Citizen Lake-Monitoring Program (CLMP+):
Advanced Volunteer Lake Monitoring on Boot Lake

March 2007

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Citizen Lake-Monitoring Program (CLMP+): Advanced Volunteer Lake Monitoring on Boot Lake, Becker County

MN DNR Lake ID 03-0030

Environmental Analysis and Outcomes Division
Water Monitoring Section
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Citizen Lake-Monitoring Program (CLMP+): Advanced Volunteer Lake Monitoring on Boot Lake

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 Becker, Itasca, and Polk Counties in 2006. In Becker County, Boot Lake was selected for monitoring during the 2006 season. All equipment and analytical costs for the samples were provided and paid for by the Minnesota Pollution Control Agency (MPCA).

As part of the CLMP+, volunteers collect water chemistry samples and temperature profiles twice per month along with taking weekly Secchi transparency readings. After sampling, the volunteers dropped off their samples at a predetermined location. For Boot Lake, Michelle Prosser, Hubbard County Soil and Water Conservation District (SWCD), coordinated the sample drop-off/pick up schedule for the samples. Special thanks to volunteer Roger Stecker who helped make this project a success. MPCA staff and volunteer monitors collected quality assurance and quality control (QA/QC) samples for this project as well.

The MPCA core lake-monitoring programs include the CLMP and the Lake Assessment Program (LAP). In addition to these programs, the MPCA annually monitors numerous lakes to provide baseline water quality data, provide data for potential LAP 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 depth can have a significant influence on lake processes and water quality. One such process is *thermal stratification* (formation of distinct temperature layers, see Figure 1a), 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* (Figure 1c). These lakes fully-mix or turn-over twice per year; typically in spring and fall (Figure 1d). Shallow lakes (maximum depths of 20 feet or less) in contrast, typically do not stratify and are often referred to as *polymictic* (Figure 1b). 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.

Figure 1. Diagrams of Lake Layers and Mixing

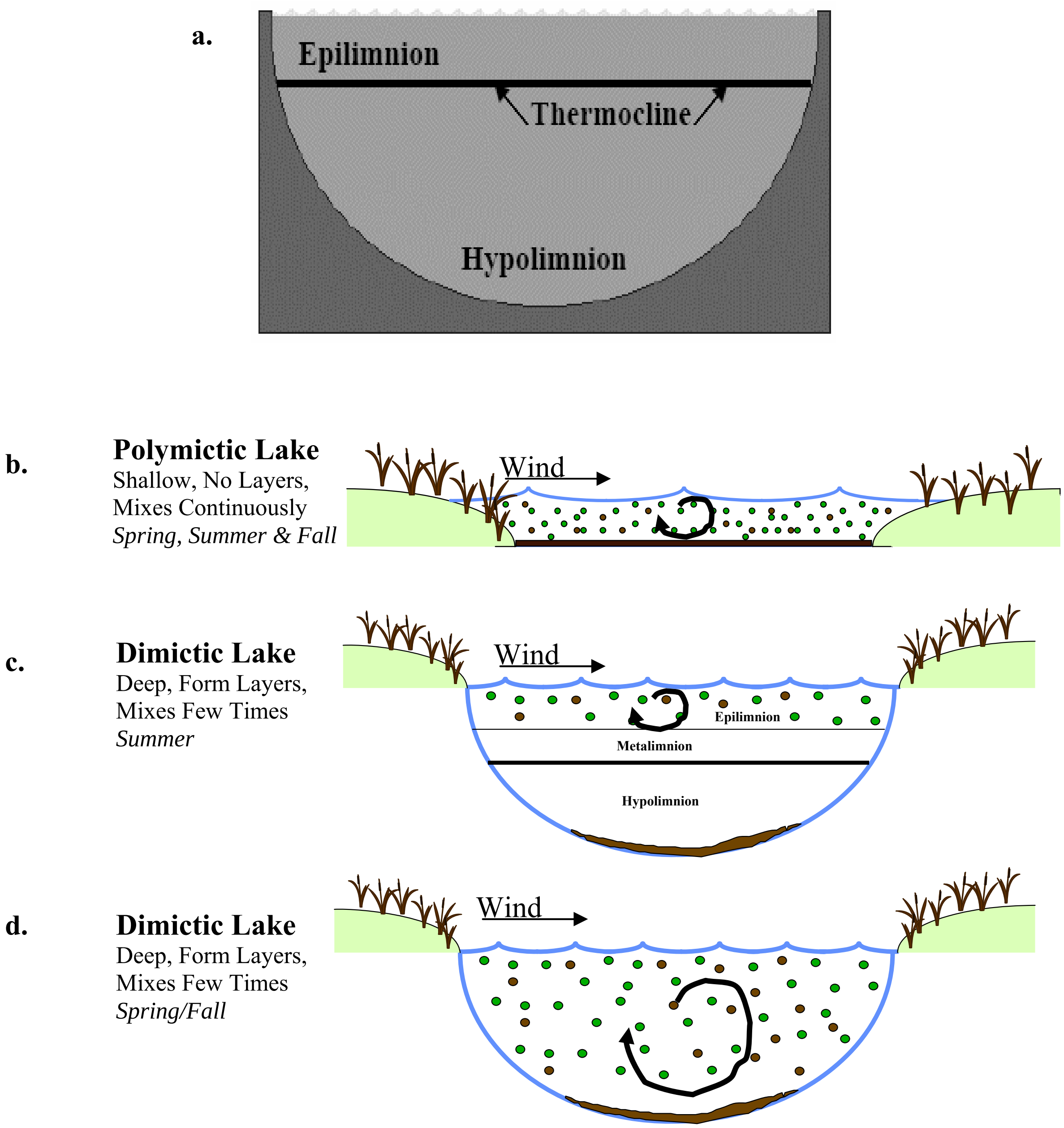
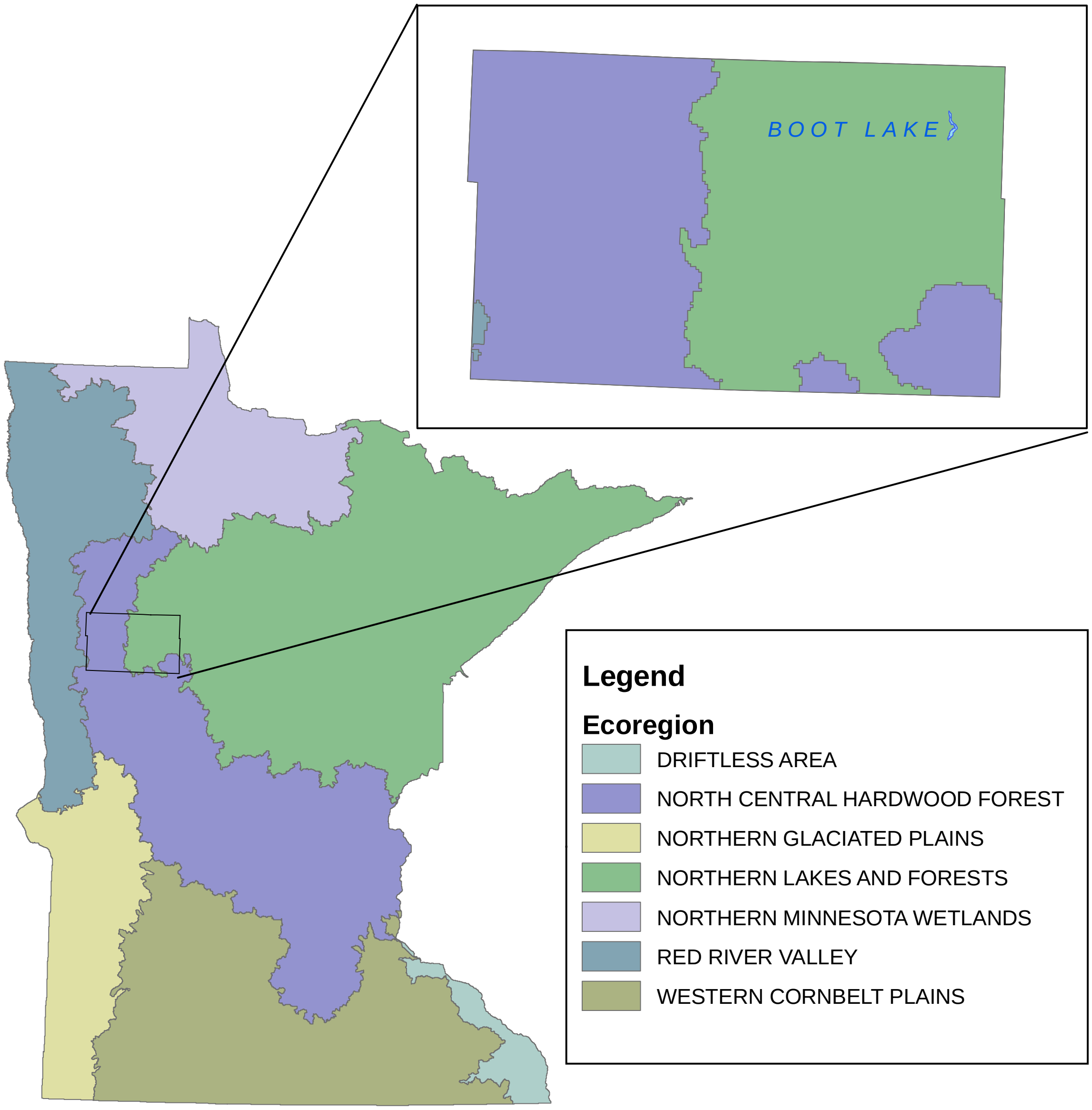


Figure 2. Lake Locations and Ecoregion Map



The state of Minnesota is divided into seven ecoregions (Figure 2), based on soils, landform, potential natural vegetation, and land use. Boot Lake is located in the Northern Lakes and Forests ecoregion. Comparing a lake's water quality to that of reference lakes in the same ecoregion provides one basis for characterizing the condition of the lake. A lake of good water quality would have Secchi, total phosphorus, and chlorophyll-*a* concentrations equal to, or better than, the range of values calculated based on minimally impacted reference lakes in their respective ecoregion. Boot Lake will be compared to the NLF ecoregion values (Table 1).

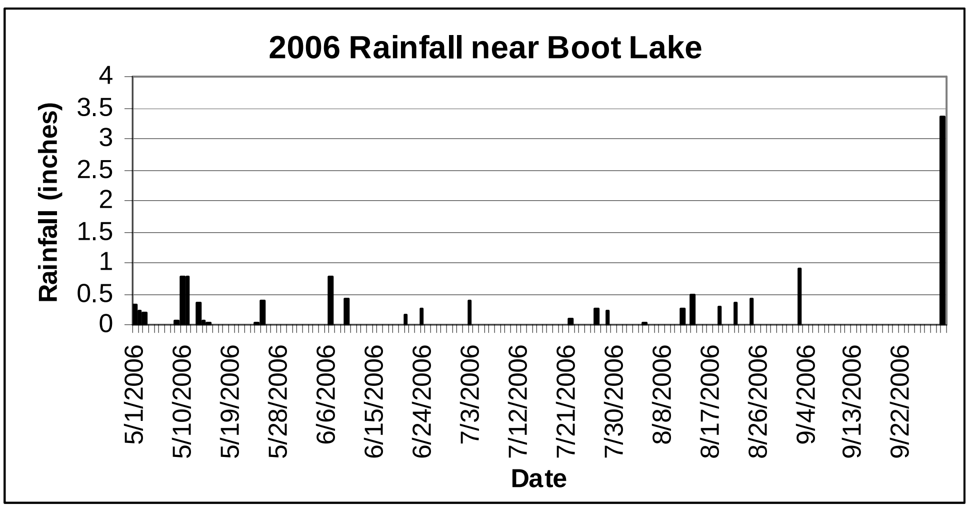
Watershed

Boot Lake has a small, rather isolated watershed. There is one intermittent outlet on the east side of the lake. No major tributaries exist for Boot Lake. It is possible that Boot Lake receives or contributes to groundwater flows; however, this study did not consider groundwater interaction.

Precipitation

Precipitation for 2006 for the Two Inlets area is summarized in Figure 3. Summer 2006 was very dry, with precipitation from May 1st to September 4th accumulating only 8.57 inches (Appendix 2). There was a gap in the data from September 5th to September 29th. The only significant rainfall event (greater than 1”) occurred on September 30th (3.35”). Major events can have a strong influence on runoff and total phosphorus loading to the lakes. DNR data for the 2006 water year (October 2005 – September 2006) indicated that precipitation was normal (26 inches) for this area (Appendix 3).

Figure 3. Summer 2006 Rainfall in Itasca State Park, near Two Inlets, MN



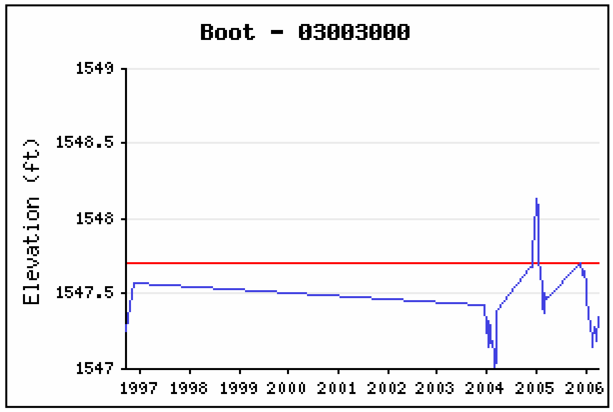
Fisheries

Boot Lake was surveyed by the Minnesota Department of Natural Resources (DNR) in August 2001. The lake is managed for walleye by the Park Rapids Area Fisheries Office; Boot Lake is best known for walleye, but also supports angling for northern pike, largemouth bass, and panfish.

The walleye population does not appear to be self sustaining, with a DNR stocking program providing most of the walleye in the lake. The food base for walleye is of concern, as yellow perch populations are very low, and have been declining since the 1991 survey.

Northern pike are smaller than expected, but maintain a healthy population – past surveys have also found few large pike. Moderate numbers of largemouth bass and bluegills are found in Boot Lake.

Lake Level



The DNR, in conjunction with volunteers, collected lake level data through the Lake Level Minnesota program. Data has been collected on Boot Lake from 1997 through 2006 (61 data points). The level of Boot Lake has ranged 1.12 feet in that period, with a low of 1547.01 feet in August of 2004 to a high of 1548.13 feet in June of 2005.

Part 2: 2006 Lake Surveys

Methods

This report includes data from 2006 as well as previously collected data available in STORET, U.S. Environmental Protection Agency's (EPA) national water quality data bank (Appendix 1). The following discussion assumes familiarity with basic limnology terms as used in a "Citizens Guide to Lake Protection" (http://www.pca.state.mn.us/water/lakeprotection.html) and 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.

Two sites in Boot Lake were monitored six times from May to August 2006. 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 Boot Lake on two 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.

Additional information, such as bathymetric (contour) maps, and site locations, were obtained from the DNR's *Lake Finder* Web site (http://www.dnr.state.mn.us/lakefind/index.html) and from U.S. Geological Survey quad maps. Watershed area information for the lakes was obtained from the DNR Data deli web page and University of Minnesota LANDSAT imagery.

Data Analysis

A series of graphs are presented for each lake including: TP, chlorophyll-*a*, Secchi disk transparency, temperature profiles, and algal composition. The raw data for Boot Lake (Site 203 and 204) are available in Appendix 1.

The Quality Assurance/Quality Control (QA/QC) samples were taken routinely throughout the sampling season. Twenty-one field duplicate TP samples and 17 field duplicate chlorophyll-*a* samples were taken from lakes in Becker, Itasca, and Polk counties. 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, 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 21 samples, the percent difference ranged from 0 – 100 percent of the original sample, with the majority (76 %) falling within the 0 – 15 percent range. Of the 17 paired chlorophyll-*a* samples, the percent difference range was 1 – 79 percent, with the majority (71 %) 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.

The Minnesota Lake Eutrophication Analysis Procedure (MINLEAP) computer model was used to predict the TP concentration, chlorophyll-*a* concentration, and Secchi disk transparency of each lake based on the lake area, lake depth, and the area of the lake's watershed. Mean depth and volumes were estimated for Boot Lake based on available bathymetric maps. 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). Carlson's Trophic State Index (TSI) values were also calculated for each site (Table 1, Figure 4).

Table 1. Summer-Mean Water Quality Parameters for Boot Lake.
(Based on 2006 summer epilimnetic data.)

Parameter	Boot 203	Boot 204	Typical Range for NLF[1] Ecoregion
TP (µg/L)	10	10	14 – 27
Chl-a (µg/L)[2]	1.3	1.3	4 – 10
Secchi (m)	6.5	7	2.4 – 4.6
Secchi (ft)	21.4	22	8 – 15
TKN (mg/L)	0.3	0.3	0.40 – 0.75
Alkalinity (mg/L)	160	160	40 – 140
Color (Pt-Co Units)	5	5	10 – 35
Chloride(mg/L)	2	2.1	0.6 – 1.2
TSS (mg/L)[3]	< 1	< 1	< 1 – 2
TSIS (mg/L)[4]	< 1	< 1	< 1 – 2
Conductivity(umhos/cm)	284	286	50 - 250
TN:TP ratio	30:1	30:1	25:1 – 35:1
TSI Secchi	33	32	
TSI Chlorophyll-a	33	33	
TSI Phosphorus	37	37	
TSI Average	35	34	

[1]NLF Ecoregion" range is the 25th – 75th percentile of summer means from ecoregion reference lakes.
[2]Chlorophyll-*a* measurements have been corrected for pheophytin.
[3]TSS = Total Suspended Solids. [4]TSIS = Total Suspended Inorganic Solids

Table 2a. Lake Morphometry and Watershed Areas for Boot Lake.

Lake	Lake	Lake Basin	Littoral Area		Immediate Watershed	Total Watershed Area	Total Watershed To Lake	Max. Depth	Average Depth	Lake Volume
Name	ID	Acres	Acres	% Littoral	Acres	Acres	Ratio	Ft.	Ft.	Acre-Ft.
Boot	03-0030	348	81	23	1,567	1,567	4.5:1	109	40	13,920

[1]Mean depth and volume was *estimated* on Boot Lake.
[2]Watershed area calculated from MN DNR data and USGS web site:
http://gisdmnspl.cr.usgs.gov/watershed/index.htm
[3]Watershed:lake area ratio based on TOTAL watershed.
[4]Provided by MN DNR LakeFinder website: http://www.dnr.state.mn.us/lakefind/index.html

Table 2b. Watershed Land Use

Land Use	Forest	Water/Wetlands	Pasture/Open	Agriculture	Urban
Boot	42	27	0	25	6
NLF Ecoregion (%)	54 - 81	14 – 31	0 - 6	< 1	0 - 7

Boot Lake Watershed Land Use

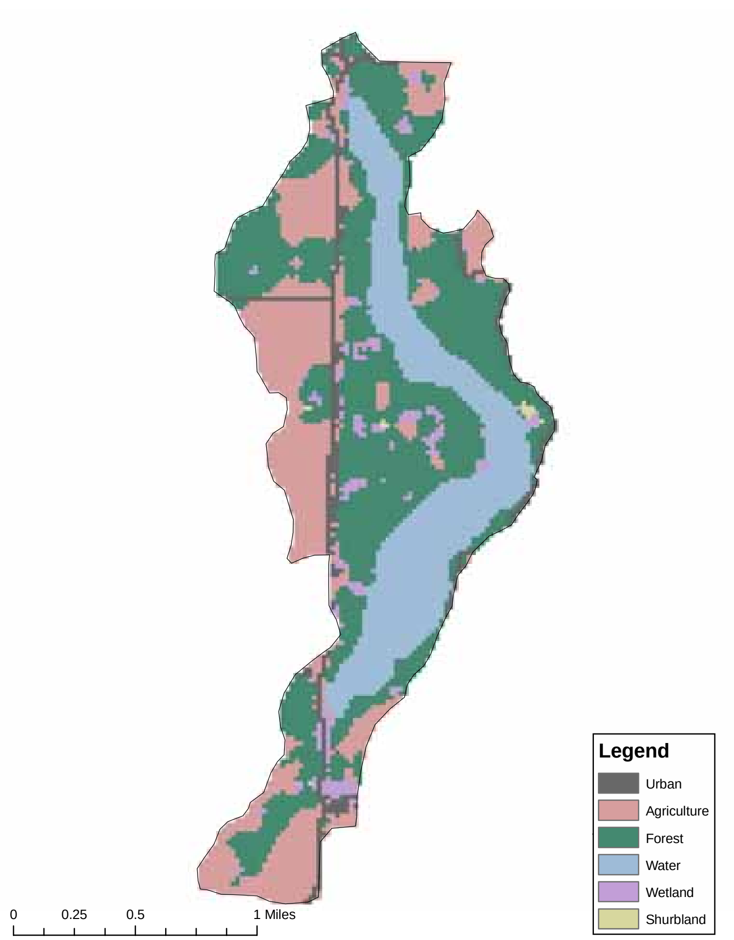


Figure 4. **Carlson's Trophic State Index, based on a scale of 0 – 100. (Carlson 1977)**

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.

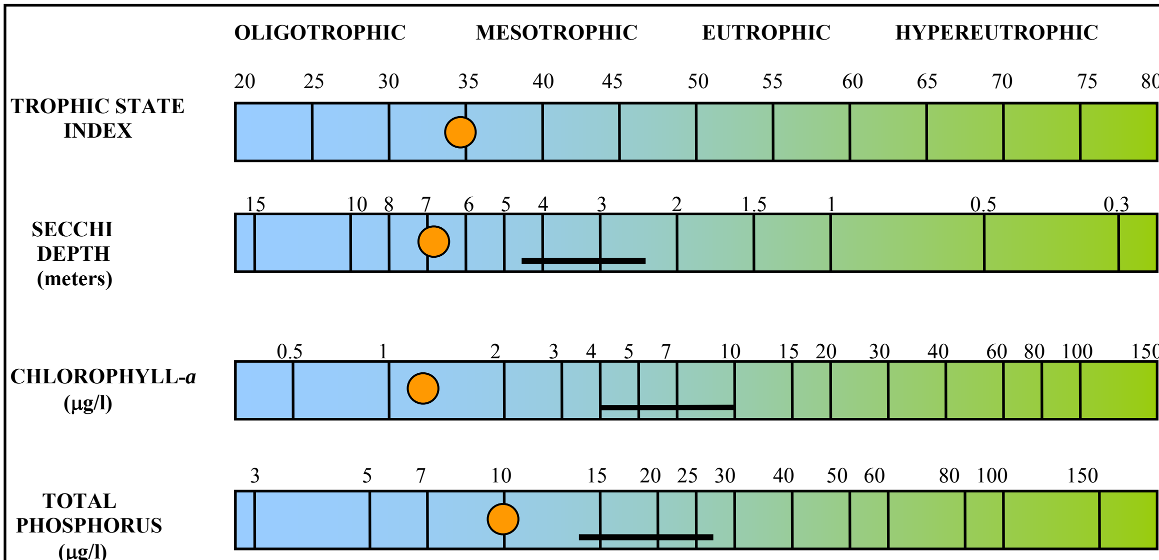
TSI 40 - 50 Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.

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.

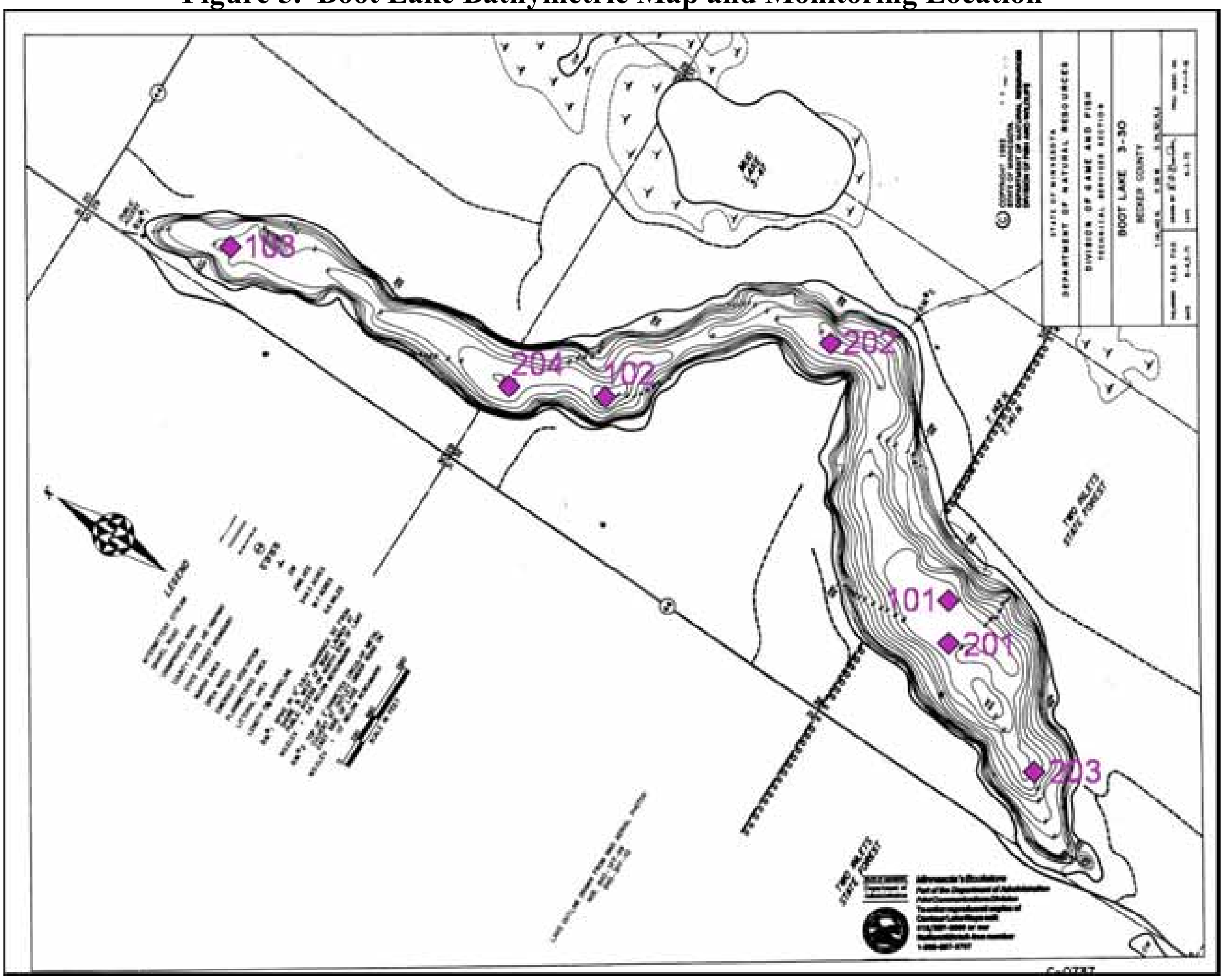
NLF Ecoregion Range 25th – 75th percentile: Boot:

BOOT (03-0030)

Boot Lake is a moderate-sized (348 acres), deep lake with a maximum depth of 109 feet (33 m) and estimated mean depth of 40 feet (12 m). The lake is located about six miles northwest of Two Inlets, Minnesota. The lake is deep, with only 23% of the lake area being littoral; there is one public access for the lake located at the north end. Boot Lake's direct (immediate drainage) and total drainage (all contributing) watershed areas are the same, 2.5 mi^2. The watershed to lake ratio is rather small at 4.5:1 (Table 2a). The water residence time for Boot Lake is on the order of 10 years. Boot Lake was one of our ecoregion reference lakes for the NLF ecoregion. As such, there will be some previous data for comparison.

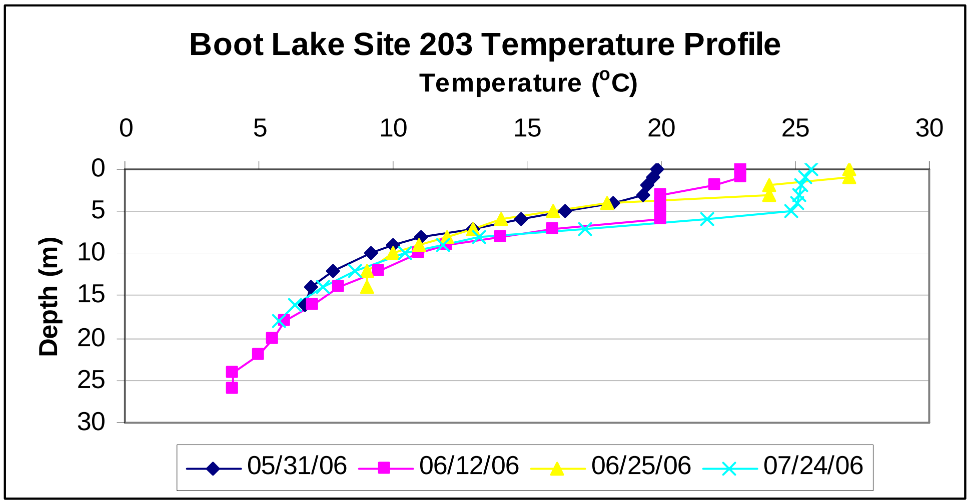
Water quality data was collected in May, June, July, August 2006 by volunteer Roger Stecker and MPCA staff. Two sites were used on Boot Lake for all dates: Site 203 – located in the southwest end of the lake and site 204 in the northern end of the lake (Figure 5).

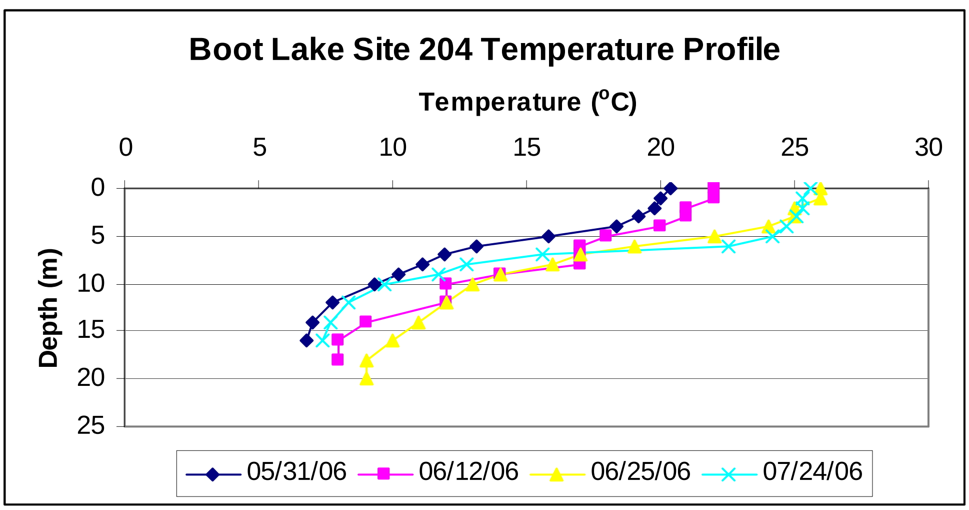
Figure 5. Boot Lake Bathymetric Map and Monitoring Location



Temperature data indicated that the lake was stratified through July (Figure 6) with a thermocline (zone of rapid temperature change) developing between 7 and 10 meters at both sites. Due to the depth of the sites, it was not possible to anchor the boat, and some drift did occur. This may explain why the drop in temperature is more gradual than what would be expected (Figure 6). Dissolved oxygen (DO) concentrations peaked near a depth of 7 meters at both sites; below that depth, the concentration declined sharply at both site 203 and 204. To a depth of 10 meters, the DO concentration remained above the 5 mg/L necessary to support game fish.

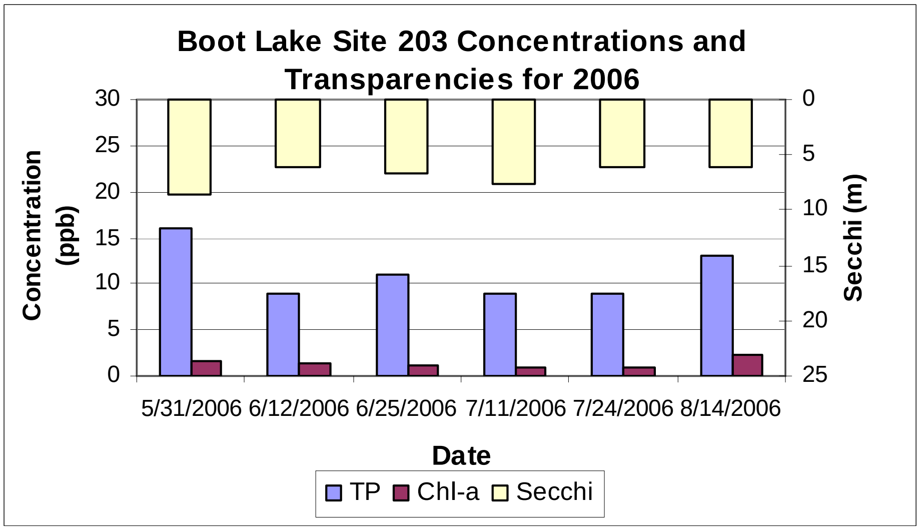
Figure 6. Boot Lake Temperature Profile Data for 2006

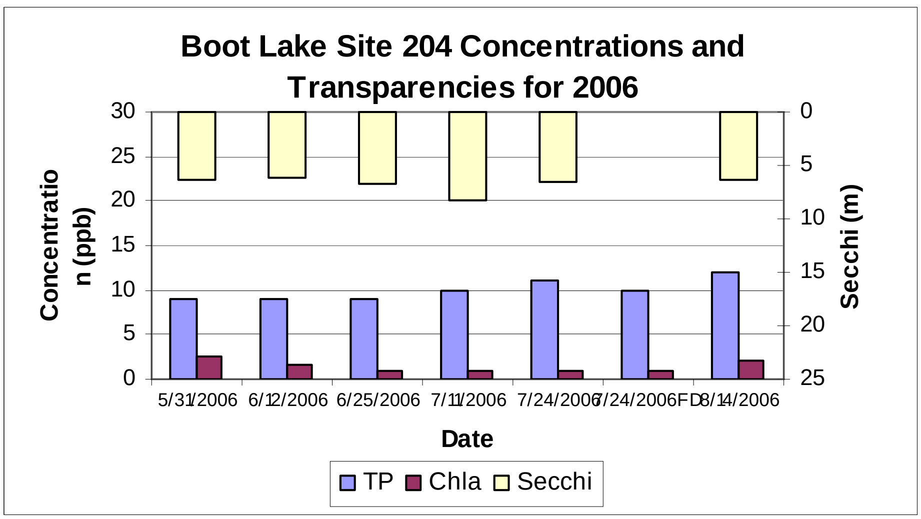




Total phosphorus (TP) concentrations averaged 10 µg/L (micrograms per liter or parts per billion) at site 203 and 204 in Boot Lake during the summer of 2006. The TP summer mean concentration is below (better than) the range of concentrations for reference lakes in the NLF ecoregion (Table 1). TP concentrations ranged from 9 – 16 µg/L at site 203 and 9 – 12 µg/L at site 204 (Figure 7). Hypolimnetic (near bottom) TP samples were collected in May and July. Hypolimnetic TP concentrations were slightly elevated, which indicates that phosphorus was being released from the bottom sediments, as a result of low (or no) DO at the water-sediment interface.

Figure 7. Boot Lake Concentrations and Transparencies for 2006



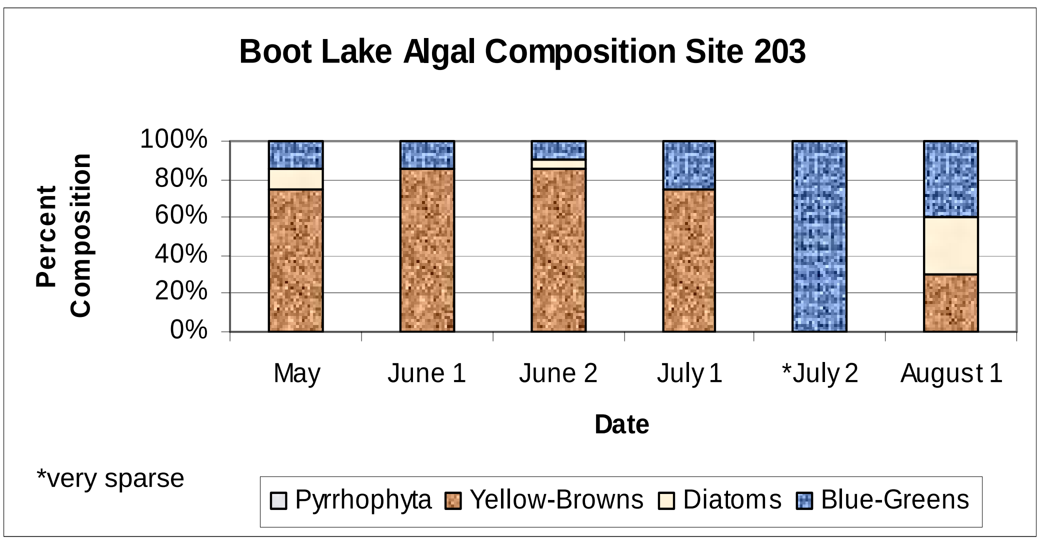


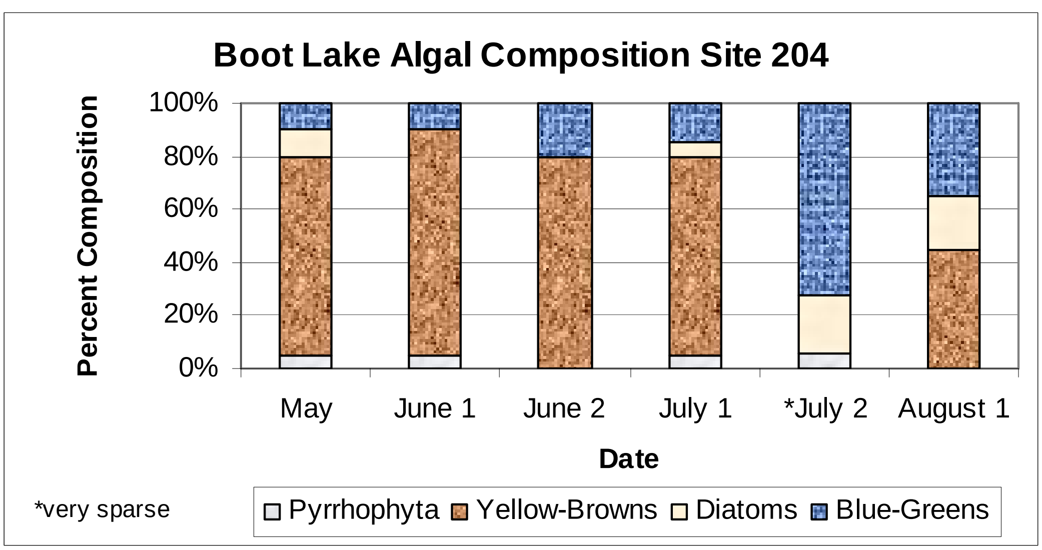
Chlorophyll-*a* concentrations for Boot Lake averaged 1.3 µg/L at both sites and were below (better than) the NLF ecoregion range (Table 1). Concentrations on Boot Lake ranged from 0.8 – 2.5 µg/L (Figure 7). While chlorophyll-*a* varied little across the season, values dropped from May to July and then began increasing in concentration through August.

Secchi disk transparency on Boot Lake at site 203 ranged from 20 feet (6.1 meters) in late July and August to 28 feet (8.5 meters) in May (Figure 7) and averaged 21.4 feet (6.5 meters). At site 204, transparency ranged from a low of 21 feet (6.4 m) in May and August to a high of 27 feet (8.2 m) in early July with an average of 22 feet (7 m). These transparency measures are well below (better than) the typical range for NLF ecoregion reference lakes (Table 1). Along with transparency measurements, subjective measures of Boot Lake's "physical appearance" and "recreational suitability" were made. Lake conditions varied, and characterizations ranged from as "beautiful, crystal clear water" (Class 1) and "minor aesthetic problems, not quite crystal clear" (Class 2) during the summer for Boot Lake.

The composition of the phytoplankton (algae) population of Boot Lake is presented in Figure 8. Data are presented in terms of algal type. Samples were collected at Site 203 and 204. The yellow-browns (Chrysophyta) dominated throughout the summer, with diatoms and blue-greens present on most dates. The late July samples were very sparse (very few specimens available), and may not adequately represent the types of algae present. Mild nuisance algae bloom conditions (10 µg/l to 20 µg/l chlorophyll-*a*) were never present during sampling dates in 2006. A seasonal transition in algal types from diatoms to blue-greens is more typical for mesotrophic and eutrophic lakes in Minnesota.

Figure 8. Boot Lake Algal Populations for 2006





Other parameters, such as total suspended solids, total suspended inorganic solids, color, and total Kjeldahl nitrogen analyzed for Boot Lake were all below the typical range of values for NLF ecoregion reference lakes (Table 1). However, parameters such as alkalinity, conductivity, and chloride were slightly above the typical range based on NLF ecoregion reference lakes (Table 1).

Trophic State Index (TSI) values for Boot Lake compare favorably to each other (Table 1); indicating *oligotrophic to mesotrophic* conditions. The TSI calculated for phosphorus was slightly above that of Secchi and chlorophyll-*a*; this suggests that algae is being limited by something other than phosphorus concentration (likely zooplankton grazing). However, because the TSI values only varied by 4 - 5 points, the Secchi transparency should be a relatively good estimator for TP and chlorophyll-*a* values as well as an indicator of overall water quality for Boot Lake.

Part 3. Water Quality Trends

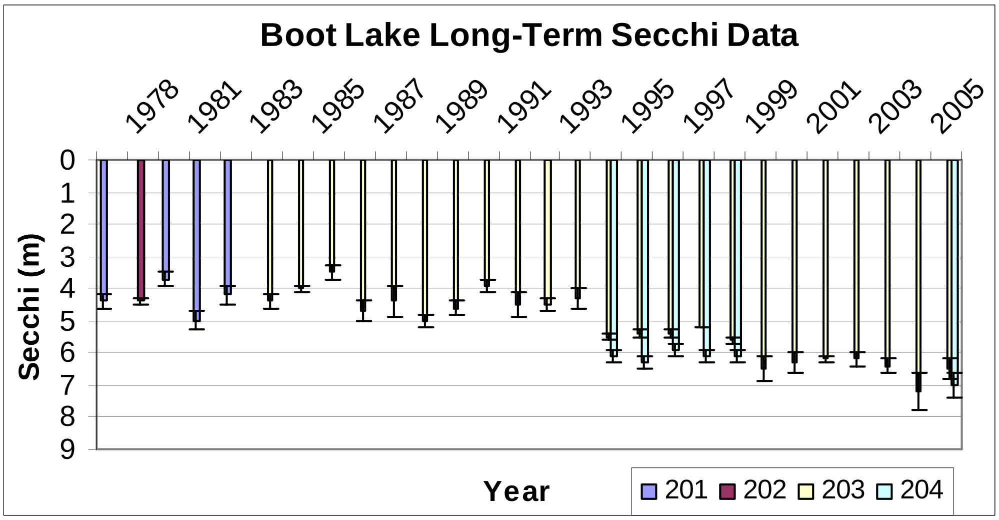
All available Secchi transparency data from STORET (U.S. EPA's national water quality database) were used for these assessments. The majority of the data collected is from volunteer lake monitors in the MPCA's Citizen Lake-Monitoring Program. For our trend analysis, we ran Kendall statistical test using 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. The figures of this section (Figures 9 - 10) 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. A small standard error means minimal variability in Secchi measurements during a given summer, whereas a large standard error implies a high degree of variability.

Where available, historical total phosphorus and chlorophyll-*a* concentrations were also plotted. There was limited data available from 1979 and 1985 through 1987 on Boot Lake. Seasonal averages (June to September) were calculated and standard error bars were included. This allows for some comparison between years.

Boot Lake (03-0030)

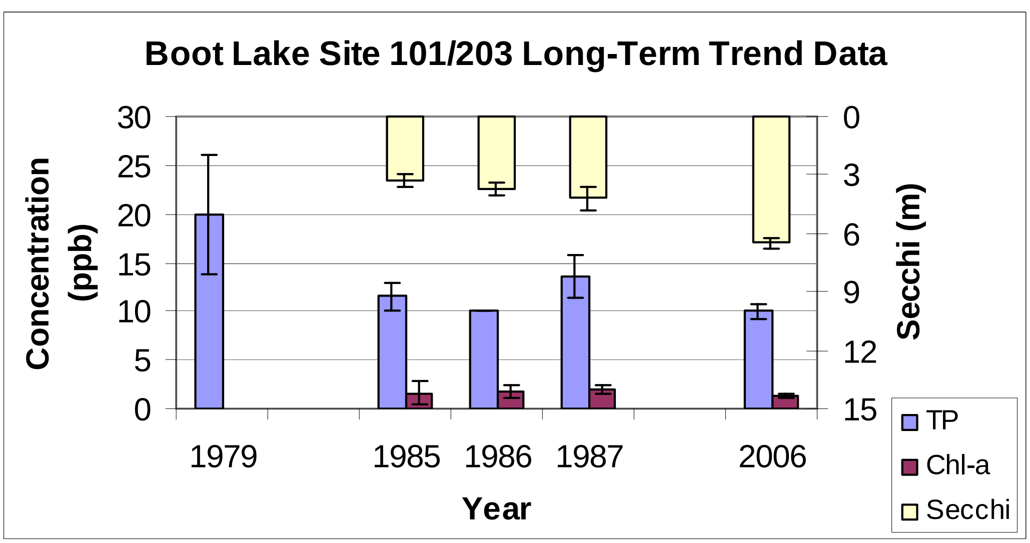
The Secchi transparency record for Boot Lake is quite long, from 1978 through 2006, with a continuous record for the 203 site (1984-2006). Using a Kendall statistical test on years with 4 or more transparency readings per summer (June – September) and 8 or more years of data, it was determined that Boot Lake is exhibiting a positive trend in transparency. The data available ranges from a low of 3.5 m (11.5 feet) in 1986 to a maximum of 7.2 m (23.6 feet) in 2005 with a long-term average of 5.2 m (17 feet) (Figure 9).

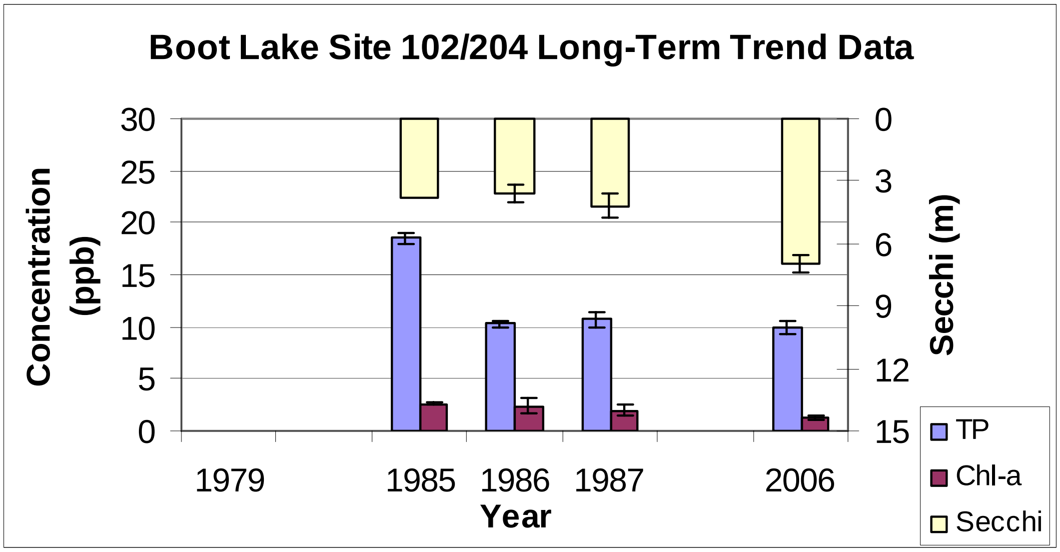
Figure 9. Boot Lake Long Term Secchi Data



Water quality samples were collected on Boot Lake in 1979 and 1985 through 1987. Data from 1985 – 1987 were collected as part of our ecoregion reference lake sampling and provide a good basis of comparison for 2006. The changes in Secchi transparency somewhat mirror changes in nutrient and chlorophyll-*a* concentrations (Figure 10). A comparison of 2006 TP and chlorophyll-*a* with the 1985 – 1987 data suggests that the recent measurements are slightly lower, which may account for the increase in Secchi over this period.

Figure 10. Boot Lake Long-Term TP, Chlorophyll-*a*, and Secchi Data





Part 4. Water Quality Modeling

The Minnesota Lake Eutrophication Analysis Procedure (MINLEAP) computer model was used to predict the TP concentration of Boot 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 and volume were estimated for Boot Lake. Watershed area information was derived for Boot Lake based on the USGS web site data and based on MNDNR minor watersheds.

Table 3. 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]
Boot 203	10.2 ± 0.8	13 ± 5	17.8	1.3 ± 0.3	2.6 ± 1.7	6.5 ± 0.3	4.4 ± 1.9
Boot 204	10 ± 0.6	13 ± 5	17.8	1.3 ± 0.3	2.6 ± 1.7	7 ± 0.4	4.4 ± 1.9

[1]Observed Values reported as summer-mean ± standard error.
[2]Predicted Values based on the Total watershed area.

Boot Lake
Boot Lake is a 348 acre lake with a total watershed area of 2.5 mi^2. Vighi-Chiaudani predicted a background TP concentration for Boot Lake (17.8 µg/l) that is higher than observed (Table 3) TP-loading for Boot Lake is estimated to be on the order of 97 kg P/yr, and the TP-retention coefficient is estimated at 0.79 (implies lake retains 79% of P loading). The predicted chlorophyll-*a* concentration for Boot Lake is higher, but not significantly different, than the 2006 observed value. As a result predicted Secchi transparency is also lower than observed. Overall, the model predictions consistently over predict the observed conditions and suggest that Boot Lake is well below predicted background conditions.

Part 5. Goal Setting

For Boot Lake, it would be desirable to maintain the currently low in-lake P-concentrations. The summer-mean P-concentration for this lake was better than both the predicted P-value and Vighi and Chiaudani “background” estimate.

Minnesota’s lakes and streams are assessed every two years as part of the 303(d) assessment process as required by USEPA. Waters found not to be in compliance with water quality standards are placed on the “TMDL” (total maximum daily load) or “Impaired Waters” list. Lakes are typically listed for mercury in fish tissue or for aquatic recreation use impairments (not meeting fishing and swimming use). Based on the thresholds for impairment (Table 4), Boot Lake is well below the criteria and based on this data would not be listed as impaired. Boot Lake is listed as “impaired” for include mercury (in fish tissue). Mercury is addressed extensively on MPCA’s website at: http://www.pca.state.mn.us/water/tmdl/tmdl-mercuryplan.html. In addition, lake specific fish consumption advisory is available online for Boot Lake at: http://www.dnr.state.mn.us/lakefind/fca/report.html?downum=03003000.

Table 4. Nutrient and Trophic Status Thresholds for Determination of Use Support for Lakes.

Ecoregion (TSI)	TP (ppb)	Chl-a (ppb)	Secchi (m)	TP Range (ppb)	TP (ppb)	Chl-a (ppb)	Secchi (m)
305(b) →	**Full Support**			**Partial Support to Potential 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)
NLF	**< 30**	**<10**	**≥ 1.6**	**30 – 35**	**> 35**	**> 12**	**< 1.4**
TSI	**< 53**	**< 53**	**< 53**	**53 – 56**	**> 56**	**> 55**	**> 55**

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

Part 6. Summary & Recommendations

During the summer of 2006, Boot Lake in Becker County was sampled by MPCA staff and volunteer Roger Stecker as a part of a monitoring program via CLMP "Plus". Boot Lake was selected because as it was prominent in the county, showed a strong positive Secchi transparency trend, and lacked recent water chemistry data in STORET beyond CLMP Secchi data. The combination of water chemistry and Secchi data provides a good baseline for these lakes, and allows verification of Secchi as an accurate predictor of trophic status in Boot Lake.

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

A. Secchi transparency monitoring: Boot Lake has participated in CLMP since 1978, and the average Secchi readings are below (better than) the range of values for reference lakes in the NLF ecoregion. 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 all the lakes 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 2006, Boot Lake TP concentrations were better than the typical range for minimally-impacted lakes in the NLF ecoregion. As such, Boot Lake would be considered to be *oligotrophic – mesotrophic*.

C. Water quality trends: Boot Lakes had a long, continuous record of Secchi data, with 28 years (1978-2006). Currently, Boot Lake is exhibiting a positive (improving) trend in transparency. Continued monitoring of Boot Lake will enhance our ability to further assess trends in this lake.

D. Model predictions: In general, MINLEAP over predicted the concentrations and transparencies on Boot Lake in 2006. Total phosphorus and chlorophyll-*a* observed values were lower, but not significantly lower than the MINLEAP predicted values. The observed Secchi depths were significantly deeper than predicted by MINLEAP.

E. Boot Lake is of excellent 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. DNR and Becker 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 lakes. The U.S. Fish and Wildlife Service at Fort Snelling may be able to provide technical and financial assistance for these activities.
- The lake associations should seek representation on boards or commissions that address land management activities so that their impact can be minimized. The booklet, Protecting Minnesota's Waters: The Land-Use Connection, may be a useful educational tool in this area.
- Macrophyte population and distribution maps for each lake may be beneficial to the associations. Exotic species such as *Eurasian water milfoil* and *curly-leaf pondweed* can dramatically impact quality resources such as Boot Lake in Becker County. 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. While their influence may not be express in terms of dramatic increases in algae in the lake, they may be expressed by increased near-shore weed growth or excessive attached algae on docks and plants. A house-to-house septic system survey may help the lake residents and Becker County determine if homeowners are somewhat familiar with the age and maintenance (pumping) of their systems and if further education is needed on proper maintenance of their systems. This may also help them encourage all homeowners with non-code systems to bring their systems up to code. If one exists, a lake association may want to facilitate a lake-wide schedule for pumping systems.

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 associations 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 Becker County as well. In April 2005, a new law came into effect restricting the use of phosphorus fertilizers in Minnesota. The lake associations, together with Becker County, should encourage the use of P-free fertilizers and educate property owners on the phosphorus ban 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.

H. Results from the Boot Lake CLMP+ show that properly trained volunteers can collect consistent and reliable data for use in lake water quality assessments, and are a resource that can and should be used to gather additional information.

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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Appendix

1. **Polk County CLMP+ Lakes Data for 2006 and Historical Data**

2. **Rainfall Data**

3. **Normal and Departure from Normal Water Year Precipitation Maps.**

Appendix 1. 2006 Boot Lake CLMP+ Data

Site	Date	Sample Depth	TP	Chl-a	Pheo	RMK	TSS	RMK	TSV	RMK	COL	RMK	ALK	CL	TKN	SDF	SDM	pH	Cond
		meter	ppb	ppb	ppb		mg/l		mg/l		cu		mg/l	mg/l	mgl	ft	m		
203	5/31/2006	0-2	16	1.6	0.21	K	1.2		1	K	5	Q	170	2.2	0.3	28	8.53	8.52	
203	5/31/2006	24	12																
203	6/12/2006	0-2	9	1.35	0.17	K										20	6.1		
203	6/25/2006	0-2	11	1.04	0.17	K										22	6.71		
203	7/11/2006	0-2	9	0.82	0.17	K										25	7.62		
203	7/24/2006	0-2	9	0.99	0.18	K	1	K	1	K	5		160	2	0.32	20.01	6.1	8.45	284
203	7/24/2006	18	16																
203	8/14/2006	0-2	13	2.21	0.19	K										20	6.1		
204	5/31/2006	0-2	9	2.5	0.31		1.6		1.2		5	Q	170	2.1	0.32	21	6.4	8.49	
204	5/31/2006	22	13																
204	6/12/2006	0-2	9	1.59	0.19	K										20	6.1		
204	6/25/2006	0-2	9	0.94	0.18	K										22	6.71		
204	7/11/2006	0-2	10	0.99	0.17	K										27	8.23		
204	7/24/2006	0-2	11	0.93	0.18	K	1	K	1	K	5		160	2.1	0.33	21.33	6.5	8.37	286
204	7/24/2006	16	10																
204 FD	7/24/2006	0-2	10	0.99	0.17	K													
204	8/14/2006	0-2	12	2.18	0.21											21	6.4		

LakeID = DNR Lake Identification Number
Lake Name = Name of Water Resource
TP = Total Phosphorus in parts per billion
Chla = Chlorophyll-*a* in parts per billion
Pheo = Pheophytin in parts per billion
SDF = Secchi Transparency in feet
pH = pH of sample (SU)
Cond = Conductivity in umhos/cm
TSS = Total Suspended Solids in mg/L
TSV = Total Suspended Volatile Solids in mg/L
COL = Color in Pt-Co units
Alk = Alkalinity in mg/L
CL = Chloride in mg/L
TKN = Total Kjeldahl Nitrogen in mg/L
RMK = Remark Codes for parameters *(K=less than the detection limit; Q = over holding time)*

Temperature and Dissolved Oxygen Profiles (C^o)

	Date	Time	Discrete Depth m	Temp °C	DO mg/L
203	**05/31/06**	**16:10**	**0**	**19.86**	**10.14**
203	05/31/06	16:10	1	19.7	9.94
203	05/31/06	16:10	2	19.46	9.84
203	05/31/06	16:10	3	19.32	9.63
203	05/31/06	16:10	4	18.18	9.95
203	05/31/06	16:10	5	16.4	10.07
203	05/31/06	16:10	6	14.78	9.29
203	05/31/06	16:10	7	12.97	10.18
203	05/31/06	16:10	8	11.02	9.5
203	05/31/06	16:10	9	10.02	8.87
203	05/31/06	16:10	10	9.2	8.25
203	05/31/06	16:10	12	7.79	6.98
203	05/31/06	16:10	14	6.97	6.76
203	05/31/06	16:10	16	6.68	6.43
203	**06/12/06**	**10:30**	**0**	**23**	
203	06/12/06	10:30	1	23	
203	06/12/06	10:30	2	22	
203	06/12/06	10:30	3	20	
203	06/12/06	10:30	4	20	
203	06/12/06	10:30	5	20	
203	06/12/06	10:30	6	20	
203	06/12/06	10:30	7	16	
203	06/12/06	10:30	8	14	
203	06/12/06	10:30	9	12	
203	06/12/06	10:30	10	11	
203	06/12/06	10:30	12	9.5	
203	06/12/06	10:30	14	8	
203	06/12/06	10:30	16	7	
203	06/12/06	10:30	18	6	
203	06/12/06	10:30	20	5.5	
203	06/12/06	10:30	22	5	
203	06/12/06	10:30	24	4	

	Date	Time	Discrete Depth m	Temp °C	DO mg/L
203	06/12/06	10:30	26	4	
203	**06/25/06**	**16:30**	**0**	**27**	
203	06/25/06	16:30	1	27	
203	06/25/06	16:30	2	24	
203	06/25/06	16:30	3	24	
203	06/25/06	16:30	4	18	
203	06/25/06	16:30	5	16	
203	06/25/06	16:30	6	14	
203	06/25/06	16:30	7	13	
203	06/25/06	16:30	8	12	
203	06/25/06	16:30	9	11	
203	06/25/06	16:30	10	10	
203	06/25/06	16:30	12	9	
203	06/25/06	16:30	14	9	
203	**07/11/06**	**16:00**	**0**		
203	**07/24/06**	**14:15**	**0**	**25.59**	**8.43**
203	07/24/06	14:15	1	25.35	8.52
203	07/24/06	14:15	2	25.21	8.5
203	07/24/06	14:15	3	25.15	8.44
203	07/24/06	14:15	4	25.07	8.4
203	07/24/06	14:15	5	24.88	8.39
203	07/24/06	14:15	6	21.72	9.84
203	07/24/06	14:15	7	17.15	11.34
203	07/24/06	14:15	8	13.18	11.69
203	07/24/06	14:15	9	11.89	10.82
203	07/24/06	14:15	10	10.46	10.14
203	07/24/06	14:15	12	8.56	6.02
203	07/24/06	14:15	14	7.37	4.6
203	07/24/06	14:15	16	6.37	3.89
203	07/24/06	14:15	18	5.73	2.67

	Date	Time	Discrete Depth m	Temp °C	DO mg/L
204	**05/31/06**	**16:40**	**0**	**20.36**	**8.34**
204	05/31/06	16:40	1	20.02	8.68
204	05/31/06	16:40	2	19.74	9.07
204	05/31/06	16:40	3	19.19	9.5
204	05/31/06	16:40	4	18.38	9.95
204	05/31/06	16:40	5	15.83	10.5
204	05/31/06	16:40	6	13.1	10.89
204	05/31/06	16:40	7	11.96	10.05
204	05/31/06	16:40	8	11.11	9.71
204	05/31/06	16:40	9	10.22	8.65
204	05/31/06	16:40	10	9.3	7.31
204	05/31/06	16:40	12	7.79	6.04
204	05/31/06	16:40	14	7.02	5.05
204	05/31/06	16:40	16	6.82	4.46
204	**06/12/06**	**10:45**	**0**	**22**	
204	06/12/06	10:45	1	22	
204	06/12/06	10:45	2	21	
204	06/12/06	10:45	3	21	
204	06/12/06	10:45	4	20	
204	06/12/06	10:45	5	18	
204	06/12/06	10:45	6	17	
204	06/12/06	10:45	7	17	
204	06/12/06	10:45	8	17	
204	06/12/06	10:45	9	14	
204	06/12/06	10:45	10	12	
204	06/12/06	10:45	12	12	
204	06/12/06	10:45	14	9	
204	06/12/06	10:45	16	8	
204	06/12/06	10:45	18	8	
204	**06/25/06**	**15:30**	**0**	**26**	
204	06/25/06	15:30	1	26	
204	06/25/06	15:30	2	25	
204	06/25/06	15:30	3	25	
204	06/25/06	15:30	4	24	
204	06/25/06	15:30	5	22	
204	06/25/06	15:30	6	19	
204	06/25/06	15:30	7	17	
204	06/25/06	15:30	8	16	
204	06/25/06	15:30	9	14	
204	06/25/06	15:30	10	13	
204	06/25/06	15:30	12	12	
204	06/25/06	15:30	14	11	
204	06/25/06	15:30	16	10	
204	06/25/06	15:30	18	9	
204	06/25/06	15:30	20	9	
204	**07/11/06**	**15:00**	**0**	**26**	
204	**07/24/06**	**13:45**	**0**	**25.61**	**8.33**
204	07/24/06	13:45	1	25.33	8.5
204	07/24/06	13:45	2	25.28	8.51
204	07/24/06	13:45	3	25.1	8.44
204	07/24/06	13:45	4	24.69	8.46
204	07/24/06	13:45	5	24.17	8.57
204	07/24/06	13:45	6	22.57	9.12
204	07/24/06	13:45	7	15.59	10.8
204	07/24/06	13:45	8	12.74	10.2
204	07/24/06	13:45	9	11.75	7.57
204	07/24/06	13:45	10	9.68	4.24
204	07/24/06	13:45	12	8.35	1.73
204	07/24/06	13:45	14	7.71	1.45
204	07/24/06	13:45	16	7.38	0.83

Historic Data

101/203	TP	SEP	Chl-a	SEC	Secchi (m)	SES
1979	20	6.1				
1985	11.5	1.5	1.6	1.2	3.3	0.3
1986	10	0	1.7	0.7	3.7	0.3
1987	13.5	2.2	2	0.4	4.2	0.6
2006	10	0.8	1.3	0.3	6.5	0.3

102/204	TP	SEP	Chl-a	SEC	Secchi (m)	SES
1979						
1985	18.5	0.5	2.6	0.07	3.78	
1986	10.3	0.3	2.4	0.8	3.6	0.4
1987	10.7	0.7	2	0.6	4.2	0.6
2006	10	0.6	1.3	0.2	7	0.4

Lake Name = Name of Water Resource
Lake ID = DNR Lake Identification Number
Year = Year Monitored
SDF = Secchi Transparency in feet
SES = Standard Error for SDF
NS = # Secchi Readings/yr

TP = Total Phosphorus in parts per billion
SEP = Standard Error for TP
NP = # TP samples/yr
Chla = Chlorophyll-*a* in parts per billion
SEC = Standard Error for Chl-a
NC = # Chl-a samples/yr

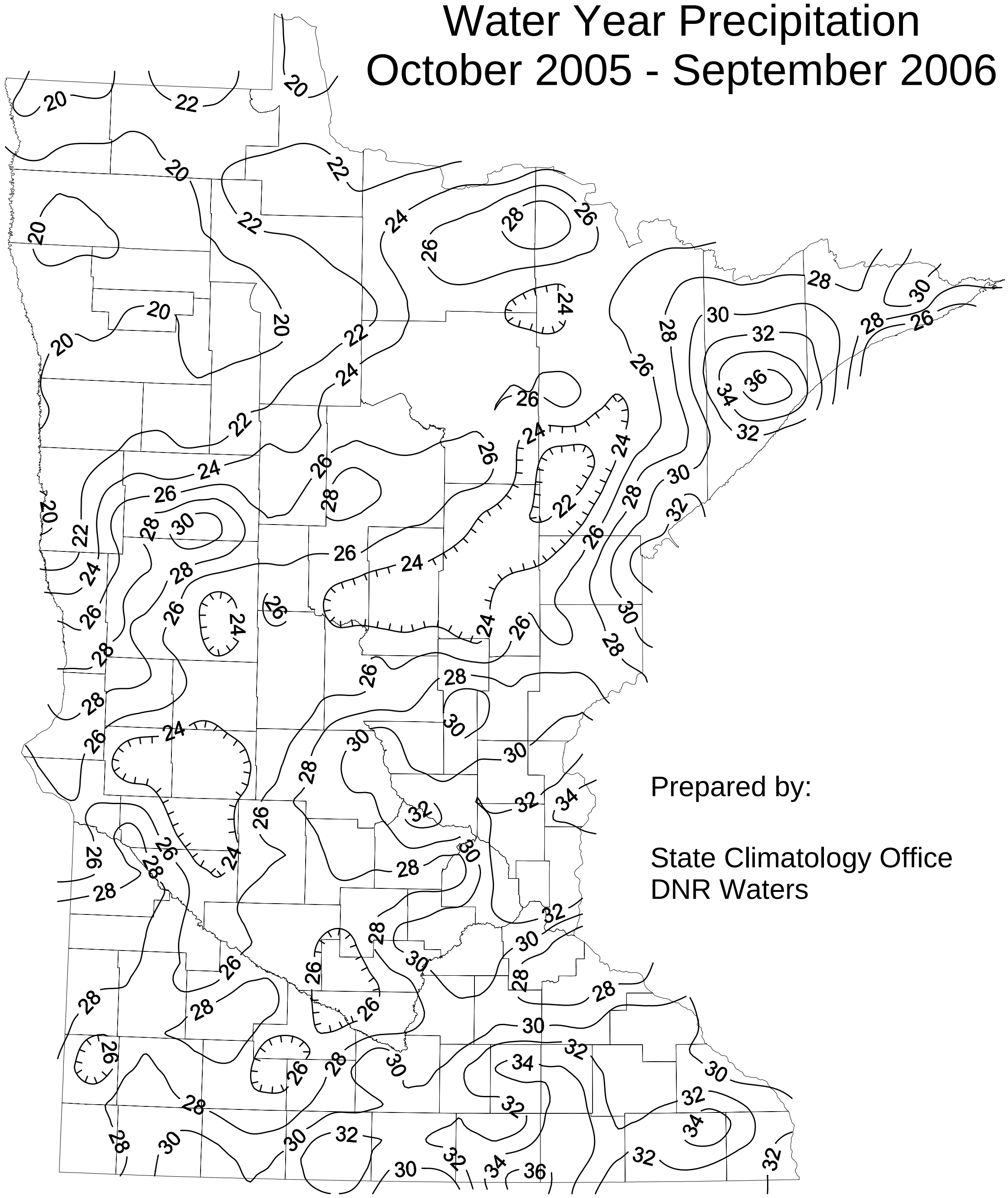
Historical Seasonal Secchi Averages (all values in meters)

	201	SES	202	SES	203	SES	204	SES
1978	4.4	0.2						
1980			4.4	0.1				
1981	3.7	0.2						
1982	5	0.3						
1983	4.2	0.3						
1984					4.4	0.2		
1985					4	0.1		
1986					3.5	0.2		
1987					4.7	0.3		
1988					4.4	0.5		
1989					5	0.2		
1990					4.6	0.2		
1991					3.9	0.2		
1992					4.5	0.4		
1993					4.5	0.2		
1994					4.3	0.3		
1995					5.5	0.1	6.1	0.2
1996					5.4	0.1	6.3	0.2
1997					5.4	0.1	5.9	0.2
1998					5.2	0	6.1	0.2
1999					5.6	0.1	6.1	0.2
2000					6.5	0.4		
2001					6.3	0.3		
2002					6.2	0.1		
2003					6.2	0.2		
2004					6.4	0.2		
2005					7.2	0.6		
2006					6.5	0.3	7	0.4

Appendix 2. Precipitation Events near Two Inlets, MN
(Precipitation Values are in Inches)

5/1/2006	0.32	6/1/2006	0	7/1/2006	0	8/1/2006	0	9/1/2006	0
5/2/2006	0.23	6/2/2006	0	7/2/2006	0	8/2/2006	0	9/2/2006	0
5/3/2006	0.2	6/3/2006	0	7/3/2006	0.4	8/3/2006	0	9/3/2006	0.9
5/4/2006	0	6/4/2006	0	7/4/2006	0	8/4/2006	0	9/4/2006	0
5/5/2006	0	6/5/2006	0	7/5/2006	0	8/5/2006	0.04	9/5/2006	
5/6/2006	0	6/6/2006	0	7/6/2006	0	8/6/2006	0	9/6/2006	
5/7/2006	0	6/7/2006	0.78	7/7/2006	0	8/7/2006	0	9/7/2006	
5/8/2006	0	6/8/2006	0	7/8/2006	0	8/8/2006	0	9/8/2006	
5/9/2006	0.06	6/9/2006	0	7/9/2006	0	8/9/2006	0	9/9/2006	
5/10/2006	0.79	6/10/2006	0.42	7/10/2006	0	8/10/2006	0	9/10/2006	
5/11/2006	0.78	6/11/2006	0	7/11/2006	0	8/11/2006	0	9/11/2006	
5/12/2006	0	6/12/2006	0	7/12/2006	0	8/12/2006	0.25	9/12/2006	
5/13/2006	0.35	6/13/2006	0	7/13/2006	0	8/13/2006	0	9/13/2006	
5/14/2006	0.05	6/14/2006	0	7/14/2006	0	8/14/2006	0.47	9/14/2006	
5/15/2006	0.03	6/15/2006	0	7/15/2006	0	8/15/2006	0	9/15/2006	
5/16/2006	0	6/16/2006		7/16/2006	0	8/16/2006	0	9/16/2006	
5/17/2006	0	6/17/2006		7/17/2006	0	8/17/2006	0	9/17/2006	
5/18/2006	0	6/18/2006		7/18/2006	0	8/18/2006	0	9/18/2006	
5/19/2006	0	6/19/2006		7/19/2006	0	8/19/2006	0.3	9/19/2006	
5/20/2006	0	6/20/2006		7/20/2006	0	8/20/2006	0	9/20/2006	
5/21/2006	0	6/21/2006	0.15	7/21/2006	0	8/21/2006	0	9/21/2006	
5/22/2006	0	6/22/2006	0	7/22/2006	0.11	8/22/2006	0.35	9/22/2006	
5/23/2006	0	6/23/2006	0	7/23/2006	0	8/23/2006	0	9/23/2006	
5/24/2006	0.04	6/24/2006	0.25	7/24/2006	0	8/24/2006	0	9/24/2006	
5/25/2006	0.39	6/25/2006	0	7/25/2006	0	8/25/2006	0.42	9/25/2006	
5/26/2006	0	6/26/2006	0	7/26/2006	0	8/26/2006	0	9/26/2006	
5/27/2006	0	6/27/2006	0	7/27/2006	0.25	8/27/2006	0	9/27/2006	
5/28/2006	0	6/28/2006	0	7/28/2006	0	8/28/2006	0	9/28/2006	
5/29/2006	0	6/29/2006	0	7/29/2006	0.24	8/29/2006	0	9/29/2006	
5/30/2006	0	6/30/2006	0	7/30/2006	0	8/30/2006	0	9/30/2006	3.35
5/31/2006	0	6/1/2006	0	7/31/2006	0	8/31/2006	0	9/1/2006	0

Water Year Precipitation
October 2005 - September 2006

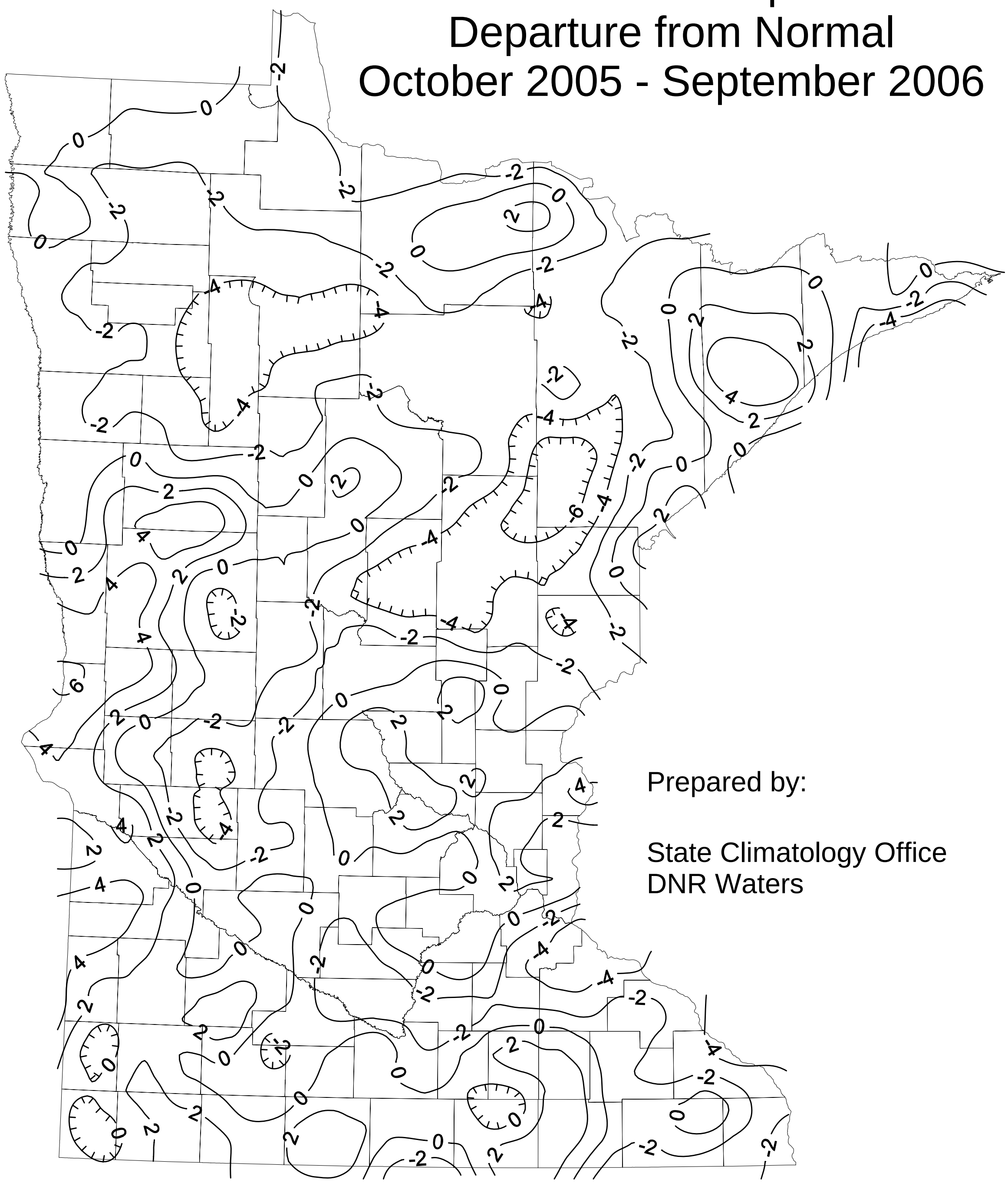


Prepared by:

State Climatology Office
DNR Waters

values are in inches

Water Year Precipitation Departure from Normal October 2005 - September 2006



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values are in inches