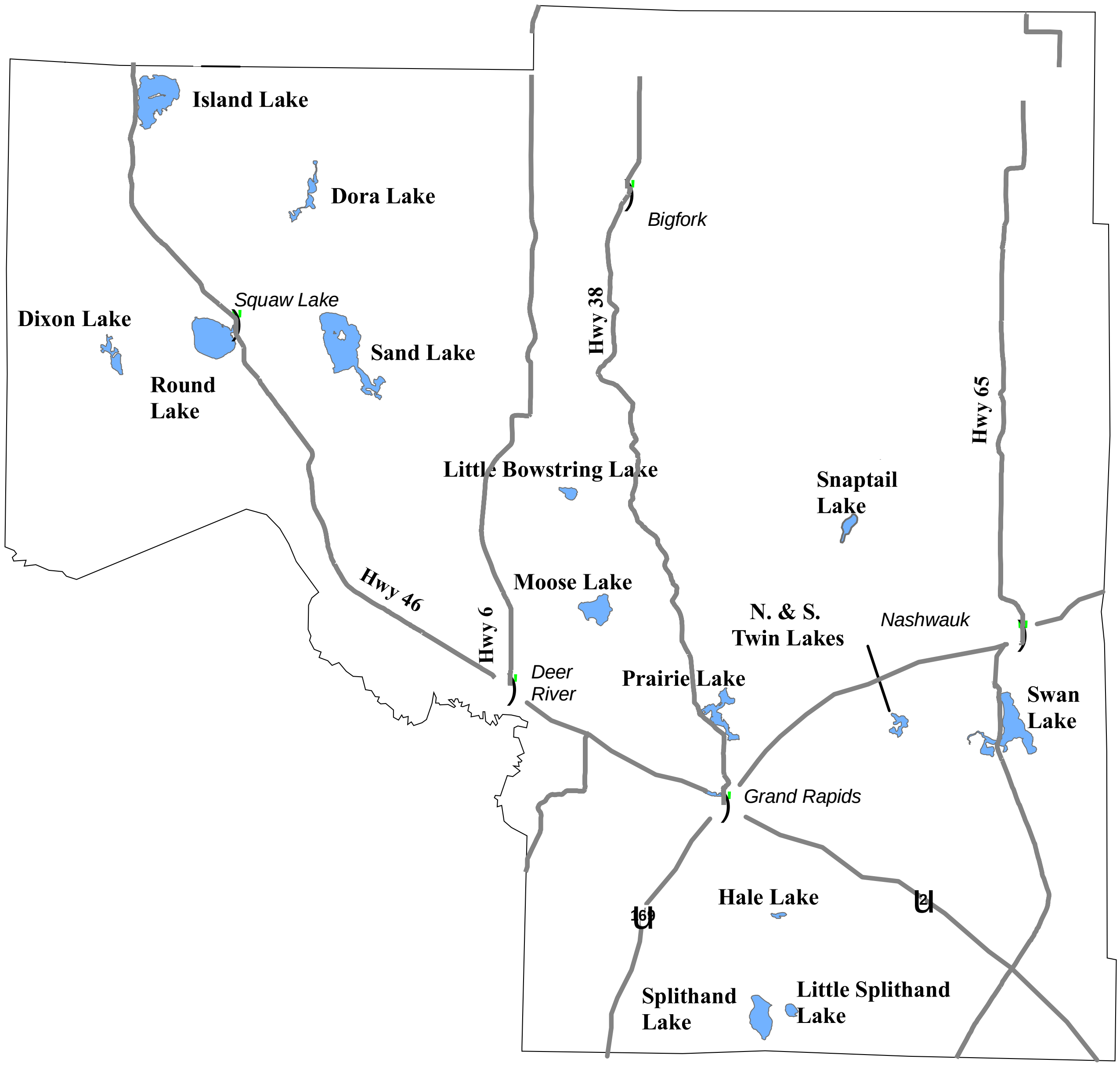
Citizen Lake-Monitoring Program (CLMP+):
Advanced Volunteer Lake Monitoring in Itasca County



Minnesota Pollution Control Agency

May 2007

Wq-clmp31-0921

Citizen Lake-Monitoring Program (CLMP+): Advanced Volunteer Lake Monitoring in Itasca County

Dixon Lake (31-0921)
Dora Lake (31-0882)
Hale Lake (31-0361)
Island Lake (31-0913)
Little Bowstring (31-0758)
Little Split Hand (31-0341)
Moose Lake (31-0722)
Prairie Lake (31-0384)
Round Lake (31-0896)
Sand Lake (31-0826)
Snaptail Lake (31-0255)
Split Hand Lake (31-0353)
Swan Lake (31-0067-01 & 31-0067-02)
Twin (North) Lake (31-0190)
Twin (South) Lake (31-0191)

Minnesota Pollution Control Agency

Environmental Analysis and Outcomes Division
Water Assessment and Environmental Information Section
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May 2007

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Part 1: Program History and Background Information on Minnesota Lakes

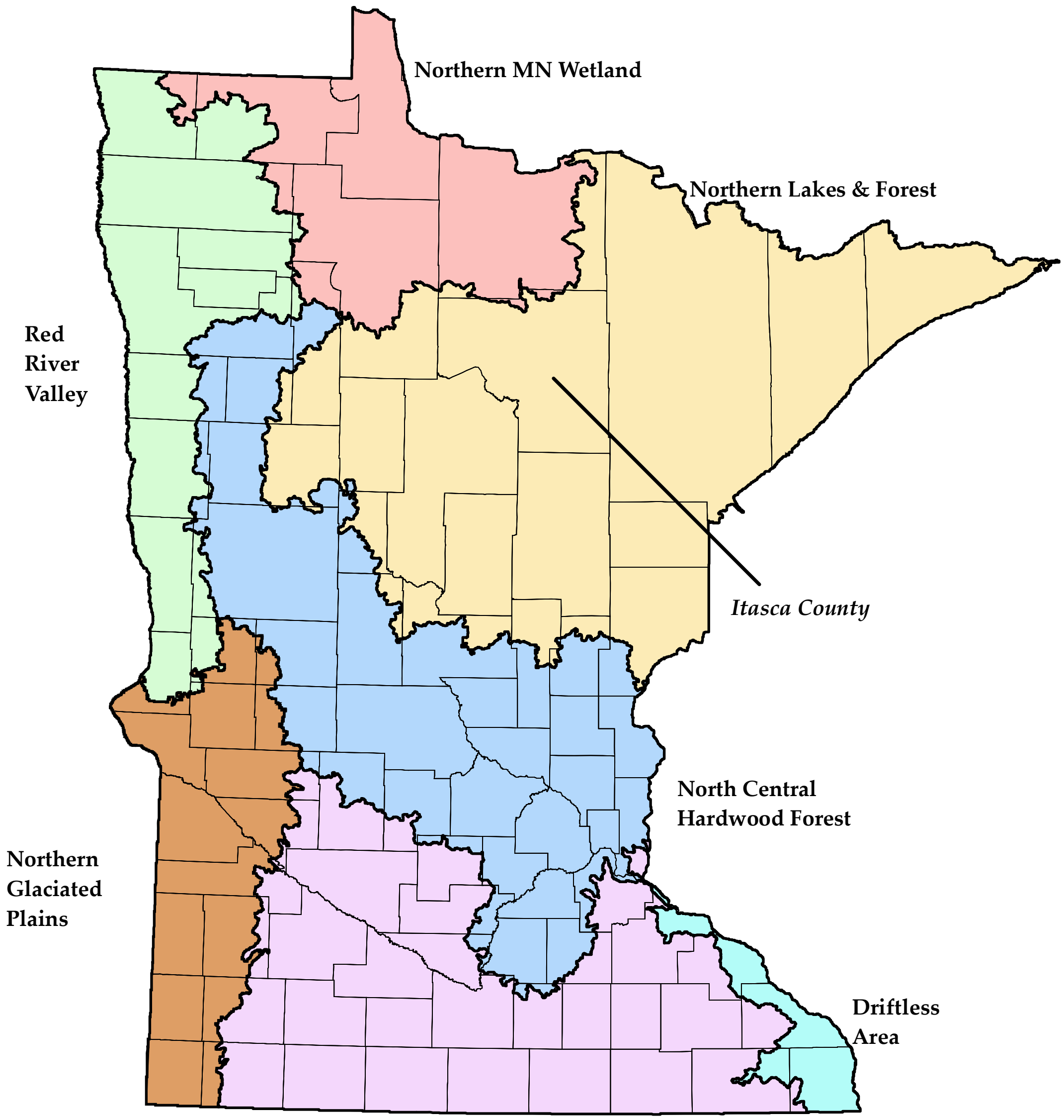
Minnesota's Citizen Lake-Monitoring Program (CLMP) is the largest and oldest volunteer lake-monitoring program in the country. Volunteers in the CLMP currently use a Secchi disk to measure the clarity on hundreds of Minnesota's lakes. The expanded program, including the collection of water chemistry samples for analysis along with Secchi transparency collection, was conducted in Itasca County. A total of fourteen lakes were selected for monitoring in 2006 by volunteer lake monitors. These lakes were: Dixon, Dora, Hale, Island, Little Bowstring, Little Split Hand, Moose, Prairie, Round, Sand, Snaptail, Split Hand, Swan, and Twin (North & South) Lakes. All equipment and analytical costs for the samples were provided for and paid by the Minnesota Pollution Control Agency (MPCA).

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. Noel Griese of the Itasca Soil and Water Conservation District Office (SWCD) helped plan and coordinate the sample drop-off/pick up schedule for the samples in Itasca County. Special thanks to the volunteers who helped make this project a success: Dave Lathrop (Dixon Lake), Dick Lacher (Dora Lake), Rich Libbey (Hale Lake), William Luadtke (Island Lake), Norman Ford (Little Bowstring Lake), John Rademacher (Little Split Hand Lake), Marty Christensen (Moose Lake), Jeff Kleinert (Prairie Lake), Donald Ward (Round Lake), Dave Smith (Sand Lake), Al Hupila & Darrell Johnson (Snaptail Lake), Greg Winkler (Split Hand Lake), Lou Mattson (Swan Lake), and Tony Appelget & Noel Griese (North & South Twin Lakes). 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.

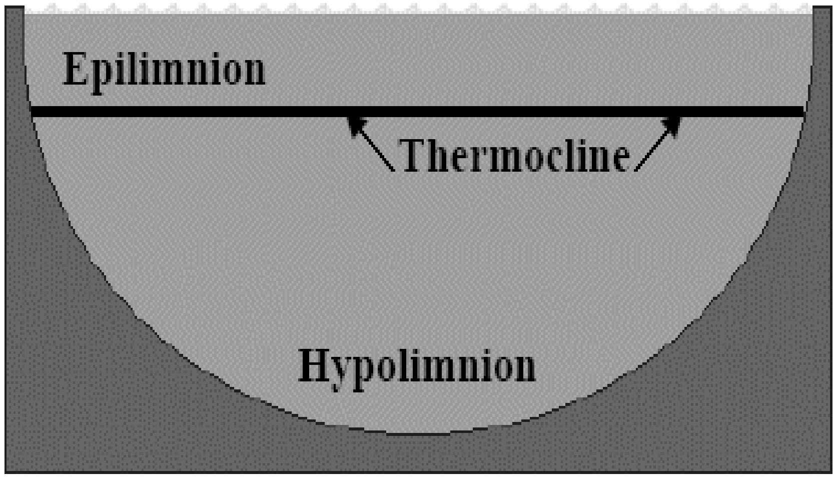
The state of Minnesota is divided into seven ecoregions (Figure 1), based on soils, landform, potential natural vegetation, and land use. Itasca County is located within the Northern Lakes and Forest (NLF) ecoregion. Comparing a lake's water quality to that of reference lakes in the same ecoregion provided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

Figure 1. Minnesota Ecoregions

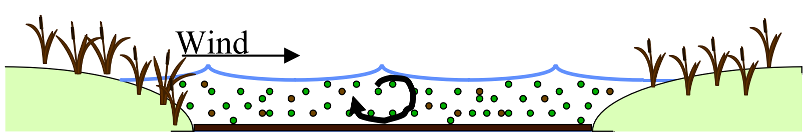


Lake depth can have a significant influence on lake processes and water quality. One such process is *thermal stratification* (formation of distinct temperature layers), in which deep lakes (maximum depths of 30 - 40 feet or more) often stratify (form layers) during the summer months and are referred 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.

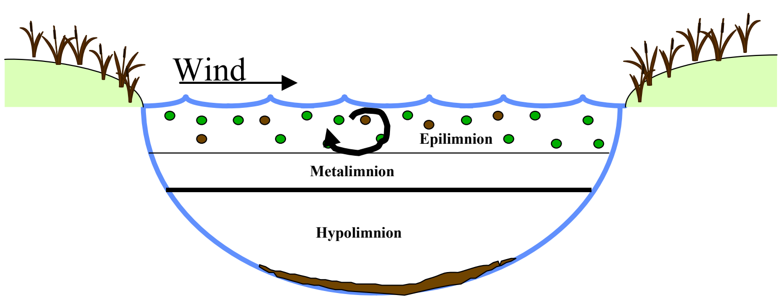
Diagrams of Lake Layers for Shallow and Deep Lakes



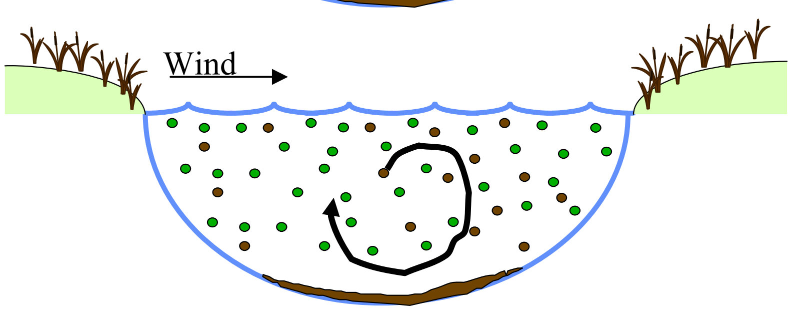
Polymictic Lake
Shallow, No Layers,
Mixes Continuously
Spring, Summer & Fall



Dimictic Lake
Deep, Form Layers,
Mixes Few Times
Summer

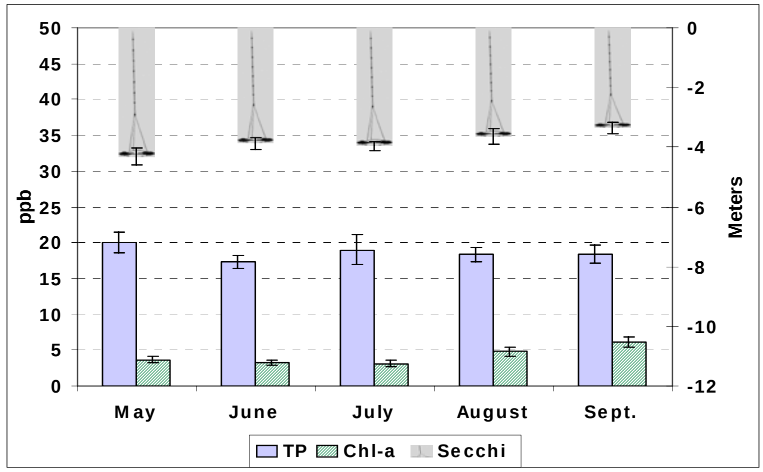


Dimictic Lake
Deep, Form Layers,
Mixes Few Times
Spring/Fall



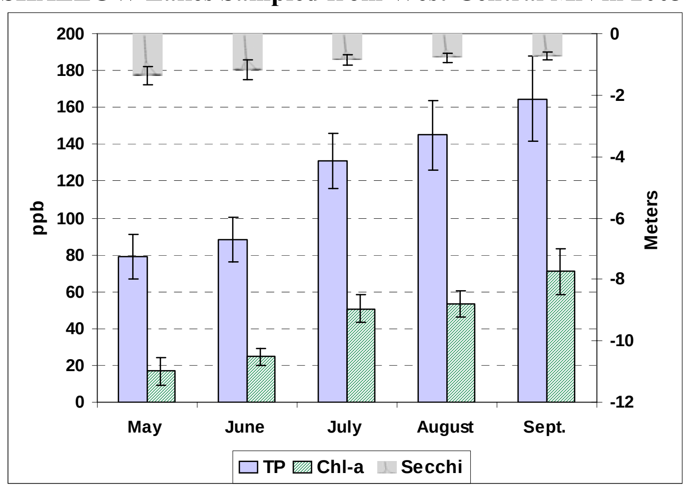
In the case of deeper lakes that are typically well-mixed in April and May following ice-out and wind-mixing, we often see elevated TP and chlorophyll-*a*. As the lakes begin to stratify a reduction in TP and chlorophyll-*a* is often noted for the May and June time periods (see chart on right). If the lake remains stratified over the summer we often observe stable or slightly declining TP over the summer, absent any major summer loading events. This decline is a reflection of algal uptake of P combined with natural sedimentation processes. While internal recycling of P will often occur it is often limited to the hypolimnion and does not tend to mix with the surface waters till fall overturn. Chlorophyll-*a* concentrations often increase over the summer as the waters warm and algal dominance shifts from diatoms, to greens, to blue-greens. As algal (i.e. chlorophyll-*a*) concentrations increase Secchi will decrease.

Monthly Mean TP, Chlorophyll-*a* and Secchi. Based on 21 DEEP Lakes Sampled from Cass & Crow Wing Counties.



In shallow lakes we see a somewhat different pattern in that if TP and chlorophyll-*a* are measured in April, it is not uncommon to see high concentrations followed by a decline in May. May and sometimes early June chlorophyll-*a* concentrations may be kept relatively low as a result of zooplankton grazing and perhaps rooted plant growth; however, as the summer progresses we often see a marked increase in both TP and chlorophyll-*a* in shallow lakes (see chart on right). In these shallow, well-mixed lakes internal recycling of P (absent significant summer runoff events) is likely cause of the seasonal increase in TP. Various factors can contribute to the recycling and likely include things such as: die-off of curly-leaf pondweed, frequent wind mixing, increased temperatures and internal P-release along with various other factors (Heiskary and Wilson, 2005). As a result, dramatic increases in chlorophyll-*a* concentrations are noted over the summer and these blooms are often dominated by blue-green algae, which accumulate near the surface. In turn, Secchi tends to decline over the summer in response to increased algae concentrations.

Monthly Mean TP, Chlorophyll-*a* and Secchi. Based on 30 SHALLOW Lakes Sampled from West-Central MN in 2003.



Awareness of these differing seasonal patterns will aid in the assessment of Minnesota lakes; which in turn, should aid in the development of the TMDL and may be of particular use in developing an implementation plan and projecting improvements that may result from its implementation.

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). 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 on each lake was monitored twice per month from June through September; with the exceptions of Dora, Sand, Prairie and Swan Lakes. These lakes were sampled at two sites each. 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, preserved with Lugol's solution and analyzed by MPCA staff: Dr. Howard Markus and Matt Lindon.

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 (USGS) quad maps. Watershed area information for the lake was provided by the Minnesota Department of Natural Resources Data Deli.

Data Analysis

A series of graphs are presented for each lake 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 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. 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.

Several TP samples from early June, for the CLMP+ lakes, were held for one week longer than the recommended holding time due to the shipping coordination issues. These samples are denoted by a "Q" in the data column following the indicated parameter in the Appendix; 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 color results were also held over the recommended holding time by one or two days. 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 lakes based on lake area, lake depth, and the total area of the lakes' 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 Morphometry & Watershed Areas for Itasca County CLMP+ Lakes

Characteristic	Dixon	Dora	Hale	Island	Little Bowstring	Little Split Hand	Moose	Prairie
DNR Lake ID #	31-0921	31-0882	31-0361	31-0913	31-0758	31-0341	31-0722	31-0384
Maximum depth	29 ft 8.8 m	18 ft 5.5 m	59 ft 18 m	35 ft 10.7 m	33 ft 10.1 m	25 ft 7.6 m	61 ft 18.6 m	31 ft 9.5 m
[1]*Mean depth*	11 ft 3.4 m	10 ft 3.0 m	15 ft 4.6 m	15 ft 4.6 m	16 ft 4.9 m	12 ft 3.7 m	18.5 ft 5.6 m	11 ft 3.4 m
Lake area *(ha = hectares)* *(mi^2 = square miles)*	616 acres 249 ha 0.96 mi^2	447 acres 181 ha 0.70 mi^2	131 acres 53 ha 0.20 mi^2	3,088 acres 1,250 ha 4.8 mi^2	319 acres 129 ha 0.50 mi^2	223 acres 90 ha 0.35 mi^2	1,265 acres 512 ha 1.98 mi^2	1,064 acres 431 ha 1.66 mi^2
[2]*Watershed area* *(Excludes lake area)*	47,770 acres 19,340 ha 74.6 mi^2	281,088 acres 113,801 ha 439.2 mi^2	2,624 acres 1,062 ha 4.1 mi^2	7,453 acres 3,017 ha 11.6 mi^2	7,680 acres 3,109 ha 12.0 mi^2	22,784 acres 9,224 ha 35.6 mi^2	10,432 acres 4,224 ha 16.3 mi^2	311,040 acres 125,927 ha 486.0 mi^2
Watershed:lake area ratio	78:1	629:1	20:1	2:1	24:1	102:1	8:1	292:1
Volume (acre-ft) *(hm^3)*	6,776 acre-ft 8.4 hm^3	4,470 acre-ft 5.5 hm^3	1,965 acre-ft 2.4 hm^3	46,320 acre-ft 57.2 hm^3	5,104 acre-ft 6.3 hm^3	2,676 acre-ft 3.3 hm^3	23,402 acre-ft 28.9 hm^3	11,704 acre-ft 14.4 hm^3
Littoral Area	478 acres 78 %	422 acres 94 %	114 acres 87 %	1,195 acres 39 %	115 acres 36 %	140 acres 63 %	345 acres 27 %	853 acres 80 %
Ecoregion	NLF	NLF	NLF	NLF	NLF	NLF	NLF	NLF
Accesses[2]	1	1	1 (canoe)	2	1	1	2	2

[1]Mean depth and volume provided by MN DNR, historic MPCA reports, or estimated by MPCA staff.
[2]Source: MN DNR Data Deli (http://deli.dnr.state.mn.us/) & USGS (http://gisdmnspl.cr.usgs.gov/watershed/)

Table 1. Lake Morphometry & Watershed Areas for Itasca County CLMP+ Lakes Continued.

Characteristic	Round	Sand	Snaptail	Split Hand	Swan (Main)	Twin (North)	Twin (South)
DNR Lake ID #	31-0896	31-0826	31-0255	31-0353	31-0067-02	31-0190	31-0191
Maximum depth	24 ft 7.3 m	70 ft 21.3 m	70 ft 21.3 m	34 ft 10.4 m	67 ft 20.4 m	42 ft 12.8 m	40 ft 12.2 m
[1]*Mean depth*	11 ft 3.4 m	16 ft 4.9 m	20 ft 6.1 m	15 ft 4.6 m	39.5 ft 10.7 m	17 ft 5.2 m	15 ft 4.6 m
Lake area *(ha = hectares)* *(mi^2 = square miles)*	2,828 acres 1,145 ha 4.41 mi^2	4,328 acres 1,752 ha 6.76 mi^2	146 acres 59 ha 0.23 mi^2	1,420 acres 575 ha 2.22 mi^2	2,116 acres 857 ha 3.38 mi^2	250 acres 101 ha 0.39 mi^2	179 acres 73 ha 0.28 mi^2
[2]*Watershed area* *(Excludes lake area)*	63,488 acres 25,704 ha 99.2 mi^2	151,424 acres 61,305 ha 236.6 mi^2	1,750 acres 709 ha 2.7 mi^2	15,936 acres 6,452 ha 24.9 mi^2	64,256 acres 26,015 ha 100.4 mi^2	1,260 acres 510 ha 2.0 mi^2	1,715 acres 694 ha 2.7 mi^2
[3]*Watershed:lake area ratio*	22:1	35:1	12:1	11:1	30:1	5:1	10:1
Volume (acre-ft) *(hm^3)*	31,108 acre-ft 38.4 hm^3	69,248 acre-ft 85.5 hm^3	2,920 acre-ft 3.6 hm^3	21,300 acre-ft 26.3 hm^3	83,582 acre-ft 103.1 hm^3	4,250 acre-ft 5.2 hm^3	2,685 acre-ft 3.3 hm^3
Littoral Area	1,968 acres 70 %	1,897 acres 44 %	57 acres 39 %	510 acres 36 %	507 acres 24 %	73 acres 29 %	63 acres 35 %
Ecoregion	NLF	NLF	NLF	NLF	NLF	NLF	NLF
Accesses	2	1	1	1	2	1	1 - via N. Twin

[1]Mean depth and volume provided by MN DNR, historic MPCA reports, or estimated by MPCA staff.
[2]Source: MN DNR Data Deli (http://deli.dnr.state.mn.us/) & USGS (http://gisdmnspl.cr.usgs.gov/watershed/)

Table 2a. Summer-Mean Water Quality Parameters for Itasca County CLMP+ Lakes.
(Based on 2006 summer epilimnetic data.)

Parameters	Dixon	Dora	Hale	Island	Little Bowstring	Little Split Hand	Moose	Prairie	Typical Range for NLF Ecoregion[1]
Total Phosphorus (µg/L)	50	41	18	46	30	42	16	32	**14 – 27**
Chlorophyll-*a* (µg/L)[2] **Mean**	20	7	3	23	9	17	4	11	**< 10**
Chlorophyll-*a*(µg/L)[2] **Max.**	31	13	5	61	26	36	6	24	**< 15**
Secchi disk (m)	1.4	2.5	3.4	1.9	2.0	2.0	3.7	1.6	**2.4 – 4.6**
Secchi disk (feet)	4.7	8.1	11.3	6.4	6.6	6.6	12.2	5.4	**8 – 15**
Total Kjeldahl Nitrogen (mg/L)	1.2	0.9	0.6	0.8	0.7	0.9	0.4	0.7	**< 0.75**
Alkalinity (mg/L)	130	130	78	110	140	97	140	87	**40 – 140**
Color (Pt-Co Units)	50	33	10	15	8	25	5	45	**10 – 35**
pH (SU)	8.9	8.0	8.7	8.5	8.4	8.7	8.5	8.1	**7.2 – 8.3**
Chloride (mg/L)	1.2	2.1	6.8	2.5	2.6	1.8	2.0	2.3	**< 2**
Total Suspended Solids (mg/L)	5.6	3.8	1.4	3.6	4.4	5.0	1.2	4.1	**< 1 – 2**
Total Suspended Inorganic Solids (mg/L)	4.4	2.5	1.4	2.8	2.4	4.2	1.2	2.5	**< 1 – 2**
Conductivity (µmhos/cm)	235	233	162	207	255	179	251	166	**50 – 250**
TN:TP Ratio	24:1	22:1	33:1	17:1	23:1	21:1	25:1	22:1	**25:1 – 35:1**

[1]Ecoregion" range is the 25th – 75th percentile of summer means from ecoregion reference lakes.
[2]Chlorophyll-*a* measurements have been corrected for pheophytin.

Table 2b. 2006 Trophic State Index Values for Itasca County CLMP+ Lakes.

2006 Trophic State Index	Dixon	Dora	Hale	Island	Little Bowstring	Little Split Hand	Moose	Prairie
TISP	61	58	46	59	53	58	44	50
TSIC	60	50	41	61	52	58	44	54
TSIS	55	47	42	51	50	50	41	53
Overall TSI	59	52	43	57	52	55	43	52

Table 2a. Summer-Mean Water Quality Parameters for Itasca County CLMP+ Lakes Continued.

(Based on 2006 summer epilimnetic data.)

Parameters	Round	Sand	Snaptail	Split Hand	Swan (Main)	Swan (West)	Twin (North)	Twin (South)	Typical Range for NLF Ecoregion[1]
Total Phosphorus (µg/L)	89	27	12	44	21	39	17	14	**14 – 27**
Chlorophyll-*a* (µg/L)[2] **Mean**	32	11	3	18	7	16	4	4	**< 10**
Chlorophyll-*a*(µg/L)[2] **Max.**	57	25	5	35	14	34	7	12	**< 15**
Secchi disk (m)	1.3	2.2	4.0	1.6	4.3	2.4	2.8	3.5	**2.4 – 4.6**
Secchi disk (feet)	4.3	7.3	13.2	5.1	14.1	7.8	9.3	11.6	**8 – 15**
Total Kjeldahl Nitrogen (mg/L)	1.3	0.7	0.6	0.9	0.5	0.6	0.5	0.5	**< 0.75**
Alkalinity (mg/L)	120	115	53	98	150	150	135	125	**40 – 140**
Color (Pt-Co Units)	35	20	30	25	10	10	8	8	**10 – 35**
pH (SU)	9.1	8.4	8.3	8.7	8.5	8.7	8.2	8.3	**7.2 – 8.3**
Chloride (mg/L)	2.0	2.0	3.2	1.8	7.1	7.3	9.6	6.7	**< 2**
Total Suspended Solids (mg/L)	10.3	3.3	1.3	7.2	1.8	2.8	1.8	1.5	**< 1 – 2**
Total Suspended Inorganic Solids (mg/L)	7.6	2.6	1.1	5.2	1.4	2.4	1.4	1.3	**< 1 – 2**
Conductivity (µmhos/cm)	214	210	113	183	316	307	303	275	**50 – 250**
TN:TP Ratio	15:1	26:1	50:1	21:1	24:1	15:1	29:1	36:1	**25:1 – 35:1**

[1]Ecoregion" range is the 25th – 75th percentile of summer means from ecoregion reference lakes.
[2]Chlorophyll-*a* measurements have been corrected for pheophytin.

Table 2b. 2006 Trophic State Index Values for Itasca County CLMP+ Lakes Continued.

2006 Trophic State Index	Round	Sand	Snaptail	Split Hand	Swan (Main)	Swan (West)	Twin (North)	Twin (South)
TISP	69	52	40	59	48	57	45	42
TSIC	65	54	41	59	50	58	44	44
TSIS	56	49	40	53	39	47	45	42
Overall TSI	63	52	40	57	46	54	45	43

Figure 2. 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.

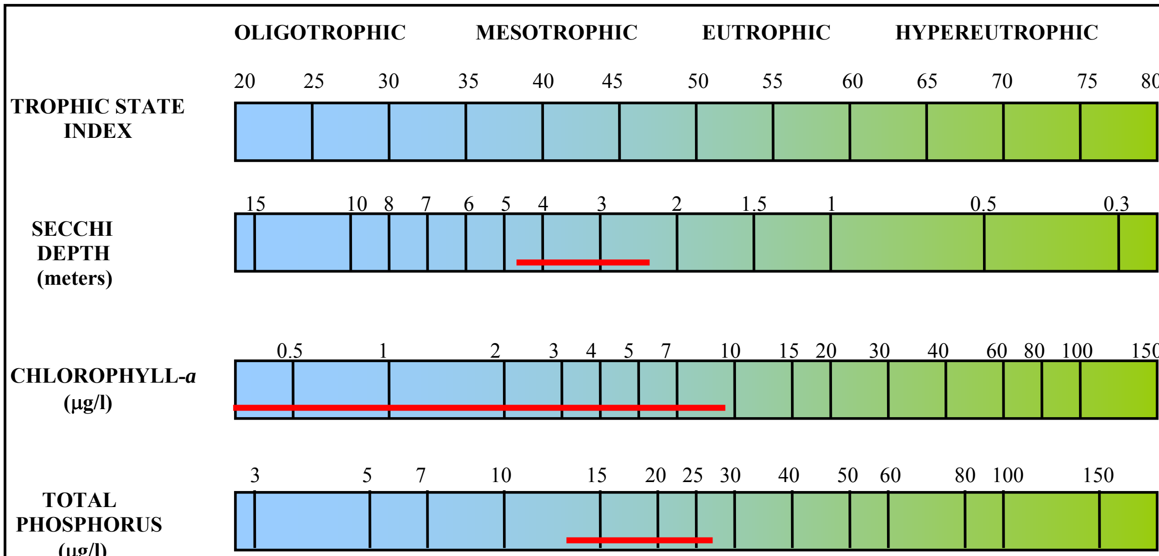
TSI 40 - 50 Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.

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. US EPA. EPA 440/5-88-002.

NLF Ecoregion Range, 25th – 75th percentile:

DIXON (31-0921)

Dixon Lake is a fairly large, shallow lake. It is in the upper five percent of lake in terms of its size; covering 616 acres. Dixon Lake has a maximum depth of 29 feet; however, a very large portion of the lake is less than 10 feet deep (Table 1, Figure 4). The lake is located seven miles west of the town of Squaw Lake, Minnesota. Over 75 percent of the lake is littoral (percent of the lake that is 15 feet or less) and there is only one viable public access for the lake; although during low water periods such as those encountered in late September, public access to the lake is nearly impossible. It has a moderate-sized immediate watershed with land uses that consist primarily of forested and water/marsh uses (Figure 3). The total watershed area for the lake is very large, covering nearly 75 mi^2 (Appendix 2). The watershed to lake ratio is 78:1 (Table 1). Based on the total watershed area, its water residence time is estimated to be less than six months.

Water quality data was collected in June, July, August, and September, 2006 by volunteer lake monitor: Dave Lathrop. One site was used on Dixon Lake: Site 101 – located in the southern end of the lake over the point of maximum depth (Figure 4).

Temperature data indicated that the lake was well-mixed in May and September, but did show evidence of minor thermal stratification mid-summer starting near three meters (Figure 5). Based on its large fetch and shallowness, it is likely that the lake mixes intermittently throughout the summer. Surface water temperatures in Dixon Lake ranged from 13° C in May to 26° C in July.

Total phosphorus (TP) concentrations averaged 50 µg/L[1] in Dixon Lake during the summer of 2006. This value is well above the range of concentrations for reference lakes in this ecoregion (Table 2a); however, given the vast size of the watershed that drains through Dixon Lake (76 mi^2, Table 1), concentrations above the expected ecoregion range are not unexpected. TP concentrations ranged from 27 – 68 µg/L (Figure 6) and steadily increased over the summer through early August; and then declined slightly in September. This pattern of increasing TP over the summer is consistent with what we see in other shallow Minnesota lakes (see Background, Heiskary and Lindon, 2005).

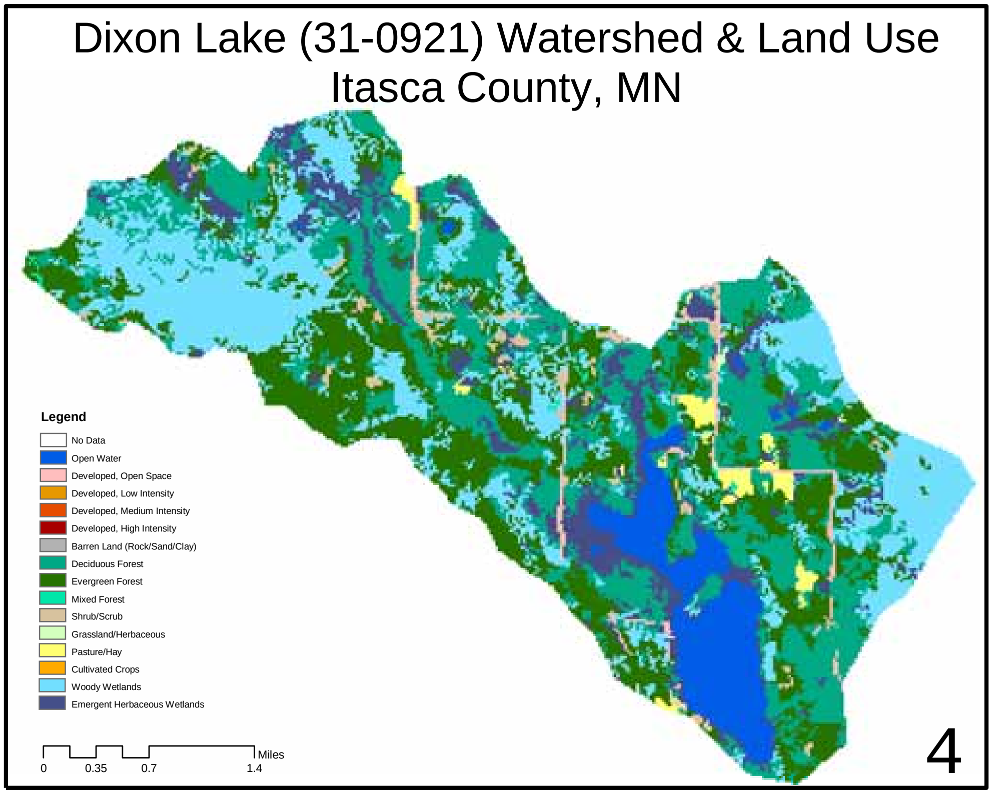
Chlorophyll-*a* concentrations for Dixon Lake averaged 20 µg/L; which is greater than the ecoregion reference range (Table 2a). These higher levels were expected given the elevated TP levels and appearance of the lake during sampling trips. Concentrations on Dixon Lake ranged from 3.9 – 31.3 µg/L and steadily increased over the summer (Figure 6). Based on the 2006 data, Dixon Lake would have experienced nuisance and near severe nuisance algae blooms[2] from late-July through September.

The composition of the phytoplankton (algae) population of Dixon Lake is presented in Figure 7. Data are presented in terms of algal type. Samples were collected at Site 101. The bluegreens were the dominant form throughout most of the summer, with the form *Aphanizomenon* being most common. Bluegreens, as a whole, are the group most often associated with nuisance algal

[1] µg/L = micrograms per liter or parts per billion
[2] Algae blooms are categorized as **mild** (chl-*a* >10 µg/L), **nuisance** (chl-*a* >20 µg/L), or **severe** (chl-*a* > 30 µg/L)

blooms. A seasonal transition in algal types from diatoms to greens to bluegreen is more typical for mesotrophic and eutrophic lakes in Minnesota.

Figure 3. Dixon Lake Watershed & Land Use Map



Land Use Type	Dixon Lake Percent	NLF Ecoregion Percent
Forest	54	54 - 81
Water & Marsh	42	14 - 31
Pasture & Open	3	0 - 6
Cultivated	0	< 1
Urban	1	0 - 7

Figure 4. Dixon Lake Bathymetric Map and Monitoring Location

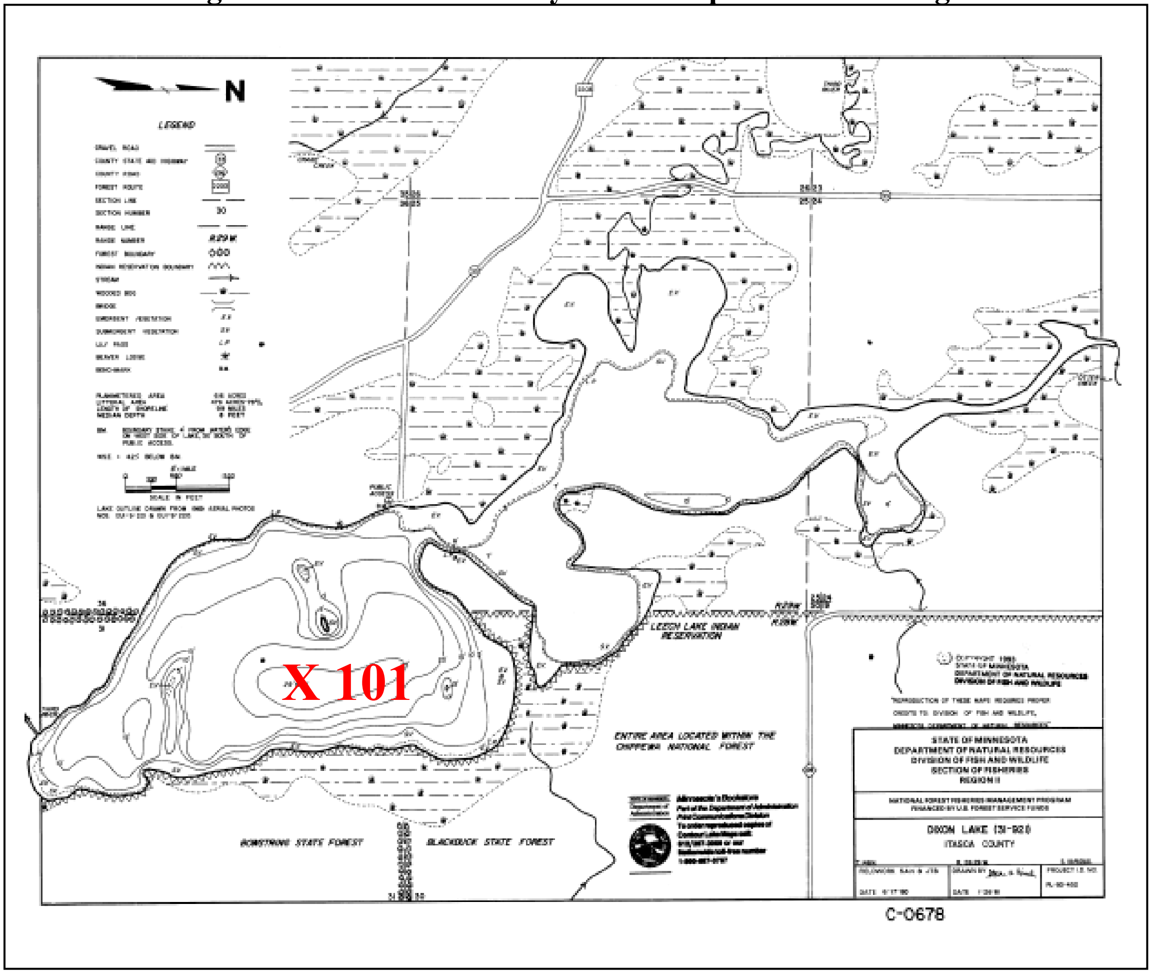


Figure 5. Dixon Lake Temperature Profile Data for 2006

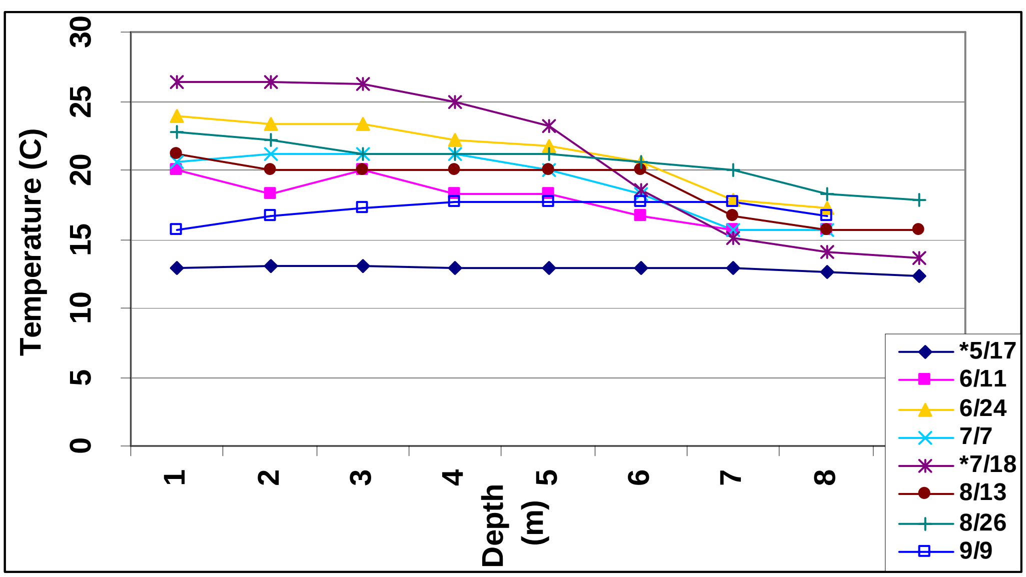


Figure 6. Dixon Lake Total Phosphorus & Chlorophyll-*a* Results for 2006

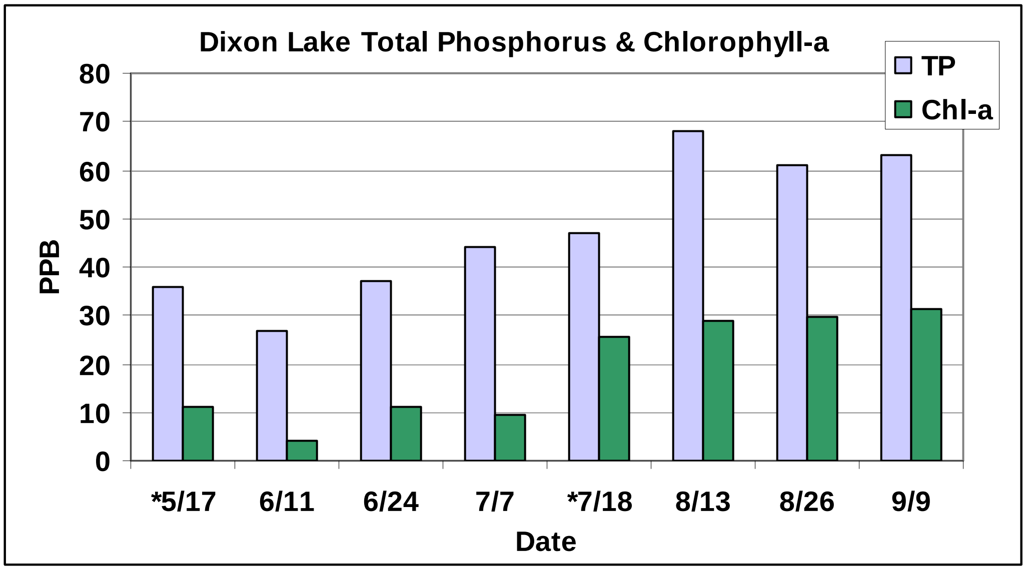
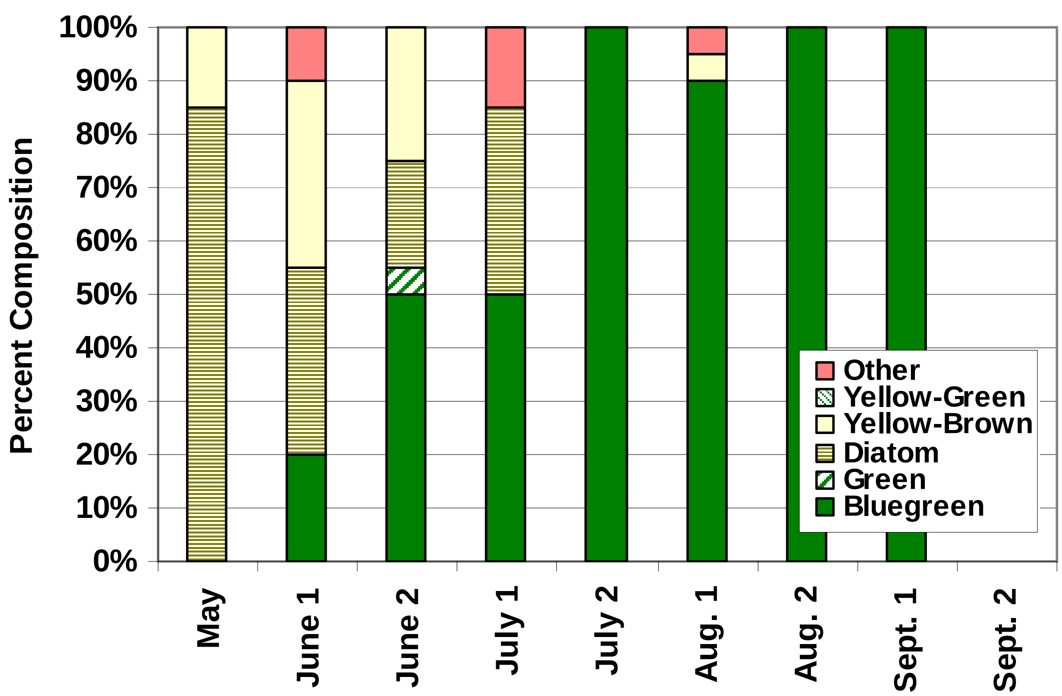
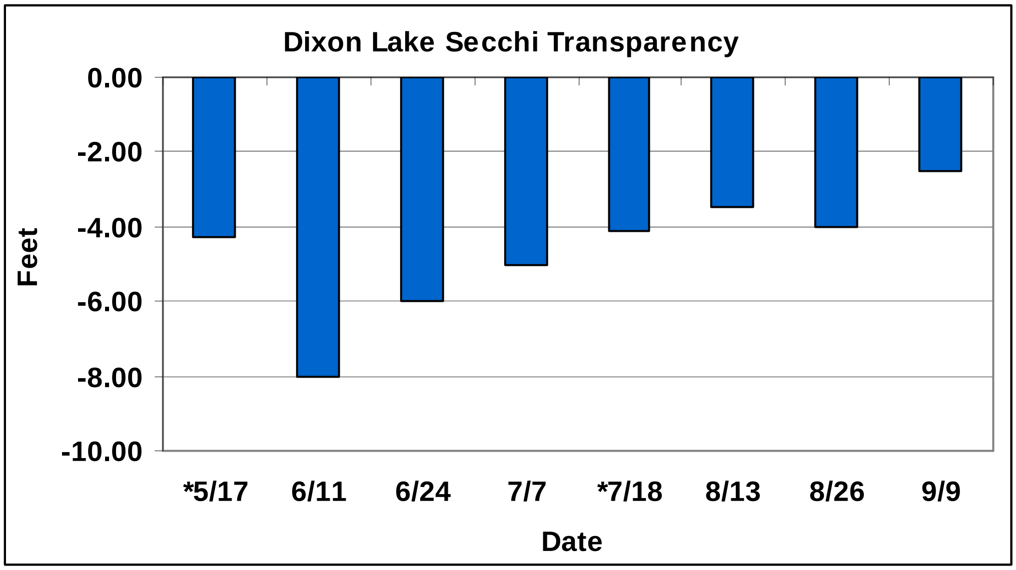


Figure 7. Dixon Lake Algal Populations for 2006



Secchi disk transparency on Dixon Lake ranged from 2.5 – 8.0 feet (0.8 – 2.4 meters) and averaged 4.7 feet (1.4 meters) (Figure 8). These transparency measures are below the typical range for this ecoregion (Table 2a). Secchi transparency tended to follow an inverse pattern in comparison to TP and chlorophyll-*a*. In general, as TP and chlorophyll-*a* values increased, Secchi transparency declined throughout the summer. Along with transparency measurements, subjective measures of Dixon Lake's "physical appearance" and "recreational suitability" were made. Lake physical condition for Dixon Lake was typically characterized as "not quite crystal clear" (Class 2) from May through July and then were characterized as "high algal color" (Class 4) in August and September. Recreational suitability was typically characterized as "minor aesthetic problems" (Class 2) through July and then characterized as "no swimming, but boating okay" (Class 4) for August and September (Appendix 1).

Figure 8. Dixon Lake Secchi Transparency for 2006



Other parameters, such as alkalinity, chloride and conductivity, analyzed for Dixon Lake were all near or well within the typical range of values for ecoregion reference lakes (Table 2a). Concentrations for nitrogen, pH and suspended solids; however, were higher than the typical range for this ecoregion. Color values were also higher than the typical range; however, given the vast amount of wetlands in the watershed area, this bog stain coloration is not unexpected.

Trophic State Index (TSI) values for TP and chlorophyll-*a* for Dixon Lake compare very favorably to each other (Table 2b); whereas, the TSI value for Secchi transparency is slightly, but no significantly lower. As such, Secchi transparency should be a good *estimator* for overall water quality within Dixon Lake as well as a good tool for examining water quality trends within Dixon Lake. The overall TSI value of 59 indicates *eutrophic* conditions for Dixon Lake.

DORA (31-0882)

Dora Lake is a moderate-sized lake (447 acres) located eight miles northeast of the town of Squaw Lake, Minnesota. The lake has two distinct basins separated by a bridge over the lake on County Rd 29 and a wild rice bed on the south end of the lake. It is heavily influenced by the flow of the Big Fork, Bowstring and Popple Rivers as well as Moose Brook and Wendigo Creek. As such, this lake system is more characteristic of a reservoir than a typical glacial lake. Dora Lake has a surface area of 447 acres, a maximum depth of 18 feet (5.5 m) and a mean depth of about 10 feet (3.0 m). Nearly all (94 %) of the lake is littoral and there is one public access for the lake located off County Road 29 into the north basin of the lake. Although its immediate watershed area is fairly small (Figure 9) and is comprised of mostly forest and water/marsh uses, its total watershed area is massive covering close to 440 mi^2 area (Table 1, Appendix 2). The watershed to lake ratio is 629:1 (Table 1). Based on the total watershed area, its water residence time is estimated to be less than six months.

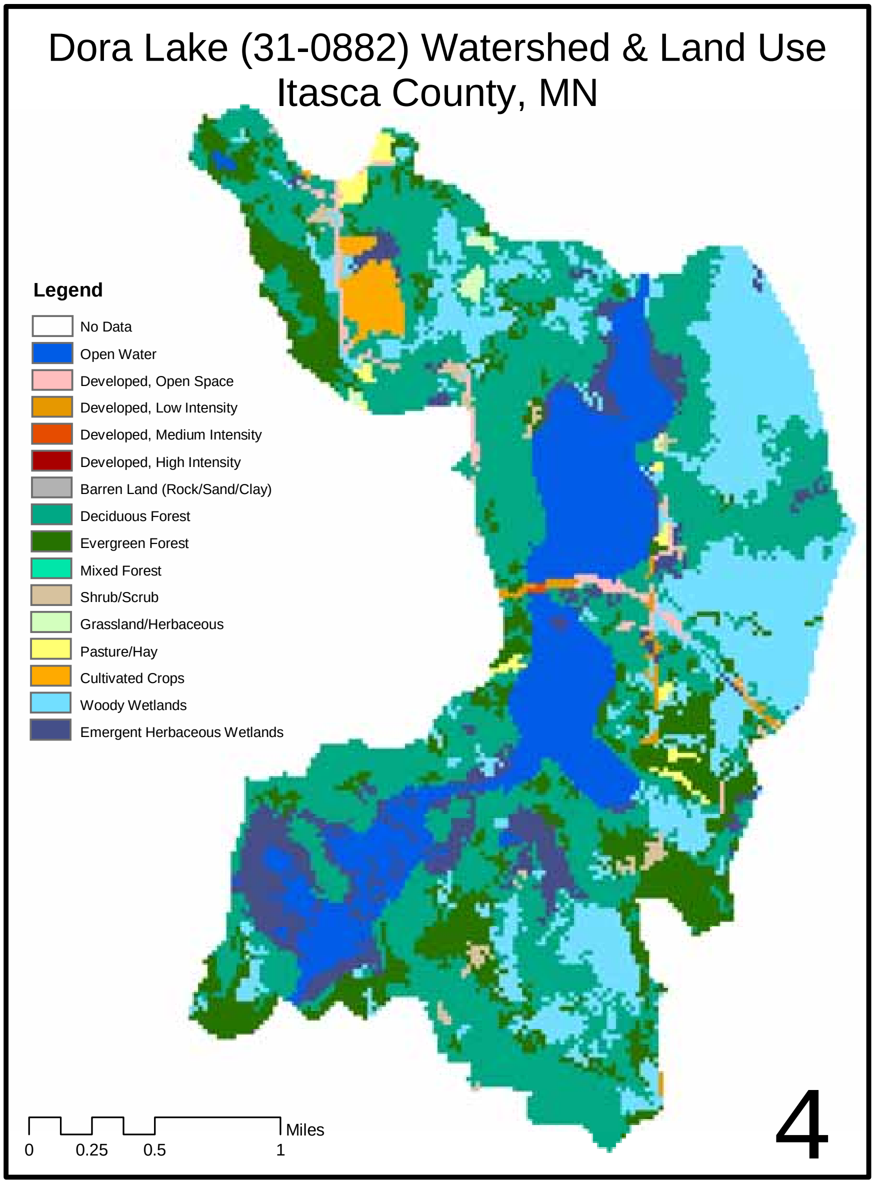
Water quality data was collected in June, July, August, and September, 2006 by volunteer lake monitor: Dick Lacher. One site was used in each basin of Dora Lake: Site 101, located near the point of maximum depth in the north basin and Site 201, located near the point of maximum depth in the southern basin (Figure 10).

Temperature data indicated that the lake was well mixed throughout the entire summer at both sites (Figure 11). Surface temperatures ranged from 13.4°C in May to 25.7° C in July at Site 101 and from 14.3°C in September to 25.4° C in July at Site 201.

Total phosphorus (TP) concentrations averaged 41 µg/L for all of Dora Lake during the summer of 2006. This concentration is higher than the expected range of concentrations for reference lakes in this ecoregion (Table 2a). TP concentrations ranged from 32 – 55 µg/L (Figure 12). Concentrations tended to increase through July, peaking in August and then steadily declined through September; again, somewhat consistent with other shallow lakes. In general, TP in the north basin (Site 101) was slightly higher than the southern basin (Site 201). TP samples collected one meter off the bottom of the lake in May, late-July, and late-September by MPCA staff were nearly identical to the surface samples collected during those same sampling events. This data, along with the temperature profile data, indicates that Dora Lake is polymictic and has the potential for internal loading of phosphorus from the sediments (Appendix).

Chlorophyll-*a* concentrations for Dora Lake averaged 7 µg/L and were well within the ecoregion reference range (Table 2a). Concentrations on Dora Lake ranged from 4.3 – 13.1 µg/L and followed a similar pattern to TP concentrations – peaking in August. No nuisance or severe nuisance algae blooms were noted for the entire summer based on these concentrations.

Figure 9. Dora Lake Watershed & Land Use Map



Land Use Type	Dora Lake Percent	NLF Ecoregion Percent
Forest	54	54 - 81
Water & Marsh	41	14 - 31
Pasture & Open	2	0 - 6
Cultivated	1	< 1
Urban	2	0 - 7

Figure 10. Dora Lake Bathymetric Map and Monitoring Locations

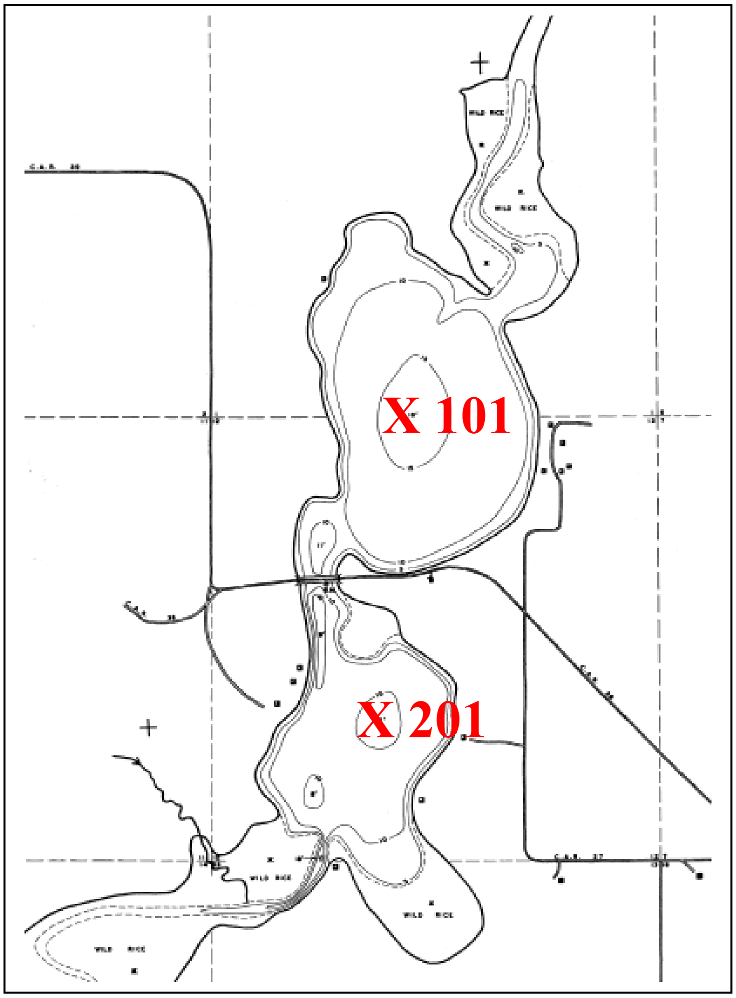
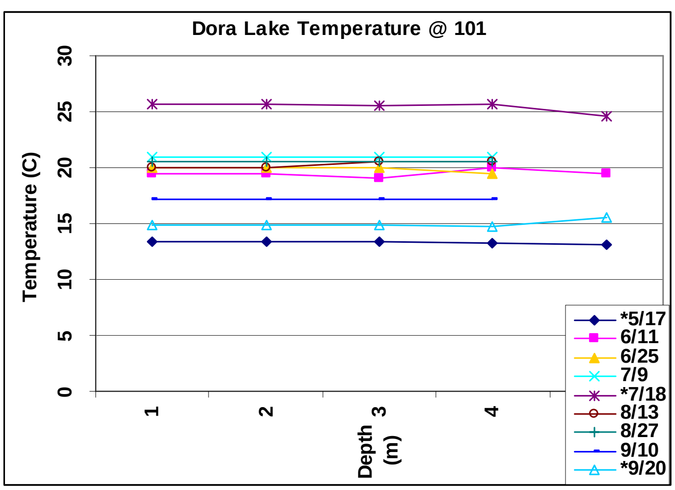


Figure 11. Dora Lake Temperature Profile Data for 2006



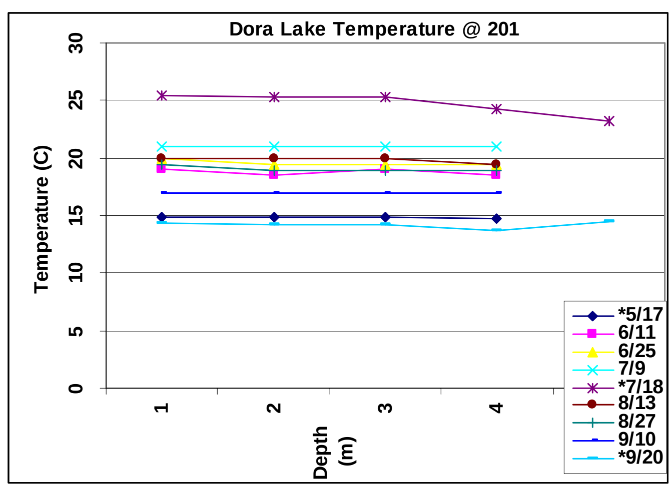
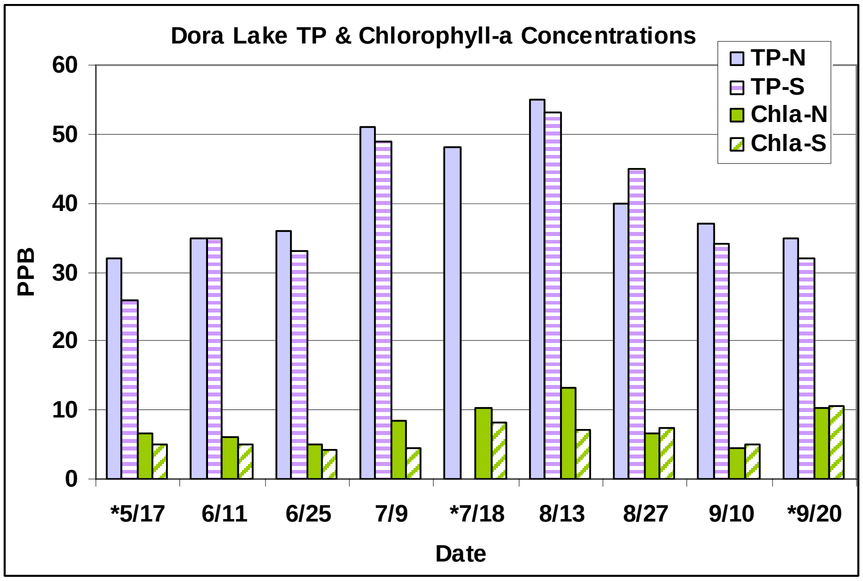
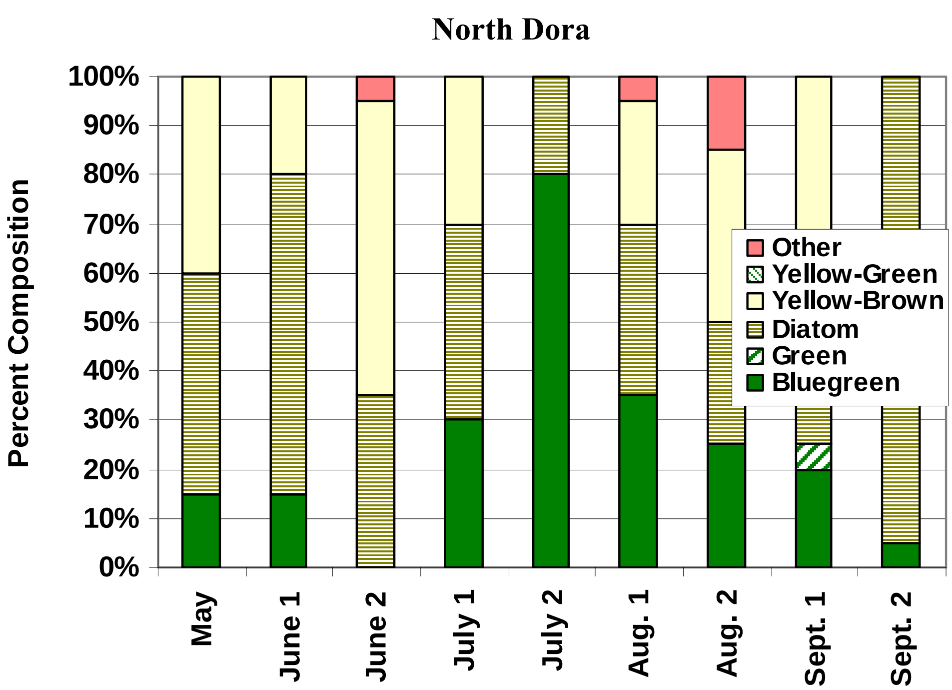


Figure 12. Dora Lake Total Phosphorus & Chlorophyll-*a* Results for 2006

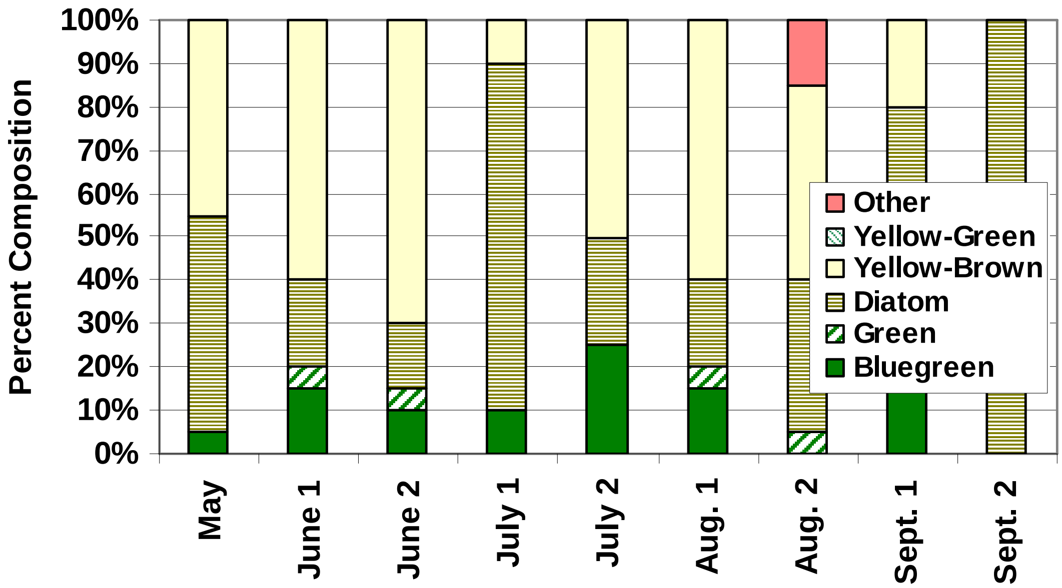


The composition of the phytoplankton (algae) population of Dora Lake is presented in Figure 13. Data are presented in terms of algal type and samples were collected at Site 101 and Site 201. The diatoms and yellow-browns dominated the algae population throughout the summer at both sites, with the forms *Centric* (diatom) and *Dinobryon* (yellow-brown) being most common. There was a marked increase in the bluegreen population in late-July in the north site. This was not noted at the south site. Bluegreens, as a whole, are the form most often associated with nuisance bloom conditions.

Figure 13. Dora Lake Algal Populations for 2006

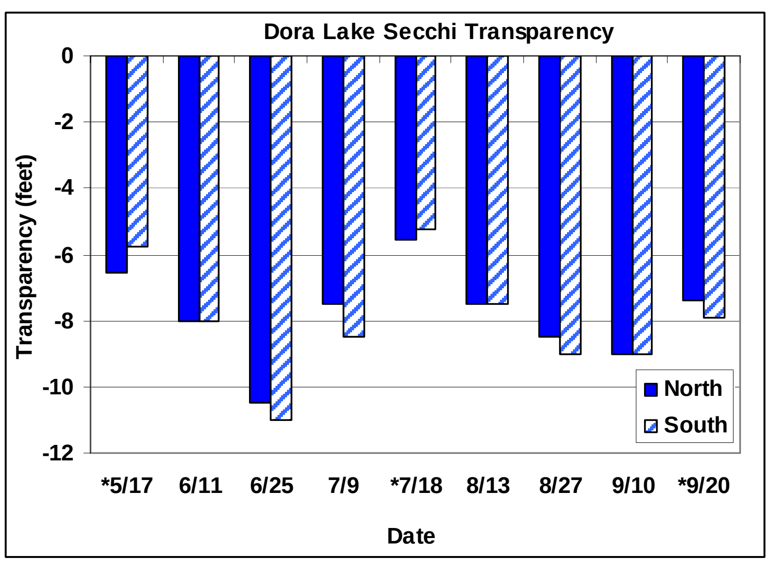


South Dora



Secchi disk transparency on Dora Lake ranged from 5.3 feet (1.6 meters) in late-July to 11 feet (3.4 meters) in late-June (Figure 14) and averaged 8.1 feet (2.5 meters). The average transparency value is within the typical range for NLF ecoregion reference lakes (Table 2a). Dora Lake's physical condition was generally characterized as "not quite clear" (Class 2); while its recreational suitability was characterized as "minor aesthetic problems" (Class 2) throughout the summer (Appendix 1).

Figure 14. Dora Lake Secchi Transparency for 2006



Other parameters, such as alkalinity, chloride, color, pH and conductivity, analyzed for Dora Lake were all within or near the typical range of values for ecoregion reference lakes (Table 2a). It should be noted that total Kjeldahl nitrogen and total suspended solids and total suspended inorganic solids were above the typical range of values for ecoregion reference lakes (Table 2a) for Dora Lake.

Trophic State Index (TSI) values for Secchi and chlorophyll-*a* compare very favorably to each other for Dora Lake (Table 2b); however, the TSI value for TP was significantly lower than the other TSI values. Based on the 2006 data, Secchi transparency may not be a good estimator for TP; but may be sufficient for chlorophyll-*a*. In addition, Secchi should continue to be an indicator of overall water quality for Dora Lake as well as a good tool for examining transparency trends within the lake. The overall TSI value of 52 for Dora Lake indicates *mesotrophic – eutrophic* conditions.

HALE (31-0361)

Hale Lake is a small lake located seven miles southeast of Grand Rapids, Minnesota and near the far southeast end of Pokegama Lake. It was the smallest lake participating in the 2006 survey in Itasca County for 2006. It has a surface area of 131 acres, a maximum depth of 59 feet and a mean depth of 15 feet. Approximately 87 percent of the lake is littoral and there is one canoe-carry in access for the lake. It has a fairly small watershed area of 4.1 mi^2 comprised of mainly forested and water/marsh land uses (Table 1, Figure 15). Its water residence time is on the order of five years.

Water quality data was collected in June, July, August, and September, 2006 by volunteer lake monitor: Rich Libbey. One site was used on Hale Lake: Site 201– located over the point of maximum depth in the lake (Figure 16).

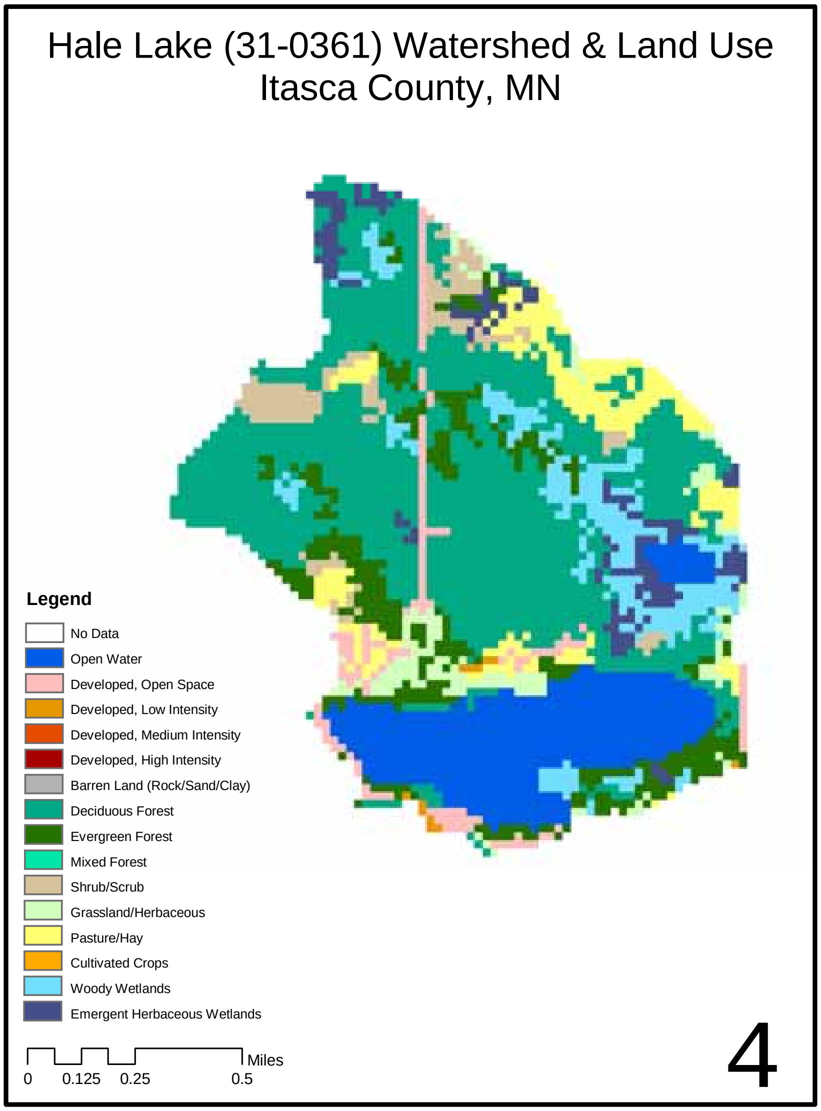
Temperature data indicated that the lake was stratified, starting between 3 – 5 meters (Figure 17) for most of the summer, but shifted to below 5 meters in September. Surface temperatures ranged from 15° C in May to 26° C in July.

Total phosphorus (TP) concentrations averaged 18 µg/L in Hale Lake during the summer of 2006. This value is well within the range of concentrations for reference lakes in this ecoregion (Table 2a). TP concentrations in Hale Lake ranged from 15 – 22 µg/L (Figure 18). After an initial decline from May to June, TP was rather stable during the summer; which is consistent with other dimictic lakes (see Background). TP samples collected one meter off the bottom of the lake in May, July and September were considerably higher as compared to the surface samples collected at those same sampling events (Appendix). These data, combined with the temperature data, indicate the lake remained stratified throughout the summer.

Chlorophyll-*a* concentrations for Hale Lake averaged 3 µg/L and were well below the expected range of values for the NLF ecoregion (Table 2a). Concentrations on Hale Lake ranged from 1.9 – 4.7 µg/L with no mild, nuisance or severe algae blooms noted for the lake (Figure 18).

The composition of the phytoplankton (algae) population of Hale Lake is presented in Figure 19. Data are presented in terms of algal type. Samples were collected at Site 201. The bluegreens dominated the algal population throughout most of the summer, with the form *Anabaena* being the most common. The bluegreens, as a whole, are the forms most commonly associated with nuisance algal conditions; however, given the extremely low chlorophyll-*a* values for the lake, nuisance blooms would not have been noted.

Figure 15. Hale Lake Watershed & Land Use Map



Land Use Type	Hale Lake Percent	NLF Ecoregion Percent
Forest	52	54 - 81
Water & Marsh	28	14 - 31
Pasture & Open	15	0 - 6
Cultivated	0	< 1
Urban	5	0 - 7

Figure 16. Hale Lake Bathymetric Map and Monitoring Location

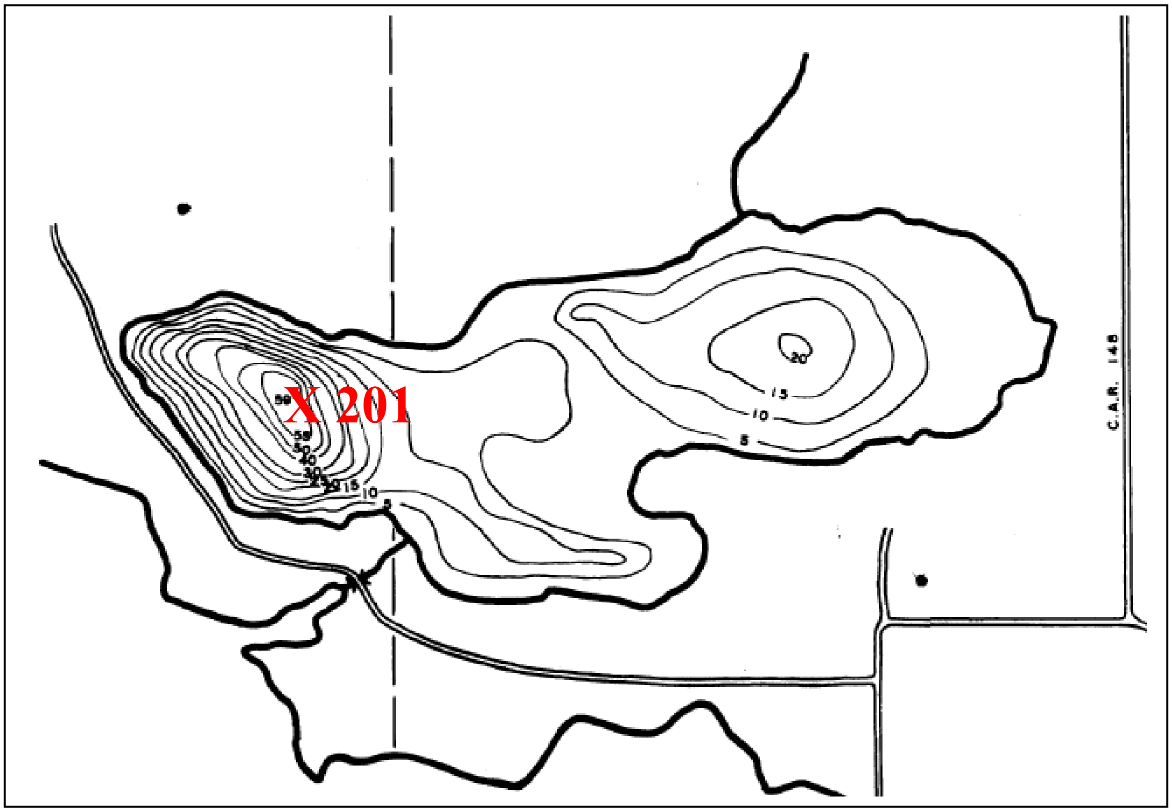


Figure 17. Hale Lake Temperature Profile Data for 2005

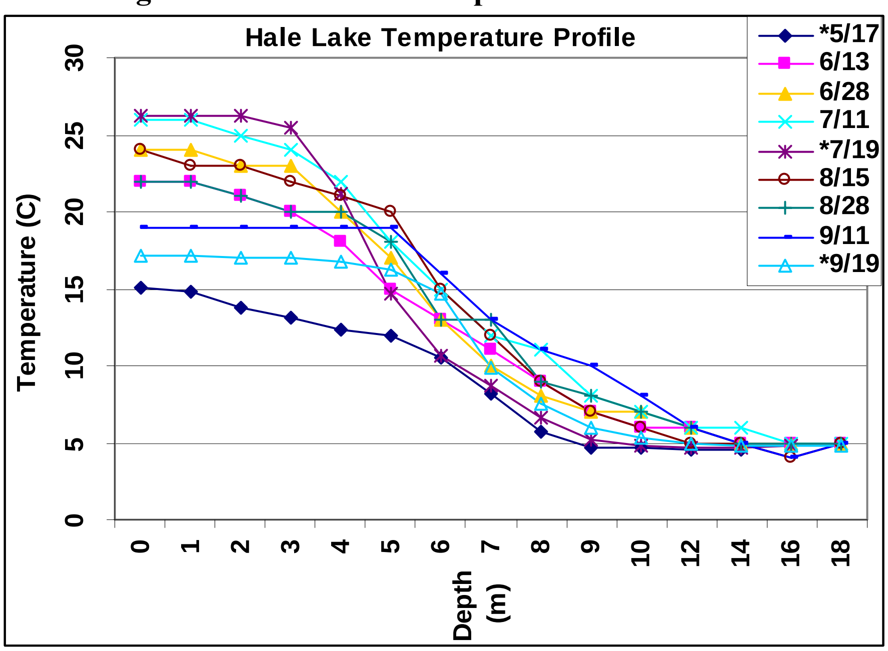


Figure 18. Hale Lake Total Phosphorus and Chlorophyll-*a* Results for 2006

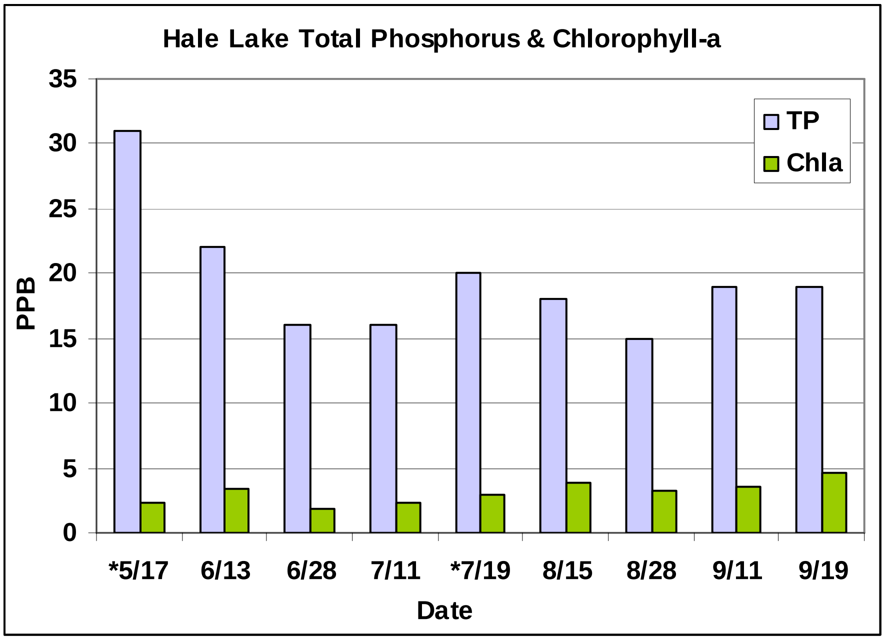


Figure 19. Hale Lake Algal Populations for 2006

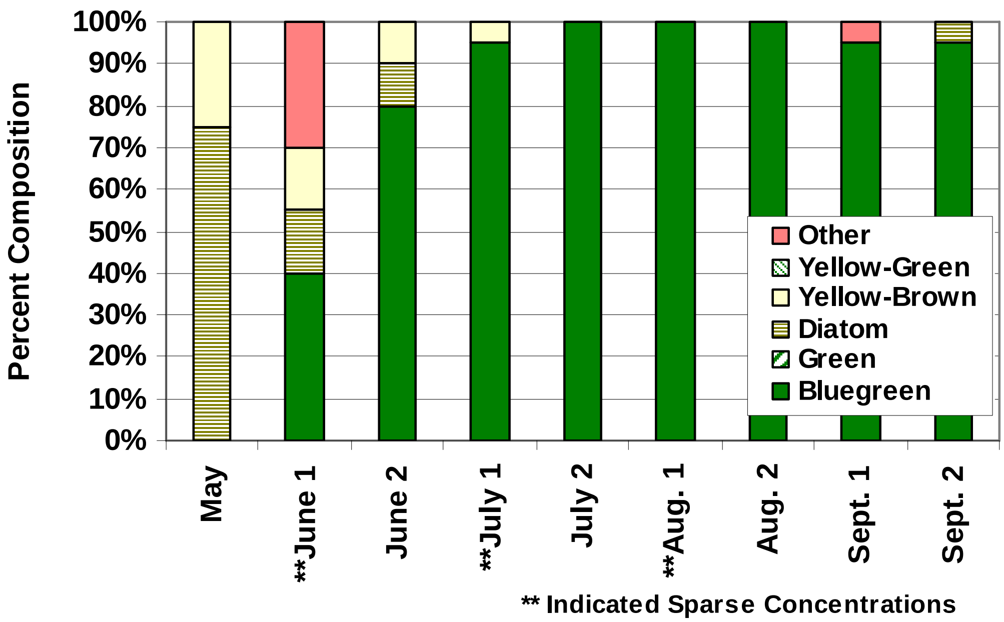
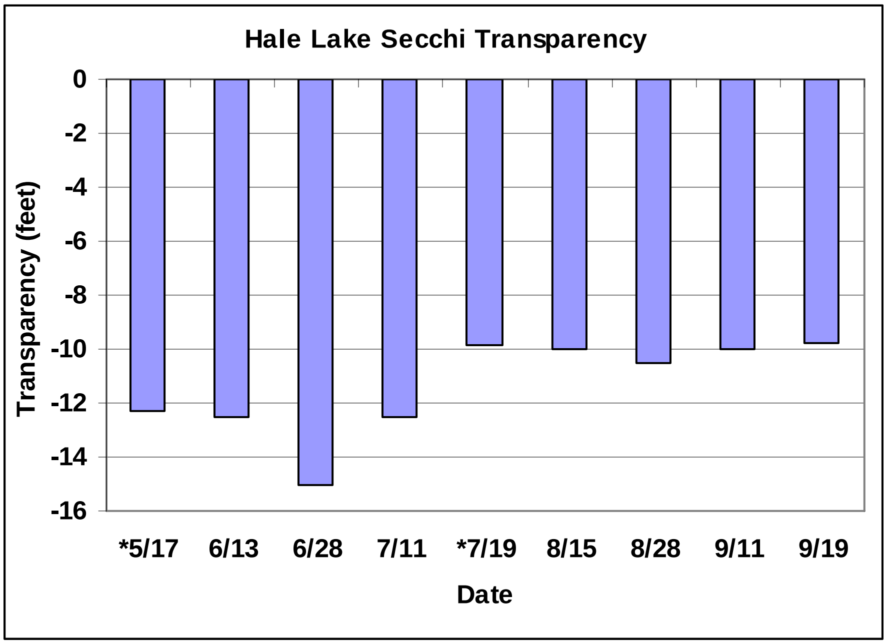


Figure 20. Hale Lake Secchi Transparency for 2006



Secchi disk transparency on Hale Lake ranged from 9.8 feet (3.0 meters) in late-July and September to 15 feet (4.6 meters) in late-June (Figure 20) and averaged 11.3 feet (3.4 meters). These transparency measures are within the typical range for NLF ecoregion reference lakes (Table 2a). Physical condition ratings for Hale Lake were primarily characterized as "not quite crystal clear" (Class 2); while recreational suitability ratings were characterized as "minor aesthetic problems" (Class2) (Appendix).

Other parameters, such as total suspended solids, total suspended inorganic solids, total Kjeldahl nitrogen, conductivity and color, analyzed for Hale Lake were all within the typical range of values for NLF ecoregion reference lakes (Table 2a). Chloride and pH values; however, were above the ecoregion reference range (Table 2a). Though chloride is high relative to the typical range, it is well below levels that may impact aquatic biota. The most likely source of excess chloride is from the use of road salt on the adjacent road network.

Trophic State Index (TSI) values for TP, chlorophyll-*a* and Secchi compare very favorably to each other for Hale Lake (Table 2b). Based on the 2006 data, Secchi transparency should be a good estimator for TP and chlorophyll-*a* values within the lake, as well as a good indicator of overall water quality for Hale Lake. In addition, Secchi transparency should also continue to be a good tool for examining transparency trends within the lake. The overall TSI value of 43 for Hale Lake indicates *mesotrophic* conditions.

ISLAND (31-0913)

Island Lake is located four miles south of Northome, Minnesota. It is a very large lake, covering 3,088 acres; and as such, it is in the upper five percent of lakes in terms of size. It has a maximum depth of 35 feet and mean depth of 15 feet. Approximately 39 percent of the lake is littoral and there are two public accesses for the lake. Its watershed area is moderate at 11.6 mi^2 and is comprised of mainly forest and water/marsh land uses (Table 1, Figure 21). Its water residence time is on the order of seven years.

Water quality data was collected in June, July, August, and September, 2006 by volunteer lake monitor: William (Bill) Luadtke. One site was used for collecting chemistry data and temperature profiles on Island Lake: Site 101 – located in the north end of the lake (Figure 22).

The temperature meter used for Island Lake was not working properly, so the only temperature data collected for this lake was done by MPCA staff. Temperature data indicated that the lake was well mixed on all three MPCA sampling events (Figure 23). Surface water temperatures ranged from 11.9°C in May to 24.9°C in July.

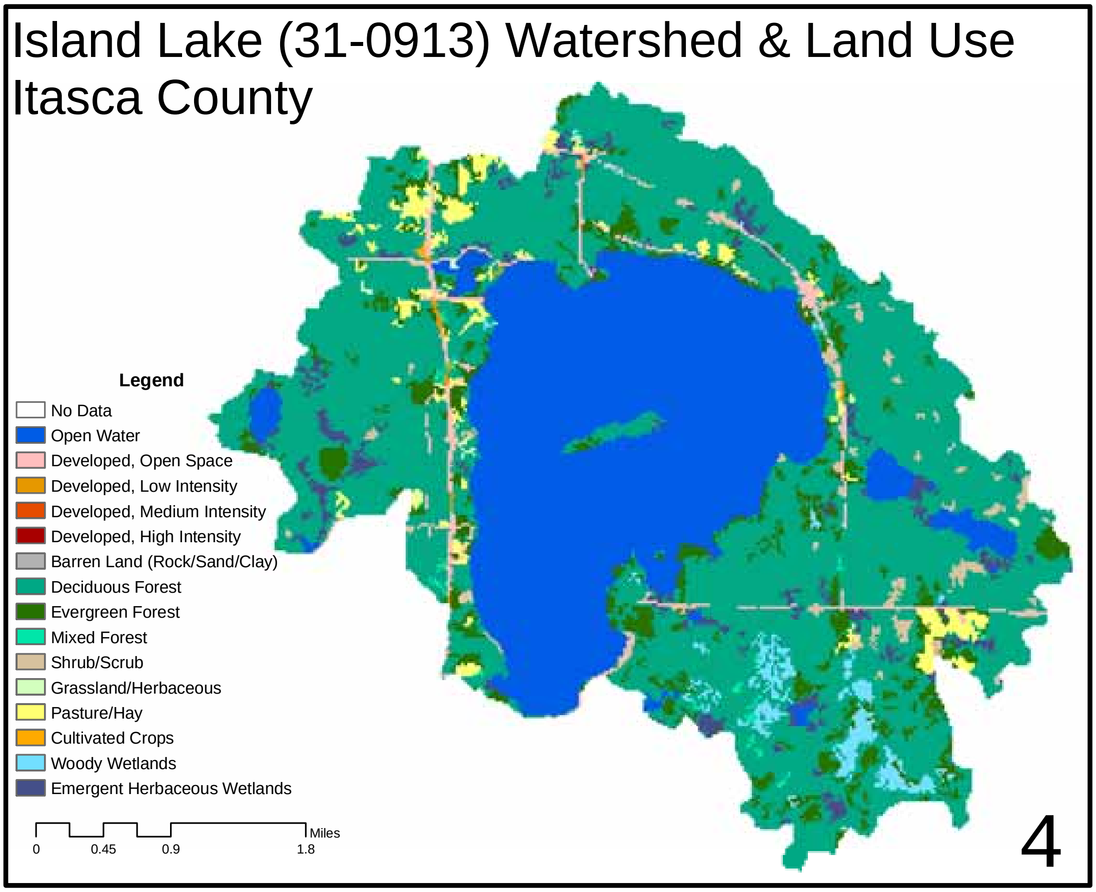
Total phosphorus (TP) concentrations averaged 46 µg/L during the summer of 2006. This value is higher than the expected range of concentrations for reference lakes in the NLF ecoregion (Table 2a). TP concentrations ranged from 21 – 73 µg/L (Figure 24) with a peak in concentrations during the month of August; again, consistent with other shallow lakes.

Chlorophyll-*a* concentrations for Island Lake averaged 23 µg/L and were within the expected range for the NLF ecoregion (Table 2a). Concentrations on Island Lake ranged from 1.4 – 60.5 µg/L with a peak in concentrations in August, corresponding to the peak in TP concentrations from that same sampling events (Figure 24).

The composition of the phytoplankton (algae) population of Island Lake is presented in Figure 25. Data are presented in terms of algal type. Samples were collected at site 101. While the diatoms and yellow-browns were well represented in May and June, bluegreens were the dominant form throughout the remaining summer. The forms *Anabaena* and *Aphanizomenon* were the most dominate forms of bluegreens observed.

Secchi disk transparency at site 101 on Island Lake ranged from 3.0 feet in August to 11.5 feet in late-September (Figure 26) and averaged 6.4 feet (1.1 meters). The average transparency measure is below the typical range for NLF ecoregion reference lakes (Table 2a). Overall, transparency tended to decline through August, and then increased again in September. The physical condition of Island Lake was generally characterized as "not quite crystal clear" (Class 2) through July. Following July, the lake was generally characterized as “high algal levels” (Class 4). The recreational suitability for Island Lake was generally characterized as “minor aesthetic problems” (Class 2) through July, followed by “no swim, but boating okay” (Class 4) for the remainder of the summer (Appendix).

Figure 21. Island Lake Watershed & Land Use Map



Land Use Type	Island Lake Percent	NLF Ecoregion Percent
Forest	58	54 - 81
Water & Marsh	36	14 - 31
Pasture & Open	4	0 - 6
Cultivated	0	< 1
Urban	2	0 - 7

Figure 22. Island Lake Bathymetric Map and Monitoring Location

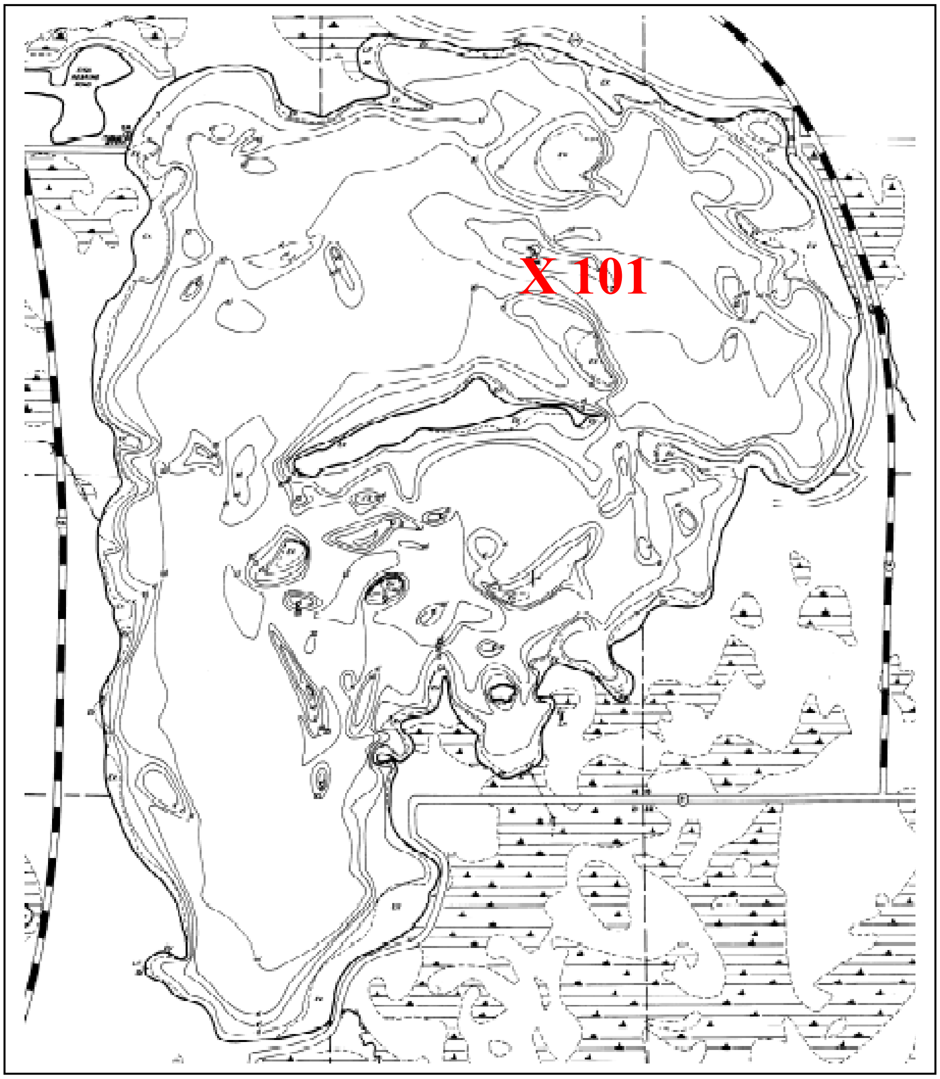


Figure 23. Island Lake Temperature Profile Data for 2006

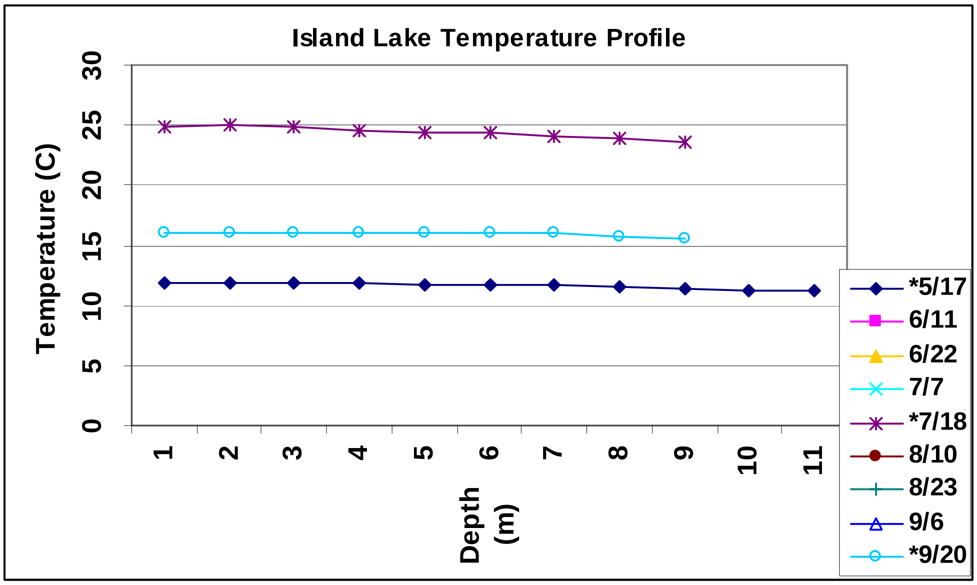


Figure 24. Island Lake Total Phosphorus and Chlorophyll-*a* Results for 2006

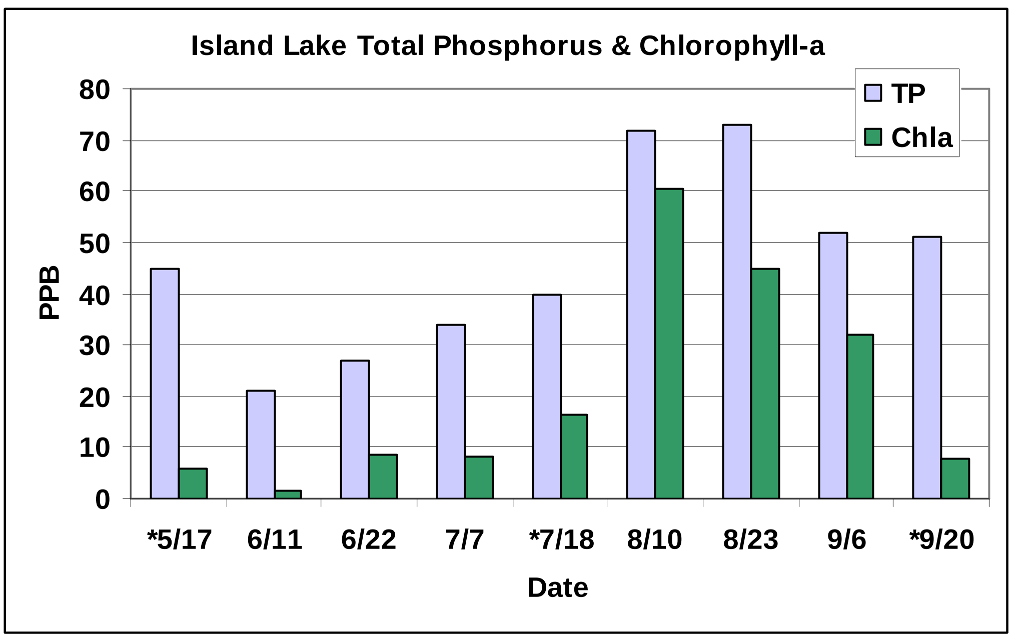


Figure 25. Island Lake Algal Populations for 2006

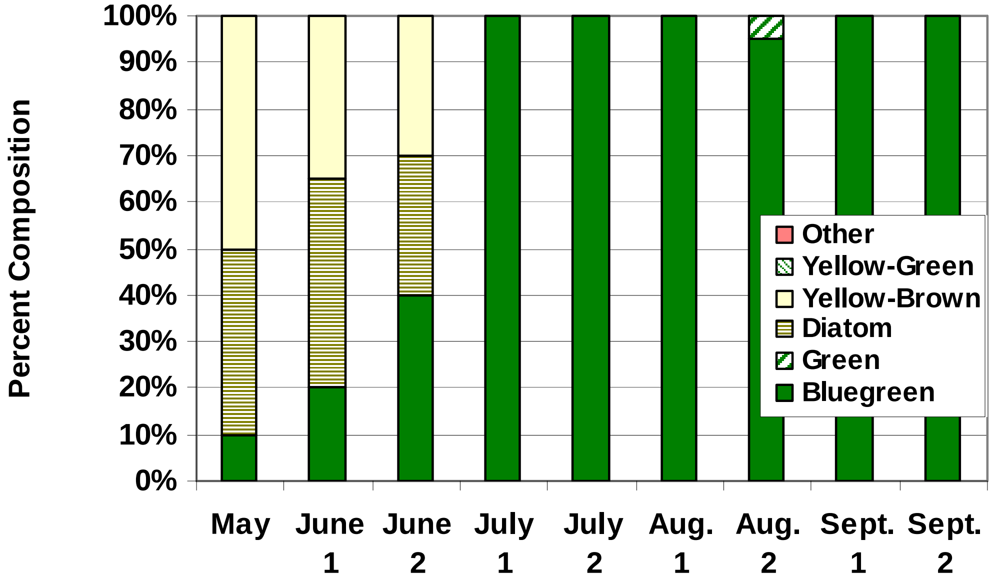
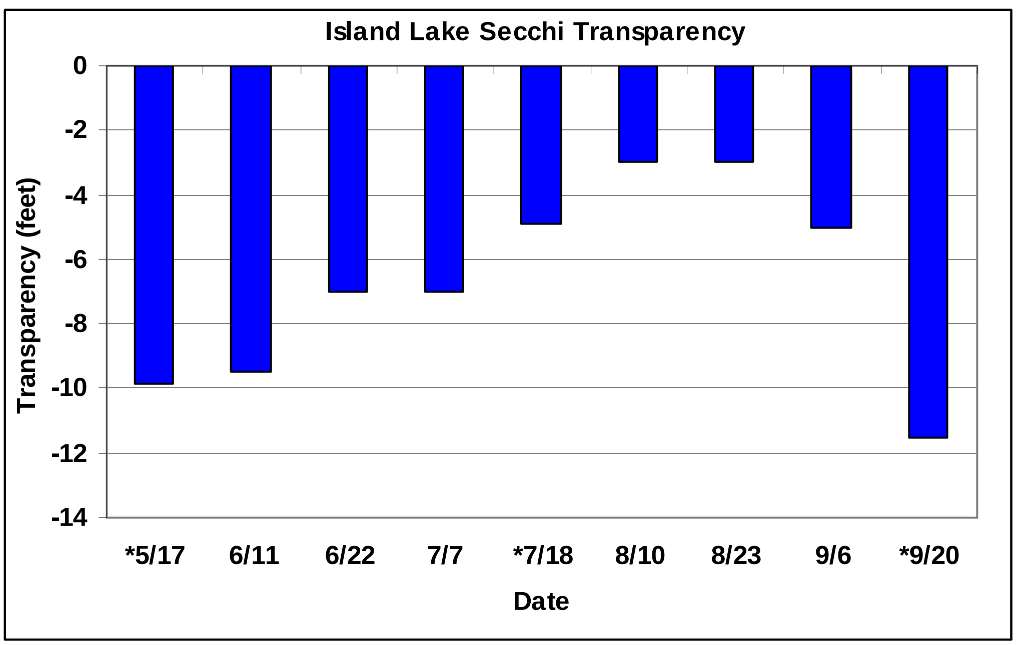


Figure 26. Island Lake Secchi Transparency for 2006



Other parameters, such as total suspended solids, total suspended inorganic solids, total Kjeldahl nitrogen, chloride, and pH analyzed for Island Lake were all above the typical range of values for ecoregion reference lakes (Table 2a). Color, alkalinity, and conductivity values were within the range for NLF ecoregion reference lakes (Table 2a).

Trophic State Index (TSI) values for TP and chlorophyll-*a* compare very favorably to each other for Long Lake (Table 2b); however, the TSI value for Secchi transparency was significantly lower than the other TSI values. Based on the 2006 data, Secchi transparency is not a good estimator for TP and chlorophyll-*a* values or indicator of overall water quality for Island Lake; however, it should still continue to be a good tool for examining transparency trends within the lake. The overall TSI value of 57 for Island Lake indicates *eutrophic* conditions.

LITTLE BOWSTRING (31-0758)

Little Bowstring Lake is a moderate-sized lake located three miles southeast of the town of Bowstring, Minnesota. It has a surface area of 319 acres, a maximum depth of 33 feet and a mean depth of about 16 feet. Approximately 36 percent of the lake is littoral and there is one public access for the lake. It has fairly large watershed area of 12 mi^2 (Table 1, Appendix 2), considering the actual size of the lake itself. As such, the watershed to lake ratio is fairly large at 24:1 (Table 2). The watershed land use is comprised primarily of forested use, followed distantly by water/marsh and pasture/open uses (Figure 27). Its water residence time is estimated to be on the order of one year.

Water quality data was collected in June, July, August, and September, 2006 by volunteer lake monitor: Norman Ford. One site was used on Little Bowstring Lake: Site 201– located over the point of maximum depth in the lake (Figure 28).

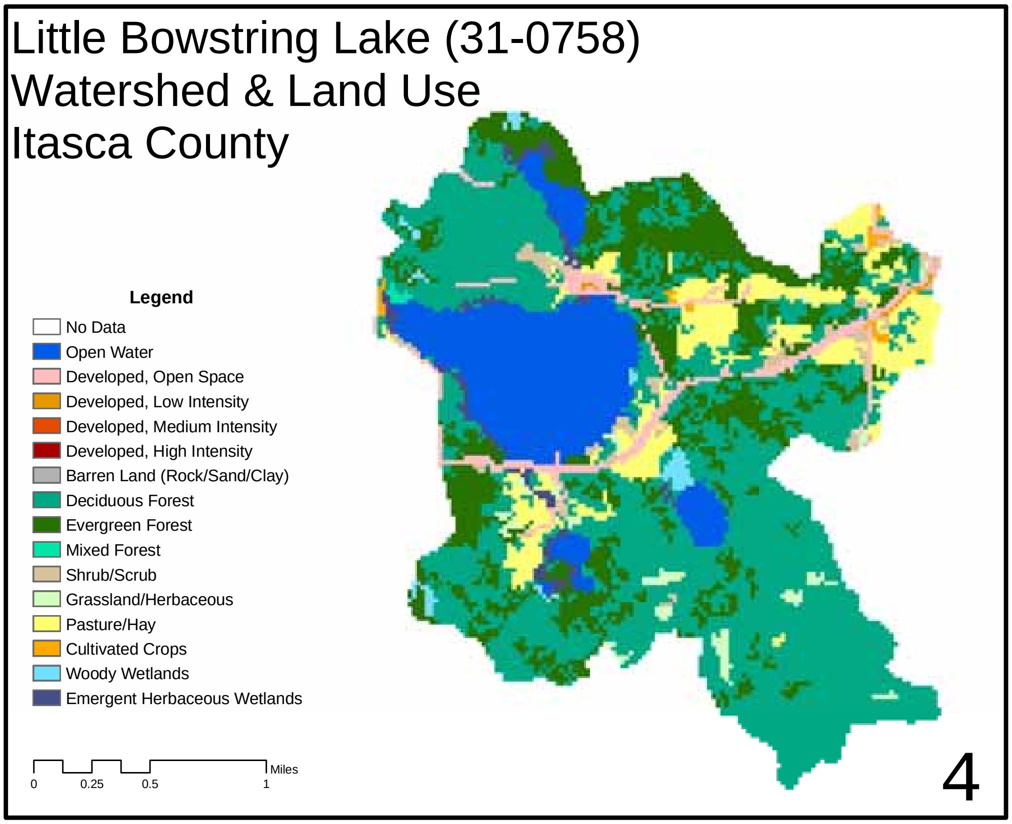
Temperature data indicated that the lake was well mixed in early spring (May) and September (Figure 29) with mild thermal stratification below four meters from June through August. Surface temperatures ranged from 12.8° C in May to 26.5° C in July.

Total phosphorus (TP) concentrations averaged 30 µg/L during the summer of 2006. This value is slightly above the expected range of concentrations for reference lakes in this ecoregion (Table 2a). TP concentrations ranged from 18 – 44 µg/L (Figure 30). Following an initial decline in June, concentrations generally increased over the summer. TP samples collected one meter off the bottom (deep samples) of the lake in May and September (Appendix), as well as the temperature data from the same sampling dates; indicate Little Bowstring was well-mixed during those sampling events. In contrast, the July deep TP sample, and corresponding temperature and surface TP data indicate that Little Bowstring was stratified on that sampling date.

Chlorophyll-*a* concentrations for Little Bowstring Lake averaged 9 µg/L and were well within the expected NLF ecoregion range (Table 2a). Concentrations on Little Bowstring Lake ranged from 1.8 – 25.5 µg/L (Figure 30). Generally, concentrations increased over the course of the summer, with the exception of a slight drop in chlorophyll concentrations in early-September. This early-September reduction in chlorophyll concentrations corresponds to the early-September decline in TP. In fact, given the concentration levels, near-nuisance algae blooms may have been noted in late-August and September (Figure 30); however, severe algae blooms were not noted on any of the sampling occasions.

The composition of the phytoplankton (algae) population of Little Bowstring Lake is presented in Figure 31. Data are presented in terms of algal type. Samples were collected at Site 201. The diatoms and yellow-browns were fairly well represented in May and June; while bluegreens dominated the algal population for the remaining summer months. The forms of *Anacystis*, *Aphanizomenon* and *Oscillatoria/Lyngbya* were the most common bluegreens observed throughout the summer.

Figure 27. Little Bowstring Lake Watershed & Land Use Map



Land Use Type	Little Bowstring Lake Percent	NLF Ecoregion Percent
Forest	67	54 - 81
Water & Marsh	17	14 - 31
Pasture & Open	12	0 - 6
Cultivated	0	< 1
Urban	4	0 - 7

Figure 28. Little Bowstring Lake Bathymetric Map and Monitoring Location

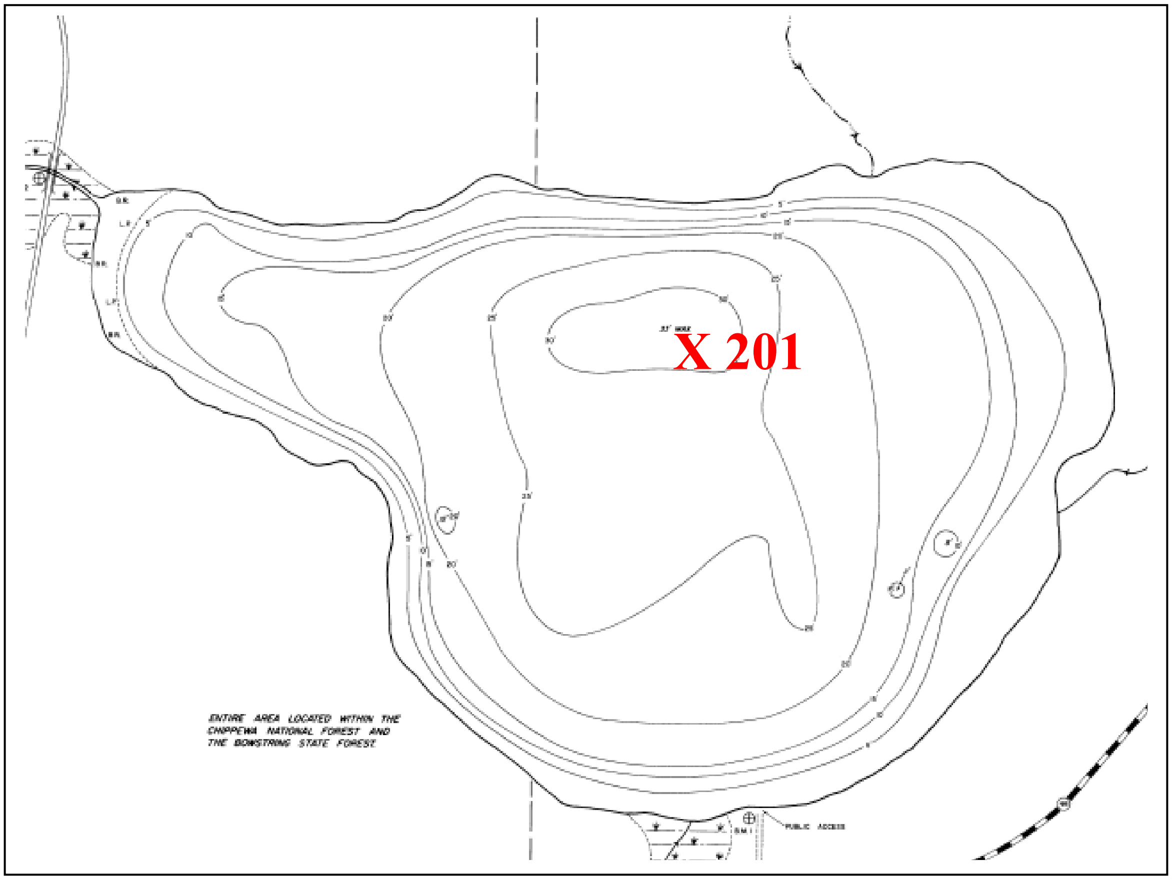


Figure 29. Little Bowstring Lake Temperature Profile Data for 2006

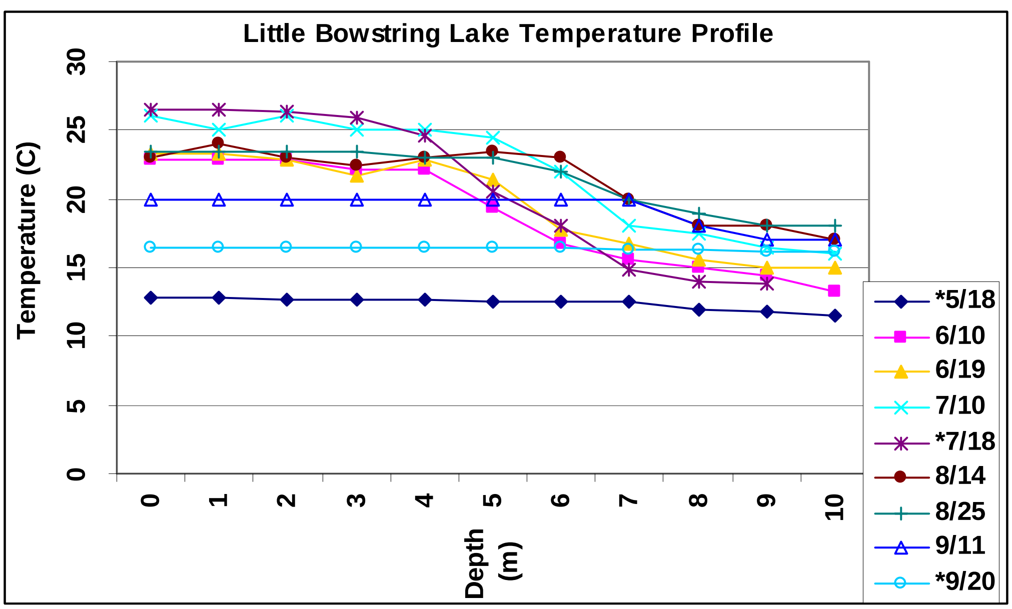


Figure 30. Little Bowstring Lake Total Phosphorus and Chlorophyll-*a* Results for 2006

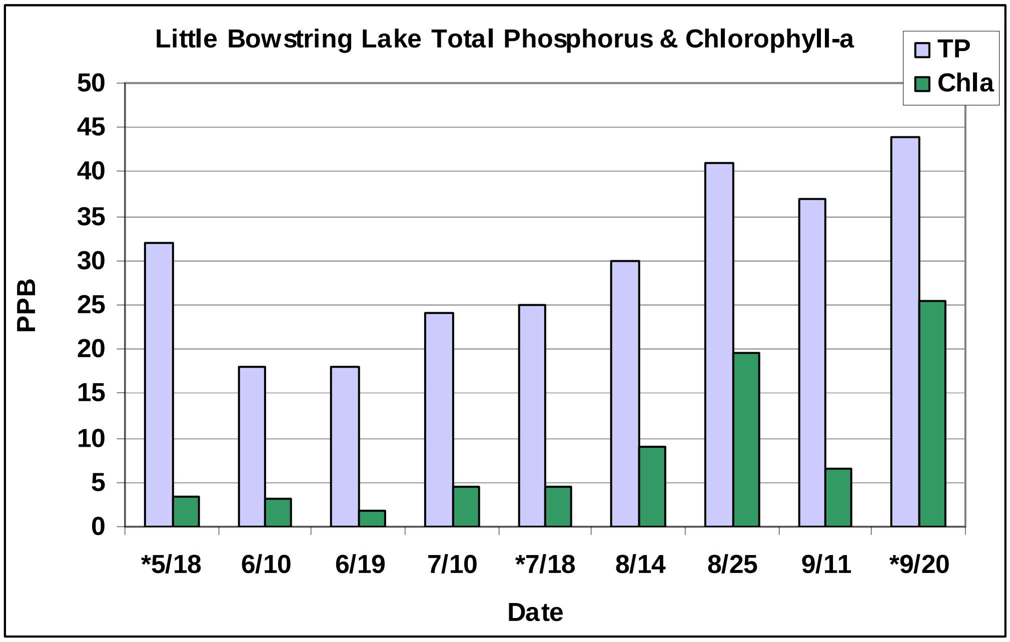


Figure 31. Little Bowstring Lake Algal Populations for 2006

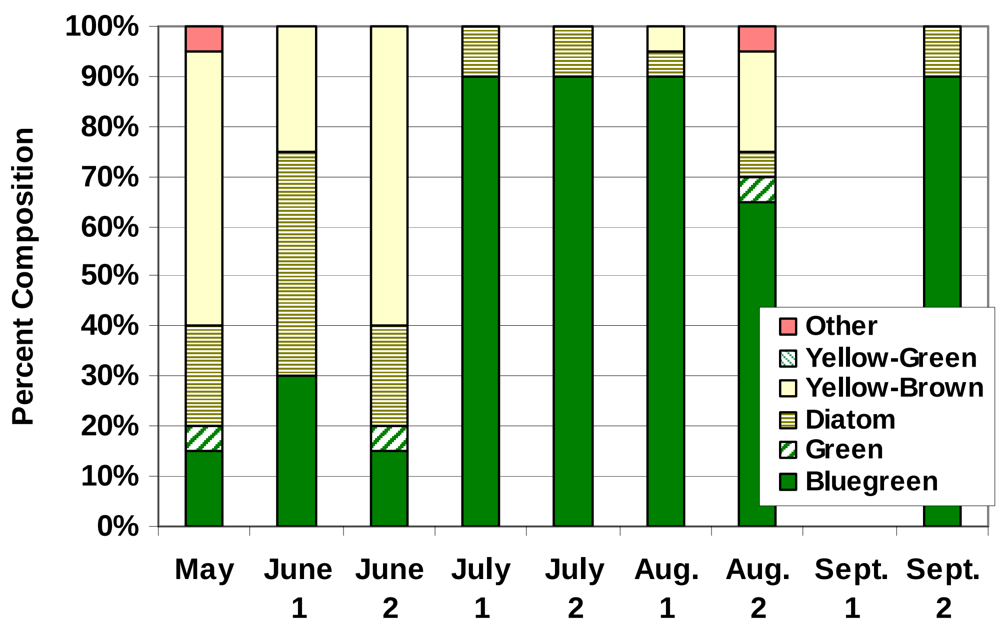
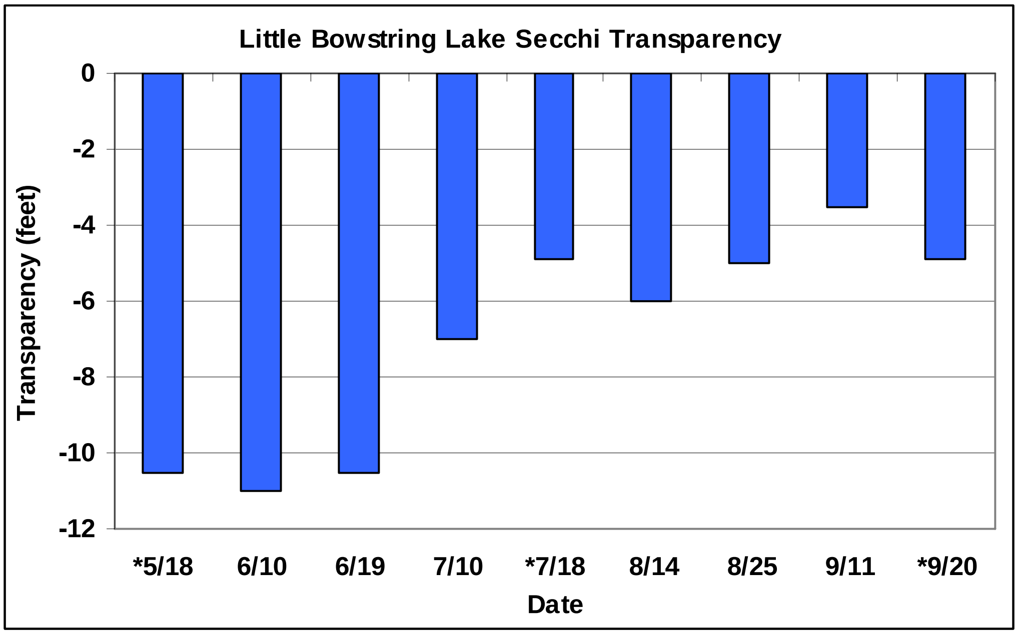


Figure 32. Little Bowstring Lake Secchi Transparency for 2006



Secchi disk transparency on Little Bowstring Lake ranged from 3.5 feet (1.1 meters) in early-September to 11 feet (3.4 meters) in early-June (Figure 32) and averaged 6.6 feet (2.0 meters). These transparency measures are slightly below the typical range for NLF ecoregion reference lakes (Table 2a). Physical condition ratings ranged from "not quite crystal clear" (Class 2) in the early part of the summer to "definite algae color" (Class 3) in the latter half of the summer (Appendix). Recreational suitability ratings followed a similar pattern ranging from "minor aesthetic problems" (Class 2) in the early half of the summer to "slightly impaired" (Class 3) in the latter portion of the summer.

Other parameters, such as total Kjeldahl nitrogen, alkalinity, color, pH, chloride and conductivity and total suspended inorganic solids analyzed for Little Bowstring Lake were all within or near the typical range of values for NLF ecoregion reference lakes (Table 2a). In contrast, total suspended solids were slightly above the range of values for this ecoregion (Table 2a).

Trophic State Index (TSI) values for TP, chlorophyll-*a*, and Secchi transparency all compared very favorably to each other for Little Bowstring Lake (Table 2b). Based on the 2006 data, Secchi transparency is a fairly good estimator of TP and chlorophyll-*a* values. It should also be a good indicator of overall water quality for Little Bowstring Lake. In addition, Secchi transparency should also continue to be a good tool for examining transparency trends within the lake. The overall TSI value of 52 for Little Bowstring Lake indicates borderline *mesotrophic* to *eutrophic* conditions.

LITTLE SPLIT HAND (31-0341) & SPLIT HAND (31-0353)

Little Split Hand and Split Hand Lakes are located eleven miles south of Grand Rapids, Minnesota. Although they are located very close to one another in proximity and similar in overall water quality, they are vastly different in size. Little Split Hand Lake has a surface area of 223 acres, a maximum depth of 25 feet and a mean depth of about 12 feet while Split Hand Lake is more than six times the size of Little Split Hand covering 1,420 acres with a maximum depth of 34 feet and mean depth of about 15 feet. Approximately 63 percent of Little Split Hand Lake is littoral as compared to the littoral area of Split Hand Lake at 36 percent. The total watershed area of Little Split Hand Lake is very large at 35.6 mi^2 (Table 1, Figure 33). The majority of this area is consists of the Split Hand Lake watershed (24.9 mi^2) which drains to Little Split Hand Lake and the primary land uses within both watershed consist of forested and water/marsh uses (Figure 33). The water residence time for Little Split Hand is estimated to be less than six months; while for Split Hand Lake, it is more on the order of 1.5 – 2 years. There is one public access for each lake.

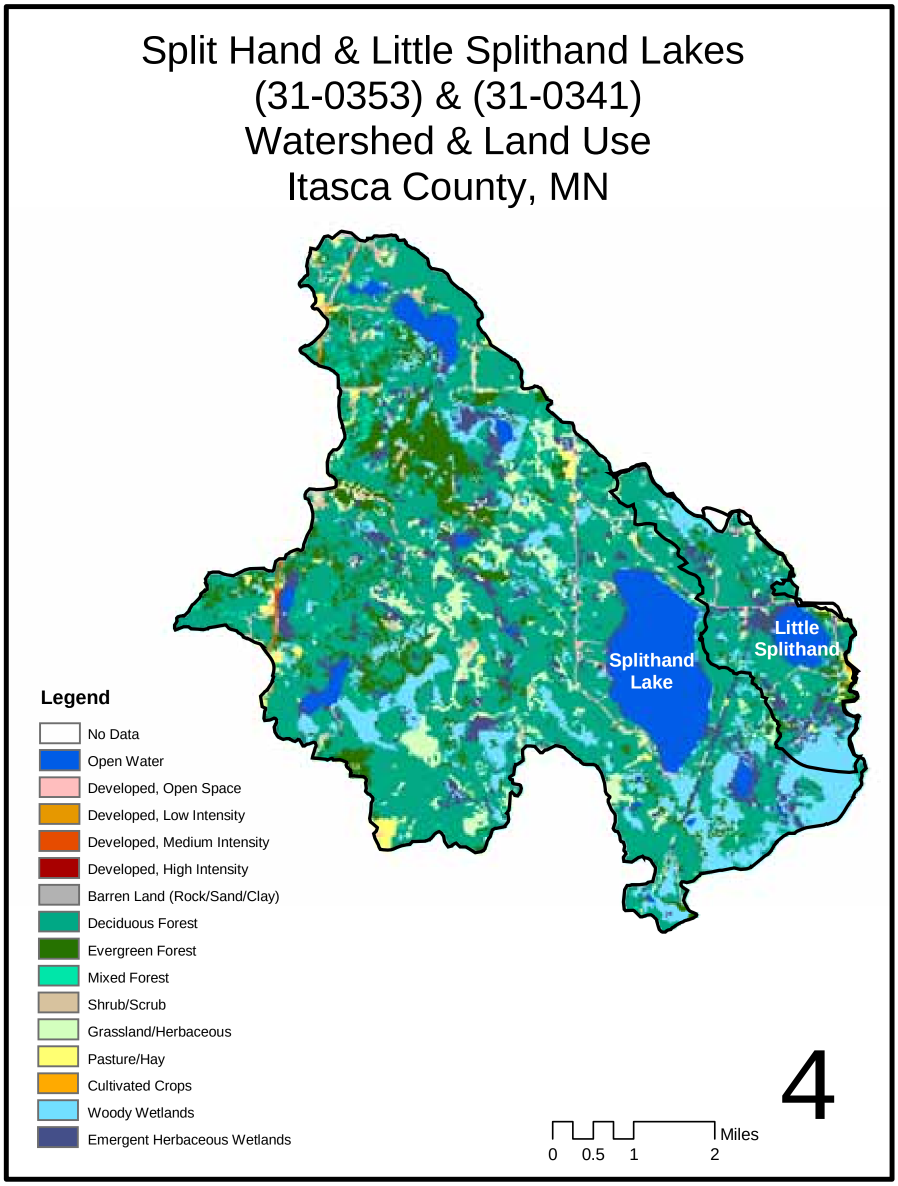
Water quality data was collected in June, July, August, and September, 2006 by volunteer lake monitors: John Rademacher (Little Split Hand) and Greg Winkler (Split Hand). One site (Site 101-Little Split Hand; Site 202-Split Hand), centrally located and representative of the whole lake was used for each lake (Figure 34).

Temperature data indicated that Little Split Hand Lake was well-mixed in May above six meters, but did show slight thermal stratification beyond that point (Figure 35). Little Split Hand showed slight thermal stratification below three to four meters in late June through August; but was well-mixed by late-September. Surface temperatures for the lake ranged from 13.8° C in May to 27.2° C in July. For Split Hand Lake, temperature data indicated that the lake was well mixed throughout the summer (Figure 35) with the exception of very slight thermal stratification evident in late-July and August. Surface temperatures for Split Hand Lake ranged from 13.1° C in May to 26.6° C in July.

Total phosphorus (TP) concentrations averaged 42 and 44 µg/L, respectively for Little Split Hand and Split Hand Lakes during the summer of 2006. These values are above the typical range for NLF reference lakes (Table 2a). TP concentrations ranged from 25 – 65 µg/L in Little Split Hand and from 22 – 81 µg/L in Split Hand (Figure 36). In general, concentrations increased over the summer in both lakes. TP concentrations in Little Split Hand were higher than Split Hand from May through July. In August and September, however; concentrations in Split Hand were higher than Little Split Hand. Intermittent stratification followed by wind-mixing, allowing for internal TP-recycling, is one explanation for this observed pattern.

Chlorophyll-*a* concentrations for Little Split Hand and Split Hand Lakes averaged 17 and 18 µg/L, respectively. These values are above the expected range for NLF reference lakes (Table 2a). Concentrations on Little Split Hand Lake ranged from 3 – 36 µg/L; while concentrations on Split Hand ranged from 3.6 – 34.6 µg/L (Figure 36). Mild to nuisance algae blooms were noted for both lakes beginning in July for 2006 (Figure 15). Severe algae blooms were noted on the late-September sampling event.

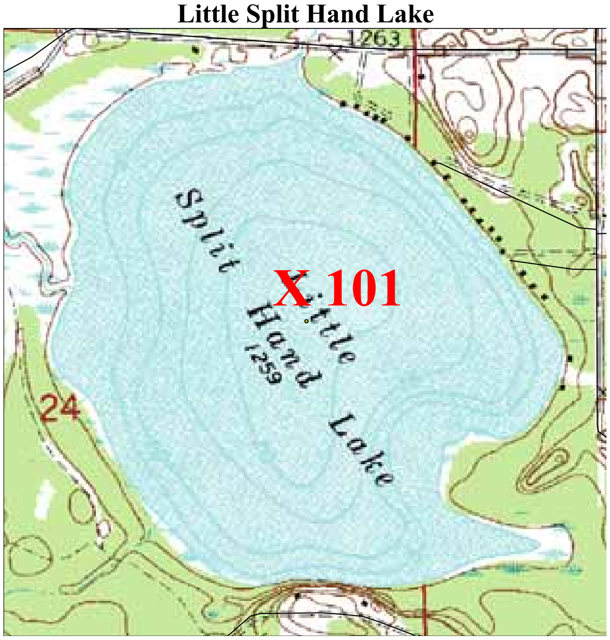
Figure 33. Split Hand Lakes Watershed & Land Use Maps



Land Use Type	Big Split Hand Lake Percent	Little Split Hand Lake Percent	NLF Ecoregion Percent
Forest	62	56	54 - 81
Water & Marsh	27	36	14 - 31
Pasture & Open	9	6	0 - 6
Cultivated	0	0	< 1
Urban	2	2	0 - 7

Figure 34. Split Hand Lakes Bathymetric Maps & Monitoring Locations

Little Split Hand Lake



Split Hand Lake

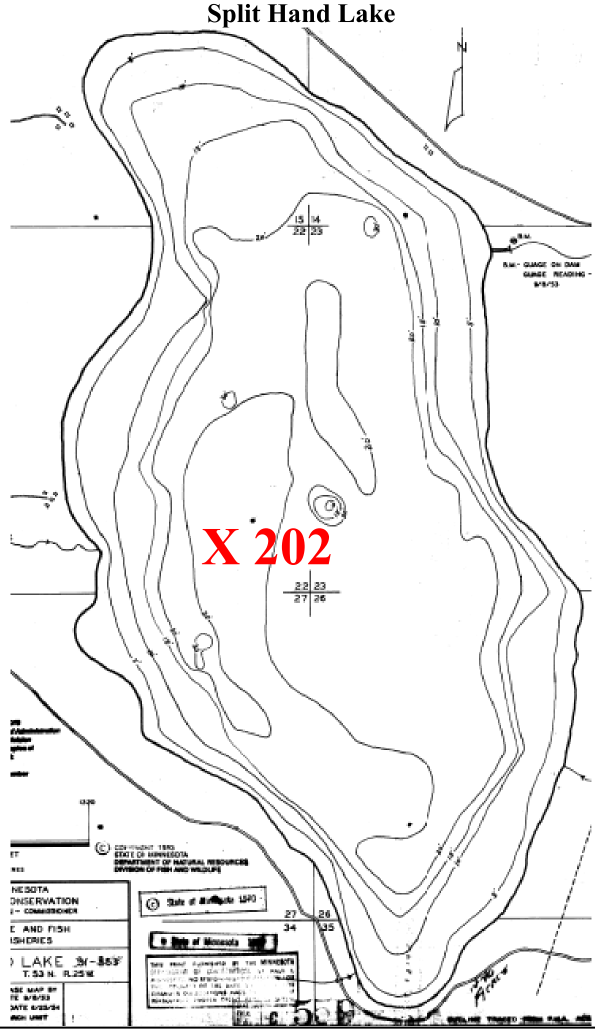
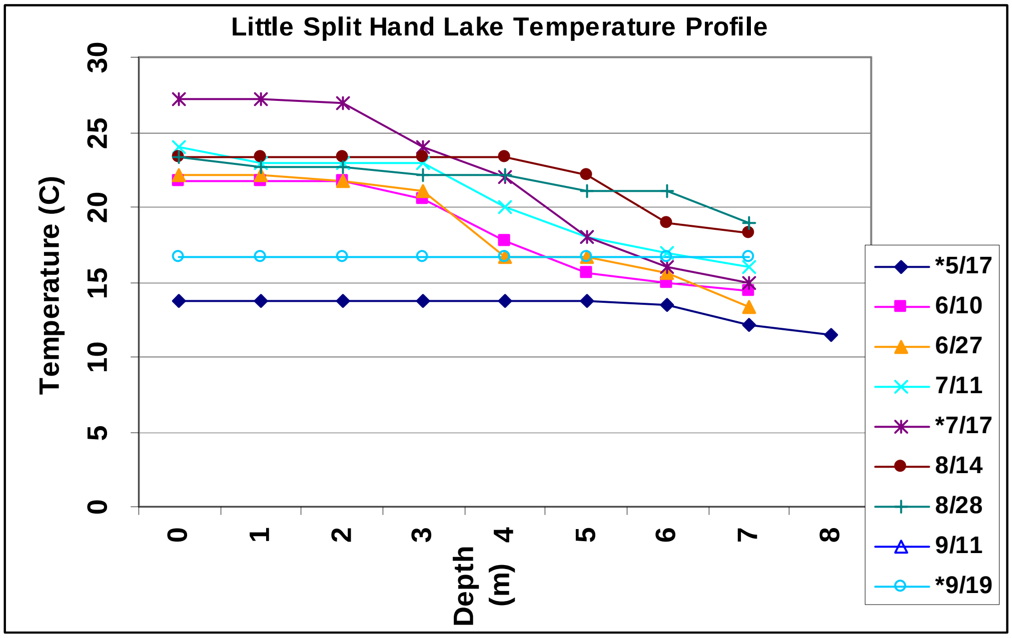


Figure 35. Split Hand Lakes Temperature Profile Data for 2006



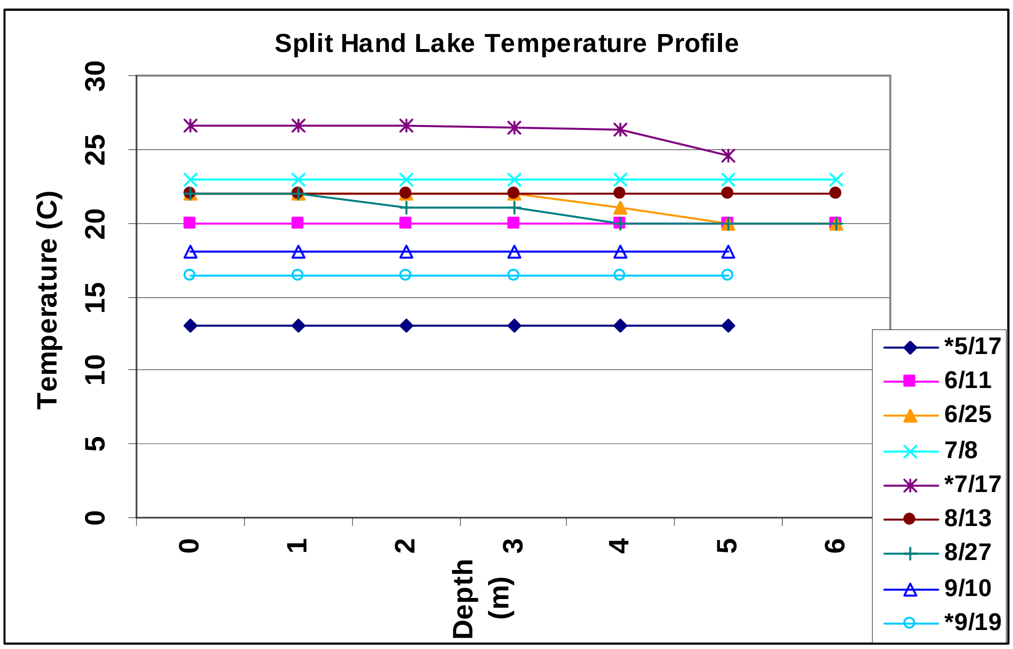
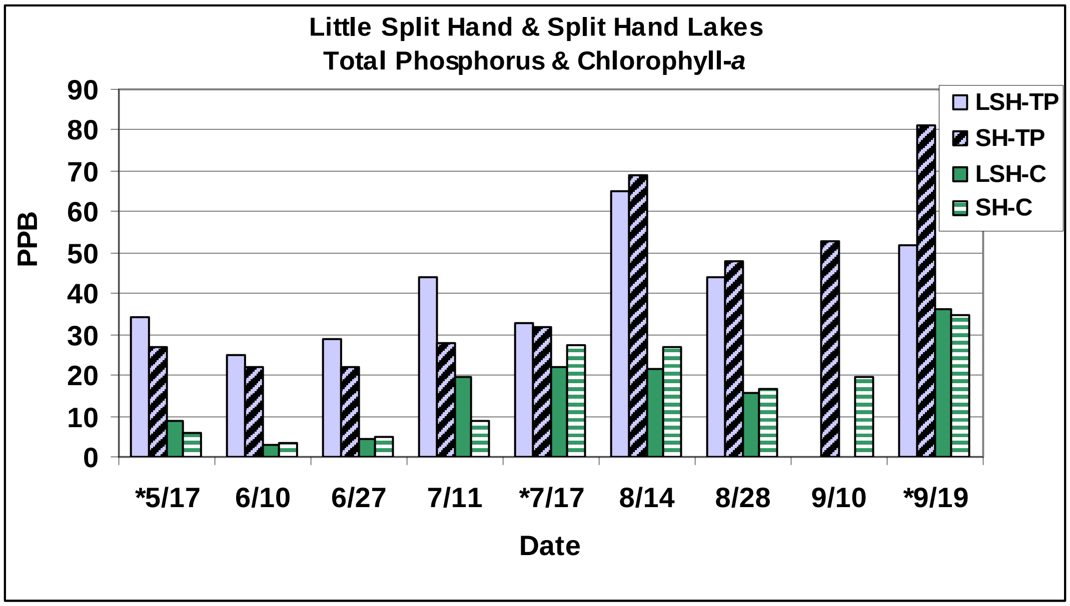
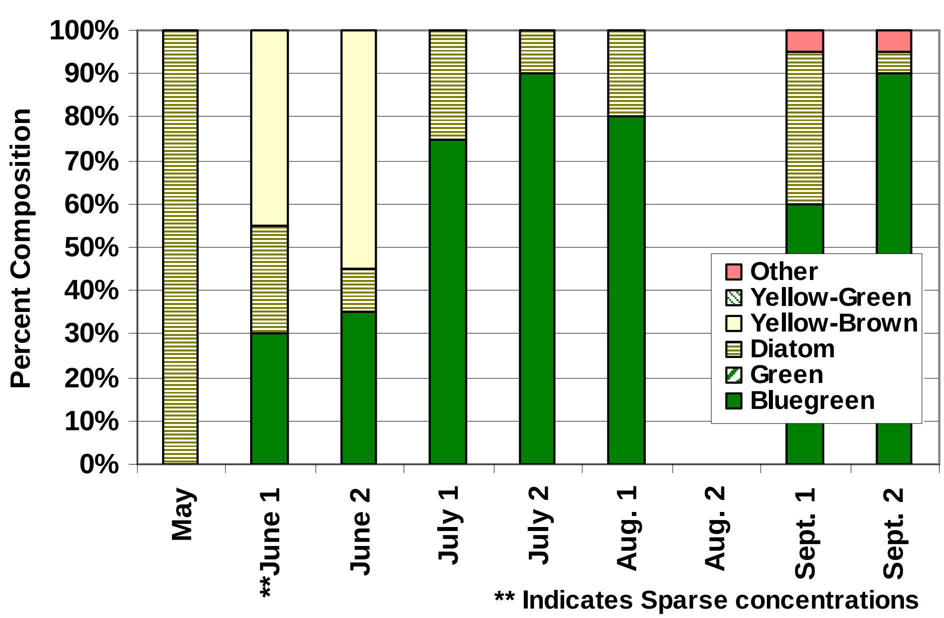


Figure 36. Split Hand Lakes Total Phosphorus and Chlorophyll-*a* Results for 2006

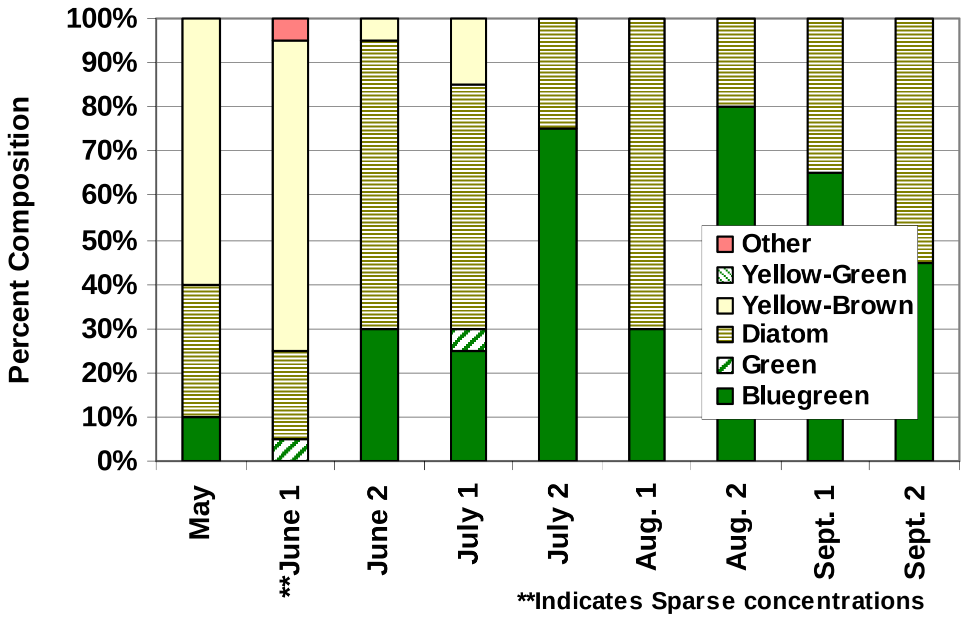


The composition of the phytoplankton (algae) population of Little Split Hand and Split Hand Lakes is presented in Figure 37. Data are presented in terms of algal type. Samples were collected at Site 101 (Little Split Hand) and Site 202 (Split Hand Lake). The bluegreens dominated the algal population in Little Split Hand Lake; while the diatoms and bluegreens were most common in Split Hand Lake. The form *Anabaena* was the most common bluegreen observed throughout the summer in Little Split Hand Lake; while *Centric* (diatom) and *Anabaena* (bluegreen) were the most common forms observed in Split Hand Lake. The bluegreens, as a whole, are the forms most commonly associated with nuisance algal conditions.

Figure 37. Split Hand Lakes Algal Populations for 2006

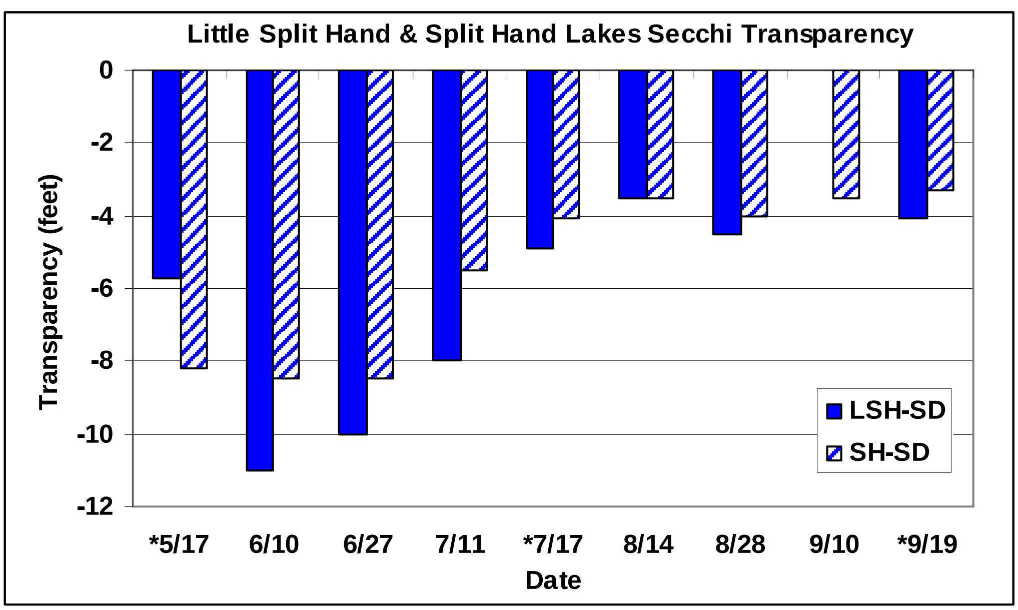


Little Split Hand



Split Hand Lake

Figure 38. Split Hand Lakes Secchi Transparency for 2006



Secchi disk transparency on Little Split Hand Lake ranged from 3.5 feet (1.1 meters) in early-August to 11 feet (3.4 meters) in early-June (Figure 38) and averaged 6.6 feet (2 meters). For Split Hand Lake, transparency ranged from 3.3 feet (1 meter) in late-September to 8.5 feet (2.6 meters) in June and averaged 5.1 feet (1.6 meters). These transparency measures are slightly below the typical range for NLF ecoregion reference lakes (Table 2a). Physical condition ratings for Little Split Hand Lake ranged from “crystal clear” to “definite algae color” (Classes 1 – 3); while recreational suitability ratings ranged from “beautiful” to “slightly impaired” (Classes 1 – 3) (Appendix). Physical condition ratings for Split Hand Lake ranged from “not quite crystal clear” to “definite algae color” (Classes 2 and 3); while recreational suitability ratings ranged from “minor aesthetic problems” to “slightly impaired” (Classes 2 and 3).

Other parameters, such as total suspended solids, total suspended inorganic solids, pH and total Kjeldahl nitrogen, analyzed for the Split Hand Lakes, were all above the typical range of values for NLF ecoregion reference lakes (Table 2a). Alkalinity, color, chloride and conductivity were within or near the range of values for both lakes (Table 2a).

Trophic State Index (TSI) values for TP and chlorophyll-*a* compare very favorably to each other in both Little Split Hand and Split Hand Lakes (Table 2b); however, the TSI value for Secchi transparency was slightly lower than the other TSI values for both lakes. Based on the 2006 data, Secchi transparency may not be a good estimator for TP and chlorophyll-*a* values for either lake; however, it should still continue to be a good tool for examining transparency trends within the lakes. The overall TSI values of 55 and 57, respectively, for Little Split Hand and Split Hand Lakes indicate *eutrophic* conditions for both lakes.

MOOSE (31-0722)

Moose Lake is a large lake located 12 miles northwest of Grand Rapids, Minnesota. In fact, with a surface area of 1,265 acres, it is in the upper two percent of lakes in terms of its size. It has a maximum depth of 61 feet and a mean depth of 18.5 feet. Approximately 27 percent of the lake is littoral and there are two accesses for the lake. It has fairly large watershed area of 16.3 mi^2; which consists primarily of water/marsh and forested land uses (Table 1, Figure 39, Appendix 2). Its water residence time is on the order of about three years. No late-September sample was collected for this lake by MPCA staff due to extremely low lake/water levels which made launching a boat at the public access; which was extremely shallow on the previous occasions, impossible.

Water quality data was collected in June, July, August, and September, 2006 by volunteer lake monitor: Marty Christensen. One site was used on Moose Lake: Site 102– located over the point of maximum depth in the lake (Figure 40).

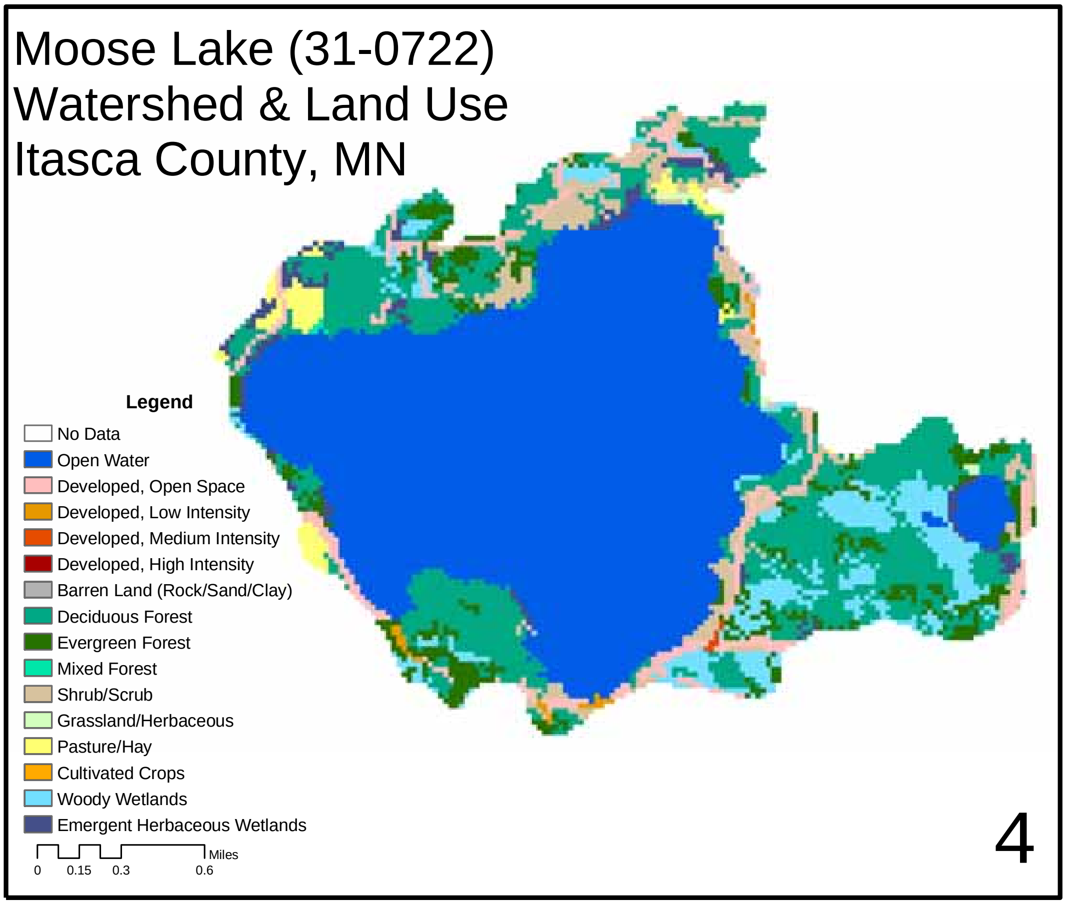
Temperature data indicated that the lake was well-mixed in May (Figure 41) with weak thermal stratification below five to six meters in June and July. In July, dissolved oxygen (DO) was less than 1 mg/L near the bottom of the lake (Appendix). In August and September, thermal stratification was not evident until around 10 meters. Surface temperatures ranged from 12.3° C in May to 26° C in early-July.

Total phosphorus (TP) concentrations averaged 16 µg/L during the summer of 2006. This value is within the expected range of concentrations for NLF reference lakes (Table 2a). TP concentrations ranged from 11 – 23 µg/L (Figure 42) and steadily increased over the summer; peaking in late-August.

Chlorophyll-*a* concentrations for Moose Lake extremely low; averaging 4 µg/L. This value is within the range of values for the NLF ecoregion (Table 2a). Concentrations on Moose Lake ranged from 1.6 – 5.8 µg/L and showed a slight increase in concentrations over the summer. No mild, nuisance, or severe algae blooms were noted for 2006 (Figure 42).

The composition of the phytoplankton (algae) population of Moose Lake is presented in Figure 43. Data are presented in terms of algal type. Samples were collected at Site 102. The diatoms, bluegreens and yellow-browns were fairly well represented throughout the summer. The forms of *Anacystis* and *Anabaena* were the most common bluegreens throughout the summer. On two sampling events (early-July and late-August), no algae population assessment was done due to the extremely low levels of algae present; which is a direct result of the exceptionally low chlorophyll-*a* concentrations in the lake.

Figure 39. Moose Lake Watershed & Land Use Map



Land Use Type	Moose Lake Percent	NLF Ecoregion Percent
Forest	27	54 - 81
Water & Marsh	62	14 - 31
Pasture & Open	6	0 - 6
Cultivated	0	< 1
Urban	5	0 - 7

Figure 40. Moose Lake Bathymetric Map and Monitoring Location

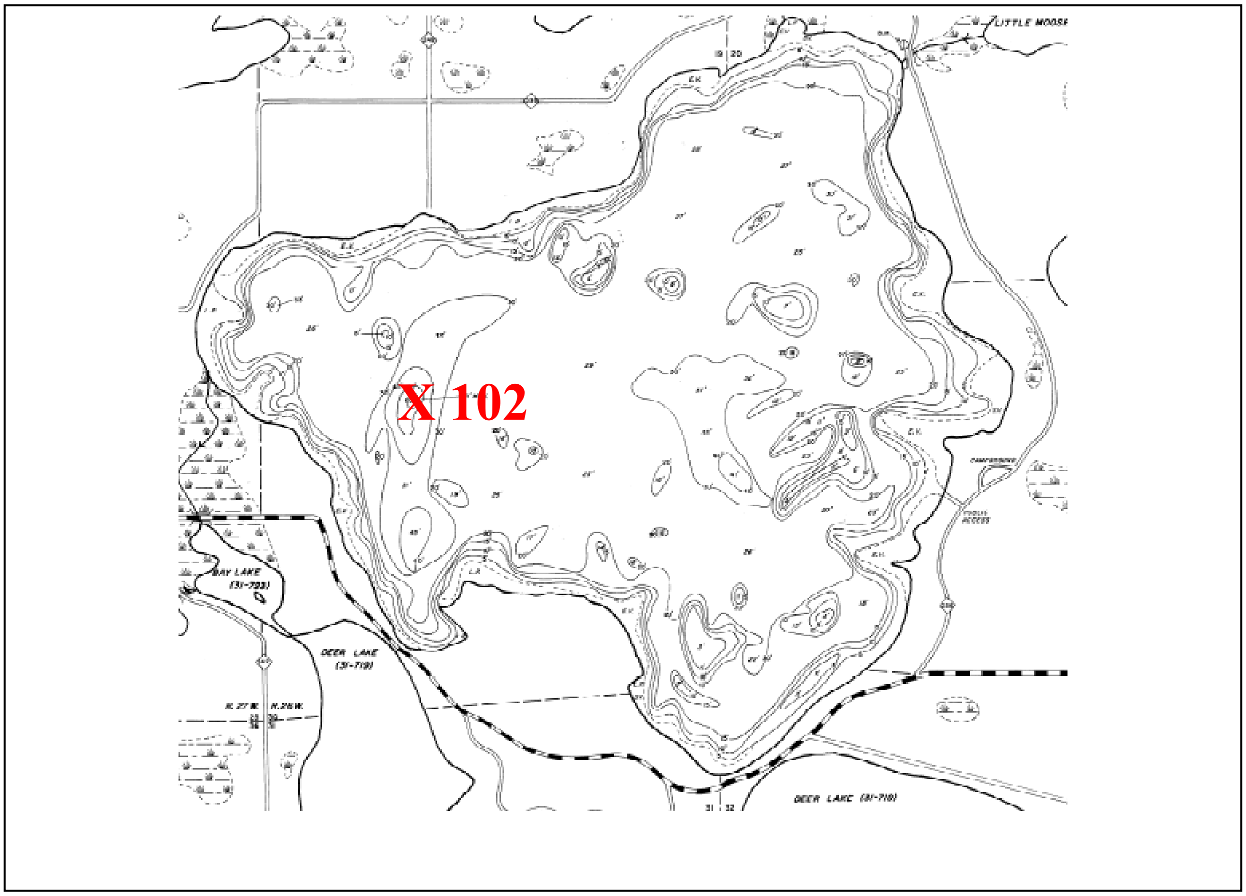


Figure 41. Moose Lake Temperature Profile Data for 2006

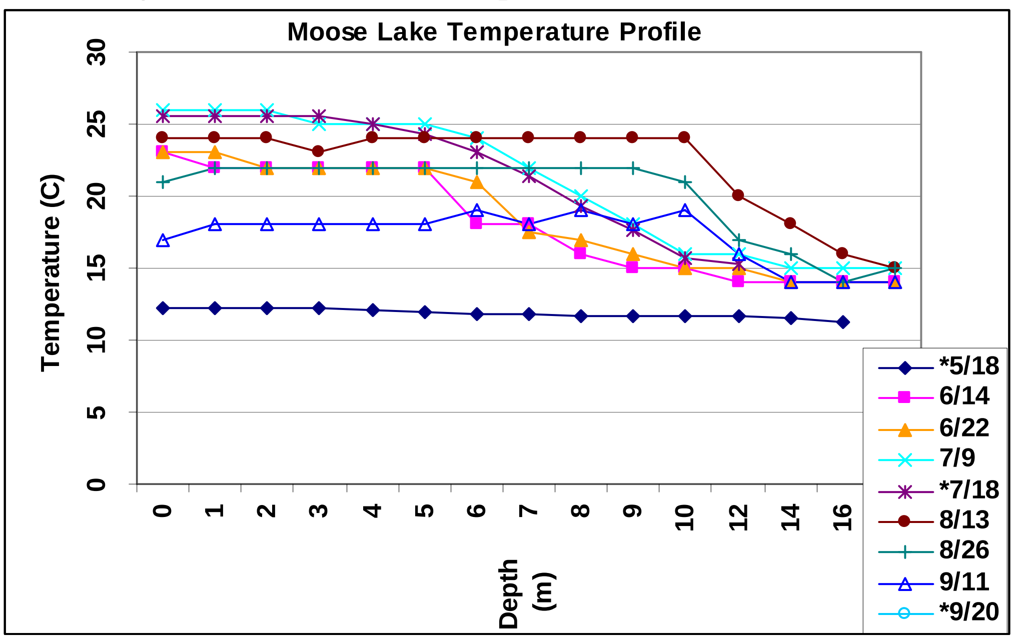


Figure 42. Moose Lake Total Phosphorus and Chlorophyll-*a* Results for 2006

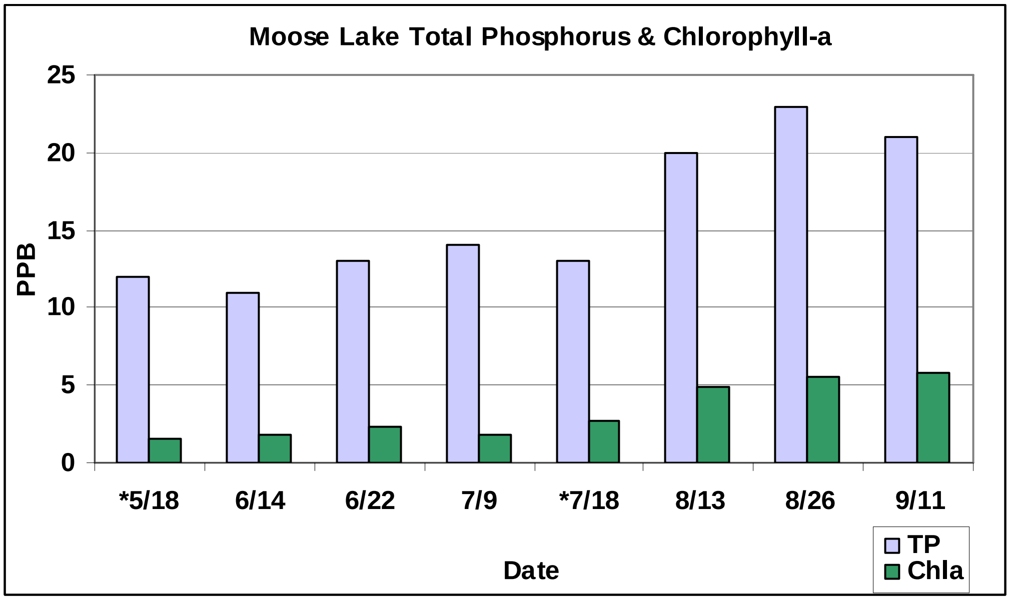


Figure 43. Moose Lake Algal Populations for 2006

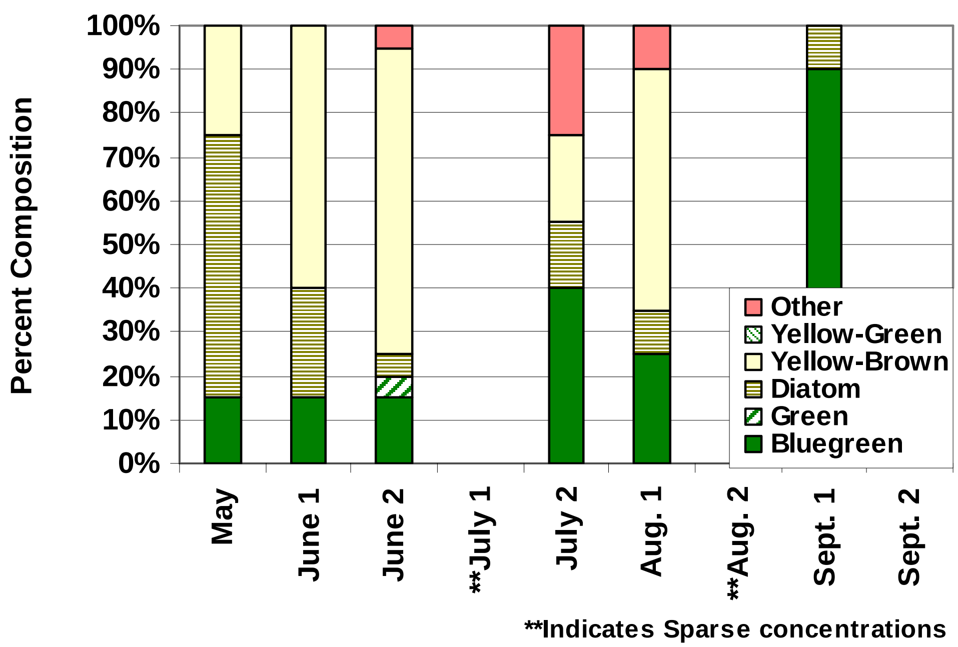
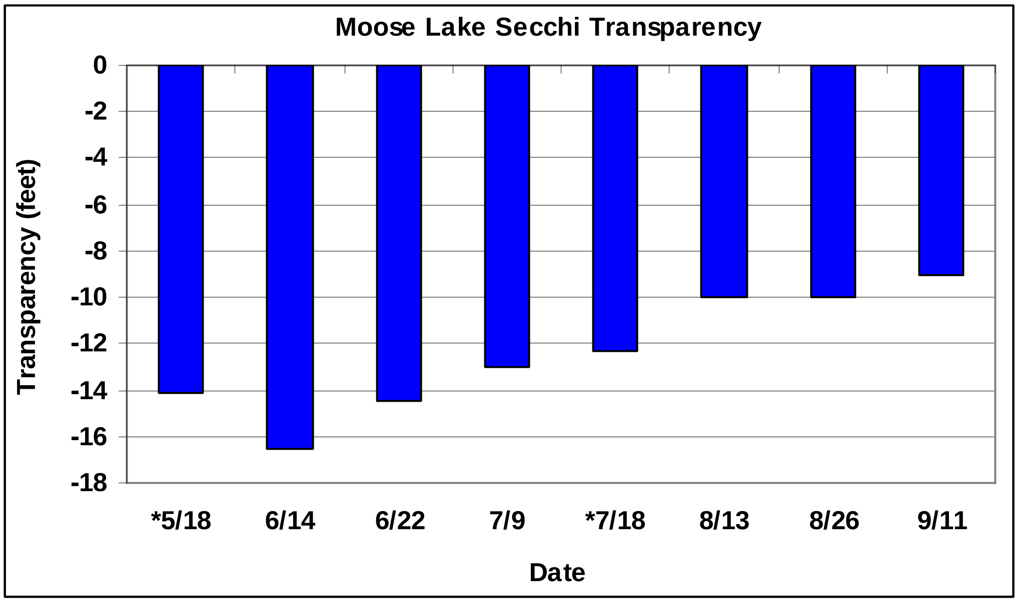


Figure 44. Moose Lake Secchi Transparency for 2006



Secchi disk transparency on Moose Lake ranged from 9 feet (2.7 meters) in September to 16.5 feet (5 meters) in early-June (Figure 44) and averaged 12.2 feet (3.7 meters). These transparency measures are within or better than the typical range for NLF ecoregion reference lakes (Table 2a). Physical condition ratings ranged from "crystal clear" to "not quite crystal clear" (Classes 1 and 2); while recreational suitability was rated as "beautiful" (Class 1) throughout the summer (Appendix).

Other parameters, such as total suspended solids, total suspended inorganic solids, total Kjeldahl nitrogen, chloride, pH, and alkalinity analyzed for Moose Lake were all within or very near the typical range for NLF ecoregion reference (Table 2a) with the exception of color. Color was found to be below the typical range indicating a lack of bog staining in the lake (Table 2a).

Trophic State Index (TSI) values for TP, chlorophyll-*a*, and Secchi transparency compare very favorably to each other for Moose Lake (Table 2b). Based on the 2006 data, Secchi transparency is a good estimator for TP and chlorophyll-*a* values and indicator of overall water quality for Moose Lake. It should also continue to be a good tool for examining transparency trends within the lake. The overall TSI value of 43 for Moose Lake indicates *mesotrophic* conditions.

PRAIRIE (31-0384)

Prairie Lake is a large lake located six miles north of Grand Rapids, Minnesota. It has a surface area of 1,064 acres, a maximum depth of 31 feet and a mean depth of about 11 feet (Table 1). Approximately 80 percent of the lake is littoral and there are two public accesses for the lake. It has a very large watershed area of 486 mi^2; which is comprised primarily of forested and water/marsh land uses (Table 1, Figure 45, Appendix 2). Its water residence time is estimated to be less than six months.

Water quality data was collected in June, July, August, and September, 2006 by volunteer lake monitor: Jeff Kleinert. Two sites were used on Prairie Lake: Site 101– located over a deep hole in the north end of the lake and Site 102 – located over a deep hole in the south end of the lake (Figure 46).

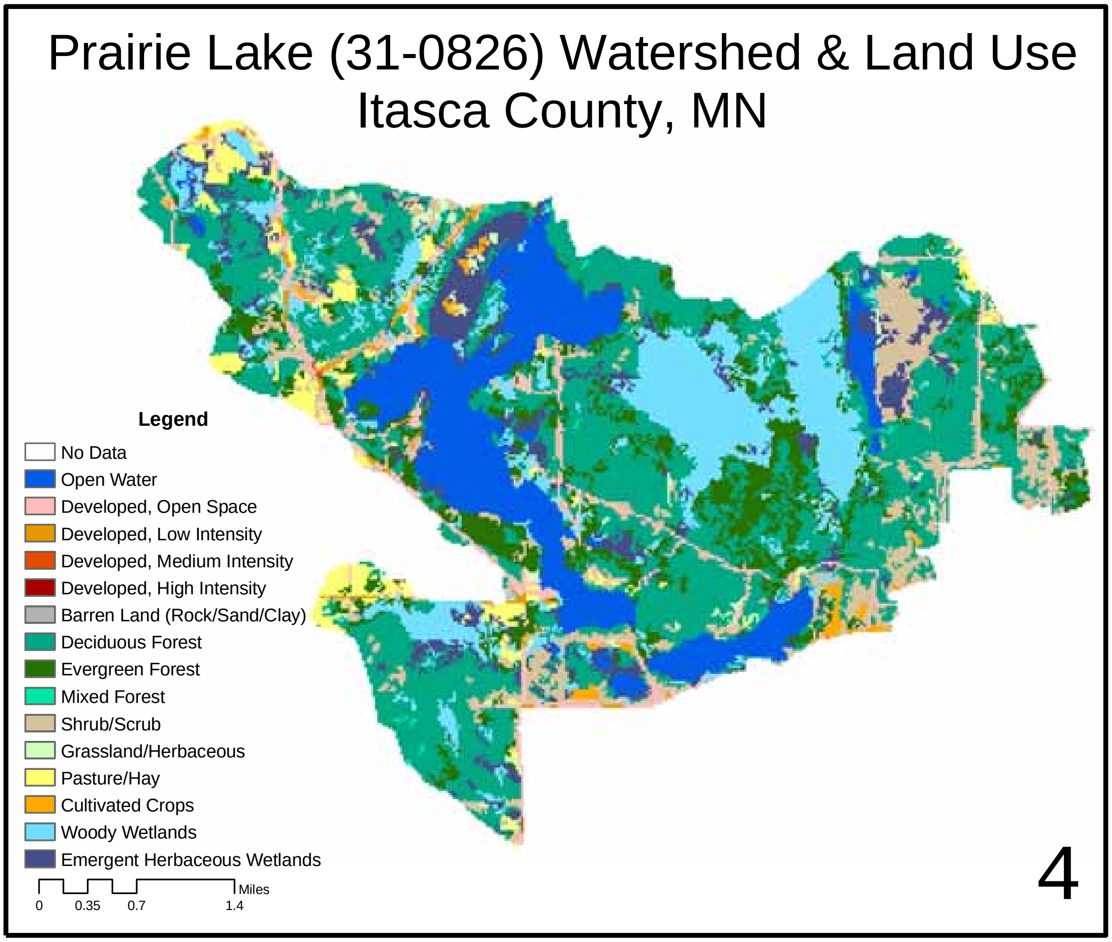
Temperature data indicated the lake was weakly stratified at both sites beginning in early-June and throughout the summer (Figure 47). Near-bottom dissolved oxygen was less than 1 mg/L in mid-July (Appendix). Thermal stratification was still slightly evident in early-September at Site 101 below five meters, but was no longer evident at Site 102. By late-September, the lake was well-mixed at both sites. Surface temperatures at Site 101 ranged from 14° C in May to 25.6° C in July. Surface temperatures at Site 102 were slightly cooler ranging from 13.7° C in May to 25° C in July.

Total phosphorus (TP) concentrations averaged 29 and 35 μg/L, respectively, for Sites 101 and 102 in Prairie Lake during the summer of 2006; while the lake as a whole averaged 32 μg/L. These values are above the range of concentrations for NLF reference lakes (Table 2a). TP concentrations at Site 101 ranged from 27 – 37 μg/L and were generally lower than those at Site 102; which ranged from 28 – 46 μg/L over the summer (Figure 48). An overall increase in TP concentrations over the summer was noted.

Chlorophyll-*a* concentrations for Prairie Lake averaged 7.9 and 14.8 μg/L for Sites 101 and 102, respectively; while the lake as a whole averaged 11 μg/L in 2006. The chlorophyll-*a* concentrations at Site 101 ranged from 3.2 – 11.9 μg/L and were generally lower than the concentrations at Site 102; which ranged from 8.9 – 23.6 μg/L (Table 2a, Figure 48). The chlorophyll-*a* values at Site 101 were generally at or below ecoregion reference values for the summer as opposed to Site 102 where concentrations were typically above these reference values. Mild to nuisance algae blooms may have been noted at Site 102 for most of the summer as well; however, severe algae blooms were not noted on any of the sampling occasions at either site.

The composition of the phytoplankton (algae) population of Prairie Lake is presented in Figure 49. Data are presented in terms of algal type. Samples were collected at Sites 101 and 102. The diatoms and bluegreens were well represented over the summer at both sites; however, there was a distinct increase in bluegreens from June through early-September at Site 101 but not at Site 102. The forms of *Anabaena* and *Aphanizomenon* were the most common bluegreens observed at both sites over the summer. The bluegreens, as a whole, are the forms most commonly associated with nuisance algal conditions.

Figure 45. Prairie Lake Watershed & Land Use Map



Land Use Type	Prairie Lake Percent	NLF Ecoregion Percent
Forest	48	54 - 81
Water & Marsh	34	14 - 31
Pasture & Open	14	0 - 6
Cultivated	0	< 1
Urban	4	0 - 7

Figure 46. Prairie Lake Bathymetric Map and Monitoring Location

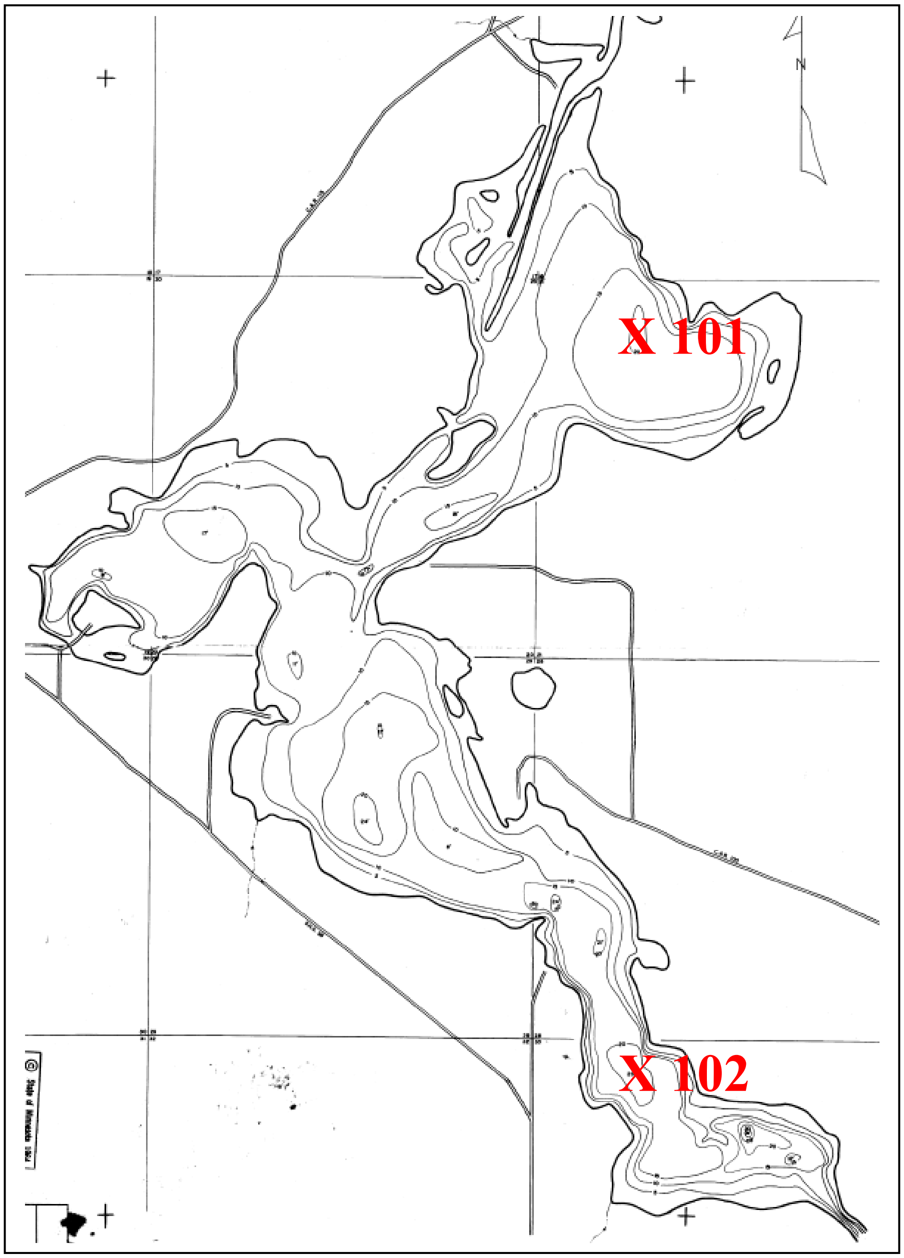
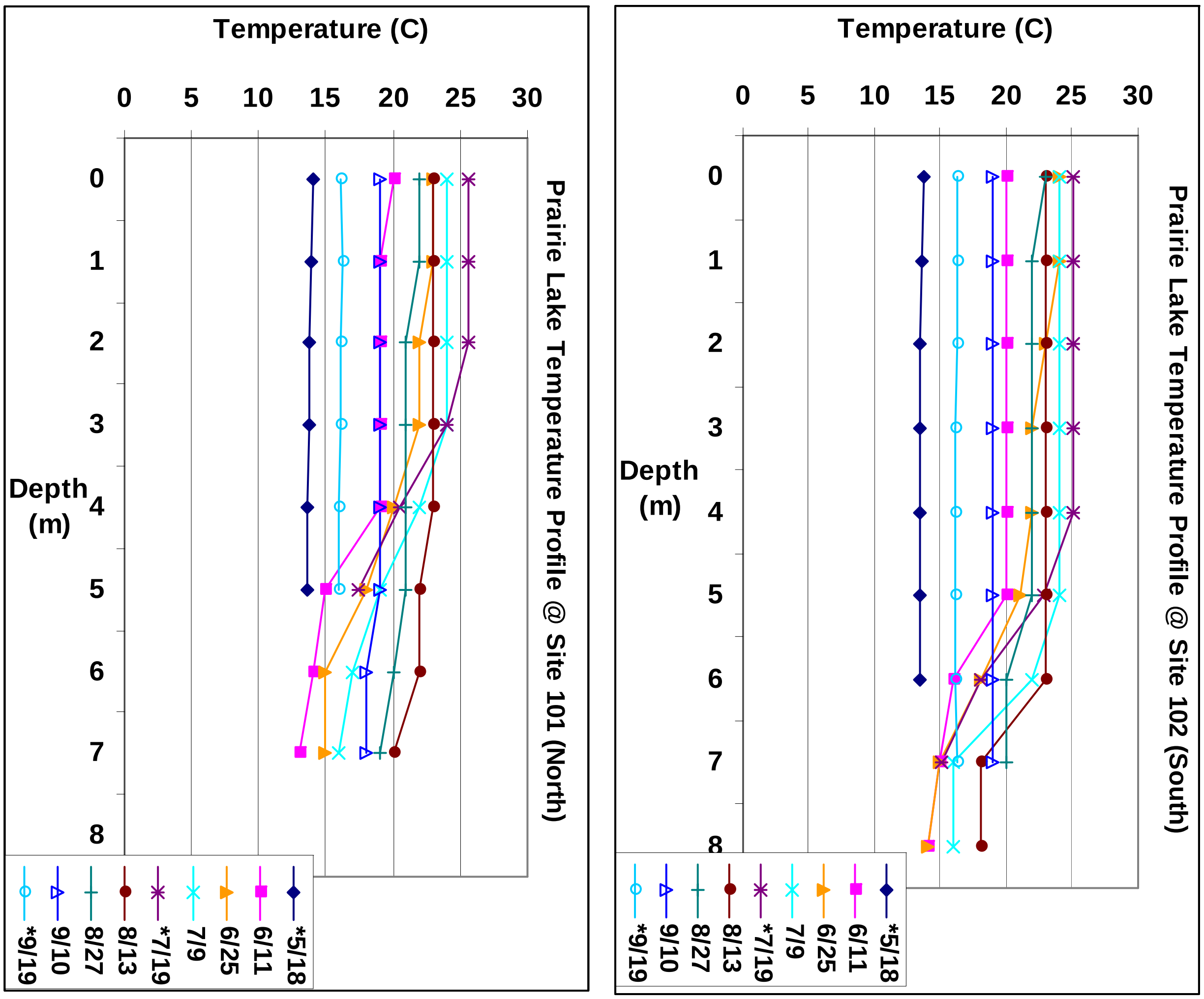


Figure 47. Prairie Lake Temperature Profile Data for 2006



Secchi disk transparency on Prairie Lake ranged from 2.6 feet (0.8 meters) in May to 6.6 feet (2 meters) in July at Site 101. The transparency at Site 101 was generally better than transparency at Site 102; which ranged from 2.6 feet (0.8 meters) in May to 6 feet (1.8 meters) in late-June (Figure 50). The "whole lake" average transparency for Prairie Lake for 2006 was 5.4 feet (1.6 meters). This transparency value is below the typical range for NLF ecoregion reference lakes (Table 2a). The physical condition of Prairie Lake at both sites was primarily characterized as "not quite crystal clear" (Class 2); while the recreational suitability rating at both sites was typically characterized as "minor aesthetic problems" (Class 2).

Other parameters analyzed for Prairie Lake**,** such as total Kjeldahl nitrogen, alkalinity, pH, total suspended inorganic solids, chloride and conductivity were all within or near the typical range of values for the NLF ecoregion. Total suspended solids and color were above the typical range of values for NLF ecoregion reference lakes (Table 2a); however, given the size of the watershed and the amount of wetlands within the watershed, these elevated values were not unanticipated.

Figure 48. Prairie Lake Total Phosphorus and Chlorophyll-*a* Results for 2006

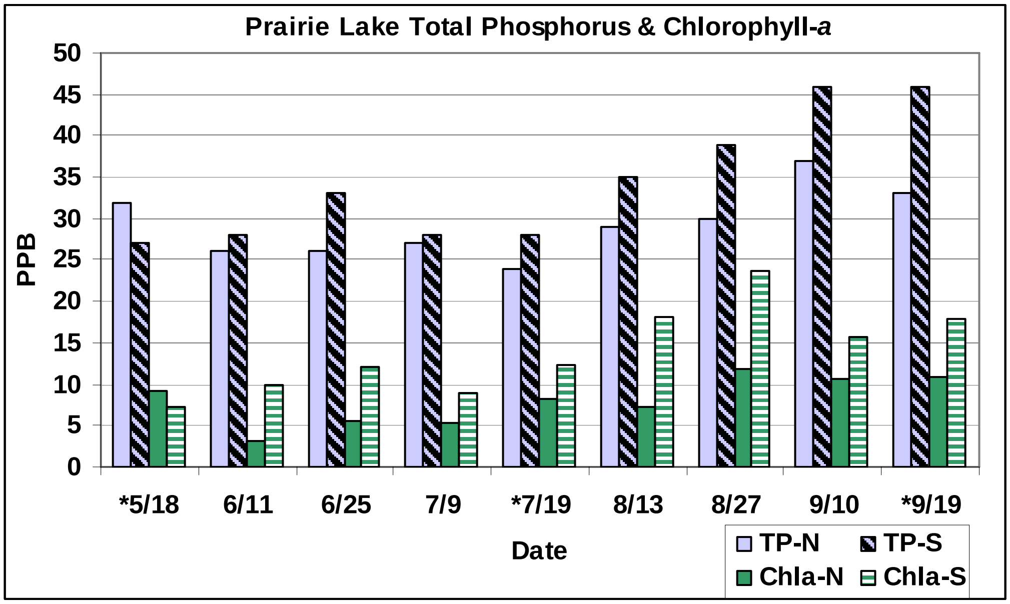
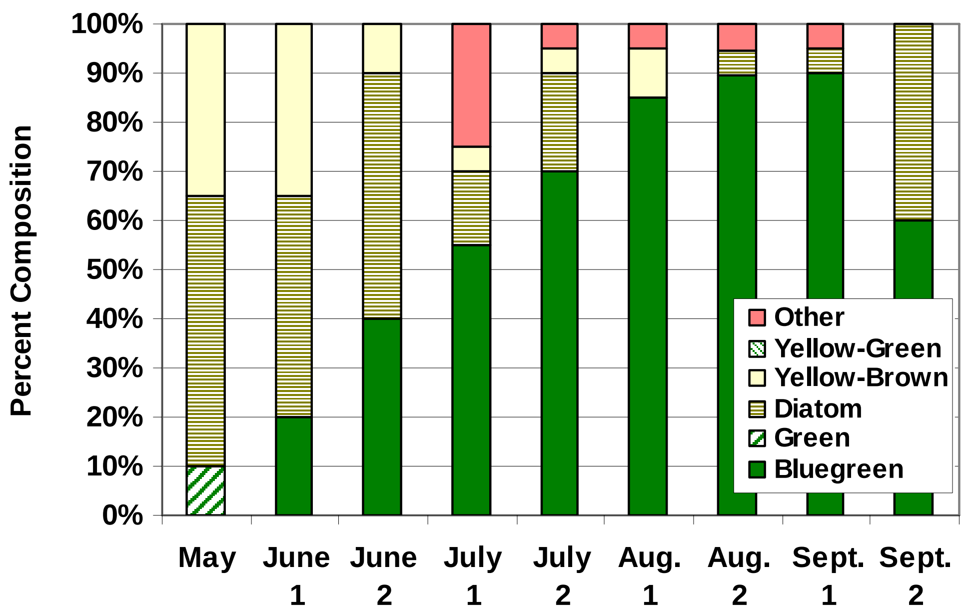
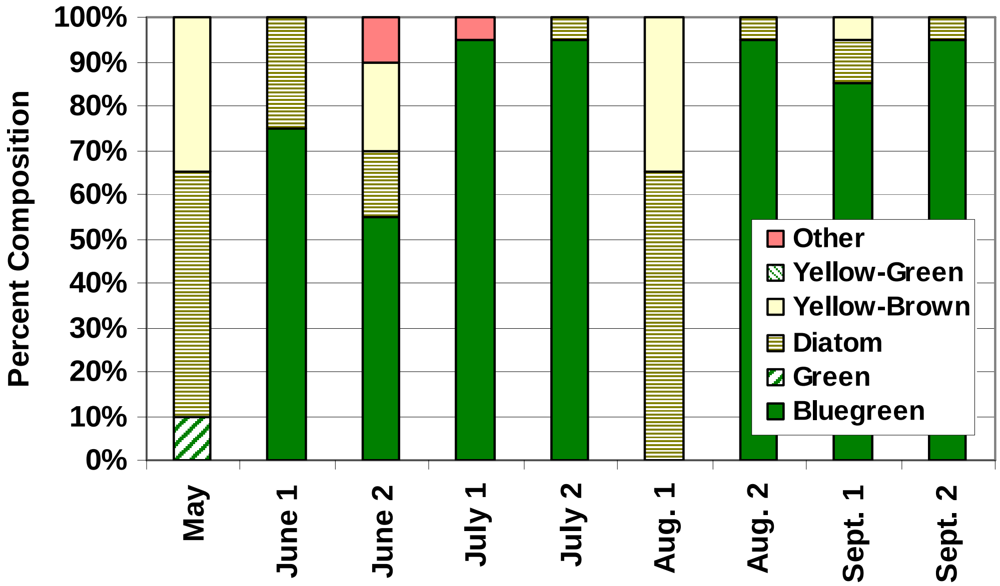


Figure 49. Prairie Lake Algal Populations for 2006

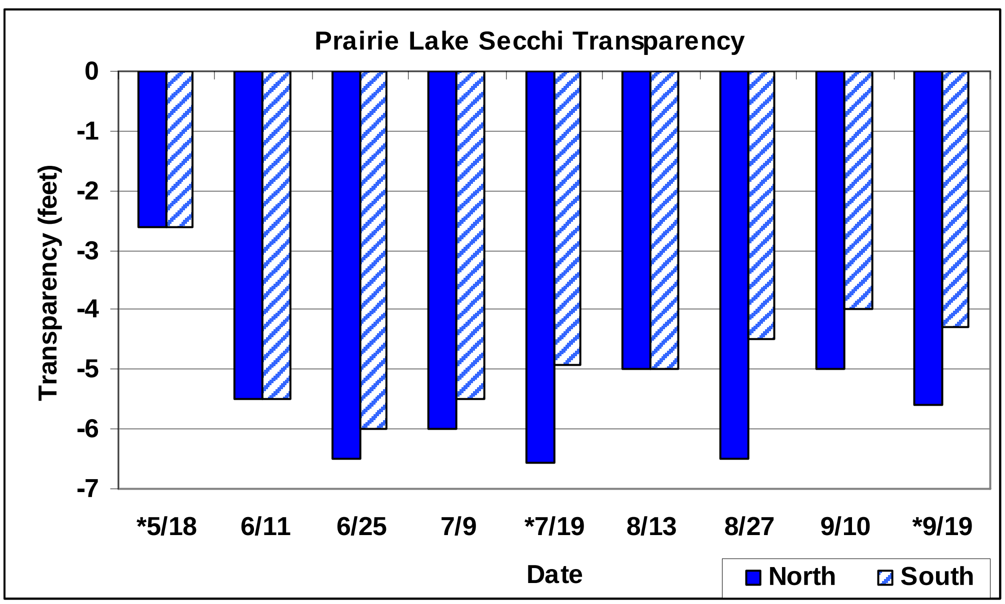


Prairie Lake – North (101)



Prairie Lake – South (102)

Figure 50. Prairie Lake Secchi Transparency for 2006



Trophic State Index (TSI) values for TP, chlorophyll-*a*, and Secchi transparency do compare very favorably to each other for Prairie Lake (Table 2b). Based on the 2006 data, Secchi transparency is would be a good estimator for TP and chlorophyll-*a* values as well as an indicator of overall water quality for Prairie Lake. It should also continue to be a good tool for examining transparency trends within the lake. The overall TSI value of 52 for Prairie Lake indicates *mesotrophic* to *eutrophic* conditions.

ROUND (31-0896)
Round Lake is a very large, round-shaped lake located at the town of Squaw Lake, Minnesota. In fact, with a surface area of 2,828 acres, it is in the upper one percent of lakes in Minnesota in terms of its size. It has a maximum depth of 24 feet and a mean depth of 11 feet. Approximately 70 percent of the lake is littoral and there are two public accesses noted for the lake. Round Lake has large total watershed area of 99 mi^2 (Table 1, Appendix 2), which consists primarily of water/marsh and forested land uses (Figure 51). Due to the large watershed draining through the lake, its water residence time is estimated to be on the order of about six months. MPCA staff sampling on this lake was limited in May and late-September due to high winds and large waves. These conditions prevented anchoring, making temperature and dissolved oxygen profiles, as well as any 1-meter off the bottom samples, too difficult to collect.

Water quality data was collected in June, July, August, and September, 2006 by volunteer lake monitor: Donald Ward. One site was used on Round Lake: Site 202– located over the point of maximum depth in the middle of the lake (Figure 52).

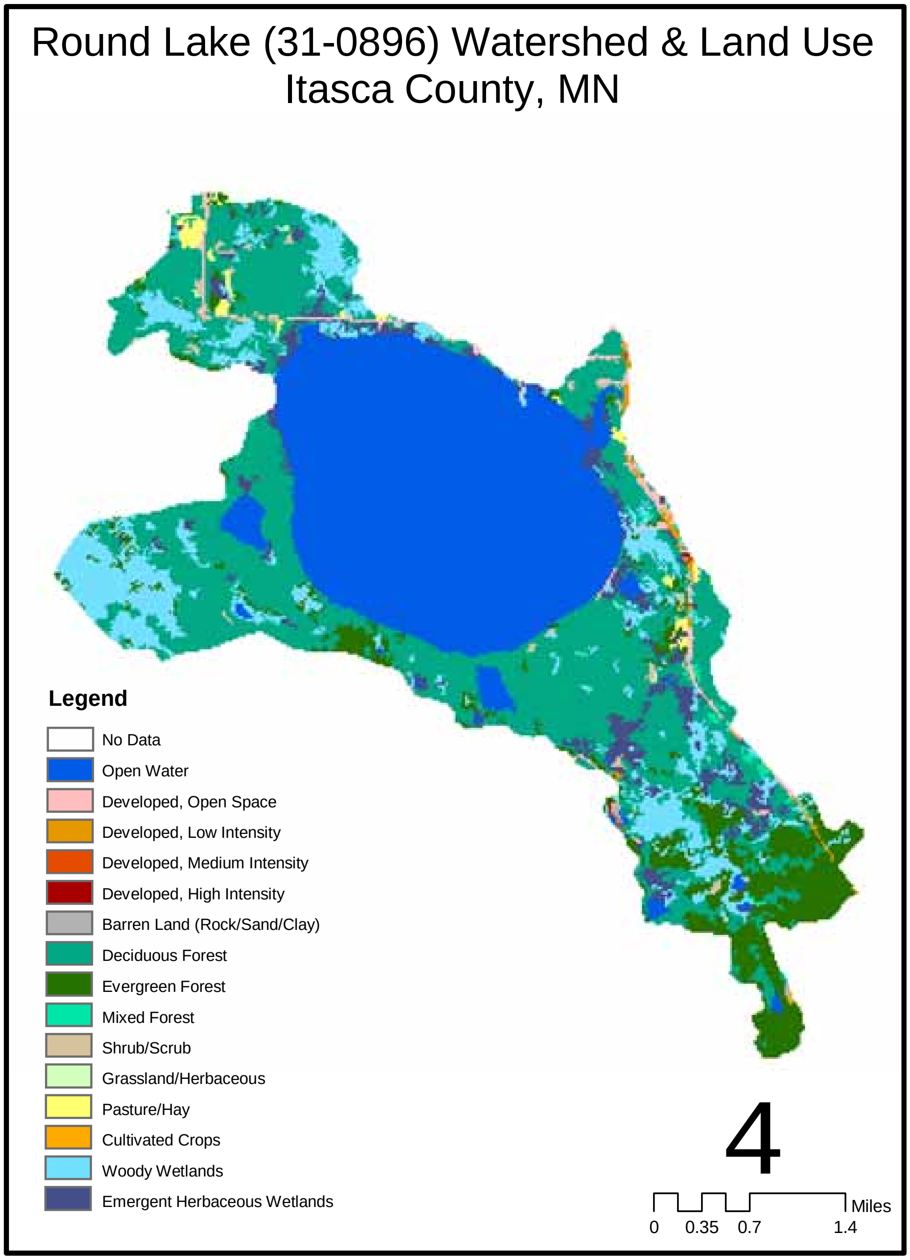
Temperature data indicated that the lake was well-mixed throughout the summer (Figure 53) with slight thermal stratification below five meters in early-June through September. Given the large surface area and shape of this lake, it is not unexpected that the lake would be well-mixed. Surface temperatures ranged from 19° C in September to 29° C in late-July. No May or late-September temperature profiles were taken due to an inability to anchor due to high winds and large waves.

Total phosphorus (TP) concentrations averaged 89 µg/L during the summer of 2006. This value is well above the range of concentrations for NLF reference lakes (Table 2a). TP concentrations ranged from 34 – 158 µg/L (Figure 54) and increased over the summer; peaking in late-August.

Chlorophyll-*a* concentrations averaged 32 µg/L; which is considerably higher than range of values for NLF ecoregion reference lakes (Table 2a). Concentrations ranged from 8 – 57 µg/L, with an increase in concentrations over the summer peaking in July (Figure 54). Based on the available data, mild to nuisance algae blooms were not evident in May and June; however, severe nusiance blooms were noted in July and early-August, followed by nuisance blooms in late-August and September.

The composition of the phytoplankton (algae) population of Round Lake is presented in Figure 55. Data are presented in terms of algal type. Samples were collected at Site 202. The diatoms and bluegreens were well represented throughout the summer with a marked increase in bluegreens from July – September. The form, *Centric*, was the most common diatom observed over the summer. The forms of *Anabaena, Aphanizomenon* and *Coelosphaerium* were the most common bluegreens observed over the summer.

Figure 51. Round Lake Watershed & Land Use Map



Land Use Type	Round Lake Percent	NLF Ecoregion Percent
Forest	45	54 - 81
Water & Marsh	51	14 - 31
Pasture & Open	2	0 - 6
Cultivated	0	< 1
Urban	2	0 - 7

Figure 52. Round Lake Bathymetric Map and Monitoring Location

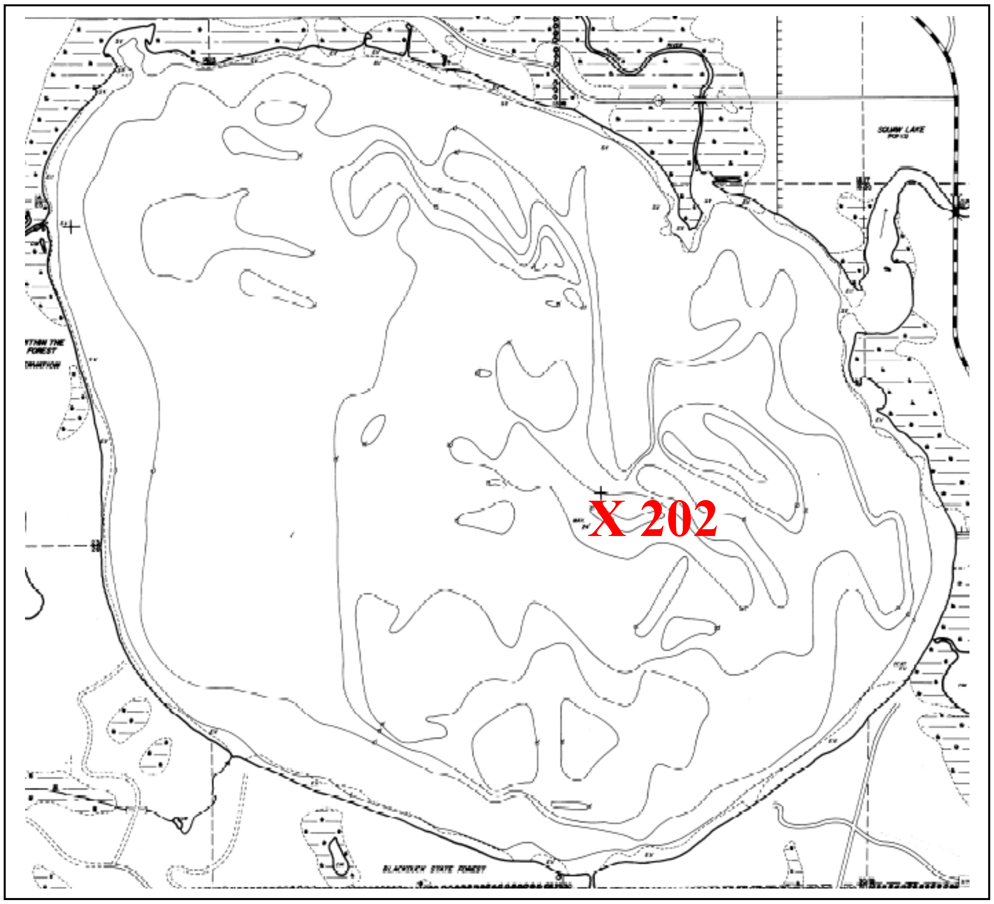


Figure 53. Round Lake Temperature Profile Data for 2006

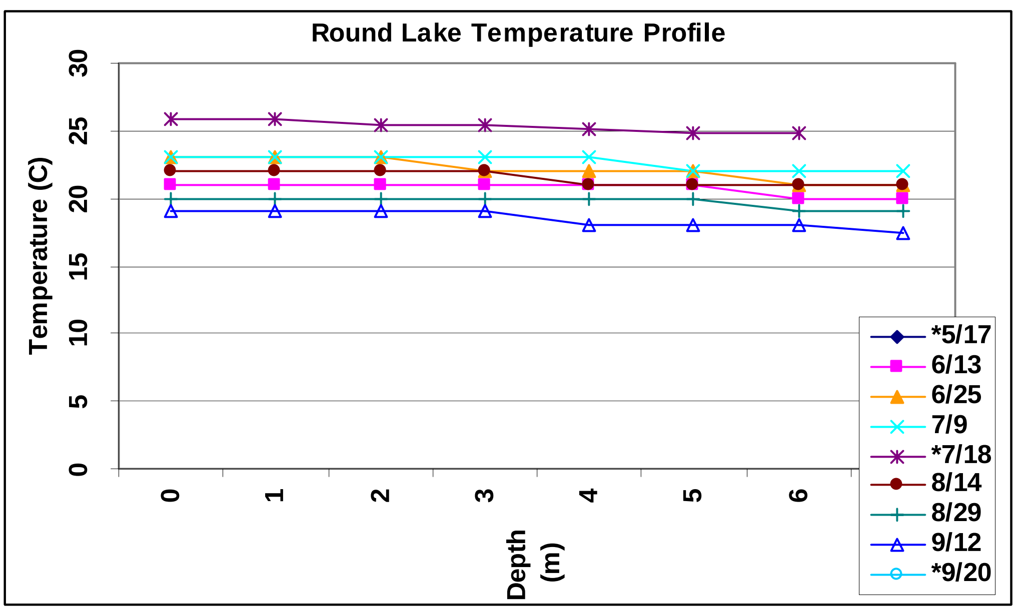


Figure 54. Round Lake Total Phosphorus and Chlorophyll-*a* Results for 2006

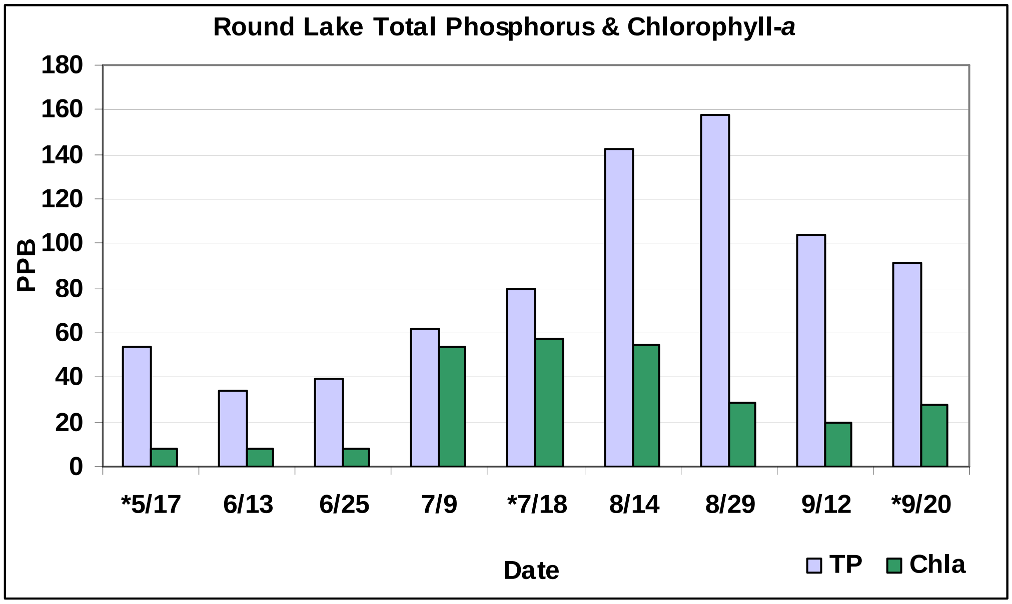


Figure 55. Round Lake Algal Populations for 2006

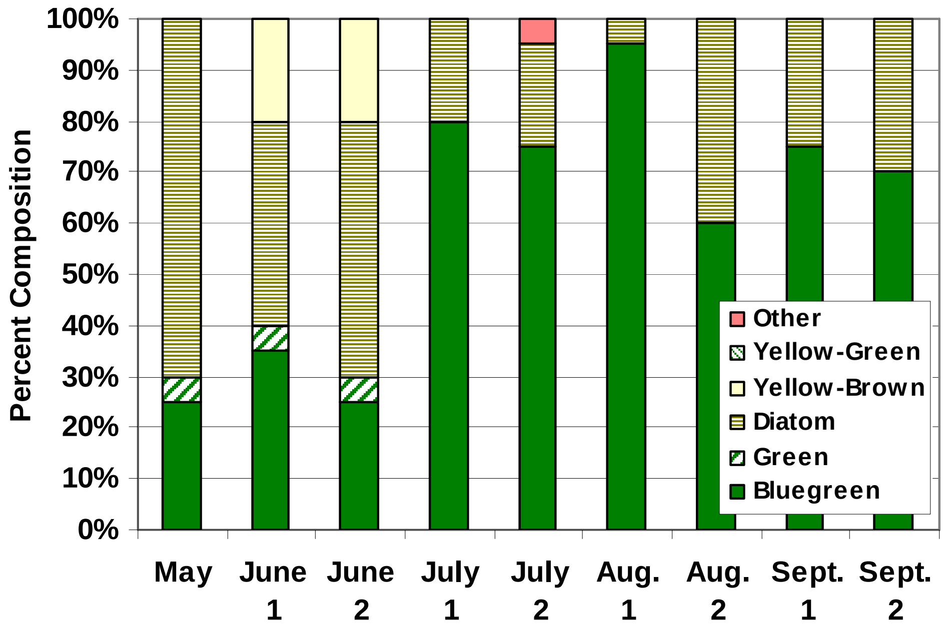
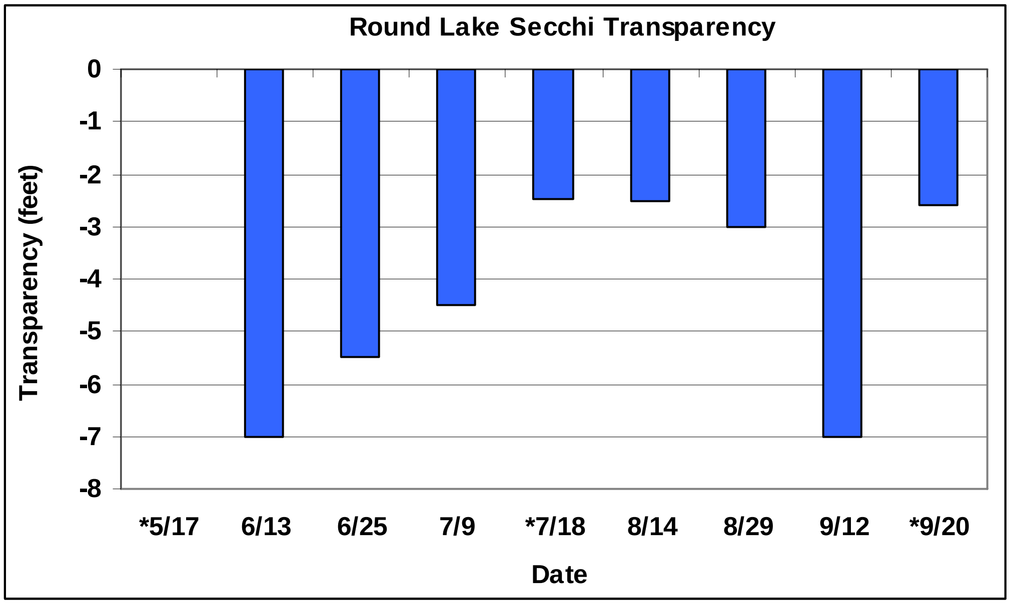


Figure 56. Round Lake Secchi Transparency for 2006



Secchi disk transparency on Round Lake ranged from 2.5 feet (0.8 meters) in late-July and early-August to 7 feet (2.1 meters) in early- June and early-September (Figure 56) and averaged 4.3 feet (1.3 meters). These transparency measures are below the typical range for NLF ecoregion reference lakes (Table 2a). The physical condition ratings for Round Lake were characterized primarily as "not quite crystal clear" to "definite algae color" (Classes 2 and 3); while recreational suitability ratings were primarily characterized as "minor aesthetic problems" to "slightly impaired" (Classes 2 and 3).

Other parameters, such as total suspended solids, total suspended inorganic solids, total Kjeldahl nitrogen, and pH, analyzed for Round Lake were all above the typical range of values for NLF ecoregion reference lakes (Table 2a). Alkalinity, color, chloride and conductivity were within the typical range of values (Table 2a).

Trophic State Index (TSI) values for TP and chlorophyll-*a* compare very favorably to each other for Round Lake (Table 2b); however, the TSI value for Secchi transparency was significantly lower than the other TSI values. Based on the 2006 data, Secchi transparency is not a good estimator for TP and chlorophyll-*a* values or indicator of overall water quality for Round Lake; however, it should still continue to be a good tool for examining transparency trends within the lake. The overall TSI value of 63 for Round Lake indicates *eutrophic* conditions.

SAND (31-0826)

Sand Lake is a very large lake located six miles east of the town of Squaw Lake, Minnesota. It has a surface area of 4,328 acres, placing it in the upper one percent of lakes in Minnesota in terms of its size and the largest lake in Itasca County that participated in this 2006 study. It has a maximum depth of 70 feet and a mean depth of 16 feet. Approximately 44 percent of the lake is littoral and there is one public access for the lake. It has very large watershed area covering nearly 237 mi^2 which consists primarily of forested and water/marsh land uses (Table 1, Figure 57, Appendix 2). Its water residence time is estimated to be on around six months.

Water quality data was collected in June, July, August, and September, 2006 by volunteer lake monitor: Dave Smith. Two sites were used on Sand Lake: Site 101 – located over a deep hole in the large, northeast part of the lake and Site 102 – located over the point of maximum depth in the lake in the southern, narrow part of the lake (Figure 58).

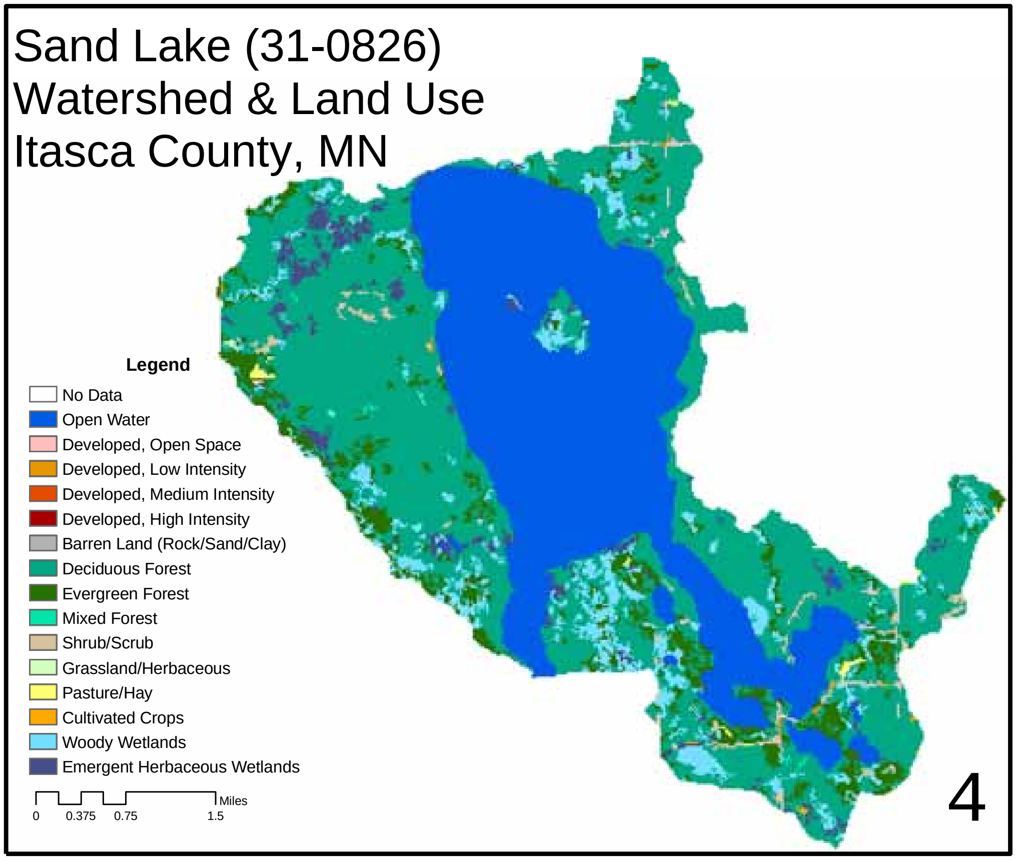
Temperature data indicated that the lake was well-mixed in May and September with very slight thermal stratification below four to five meters in June, July and August at Site 101 (Figure 59). Located in much deeper water, Site 102 displayed a stronger pattern of thermal stratification below six meters for the majority of the summer. Near-bottom dissolved oxygen fell below 1 mg/L in July (Appendix). Surface temperatures at Site 101 ranged from 12.2° C in May to 25.2° C in July while surface temperatures at Site 102 ranged from 12.4° C in May to 25.1° C in July.

Total phosphorus (TP) concentrations averaged 30 and 25 µg/L, respectively, for Sites 101 and 102 during the summer of 2006; however, the lake-wide average was 27 µg/L. These values are within or near the range of concentrations for NLF reference lakes (Table 2a). TP concentrations at Site 101 ranged from 14 – 40 µg/L and were generally higher than concentrations at Site 102; which ranged from 18 – 29 µg/L over the summer (Figure 60). A consistent increase in TP in the lake over the summer was noted.

Chlorophyll-*a* concentrations for Sand Lake averaged 12.8 and 8.3 µg/L for Sites 101 and 102, respectively; while the lake as a whole averaged 11 µg/L in 2006 (Table 2a). The chlorophyll-*a* concentrations at Site 101 ranged from 3 – 25 µg/L and were generally higher than the concentrations at Site 102; which ranged from 3 – 14 µg/L (Figure 60). The chlorophyll-*a* values at Site 101 were generally below nuisance algae blooms levels until the later half of the summer; as compared to Site 102 chlorophyll-a levels, which were consistently below nuisance levels. Mild algal blooms were noted at both sites, but severe blooms were not noted on any of the sampling occasions at either site.

The composition of the phytoplankton (algae) population of Sand Lake is presented in Figure 61. Data are presented in terms of algal type. Samples were collected at Site 101 and Site 102. The diatoms and bluegreens were well represented over the summer, with a strong dominance of bluegreens from July – September at both sites. The form, *Centric*, was the most diatom; while the form, *Anacystis*, was the most common bluegreen observed in the lake over the summer.

Figure 57. Sand Lake Watershed & Land Use Map



Land Use Type	Sand Lake Percent	NLF Ecoregion Percent
Forest	53	54 - 81
Water & Marsh	45	14 - 31
Pasture & Open	1	0 - 6
Cultivated	0	< 1
Urban	1	0 - 7

Figure 58. Sand Lake Bathymetric Map and Monitoring Location

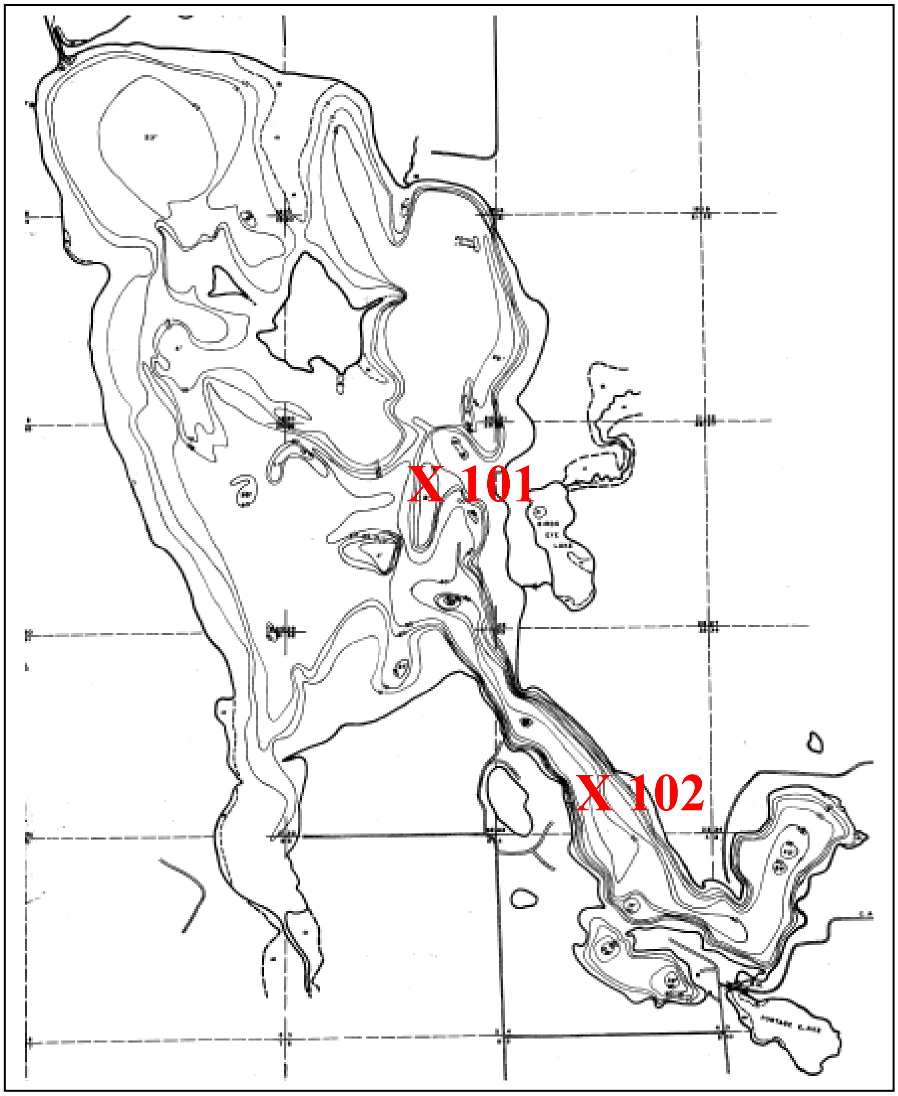
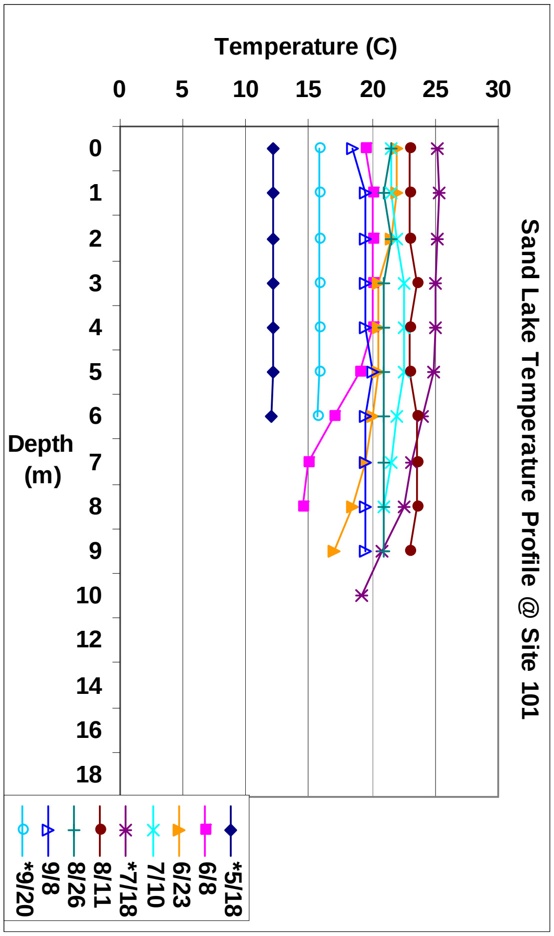


Figure 59. Sand Lake Temperature Profile Data for 2006



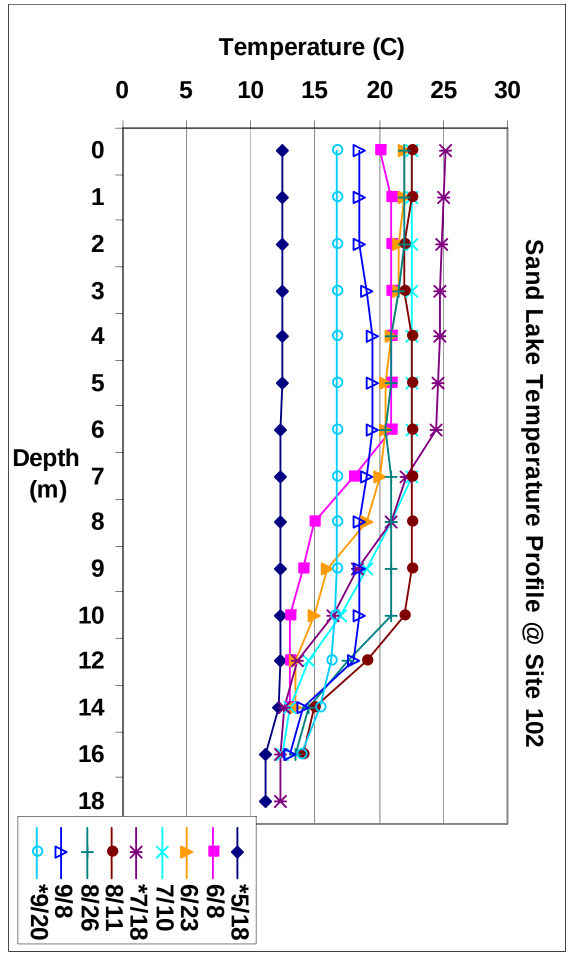


Figure 60. Sand Lake Total Phosphorus & Chlorophyll-*a* Results for 2006

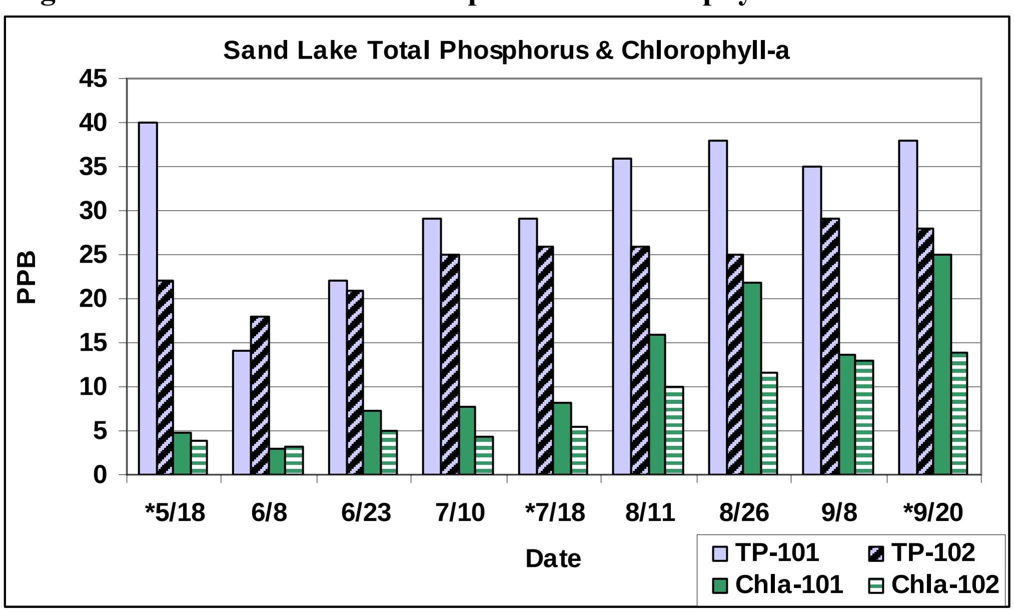
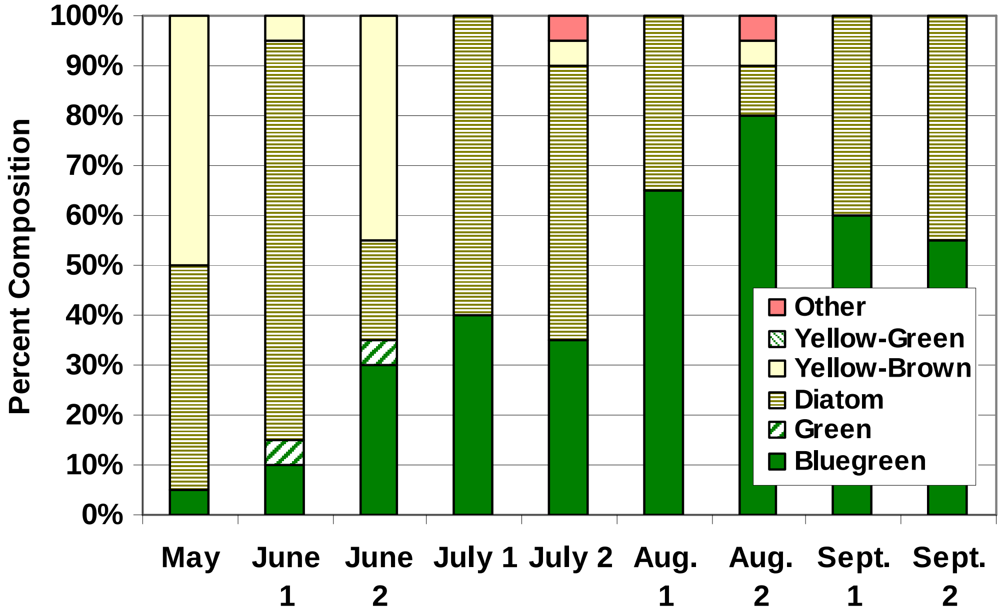
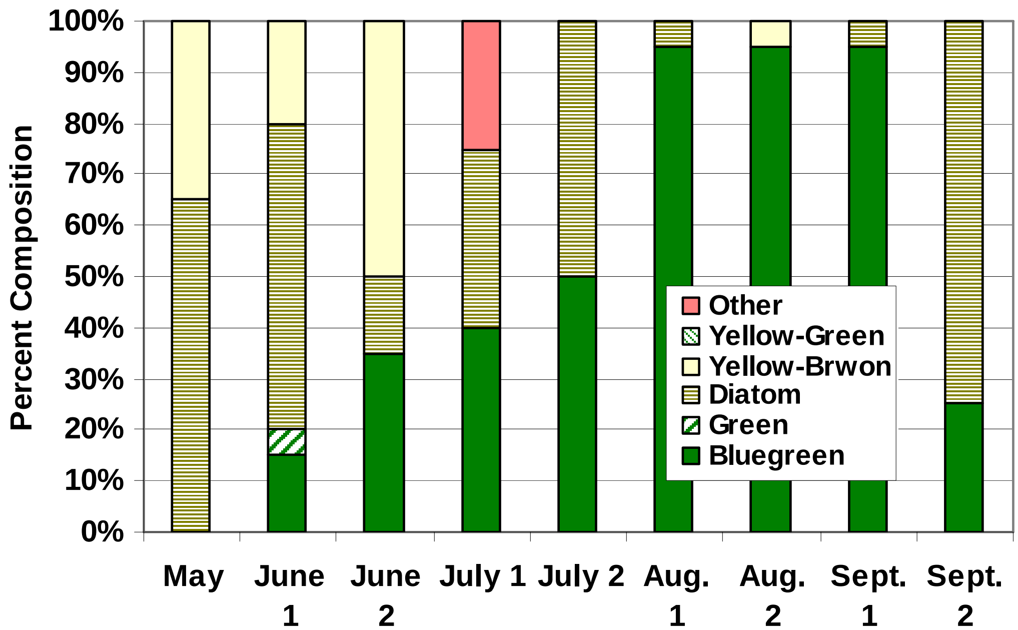


Figure 61. Sand Lake Algal Populations for 2006

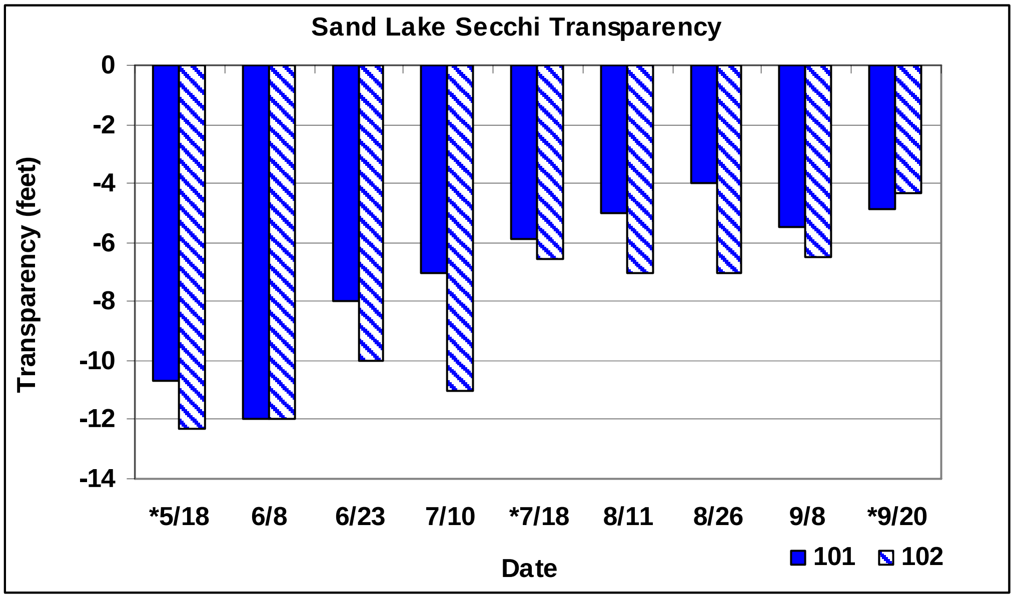


Sand Lake – Main (101)



Sand Lake – South (102)

Figure 62. Sand Lake Secchi Transparency for 2006



Secchi disk transparency on Sand Lake ranged from 4 feet (1.2 meters) in August to 12 feet (3.7 meters) in early-June at Site 101. The transparency at Site 101 was generally less than transparency at Site 102; which ranged from 4.3 feet (1.3 meters) in late-September to 12.3 feet (3.8 meters) in May (Figure 62). The "whole lake" average transparency for Sand Lake for 2006 was 7.3 feet (2.2 meters). This transparency value is near, but below the typical range for NLF ecoregion reference lakes (Table 2a). The physical condition of Sand Lake at both sites was primarily characterized as "not quite crystal clear" and "definite algae color" (Classes 2 and 3); while the recreational suitability rating at both sites was typically characterized as "beautiful" and "minor aesthetic problems" (Classes 1 and 2).

Other parameters, such as total Kjeldahl nitrogen, alkalinity, color pH, chloride and conductivity analyzed for Sand Lake were all within or near the typical range of values for NLF reference lakes (Table 2). Total suspended solids and total suspended inorganic solids were slightly above the range of values for NLF reference lakes (Table 2).

Trophic State Index (TSI) values for TP and chlorophyll-*a* and Secchi transparency compare favorably to each other for Sand Lake (Table 2b); however, the TSI value for Secchi transparency was slightly, but not significantly lower than the other TSI values. Based on the 2006 data, Secchi transparency may be a good estimator for TP and chlorophyll-*a* values. It may also be a good indicator of overall water quality for Sand Lake and should continue to be a good tool for examining transparency trends within the lake. The overall TSI value of 52 for Sand Lake indicates *mesotrophic* to *eutrophic* conditions for the lake.

SNAPTAIL (31-0255)

Snaptail Lake is a small but deep lake located 12 miles north of Taconite, Minnesota. It has a surface area of 146 acres, a maximum depth of 70 feet and a mean depth of 20 feet. Nearly 40 percent of the lake is littoral and there is one public access for the lake. It has a very small watershed area of 0.23 mi^2 which consists primarily of forested and pasture/open land uses (Table 1, Figure 63). Its water residence time is on the order of two years.

Water quality data was collected in June, July, August, and September, 2005 by volunteer lake monitors: Al Hupila and Darrell Johnson. One site was used on Snaptail Lake: Site 101– located over the point of maximum depth in the lake (Figure 64).

Temperature data indicated that the lake was thermally stratified below five meters on most sampling occasions (Figure 65). Dissolved oxygen fell below 1mg/L in the hypolimnion in July through September (Appendix). Surface temperatures ranged from 13.8° C in May to 27.6° C in late-July.

Total phosphorus (TP) concentrations averaged 12 µg/L in Snaptail Lake during the summer of 2006. This value is well within the range of concentrations for reference lakes in this ecoregion (Table 2a). TP concentrations ranged from 9 – 25 µg/L over the course of the summer with no distinct patter evident (Figure 66).

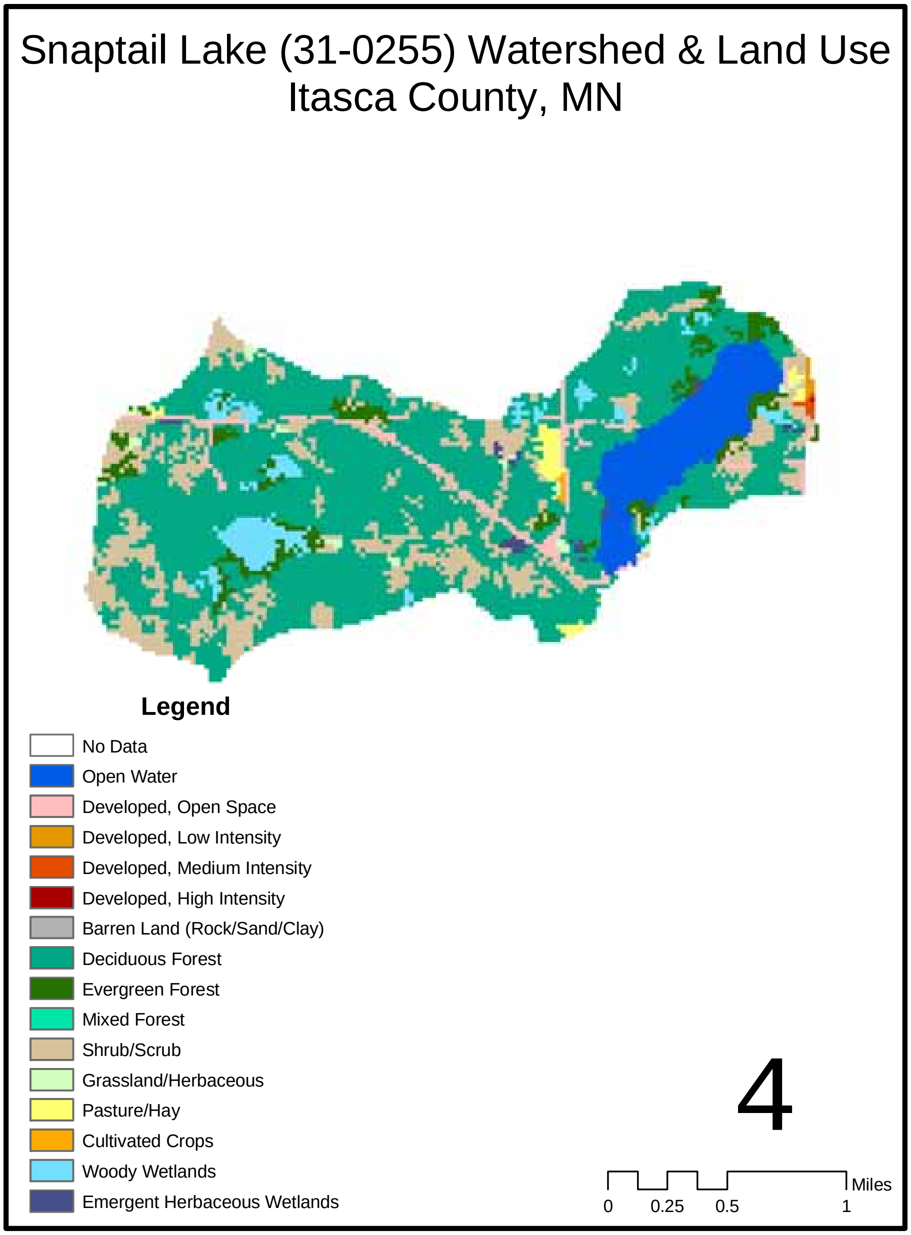
Chlorophyll-*a* concentrations in Snaptail Lake averaged 3 µg/L and were well within the NLF ecoregion range (Table 2a). Concentrations on Snaptail Lake ranged from 2 – 4.5 µg/L with a slight increase in concentrations noted at the end of the summer (Figure 66). No mild, nuisance or severe algae blooms were noted in this lake.

The composition of the phytoplankton (algae) population of Snaptail Lake is presented in Figure 67. Data are presented in terms of algal type. Samples were collected at Site 101. The yellow-browns and bluegreens were well represented over the summer, with a strong dominance of bluegreens in late-August and September. The forms of *Dinobryon* (yellow-brown), *Anacystis* and *Aphanizomenon* (bluegreens) were the most common algal forms observed in the lake throughout the summer.

Secchi disk transparency on Snaptail Lake ranged from 8.2 feet (2.5 meters) in late-September to 15 feet (4.6 meters) in late-August (Figure 68) and averaged 13.2 feet (4 meters). These transparency measures are well within the typical range for NLF ecoregion reference lakes (Table 2a). The physical condition of the lake was generally characterized as "crystal clear" or "not quite crystal clear" (Classes 1 and 2); while recreational suitability was characterized as "beautiful" or "minor aesthetic problems" (Classes 1 and 2).

Other parameters, such as total Kjeldahl nitrogen, alkalinity, color, pH, total suspended solids, total suspended inorganic solids, and conductivity, analyzed for Snaptail Lake were all within the typical range of values for NLF reference lakes (Table 2a). Chloride values were slightly, but not significantly, above the typical ecoregion range (Table 2a).

Figure 63. Snaptail Lake Watershed & Land Use Map



Land Use Type	Snaptail Lake Percent	NLF Ecoregion Percent
Forest	63	54 - 81
Water & Marsh	13	14 - 31
Pasture & Open	20	0 - 6
Cultivated	0	< 1
Urban	4	0 - 7

Figure 64. Snaptail Lake Bathymetric Map and Monitoring Location

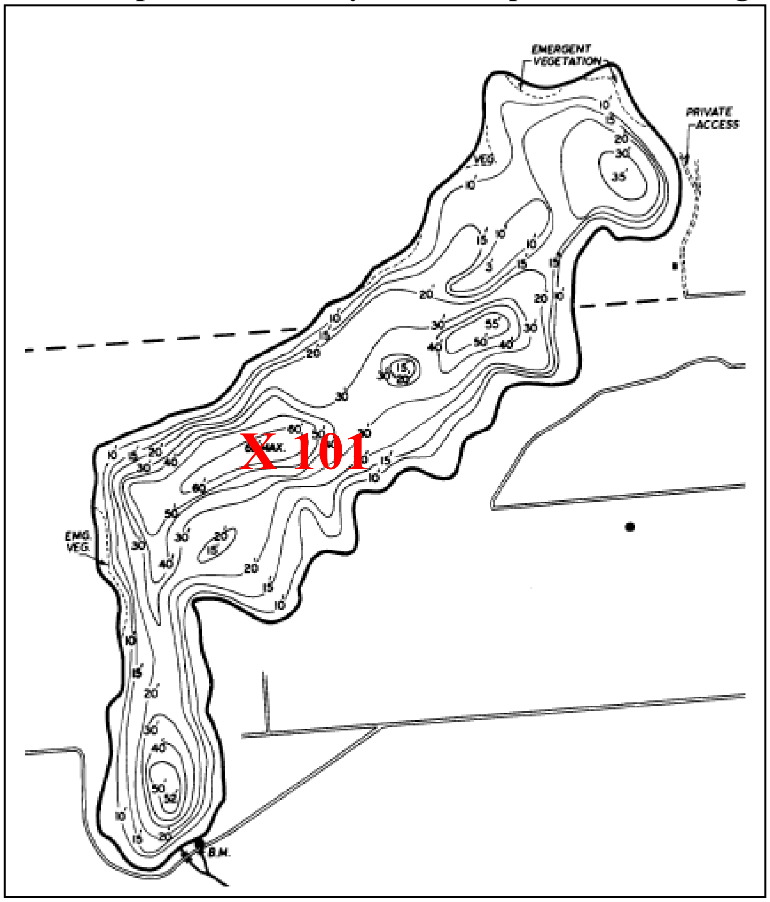


Figure 65. Snaptail Lake Temperature Profile Data for 2006

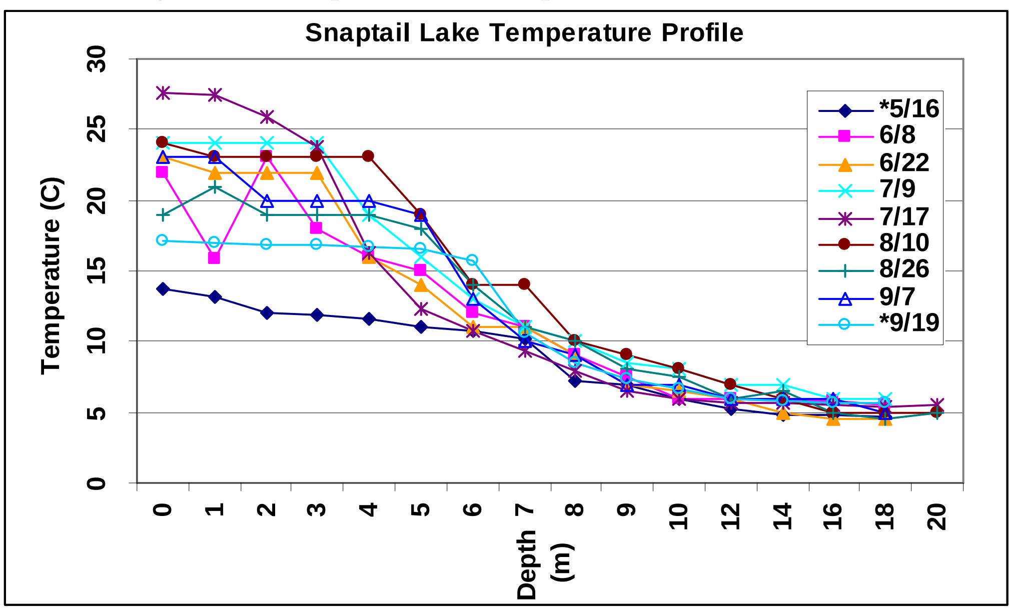


Figure 66. Snaptail Lake Total Phosphorus and Chlorophyll-*a* Results for 2006

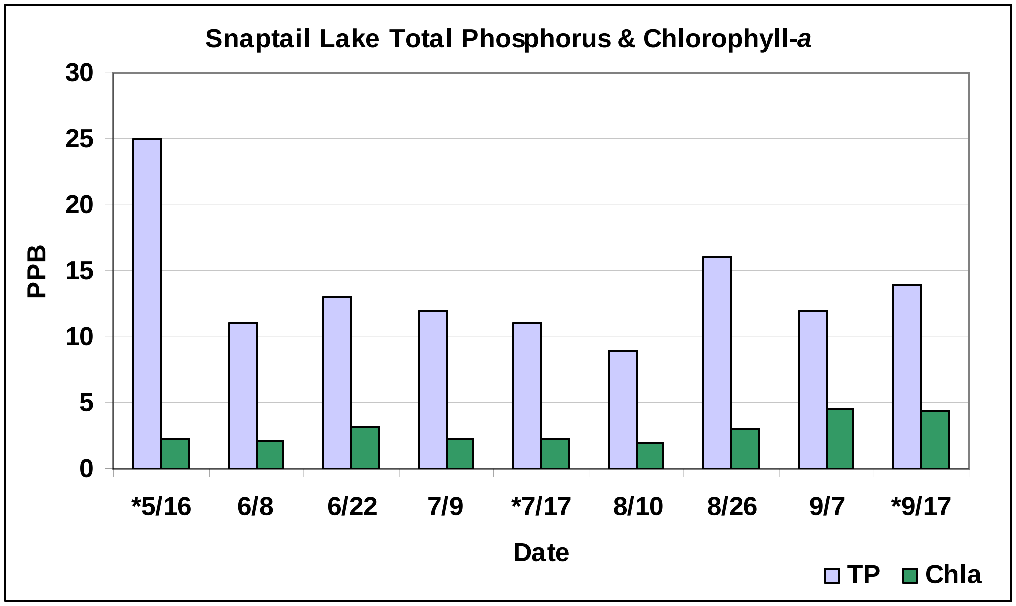


Figure 67. Snaptail Lake Algal Populations for 2006

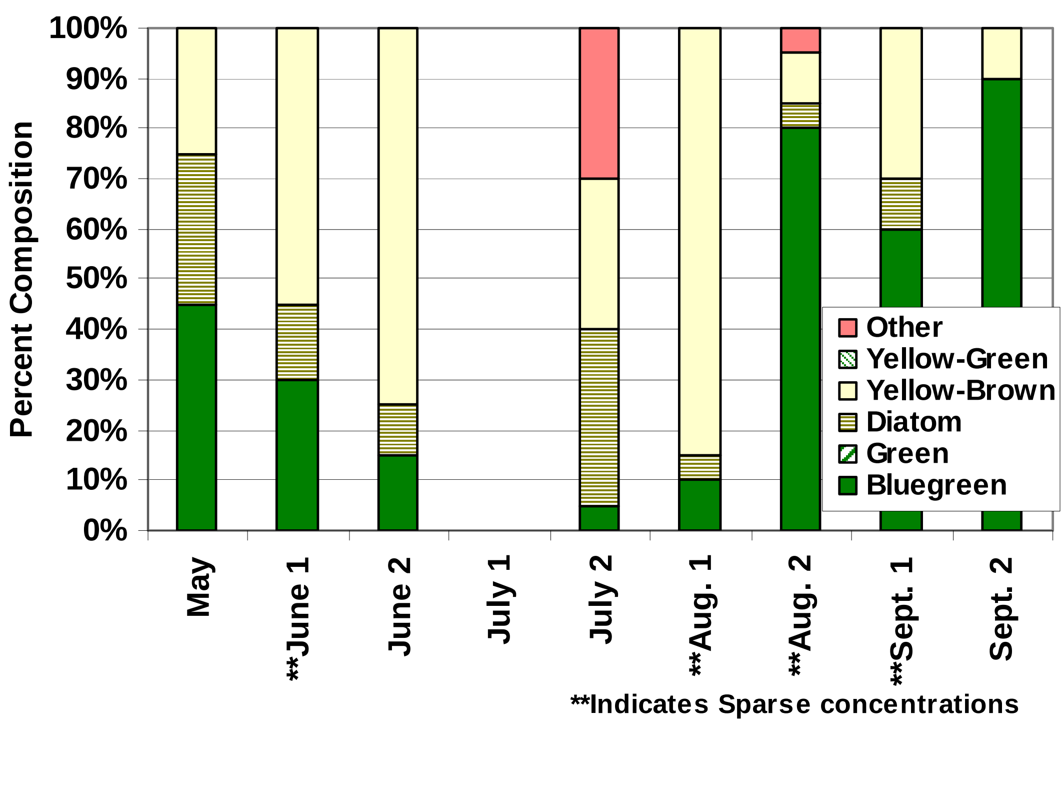
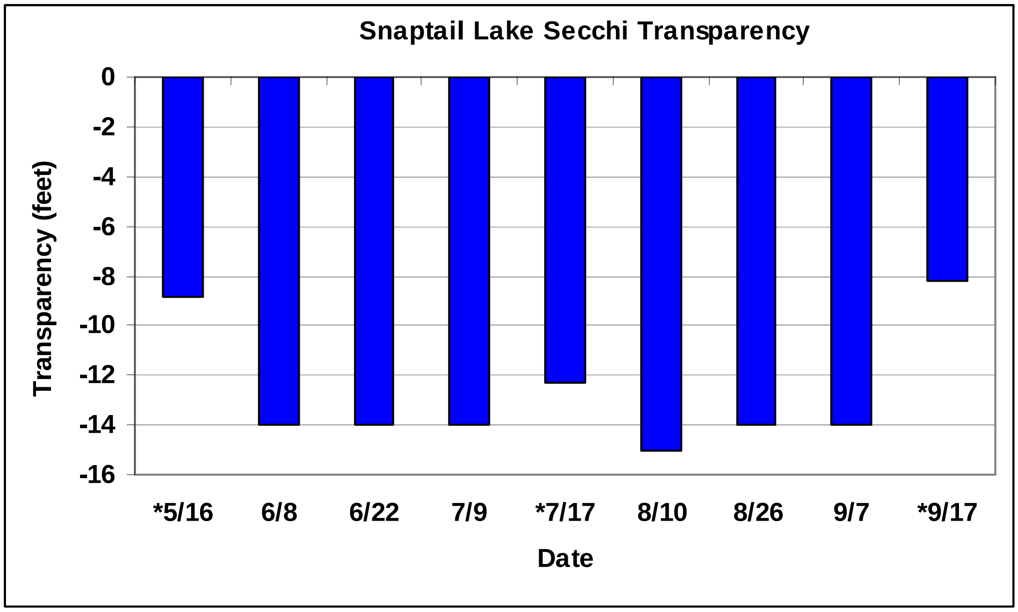


Figure 68. Snaptail Lake Secchi Transparency for 2006



Trophic State Index (TSI) values for TP, chlorophyll-*a* and Secchi transparency compare very favorably to each other for Snaptail Lake (Table 2b). Based on the 2006 data, Secchi transparency would be a good estimator for TP and chlorophyll-*a* values. In addition, it would also be a good indicator of overall water quality for the lake and should continue to be a good tool for examining transparency trends within Snaptail Lake. The overall TSI value of 40 for Snaptail Lake indicates *mesotrophic* conditions.

SWAN: WEST & MAIN (31-0067-01 & 31-0067-02)
Swan Lake is a large lake located at the town of Pengilly, Minnesota. The lake is divided by Hwy 65 into two distinct basins. The larger and deeper, east basin is referred to as Swan-Main, while the western, shallow arm (through which the lake outlets) is referred to as Swan-West. Swan Lake has a surface area of 2,116 acres, a maximum depth of 67 feet and a mean depth of 39.5 feet. Approximately 24 percent of the lake is littoral and there are two public accesses noted for the lake. It has a large watershed area of approximately 100 mi^2, which consists primarily of forested and water/marsh land uses (Table 1, Figure 69, Appendix 2). Its water residence time is on the order of 3.5 years.

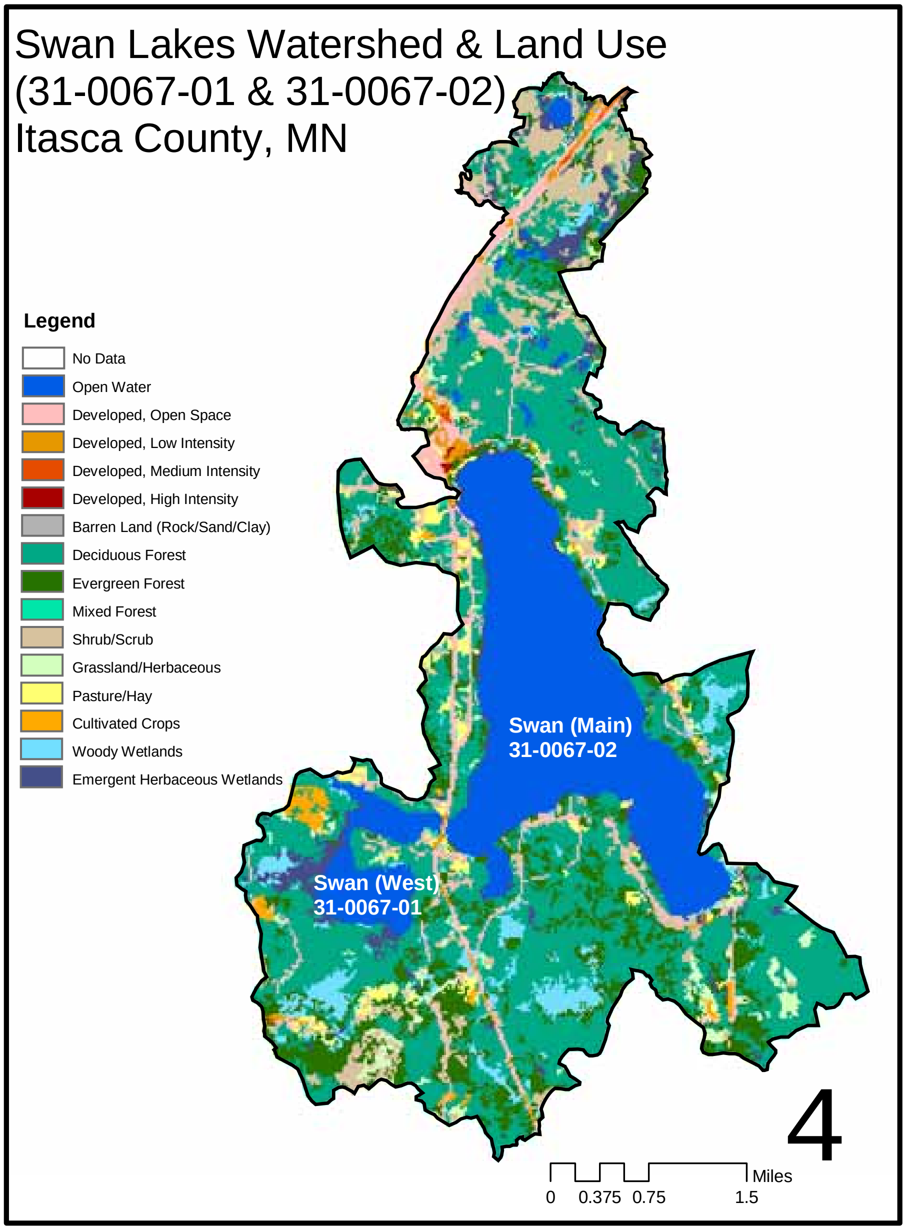
Water quality data was collected in June, July, August, and September, 2006 by volunteer lake monitor: Lou Mattson. Two sites were monitored on the lake: Site 101– located over the point of maximum depth in the west portion of the lake and Site 102 – located over the point of maximum depth in the main portion of the lake (Figure 70).

Temperature data indicated Swan Lake was well mixed in May, but displayed thermal stratification below five meters in June (Figure 71). In July and August, the thermocline had shifted below 7 meters. Swan Lake still showed signs of thermal stratification below 10 meters on the last sampling event in late September. Dissolved oxygen fell below 1 mg/L in the hypolimnion from July through September (Appendix). Surface temperatures ranged from 10.7° C in May to 24.3° C in July. West Swan Lake was fairly well mixed on most sampling events with only slight thermal stratification below 4 meters. Surface temperatures in this smaller and shallower bay ranged from 13.2° C in May to 24.8° C in July.

Total phosphorus (TP) concentrations averaged 21 and 39 µg/L, respectively, for the main and west basins of Swan Lake (Figure 72). The main basin value is within the range of concentrations for NLF reference lakes; however, the west basin concentration is above the typical range (Table 2a). TP concentrations in the main basin ranged from 14 – 32 µg/L and increased slightly over the summer. Hypolimnion TP was elevated in the July and September samples (Appendix). Concentrations in the west basin were generally higher than the main basin; ranging from 18 – 59 µg/L. In addition, west basin concentrations also increased more dramatically over the course of the summer as compared to the main basin concentrations.

Chlorophyll-*a* concentrations for the main basin of Swan Lake averaged 7 µg/L while concentrations in the west basin averaged 16 µg/L in 2006 (Table 2a). The chlorophyll-*a* concentrations in the main basin ranged from 2 – 14 µg/L and were generally lower than the concentrations in the west basin; which ranged from 3 – 34 µg/L (Figure 72). The chlorophyll-*a* values in the main basin were generally below nuisance algae blooms levels with the exception of the August sampling events. A mild algal bloom may have been noted during this time period. Nuisance algal blooms in the west basin may have been noted from late-July through September with potentially severe blooms noted in August.

Figure 69. Swan Lake Watershed & Land Use Map



Land Use Type	Swan Lake Percent	NLF Ecoregion Percent
Forest	52	54 - 81
Water & Marsh	30	14 - 31
Pasture & Open	12	0 - 6
Cultivated	0	< 1
Urban	6	0 - 7

Figure 70. Swan Lake Bathymetric Map and Monitoring Locations

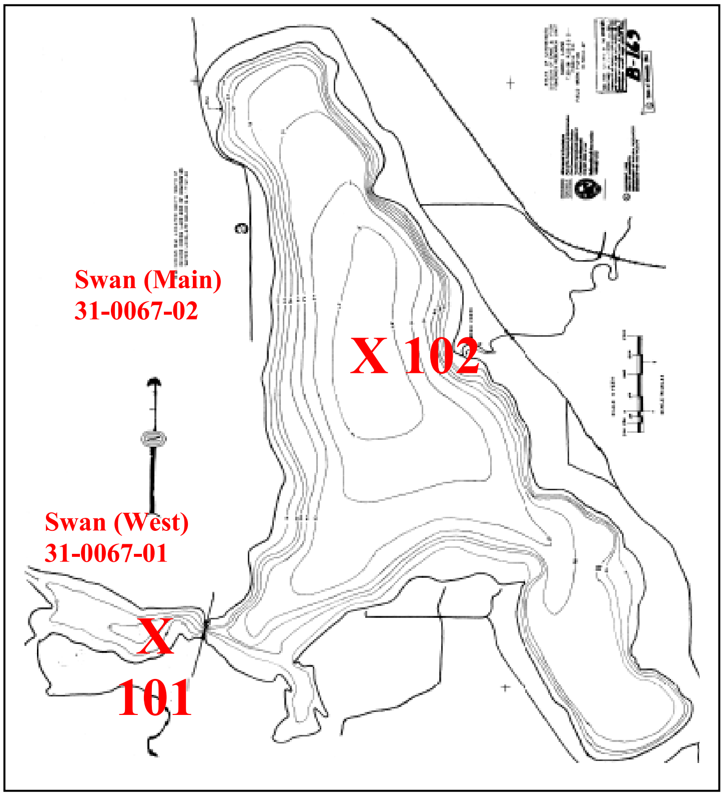
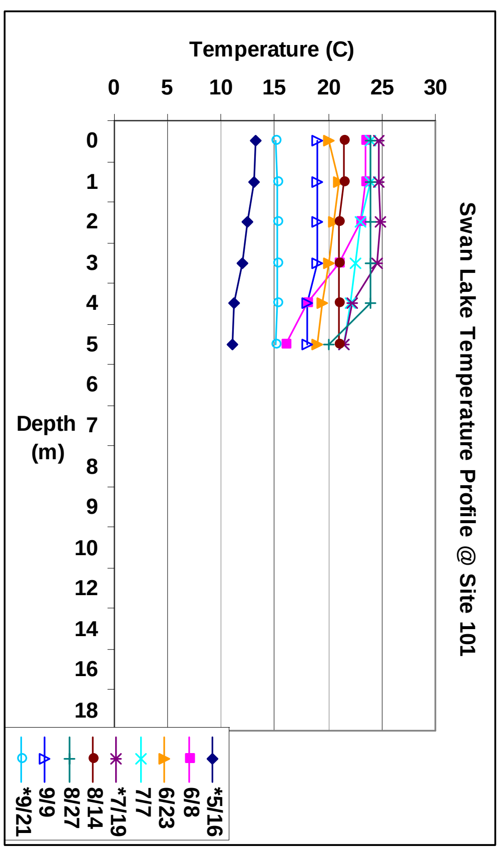


Figure 71. Swan Lake Temperature Profile Data for 2006



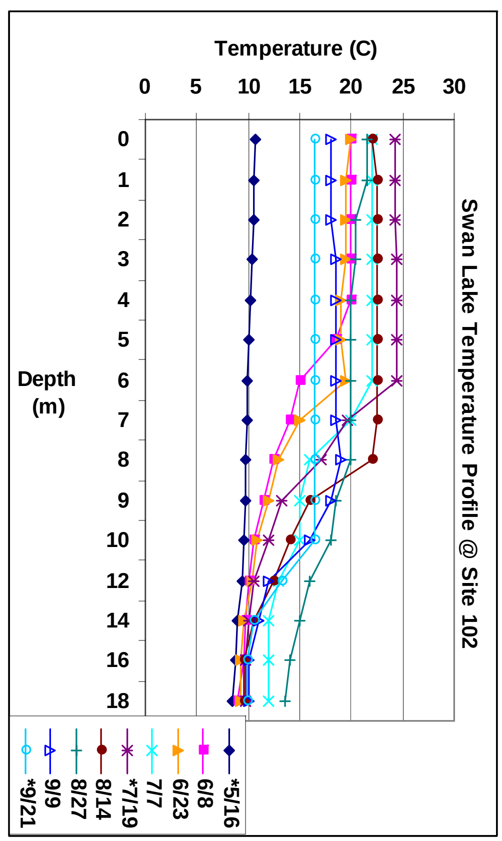
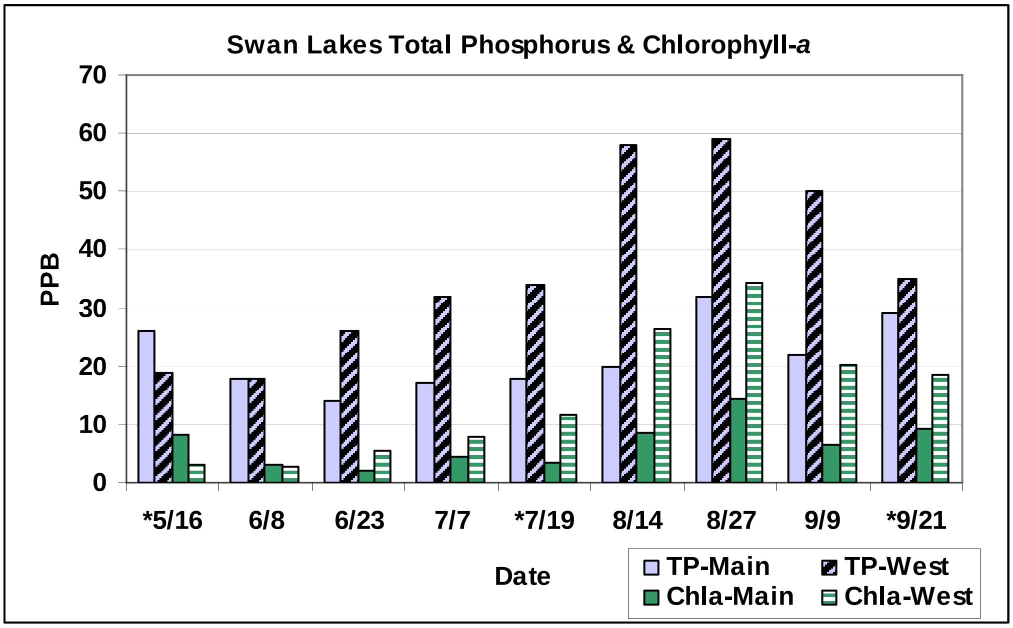
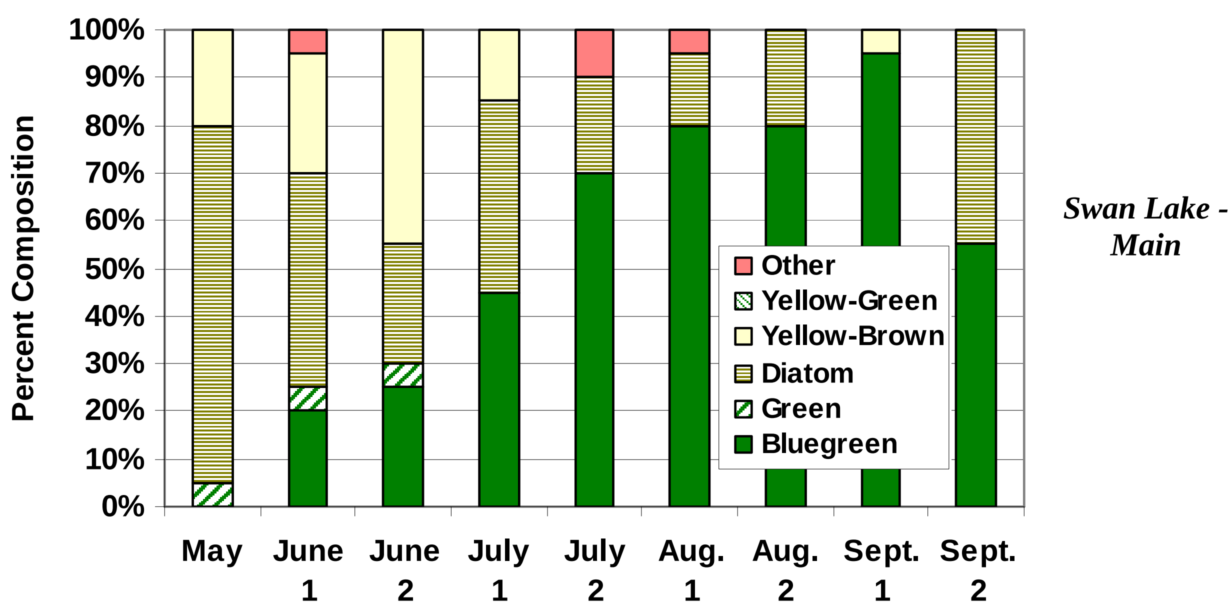


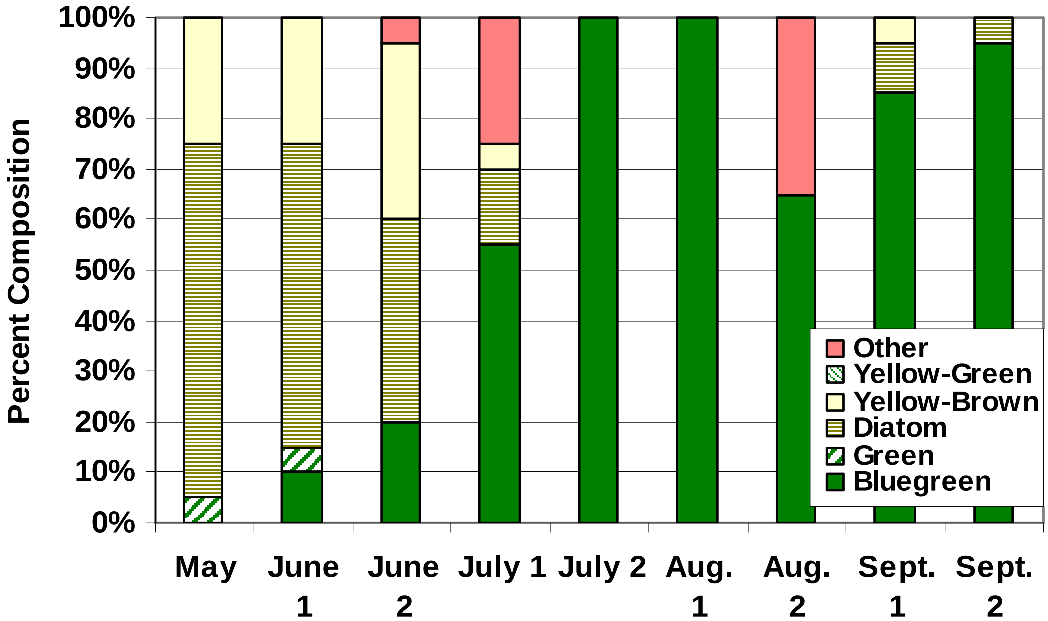
Figure 72. Swan Lake Total Phosphorus and Chlorophyll-*a* Results for 2006



The composition of the phytoplankton (algae) population in both Swan Lakes is presented in Figure 73. Data are presented in terms of algal type. Samples were collected at Sites 101 and 102 for both lakes. The diatoms and yellow-browns were well represented in the algal population in May and June; however, bluegreens dominated the population at both sites from July – September. The forms, *Anabaena, Aphanizomenon* and *Oscillatoria/Lyngbya*, were the most common bluegreens observed at both sites over the summer.

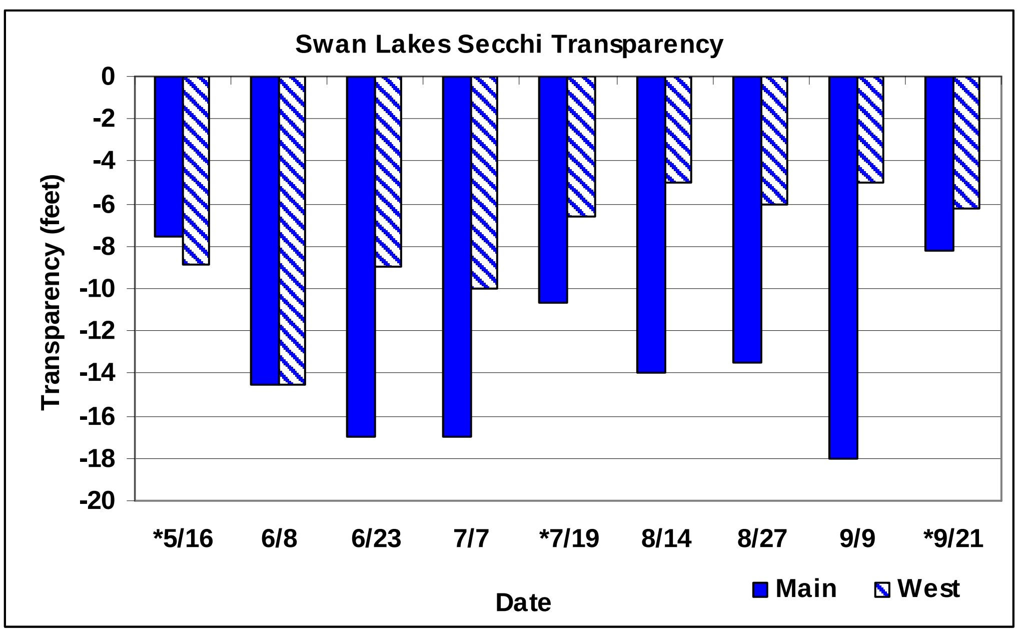
Figure 73. Swan Lake Algal Populations for 2006





Swan Lake - West

Figure 74. Swan Lake Secchi Transparency for 2006



Secchi disk transparency in the main basin of Swan Lake ranged from 7.6 feet (2.3 meters) in May to 18 feet (5.5 meters) in early-September (Figure 74). Transparency for the entire summer averaged 14.1 feet (4.3 meters) and, with the exception of May, was consistently better than transparency in the west basin; which ranged from 6.2 feet (1.9 meters) in late-September to 14.5 feet (4.4 meters) in early-June. Transparency in the west basin averaged 7.8 feet (2.4 meters) and generally declined over the course of the summer following the early-June maximum reading. The transparency measures for both basins are within or very near the typical range for NLF ecoregion reference (Table 2a). Physical condition ratings for both basins ranged from “not quite crystal clear” to “definite algal color” (Classes 1 – 3); while recreational suitability ratings ranged from “beautiful” to “slight impairment” (Classes 1 – 3).

Other parameters, such as alkalinity, pH, chloride and conductivity, total suspended solids (west) and total suspended inorganic solids (west), analyzed for Swan Lake were all above the typical range of values for NLF ecoregion reference lakes (Table 2a). Total Kjeldahl nitrogen, color and total suspended solids (main) and total suspended inorganic solids (main) were within the range of values for the ecoregion (Table 2a).

Trophic State Index (TSI) values for TP and chlorophyll-*a* compare very favorably to each other for both basins of Swan Lake (Table 2b); however, the TSI value for Secchi transparency was significantly lower in both basins than the other TSI values. Based on the 2006 data, Secchi transparency is not a good estimator for TP and chlorophyll-*a* values for Swan Lake; however, it should still continue to be a good tool for examining transparency trends within the lake. The overall TSI value of 46 for the main basin of Swan Lake indicates *mesotrophic* conditions; while the overall TSI value of 54 for the west basin indicates *eutrophic* conditions.

TWIN: NORTH & SOUTH (31-0190 & 31-0191)

North and South Twin Lakes are located one mile south of Marble, Minnesota. North Twin, the larger of the two lakes, has a surface area of 250 acres, a maximum depth of 42 feet and a mean depth of 17 feet and drains toward South Twin. South Twin has a surface area of 179 acres, a maximum depth of 40 feet and mean depth of 15 feet. Approximately 29 and 35 percent of the lake is littoral, respectively, for North and South Twin Lakes and there is one public access for the lakes on North Twin. They are considered to be two separate lakes, but are connected via a small navigable channel between the lakes. The watershed areas of these small lakes is also small at 2 and 2.7 mi^2, respectively for North and South Twin Lakes and consists primarily of forested land uses (Table 1, Figure 75). The water residence time for these lakes is estimated to be on the order of 2 – 4 years.

Water quality data was collected in June, July, August, and September, 2006 by volunteer lake monitor: Tony Appelget and SWCD staff, Noel Griese. One site was used on each lake: Site 101 – located over the point of maximum depth in each lake (Figure 76).

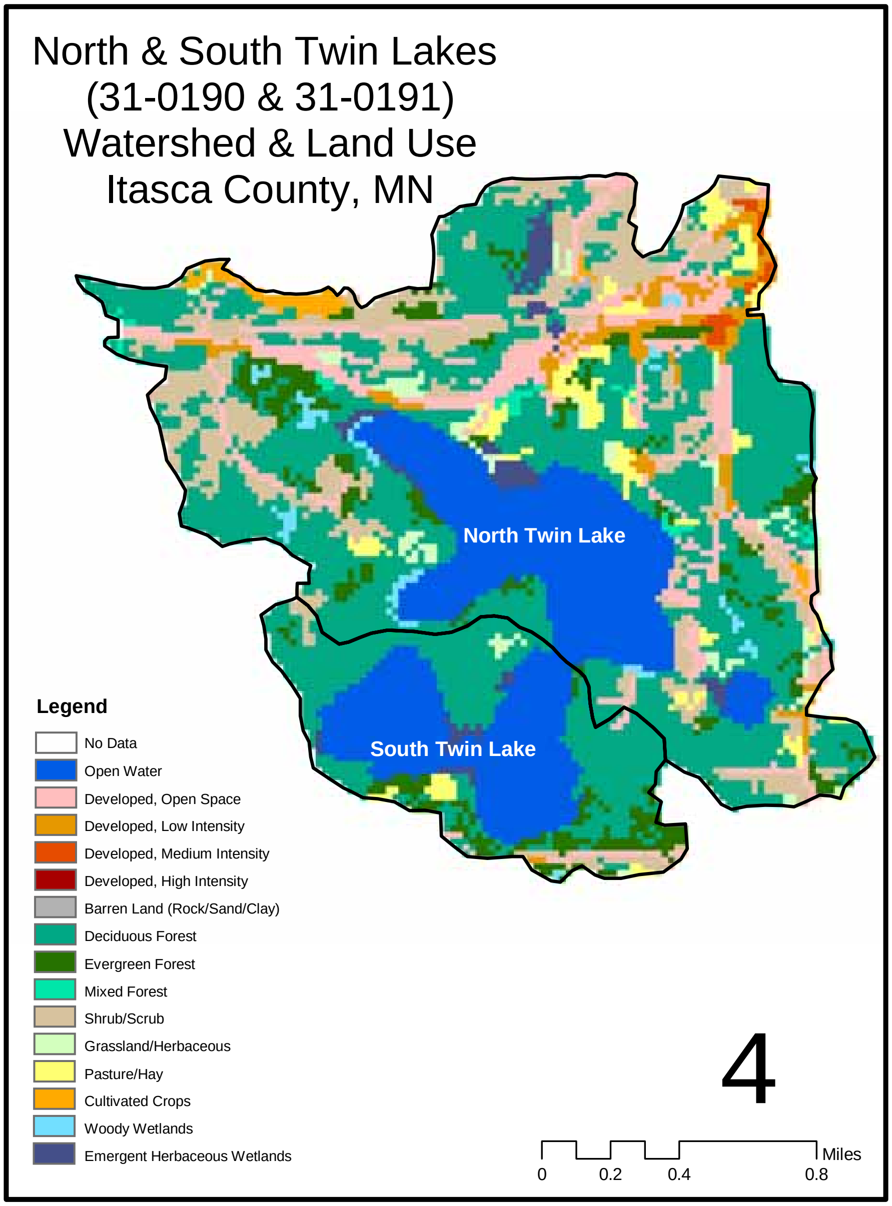
Temperature data indicated slight thermal stratification below four to six meters throughout most of the summer (Figure 77). Dissolved oxygen fell below 1 mg/L during July (Appendix). Surface temperatures ranged from 14.5° C in May to 27.3° C in July for North Twin and ranged from 13.1° C in May to 27.2° C in July for South Twin.

Total phosphorus (TP) concentrations averaged 17 and 14 µg/L, respectively, for North and South Twin Lakes (Figure 78). These values are both well within the range of concentrations for NLF reference lakes (Table 2a). TP concentrations in North Twin ranged from 12 – 22 µg/L and increased slightly at the end of the summer. Concentrations in South Twin were generally lower than North Twin; ranging from 12 – 29 µg/L. Hypolimnetic P was elevated in both lakes (Appendix). In addition, South Twin Lake concentrations also increased at the end of the summer in a pattern similar to that in North Twin. Fall mixing was underway by mid-September (Figure 77).

Chlorophyll-*a* concentrations for both North and South Twin Lakes averaged 4 µg/L in 2006 (Table 2a). The chlorophyll-*a* concentrations in North Twin ranged from 1.7 – 7.1 µg/L and were generally higher than the concentrations in South Twin; which ranged from 1.1 – 12 µg/L (Figure 78). The chlorophyll-*a* values in both lakes were below nuisance bloom levels. A mild algal bloom; however, may have been evident on South Twin during the late-June time period.

The composition of the phytoplankton (algae) population of North and South Twin Lakes are presented in Figure 79. Data are presented in terms of algal type. Samples were collected at Site 101 for both lakes. Several observations on South Twin were missing because they were either not collected, lost or were too sparse in concentration for assessment. The diatoms, yellow-browns and bluegreens were all well represented over the summer. The forms of *Anacystis* (North Twin) and *Anabaena* (South Twin) were the most common bluegreens observed over the summer.

Figure 75. Twin Lakes Watershed & Land Use Map



Land Use Type	N Twin Lake Percent	S Twin Lake Percent	NLF Ecoregion Percent
Forest	46	47	54 - 81
Water & Marsh	19	23	14 - 31
Pasture & Open	21	18	0 - 6
Cultivated	0	0	< 1
Urban	14	12	0 - 7

Figure 76. Twin Lakes Bathymetric Map and Monitoring Locations

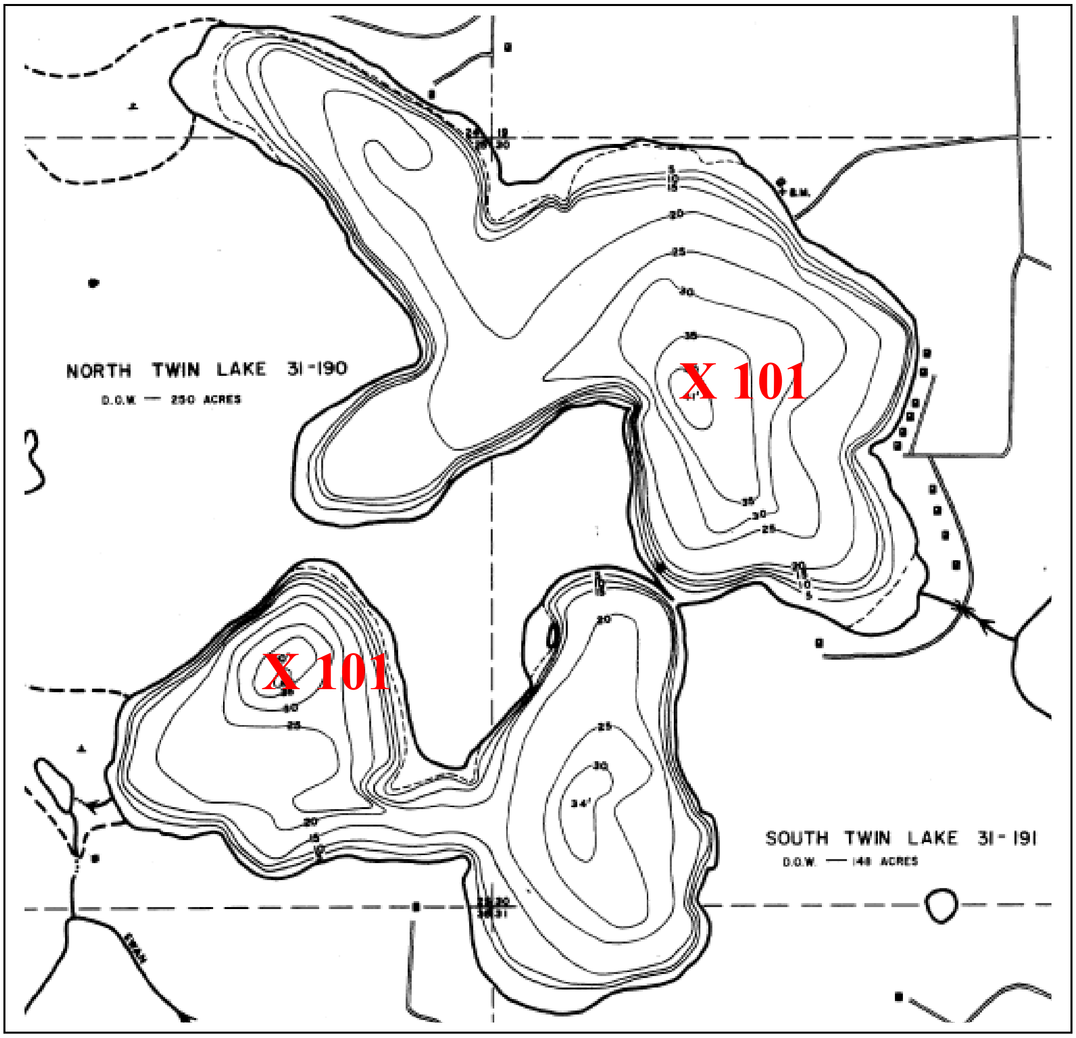


Figure 77. Twin Lakes Temperature Profile Data for 2006

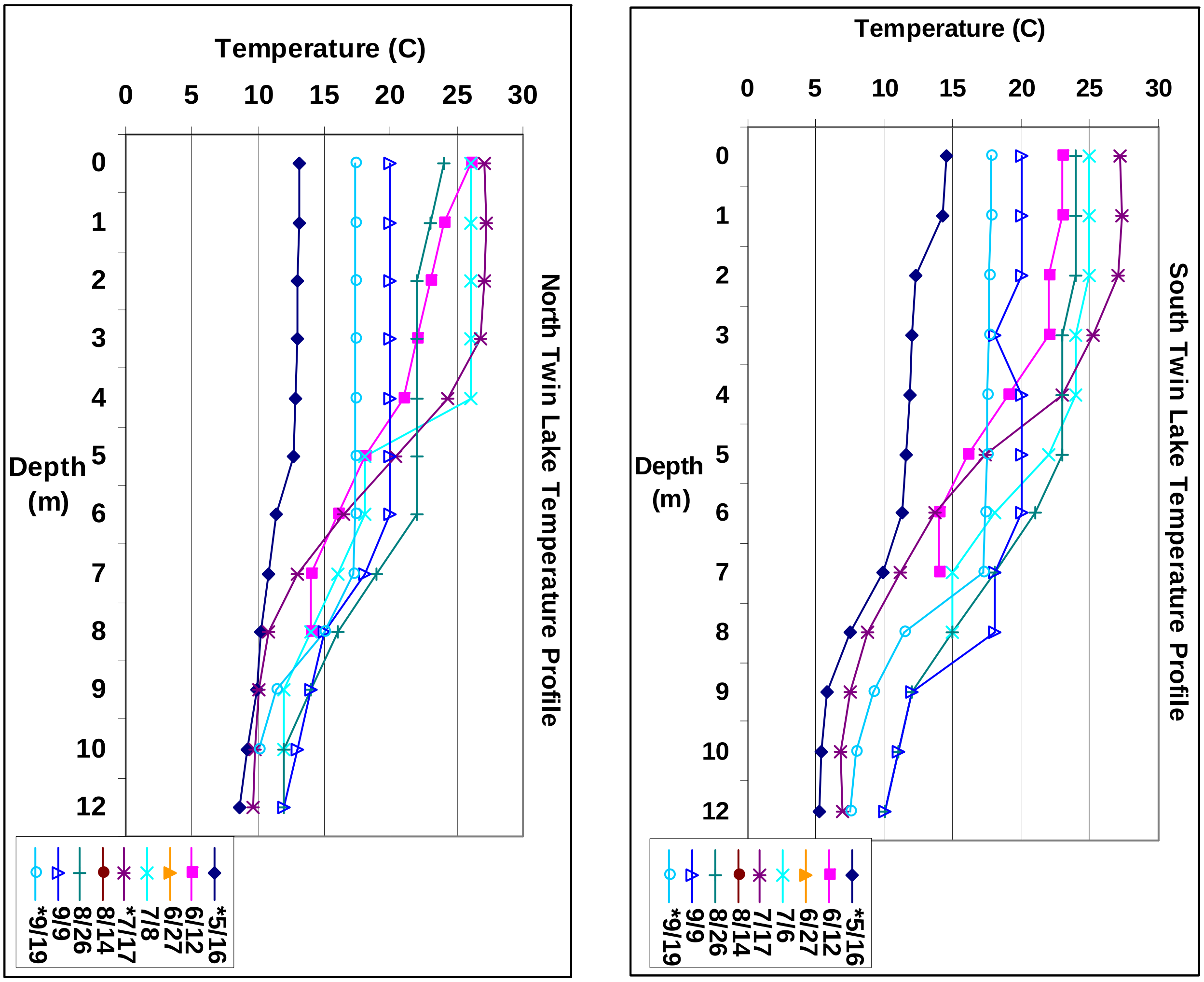


Figure 78. Twin Lakes Total Phosphorus and Chlorophyll-*a* Results for 2006

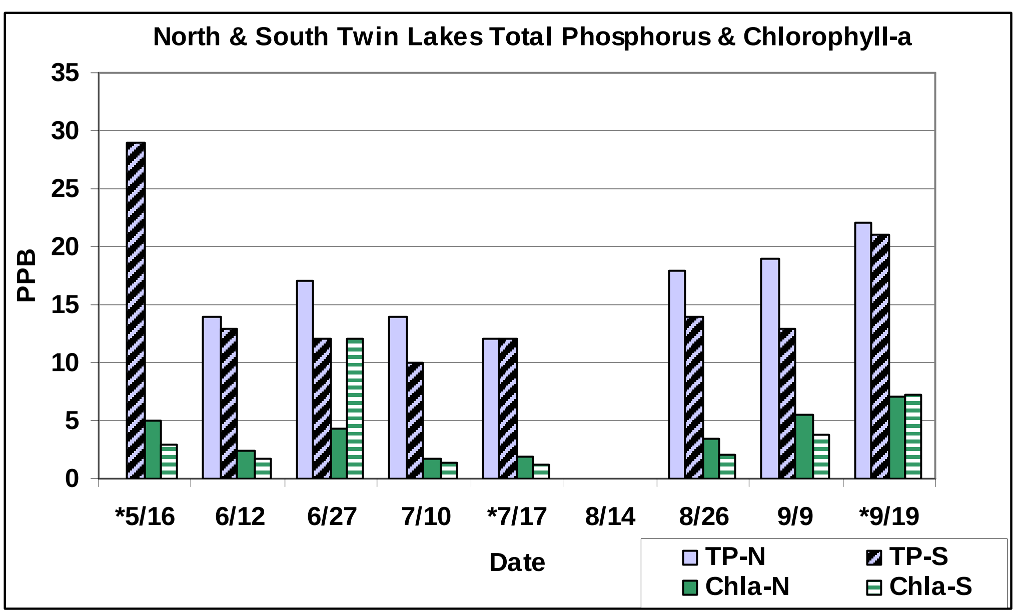
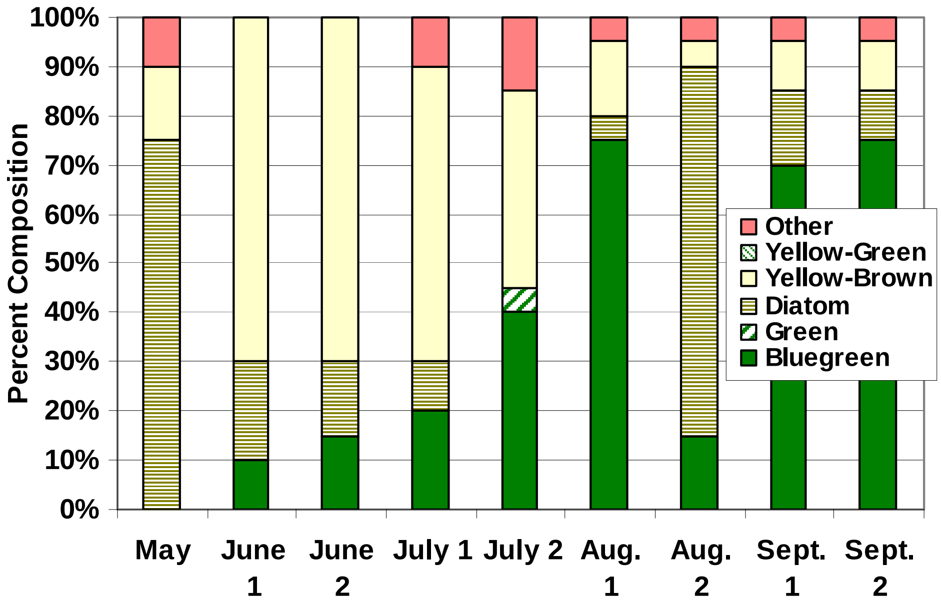
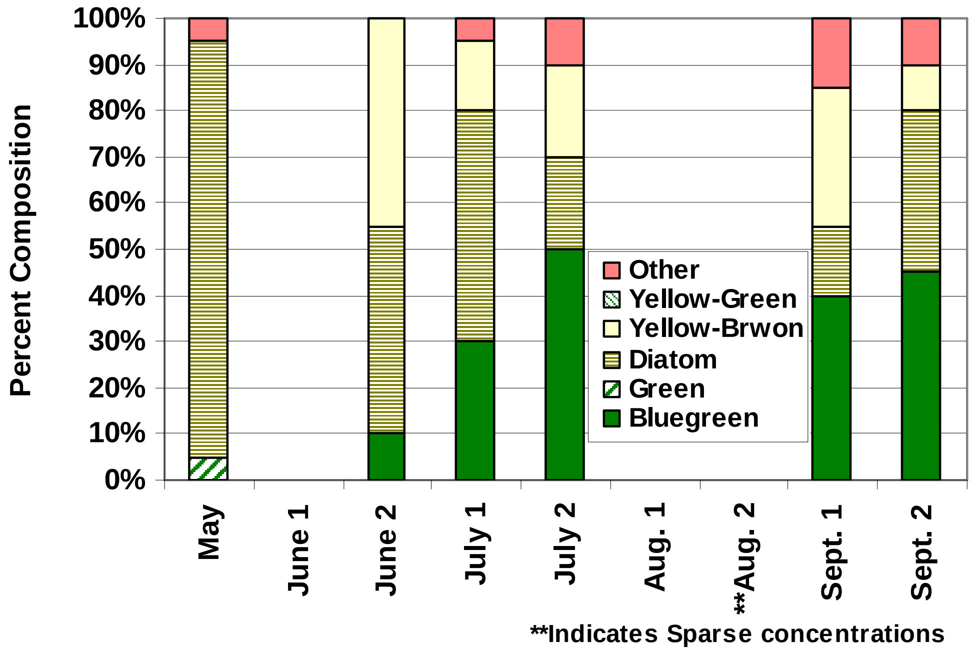


Figure 79. Twin Lakes Algal Populations for 2006

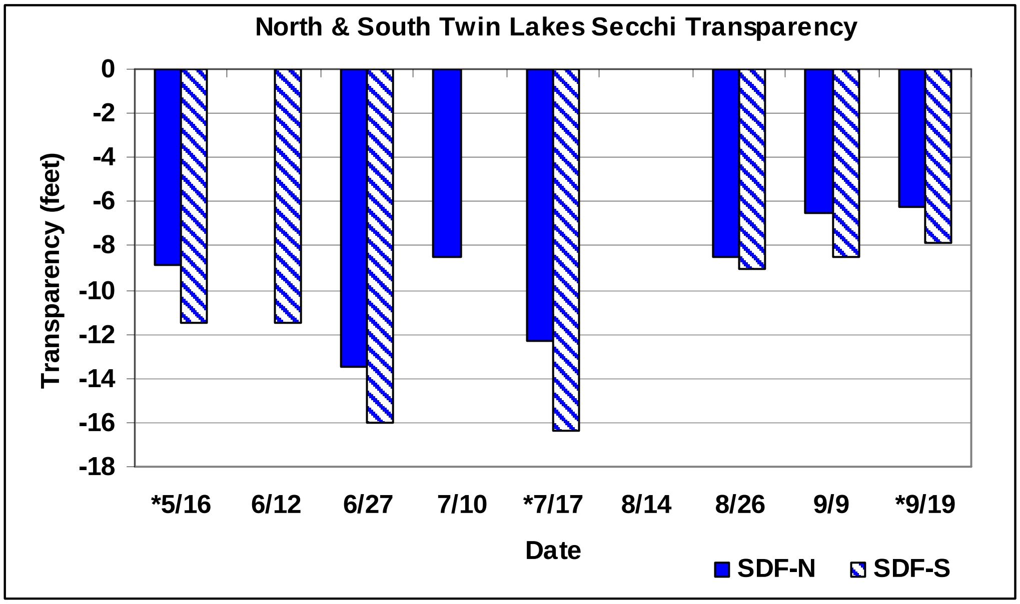


North Twin Lake



South Twin Lake

Figure 80. Twin Lakes Secchi Transparency for 2006



Secchi disk transparency in North Twin Lake ranged from 6.2 feet (1.9 meters) in late-September to 13.5 feet (4.1 meters) in late-June (Figure 80). Transparency for the entire summer averaged 9.3 feet (2.8 meters) and, with the exception of May, was consistently less than transparency in South Twin Lake; which ranged from 7.9 feet (2.4 meters) in late-September to 16.4 feet (5.0 meters) in late-July. Transparency in South Twin Lake averaged 11.6 feet (3.5 meters) and declined considerably following the late-July maximum reading. The transparency measures for both lakes are within the typical range for NLF ecoregion reference (Table 2a). Physical condition ratings for both lakes ranged from "not quite crystal clear" to "definite algal color" (Classes 1 – 3); while recreational suitability ratings ranged from "beautiful" to "minor aesthetic problems" (Classes 1 and 2).

Other parameters, such as total Kjeldahl nitrogen, alkalinity, pH, total suspended solids and total suspended inorganic solids, analyzed for North and South Twin Lakes were all within the typical range of values for NLF ecoregion reference lakes (Table 2a). In contrast, color, chloride and conductivity were outside the typical range of values for the ecoregion (Table 2a). As with the other lakes, the elevated chloride is likely a result of road salt application on roads within the watershed.

Trophic State Index (TSI) values for North and South Twin Lakes TP, chlorophyll-*a*, and Secchi transparency values compare favorably to each (Table 2b). Based on the 2006 data, Secchi transparency is a good estimator for TP and chlorophyll-*a* values for both lakes and should continue to be a good tool for estimating overall water quality and examining transparency trends within the lake. The overall TSI values of 45 and 42 for North and South Twin Lakes, respectively, indicate *mesotrophic* conditions for both lakes.

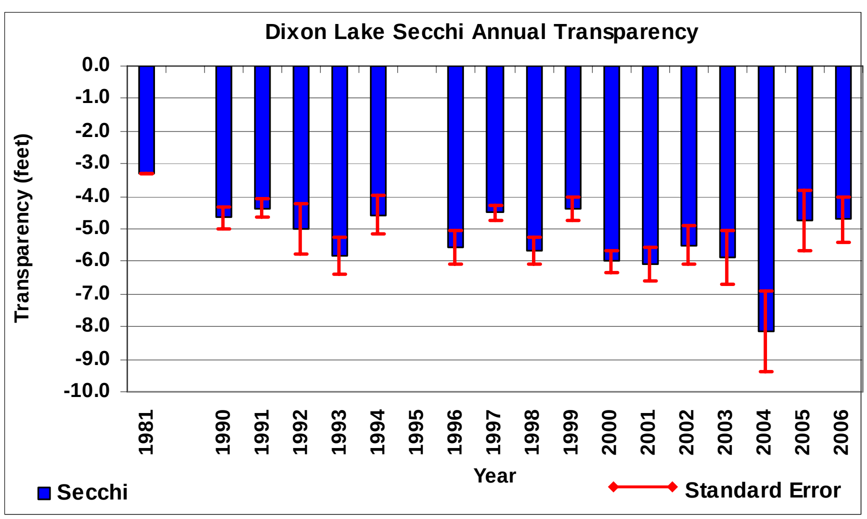
Part 3. Water Quality Trends

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 four 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. Eleven of the Itasca County CLMP+ lakes (Dixon, Dora, Hale, Island, Moose, Prairie, Sand, Snaptail, Split Hand, Swan and South Twin) were included for Secchi transparency trend analysis. The other lakes (Little Bowstring, Little Split Hand and North Twin) did not have the sufficient number of years to run the trend analysis model, but were still included in the following discussion. The figures of this section (Figures 81 – 93) contain a factor called standard 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 data during a given summer, whereas a large standard error implies a high degree of variability. None of these lakes met the required criteria for total phosphorus or chlorophyll-*a* trend analysis.

Dixon Lake (31-0921)

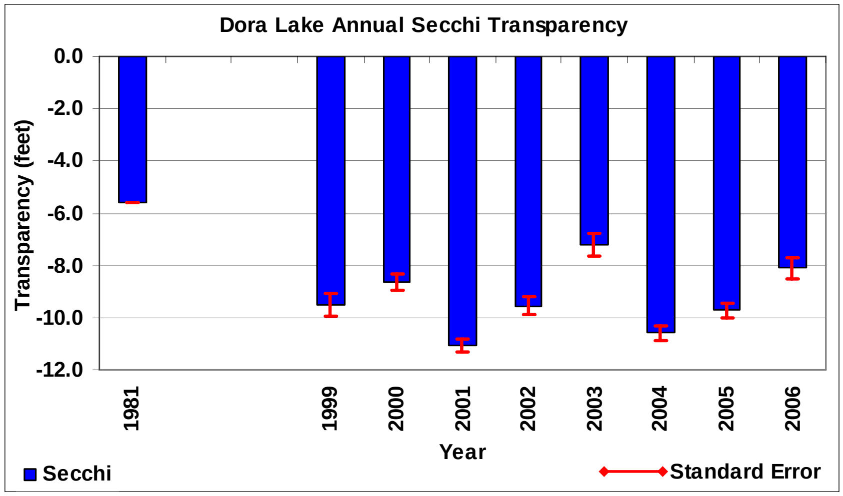
Based on 15 years of data (with four or more readings per year), there has been no overall trend noted (p>0.2). Secchi transparency has ranged from a low of 3.3 feet in 1981 to a maximum of 8.1 feet in 2004 with a long-term average of 5.2 feet (Figure 81). It should be noted that there is a considerable break in the data record between 1981 and 1990. Data from this missing time period would help us improve our trend assessment of Dixon Lake. Continued Secchi transparency monitoring of this lake for trend analysis is recommended.

Figure 81. Dixon Lake Long-Term Secchi Transparency



Dora Lake (31-0882)

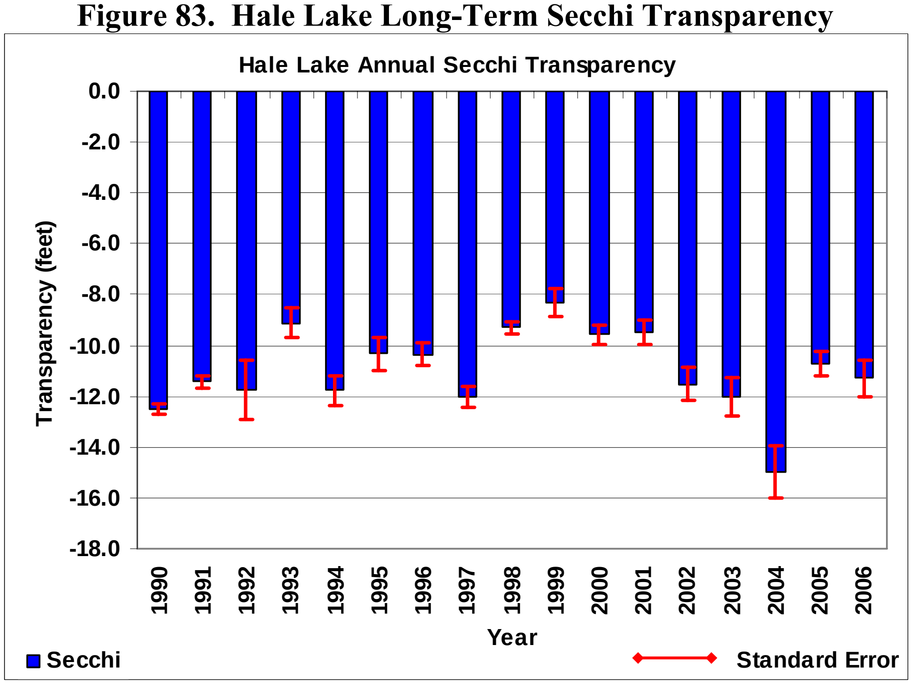
Figure 82. Dora Lake Long-Term Secchi Transparency



Based on 8 years of data there has been some fluctuation in Secchi transparency but no overall trend is noted ($p>0.2$). Secchi transparency has ranged from a low of 5.6 feet in 1981 to a maximum of 11.1 feet in 2001 with a long-term average of 8.9 feet (Figure 82). It is important to note that there is a significant break in the record between the years: 1981 – 1999. Data for this period would help us improve our assessment of trends in Dora Lake. Continued monitoring of this lake for trend analysis is recommended.

Hale Lake (31-0361)

Figure 83. Hale Lake Long-Term Secchi Transparency

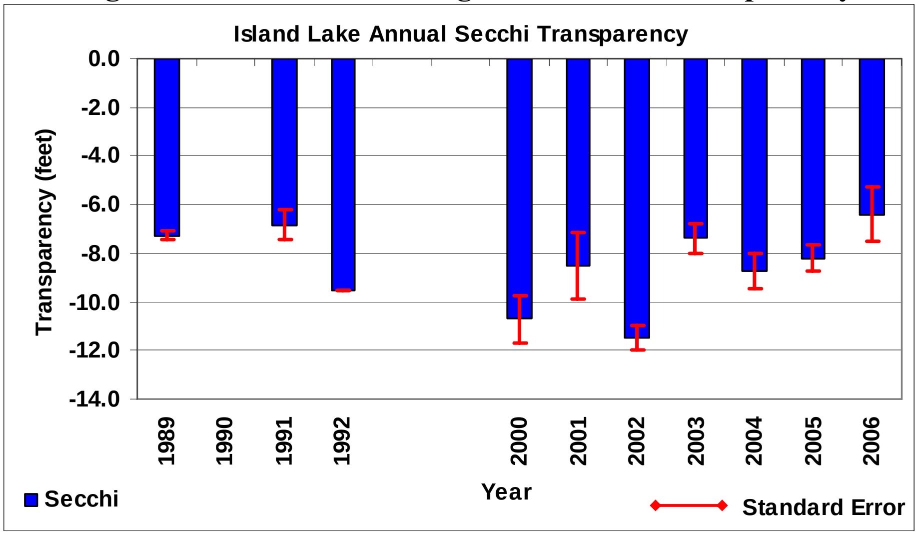


Hale Lake has a long and continuous record which is ideal for assessing transparency trends. Based on 17 years of data there has been some fluctuation, but no overall trend in transparency is noted ($p>0.2$). There was a short-term increase in transparency from 2001 – 2004; however, measures in 2005 and 2006 were consistent with the long-term average of 11 feet (Figure 83). Further Secchi transparency monitoring for this lake is recommended to continue the already long-term records for this lake.

Island Lake (31-0913)

The Secchi dataset for Island Lake is fairly poor because of some significant breaks in the record and several of the years have only one or two readings. Based on 8 years of data there is no overall trend in transparency ($p>0.2$); however, the years: 2000 – 2006 exhibit to show a slight decline in transparency. Secchi transparency has ranged from a low of 6.4 feet in 2006 to a maximum of 11.5 feet in 2002 with a long-term average of 8.5 feet (Figure 84). Continued Secchi transparency monitoring is recommended for this lake to determine if the apparent decline noted from 2000 – 2006 continues and to build a more robust, continuous dataset for Island Lake.

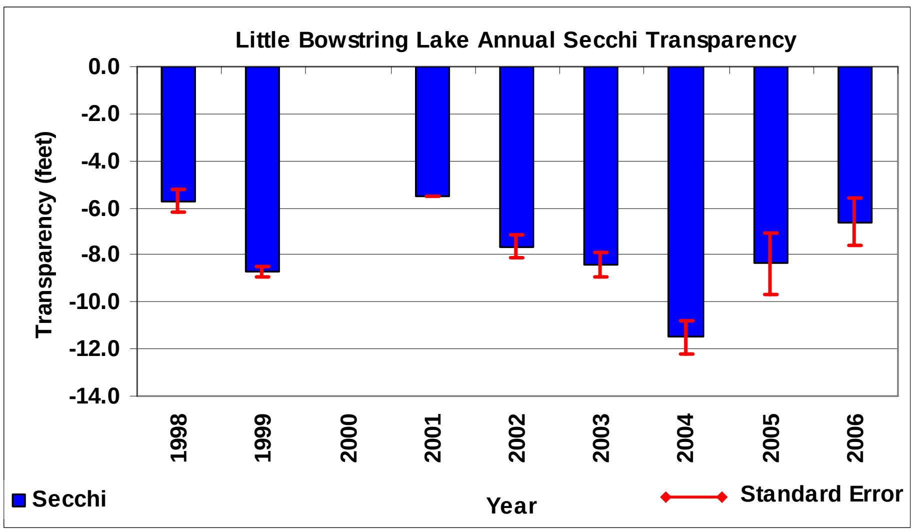
Figure 84. Island Lake Long-Term Secchi Transparency



L. Bowstring Lake (31-0758)

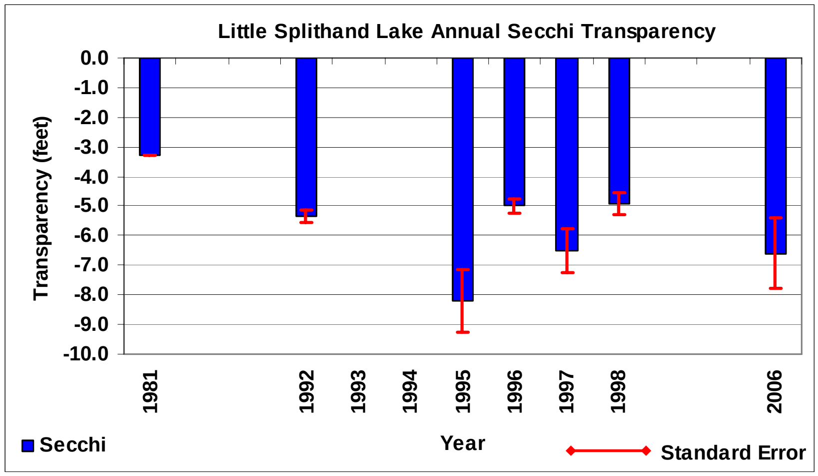
There were not enough years of data meeting the required criteria to use the trend model for Little Bowstring Lake. Secchi transparency has ranged from a low of 5.5 feet in 2001 to a maximum of 11.5 feet in 2004 with a long-term average of 7.8 feet (Figure 85). The dataset itself is fairly continuous, with only one small break in the record. Continued monitoring of Little Bowstring Lake is recommended to add to the existing dataset for future trend assessments.

Figure 85. L. Bowstring Lake Long-Term Secchi Transparency



L. Split Hand Lake (31-0341)

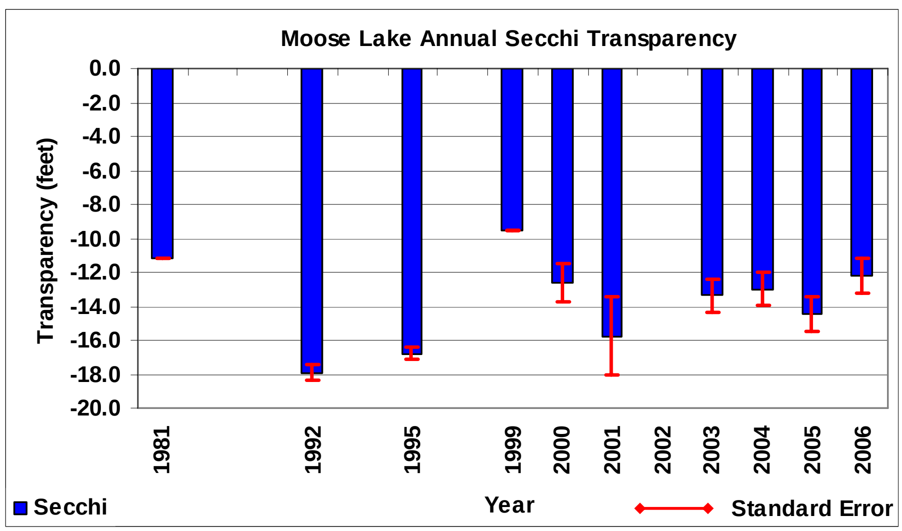
Figure 86. L. Split Hand Lake Long-Term Secchi Transparency



There were not enough years of data meeting the required criteria to use the trend model for Little Split Hand Lake. Secchi transparency has ranged from a low of 3.3 feet in 1981 to a maximum of 8.2 feet in 1995 with a long-term average of 5.7 feet (Figure 86). The dataset itself has several breaks in the record. Continued monitoring of Little Split Hand Lake is recommended to add to the existing dataset for future trend assessments.

Moose Lake (31-0722)

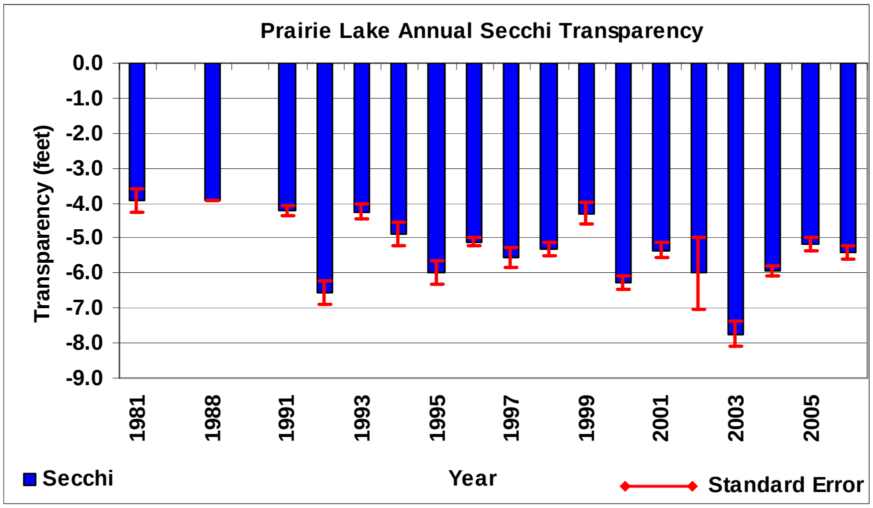
Figure 87. Moose Lake Long-Term Secchi Transparency



Based on 8 years of data, no overall trend in transparency is noted ($p>0.2$). Secchi transparency has ranged from a low of 9.5 feet in 1999 to a maximum of 17.9 feet in 1992 with a long-term average of 13.7 feet (Figure 87). There are significant breaks in the data record which would have improved our ability to assess trends in the lake. Continued monitoring of Moose Lake is recommended to further build a more continuous dataset for future trend assessments.

Prairie Lake (31-0384)

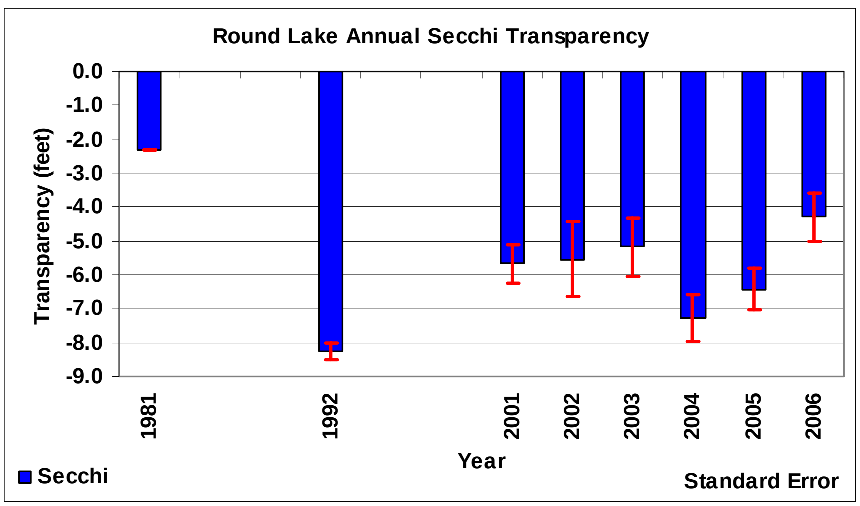
Figure 88. Prairie Lake Long-Term Secchi Transparency



Prairie Lake has a slight break in its Secchi transparency record prior to 1991, but from 1991 to present, the record is very robust and continuous. Based on 16 years of data there has been no overall trend in transparency noted ($p>0.2$). Secchi transparency has ranged from a low of 3.9 feet in 1981 and 1988 to a maximum of 7.8 feet in 2003 with a long-term average of 5.3 feet (Figure 88). A decline since the peak transparency in 2003 is evident over the past three years; however, the recent measures are at or above the long-term mean. Continued monitoring of Prairie Lake is recommended to continue to add to the existing dataset for future trend assessments.

Round Lake (31-0896)

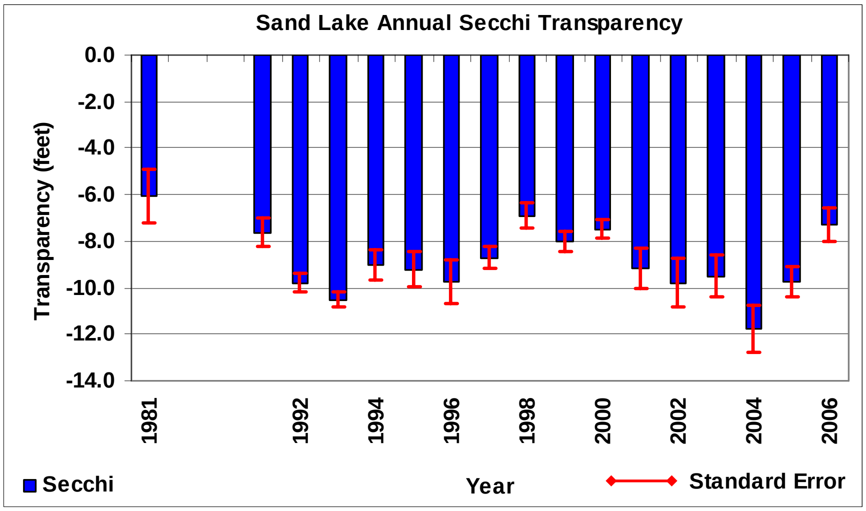
Figure 89. Round Lake Long-Term Secchi Transparency



There were not enough years of data meeting the required criteria to use the trend model for Round Lake. Secchi transparency has ranged from a low of 2.3 feet in 1981 to a maximum of 8.3 feet in 1992 with a long-term average of 5.6 feet (Figure 89). The dataset itself has several breaks in the record, although the most recent six year's data are continuous. Continued monitoring of Round Lake is recommended to add to the existing dataset for future trend assessments.

Sand Lake (31-0826)

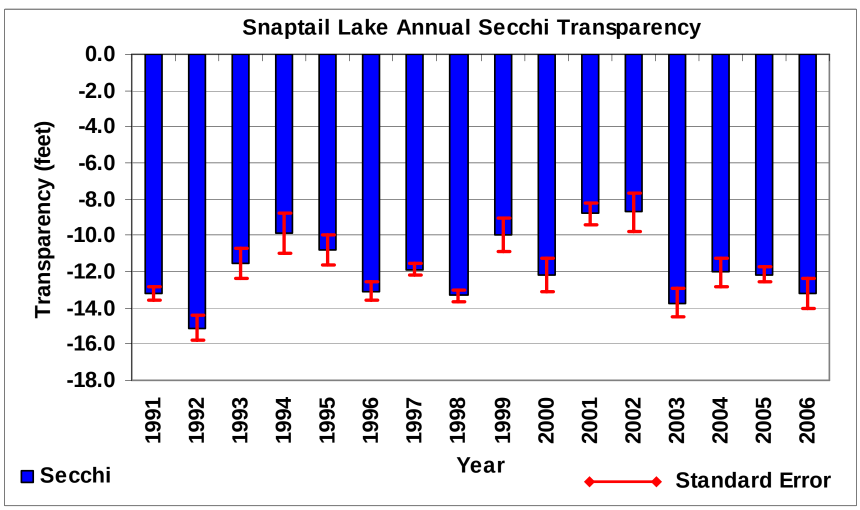
Figure 90. Sand Lake Long-Term Secchi Transparency



Sand Lake has a slight break in the record noted between 1981 – 1991; however, the remaining dataset: 1991 – 2006 is robust and continuous. Based on 16 years of data, there has been some fluctuation, but no overall trend in transparency is noted ($p>0.2$). Secchi transparency has ranged from a low of 6.1 feet in 1981 to a maximum of 11.8 feet in 2004 with a long-term average of 8.8 feet (Figure 90). There has been an apparent decline in transparency in the most recent two years. Further Secchi transparency monitoring for this lake is recommended to continue the already long-term records for this lake.

Snaptail Lake (31-0255)

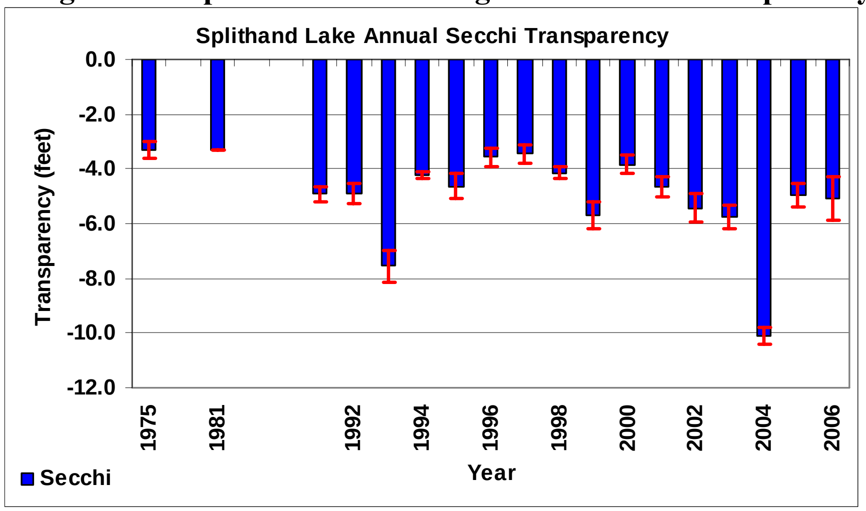
Figure 91. Snaptail Lake Long-Term Secchi Transparency



Snaptail Lake has a long and continuous record, making it ideal for assessing transparency trends. Based on 16 years of data there has been some fluctuation, but no overall trend in transparency is noted ($p>0.2$). Secchi transparency has ranged from a low of 8.7 feet in 2002 to a maximum of 15.1 feet in 1992 with a long-term average of 11.9 feet (Figure 91). Further Secchi transparency monitoring for this lake is recommended to continue the already long-term records for this lake.

Split Hand Lake (31-0353)

Figure 92. Split Hand Lake Long-Term Secchi Transparency



Based on 17 years of data there has been some fluctuation, but no overall trend in transparency is noted (p>0.2). Secchi transparency has ranged from a low of 3.3 feet in 1975 and 1981 to a maximum of 10.1 feet in 2004 with a long-term average of 5 feet (Figure 92). It is important to note that there is a significant break in the record between the years: 1975 – 1981 and 1981 – 1991; although, the record from 1991 – 2006 is continuous. Data from these missing time periods would help us improve our assessment of trends in Split Hand Lake. Continued monitoring of Split Hand Lake is recommended to add to the existing dataset for future trend assessments.

Swan – West and Main Lakes (31-0067-01 & 31-0067-02)

Swan Lake Secchi transparency records date as far back as 1976 for the main basin and to 1986 for the west basin. Based on 18 years of data for the main basin, there has been some fluctuation in transparency with an overall improvement noted (p< 0.01). Based on 11 years of data for the west basin, no overall trend in transparency is noted (p> 0.2). Secchi transparency in the main basin has ranged from a low of 7.5 feet in 1986 to a maximum of 16.7 feet in 2004 with a long-term average of 11.9 feet (Figure 93). Secchi transparency in the west basin has ranged from a low of 6.8 feet in 1986 to a maximum of 13 feet in 2004 with a long-term mean of 9.9 feet (Figure 93). It is important to note that there is a significant break in the record between the years: 1978 – 1986 for the main basin and 1986 – 1996 for the west basin. Data for these missing periods would help us improve our assessment of trends in Swan Lake. Continued monitoring of both basin of Swan Lake is recommended to add to the existing dataset for future trend assessments.

Twin – North and South Lakes (31-0190 & 31-0191)

The data set for North Twin Lake is very poor with only three years of Secchi transparency data spread over a twenty-five year period. Secchi transparency in North Twin has ranged from a minimum of 9.2 feet in 1981 to a maximum of 11.4 feet in 1991 with a long-term average of 10 feet. In contrast, South Twin Lake Secchi transparency records are very robust and continuous back to 1991. Based on 14 years of data for South Twin, there has been a slight decline in transparency noted (p< 0.1). Secchi transparency in South Twin Lake has ranged from a low of 9.7 feet in 2002 to a maximum of 14 feet in 1995 and 1997 with a long-term average of 12.5 feet

(Figure 94). Secchi transparency in the west basin has ranged from a low of 6.8 feet in 1986 to a maximum of 13 feet in 2004 with a long-term mean of 9.9 feet (Figure 94). It is important to note that where there are corresponding years of data between the two lake (1991 and 2006), transparency in South Twin was consistently better than North Twin. Continued monitoring of both Twin Lakes is recommended to add to theses lakes' existing datasets for future trend assessments.

Figure 93. Swan Lake Long-Term Secchi Transparency

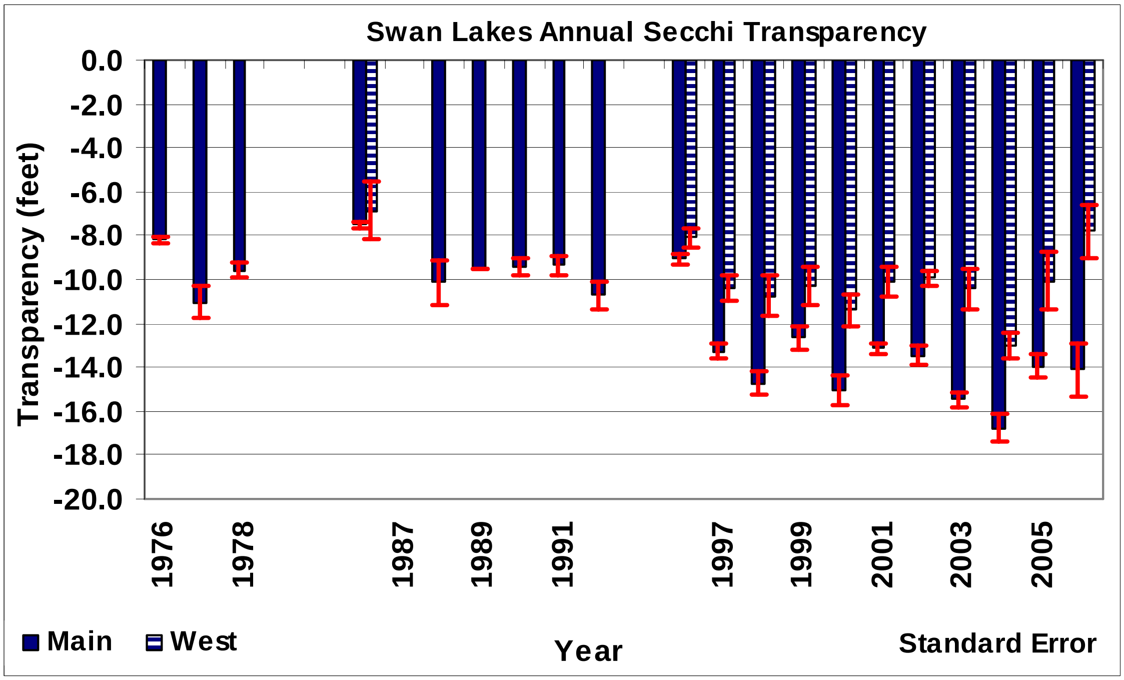
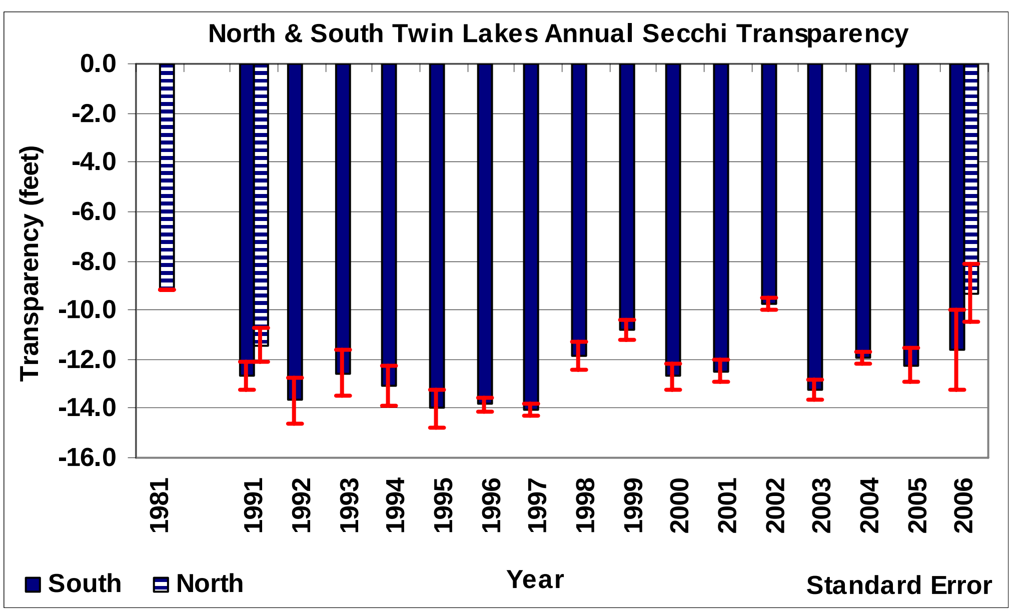


Figure 94. Twin Lakes Long-Term Secchi Transparency



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 and volumes were found for each lake in existing literature or from the MNDNR. Watershed area information was derived for all lakes based on the MNDNR and USGS web sites.

DIXON (31-0921)

Dixon Lake is fairly large, covering 616 acres. It has a moderate sized immediate watershed area; however, the total watershed area for the lake is very large at nearly 75 mi^2 (Appendix 2). Using this watershed area, along with the morphometric data from Table 2a, MINLEAP predicted an in-lake TP of 37 ± 8 µg/L. This value is slightly, but not significantly, lower than the 2006 observed mean. The Vighi-Chiaudani model predicted a significantly lower TP concentration for lake as compared to the 2006 observed value (Table 3). TP-loading for Dixon Lake is estimated to be on the order of 2,350 kg P/yr, based on the total watershed area and the predicted in-lake TP value. *(Note: there are 2.2 pounds of phosphorus per kilogram.)* The TP-retention coefficient is estimated to be 0.29. This means that roughly 29 percent of the TP that enters Dixon Lake stays in the lake. The observed 2006 chlorophyll-*a* concentration for the lake (20 µg/L) is slightly higher than the MINLEAP predicted value (13.1 ± 6.2 µg/L). The predicted Secchi transparency (1.7 ± 0.6 m) is slightly better than the 2006 observed (1.4 m) for Dixon Lake. Overall, the model predictions suggest that in-lake quality could be slightly better than observed based on the size of the lake, its depth and watershed size.

DORA (31-0882)

Dora Lake is a good-sized lake (447 acres) with two distinct basins and a wild rice bed on the south end of the lake. Dora Lake is heavily influenced by the flow of the Big Fork, Bowstring and Popple Rivers as well as Moose Brook and Wendigo Creek. As such, its total watershed area is massive covering close to 440 mi^2 area (Table 1, Appendix 2) giving it a watershed to lake ratio is 629:1 (Table 1). Using this total watershed area and morphometric data from Table

2a, MINLEAP predicted an in-lake TP concentration of 46 ± 9 µg/L, which is slightly, but not significantly higher than the 2006 observed value of 41 µg/L. The Vighi-Chiaudani model predicted a background TP of 26 µg/L (Table 3). TP-loading for Dora Lake is estimated to be on the order of 13,638 kg P/yr, based on the total watershed area. The TP-retention coefficient is estimated to be 0.11 based on the predicted TP value. Predicted chlorophyll-*a* (17.9 ± 8.2 µg/L) is considerably higher than 2006 observed value (7 µg/L). The predicted Secchi transparency (1.4 ± 0.5 m) is slightly less than the observed (2.5 m) for Dora Lake. Overall, the model does a good job of predicting TP. It does not; however, do a good job predicting chlorophyll-*a* and transparency values for the lake based on comparison with the 2006 observed values.

HALE (31-0361)

Hale Lake is a small lake covering 131 acres. It has a fairly small watershed area of 4.1 mi^2. MINLEAP predicted a slightly higher TP concentration (27 ± 7 µg/L) as compared to the 2006 observed value (Table 3). The Vighi-Chiaudani model was very near the 2006 value. TP-loading for the lake is estimated to be on the order of 135 kg P/yr, and the TP-retention coefficient is estimated to be 0.50. The predicted chlorophyll-*a* concentration was significantly higher than the 2006 observed value; and subsequently, the predicted Secchi transparency value was slightly lower than the 2006 observed value. Overall, the model does a good job of estimating TP concentrations and values for Hale Lake and suggests the lake is at or near "background" conditions.

Table 3. MINLEAP Model Outputs & Predictions for Itasca CLMP+ Lakes

LAKE	TP (µg/L) Observed[1]	TP (µg/L) Predicted	TP (µg/L) Vighi-Chiaudani	Chl-a (µg/L) Observed[1]	Chl-a (µg/L) Predicted	Secchi (m) Observed[1]	Secchi (m) Predicted
Dixon	**50 ± 5.7**	37 ± 8	25	**20 ± 4.3**	13.1 ± 6.2	**1.4 ± 0.2**	1.7 ± 0.6
Dora[2]	**41 ± 2.1**	46 ± 9	26	**7 ± 0.7**	17.9 ± 8.2	**2.5 ± 0.1**	1.4 ± 0.5
Hale	**18 ± 0.8**	27 ± 7	19	**3 ± 0.3**	8.1 ± 4.3	**3.4 ± 0.2**	2.3 ± 0.8
Island	**46 ± 6.9**	16 ± 6	22	**23 ± 7.5**	3.7 ± 2.4	**1.9 ± 0.3**	3.6 ± 1.5
Little Bowstring	**30 ± 3.6**	28 ± 7	23	**9 ± 3.0**	8.5 ± 4.5	**2.0 ± 0.3**	2.2 ± 0.8
Split Hand	**44 ± 7.9**	23 ± 7	21	**18 ± 4.0**	6.6 ± 3.7	**1.6 ± 0.2**	2.6 ± 1.0
Split Hand[3]	**44**	25 ± 7	22	**18**	7.3 ± 4.0	**1.7**	2.4 ± 0.9
Moose	**16 ± 1.8**	20 ± 6	22	**4 ± 0.7**	5.3 ± 3.1	**3.7 ± 0.3**	2.9 ± 1.2
Prairie[2]	**32 ± 1.7**	44 ± 9	22	**11 ± 1.3**	16.3 ± 7.5	**1.6 ± 0.1**	1.5 ± 0.5
Round	**89 ± 15.9**	30 ± 8	25	**32 ± 7.3**	9.5 ± 4.9	**1.3 ± 0.2**	2.1 ± 0.7
Sand[2]	**27 ± 1.7**	30 ± 8	22	**11 ± 1.6**	9.6 ± 4.9	**2.2 ± 0.2**	2.0 ± 0.7
Snaptail	**12 ± 0.8**	22 ± 7	16	**3 ± 0.4**	5.9 ± 3.4	**4.0 ± 0.2**	2.7 ± 1.1
Swan-Main	**21 ± 2.2**	18 ± 6	18	**7 ± 1.5**	4.5 ± 2.7	**4.3 ± 0.4**	3.2 ± 1.3
North Twin	**17 ± 1.3**	18 ± 6	22	**4.0 ± 0.8**	4.5 ± 2.8	**2.8 ± 0.4**	3.2 ± 1.3
Twin Lakes[3]	**16**	17 ± 6	22	**4**	4.3 ± 2.7	**3.2**	3.3 ± 1.4

[1]Observed values reported as summer-mean ± standard error.
[2]Based on a "whole" lake summary.
[3]Based on an "area-weighted" mean.

ISLAND (31-0913)

Island Lake is a very large lake covering 4.8 mi^2. Its watershed area is about twice as large at 11.6 mi^2. MINLEAP predicted a significantly lower TP concentration (16 ± 6 µg/L) than the 2006 observed value (Table 3). The Vighi-Chiaudani model was in the same range as the predicted value and was significantly lower than observed TP value (Table 3). TP-loading for the lake is estimated to be on the order of 548 kg P/yr, and the TP-retention coefficient is estimated to be 0.75. The predicted chlorophyll-*a* concentration also significantly lower than the 2006 observed value; and subsequently, the predicted Secchi transparency value was significantly better than the 2006 observed value. Overall, the model suggests the lake is more phosphorus-rich than anticipated, based on its size, depth and watershed area. This is not surprising since the observed TP and chlorophyll-*a* were above the typical range.

LITTLE BOWSTRING (31-0758)

Little Bowstring Lake is a moderate-sized lake covering 319 acres. It has fairly large watershed area of 12 mi^2 (Table 1, Appendix 2). MINLEAP predicted a similar TP concentration (28 ± 7 µg/L) as compared to the 2006 observed value (Table 3). The Vighi-Chiaudani model predicted a slightly lower TP value (Table 3). TP-loading for the lake is estimated to be on the order of 391 kg P/yr, and the TP-retention coefficient is estimated to be 0.48. The predicted chlorophyll-*a* concentration was also similar to the 2006 observed value; and subsequently, the predicted Secchi transparency value was similar to the 2006 observed value. Overall, the model does a good job of estimating observed concentrations for Little Bowstring Lake and suggests the lake may be slightly, but not significantly above "background" conditions.

LITTLE SPLIT HAND (31-0341) & SPLIT HAND (31-0353)

Little Split Hand Lake has a surface area of 223 acres. Split Hand Lake is more than six times the size of Little Split Hand covering 1,420 acres. The total watershed area of Little Split Hand Lake is very large at 35.6 mi^2 (Table 1, Figure 33). The majority of the watershed flows through Split Hand Lake prior to entering Little Split Hand. For Split Hand Lake, MINLEAP predicted a significantly lower TP concentration (23 ± 7 µg/L) as compared to the 2006 observed value (Table 3). The Vighi-Chiaudani model prediction was also significantly lower than the 2006 observed value. TP-loading for Split Hand is estimated to be on the order of 858 kg P/yr, and the TP-retention coefficient is estimated to be 0.57. The predicted chlorophyll-*a* and Secchi transparency values were also better than the 2006 observed values.

No MINLEAP run was done solely for Little Split Hand Lake as the MINLEAP model cannot account for P-trapping in upstream lakes, such as Split Hand Lake. Instead, the model was run with a calculated area-weighted mean depth and 2006 observed values by combining both Split Hand and Little Split Hand Lakes and treating them as one whole lake (Table 3). As with Split Hand Lake, MINLEAP predicted a significantly lower TP concentration (25 ± 7 µg/L) as compared to the calculated 2006 area-weighted value (Table 3). The Vighi-Chiaudani model prediction was similar to the Split Hand MINLEAP model run and was significantly lower than the calculated 2006 area-weighted value. TP-loading was estimated to be on the order of 1,206 kg P/yr and the TP-retention coefficient was estimated at 0.54. Given that the calculated 2006 area-weighted TP value was higher than predicted, it was not surprising that the model-predicted chlorophyll-*a* and Secchi values were also significantly better than the calculated 2006 area-weighted values (Table 3). Overall, the model suggests that both Little Split Hand and Split Hand Lakes may be more phosphorus-rich than anticipated based on their size, depths and watershed areas.

MOOSE (31-0722)

Moose Lake is a large lake with a surface area of 1,265 acres. It has fairly large watershed area of 16.3 mi^2 (Table 1, Figure 39, Appendix 2). MINLEAP predicted a similar TP concentration (20 ± 6 µg/L) as compared to the 2006 observed value (Table 3). The Vighi-Chiaudani model was in the same range as well and was only slightly higher than the predicted and observed TP values (Table 3). TP-loading for the lake is estimated to be on the order of 582 kg P/yr, and the TP-retention coefficient is estimated to be 0.64. The predicted chlorophyll-*a* and Secchi transparency values were also similar to the 2006 predicted values. Overall, the model does a good job of estimating concentrations and values for Moose Lake and suggests the lake is at or better than “background” conditions.

PRAIRIE (31-0384)

Prairie Lake is a large lake with a surface area of 1,064 acres. It has a very large watershed area of 486 mi^2 (Table 1, Figure 45, Appendix 2). MINLEAP predicted a significantly higher TP concentration (44 ± 9 µg/L) as compared to the 2006 observed value (Table 3). The Vighi-Chiaudani model prediction was considerably less than both the predicted and 2006 observed values (Table 3). TP-loading for the lake is estimated to be on the order of 15,126 kg P/yr, and the TP-retention coefficient is estimated to be 0.16. The predicted chlorophyll-*a* and Secchi transparency values were somewhat similar to the 2006 observed values. These results suggest the lake is less phosphorus-rich than anticipated, based on its size and watershed area. Mean depth for this lake was estimated, and if the actual mean depth is greater than our estimate, the predicted TP would be lower; and therefore, closer to the 2006 observed values.

ROUND (31-0896)

Round Lake is a very large, round-shaped lake with a surface area of 2,828 acres. It has large total watershed area of 99 mi^2 (Table 1, Appendix 2). The MINLEAP model predicted a significantly lower TP concentration (30 ± 8 µg/L) than the 2006 observed value (Table 3). The Vighi-Chiaudani model was comparable to the predicted value and was also significantly lower than the 2006 observed TP values (Table 3). TP-loading for the lake is estimated to be on the order of 3,246 kg P/yr, and the TP-retention coefficient is estimated to be 0.44. The predicted chlorophyll-*a* concentration was significantly lower than the 2006 observed value; and subsequently, the predicted Secchi transparency value was slightly better than the 2006 observed value. Overall, the model suggests the lake is more phosphorus-rich than anticipated, based on its size, depth and watershed area. Mean depth for this lake was estimated, and if the actual mean depth is less than our estimate, the predicted TP would be higher; and therefore, closer to the 2006 observed values.

SAND (31-0826)

Sand Lake is a very large lake with a surface area of 4,328 acres. It also has very large watershed area covering nearly 237 mi^2 (Table 1, Figure 57, Appendix 2). MINLEAP predicted a similar TP concentration (30 ± 8 µg/L) as compared to the 2006 observed value (Table 3). The Vighi-Chiaudani model was slightly lower than the observed TP values (Table 3). TP-loading for the lake is estimated to be on the order of 7,595 kg P/yr, and the TP-retention coefficient is estimated to be 0.43. The predicted chlorophyll-*a* and Secchi transparency values were similar as well to the 2006 observed values. Overall, the model does a good job of estimating concentrations and values for SandLake.

SNAPTAIL (31-0255)

Snaptail Lake is a small lake with a surface area of 146 acres. It has very small watershed area of 0.23 mi^2 (Table 1, Figure 63). The MINLEAP model predicted a significantly higher TP concentration (22 ± 7 μg/L) than the 2006 observed value (Table 3). The Vighi-Chiaudani model predicted a background TP concentration close to the observed TP values (Table 3). TP-loading for the lake is estimated to be on the order of 94 kg P/yr, and the TP-retention coefficient is estimated to be 0.60. The 2006 observed chlorophyll-*a* and Secchi transparency values were also better than the MINLEAP predicted values for these same parameters. These results suggest the lake is less phosphorus-rich than anticipated, based on its size and watershed area. Mean depth for this lake was estimated, and if the actual mean depth is greater than our estimate, the predicted TP would be lower; and therefore, closer to the 2006 observed values.

SWAN: MAIN (31-0067-02)

Swan Lake is a large lake covering 2,116 acres. It has a large watershed area of approximately 100 mi^2 (Table 1, Figure 69, Appendix 2). MINLEAP predicted a slightly, but not significantly lower TP concentration (18 ± 6 μg/L) than the 2006 observed value (Table 3). The Vighi-Chiaudani model was very comparable to both the MINLEAP predicted and 2006 observed TP values (Table 3). TP-loading for the lake is estimated to be on the order of 3,429 kg P/yr, and the TP-retention coefficient is estimated to be 0.67. The predicted chlorophyll-*a* concentration was slightly, but not significantly, lower than the 2006 observed value. The predicted Secchi transparency value was slightly, but not significantly, less than the 2006 observed value. Overall, the model does a fairly good job of estimating concentrations for Swan (Main) Lake and suggests the lake is near "background" conditions.

TWIN: NORTH & SOUTH (31-0190 & 31-0191)

North and South Twin Lakes have surface areas of 250 and 179 acres, respectively. They also have very small watershed areas of 2 and 2.7 mi^2, (Table 1, Figure 75). MINLEAP predicted a very similar TP concentration (18 ± 6 μg/L) as compared to the 2006 observed value for North Twin Lake (Table 3). The Vighi-Chiaudani model prediction for North Twin was slightly higher than the 2006 observed and MINLEAP TP values (Table 3). TP-loading for North Twin is estimated to be on the order of 76 kg P/yr, and the TP-retention coefficient is estimated to be 0.69. The predicted chlorophyll-*a* concentration for North Twin was slightly, but not significantly higher than the 2006 observed value; and subsequently, the predicted Secchi transparency value was better than the 2006 observed value.

No MINLEAP run was done solely for South Twin Lake as the MINLEAP model cannot account for P-trapping in upstream lakes, such as North Twin Lake. Instead, the model was run with a calculated area-weighted mean depth and 2006 observed values by combining both North and South Twin Lakes and treating them as one whole lake (Table 3). As with North Twin Lake, MINLEAP predicted a very comparable TP concentration (17 ± 6 μg/L) as compared to the calculated 2006 area-weighted value of 16 μg/L (Table 3). The Vighi-Chiaudani model prediction was similar to the North Twin Lake MINLEAP model run and was slightly, but not significantly higher as compared to the calculated 2006 area-weighted value. TP-loading was estimated to be on the order of 109 kg P/yr and the TP-retention coefficient was estimated at 0.71. Given that the calculated 2006 area-weighted TP value was very comparable to the model-predicted value, it was not surprising that the model-predicted chlorophyll-*a* and Secchi values were also comparable to the calculated 2006 area-weighted values (Table 3). Overall, the model does a good job of estimating concentrations and values for North and South Twin Lakes and suggests the lakes are at or near "background" conditions.

Part 5. Goal Setting

For several of the lakes involved in this study: Dixon, Dora, Island, Little Bowstring, Little Split Hand, Prairie, Round, Split Hand and Swan (West) Lakes; it would be desirable to reduce overall in-lake TP concentrations. In particular, Dixon, Dora, Island, Little Bowstring, Little Split Hand, Prairie, Round and Split Hand Lakes were significantly more nutrient rich than predicted "background" conditions expected and an overall reduction in in-lake TP and nutrients from the contributing watersheds would be needed to achieve "background" conditions. For some of these lakes such as Dixon, Dora and Prairie which have such extremely large contributing watershed areas (Table 1), this may be very difficult. It would be desirable to maintain the currently low in-lake TP-concentrations for the remaining lakes in this study: Hale, Moose, Sand, Snaptail, Swan (Main) and Twin (North and South) Lakes. The summer-mean TP-concentrations for these lakes was near or better than both the predicted TP-value and Vighi and Chiaudani "background" estimate.

Based on 2006 data Dixon, Dora, Island, Little Split Hand, Split Hand and Round Lakes exceed the listing thresholds for the 303(d) "Impaired Waters Listing" (Tables 4 and 5); while Little Bowstring and Prairie Lakes would need further review. Hale, Moose, Sand Snaptail, Swan (both basins) and Twin (North and South) Lakes would be considered as fully supporting for all recreational and aquatic uses. Twelve pairs of TP, chlorophyll-*a*, and Secchi data are needed to "officially" determine whether a lake is listed on the impaired waters list. Once a lake is listed, a detailed and formal study of the lake and watershed are conducted to determine actual nutrient sources and loadings to the resource. Subsequently, a plan is developed for the resource for overall nutrient reduction. This can be a long, detailed, and sometimes complicated process but Federal 319 funds and CWP grant funds are available to help develop the TMDLs.

In the meantime, some important considerations for improving and protecting the water quality of all the lakes in this study include implementation of BMP's in the shoreland areas and ultimately through the watersheds with a particular emphasis on the direct drainage areas. A more comprehensive review of land use practices in the watersheds may reveal opportunities for implementing BMPs in the watersheds and reducing TP-loading to the lakes. Proper maintenance of buffer areas between lawns and the lakeshore, minimizing use of fertilizers, and minimizing the introduction of new significant sources of TP-loading (e.g., stormwater from near-shore development activities in the watershed) will serve to minimize loading to the lakes. These and other considerations will be important if the water quality of these Itasca County lakes is to be maintained or improved over the long term.

Table 4. 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**		
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

Table 5. Draft Eutrophication Criteria by Ecoregion & Lake Type with 2006 Observed Summer-Means (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

Itasca Lakes: 2006 Observed (Ecoregion)	TP (ppb)	Chl-*a* (ppb)	Secchi (meters)
Dixon	50	20	1.4
Dora	41	7	2.5
Hale	18	3	3.4
Island	46	23	1.9
L. Bowstring	30	9	2.0
L. Split Hand	42	17	2.0
Moose	16	4	3.7
Prairie	32	11	1.6
Round	89	32	1.3
Sand	27	11	2.2
Snaptail	12	3	4.0
Split Hand	44	18	1.6
Swan (Main)	21	7	4.3
Swan (West)	39	16	2.4
Twin (North)	17	4	2.8
Twin (South)	14	4	3.5

Part 6. Summary & Recommendations

During the summer of 2006, sixteen lakes in Itasca County were sampled by CLMP volunteers as a part of a monitoring program, CLMP "Plus". These lakes (Dixon, Dora, Hale, Island, Little Bowstring, Little Split Hand, Moose, Prairie, Round, Sand, Snaptail, Split Hand, Swan-Main and West, North Twin and South Twin) were selected because they were a priority, exhibited a trend or lacked data beyond CLMP Secchi data. The combination of water chemistry and Secchi data provides a good baseline for these lakes. Following are a few general observations and recommendations based on our monitoring and data analysis:

A. Secchi transparency monitoring: All the selected lakes have had some level of Secchi monitoring in the past. Monitoring Secchi transparency provides a good basis for estimating trophic status and detecting trends; therefore, routine and continuous monitoring is essential to allow for trend analysis. Of the sixteen lakes, only three lakes (Little Bowstring, Little Split Hand and North Twin Lakes) lacked enough years of data needed for trend analysis. Continued transparency monitoring on all the lakes will contribute to the strong database which already exists for the majority of the lakes studied and allow for further and future trend assessments.

B. Water quality status: Based on data collected in 2006, half of the lakes studied (Dixon, Dora, Island, Little Bowstring, Little Split Hand, Prairie, Round and Split Hand) exhibited summer-mean TP concentrations above the typical range for minimally-impacted lakes in the NLF ecoregion. Some of these lake's TP concentrations were much higher than the typical range; most likely as a result of the lakes having very large watersheds and being more eutrophic. Conversely, the TP concentrations in the remaining lakes: Hale, Moose, Sand, Snaptail, Twin-North and Twin-South were actually well within or better than the typical range. Dixon, Island, Little Split Hand, Prairie, Round, Sand and Split Hand Lakes exhibited average chlorophyll-*a* concentrations above the typical range for reference lakes, while Dora, Hale, Little Bowstring, Moose, Snaptail, Swan, and both Twin Lakes average values were within the typical range. Secchi transparency values for the following lakes were all within ecoregion reference ranges: Dora, Hale, Moose, Snaptail, Swan, and both Twin Lakes; while Dixon, Island, Little Bowstring, Little Split Hand, Prairie, Round, Sand and Split Hand average transparency values were below the NLF ecoregion reference range. Dixon, Dora, Island, Little Split Hand, Round and Split Hand Lakes may be candidates for 303(d) listing, based on the 2006 data collected.

C. Water quality trends: Of the sixteen lakes, only three lakes (Little Bowstring, Little Split Hand and North Twin Lakes) lacked enough years of data needed for trend analysis. Statistical changes in transparency were found for only two lakes from the study. A statistically significant ($p< 0.01$) improvement in transparency was noted in the main basin of Swan Lake; while a statistically significant decline ($p< 0.1$) in transparency was noted for South Twin Lake. The remaining lakes in the study (Dixon, Dora, Hale, Island, Moose, Prairie, Sand, Snaptail, Split Hand, and Swan-West) showed no statistical trend over time. Several of the lakes did have significant breaks in their monitoring records; therefore, continued monitoring of all of these lakes is recommended to further enhance our ability to assess future trends in these lakes.

D. Model predictions: MINLEAP significantly underestimated in-lake TP for Island, Round and Split Hand Lakes, which implies that these lakes are much more nutrient-rich than we would anticipate based on their size, depth and the ecoregion in which they are located. MINLEAP estimates for Hale, Prairie and Snaptail Lakes were significantly higher than the observed values; suggesting these lakes are actually less nutrient-rich than anticipated. In addition, Hale, Moose, Snaptail, North Twin and South Twin Lakes were actually found to have lower average TP concentrations in 2006 than Vighi-Chiaudani "background" estimates as well. The remaining lakes from this study had MINLEAP estimates that corresponded fairly well with 2006 observed values. In general the model estimates can provide some perspective on the load reductions that might be required to achieve reduced concentrations as well as the potential changes in chlorophyll-*a* and Secchi as a result of those changes.

E. Watersheds: Every effort to protect the lakes in this study from degradation and reduce TP-loading to the lakes should be taken. Further development or land use change in the watersheds should occur in a manner that minimizes water quality impacts on the lakes. In the shoreland areas, setback provisions should be strictly followed. MDNR and County shoreland regulations will be important in this regard. Other considerations for these lakes follow:

- Stormwater regulations should be strictly 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 as both high volume and high concentration can impact downstream wetlands, rivers and lakes. Properly designed sedimentation ponds, where needed, should be included in any development to minimize P-loading to the lakes. A "no-net-increase" in TP is recommended in the case of Dixon, Dora, Island Little Bowstring, Little Split Hand, Prairie, Round and Split Hand Lakes and would be beneficial to the remaining lakes as well.
- Any agricultural activities in the watershed including row crop cultivation and land application of bio-solids from animal confinement areas should be conducted in such a way as to minimize runoff of nutrient and sediment rich water to watercourses (ditches, rivers, wetlands and lakes) in the watershed. Likewise pasturing operations should be managed so as to minimize erosion adjacent to watercourses and when possible animals should be kept out of watercourses. Maintaining vegetated buffers (1 rod minimum) will help to stabilize ditch and stream banks and should help minimize transport of nutrients and sediments from upland areas in the watershed.
- Activities in the watersheds 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 watersheds 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 continue to 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 resources such as these CLMP+ lakes in Itasca 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. Septics: On-site septic systems are a *potential* source of nutrients to lakes that are not sewered. The relative significance of septic systems as compared to watershed and atmospheric sources will vary among the lakes in this study. In general, the relative significance of septic systems is greatest on densely developed lakes with small watershed to lake surface ratios. While their influence may not be expressed 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 individual lake associations and Itasca 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. The lake associations may want to facilitate a lake-wide schedule for pumping systems.

G. Loadings: 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. In April 2004, a 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 Itasca County, should encourage the use of P-free fertilizers 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.

H. Overall: Results from the Itasca County 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 for further studies of this kind.

Appendix

1. **Itasca County CLMP+ Lakes Data for 2006 and Historic Data**

2. **Watershed Maps for Itasca County CLMP+ Lakes**

Appendix 1. Itasca County CLMP+ Lakes Data

Dixon Lake (31-0921) 2006 Data @ Site 101

Sampler	Date	Time	Depth	TP	Chl-*a*	Pheo	TSS	TSV	Color	ALK	CL	TKN	SDM	pH	Cond	PC	RS
MPCA	05/17	12:00	0	36	11.00	3.14	3.6	1.6	70	130	1.3	0.75	1.30	8.81	229	1	1
MPCA	05/17	12:00	7.5	42													
Volunteer	06/11	10:15	0	27	3.92	0.90							2.44			2	1
Volunteer	06/24	12:30	0	37	11.10	2.70							1.83			2	2
Volunteer	07/07	10:45	0	44	9.42	2.03							1.52			2	2
MPCA	07/18	14:45	0	47	25.70	3.86	5.6	4.4	50	130	1.2	1.24	1.25	8.88	235	2	2
MPCA	07/18	14:45	7	461													
Volunteer	08/13	14:00	0	68 Q	29.00	2.50							1.07			4	4
Volunteer	08/26	10:40	0	61	29.80	1.33							1.22			4	4
Volunteer	09/09	10:20	0	63	31.30	2.63							0.76			5	4

Dora Lake (31-0882) 2006 Data @ Site 101

Sampler	Date	Time	Depth	TP	Chl-*a*	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDM	pH	Cond	PC	RS
MPCA	05/17	10:30	0	32	6.70	1.65	3.2	2.0	50	100.0	1.9	0.66	2.00	8.81	193	3	2
MPCA	05/17	10:30	3.5	33													
Volunteer	06/11	11:15	0	35	6.14	2.53							2.44			2	2
Volunteer	06/25	10:45	0	36	5.12	2.08							3.20			2	2
Volunteer	07/09	10:45	0	51	8.44	3.15							2.29			2	2
MPCA	07/18	9:30	0	48	10.30	3.34	3.6	2.8	30	120.0	1.7	0.98	1.70	7.99	216	2	2
MPCA	07/18	9:30	3.5	47													
Volunteer	08/13	12:00	0	55 Q	13.10	4.56							2.29			2	2
Volunteer	08/27	10:15	0	40	6.52	3.28							2.59			2	2
Volunteer	09/10	11:30	0	37	4.50	2.21							2.74			2	2
MPCA	09/20	12:00	0	35	10.30	3.34	4.8	2.8	30	140.0	2.3	0.91	2.25	7.95	244	2	2
MPCA	09/20	12:00	3	35													

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)
SDM = Secchi Transparency (meters)
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)*

Dora Lake (31-0882) 2006 Data @ Site 201

Sampler	Date	Time	Depth	TP	Chl-*a*	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDM	pH	Cond	PC	RS
MPCA	**05/17**	**11:00**	**0**	26	**4.97**	**1.62**	**3.2**	**2.4**	**40**	**110**	**1.9**	**0.58**	**1.75**	**8.8**	**195**	**2**	**2**
MPCA	**05/17**	**11:00**	**3**	30													
Volunteer	**06/11**	**10:45**	**0**	35	**4.94**	**1.68**							**2.44**			**2**	**2**
Volunteer	**06/25**	**10:30**	**0**	33	**4.28**	**1.15**							**3.35**			**2**	**2**
Volunteer	**07/09**	**10:30**	**0**	49	**4.61**	**2.56**							**2.59**			**2**	**2**
MPCA	**07/18**	**9:00**	**0**		**8.2**	**3.42**	**4**	**2.8**	**40**	**120**	**1.8**		**1.6**	**8.04**	**223**	**2**	**2**
MPCA	**07/18**	**9:00**	**3**	50													
Volunteer	**08/13**	**12:30**	**0**	53 Q	**7.17**	**3.08**							**2.29**			**2**	**2**
Volunteer	**08/27**	**10:30**	**0**	45	**7.3**	**2.35**							**2.74**			**2**	**2**
Volunteer	**09/10**	**11:15**	**0**	34	**4.94**	**2.92**							**2.74**			**2**	**2**
MPCA	**09/20**	**11:45**	**0**	32	**10.5**	**2.37**	**2.8**	**1.6**	**30**	**140**	**2.6**	**0.95**	**2.4**	**7.85**	**250**	**2**	**2**
MPCA	**09/20**	**11:45**	**3**	32													

Hale Lake (31-0361) 2006 Data @ Site 201

Sampler	Date	Time	Depth	TP	Chl-*a*	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDM	pH	Cond	PC	RS
MPCA	5/17	17:30	0	31	2.27	0.37	1.3	1.3	20	87	6.6	0.76	3.75	9.05	180	1	1
MPCA	5/17	17:30	12	80													
Volunteer	6/13	15:00	0	22	3.43	0.58							3.81			2	2
Volunteer	6/28	14:00	0	16	1.92	0.35							4.57			2	2
Volunteer	7/11	14:00	0	16	2.37	0.26							3.81			2	2
MPCA	7/19	10:30	0	20	3	0.36	1.6	1.6	10	72	6.6	0.56	3	9.12	155	1	1
MPCA	7/19	10:30	15	206													
Volunteer	8/15	14:00	0	18 Q	3.82	1.22							3.05			2	2
Volunteer	8/28	14:00	0	15	3.26	0.53							3.2			2	2
Volunteer	9/11	14:30	0	19	3.59	0.54							3.05			2	2
MPCA	9/19	16:40	0	19	4.68	0.6	1.2	1.2	10	84	7	0.62	3	8.2	168	1	1
MPCA	9/19	16:40	16	285													

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)
SDM = Secchi Transparency (meters)
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)*

Island Lake (31-0913) 2006 Data @ Site 101

Sampler	Date	Time	Depth	TP	Chl-*a*	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDM	pH	Cond	PC	RS
MPCA	5/17	9:00	0	45	5.73	1.69	2.8	1.6	10	110	2.5	0.61	3	8.95	205	2	2
MPCA	5/17	9:00	9	30													
Volunteer	6/11	14:30	0	21	1.42	0.47 K							2.9			2	1
Volunteer	6/22	10:00	0	27	8.61	1.88							2.13			2	2
Volunteer	7/7	10:30	0	34	8.2	1.45							2.13			2	2
MPCA	7/18	8:00	0	40	16.5	2.96	4.8	3.2	10	110	2.4	0.81	1.5	8.95	206	3	2
MPCA	7/18	8:00	7.5	62													
Volunteer	8/10	10:00	0	72 Q	60.5	2.13							0.91			4	4
Volunteer	8/23	11:30	0	73 Q	45	3.06							0.91			4	4
Volunteer	9/6	10:30	0	52	31.9	1.28							1.52			4	4
MPCA	9/20	8:20	0	51	8	0.9	2.4	2.4	20	110	2.5	0.76	3.5	8	207	3	3
MPCA	9/20	8:20	7	45													

Little Bowstring Lake (31-0758) 2006 Data @ Site 201

Sampler	Date	Time	Depth	TP	Chl-*a*	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDM	pH	Cond	PC	RS
MPCA	5/18	9:40	0	32	3.3	0.76	3.2	1.6	10	150	2.7	0.41	3.2	8.91	287	1	1
MPCA	5/18	9:40	10.5	24													
Volunteer	6/10	14:00	0	18	3.14	0.24							3.35			2	2
Volunteer	6/19	12:05	0	18	1.82	0.79							3.2			2	2
Volunteer	7/10	12:45	0	24	4.53	0.86							2.13			2	2
MPCA	7/18	16:30	0	25	4.61	0.6	4.8	2	5	140	2.5	0.49	1.5	8.6	252	3	2
MPCA	7/18	16:30	8	50													
Volunteer	8/14	12:30	0	30 Q	8.9	2.51							1.83			2	2
Volunteer	8/25	14:45	0	41	19.7	2.09							1.52			3	3
Volunteer	9/11	12:00	0	37	6.5	0.82							1.07			3	3
MPCA	9/20	15:15	0	44	25.5	1.87	4	2.8	10	140	2.6	0.9	1.5	8.16	257	3	3
MPCA	9/20	15:15	9	44													

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)
SDM = Secchi Transparency (meters)
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)*

Little Split Hand Lake (31-0341) 2006 Data @ Site 101

Sampler	Date	Time	Depth	TP	Chl-*a*	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDM	pH	Cond	PC	RS
MPCA	5/17	16:00	0	34	8.96	2.56	5.6	2.4	50	89	2	0.69	1.75	8.91	167	2	2
MPCA	5/17	16:00	8	37													
Volunteer	6/10	15:00	0	25	2.99	0.34 K							3.35			1	1
Volunteer	6/27	9:30	0	29	4.45	0.69							3.05			1	1
Volunteer	7/11	10:30	0	44	19.4	1.72							2.44			1	1
MPCA	7/17	16:30	0	33	22.1	2.07	4	3.6	30 Q	94	1.7	0.84	1.5	9.06	175	3	2
MPCA	7/17	16:30	6	60													
Volunteer	7/18	9:00	0										1.83			2	3
Volunteer	8/14	14:00	0	65 Q	21.4	6.89							1.07			3	3
Volunteer	8/28	18:30	0	44	15.6	2.49							1.37			2	2
MPCA	9/19	17:30	0	52	36	5.62	6	4.8	20	100	1.8	0.96	1.25	8.33	183	3	3
MPCA	9/19	17:30	6	52													

Moose Lake (31-0722) 2006 Data @ Site 102

Sampler	Date	Time	Depth	TP	Chl-*a*	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDM	pH	Cond	PC	RS
MPCA	5/18	10:30	0	12	1.55	0.45	1 K	1 K	5	140	2.1	0.28	4.3	8.95	257	1	1
MPCA	5/18	10:30	17	20													
Volunteer	6/14	11:30	0	11	1.78	0.18 K							5.03			1	1
Volunteer	6/22	17:30	0	13	2.36	0.34							4.42			1	1
Volunteer	7/9	10:00	0	14	1.79	0.39							3.96			1	1
MPCA	7/18	17:30	0	13	2.66	0.29	1.2	1.2	5	140	2	0.41	3.75	8.54	251	1	1
MPCA	7/18	17:30	11	22													
Volunteer	8/13	8:30	0	20 Q	4.96	0.99							3.05			2	1
Volunteer	8/26	10:00	0	23	5.5	1.18							3.05			2	1
Volunteer	9/11	7:00	0	21	5.79	0.95							2.74			2	1

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)
SDM = Secchi Transparency (meters)
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)*

Prairie Lake (31-0384) 2006 Data @ Site 101

Sampler	Date	Time	Depth	TP	Chl-*a*	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDM	pH	Cond	PC	RS
MPCA	5/18	11:45	0	32	9.24	2.05	3.6	1.2	100	64	2.6	0.59	0.8	8.62	129	2	2
MPCA	5/18	11:45	4.5	32													
Volunteer	6/11	10:30	0	26	3.15	1.05							1.68			2	2
Volunteer	6/25	10:00	0	26	5.54	1.18							1.98			2	2
Volunteer	7/9	10:00	0	27	5.23	0.96							1.83			2	2
MPCA	7/19	7:00	0	24	8.3	1.46	2.4	1.6	50	86	2.1	0.68	2	8.21	168	2	1
MPCA	7/19	7:00	4.5	54													
Volunteer	8/13	12:20	0	29 Q	7.28	3.64							1.52			2	2
Volunteer	8/27	10:09	0	30	11.9	2.4							1.98			2	2
Volunteer	9/10	10:25	0	37	10.6	2.59							1.52			2	2
MPCA	9/19	13:00	0	33	10.8	1.91	4.8	2.4	40 Q	97	2.2	0.66	1.7	7.84	179	2	2
MPCA	9/19	13:00	4.5	31													

Prairie Lake (31-0384) 2006 Data @ Site 102

Sampler	Date	Time	Depth	TP	Chl-*a*	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDM	pH	Cond	PC	RS
MPCA	**5/18**	**11:30**	**0**	27	**7.28**	**1.85**	**3.6**	**1.6**	**100**	**63**	**2.7**	**0.61**	**0.8**	**8.79**	**129**	**1**	**1**
MPCA	**5/18**	**11:30**	**6**	28													
Volunteer	**6/11**	**11:15**	**0**	28	**9.95**	**3.09**							**1.68**			**2**	**2**
Volunteer	**6/25**	**10:30**	**0**	33	**12**	**2.58**							**1.83**			**2**	**2**
Volunteer	**7/9**	**10:40**	**0**	28	**8.89**	**2.1**							**1.68**			**2**	**2**
MPCA	**7/19**	**7:30**	**0**	28	**12.4**	**1.79**	**3.6**	**2.8**	**50**	**78**	**2.3**	**0.75**	**1.5**	**8.4**	**154**	**2**	**1**
MPCA	**7/19**	**7:30**	**6.5**	49													
Volunteer	**8/13**	**12:50**	**0**	35 Q	**18**	**2.83**							**1.52**			**2**	**2**
Volunteer	**8/27**	**10:38**	**0**	39	**23.6**	**3.03**							**1.37**			**3**	**3**
Volunteer	**9/10**	**10:49**	**0**	46	**15.8**	**2.23**							**1.23**			**2**	**2**
MPCA	**9/19**	**12:40**	**0**	46	**17.9**	**3.86**	**5.6**	**3.2**	**40 Q**	**87**	**2.4**	**0.84**	**1.3**	**7.99**	**162**	**2**	**2**
MPCA	**9/19**	**12:40**	**6.5**	45													

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)
SDM = Secchi Transparency (meters)
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)*

Round Lake (31-0896) 2006 Data @ Site 202

Sampler	Date	Time	Depth	TP	Chl-*a*	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDM	pH	Cond	PC	RS
MPCA	5/17	13:30	0	54	7.86	6.18	15	6.8	40	110	2.1	0.92				2	2
Volunteer	6/13	8:00	0	34	8.27	2.4							2.13			2	2
Volunteer	6/25	15:00	0	39	8.1	2.15							1.68			2	2
Volunteer	7/9	11:00	0	62	54.1	18.3							1.37			2	2
MPCA	7/18	13:30	0	80	57.3	8.97	9.6	8	40	120	2	1.45	0.75	9.05	214	3	3
MPCA	7/18	13:30	5	69													
Volunteer	8/14	9:00	0	142 Q	54.7	14							0.76			3	2
Volunteer	8/29	8:00	0	158	28.6	4.26							0.91			2	3
Volunteer	9/12	8:00	0	104	19.8	2.39							2.13			2	1
MPCA	9/20	9:20	0	91	27.7	7.02	11	7.2	30	120	2	1.18	0.8			3	3

Sand Lake (31-0826) 2006 Data @ Site 101

Sampler	Date	Time	Depth	TP	Chl-*a*	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDM	pH	Cond	PC	RS
MPCA	5/18	8:00	0	40	4.74	0.93	3.2	1.2	20	110	2.1	0.49	3.25	8.75	198	1	1
MPCA	5/18	8:00	7.5	20													
Volunteer	6/8	7:00	0	14	3.05	2.02							3.66			2	1
Volunteer	6/23	15:00	0	22	7.23	1.62							2.44			2	2
Volunteer	7/10	8:00	0	29	7.65	2.81							2.13			3	2
MPCA	7/18	10:45	0	29	8.29	2.08	2.4	2	20	110	2	0.66	1.8	8.55	210	2	1
MPCA	7/18	10:45	9.5	43													
Volunteer	8/11	8:30	0	36 Q	16	2.75							1.52			3	2
Volunteer	8/26	10:00	0	38	21.9	3.02							1.22			3	2
Volunteer	9/8	9:00	0	35	13.7	2.44							1.68			4	3
MPCA	9/20	10:30	0	38	24.9	3.17	5.6	4.4	20	120	2.1	0.8	1.5	8.32	210	2	2
MPCA	9/20	10:30	5.5	41													

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)
SDM = Secchi Transparency (meters)
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)*

Sand Lake (31-0826) 2006 Data @ Site 102

Sampler	Date	Time	Depth	TP	Chl-*a*	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDM	pH	Cond	PC	RS
MPCA	5/18	8:30	0	22	3.77	0.26	2.8	1.6	20	110	2	0.6	3.75	8.92	203	1	1
MPCA	5/18	8:30	20	27													
Volunteer	6/8	7:40	0	18	3.26	0.93							3.66			2	1
Volunteer	6/23	14:30	0	21	5.08	0.94							3.05			2	2
Volunteer	7/10	8:30	0	25	4.41	1.67							3.35			2	2
MPCA	7/18	11:15	0	26	5.51	2.34	2	1.6	20	110	1.9	0.67	2	8.59	208	2	1
MPCA	7/18	11:15	16.5	93													
Volunteer	8/11	8:00	0	26 Q	10.1	2.21							2.13			3	2
Volunteer	8/26	9:30	0	25	11.5	1.84							2.13			4	2
Volunteer	9/8	8:30	0	29	12.9	1.91							1.98			4	3
MPCA	9/20	11:00	0	28	13.8	1.9	3.2	2.4	20	120	2.1	0.76	1.3	8.21	213	2	2
MPCA	9/20	11:00	15.5	44													

Snaptail Lake (31-0255) 2006 Data @ Site 101

Sampler	Date	Time	Depth	TP	Chl-*a*	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDM	pH	Cond	PC	RS
MPCA	5/16	12:30	0	25	2.24	0.38	1.3	1 K	50 Q	49	3.4	0.88	2.7	7.2	101	1	1
MPCA	5/16	12:30	16	28													
Volunteer	6/8	11:15	0	11	2.18	1.25							4.27			2	3
Volunteer	6/22	14:15	0	13	3.19	0.75							4.27			2	2
Volunteer	7/9	13:30	0	12	2.29	0.75							4.27			1	2
MPCA	7/17	13:15	0	11	2.25	0.87	1 K	1 K	30 Q	51	3.2	0.58	3.75	8.21	114	1	1
MPCA	7/17	13:15	19.5	17													
Volunteer	8/10	10:00	0	9 Q	2	0.7							4.57			1	1
Volunteer	8/26	12:00	0	16	3.04	0.85							4.27			1	2
Volunteer	9/7	13:15	0	12	4.49	0.82							4.27			1	2
MPCA	9/19	14:10	0	14	4.4	0.76 K	1.6	1.2	30 Q	55	3.2	0.58	2.5	8.29	112	2	1
MPCA	9/19	14:10	17	58													

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)
SDM = Secchi Transparency (meters)
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)*

Split Hand Lake (31-0353) 2006 Data @ Site 202

Sampler	Date	Time	Depth	TP	Chl-*a*	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDM	pH	Cond	PC	RS
MPCA	5/17	16:45	0	27	5.8	2.02	2.4	1.6	30	85	1.8	0.57	2.5	8.84	162	2	2
MPCA	5/17	16:45	6.5	37													
Volunteer	6/11	11:50	0	22	3.62	1.33							2.59			2	2
Volunteer	6/25	10:00	0	22	5.07	1.54							2.59			2	2
Volunteer	7/8	10:00	0	28	8.67	2.08							1.68			2	2
MPCA	7/17	16:00	0	32	27.2	3.4	5.2	4.4	20 Q	95	1.7	0.87	1.25	8.82	179	3	2
MPCA	7/17	16:00	4	34													
Volunteer	8/13	10:00	0	69 Q	26.9	5.56							1.07			3	3
Volunteer	8/27	10:00	0	48	16.6	2.24							1.22			2	3
Volunteer	9/10	10:00	0	53	19.6	3.15							1.07			2	3
MPCA	9/19	18:15	0	81	34.6	4.35	9.2	6	30	100	1.8	0.97	1	8.66	187	3	3
MPCA	9/19	18:15	4.5	57													

Swan-Main Lake (31-0067-02) 2006 Data @ Site 102

Sampler	Date	Time	Depth	TP	Chl-*a*	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDM	pH	Cond	PC	RS
MPCA	5/16	14:00	0	26	8.25	2.28	4.4	2.4	20 Q	150	7.3	0.38	2.3	7.63	309	1	1
MPCA	5/16	14:00	17	23													
Volunteer	6/8	10:30	0	18	3.17	0.86							4.42			2	2
Volunteer	6/23	10:15	0	14	2.01	0.55							5.18			2	2
Volunteer	7/7	10:20	0	17	4.39	0.87							5.18			2	2
MPCA	7/19	8:45	0	18	3.31	0.89	1.6	1.6	10	150	7.1	0.43	3.25	8.66	319	1	1
MPCA	7/19	8:45	16.5	76													
Volunteer	8/14	10:20	0	20 Q	8.66	1.2							4.27			2	2
Volunteer	8/27	10:20	0	32	14.4	1.42							4.11			3	3
Volunteer	9/9	10:20	0	22	6.56	1.28							5.49			3	3
MPCA	9/21	8:00	0	29	9.41	1.24	2	1.2	10	150	7.1	0.49	2.5	8.33	313	1	1
MPCA	9/21	8:00	17	322													

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)
SDM = Secchi Transparency (meters)
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)*

Swan-West Lake (31-0067-01) 2006 Data @ Site 101

Sampler	Date	Time	Depth	TP	Chl-*a*	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDM	pH	Cond	PC	RS
MPCA	5/16	14:30	0	19	3.1	0.73	2	1.2	20 Q	140	7	0.54	2.7	8.71	298	1	1
MPCA	5/16	14:30	4.5	23													
Volunteer	6/8	11:10	0	18	2.86	0.86							4.42			2	2
Volunteer	6/23	10:46	0	26	5.57	1.87							2.74			2	2
Volunteer	7/7	11:30	0	32	7.96	1.48							3.05			2	2
MPCA	7/19	9:00	0	34	11.5	2.17	2.8	2.4	10	150	7.2	0.57	2	8.88	311	2	1
MPCA	7/19	9:00	4.5	53													
Volunteer	8/14	11:10	0	58 Q	26.4	4.85							1.52			2	2
Volunteer	8/27	11:10	0	59	34.3	3.44							1.83			3	3
Volunteer	9/9	14:10	0	50	20.1	3.08							1.52			3	3
MPCA	9/21	8:30	0	35	18.5	2.38	2.8	2.4	10	150	7.3	0.68	1.9	8.59	303	1	1
MPCA	9/21	8:30	4	35													

Twin-North Lake (31-0190) 2006 Data @ Site 101

Sampler	Date	Time	Depth	TP	Chl-*a*	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDM	pH	Cond	PC	RS
MPCA	5/16	16:00	0		5.08	0.55	2.7	2	10 Q	140	9.7		2.7	9.06	316	1	1
MPCA	5/16	16:00	10.5	35													
Volunteer	6/12	14:00	0	14	2.41	0.31										2	1
Volunteer	6/27	14:00	0	17	4.26	0.58							4.11			3	1
Volunteer	7/8	12:30	0	14	1.65	0.33							2.59			3	2
MPCA	7/17	14:45	0	12	1.95	0.3	1.2	1.2	5 Q	130	9.5	0.45	3.75	8.44	301	2	1
MPCA	7/17	14:45	10.5	48													
Volunteer	8/26	11:45	0	18	3.5	1.15							2.59			2	2
Volunteer	9/9	12:25	0	19	5.59	1.19							1.98			3	2
MPCA	9/19	15:30	0	22	7.08	2.2	2.4	1.6	10	140	9.6	0.47	1.9	8.05	305	1	1
MPCA	9/19	15:30	10.5	48													

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)
SDM = Secchi Transparency (meters)
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)*

Twin-South Lake (31-0191) 2006 Data @ Site 101

Sampler	Date	Time	Depth	TP	Chl-*a*	Pheo	TSS	TSV	COL	ALK	CL	TKN	SDM	pH	Cond	PC	RS
MPCA	5/16	15:30	0	29	2.93	0.42	2.4	1.6	10 Q	130	6.8	0.59	3.5	8.77	281	1	1
MPCA	5/16	15:30	11	43													
Volunteer	6/12	13:00	0	13	1.64	0.18							3.5			2	1
Volunteer	6/27	15:00	0	12	12	1.1 K							4.88			2	1
Volunteer	7/10	12:15	0	10	1.39	0.2										3	2
MPCA	7/17	14:15	0	12	1.14	0.26	1 K	1 K	5 Q	120	6.7	0.44	5	8.48	272	2	1
MPCA	7/17	14:15	10.5	98													
Volunteer	8/26	13:00	0	14	2.06	0.5							2.74			2	2
Volunteer	9/9	13:25	0	13	3.85	0.84							2.59			3	2
MPCA	9/19	15:15	0	21	7.31	0.78	2	1.6	10 Q	130	6.7	0.55	2.4	8.09	277	1	1
MPCA	9/19	15:15	11	101													

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)
SDM = Secchi Transparency (meters)
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)*

2006 Temperature Data for Itasca County CLMP+ Lakes

Dixon Lake (31-0921) Temperature °C @ Site 101

Depth (m)	*5/17	6/11	6/24	7/7	*7/18	8/13	8/26	9/9	*9/27
0	12.95	20	23.9	20.6	26.34	21.1	22.8	15.6	
1	13	18.3	23.3	21.1	26.33	20	22.2	16.7	
2	12.98	20	23.3	21.1	26.2	20	21.1	17.2	
3	12.95	18.3	22.2	21.1	24.96	20	21.1	17.7	
4	12.94	18.3	21.7	20	23.15	20	21.1	17.7	
5	12.96	16.7	20.6	18.3	18.59	20	20.6	17.7	
6	12.93	15.6	17.8	15.6	15.13	16.7	20	17.7	
7	12.66	15.6	17.2	15.6	13.99	15.6	18.3	16.7	
8	12.28				13.68	15.6	17.8		

Dora Lake (31-0882) Temperature °C

N Dora Site 101

Depth (m)	*5/17	6/11	6/25	7/9	*7/18	8/13	8/27	9/10	*9/20
0	13.42	19.5	20	21	25.69	20	20.6	17.2	14.88
1	13.38	19.5	20	21	25.67	20	20.6	17.2	14.88
2	13.33	19	20	21	25.6	20.6	20.6	17.2	14.88
3	13.29	20	19.5	21	25.61	20.6	20.6	17.2	14.79
4	13.07	19.5			24.6				15.57

S Dora Site 201

Depth (m)	*5/17	6/11	6/25	7/9	*7/18	8/13	8/27	9/10	*9/20
0	14.86	19	20	21	25.39	20	19.4	16.9	14.3
1	14.86	18.5	19.5	21	25.33	20	18.9	16.9	14.24
2	14.82	19	19.5	21	25.32	20	18.9	16.9	14.22
3	14.79	18.5	19.5	21	24.29	19.4	18.9	16.9	13.68
4					23.28				14.47

Hale Lake (31-0361) Temperature °C @ Site 201

Hale (31-0361) @ 201

Depth (m)	*5/17	6/13	6/28	7/11	*7/19	8/15	8/28	9/11	*9/19
0	15.06	22	24	26	26.23	24	22	19	17.14
1	14.85	22	24	26	26.21	23	22	19	17.14
2	13.76	21	23	25	26.18	23	21	19	17.04
3	13.13	20	23	24	25.4	22	20	19	16.98
4	12.37	18	20	22	21.22	21	20	19	16.75
5	11.96	15	17	18	14.71	20	18	19	16.19
6	10.54	13	13	15	10.64	15	13	16	14.7
7	8.16	11	10	12	8.67	12	13	13	9.89
8	5.66	9	8	11	6.68	9	9	11	7.48
9	4.73	7	7	8	5.22	7	8	10	6
10	4.65	6	7	7	4.81	6	7	8	5.26
12	4.51	6	6	6	4.65	5	6	6	4.93
14	4.58	5	5	6	4.67	5	5	5	4.84
16		5	5	5	4.77	4	5	4	4.82
18		5	5	5		5	5	5	4.82

Island Lake (31-0913) Temperature °C @ Site 101

Depth (m)	*5/17	6/11	6/22	7/7	*7/18	8/10	8/23	9/6	*9/20
0	11.85				24.86				16.01
1	11.8				24.96				16.04
2	11.8				24.93				16.05
3	11.8				24.49				16.06
4	11.77				24.34				16.03
5	11.73				24.31				16.04
6	11.72				24.02				15.97
7	11.61				23.84				15.77
8	11.36				23.62				15.6
9	11.29								
10	11.25								

L. Bowstring Lake (31-0758) Temperature °C @ Site 201

Depth (m)	*5/18	6/10	6/19	7/10	*7/18	8/14	8/25	9/11	*9/20
0	12.76	22.8	23.3	26	26.51	23	23.5	20	16.46
1	12.75	22.8	23.3	25	26.53	24	23.5	20	16.45
2	12.71	22.8	22.8	26	26.37	23	23.5	20	16.44
3	12.64	22.2	21.7	25	25.99	22.5	23.5	20	16.44
4	12.62	22.2	22.8	25	24.59	23	23	20	16.43
5	12.57	19.4	21.4	24.5	20.6	23.5	23	20	16.43
6	12.46	16.7	17.8	22	18.06	23	22	20	16.42
7	12.46	15.6	16.7	18	14.82	20	20	20	16.28
8	11.88	15	15.6	17.5	14.02	18	19	18	16.25
9	11.73	14.4	15	16.5	13.85	18	18	17	16.21
10	11.47	13.3	15	16		17	18	17	16.17

L. Split Hand Lake (31-0341) Temperature °C @ Site 101

Depth (m)	*5/17	6/10	6/27	7/11	*7/17	8/14	8/28	9/11	*9/19
0	13.79	21.7	22.2	24	27.18	23.3	23.3		16.6
1	13.74	21.7	22.2	23	27.19	23.3	22.7		16.64
2	13.73	21.7	21.7	23	26.88	23.3	22.7		16.62
3	13.72	20.6	21.1	23	23.99	23.3	22.2		16.66
4	13.67	17.8	16.7	20	22.04	23.3	22.2		16.66
5	13.68	15.6	16.7	18	18.01	22.2	21.1		16.66
6	13.51	15	15.6	17	15.99	18.9	21.1		16.65
7	12.07	14.4	13.3	16	14.99	18.3	18.9		16.65
8	11.48								

Moose Lake (31-0722) Temperature °C @ Site 102

Depth (m)	*5/18	6/14	6/22	7/9	*7/18	8/13	8/26	9/11	*9/20
0	12.27	23	23	26	25.59	24	21	17	
1	12.28	22	23	26	25.61	24	22	18	
2	12.28	22	22	26	25.61	24	22	18	
3	12.17	22	22	25	25.57	23	22	18	
4	12.15	22	22	25	25.02	24	22	18	
5	11.95	22	22	25	24.25	24	22	18	
6	11.81	18	21	24	23	24	22	19	
7	11.76	18	17.5	22	21.41	24	22	18	
8	11.71	16	17	20	19.37	24	22	19	
9	11.68	15	16	18	17.57	24	22	18	
10	11.67	15	15	16	15.69	24	21	19	
12	11.6	14	15	16	15.31	20	17	16	
14	11.47	14	14	15		18	16	14	
16	11.25	14	14	15		16	14	14	
18		14	14	15		15	15	14	

Prairie Lake (31-0384) Temperature °C @ Site 102

Depth (m)	*5/18	6/11	6/25	7/9	*7/19	8/13	8/27	9/10	*9/19
0	13.66	20	24	24	25.05	23	23	19	16.23
1	13.57	20	24	24	25.06	23	22	19	16.22
2	13.48	20	23	24	25.08	23	22	19	16.21
3	13.46	20	22	24	25.08	23	22	19	16.19
4	13.48	20	22	24	25.06	23	22	19	16.18
5	13.45	20	21	24	22.82	23	22	19	16.17
6	13.39	16	18	22	18.08	23	20	19	16.17
7		15	15	16	15.01	18	20	19	16.21
8		14	14	16		18			

Prairie Lake (31-0384) Temperature °C @ Site 101

Depth (m)	*5/18	6/11	6/25	7/9	*7/19	8/13	8/27	9/10	*9/19
0	13.99	20	23	24	25.58	23	22	19	16.16
1	13.9	19	23	24	25.59	23	22	19	16.18
2	13.77	19	22	24	25.57	23	21	19	16.17
3	13.72	19	22	24	23.97	23	21	19	16.17
4	13.67	19	20	22	20.54	23	21	19	15.93
5	13.59	15	18	19	17.47	22	21	19	15.89
6		14	15	17		22	20	18	
7		13	15	16		20	19	18	

Round Lake (31-0896) Temperature °C @ Site 202

Depth (m)	*5/17	6/13	6/25	7/9	*7/18	8/14	8/29	9/12	*9/20
0		21	23	23	25.91	22	20	19	
1		21	23	23	25.84	22	20	19	
2		21	23	23	25.49	22	20	19	
3		21	22	23	25.37	22	20	19	
4		21	22	23	25.12	21	20	18	
5		21	22	22	24.9	21	20	18	
6		20	21	22	24.78	21	19	18	
7		20	21	22		21	19	17.5	

Sand Lake (31-0826) Temperature °C @ Site 101

Depth (m)	*5/18	6/8	6/23	7/10	*7/18	8/11	8/26	9/8	*9/20
0	12.18	19.5	22	21.5	25.21	23	21.5	18.5	15.81
1	12.17	20	22	21.5	25.27	23	21	19.5	15.84
2	12.17	20	21.5	22	25.14	23	21.5	19.5	15.84
3	12.16	20	20.5	22.5	25.09	23.5	21	195	15.83
4	12.15	20	20.5	22.5	25.06	23	21	19.5	15.84
5	12.1	19	20.5	22.5	24.92	23	21	20	15.8
6	12.05	17	20	22	23.95	23.5	21	19.5	15.71
7		15	19.5	21.5	23.14	23.5	21	19.5	
8		14.5	18.5	21	22.56	23.5	21	19.5	
9			17		20.74	23	21	19.5	
10					19.18				

Sand Lake (31-0826) Temperature °C @ Site 102

Depth (m)	*5/18	6/8	6/23	7/10	*7/18	8/11	8/26	9/8	*9/20
0	12.41	20	22	22.5	25.1	22.5	22	18.5	16.62
1	12.42	21	22	22.5	25.02	22.5	22	18.5	16.69
2	12.42	21	21.5	22.5	24.89	22	22	18.5	16.69
3	12.41	21	21.5	22.5	24.75	22	21.5	19	16.7
4	12.42	21	21	22.5	24.69	22.5	21	19.5	16.7
5	12.37	21	20.5	22.5	24.64	22.5	21	19.5	16.71
6	12.32	21	20.5	22.5	24.48	22.5	20.5	19.5	16.7
7	12.32	18	20	22.5	22.17	22.5	21	19	16.7
8	12.31	15	19	21	20.95	22.5	21	18.5	16.68
9	12.31	14	16	19	18.27	22.5	21	18.5	16.66
10	12.3	13	15	17	16.41	22	21	18.5	16.53
12	12.26	13	13.5	14.5	13.65	19	17.5	18	16.23
14	12.11	13	13.5	13	12.62	15	14.5	14	15.42
16	11.18			12.5	12.33	14	13.5	13	13.89
18	11.13				12.24				

Snaptail Lake (31-0255) Temperature °C @ Site 101

Depth (m)	*5/16	6/8	6/22	7/9	7/17	8/10	8/26	9/7	*9/19
0	13.75	22	23	24	27.64	24	19	23	17.1
1	13.11	15.9	22	24	27.47	23	21	23	17.05
2	12.02	23	22	24	25.92	23	19	20	16.89
3	11.86	18	22	24	23.75	23	19	20	16.8
4	11.64	16	16	19	16.22	23	19	20	16.7
5	11.07	15	14	16	12.35	19	18	19	16.61
6	10.73	12	11	13	10.71	14	14	13	15.71
7	10.23	11	11	11	9.4	14	11	10	10.57
8	7.21	9	9	10	7.96	10	10	9	8.48
9	6.99	7.5	7	8.5	6.49	9	8	7	7.33
10	5.92	6	6.5	8	5.91	8	7.5	7	6.6
12	5.29	5.9	6	7	5.61	7	6	6	5.94
14	4.86	5.8	5	7	5.62	6	6.5	6	5.8
16	4.75	5.8	4.5	6	5.49	5	5	6	5.66
18	4.63	5.5	4.5	6	5.41	5	4.5	5	5.66
20					5.45	5	5		

Split Hand Lake (31-0353) Temperature °C @ Site 202

Depth (m)	*5/17	6/11	6/25	7/8	*7/17	8/13	8/27	9/10	*9/19
0	13.08	20	22	23	26.59	22	22	18	16.37
1	13.07	20	22	23	26.58	22	22	18	16.42
2	13.07	20	22	23	26.58	22	21	18	16.44
3	13.07	20	22	23	26.49	22	21	18	16.47
4	13.07	20	21	23	26.37	22	20	18	16.47
5	13.06	20	20	23	24.63	22	20	18	16.47
6		20	20	23		22	20		

Swan-West Lake (31-0067-01) Temp °C @ Site 101

Depth (m)	*5/16	6/8	6/23	7/7	*7/19	8/14	8/27	9/9	*9/21
0	13.24	23.5	20	24	24.77	21.5	24	19	15.06
1	13.11	23.5	21	24	24.78	21.5	24	19	15.19
2	12.49	23	20.5	23	24.8	21	24	19	15.19
3	11.93	21	20	22.5	24.62	21	24	19	15.18
4	11.14	18	19.5	22	22.22	21	24	18	15.16
5	11.06	16	19	21.5	21.48	21	20	18	15.01

Swan-Main Lake (31-0067-02) Temperature °C @ Site 102

Depth (m)	*5/16	6/8	6/23	7/7	*7/19	8/14	8/27	9/9	*9/21
0	10.66	20	20	22	24.29	22	21.5	18	16.38
1	10.52	20	19.5	22	24.3	22.5	21.5	18	16.42
2	10.5	20	19.5	22	24.32	22.5	20.5	18	16.44
3	10.4	20	19.5	22	24.34	22.5	20.5	18.5	16.45
4	10.29	20	19	22	24.35	22.5	20	18.5	16.44
5	10.11	18.5	19	22	24.35	22.5	20	18.5	16.45
6	9.92	15	19.5	22	24.34	22.5	20	18.5	16.46
7	9.82	14	15	20	19.64	22.5	20	18.5	16.45
8	9.72	12.5	13	16	17.03	22	20	19	16.45
9	9.67	11.5	12	15	13.27	16	18.5	18	16.45
10	9.59	10.5	10.8	15	11.94	14	18	16	16.4
12	9.46	10	10.3	13	10.48	12.5	16	12	13.22
14	9	9.8	9.5	12	10.07	10.5	15	11	10.48
16	8.7	9.5	9.2	12	9.7	9.5	14	10	9.87
18	8.5	9	9.2	12	9.81	9.5	13.5	10	9.95

S. Twin Lake (31-0191) Temperature °C @ Site 101

Depth (m)	*5/16	6/12	6/27	7/6	7/17	8/14	8/26	9/9	*9/19
0	14.49	23		25	27.25		24	20	17.74
1	14.16	23		25	27.26		24	20	17.76
2	12.24	22		25	27.07		24	20	17.54
3	11.98	22		24	25.2		23	18	17.55
4	11.83	19		24	23.02		23	20	17.53
5	11.48	16		22	17.26		23	20	17.5
6	11.2	14		18	13.62		21	20	17.3
7	9.86	14		15	11.06		18	18	17.17
8	7.42			15	8.8		15	18	11.44
9	5.77				7.49		12	12	9.15
10	5.35				6.79		11	11	7.94
12	5.2				6.86		10	10	7.43

N. Twin Lake (31-0190) Temperature °C @ Site 101

Depth (m)	*5/16	6/12	6/27	7/8	*7/17	8/14	8/26	9/9	*9/19
0	13.1	26		26	27.16		24	20	17.33
1	13.07	24		26	27.17		23	20	17.31
2	12.99	23		26	27.12		22	20	17.31
3	12.94	22		26	26.82		22	20	17.28
4	12.77	21		26	24.33		22	20	17.28
5	12.67	18		18	20.43		22	20	17.27
6	11.29	16		18	16.42		22	20	17.27
7	10.81	14		16	12.93		19	18	17.25
8	10.2	14		14	10.73		16	15	15.03
9	9.87			12	9.98		14	14	11.39
10	9.11			12	9.7		12	13	10.07
12	8.64				9.68		12	12	

2006 Dissolved Oxygen Concentrations for Itasca County CLMP+ Lakes

Dixon (31-0921) @ Site 101
Oxygen (mg/L)

Depth (m)	*5/17	*7/18	9/27
0	10.9	10.14	
1	9.92	10.03	
2	9.59	9.86	
3	9.61	7.92	
4	9.54	3.48	
5	9.5	0.85	
6	9.34	0.54	
7	9.1	0.46	
8	8.78	0.43	

N. Dora (31-0882) @ Site 101
Oxygen (mg/L)

Depth (m)	*5/17	*7/18	*9/20
0	10.57	7.01	7.35
1	10.23	7.22	7.19
2	10.3	7.17	7.15
3	10.23	7.14	7.14
4	9.07	3.58	5.67

S. Dora (31-0882) @ Site 201
Oxygen (mg/L)

Depth (m)	*5/17	*7/18	*9/20
0	9.26	6.64	8.82
1	9.22	6	7.08
2	9.31	5.84	6.7
3	9.38	1.77	5.51
4		0.61	4.19

Hale (31-0361) @ Site 201
Oxygen (mg/L)

Depth (m)	*5/17	*7/19	*9/19
0	10.64	8.94	6.56
1	10.26	8.73	6.45
2	10.47	8.65	6.31
3	10.61	7.97	6.2
4	10.37	8.23	6.14
5	10.21	6.35	5.62
6	9.64	2.98	4.34
7	7.77	1.12	3.16
8	5.48	0.73	1.57
9	3.29	0.67	1.07
10	1.97	0.55	0.64
12	1.35	0.43	0.36
14	1.09	0.43	0.28
16		0.38	0.27
18			0.18

Island (31-0913) @ Site 101
Oxygen (mg/L)

Depth (m)	*5/17	*7/18	*9/20
0	13.74	9.4	5.1
1	11.51	8.98	4.86
2	10.49	8.89	4.77
3	10.24	8.06	4.68
4	10.14	7.09	4.6
5	10.12	7.01	4.65
6	9.96	5.47	4.68
7	9.85	4.01	4.7
8	9.57	3.29	4.51
9	9.14		
10	9.03		

L. Bowstring (31-0758) @ Site 201
Oxygen (mg/L)

Depth (m)	*5/18	*7/18	*9/20
0	10.23	9.24	7.07
1	9.65	9.42	6.8
2	9.6	9.53	6.68
3	9.53	9.42	6.61
4	9.33	8.16	6.5
5	9.29	6.19	6.39
6	9.29	1.98	6.4
7	8.99	1.37	6.27
8	8.52	0.98	6.22
9	7.81	0.74	6.13
10	7.21		5.6

L. Split Hand (31-0341) @ Site 101
Oxygen (mg/L)

Depth (m)	*5/17	*7/17	*9/19
0	10.95	9.42	9.27
1	10.49	9.63	7.6
2	10.32	9.67	7.25
3	10.21	7.28	7.11
4	10.1	3.64	7.05
5	10.04	1.16	6.98
6	9.85	0.9	6.97
7	8.52	0.78	6.72
8	7.36		

Moose (31-0722) @ Site 102
Oxygen (mg/L)

Depth (m)	*5/18	*7/18	*9/20
0	11.49	8.93	
1	10.42	8.45	
2	10.08	8.43	
3	9.98	8.44	
4	10.02	8.09	
5	9.9	7.85	
6	10.05	6.46	
7	9.89	5.2	
8	10.03	2.27	
9	9.88	0.61	
10	9.92	0.45	
12	9.83	0.42	
14	9.81		
16	9.25		
18			

Prairie (31-0384) @ Site 102
Oxygen (mg/L)

Depth (m)	*5/18	*7/19	*9/19
0	9.41	7.63	7.24
1	9.32	7.39	6.78
2	9.26	7.35	6.63
3	9.3	7.31	6.48
4	9.21	7.23	6.38
5	9.18	3.22	6.36
6	8.96	0.66	6.34
7		0.49	5.84

Prairie (31-0384) @ Site 101
Oxygen (mg/L)

Depth (m)	*5/18	*7/19	*9/19
0	8.97	7.54	6.65
1	9.18	7.29	6.41
2	9.27	7.24	6.43
3	9.47	4.93	6.36
4	9.47	2.05	6.27
5	9.43	0.71	6.12

Round (31-0896) @ Site 202
Oxygen (mg/L)

Depth (m)	*5/17	*7/18	*9/20
0		11.89	
1		11.51	
2		10.19	
3		9.34	
4		8.88	
5		7.44	
6		5.16	
7			

Sand (31-0826) @ Site 101
Oxygen (mg/L)

Depth (m)	*5/18	*7/18	*9/20
0	10.44	8.79	8.76
1	9.99	8.23	7.76
2	9.83	8.06	7.43
3	9.76	7.88	7.35
4	9.66	7.81	7.23
5	9.64	7.54	7.21
6	9.71	4.45	7.21
7		3.34	
8		1.15	
9		0.65	
10		0.32	

Sand (31-0826) @ Site 102
Oxygen (mg/L)

Depth (m)	*5/18	*7/18	*9/20
0	9.31	8.77	7.04
1	9.33	8.51	6.22
2	9.45	8.39	6.11
3	9.59	8.21	6.04
4	9.55	8.02	6.02
5	9.7	7.81	5.94
6	9.67	7.45	5.95
7	9.58	5.17	5.96
8	9.58	2.67	5.9
9	9.63	0.79	5.84
10	9.65	0.51	5.84
12	9.49	0.35	5.88
14	9.53	0.32	5.52
16	8.41	0.25	2.03
18	6.75	0.2	

Snaptail (31-0255) @ Site 101
Oxygen (mg/L)

Depth (m)	*5/16	*7/17	*9/19
0	9.66	7.86	7.58
1	9.86	7.71	6.82
2	10.1	7.86	6.62
3	10.18	7.79	6.6
4	10.38	4.82	6.41
5	10.37	3.63	6.05
6	10.31	2.82	4.78
7	9.78	1.54	3.28
8	7.5	1.05	1.63
9	6.78	0.71	0.83
10	6.41	0.42	0.51
12	5.77	0.33	0.35
14	4.86	0.38	0.18
16	4.24	0.37	0.16
18	3.81	0.29	0.19
20		0.26	

Split Hand (31-0353) @ Site 202
Oxygen (mg/L)

Depth (m)	*5/17	*7/17	*9/19
0	10.71	9.31	11.7
1	10.31	9.24	9.08
2	10.09	9.2	8.27
3	9.93	9.09	7.85
4	9.99	8.92	7.72
5	10.04	3.22	7.68

Swan-Main (31-0067-02) @ Site 102 Oxygen (mg/L)

Depth (m)	*5/16	*7/19	*9/21
0	10.74	8.81	8.04
1	11.09	8.28	7.19
2	11.29	8.2	6.94
3	11.43	8.12	6.9
4	11.52	8.11	6.81
5	11.49	8.09	6.71
6	11.24	8.02	6.81
7	11	6.52	6.68
8	10.95	3.12	6.66
9	10.85	1.26	6.62
10	10.62	1.04	6.59
12	10.54	0.72	4.99
14	10.35	0.55	1.06
16	9.65	0.39	0.53
18	8.5	0.28	0.36

Swan-West (31-0067-01) @ Site 101 Oxygen (mg/L)

Depth (m)	*5/16	*7/19	*9/21
0	11.54	9.43	11.73
1	11.25	8.64	8.23
2	11.23	8.57	7.65
3	11.32	8.11	7.43
4	11.36	2.29	7.32
5	11.59	0.7	6.79

S. Twin (31-0191) @ Site 101 Oxygen (mg/L)

Depth (m)	*5/16	*5/17	*9/19
0	10.76	8.38	7.75
1	10.58	8.23	6.67
2	10.65	8.26	6.53
3	10.67	8.72	6.38
4	10.43	8.13	6.24
5	10.26	6.82	6.17
6	10.19	3.53	6.03
7	5.69	1.31	5.55
8	3.06	0.77	0.93
9	1.9	0.55	0.5
10	1.42	0.5	0.31
12	1.3	0.42	0.24

N. Twin (31-0190) @ Site 101 Oxygen (mg/L)

Depth (m)	*5/16	*7/17	*9/19
0	10.27	8.23	6.47
1	10.47	8.03	6.27
2	10.64	8.04	6.21
3	10.91	8.01	6.18
4	11.04	8.04	6.18
5	11.13	6.21	6.18
6	11.16	4.41	6.19
7	10.36	1.28	6.15
8	9.62	0.64	4.99
9	8.5	0.5	2.78
10	7.34	0.47	1.69
12	5.27	0.4	

Historic Data for Itasca County CLMP+ Lakes

Dixon Lake (31-0921)

Year	SDF	SES	NS	TP	SEP	NP	CHLa	SEC	NC
1981	3.3		1	65.00		1	36.8		1
1990	4.7	0.3	6						
1991	4.4	0.3	14						
1992	5.0	0.8	3						
1993	5.8	0.6	6	35.00	8.13	6	8.6	3.1	6
1994	4.6	0.6	7						
1995									
1996	5.6	0.5	6						
1997	4.5	0.2	8						
1998	5.7	0.4	9						
1999	4.4	0.4	4						
2000	6.0	0.3	4						
2001	6.1	0.5	6						
2002	5.5	0.6	8						
2003	5.9	0.8	4						
2004	8.1	1.2	4						
2005	4.8	0.9	4						
2006	4.7	0.7	7	49.60	5.70	7	20.0	4.3	7

Dora Lake (31-0882)

Year	SDF	SES	NS	TP	SEP	NP	CHLa	SEC	NC
1981	5.6		1	44.00		1	11.2		1
1999	9.5	0.4	5						
2000	8.6	0.3	15						
2001	11.1	0.2	16						
2002	9.5	0.4	12						
2003	7.2	0.4	7						
2004	10.6	0.3	11						
2005	9.7	0.3	15						
2006	8.1	0.4	16	41.20	2.10	15	7.3	0.7	16

Year = Year Monitored
SDF = Secchi Transparency(ft)
SES = Standard Error for SDF
NS = # Secchi Readings/yr
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

Hale Lake (31-0361)

Year	SDF	SES	NS	TP	SEP	NP	CHLa	SEC	NC
1990	12.5	0.2	4						
1991	11.4	0.3	11						
1992	11.7	1.2	8						
1993	9.1	0.6	8						
1994	11.8	0.6	11						
1995	10.3	0.7	9						
1996	10.4	0.4	14						
1997	12.0	0.4	13						
1998	9.3	0.2	12						
1999	8.3	0.5	11						
2000	9.6	0.4	14						
2001	9.5	0.5	16						
2002	11.5	0.7	13						
2003	12.0	0.8	10						
2004	15.0	1.0	9						
2005	10.7	0.5	15						
2006	11.3	0.7	8	18.1	0.8	8	3.3	0.3	8

Island Lake (31-0913)

Year	SDF	SES	NS	TP	SET	NP	CHLa	SEC	NC
1989	7.3	0.2	80						
1990									
1991	6.8	0.6	6						
1992	9.5		1	42.00		1	4.7		1
2000	10.7	0.9	7						
2001	8.5	1.4	10						
2002	11.5	0.5	2						
2003	7.4	0.6	18						
2004	8.8	0.7	13						
2005	8.2	0.5	13						
2006	6.4	1.1	8	46.30	6.90	8	22.5	7.5	8

L. Bowstring Lake (31-0758)

Year	SDF	SES	NS	TP	SEP	NP	CHLa	SEC	NC
1998	5.7	0.5	12						
1999	8.7	0.2	15						
2001	5.5	0.0	2						
2002	7.6	0.5	11						
2003	8.4	0.5	9						
2004	11.5	0.7	10						
2005	8.4	1.3	12						
2006	6.6	1.0	8	29.60	3.60	8	9.3	3.0	8

L. Split Hand Lake (31-0341)

Year	SDF	SES	NS	TP	SEP	NP	CHLa	SEC	NC
1981	3.3		1	58.00		1	40.6		1
1992	5.4	0.2	3	33.00	7.37	3	14.2	4.6	3
1993				36.33	7.84	3	7.0	3.1	3
1995	8.2	1.0	5	40.86	3.31	5	17.8	5.3	2
1996	5.0	0.2	5						
1997	6.5	0.7	4						
1998	4.9	0.4	7						
2006	6.6	1.2	7	41.70	5.30	7	17.4	4.3	7

Year = Year Monitored
SDF = Secchi Transparency(ft)
SES = Standard Error for SDF
NS = # Secchi Readings/yr
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

Moose Lake (31-0722)

Year	SDF	SES	NS	TP	SEP	NP	CHLa	SEC	NC
1981	11.2		1	28.00		1	8.8		1
1992	17.9	0.5	7	10.70	3.81	4	3.8	1.9	4
1995	16.8	0.3	9						
1999	9.5		1						
2000	12.6	1.1	6						
2001	15.7	2.3	4						
2002									
2003	13.4	1.0	7						
2004	13.0	1.0	7						
2005	14.5	1.0	11						
2006	12.2	1.0	7	16.40	1.80	7	3.5	0.7	7

Prairie Lake (31-0384)

Year	SDF	SES	NS	TP	SEP	NP	CHLa	SEC	NC
1981	3.9	0.3	2	40.50	6.50	2	13.6	2.7	2
1988	3.9		1	43.50	3.50	2			
1991	4.2	0.2	15						
1992	6.5	0.3	36	27.33	1.31	15	3.5	0.5	15
1993	4.2	0.2	8						
1994	4.9	0.3	10						
1995	6.0	0.3	7						
1996	5.1	0.1	9						
1997	5.5	0.3	12						
1998	5.3	0.2	9						
1999	4.3	0.3	12						
2000	6.3	0.2	9						
2001	5.4	0.2	10						
2002	6.0	1.0	5						
2003	7.8	0.4	6						
2004	5.9	0.1	8						
2005	5.2	0.2	6						
2006	5.4	0.2	16	32.20	1.70	16	11.3	1.3	16

Year = Year Monitored
SDF = Secchi Transparency(ft)
SES = Standard Error for SDF
NS = # Secchi Readings/yr
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

Round Lake (31-0896)

Year	SDF	SES	NS	TP	SEP	NP	CHLa	SEC	NC
1981	2.3		1	82.00		1	66.0		1
1992	8.3	0.2	4	30.00	10.26	4	8.0	1.0	3
2001	5.7	0.6	9						
2002	5.5	1.1	11						
2003	5.2	0.9	11						
2004	7.3	0.7	11						
2005	6.4	0.6	14						
2006	4.3	0.7	8	88.80	15.90	8	32.3	7.3	8

Sand Lake (31-0826)

Year	SDF	SES	NS	TP	SEP	NP	CHLa	SEC	NC
1981	6.1	1.1	2	32.00	10.00	2	15.2	5.6	2
1991	7.6	0.6	13						
1992	9.8	0.4	27	15.50	3.01	10	4.7	1.2	8
1993	10.5	0.3	16						
1994	9.0	0.6	19						
1995	9.2	0.8	18						
1996	9.8	0.9	16						
1997	8.7	0.5	10						
1998	6.9	0.6	16						
1999	8.0	0.5	21						
2000	7.5	0.4	16						
2001	9.1	0.9	10						
2002	9.8	1.1	10	27.50	4.50	2	7.0	1.7	2
2003	9.5	0.9	9						
2004	11.8	1.0	7						
2005	9.8	0.6	10						
2006	7.3	0.7	16	27.40	1.70	16	10.6	1.6	16

Year = Year Monitored
SDF = Secchi Transparency(ft)
SES = Standard Error for SDF
NS = # Secchi Readings/yr
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

Snaptail Lake (31-0255)

Year	SDF	SES	NS	TP	SEP	NP	CHLa	SEC	NC
1991	13.2	0.4	16						
1992	15.1	0.7	14						
1993	11.6	0.8	8						
1994	9.9	1.1	6						
1995	10.8	0.8	8						
1996	13.1	0.5	6	16.47	2.14	4	2.2	0.0	2
1997	11.9	0.3	8						
1998	13.3	0.3	9						
1999	10.0	0.9	7						
2000	12.2	0.9	5						
2001	8.8	0.6	8						
2002	8.7	1.1	7						
2003	13.7	0.7	7						
2004	12.0	0.8	7						
2005	12.1	0.4	7						
2006	13.2	0.8	8	12.30	0.80	8	3.0	0.4	8

Split Hand Lake (31-0353)

Year	SDF	SES	NS	TP	SEP	NP	CHLa	SEC	NC
1975	3.3	0.3	7						
1981	3.3		1	38.00		1	39.0		1
1991	4.9	0.3	17						
1992	4.9	0.4	20	49.40	6.29	5	14.7	3.8	4
1993	7.6	0.6	17	26.67	9.94	3	5.1	0.5	3
1994	4.2	0.1	16						
1995	4.6	0.4	15	60.06	11.68	5	25.6	11.2	3
1996	3.6	0.3	18						
1997	3.5	0.3	18						
1998	4.1	0.2	17						
1999	5.7	0.5	17						
2000	3.9	0.3	17						
2001	4.7	0.4	18						
2002	5.4	0.5	18						
2003	5.7	0.4	17						
2004	10.1	0.3	18						
2005	5.0	0.4	14						
2006	5.1	0.8	8	44.40	7.90	8	17.8	4.0	8

Year = Year Monitored
TP = Total Phosphorus (ppb or µg/L)
SEC = Standard Error for CHLa
SDF = Secchi Transparency(ft)
SEP = Standard Error for TP
NC = # CHLa samples/yr
SES = Standard Error for SDF
NP = # TP samples/yr
NS = # Secchi Readings/yr
CHLa = Chlorophyll-*a* (ppb or µg/L)

Swan-West Lake (31-0067-01)

Year	SDF	SES	NS	TP	SEP	NP	CHLa	SEC	NC
1986	6.8	1.3	3						
1996	8.1	0.4	7	18.42	1.41	12	5.0	1.2	10
1997	10.4	0.6	10						
1998	10.8	0.9	10						
1999	10.3	0.9	12						
2000	11.4	0.7	12						
2001	10.1	0.7	13						
2002	9.9	0.3	14						
2003	10.4	0.9	12						
2004	13.0	0.6	10						
2005	10.1	1.3	9						
2006	7.8	1.2	8	39.00	5.30	8	15.9	3.9	8

Swan-Main Lake (31-0067-02)

Year	SDF	SES	NS	TP	SEP	NP	CHLa	SEC	NC
1976	8.2	0.1	6	18.25	1.81	12	8.4	0.6	6
1977	11.0	0.7	6	26.67	3.90	6	8.1	1.6	6
1978	9.6	0.3	6	14.50	2.53	6	11.8	1.5	6
1986	7.5	0.1	36	21.57	1.38	7	13.0	0.3	3
1988	10.1	1.0	18						
1989	9.5	0.0	3						
1990	9.4	0.4	18						
1991	9.3	0.4	3						
1992	10.7	0.6	12						
1996	9.1	0.2	38	22.23	2.45	7	7.4	1.3	5
1997	13.3	0.3	40						
1998	14.7	0.5	40						
1999	12.6	0.5	48						
2000	15.0	0.7	48						
2001	13.2	0.3	52						
2002	13.5	0.5	56						
2003	15.5	0.3	48						
2004	16.7	0.7	42						
2005	13.9	0.6	41						
2006	14.1	1.2	8	21.30	2.20	8	6.5	1.5	8

Year = Year Monitored
SDF = Secchi Transparency(ft)
SES = Standard Error for SDF
NS = # Secchi Readings/yr
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

North Twin Lake (31-0190)

Year	SDF	SES	NS	TP	SEP	NP	CHLa	SEC	NC
1981	9.2		1	27.00		1	8.5		1
1991	11.4	0.7	6						
2006	9.3	1.2	6	16.60	1.30	7	3.8	0.8	7

South Twin Lake (31-0191)

Year	SDF	SES	NS	TP	SEP	NP	CHLa	SEC	NC
1991	12.7	0.6	6						
1992	13.7	0.9	3						
1993	12.5	0.9	2						
1994	13.1	0.8	5						
1995	14.0	0.8	5						
1996	13.8	0.3	11						
1997	14.0	0.3	21						
1998	11.9	0.6	26						
1999	10.8	0.4	18						
2000	12.7	0.5	16						
2001	12.5	0.4	23						
2002	9.7	0.2	24						
2003	13.2	0.4	20						
2004	12.0	0.2	20						
2005	12.2	0.7	10						
2006	11.6	1.6	6	13.6	1.3	7	4.2	1.5	7

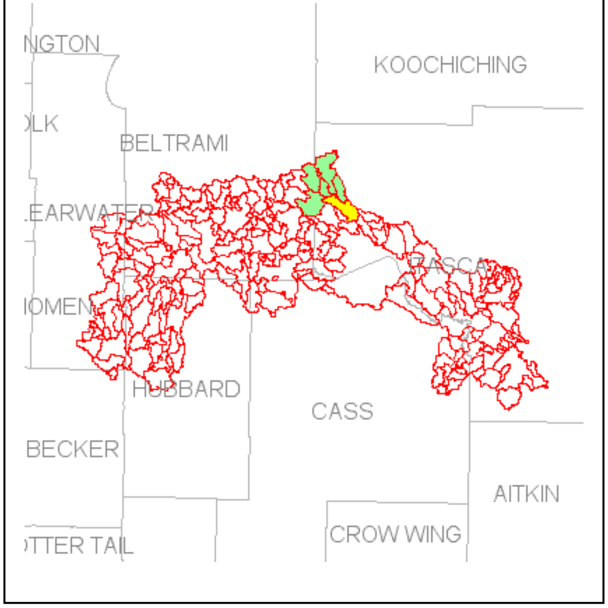
Year = Year Monitored
D-TP = Diatom-inferred TP (ppb or µg/L)
CHLa = Chlorophyll-*a* (ppb or µg/L)
SDF = Secchi Transparency(ft)
TP = Total Phosphorus (ppb or µg/L)
SEC = Standard Error for CHLa
SES = Standard Error for SDF
SEP = Standard Error for TP
NC = # CHLa samples/yr
NS = # Secchi Readings/yr
NP = # TP samples/yr

Appendix 2. Extended Watershed Maps for Selected Itasca County CLMP+ Lakes

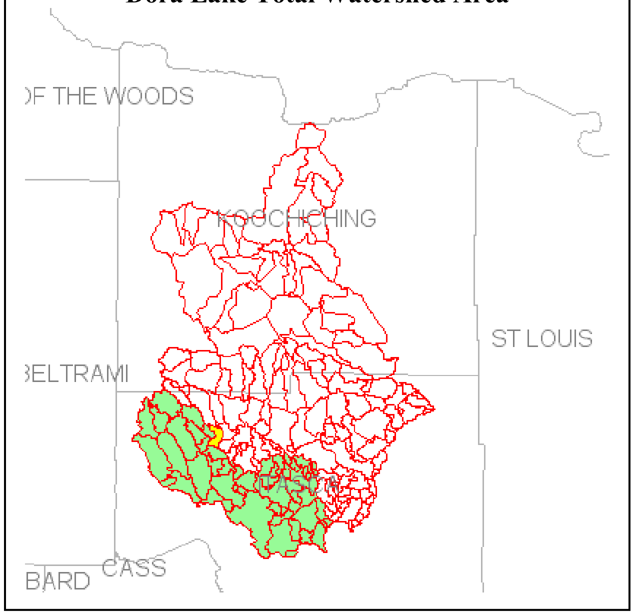
Following are the extended (i.e. total) watershed areas for selected Itasca County Lakes. The red line indicates the minor watershed boundary and sub-watershed areas. The watershed denoted in yellow is the immediate drainage area for the specified lake. The area denoted in green is the upstream contributing drainage area. Combined, the yellow and green areas are the total watershed area that drains through the selected lake. (From USGS Web site: http://gisdmnspl.cr.usgs.gov/watershed/)

Minor Watershed Boundary **Immediate Watershed** **Upstream Watershed**

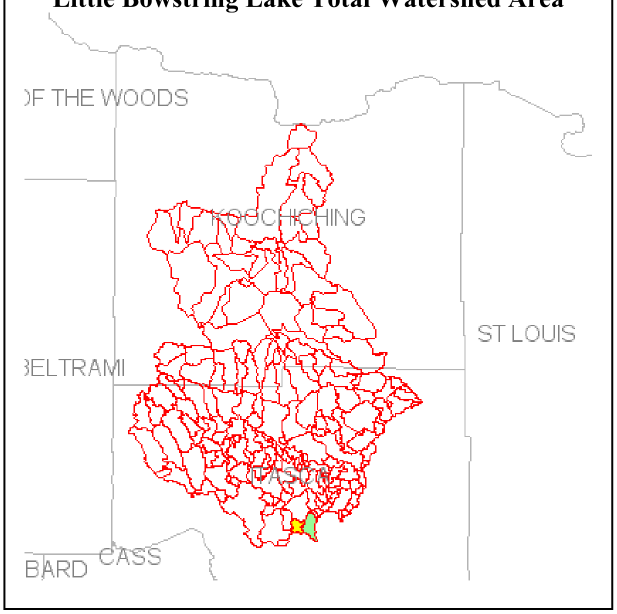
Dixon Lake Total Watershed Area



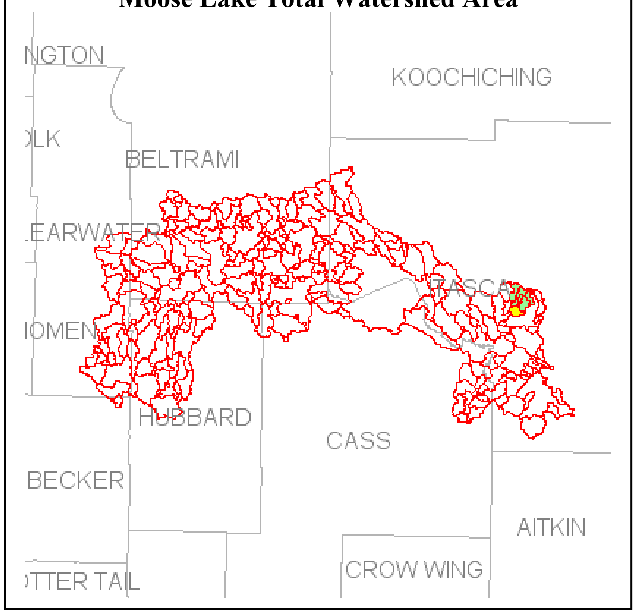
Dora Lake Total Watershed Area



Little Bowstring Lake Total Watershed Area



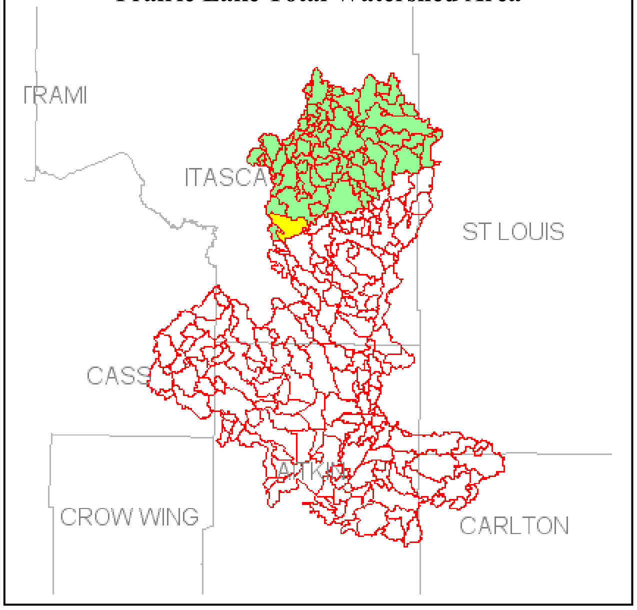
Moose Lake Total Watershed Area



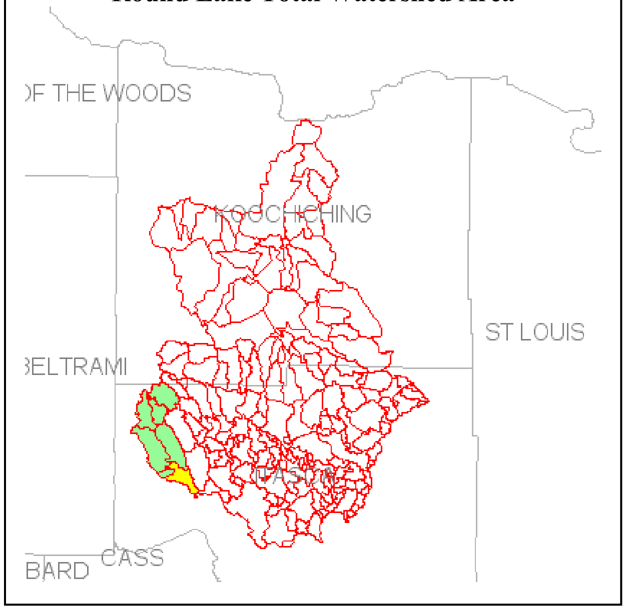
Appendix 2. Extended Watershed Maps for Selected Itasca County CLMP+ Lakes Continued.

Minor Watershed Boundary Immediate Watershed Upstream Watershed

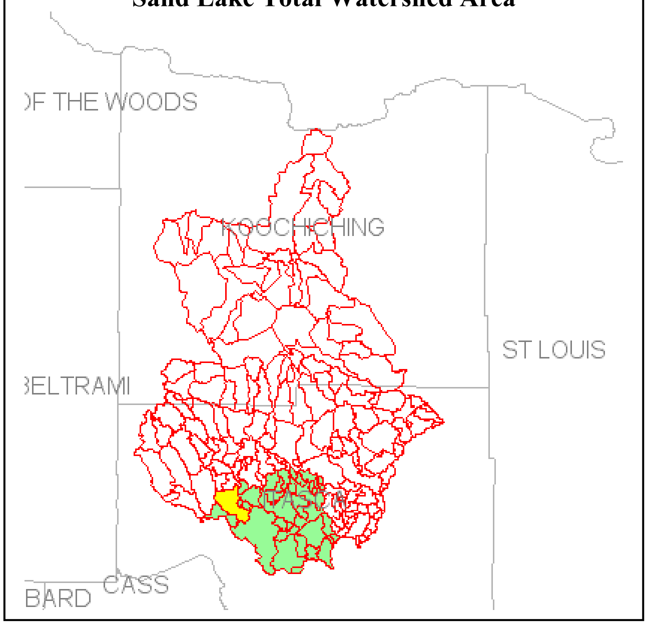
Prairie Lake Total Watershed Area



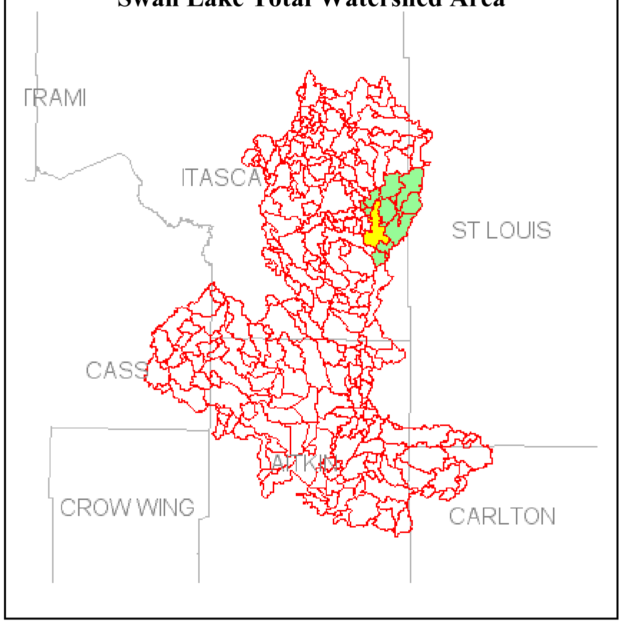
Round Lake Total Watershed Area



Sand Lake Total Watershed Area



Swan Lake Total Watershed Area



REFERENCES

Arneman, H.F. 1963. Soils of Minnesota. University of Minnesota, Agricultural Extension Service and U.S. Department of Agriculture.

Block, M.B. and S. Bergo. 1988. A Detailed Watershed Analysis of Diamond Lake Located in Itasca County, West Central Minnesota. Itasca County Soil & Water Conservation District.

Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography 22: 361-369.

Goebel, J.E. and M. Watson. 1979. Geologic Map of Minnesota. Minnesota Geological Survey. University of Minnesota.

Gunard, L. 1985. U.S. Geological Survey. Water Supply Paper 2300. U.S.G.S. 702 Post Office Building, St. Paul, Minnesota.

Heiskary, S.A. and C.B. Wilson. 1998. Phosphorus export coefficients and the Reckhow-Simpson spreadsheet: Use and application in routine assessments of Minnesota's lakes. A working paper. MPCA, St. Paul, Minnesota.

Heiskary, S.A. and C.B. Wilson. 1990. Minnesota Lake Water Quality Assessment Report. MPCA, Water Quality Division St. Paul, MN 63 pages.

Heiskary, S.A. and C.B. Wilson. 2005. Minnesota Lake Water Quality Assessment Report: Developing Nutrient Criteria. Third Ed. MPCA, Water Quality Division St. Paul, MN.

Heiskary, S.A. and J.L. Lindbloom, 1993. Lake Water Quality Trends in Minnesota. Minnesota Pollution Control Agency, St. Paul, Minnesota.

Heiskary, S.A. and W.W. Walker. 1988. Developing phosphorus criteria for Minnesota lakes. Lake Reservoir Management. 4(1):1-10.

Minnesota Department of Natural Resources. 1968. An Inventory of Minnesota Lakes: Bulletin 25. MDNR, St. Paul, Minnesota.

Minnesota Pollution Control Agency, 1985. A Citizen's Guide to Lake Protection. Minnesota and Freshwater Society, Navarre, Minnesota.

Minnesota Pollution Control Agency. 1986. Protecting Minnesota's Waters: The Land Use Connection. MPCA, St. Paul, Minnesota.

Montgomery, J.M. and Blue Water Science. 1994. Diagnostic/Feasibility Study for Big Kandiyohi Lake, Itasca County, Minnesota. St. Paul, Minnesota.

Prairie, Y.T. and J. Kalff. 1986. Effect of catchment size on phosphorus export. Water Resource Bulletin 22(3):465-470.

Reckhow, K.H., and J.T. Simpson. 1980. A procedure using modeling and error analysis for the prediction of the lake phosphorus concentration from land use information. Can. J. Fish Aquat. Sci. 37:1439-1448.

Reckhow, K.H., and S.C. Chapra. 1983. Engineering approaches for lake management. Volume 1: Data analysis and empirical modeling. Butterworth Publishers. U.S. EPA.

US E.P.A., 1974. National Eutrophication Survey Report on Wagonga Lake, Itasca County, Minnesota. EPA Region V, Working Paper No. 133. Corvallis, Oregon.

U.S. Geological Survey. 1973. Water Resources Data For Minnesota, Part 1. U.S. Geological Survey. 363 pages.

Vighi and Chiaudani. 1985. A simple method to estimate lake phosphorus concentrations resulting from natural background loading. Wat. Res. 19: 987-991.

Walker, W.W., Jr. 1985. Urban nonpoint source impacts on surface water supply. Pages 129-137. Perspectives on Nonpoint Source Pollution. Proceedings of a national conference. Kansas City, Missouri, May 19-22, 1985. U.S. EPA 440/5-85-01.

Wilson, C.B. 1989. Lake water quality modeling used in Minnesota. Pages 33-44 in National Conference on Enhancing State Lake Management Program. May 12-13. 1988. Chicago, Illinois.

Wilson, C.B. and W.W. Walker 1989. Development of lake assessment methods based upon the aquatic ecoregion concept. Lake and Reserv. Manage. 5(2):11-22.

Zumberge, J.H. 1952. The Lakes of Minnesota. Their origin and classification. Minnesota Geological Survey. University of Minnesota Press. Minneapolis, Minnesota.

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.

Total Maximum Daily Load (TMDL): This process determines why waters are impaired, the amount by which pollution must be reduced to meet water-quality standards and determines allocations (limits) for all contributing sources plus future growth.

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.