-*a*. The 2005 calculated observed value for Secchi transparency is slightly better than the 1993 calculated observed value.

Table 4. MINLEAP Model Outputs & Predictions

LAKE	TP (µg/L) Observed[1]	TP (µg/L) Predicted[2]	TP (µg/L) Vighi-Chiaudani	Chl-*a* (µg/L) Observed[1]	Chl-*a* (µg/L) Predicted[2]	Secchi (m) Observed[1]	Secchi (m) Predicted[2]
[3]Latoka N 1993	19	16 ± 7	19	5	4 ± 3	3.7	3.6 ± 2
Latoka 2005	20	16 ± 7	19	3	4 ± 3	4.1	3.6 ± 2

[1]Observed Values reported as an average of North and South Latoka data.
[2]Predicted Values based on the Total watershed.
[3]From 1993 LAP report.

MINLEAP predicted a slightly lower, but not significantly different TP concentration than the 1993 and 2005 calculated observed values for the lake (Table 4). The Vighi-Chiaudani model predicted slightly, but not significantly, lower TP concentrations for the lake as compared to the 1993 and 2005 calculated observed values (Table 4). TP-loading for Lake Latoka is estimated to be on the order of 215 kg P/yr in both 1993 and 2005. *(Note: there are 2.2 pounds of phosphorus per kilogram.)* The TP-retention coefficient was estimated to be 0.93 in 1993 and 2005. This means that roughly 93 percent of the TP that enters Lake Latoka stays in the lake. The calculated observed chlorophyll-*a* concentration from 1993 and 2005 are near the predicted ranges. In contrast, the predicted Secchi transparency is slightly, but not significantly poorer than the 2005 observed for Lake Latoka. Overall, model predictions compare favorably with observed results and suggest that based on the available data, the lake is near background conditions and has not changed significantly since 1993.

Part 5. Goal Setting

For Lake Latoka, it would be desirable to maintain the currently low in-lake TP concentrations. The summer-mean P-concentration for Lake Latoka was slightly above the predicted P-value and near the Vighi and Chiaudani "background" estimate. Based on Tables 5 and 6, the lake should be fully supporting for all designated uses. Continued efforts to protect this water body from any degradation are strongly recommended. Some important considerations for improving and protecting the water quality of the lake include implementation of BMP's in the shoreland area and ultimately through the watershed with a particular emphasis on the direct drainage area. 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. Proper maintenance of buffers areas between lawns and the lakeshore, minimizing use of fertilizers, and minimizing the introduction of new significant sources of P-loading (e.g., stormwater from near-shore development activities in the watershed), will serve to minimize loading to the lake. These and other considerations will be important if the water quality of this Douglas County lake is to be maintained over the long term.

Table 5. Nutrient and Trophic Status Thresholds for Determination of Use Support for Lakes.

Ecoregion (TSI)	TP (ppb)	Chl (ppb)	Secchi (m)	TP Range (ppb)	TP (ppb)	Chl (ppb)	Secchi (m)
305(b):	**Full Support**			*Partial Support*	*Non-Support*		
303(d):	**Not Listed**			**Review**	**Listed**		
NCHF	**< 40**	**< 15**	**≥ 1.2**	**40 - 45**	**> 45**	**> 18**	**< 1.1**
(TSI)	(< 57)	(< 57)	(< 57)	(57 – 59)	(> 59)	(> 59)	(> 59)

Derived from MPCA Guidance Manual for Assessing Minnesota Surface Waters for Determination of Impairment (MPCA 2003). *TSI* = Carlson's Trophic State Index; *Chl-a* = Chlorophyll-*a*, includes both pheophytin-corrected and non-pheophytin-corrected values; *ppb* = parts per billion or µg/L; *m* = meters

Table 6. Draft Eutrophication Criteria by Ecoregion and Lake Type & 2005 Observed Summer-means for Comparison (Heiskary and Wilson, 2005)

Ecoregion	TP (ppb)	Chl-*a* (ppb)	Secchi (meters)
NLF – Lake trout (Class 2A)	< 12	< 3	> 4.8
NLF – Stream trout (Class 2A)	< 20	< 6	> 2.5
NLF – Aquatic Rec. Use (Class 2B)	< 30	< 9	> 2.0
NCHF – Stream trout (Class 2a)	< 20	< 6	> 2.5
NCHF – Aquatic Rec. Use (Class 2b)	< 40	< 14	> 1.4
NCHF – Aquatic Rec. Use (Class 2b) Shallow lakes	< 60	< 20	> 1.0
WCP & NGP – Aquatic Rec. Use (Class 2B)	< 65	< 22	> 0.9
WCP & NGP – Aquatic Rec. Use (Class 2b) Shallow lakes	< 90	< 30	> 0.7

Douglas County Lakes: 2005 Observed (Ecoregion)	TP (ppb)	Chl-*a* (ppb)	Secchi (meters)
North Latoka (NCHF)	19.8	3.3	4.0
South Latoka (NCHF)	20.6	3.4	4.1

Part 6. Summary & Recommendations

During the summer of 2005, Lake Latoka was sampled by CLMP volunteers as a part of a monitoring program, CLMP "Plus". This lake was selected because it is a priority in the county and was exhibiting a trend in Secchi transparency.

Following are a few general observations and recommendations based on our monitoring and data analysis:

A. Secchi transparency monitoring: Monitoring Secchi transparency provides a good basis for estimating trophic status and detecting trends. Routine participation is essential to allow for trend analysis. Continued CLMP monitoring on both basins of the lake will contribute to the database, which already exists and allow for future trend assessments.

B. Water quality and tropic status: Based on data collected in 2005, the lake exhibited TP concentrations better than the typical range for minimally-impacted lakes in the NCHF ecoregion. The lakes also exhibited chlorophyll-*a* concentrations better than the typical range for reference lakes. There did not appear to be any statistical difference between the data collected in 1993 and 2005. Lake Latoka would be considered *mesotrophic*.

C. Water quality trends: Both North and South Latoka had a sufficient number of previous years of Secchi transparency, TP, and chlorophyll-*a* data for trend analysis. Statistical improvements in transparency were found for South Latoka. Improvements in TP were found for North Latoka; however, chlorophyll-*a* in both lakes and TP in South Latoka showed no statistical trends over time. Continued monitoring of these lakes will enhance our ability to assess trends in all three parameters.

D. Model predictions: In general, calculated-observed TP in 1993 and 2005 were slightly higher than predicted (MINLEAP) TP; however, the results were still very comparable for the lake. As a result, the predicted chlorophyll-*a* and Secchi values are also comparable to the 1993 and 2005 calculated-observed values.

E. This lake has very good water quality and every effort to protect it from degradation should be taken. Further development or land use change in the watershed should occur in a manner that minimizes water quality impacts on the lake. In the shoreland areas, setback provisions should be strictly followed. MDNR and County shoreland regulations will be important in this regard.

- Stormwater regulations should be adhered to during and following any major construction/development activities in the watershed. Limiting the amount of impervious surfaces can have beneficial affects as well, in terms of reduced runoff and P-loading. Properly designed sedimentation ponds should be included in any development to minimize P-loading to the lakes. A "no-net-increase" in TP is recommended.
- Activities in the watershed that change drainage patterns, such as wetland removal or major alterations in lake use, should be discouraged unless they are carefully planned and adequately controlled. Restoring or improving wetlands in the watershed may also be

beneficial for reducing the amount of nutrients or sediments that reach the lake. The U.S. Fish and Wildlife Service at Fort Snelling may be able to provide technical and financial assistance for these activities.

- The lake association should continue to seek representation on boards or commissions that address land management activities so that their impact can be minimized. The booklet, <u>Protecting Minnesota's Waters: The Land-Use Connection</u>, may be a useful educational tool in this area.
- Macrophyte population and distribution maps for the lake may be beneficial to the association. Exotic species such as *Eurasian water milfoil* and *curly-leaf pondweed* can dramatically impact quality resources such as Lake Latoka. Tracking the population and distribution of rooted aquatic plants can be helpful in determining if changes within the system are occurring and be a possible warning signs for those changes.

F. On-site septic systems are a *potential* source of nutrients to lakes that are not sewered. Effects from septic systems are not likely for Lake Latoka since it is sewered.

G. An examination of land use practices in the watershed and identification of possible nutrient sources such as lawn fertilizer, the effects of ditching and draining of wetlands, and development practices etc., may aid the lake association in determining areas where best management practices may be needed. For example, recent studies indicated that a majority of lawns in the Twin Cities metro area do not need additional phosphorus – this may be true for lawns in Douglas County as well. In April 2004, a new law came into effect restricting the use of phosphorus fertilizers in Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington Counties and set a three percent (by weight) limit outside the metro area. In 2005 this law was extended statewide. The lake associations, together with Douglas County, <u>should encourage the use of P-free fertilizers</u> on lawns in the watershed. There may be other opportunities to implement/promote Best Management Practices (BMP’s) that may reduce nutrient loading from other sources in the watershed as well.

Appendix

1. **Lake Latoka 2005 and Historic Lake Data**

2. **Watershed Map for Lake Latoka**

3. **Lake Level Data for Lake Latoka**

4. **Status of the Fishery for Lake Latoka**

Appendix 1. Lake Latoka 2005 and Historic Lake Data

North Latoka (21-0106-01) @ Site 101

Source	Date	Time	Depth	TP	Chla	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDF	pH	Cond	PC	RS
MPCA	05/18/2005	11:10	0	23.0	4.77	1.08	3.2	2.4	10.0	190.0	16.0	0.63	14.76	7.33	308	2	1
MPCA	05/18/2005	11:10	30	23.0													
Volunteer	06/13/2005	15:10	0	29 Q	1.38	< 0.17							14.50			2	2
Volunteer	06/23/2005	14:50	0	15.0	2.45	0.58							16.00			1	2
Volunteer	07/11/2005	9:15	0	14.0	2.13	< 0.17							13.00			2	2
MPCA	07/26/2005	9:45	0	15.0	4.31	0.75	1.6	1.2	5.0	170.0	19.0	0.62	12.47	8.79	281	2	1
MPCA	07/26/2005	9:45	28	48.0													
Volunteer	08/11/2005	16:50	0	31.0	3.03	0.62							13.00			1	1
Volunteer	08/26/2005	12:00	0	12.0	4.01	1.02							13.50			2	2
Volunteer-FD	08/26/2005	12:00	0	28.0	4.14	0.36											
Volunteer	09/11/2005	10:15	0	18.0	4.67	0.28							12.00			2	3
MPCA	09/28/2005	10:00	0	16.0	3.77	1.06	1.2	1.2	5.0	170.0	18.0	0.64	11.50	8.44	333	1	1

South Latoka (21-0106-02) @ Site 101

Source	Date	Time	Depth	TP	Chla	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDF	pH	Cond	PC	RS
MPCA	05/18/2005	10:45	0	23.0	6.06	0.46	2.4	2.4	10.0	190.0	17.0	0.71	9.02	7.24	323	2	1
MPCA	05/18/2005	10:45	19	25.0													
Volunteer	06/23/2005	14:30	0	13.0	2.13	< 0.16							17.00			1	2
Volunteer	07/11/2005	9:00	0	14.0	4.22	< 0.17							10.00			3	3
MPCA	07/26/2005	9:30	0	16.0	4.01	1.05	2.8	1.2	5.0	170.0	20.0	0.61	13.12	8.61	284	2	1
MPCA	07/26/2005	9:30	17	43.0													
Volunteer	08/11/2005	16:30	0	32.0	3.13	0.46							15.00			1	1
Volunteer	08/26/2005	12:15	0	33.0	2.10	0.43							14.50			2	2
Volunteer	09/11/2005	10:40	0	18.0	3.77	0.34							12.00			2	2
MPCA	09/28/2005	9:30	0	18.0	4.24	0.57	2.8	1.0	5.0	170.0	19.0	0.66	11.50	8.35	349	1	1
MPCA	09/28/2005	9:30	17	34.0													

TP = Total Phosphorus (ppb or µg/L)
Chla = Chlorophyll-*a* (ppb or µg/L)
Pheo = Pheophytin (ppb or µg/L)
TSS = Total Suspended Solids (mg/L)
TSV = Total Suspended Volatile Solids (mg/L)
COL = Color (Pt-Co Units)
Alk = Alkalinity (mg/L)
CL = Chloride (mg/L)
TKN = Total Kjeldahl Nitrogen (mg/L)
SDF = Secchi Transparency (ft)
pH = pH of Sample (SU)
Cond = Conductivity of sample (umhos/cm)
PC = Physical Condition
RS = Recreational Suitability
FD, Q, K = Remark codes for parameters *(FD = field duplicate sample; Q=held past holding time; K=less than the detection limit)*

2005 Temperature Data for Lake Latoka

North Latoka (21-0106-01) @ Site 101

Depth (m)	5/18	6/13	6/23	7/11	7/26	8/11	8/26	9/11	9/28
0	10.67	22	28	26	23.76	24	22	22	Too Windy
1	10.64	20	28	24	23.78	23	20	20	
2	10.61	17	28	24	23.77	23	20	20	
3	10.56	15	26	24	23.78	22	20	20	
4	10.57	18	24	24	23.77	23	20	20	
5	10.52	18	24	Too Windy	23.76	23	20	20	
6	10.51	17	22		23.74	23	20	20	
7	10.46	16	18		23.72	22	19	19	
8	10.38	14	15		18.01	22	19	19	
9	10.29	13	13		14.14	22	19	19	
10	10.15	12	13		12.13	19	16	19	
12	9.18	11	11		10.86	15	14	14	
14	8.66	10	10		9.81	13	12	12	
16	7.93	10	9		9.13	10	10	11	
18	7.33	8	7		8.84	9	9	10	
20	6.95	8	7		8.54	9	9	9	
22	6.74	8	6		8.29	8	8	9	
24	6.58	8	6		8.04		8	9	
25					7.85		8	8	
26		7	6		7.73		8	8	
27					7.63		8	8	
28		7	5					7	
30			5						

South Latoka (21-0106-02) @ Site 101

Depth (m)	5/18	6/13	6/23	7/11	7/26	8/11	8/26	9/11	9/28
0	10.74		26	26	23.94	25.6	20	22	17.67
1	10.72		26	24	23.99	25.6	20	22	17.71
2	10.66		26	24	24.01	23.8	20	21	17.75
3	10.62		26	24	24.02	23.8	20	20	17.73
4	10.47		22	24	24	23.8	20	16	17.74
5	10.32		20	24	23.8	23.8	20	20	17.75
6	10.29		18	22	18.82	23.8	19	20	17.76
7	10.09		15	22	15.09	23.8	19	19	17.76
8	10.02		15	Too Windy	12.34	20	18	19	17.7
9	9.94		11		10.97	16.7	16	18	12.82
10	9.8		11		10.22	13.3	14	15	10.86
12	6.79		9		7.64	11.7	12	12	8.67
14	5.1		8		6.59	8.9	9	10	7.02
16	4.77		7		6.27	8	8	8	6.83
18	4.45		6.5		6.28	7	7	8	6.56
20			6				7	7	
22			6				7	7	

2005 Dissolved Oxygen Data for Lake Latoka

North Latoka (21-0106-01) @ Site 101

Dissolved Oxygen (mg/L)			
Depth (m)	5/18	7/26	9/28
0	**10.71**	**7.53**	Too Windy
1	10.74	7.51	
2	10.61	7.55	
3	10.55	7.52	
4	10.44	7.54	
5	10.44	7.51	
6	10.39	7.48	
7	10.41	7.41	
8	10.35	7.16	
9	10.33	6.54	
10	10.24	5.53	
12	10.03	3.79	
14	9.59	2.52	
16	8.36	1.49	
18	8.39	1.03	
20	8.04	0.73	
22	7.64	0.61	
24	7.1	0.47	
25		0.34	
26		0.31	
27		0.27	

South Latoka (21-0106-02) @ Site 101

Dissolved Oxygen (mg/L)			
Depth (m)	5/18	7/26	9/28
0	**13.84**	**7.78**	**8.52**
1	11.17	7.52	8.26
2	10.69	7.54	8.09
3	10.62	7.4	8.01
4	10.57	7.44	7.9
5	10.51	7.16	7.84
6	10.48	8.86	7.89
7	10.4	8.39	7.87
8	10.17	5.1	7.36
9	10.16	3.06	1.05
10	10.13	1.21	0.53
12	9.21	0.68	0.4
14	5.32	0.45	0.38
16	3.61	0.34	0.36
18	2.65	0.28	0.26
20			
22			

Historic Data for Lake Latoka

North Latoka (21-0106-01)

Year	TP	SEP	NTP	CHLa	SEC	NC	SDM	SES	NS
1985							3.1	0.2	4
1987							4.4	0.0	16
1988							4.1	0.0	16
1989	20.0	5.8	3	4.7	1.6	2	3.8	0.1	21
1990	22.5	6.3	4	2.0	0.7	4	4.5	0.2	25
1991	22.5	2.5	4	3.0	0.9	4	4.2	0.1	24
1992	47.5	40.9	4	2.6	0.9	4	3.7	0.1	23
1993	15.2	2.3	12	3.8	0.6	12	3.3	0.1	30
1994	25.0	2.9	4	2.0	0.4	4	3.4	0.1	13
1995	56.7	12.0	3	3.3	0.3	4	4.2	0.1	27
1996	35.0	8.7	4	2.5	0.9	4	4.1	0.1	34
1997	20.0	7.1	4	2.0	0.4	4	3.2	0.1	33
1998	16.0	1.7	4	3.0	0.6	4	3.0	0.2	12
1999	19.0	7.2	8	4.4	0.2	8	3.6	0.2	12
2000	12.9	1.9	8	4.0	0.6	8	4.2	0.2	11
2001	14.7	3.0	4	3.8	0.6	4	3.1	0.2	9
2002							4.5	0.2	13
2003							4.0	0.2	8
2004							4.6	0.1	8
2005	19.8	2.5	9	3.3	0.4	9	4.0	0.2	8

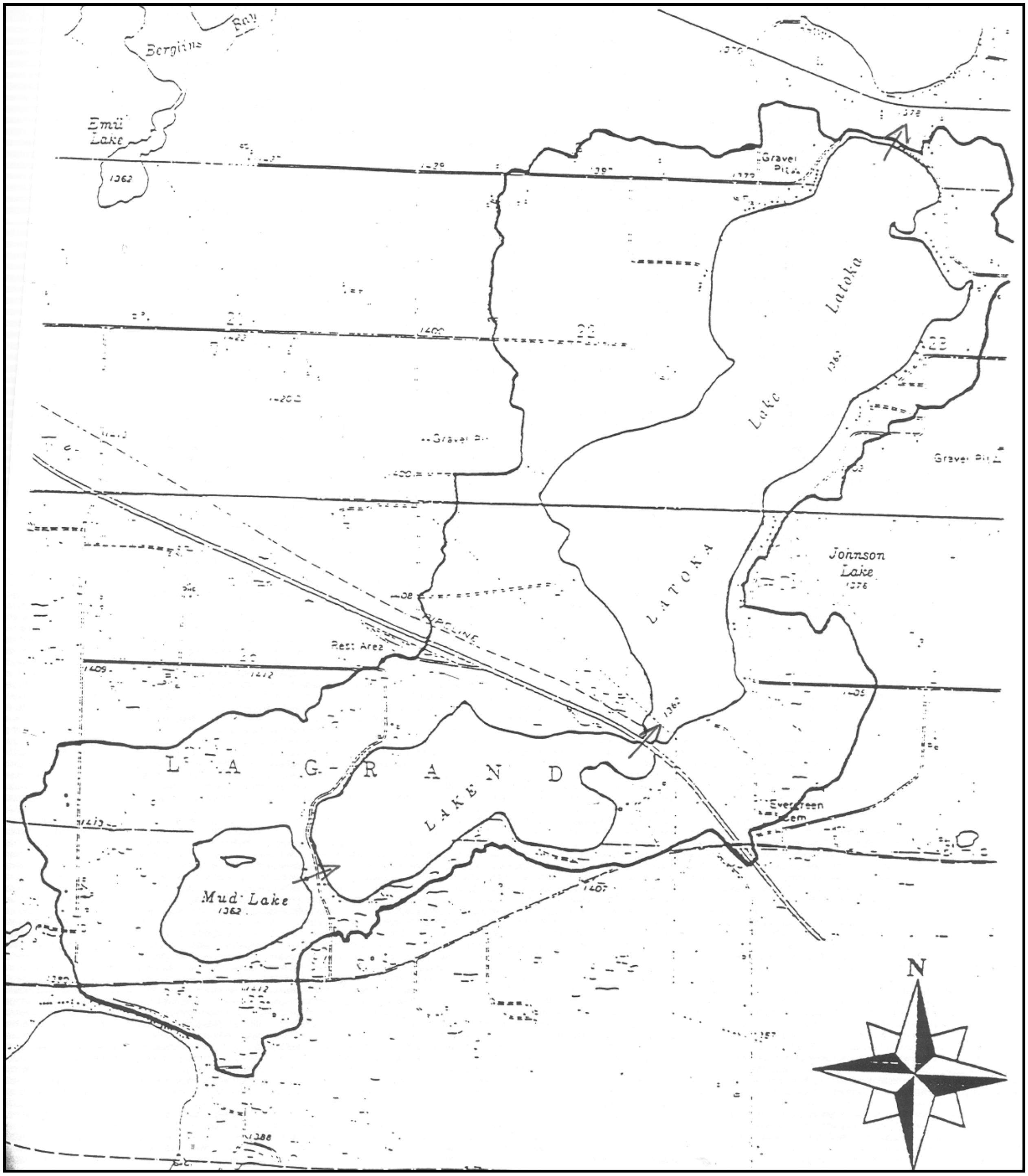
South Latoka (21-0106-02)

Year	TP	SEP	NP	CHLa	SEC	NC	SDM	SES	NS
1989	16.7	3.3	3	3.4	1.6	2	3.7	0.1	8
1990	25.0	9.6	4	2.3	0.9	3	4.7	0.3	14
1991	22.5	2.5	4	2.9	0.8	4	3.8	0.2	8
1992	17.5	4.8	4	2.8	0.7	4	3.5	0.1	11
1993	32.4	19.5	8	4.2	0.9	8	3.6	0.2	16
1994	30.0	7.1	4	2.0	1.0	4	3.7	0.3	4
1995	50.0	12.9	4	3.3	0.3	4	3.3	0.2	13
1996	32.5	8.5	4	2.8	0.8	4	3.8	0.1	18
1997	25.0	6.5	4	2.0	0.6	4	3.5	0.1	17
1998	12.0	0.0	4	3.3	0.5	4	3.8	0.2	11
1999							3.9	0.1	11
2000							4.2	0.2	9
2001							4.4	0.3	9
2002							4.4	0.1	12
2003							3.9	0.2	8
2005	20.6	3.2	7	3.4	0.4	7	4.1	0.3	7

Year = Year Monitored
TP = Total Phosphorus (ppb or µg/L)
SEP = Standard Error for TP
NP =# TP samples/yr
CHLa = Chlorophyll-*a* (ppb or µg/L)
SEC = Standard Error for CHLa
NC = # CHLa samples/yr
SDM = Secchi transparency (meters)
SES = Standard Error for SDM
NS = #Secchi readings/yr

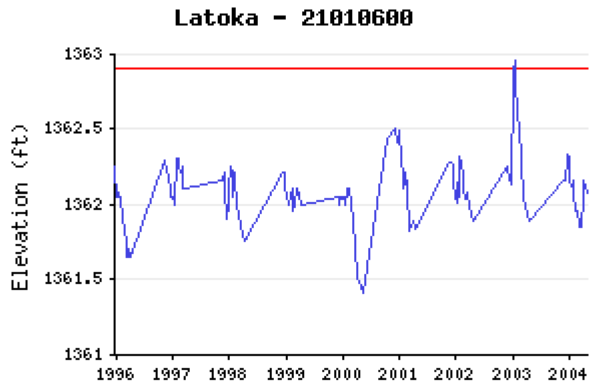
Appendix 2. Watershed Maps for Lake Latoka

(Maps provided by 1993 LAP Report)



Appendix 3. Lake Level Information for Lake Latoka
(From MN DNR Web site: www.dnr.state.mn.us)

Period of record: 09/10/1937 to 10/09/2004
of readings: 203
Highest recorded: 1362.95 ft (07/03/2003)
Lowest recorded: 1356.8 ft (09/10/1937)
Recorded range: 6.15 ft
Average water level: 1362.08 ft
Last reading: 1362.07 ft (10/09/2004)
OHW elevation: 1362.9 ft
Datum: 1929 (ft)



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Appendix 4. Status of the Fishery for Lake Latoka

Excerpts from MN DNR Web Site: www.dnr.state.mn.us
For a complete report, please visit the MDNR web site

<u>Lake Latoka Status of the Fishery (as of 07/09/2001):</u>

Walleye gillnet catches were similar to previous survey results. Average weight of sampled fish was 3.0 pounds, with the largest fish measuring 30.0 inches. Latoka is known for a moderate population of large walleye and would be a good choice for a wall-hanger walleye. Northern pike remain abundant and small; the largest fish measuring 33.1 inches. Bluegills are abundant with average size between 6 and 7 inches and should provide quality angling in the near future. Largemouth bass electrofishing survey resulted in a catch of 37.3 fish per hour. The largest fish measured just over 18.0 inches.

GLOSSARY

Alkalinity: Capacity of a lake to neutralize acid.

Chloride: Common anionic form of chlorine which carries one net negative charge. A common anion in many waters.

Chlorophyll-*a*: The main pigment in algae. It is used to measure aquatic productivity.

Ecoregion: Areas of relative homogeneity based on land use, soils, topography and potential natural vegetation.

Epilimnion: Most lakes form three distinct layers of water during summertime weather. The epilimnion is the upper layer and is characterized by warmer and lighter water.

Eutrophic: Describes a lake of high photosynthetic productivity. Nutrient rich.

Hypolimnion: The bottom layer of lake water during the summer months. The water in the hypolimnion is denser and much colder than the water in the upper two layers.

Littoral Area: The shallow areas around a lake's shoreline, dominated by aquatic plants.

Mesotrophic: Describes a lake of moderate photosynthetic productivity.

Metalimnion: The middle layer of lake water during the summer months.

Nitrite/Nitrate Nitrogen: The weight of concentration of the nitrogen in the nitrate ion.

Oligotrophic: Describes a lake of low photosynthetic productivity.

Phosphate: An essential nutrient containing phosphorus and oxygen. Phosphate is often a critical nutrient in lake eutrophication management.

Phosphorus: Phosphorus is an element that can be found in commercial products such as foods, detergents, and fertilizers as well as in larger amounts naturally in organic materials, soils, and rocks. Phosphorus is one of many essential plant nutrients. Phosphorus forms are continually recycling throughout the aquatic environment. All forms are measured under the term "Total Phosphorus" in parts per billion (ppb).

Photosynthesis: The process by which green plants produce oxygen from sunlight, water and carbon dioxide.

Secchi Disk: A metal plate used for measuring the depth of light penetration in water.

Suspended Solids: Small particles that hang in the water column and create turbid, or cloudy conditions.

Thermocline: During summertime, the middle layer of lake water. Lying below the epilimnion, this water rapidly loses warmth. Zone of maximum change in temperature over the depth interval.

Trophic Status: The level of growth or productivity of a lake as measured by phosphorus content, algae abundance, and depth of light penetration.

Turnover (Overturn): Warming or cooling surface waters, activated by wind action, mix with lower, deeper layers of water.

Watershed: Geographical area that supplies water to a stream, lake, or river.

Zooplankton: Microscopic animals.

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