Lake Assessment Report – Select Lakes in Superior National Forest, 2006

Greenwood Lake (Cook)	16-0077
Devil Track Lake (Cook)	16-0143
Wilson Lake (Lake)	38-0047
Moose Lake (St. Louis)	38-0644
Trout Lake (St. Louis)	69-0498

Minnesota Pollution Control Agency

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wq-lar3-13

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Executive Summary

In 2006 the Minnesota Pollution Control Agency (MPCA) and Superior National Forest (SNF) cooperated to conduct water quality assessments on five priority SNF lakes: Greenwood, Devil Track, Wilson, Moose, and Trout. Lakes were sampled monthly May through September, with an emphasis on the eutrophication indicators total phosphorus (TP), chlorophyll-a and Secchi transparency. In addition to the standard water quality parameters, water mercury and cations / anions were sampled on Wilson and Devil Track Lakes.

Data were compared with representative and minimally-impacted (reference) lakes within the Northern Lakes and Forest (NLF) ecoregion of northeast Minnesota. Summer-mean water quality values for all five were well within or below the typical range for minimally-impacted lakes in the NLF. A further comparison of the SNF lakes' TP, chlorophyll-a and Secchi data with the draft eutrophication criteria values for NLF ecoregion lakes indicated that each of the lakes met these draft water quality standards. As such, the data indicate excellent water quality in all five lakes. This is likely the result of limited (or no) lakeshore development and the majority of the watersheds composed of forest land under public ownership. Two of the lakes (Moose and Trout) are entirely or partially within the Boundary Waters Canoe Area Wilderness.

Three of the SNF lakes: Greenwood, Wilson, and Devil Track, have sufficient historical data to begin to assess water quality variability and trends. Based on these data, water quality has not changed significantly over the period of record (1980's to the present). Also a comparison with sediment diatom-reconstructed TP values based on 20 NLF lakes suggests that all five lakes are well within the typical range of pre-European TP values for NLF lakes. It will be valuable to continue to monitor the water quality of these lakes in the future so that temporal trends; as well as the impacts of climate, such as the severe drought of 2006, might be more fully evaluated. Continued monitoring will also be valuable to the long-term management and protection of these lakes by the Superior National Forest and the State of Minnesota.

Introduction

In 2005 staff from the Minnesota Pollution Control Agency (MPCA) and Superior National Forest (SNF) met to discuss cooperative lake water quality monitoring efforts. There are 1,977 inland lakes within Superior National Forest and 445,000 acres of surface water in total (Superior National Forest, 2004). Lake monitoring is a priority for both agencies. Monitoring activities were prioritized after gathering input from local SNF district offices, selection criteria included:

- Large lakes with limited historical data
- Lakes with a high degree of recreational use / lakeshore development
- Lakes with the potential for future shoreland development

The goal of this effort was to compile baseline water quality conditions.

Five lakes were selected for study:

- Greenwood (DNR ID # 16-0077), a 2,021 acre lake, is located approximately 20 miles northeast of Grand Marais. The lake's maximum depth is 101 feet (30 meters) and mean depth is estimated to be 45 feet. Greenwood is classified as an Outstanding Resource Value Water (ORVW) by the State of Minnesota. Portions of the north and southwest shore are developed. It forms the headwaters of the Greenwood River, a tributary to the Brule River and is one of the MPCA's ecoregion reference lakes (Heiskary and Wilson 2005).
- Devil Track (DNR ID # 16-0143), a 1,838 acre lake, is located approximately 5 miles north of Grand Marais. The lake's maximum depth is 50 feet (15.2 meters) and means depth is estimated to be 30 feet. The majority of the north and southwest shore are developed. A Superior National Forest campground is located in the northwest corner. It forms the headwaters of the Devil Track River.
- Wilson (DNR ID # 38-0047), a 622 acre lake, is located approximately 15 miles east of Isabella. The lake's maximum depth is 53 feet (16.1 meters) and means depth is estimated to be 25 feet. There is

limited lakeshore development along the lakes the north shore. It forms the headwaters Wilson Creek, a tributary to the Cross River and is one of the MPCA's ecoregion reference lakes.

- Moose (DNR ID # 38-0644), a 1,211 acre lake, located approximately 15 miles east of Ely. The lake's maximum depth is 65 feet (19.8 meters) and means depth is estimated to be 45 feet. Portions of the south shore are developed. The lake is a major entry point into the Boundary Waters Canoe Area (BWCA) Wilderness, and approximately the northern half of the lake is within the BWCA. Moose is an ORVW.
- Trout (DNR ID # 69-0498), a 7,641 acre lake adjacent to Lake Vermilion, located approximately 15 miles north of Tower. The lake's maximum depth is 98 feet (29.8 meters) and means depth is estimated to be 60 feet. A mechanized portage allows small boat access from Lake Vermilion. The entire lake is within the BWCA, and it is classified as an ORVW.

Field work for this study was conducted by MPCA staff. Area resource managers with SNF and MN DNR were consulted regarding logistics and co-locating lake monitoring sites at their established monitoring stations.

A summary of lake and watershed morphometry is shown in Table 1. All lakes are located in the Northern Lakes and Forests (NLF) ecoregion (Figure 1). Sampling locations in each lake are shown in Figures 4-8. Land use / land cover within these watersheds is almost entirely forest and wetland, with limited urban development around portions of the lakeshore. Devil Track has the greatest proportion of lake shore development, approximately 2/3 of the shoreline. Moose, Wilson, and Greenwood have a smaller portion of the shore developed, on the order of 10 percent or less. Trout Lake is entirely within the BWCAW. Land use maps in the vicinity of Trout and Devil Track lakes are shown in Figure 9.

Table 1. Lake Morphometry Summary

	Greenwood	Devil Track	Wilson	Moose	Trout
Lake Area (acres)	2,021	1,838	622	1,211	7,641
Watershed Area (ac.) [1]	4,806	21,747	1,938 [2]	10,662 [2]	24,870
Maximum Depth (ft.)	112	50	53	65	98
Mean Depth (ft.) [2]	45	30	25	45	60
Percent Littoral Area [3]	26.5	33.5	36.8	21.6	21.7
Watershed / Lake Area Ratio	2.3 : 1	11.8 : 1	3.1 : 1	8.8 : 1	3.2 : 1

1. Excludes lake area
2. Approximate
3. Lake area less than 15 feet deep; from http://www.dnr.state.mn.us/lakefind/index.html

Since land use affects water quality, it has proven helpful to divide the state into regions where land use and water resources are similar. Minnesota is divided into seven regions, referred to as ecoregions, as defined by soils, land surface form, natural vegetation and current land use. Data gathered from representative, minimally-impacted (reference) lakes within each ecoregion serve as a basis for comparing the water quality and characteristics of other lakes. Water quality data supporting ecoregion designation was derived from extensive sampling (1985-1988). Lake sampled during the establishment of the ecoregions are referred to as ecoregion reference lakes. These lakes are not necessarily the most pristine lakes in each ecoregion; rather these lakes are "representative" of the ecoregion and are minimally impacted by man. As is evident, the relative impact by human activities does vary among ecoregions. The typical range of summer mean water quality from the reference lakes provides a basis for evaluating the quality of other lakes in the ecoregion. The five lakes selected for this study are typical of lakes within the NLF ecoregion and northeast Minnesota.

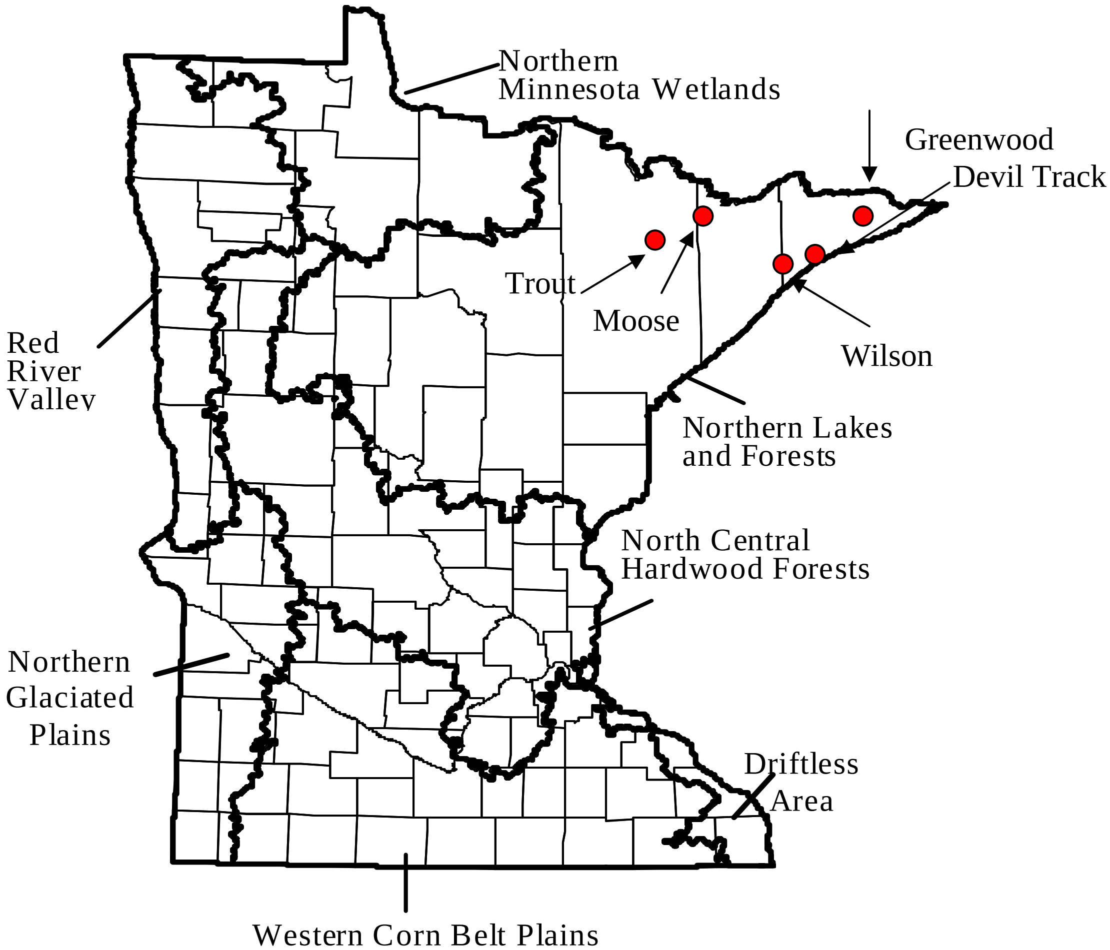


Figure 1. Ecoregions of Minnesota. Red dots indicate approximate locations of the lakes.

Climate

2006 was a severe drought year in northeast Minnesota (Figure 2). Precipitation totals for the summer and fall of 2006 were 6-12 inches below normal (Minnesota Climatology Office, 2006). Additional years of monitoring are necessary to determine the impact of 2006's low lake levels (see Figure 3, Wilson Lake) and reduced lake in-flows on water quality.

Figure 2. 2006 Calendar Year precipitation departure. Courtesy State Climatology Office.

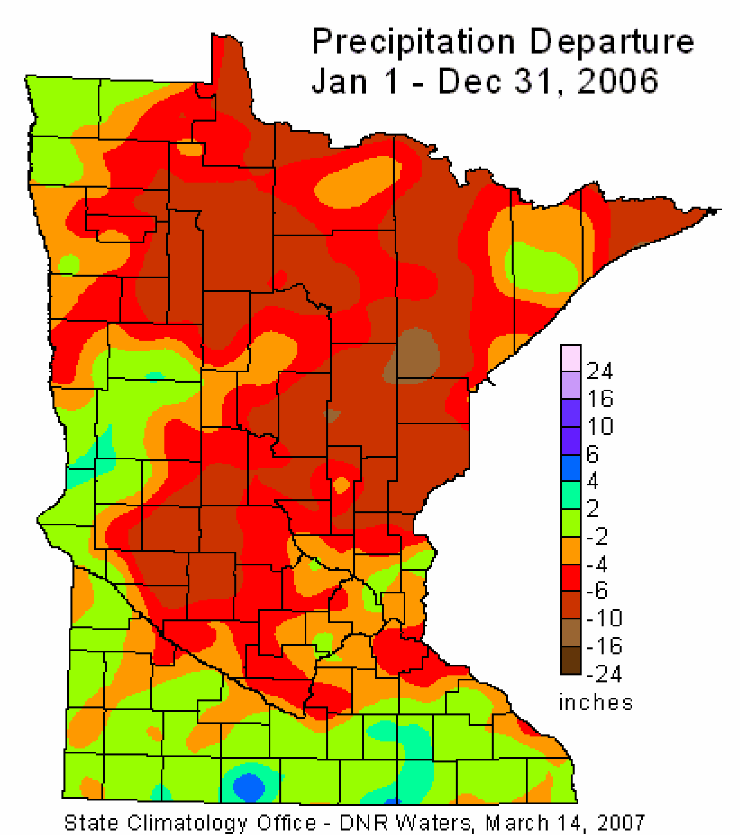
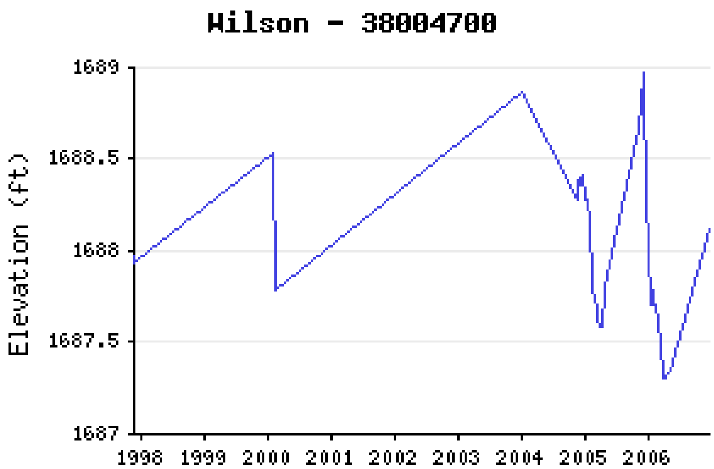


Figure 3. Historical Wilson Lake Levels, Courtesy of DNR Waters



Methods

Water quality data was collected in May, June, July, August, and September, 2006. In all lakes except Wilson, two sites were sampled to gather data within distinct lake-basins. In each lake one of these sites corresponds to the lake's point of maximum depth (Figures 4-8, lake sampling sites indicted by the 'X'). Lake surface samples were collected with an integrated sampler, which is a PVC tube 6.6 feet (2 meters) in length with an inside diameter of 1.24 inches (3.2 centimeters). Phytoplankton (algae) samples were taken at site 101 with an integrated sampler. Secchi disk monitoring through the Citizen's Lake Monitoring Program (CLMP) was conducted at the same locations. Sampling procedures were employed as described in the MPCA Quality Control Manual. Laboratory analyses were performed by the laboratory of the Minnesota Department of Health using U.S. Environmental Protection Agency (EPA)-approved methods. Samples were analyzed for nutrients, color, solids, pH, alkalinity, turbidity, conductivity, chloride and chlorophyll (Table 2). Temperature and dissolved oxygen profiles and Secchi disk transparency measurements were also taken. A phosphorus sample was collected at 1 meter above the lake bottom, to sample the hypolimnion. Phytoplankton analysis was conducted by Dr. Howard Markus using MPCA's Rapid Assessment Method.

Mercury samples were collected according to approved "clean hands / dirty hands" techniques. Detail on this method is found in Appendix 1.

Figure 4. Greenwood Lake. Site 102 is located at the lake's point of maximum depth on west side of lake; site 104 is located in east bay, at bay's maximum depth.

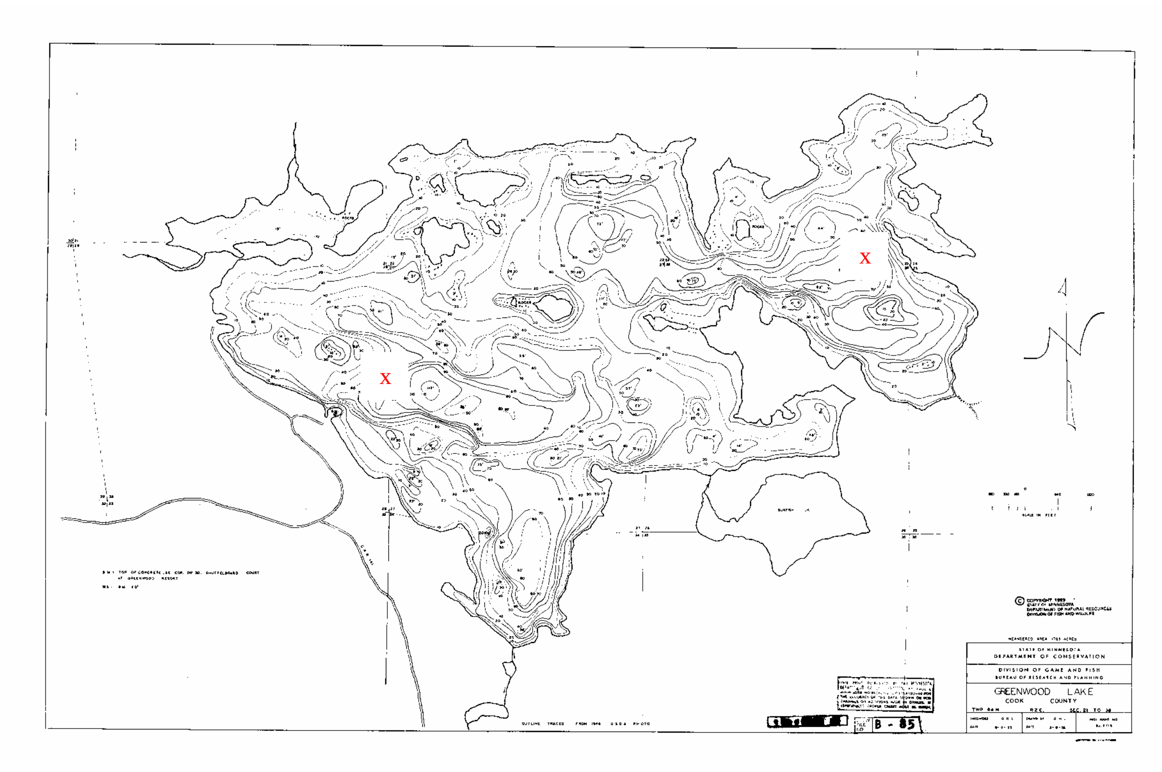


Figure 5. Devil Track Lake. Site 201 is located at the lake's point of maximum depth in the east basin; site 204 is located in the west basin

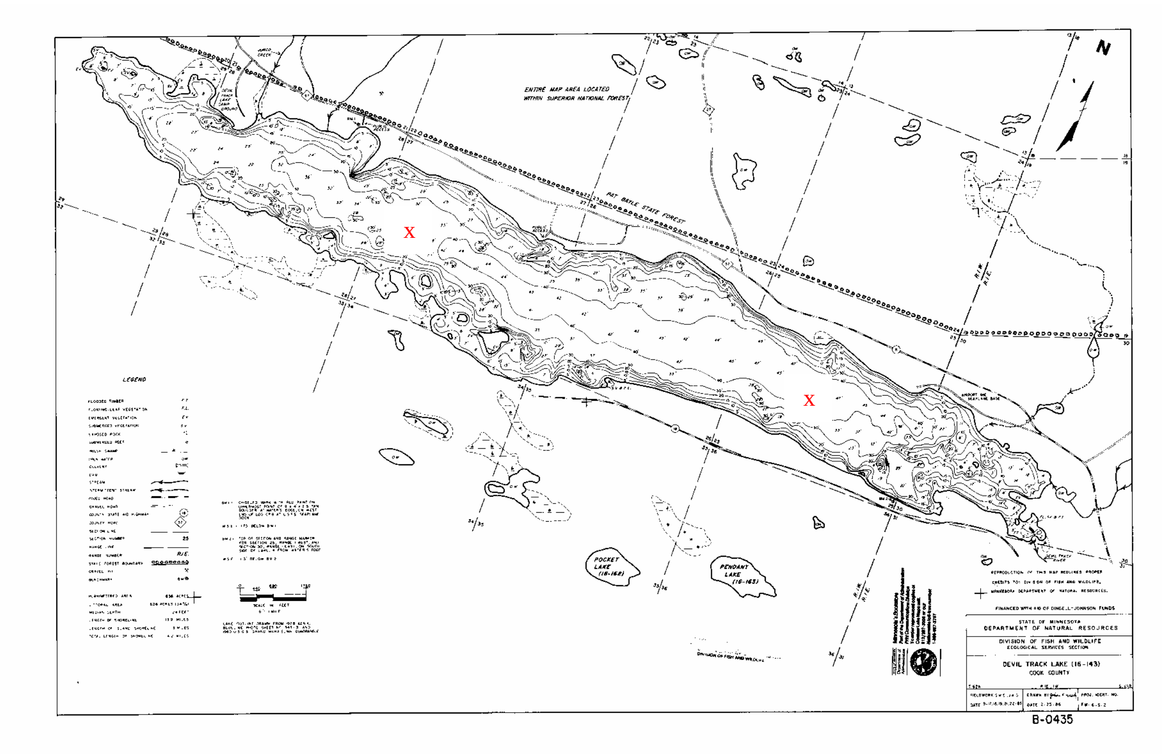


Figure 6. Wilson Lake. Site 103 is located at the lake's point of maximum depth.

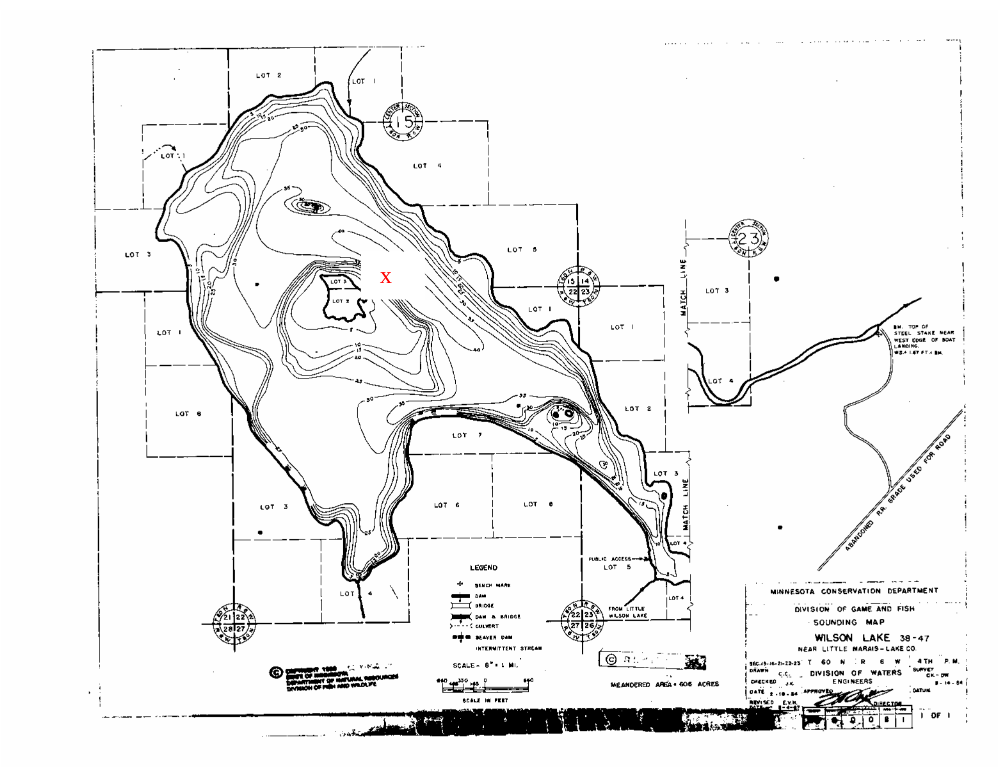


Figure 7. Moose Lake. Site 101 is located at the lake's point of maximum depth in the NE corner; site 102 is located in the W. basin.

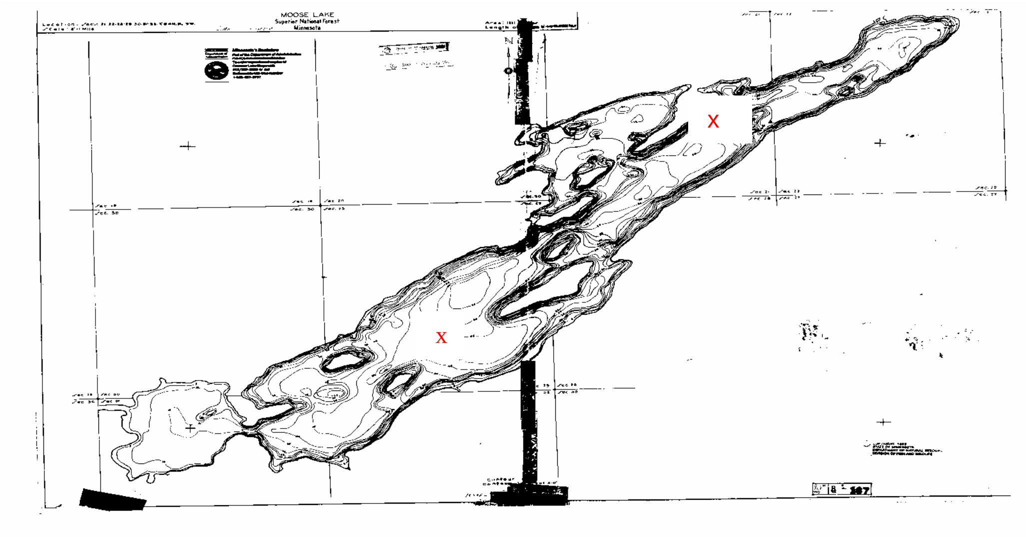


Figure 8. Trout Lake. Site 101 is located in the center of the lake at the point of max. depth; site 102 is located in the bay adjacent to the Trout Lake portage.

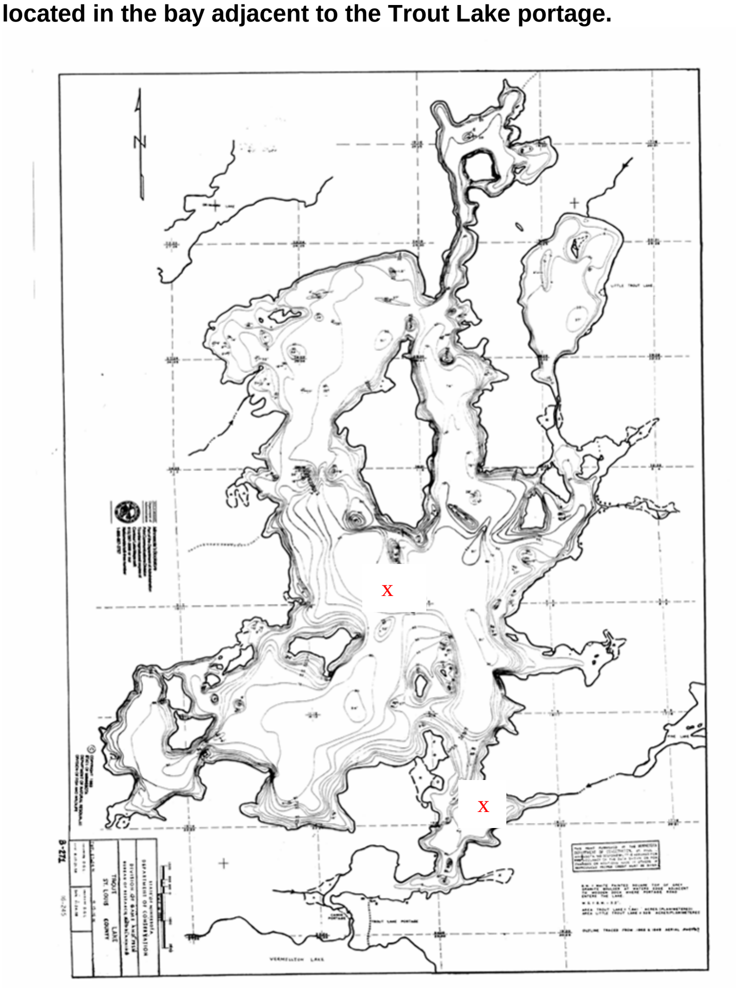
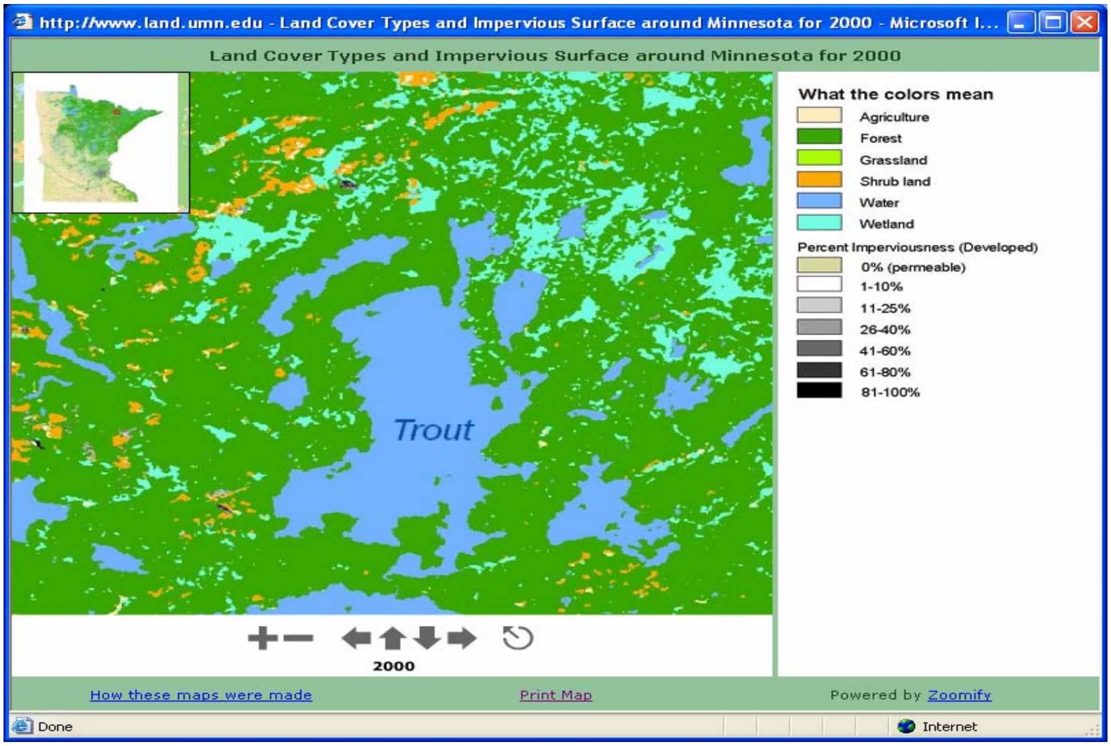
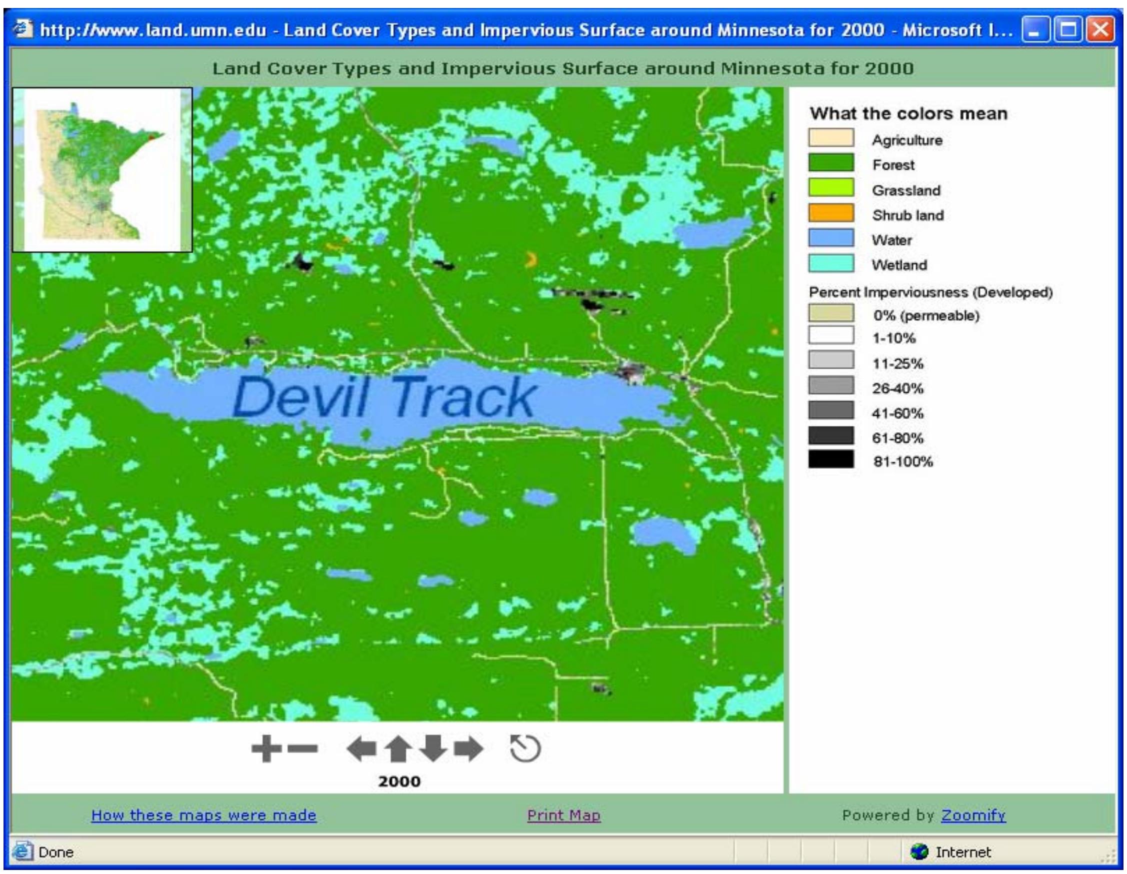


Figure 9. 2000 Land Use Land Cover data, Trout and Devil Track lake vicinity. Data from www.land.umn.edu :

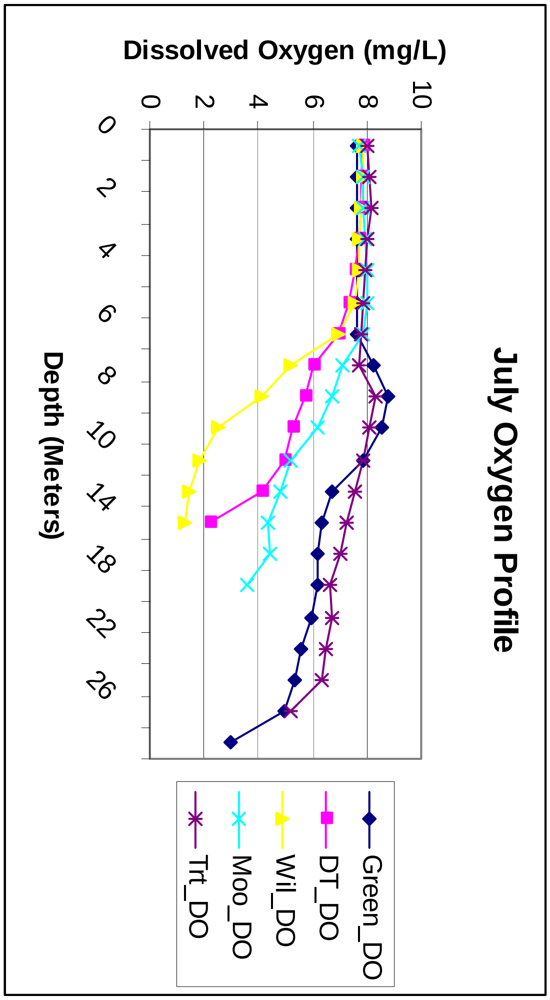


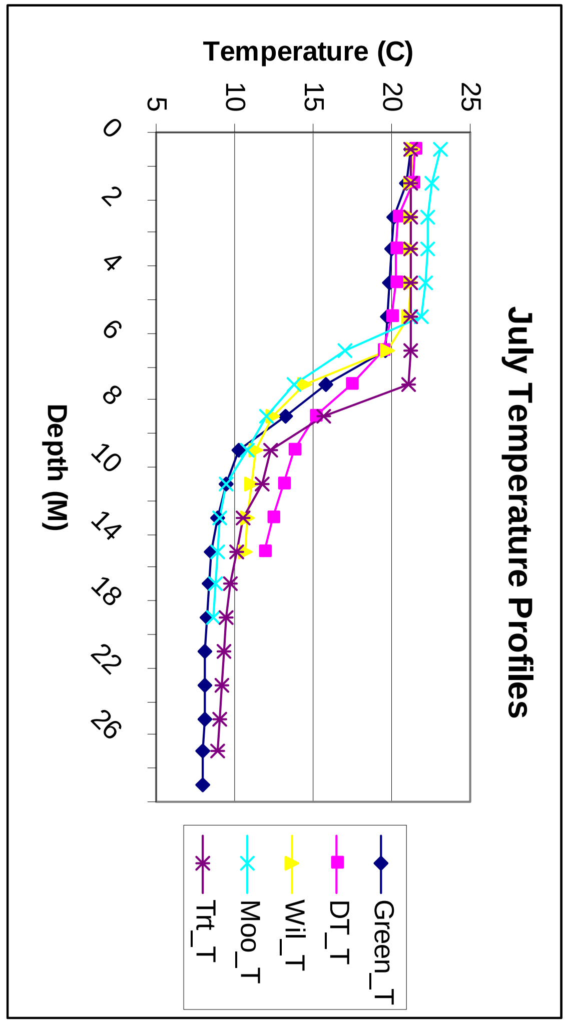


In Lake Conditions - 2006

All five lakes are fairly deep, ranging from 50-101 feet (16 – 30 meters), and are thermally stratified during the summer. Thermoclines, zones of maximum change in temperature over a small change in depth, were not yet fully developed on the lakes by the May 24th sample date. By mid-June a pronounced thermocline was evident on each lake and they remained stratified through the mid - September sampling event. Mid-summer (July) oxygen and temperature profiles are shown in Figure 10. The thermocline develops in all lakes between 20-25 feet (~7 meters). Greenwood and Trout Lakes (lake trout lakes) exhibit metalimnetic (middle layer) maxima at about 12 meters, the other three lakes exhibit a decline in DO concentrations to < 4.0 mg/L at 14 meters. Dissolved oxygen levels above 6 mg/L and temperatures of 12 C or less are needed to sustain lake trout populations and concentrations above this level were maintained on Greenwood and Trout down to a depth of about 20 meters. Temperature profiles were similar among the lakes, with Moose having slightly warmer surface temperatures.

Figure 10. mSNF Lakes' Dissolved Oxygen Profile and Temperature Profiles, July 10-11, 2006





Total Phosphorus, Chlorophyll-a and Secchi Transparency

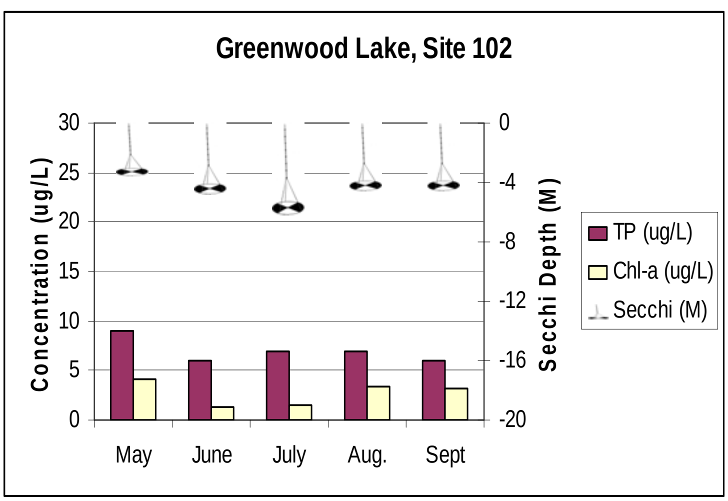
Total phosphorus (TP), chlorophyll-a and Secchi transparency are used to characterize lake trophic state. These measures are shown for the SNF Lakes in Figure 11. For most deep, oligotrophic to mesotrophic (low to moderate nutrient) lakes it is common to observe stable to slightly declining TP from May through September, accompanied by slight increases in chlorophyll-a and slight decreases in Secchi transparency. This is primarily the result of sedimentation of sediment-attached TP early in the summer along with algal uptake of P and sedimentation as algae grow and die over the summer.

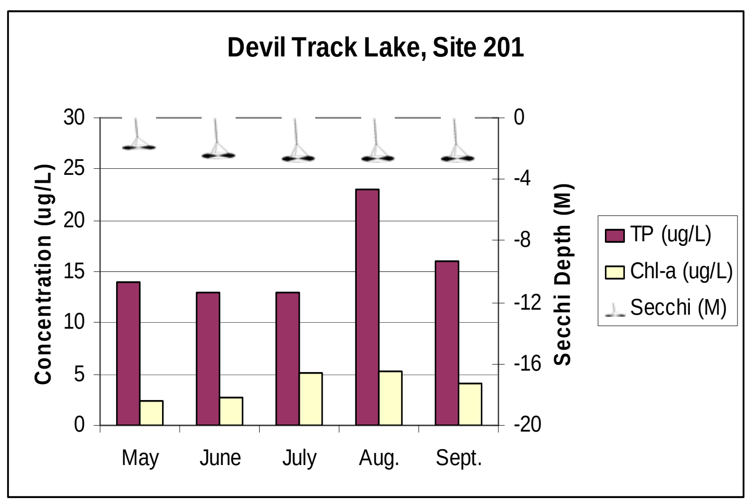
In these SNF lakes, TP and chlorophyll-a concentrations, and Secchi transparency did not vary greatly throughout the sampling season. In general, there were no significant water quality trends throughout the sampling season. Greenwood and Trout were quite consistent through the summer, with TP ranging from 6-10 µg/L and chlorophyll-a ranging from 1-4 µg/L (TP standard errors ranged from only 1.1 to 1.5 µg/l). Devil Track Lake, which has the greatest amount of lakeshore development / impervious surface (Figure 9), had the highest concentrations of TP and chlorophyll-a, however these values were still on the low end of the NLF ecoregion range (Table 2). In NLF lakes, chlorophyll-a concentrations above 10 µg/L would be perceived as a mild bloom. Based on maximum chlorophyll-a values for 2006, all five lakes remained below this level (Table 2).

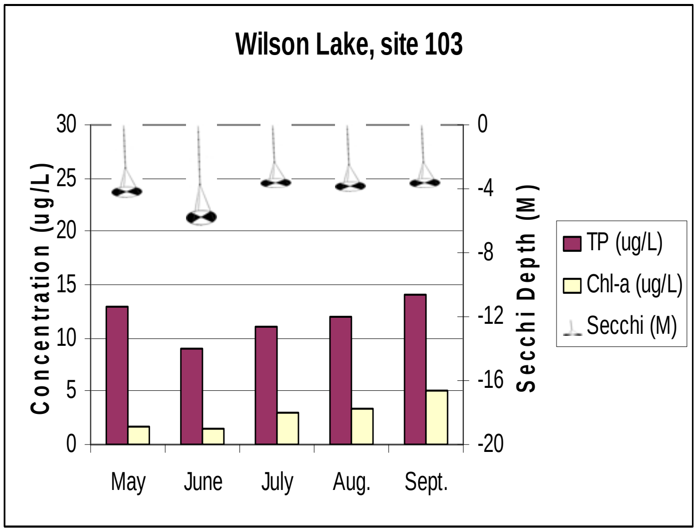
TP concentrations did not vary greatly between samples collected from the epilimnion or hypolimnion. Samples taken at depth (within 1 meter of the bottom) were only slightly higher than surface samples on all lakes except Wilson. In that case, in August and September TP concentrations were 56 and 87 ug/L at depth (see Appendix 2). This was likely the result of low DO concentrations (< 2.0 mg/L) above the sediments (Figure 10) that allows for release of iron-bound P from the sediments; whereas the other lakes tended to have slightly higher DO above the sediments (Figure 10).

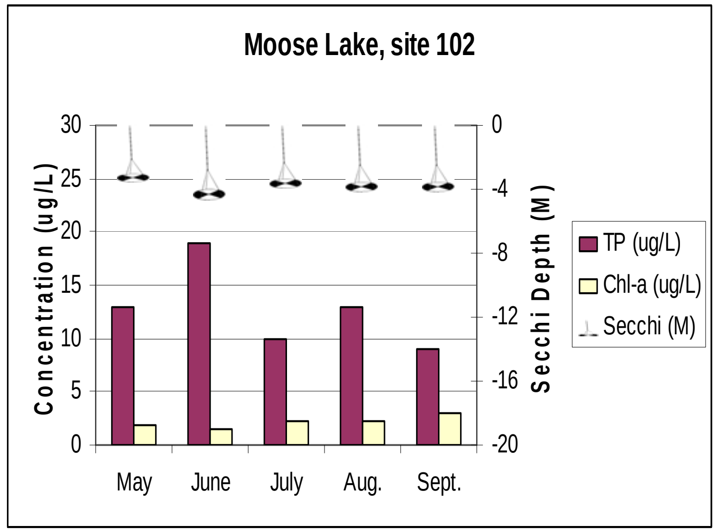
TP, chlorophyll, and Secchi transparency in the SNF lakes were within the typical range for lakes within the NLF ecoregion (Table 2). Overall these variables indicate excellent water quality. The SNF lakes are relatively un-impacted; shorelines are undeveloped or partially developed, and watershed land use is primarily forest under public ownership.

Figure 11. TP, Chlorophyll, and Secchi Data for the Study Lakes. Data from the primary monitoring station, the lake's deepest point.






Wilson Lake, site 103
Concentration (ug/L)
Secchi Depth (M)
30
25
20
15
10
5
0
0
-4
-8
-12
-16
-20
TP (ug/L)
Chl-a (ug/L)
Secchi (M)
May
June
July
Aug.
Sept.


Moose Lake, site 102
Concentration (ug/L)
Secchi Depth (M)
30
25
20
15
10
5
0
0
-4
-8
-12
-16
-20
TP (ug/L)
Chl-a (ug/L)
Secchi (M)
May
June
July
Aug.
Sept.

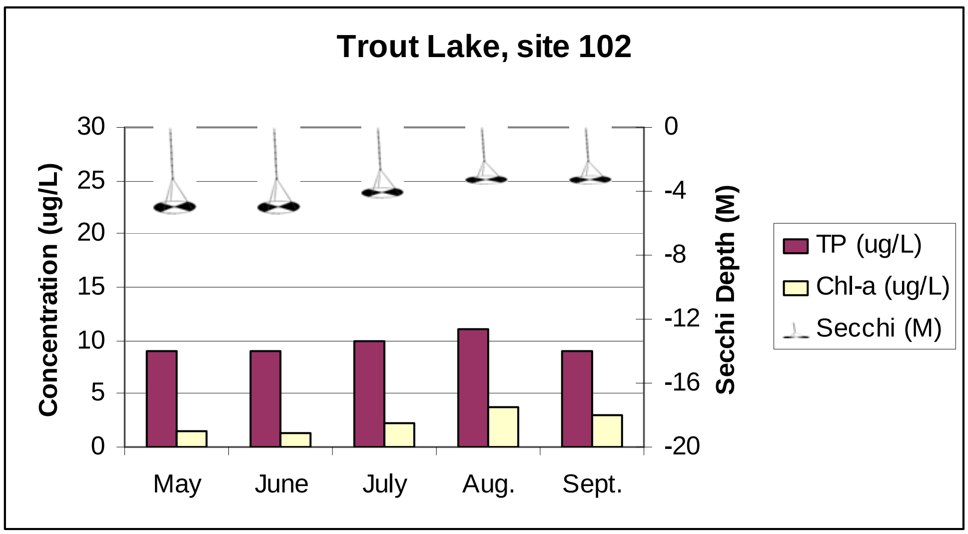

Trout Lake, site 102
Concentration (ug/L)
Secchi Depth (M)
30
25
20
15
10
5
0
0
-4
-8
-12
-16
-20
TP (ug/L)
Chl-a (ug/L)
Secchi (M)
May
June
July
Aug.
Sept.

Table 2. 2006 Summer-Mean Water Quality Data for the SNF Study Lakes. For lakes with two sites, the average of the epilimnion data was calculated. Standard error (SE) noted for trophic status variables.

Parameters	Greenwood 16-0077	Devil-Track 16-0143	Wilson 38-0047	Moose 38-0644	Trout 69-0498	Typical Range for NLF Ecoregion[1]
Total Phosphorus (µg/L) (+ / - SE)	8.0 (± 1.5)	16.0 (± 4)	11.8 (± 1.9)	12.8 (± 3)	10.0 (± 1.1)	14-27
Chlorophyll a (µg/L)[3] (+ / - SE)	2.4 (± 1.1)	4.2 (± 1.6)	2.9 (± 1.4)	2.3 (± 0.5)	2.4 (± 0.9)	4 - 10
Maximum	4.2	7.6	5.1	3.1	3.4	< 15
Secchi disk (m) (+ / - SE)	4.8 (± 1.0)	2.7 (± 0.3)	4.7 (± 1.0)	4.1 (± 0.4)	4.5 (± 0.7)	2.4 – 4.6
Total Kjeldahl Nitrogen (mg/l)	0.39	0.42	0.37	0.41	0.37	< 0.75
Alkalinity (mg/l)	< 10	18	18.8	53	< 10	40 - 140
Color (Pt-Co Units)	10	46	8	16	7.5	10-35
pH (SU)	7.6	7.6	7.7	7.9	7.7	7.2 – 8.3
Chloride (mg/l)	< 1.0	1.2	< 1.0	1.7	< 1.0	0.6 – 1.2
Total Suspended Solids (mg/l)	1.6	3.1	1.7	1.3	1.6	<1 - 2
Total Suspended Inorganic Solids	1.2	1.3	1.1	1.2	1.4	<1 - 2
Conductivity (µmhos/cm)	22	42	51	93	26	50 - 250
TN:TP Ratio	48:1	26:1	31:1	32:1	37:1	25:1-35:1
Average TSI [4]	37	45	40	40	38	
Percentile Rank, NLF Ecoregion [2]	86	52	74	74	82	

[1] Derived from Heiskary and Wilson (1990).
[2] Relative to approximately 700 assessed lakes in the Northern Lakes and Forests Ecoregion, whereby the lower the trophic state (TSI), the higher the percentile ranking (100 percent level implies lowest TP or deepest Secchi disk for that ecoregion).
[3] Chlorophyll a measurements have been corrected for pheophytin.
[4] Carlson's Trophic State Index (TSI) (Carlson 1977)

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

Total phosphorus TSI (TSIP) = 14.42 1n (TP) + 4.15
Chlorophyll a TSI (TSIC) = 9.81 1n (Chl-a) + 30.6
Secchi disk TSI (TSIS) = 60 - 14.41 1n (SD)

TP and chlorophyll-a are in µg/L and Secchi disk transparency is in meters. TSI values range from 0 (ultra-oligotrophic) to 100 (hypereutrophic). In this index, each increase of ten units represents a doubling of algal biomass.

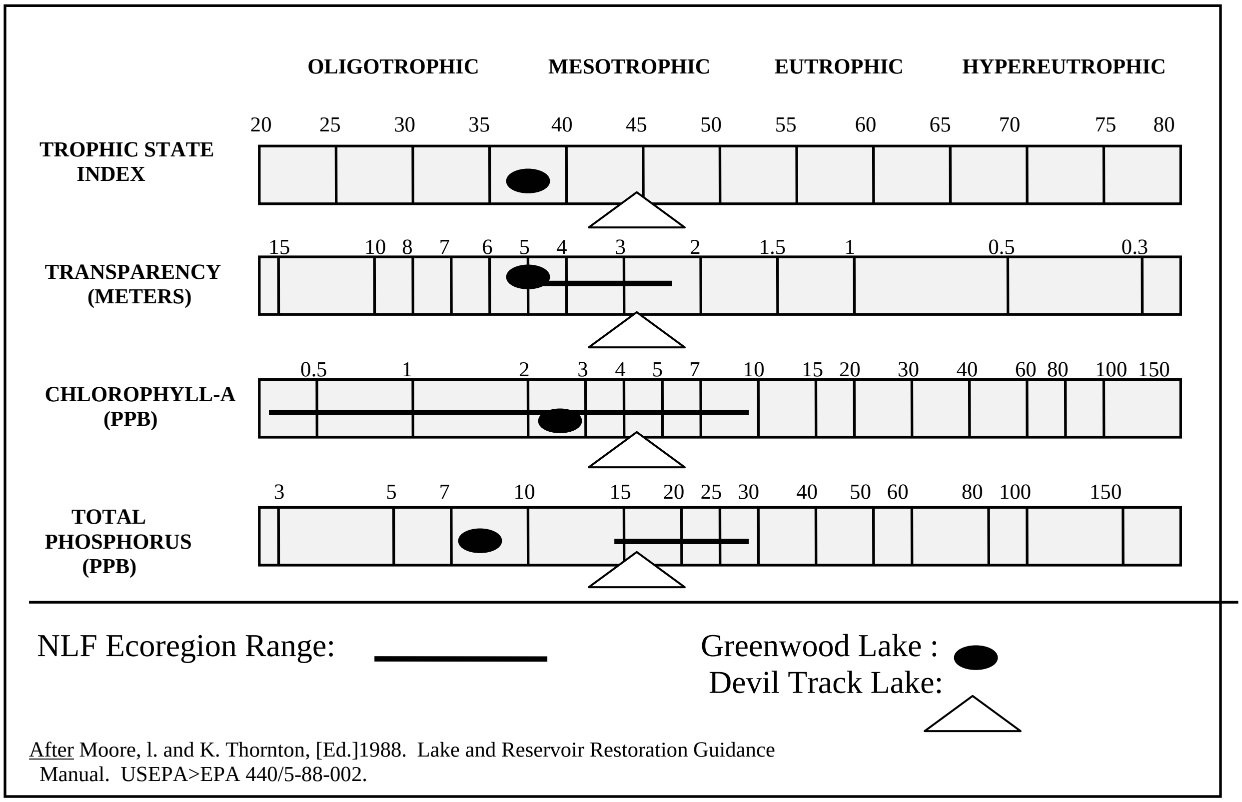
Average values for the trophic variables in Greenwood (lowest TP) and Devil Track (highest TP) Lakes and respective TSIs are presented in Figure 12. The other three SNF lakes TSI values lie between these two extremes (Table 2). In general this suggests that the lakes in this study are oligotrophic to mildly mesotrophic.

Other Water Quality Parameters

In this portion of Minnesota low nutrient concentrations are often accompanied by low mineral concentrations as well because of the paucity of limestone deposits and thin soils. The bedrock basins yield very soft water and four of the lakes had alkalinity values < 20 mg/L. In general, water with alkalinity less than 75 mg/L could be considered soft. Similarly, these lakes also had quite low specific conductivity values (Table 2). Color in these lakes (measured in platinum cobalt units) gives an indication of the amount of dissolved organic matter in the lake, and levels were very low in all lakes except for Devil Track, which reflects an increased abundance of wetlands in its watershed. This moderate coloration combined with moderate algal production yielded the lower transparency noted for Devil Track Lake.

Figure 12. Carlson's Trophic State Index (Carlson 1977). Values for Greenwood and Devil Track Lakes noted.

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 becomeanoxic in the hypolimnion during the summer.
TSI 40 - 50	Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.
TSI 50 - 60	Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimnia during the summer, macrophyte problems evident, warm-water fisheries only.
TSI 60 - 70	Dominance of blue-green algae, algal scums probable, extensive macrophyte problems.
TSI 70 - 80	Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypereutrophic.
TSI > 80	Algal scums, summer fish kills, few macrophytes, dominance of rough fish.



Comparison with 2006 Cook County Data

Dave Stark, the Cook County Water Plan Coordinator, sampled Devil Track Lake in 2006 as part of the county's routine lake monitoring program. Three stations were sampled a total of 4 times in 2006. The County's and MPCA's data are shown in Table 3. Between the two sampling programs there was no significant difference in TP, Chlorophyll-a or Secchi transparency.

Table 3. 2006 Devil Track Lake Water Quality data collected by Cook Co. and MPCA.

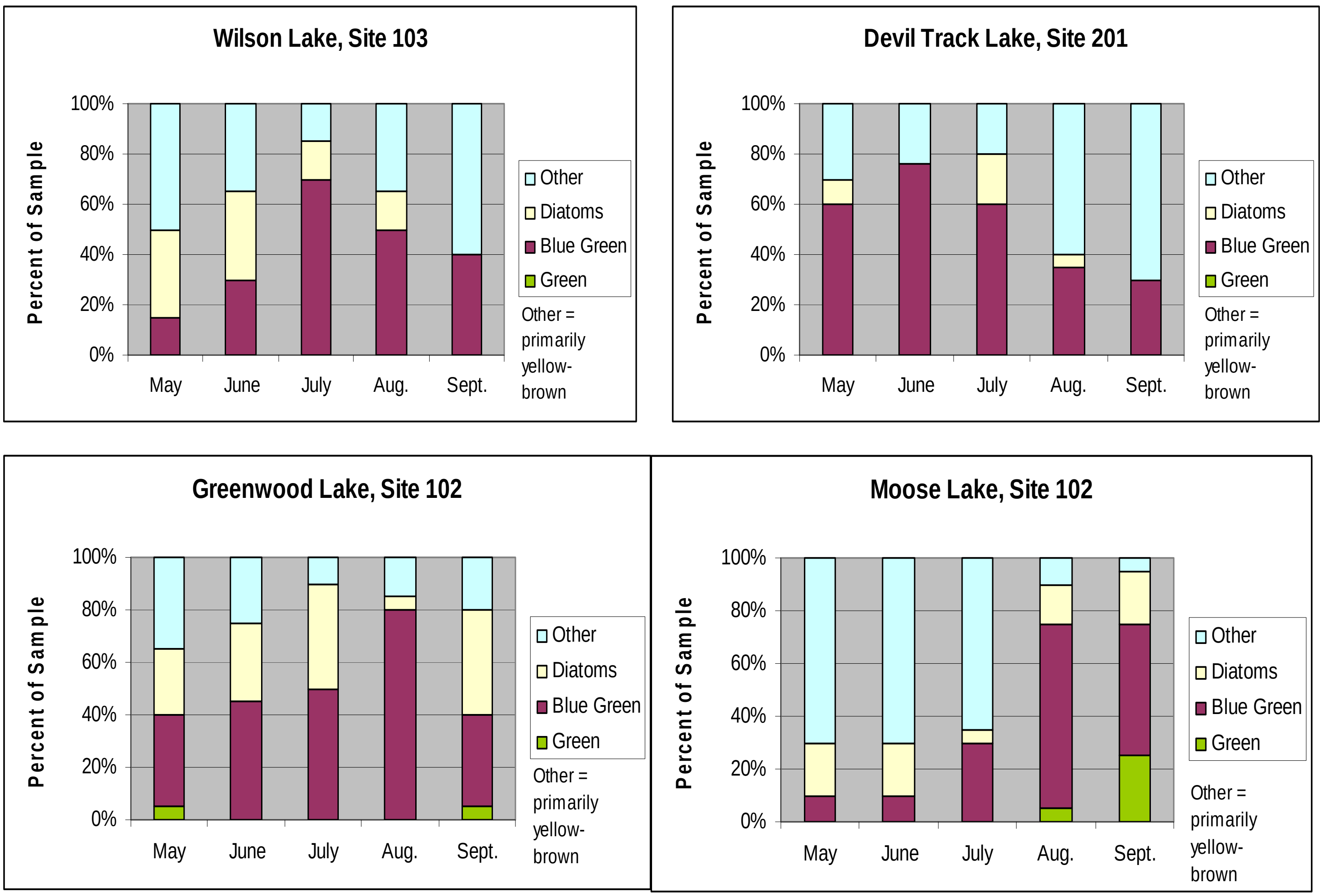
Parameter (± SE)	Cook County - 2006	MPCA- 2006
Total Phosphorus (µg/L)	11 ± 3	16 ± 4
Chlorophyll *a* (µg/L)	3.5 ± 1.8	4.2 ± 1.6
Secchi Transparency (M)	2.8 ± 0.5	2.7 ± 0.3

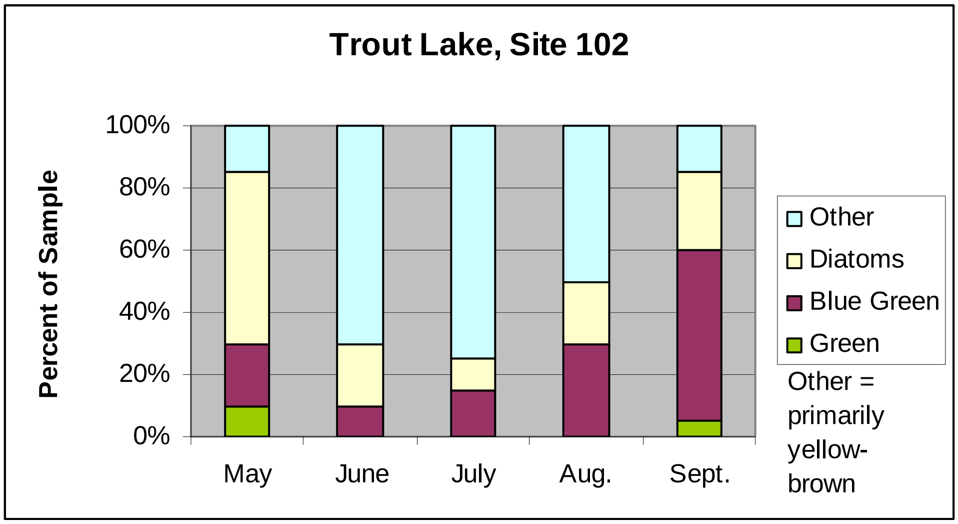
Algal Assessment

A rapid assessment of the algal community was conducted to determine dominant algal forms. Relative abundance of different algal forms was calculated for each sample based on numerical quantity (Figure 13). The relative percentages represented by the following four groups were calculated for each sample: green algae, diatoms, blue-green algae (cyanobacteria) and other taxa (including yellow, brown, and red algae, and dinoflagellates). Diatoms, blue greens, and yellow-brown algae were among the most common forms in most of the lakes. Seasonal dynamics were evident, but they were not consistent among lakes. For example, yellow-brown species peaked in Trout Lake by July, displacing blue-greens and diatoms; while on Wilson and Greenwood, blue-greens peaked in late summer.

Blue green algae blooms tend to form when one or two species dominate, typically the nitrogen-fixing taxa Anabaena or Aphanizomenon. While blooms on most NLF ecoregion lakes are often rather mild as compared to lakes elsewhere in Minnesota, some lakes such as Rainy Lake and Lake of the Woods may have rather pronounced blooms (Chen et. al 2005; and Anderson et. al, 2006).
Since chlorophyll-a concentrations were rather low throughout the summer in the SNF study lakes, any surface accumulations of blue-greens would have been rather minimal, which was the case based on observations by MPCA staff during the field visits. In some instances, such as Greenwood Lake in July of 2006, no single blue-green taxon was dominant and six separate blue-green taxa were identified. Green algal species were sparse in all five lakes. In general, a seasonal transition from diatoms (spring) to greens (early summer) to blue-green algae (late summer) is typical for most lakes in Minnesota – though this cycle may vary among lakes. This cycle is driven by competition for nutrients, predation by zooplankton, temperature, light, algal turnover rates, and other factors. In general for the SNF lakes we see low algal abundance (as reflected by low chlorophyll-a) and numerous species represented.

Figure 13. Algal community assessment for the SNF Study Lakes.





Modeling Summary

Numerous complex mathematical models are available for estimating nutrient and water budgets for lakes. These models can be used to relate the flow of water and nutrients from a lake's watershed to observed conditions in the lake. Alternatively, they may be used for estimating changes in the quality of the lake as a result of altering nutrient inputs to the lake (e.g., changing land uses in the watershed) or altering the amount of water that enters the lake. To analyze the in-lake water quality of the SNF Lakes, the model **MINLEAP** (Wilson and Walker, 1989) was used. The "Minnesota Lake Eutrophication Analysis Procedures" (MINLEAP), was developed by MPCA staff based on an analysis of data collected from the ecoregion reference lakes. It is intended to be used as a screening tool for estimating lake conditions with minimal input data and is described in greater detail in Wilson and Walker (1989). In MINLEAP in-lake TP and water budgets are estimated (predicted) based upon ecoregion-based runoff, precipitation, evaporation, and stream and atmospheric TP loading; lake surface area and mean depth; and total watershed area of the lake. In turn chlorophyll-a and Secchi are predicted based on Minnesota reference lake-derived regressions.

The SNF Lakes were modeled using data from 2006 for comparative purposes. The observed versus predicted concentrations of phosphorus, chlorophyll-a, and Secchi transparency are shown in Table 4. There was no statistically significant difference in observed versus predicted TP for any of the lakes. This implies that the observed TP is in the range anticipated for NLF ecoregion lakes of this size, depth, and watershed areas. Some differences were noted in predicted vs. observed chlorophyll-a and Secchi but most would not be deemed significant. **MINLEAP** predicted water residence times (time it would take to fill the lake if the basin was completely empty) ranging from five years on Devil Track to over 20 years on Trout Lake. Predicted P loading rates were estimated from 89 kilograms per year on Wilson to 1,150 kilograms on Trout Lake. The range in these values is due to the differences in watershed area, surface area, and mean depth (volume) among lakes-whereby lakes with large watersheds or large surface areas often have higher P loads. In some lakes like Trout, with its large surface area and small watershed: lake ratio (Table 1), atmospheric deposition on the surface of the lake is a large source of its P loading.

A second mathematical model developed by Vighi and Chiaudani (1985) is used to estimate background TP concentrations for the SNF Lakes. The Vighi and Chiaudani model is based on the morphoedaphic index routinely used in fishery science and predicts background (~ natural) P based on the lake's alkalinity and mean depth. Values for the SNF lakes ranged from 5 to 11 µg/L. In most instances the background TP concentrations are not significantly different than the MINLEAP-predicted TP and are quite close to the 2006 observed conditions. Two exceptions were Devil Track and Trout Lakes where predicted TP was lower than observed (Table 4).

Table 4. MINLEAP Model output for the SNF Lakes. Obs. = Observed 2006 Data; Pred.= model prediction. Means and standard error (SE) noted.

Parameters	Greenwood 16-0077		Devil-Track 16-0143		Wilson 38-0047		Moose 38-0644		Trout 69-0498	
	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.
TP (µg/L) ± SE	8 ± 1.4	9 ± 3	16 ± 4	11 ± 4	12 ± 2	12 ± 4	13 ± 3	11 ± 4	10 ± 1.1	8 ± 3
chl-a (µg/L) ± SE	2.5 ± 1.1	1.6 ± 1.1	4.3 ± 1.6	2.3 ± 1.4	3 ± 1.4	2.4 ± 1.5	2.3 ± 0.5	2.1 ± 1.3	2.4 ± 0.8	1.3 ± 0.8
% chl-a >20 µg/L	0	0	0	2	0	0	0	0	0	0
Secchi (meters) ± SE	4.7 ± 1	5.8 ± 2.5	2.7 ± 0.3	4.7 ± 1.9	4.7 ± 1	4.6 ± 1.9	4.1 ± 0.4	5 ± 2	4.5 ± 0.7	6.8 ± 3
P loading rate (kg / yr.)		262		667		89		371		1158
P retention (%)		81		67		74		69		82
P inflow conc. (ug/L)		46		34		44		35		43
Yearly Precip. (m)		0.74		0.74		0.74		0.74		0.74
water load (m/yr)		0.68		2.62		0.77		2.15		0.88
outflow volume (hm^3 /yr)		5.66		19.5		1.99		10.5		27.1
"background P" (ug/L)		6.9		8.3		11.1		11.8		5.8
residence time (years)		15.5		5.2		7.7		6.4		20.8

Mercury and Related Parameters

In cooperation with the Superior National Forest, mercury and cation / anion sampling was conducted on Devil Track and Wilson Lakes in 2006 (Table 5).

In general, total mercury concentrations (THg) above 1 nanogram per liter are considered high. This value was exceeded (as a summer mean) on Devil Track Lake, but not on Wilson (Table 5). However, the more valuable indicator the MPCA uses to assess mercury levels in water bodies is the percent of methyl mercury (MeHg), which is the ratio MeHg / THg (Bruce Monson, MPCA, personal communication). This percentage is an indicator of methylation efficiency in a waterbody. Lakes with high methylation are efficient at converting mercury present in the water column through the food chain and into game fish tissue. It is the MeHg in large predatory fish (such as walleye and northern pike) that poses the greatest threat to human health (MPCA, 2005).

Lakes typically have a MeHg ratio of 5-10 percent. The MeHg ratio in Devil Track is 1.7 percent and Wilson is <2.8 percent; therefore, both lakes are on the low end of methylation efficiency, which is good (Bruce Monson, MPCA, personal communication).

Table 5. Summer mean mercury and related parameters, Wilson and Devil Track Lakes. ANC and SO_4 measured at the USFS laboratory in Grand Rapids, Minnesota.

Parameter	Devil-Track Lake 16-0143	Wilson Lake 38-0047
pH (units)	7.6	7.7
ANC (mg/L $CaCO_3$)		21.3
ANC (µeq H+)		425
$S0_4$ (mg/L)		4.1
Total Hg (ng/L)	2.33	0.88
Methyl Mercury (ng/L)	0.04	< 0.025
Conductivity (µmhos/cm)	42	51

There are little historical acid neutralizing capacity (ANC) data available for comparison purposes. ANC data were collected by Heiskary and Swain (2002) in 1996; their mean value for Wilson Lake was 342 µeq H^+ / liter. This value was similar to that found in 2006 (Table 4).

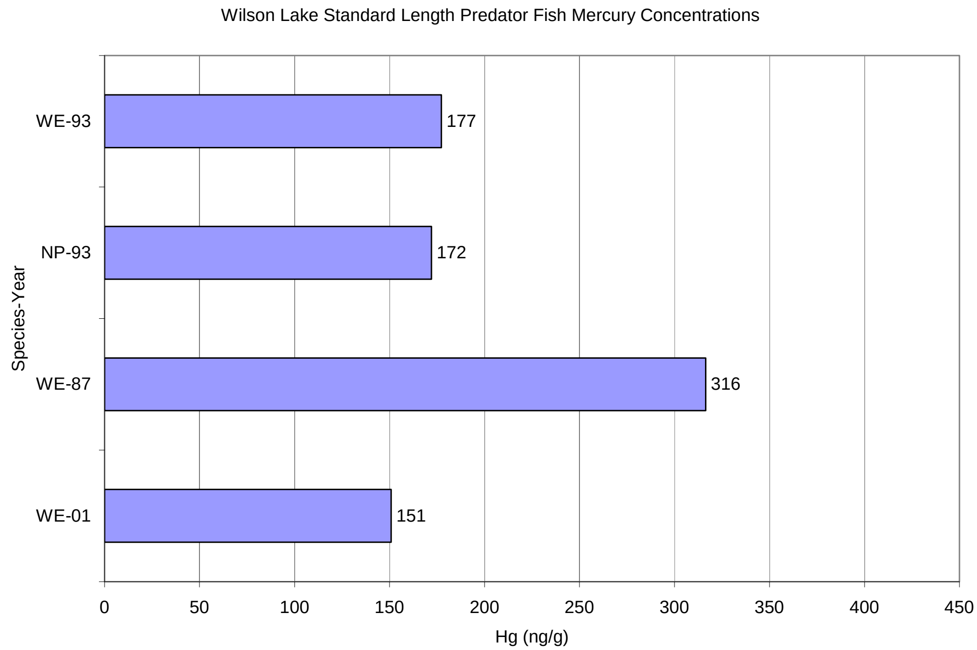
Mercury in Fish Tissue

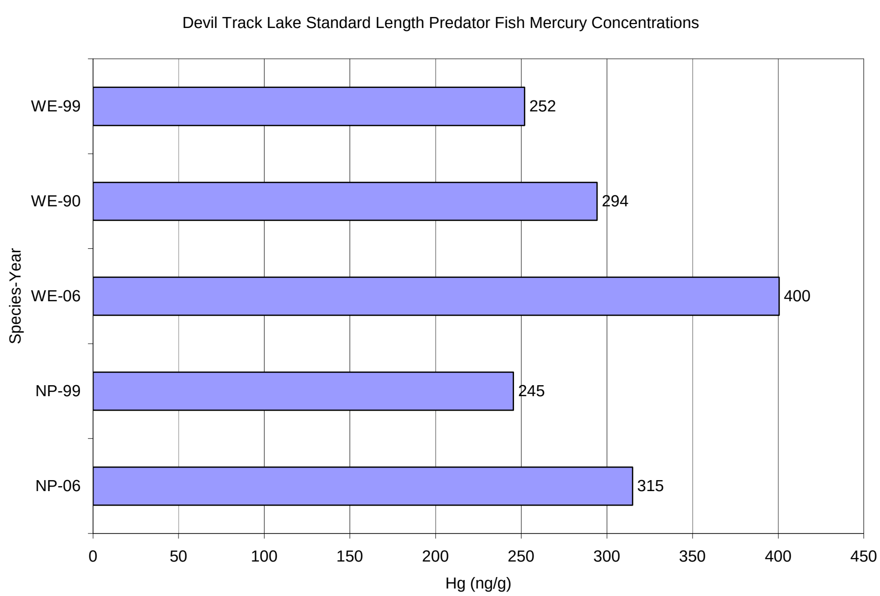
The Minnesota Department of Health has placed fish consumption advisories on many Minnesota lakes and rivers. All of these SNF lakes have an advisory.

The MPCA's water quality criterion for mercury in fish and the target level for the statewide mercury Total Maximum Daily Load (TMDL) study is 0.2 ppm (MPCA, 2007; see http://www.pca.state.mn.us/publications/wq-iw4-01b.pdf). A TMDL is basically a pollution reduction plan designed to get a water body back into meeting water quality standards.

The criterion has been historically exceeded on Wilson and Devil Track lakes (Figure 14). For more information on the Minnesota Department of Health's fish consumption advisory, see this web page: http://www.health.state.mn.us/divs/eh/fish/index.html.

Figure 14. Plots of mercury concentrations in fillets of standard length Northern Pile (NP) and Walleye (WE) from Wilson and Devil Track Lakes. The MPCA's criterion is 0.2 parts per million, or 200 ng/g. Data Courtesy of Bruce Monson, MPCA.



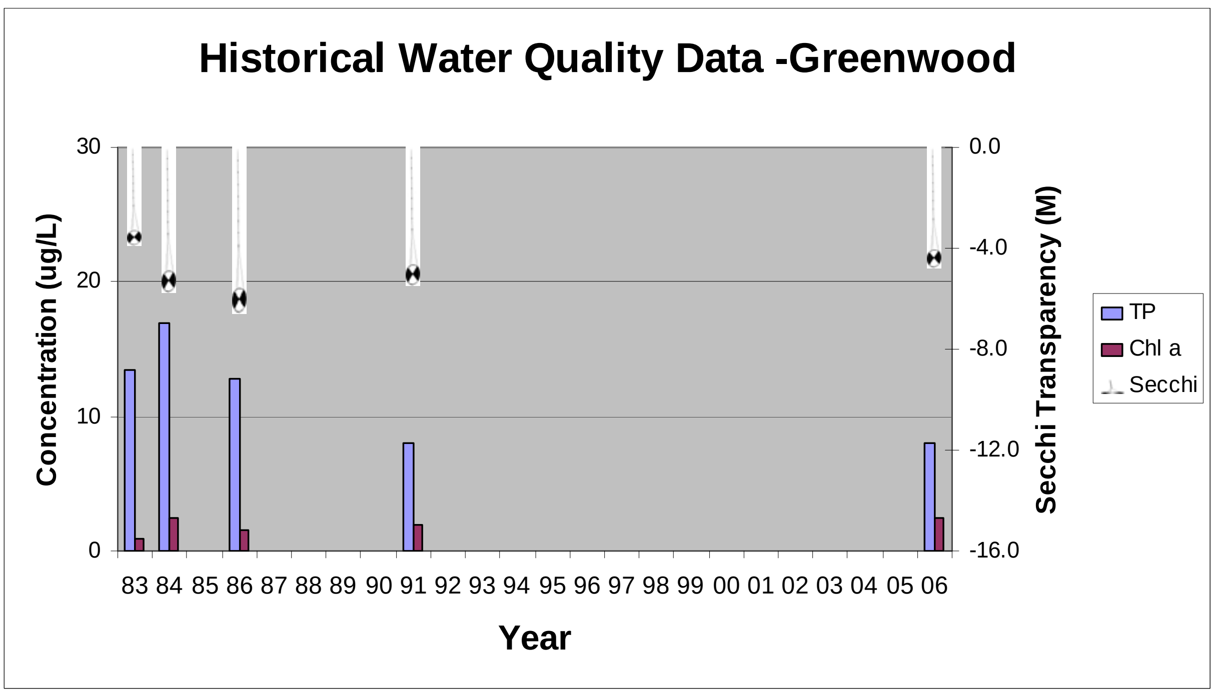


Water Quality Trends

Assessing temporal trends in water quality is important to managing and protecting lakes. With respect to eutrophication the focus is typically on TP, chlorophyll-a, and Secchi transparency based on a review of historic data records for the lakes and calculation of appropriate statistics for a common season (typically summer). For MPCA purposes we commonly rely on data that is available through Environmental Data Access (EDA), which may be accessed through the following web site link: http://www.pca.state.mn.us/data/edaWater/index.cfm. Based on previous trend assessments, using CLMP Secchi data, we typically require eight-ten or more years of data before conducting formal trend assessments as this is typically the minimum number of years needed to detect subtle shifts (e.g. 10-20%) in Secchi transparency. While few of the SNF lakes have that much data- three of the lakes - Greenwood, Devil Track, and Wilson have sufficient historical trophic status data to begin to assess temporal trends and variability. A second trend assessment technique involves the reconstruction of historic TP based on fossil diatoms in sediment cores. We will pursue the first technique with Green wood and Devil Track Lakes and a combination of the two techniques with Wilson Lake.

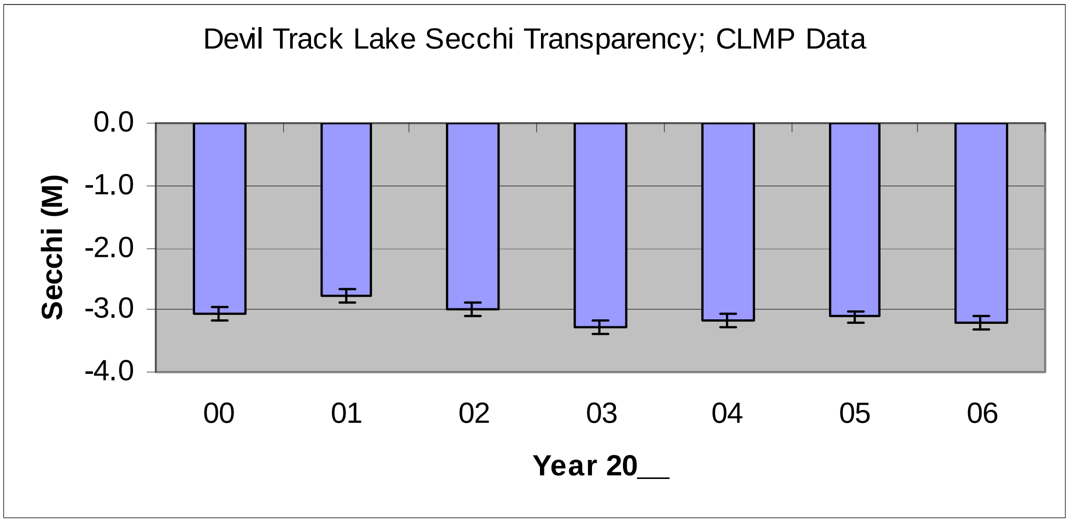
Greenwood Lake is a NLF ecoregion reference lake and was sampled for three years in the 1980's. TP data were slightly higher, but not significantly different, from the 2006 data (Figure 15). The differences in TP among these two time periods may be attributed, in part, to changes in the method detection limit for TP, which has varied somewhat over time (e.g. ~10 µg/L in 1980's and 2 µg/L in late 1990's through 2006). Chlorophyll and Secchi data also do not exhibit a statistically significant temporal trend. It is important to note that over 20 years passed between water quality assessments on Greenwood (the 1991 data includes just one sampling event and therefore is not sufficient for use in trend detection).

Figure 15. Greenwood Lake summer-mean trophic status data.



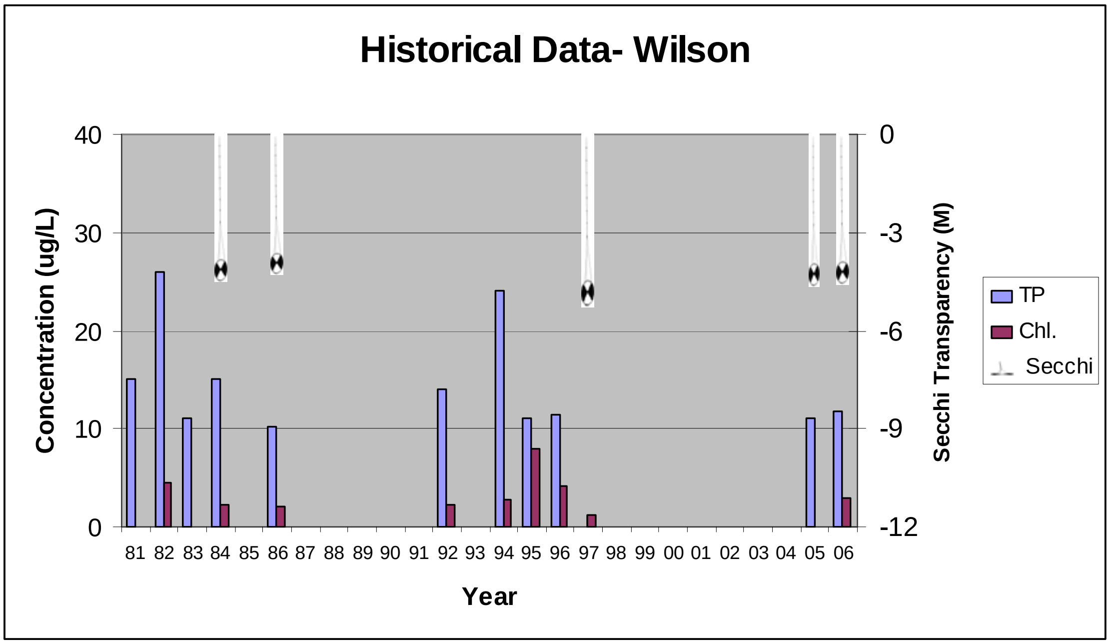
CLMP Secchi data is often the primary basis for assessing variability and trends in lake trophic status for Minnesota lakes. Because of their remote location, CLMP participation has been limited in the five SNF lakes; however in recent years Devil Track Lake has had strong participation in this program. Based on CLMP data, summer-mean Secchi ranges from about 2.5 – 3.2 m in most years and averages 3.1 m (10.1 feet) (Figure 16). No significant trend or large-scale fluctuations are evident based on this data.

Figure 16. Long term Secchi data from Citizen Lake Monitoring Program, Devil Track Lake: mean ± standard error.



Wilson Lake has the greatest amount of historical data of any of the five SNF lakes. This data was the result of its inclusion as a NLF ecoregion reference lake, part of acid rain and mercury investigations in the 1980's, and it was one of the 55 lakes in a statewide paleolimnology study (Heiskary and Swain 2002). Based on this record, TP has ranged from about 12 – 20 µg/L in most summers (Figure 17). No distinct long-term trend is evident; however recent TP values are among the lowest in its record (Figure 17). Chlorophyll-a is consistently low in most years, typically averaging about 4 - 5 µg/L and Secchi is typically between 4 – 5 m. Overall the water quality of the lake is quite good and based on these data there is no evidence of declining water quality and quite possibly there may have been minor improvements (reductions) in lake trophic status.

Figure 17. Wilson Lake Summer-mean trophic status data. Based on MPCA data.



Sediment-diatom reconstruction of phosphorus and other parameters can provide another avenue for assessing trends over time. Wilson Lake was among the lakes included in a statewide study of 55 lakes (Heiskary and Swain 2002). In that study sediment cores and modern-day water chemistry were collected from all lakes. The cores were dated and cut into small sections representing different time periods. For the purpose of the 55 lakes study, core-sections corresponding to circa 1750 and circa 1800 were used to represent pre-European influence and 1970 and 1993 represented modern-day. Data from the 55 lakes study and two subsequent studies on shallow lakes were used as a basis for characterizing pre-European condition among ecoregions and lake types as summarized in Table 6. The SNF study lakes TP data from 2006 (Table 2) compare favorably with the pre-European diatom reconstructed TP for the NLF ecoregion and suggests the SNF study lakes are well within the range of pre-European concentrations for this ecoregion.

Since Wilson Lake was among the 55 lakes studies a closer look at its data are warranted. Historical and present day (1990's) diatom inferred TP concentrations (calculated by Heiskary and Swain, 2002) are shown in Figure 18. Wilson shows little change from pre-European time (1750's) through 1970 and possibly has had a decline by the 1990's (Heiskary and Swain, 2002). The 1996 observed water quality concentrations were nearly identical to those observed in 2006 (11.5 versus 11.8 ug/L) and further suggests that modern-day TP may be slightly lower than some of the historical measures. For more information about the MPCA's paleolimnology study, see Heiskary and Swain, 2002 (http://www.pca.state.mn.us/publications/reports/lakes-wqdiatoms.pdf).

Figure 18. Wilson Lake Diatom Inferred Total Phosphorus and Observed (summer mean) values- from Heiskary and Swain, 2002.

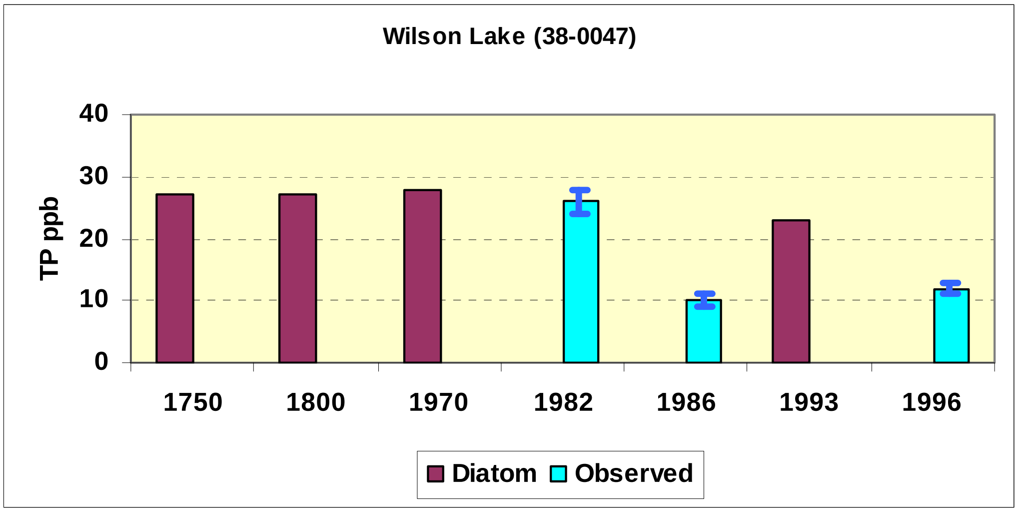


Table 6. Sediment diatom-reconstructed total phosphorus concentrations by ecoregion and lake type: includes pre-European interquartile (25th – 75th %tile) range and mean and modern-day (circa 1993) mean TP for the sediment core lakes.

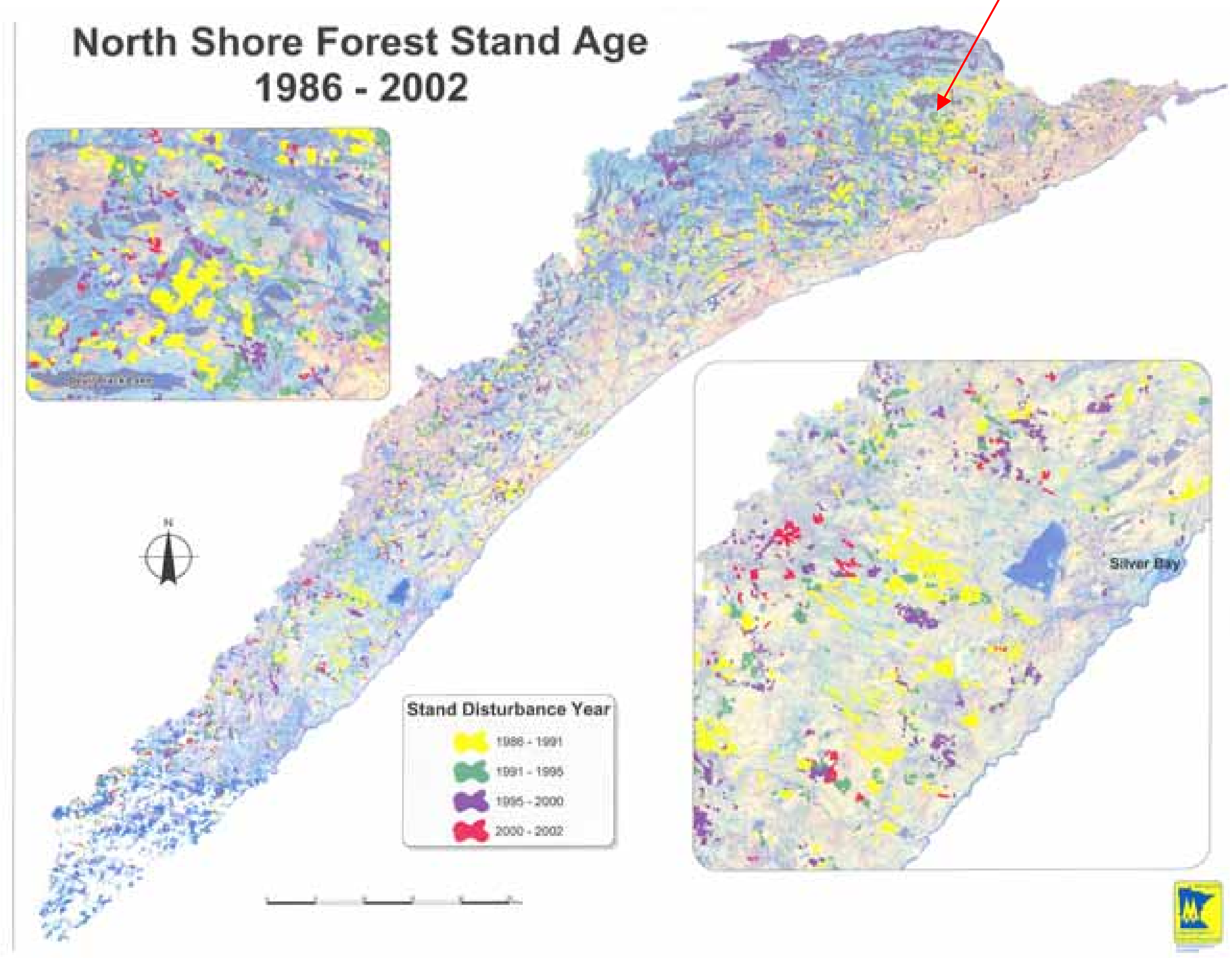
Ecoregion & lake type	# of lakes	Pre-European P IQ range	Pre-European mean P ± SE	Modern-day mean P ±SE
Northern Lakes & Forests	20	8 - 27	14.7 ±1.0	14.3 ±1.0
North Central Hardwoods Forests: deep lakes	30	20 - 29	27.3 ±2.0	32.3 ±3.0
North Central Hardwoods Forests: shallow lakes	5	31 - 47	38.8 ±4.1	98.3 ±14.0
Western Corn Belt Plains: deep lakes	4	50 - 76	63.0 ±10.0	44.0 ±3.0
Western Corn Belt & Northern Glaciated Plains: shallow lakes	6	52 - 89	67.0 ±11.0	125.0 ±8.0

Trends in Forest Harvest along the North Shore

In most lakes within the NLF ecoregion, urban lakeshore development and logging are the greatest *potential* threats to water quality. As part of MPCA stream monitoring projects on the North Shore, staff contracted with the MN DNR Division of Forestry to conduct an analysis of forestry practices within the Lake Superior watershed. Using satellite imagery and aerial photography, remote sensing experts quantified the location and acreages of forest harvests from 1986-2002 (Figure 19). Specifics on the DNR's methodology can be found here http://www.ra.dnr.state.mn.us/changeview/change_tech.html.

Forest harvest within the vicinity of Devil Track and Greenwood lakes took place primarily from 1986-1991. There has been very little harvest since that time, and extensive logging has not occurred along or near the shoreline. Given the lakes' excellent water quality, it's likely that forest practices are not impacting water quality significantly.

Figure 19. Forest Harvests along the N. Shore, 1986-2002. Devil Track Lake (inset) and Greenwood Lake noted



MPCA's Nutrient Criteria for Lakes

The MPCA's draft eutrophication criteria (Table 7) were promulgated into water quality standards as a part of the 2007 Water Quality Standards Triennial Review. This process will be formally completed with review and approval of the criteria by USEPA in early 2008 at which time they will become formal water quality standards. As such, they will be used in the 2010 impaired waters 303 (d) assessment. In that process, lakes with 10 or more observations (TP, chlorophyll-a and Secchi) collected between 1999-2008 will be assessed for compliance with these eutrophication criteria to determine whether they are in compliance with water quality standards. If the values exceed the TP and either the chlorophyll-a or Secchi criteria it is considered impaired and is placed on the 303 (d) list, which is submitted to USEPA every two years.

Trout and Greenwood are classified as 2A (Lake Trout) waters and their TP and chlorophyll-a values (Table 2) meet the criteria. Devil Track, Moose, and Wilson are classified as 2B waters and all three meet the aquatic recreation use values. For more information, see the reference document at this web page: http://www.pca.state.mn.us/publications/reports/lwq-a-nutrientcriteria.pdf.

Table 7. Eutrophication Criteria by Ecoregion and Lake Type

Ecoregion	TP	Chl-a	Secchi
	ppb	ppb	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
CHF – Stream trout (Class 2a)	< 20	< 6	> 2.5
CHF – Aquatic Rec. Use (Class 2b)	< 40	< 14	> 1.4
CHF – Aquatic Rec. Use (Class 2b) Shallow lakes	< 60	< 20	> 1.0
WCP & NGP – Aquatic Rec. Use (Class 2B)	< 65	< 22	> 0.9
WCP & NGP – Aquatic Rec. Use (Class 2b) Shallow lakes	< 90	< 30	> 0.7

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Appendix 1. MPCA's Clean Hands / Dirty Hands field techniques for mercury sampling.

The development of low-level analytical techniques has made possible the identification of mercury and various other metals and non-metals (arsenic, cadmium, chromium, copper, lead, nickel, zinc) at extremely low concentrations (ng/L; nanograms per liter; parts per trillion). Obtaining reliable analytical results at these levels requires extraordinary sampling device cleaning methods and sample handling methods. Ideally the Clean Hands – Dirty Hands sampling method is conducted by two Field Analysts. One analyst (Dirty Hands) handles only the sampling equipment and supplies that are exposed to the atmosphere and potentially contaminated surfaces during routine transport. The other analyst (Clean Hands) handles only the specially-cleaned sample bottle and supplies that are protected from incidental contamination.

EPA Methods 1669, 1631, and 1638

The new requirements for low-level analyte collection and analysis necessitate changes in sample collection procedures. Below is a summary of the recommendations drawn from EPA Methods 1669, 1631, and 1638. Each sample collection crew is responsible for determining how to best meet the clean sampling technique requirements of these methods. The information provided in this summary is generally applicable but specific circumstances may require other adaptations of the clean sampling principles (refer to EPA Methods 1669, 1631, and 1638 for additional details).

Goal: To collect, store, and ship a water sample for low-level analyte analysis without contaminating it with the analyte from other sources.

General Principle: Do not expose the sample to anything that may contain a significant amount of the analyte(s) being sampled.

Potential Contamination Sources: Sampling equipment, bailers, sampling tubing (including peristaltic pump tubing), gloves, clothing, bottles, exhaled breath from amalgam fillings (contain mercury), precipitation, dirt, dust, and airborne vapor.

The Clean Hands – Dirty Hands Sampling Technique: Method 1669 describes this clean sampling technique and provides specific guidance for many different sample collection situations.

The techniques summarized below require two people, **Dirty Hands** and **Clean Hands.** The **Dirty Hands** person handles the sample cooler, sample labels, bubble packaging, outer sample bag containing the sampling vial or bottle, and sampling equipment that does not directly contact the sample. The **Clean Hands** person handles the inner sample bag, the sample bottles, and sampling equipment that comes in direct contact with the sample and sample tubing. Changing gloves frequently is fundamental to maintaining cleanliness. When in doubt about the cleanliness of your gloves, change them!

Grab Sample Collection

Site Assessment: Be sure the sample collection area is protected from airborne sources of analyte such as dust or precipitation. If not, change sample collection location or provide a sheltered clean area for sample collection. When stream sampling collect samples upstream of bridges. When lake sampling collect samples away from roads.

Both Clean Hands and Dirty Hands wear appropriate disposable, **powderless** gloves during the entire sampling operation and change gloves frequently, usually with each change in task. (Wearing multiple layers of gloves allows rapid glove changes). The gloves must be free of trace analytes and appropriate to withstand any acid, solvent, or other chemical substance that will be used or contacted.

Using a Sharpie (or other permanent marker), **label the outside plastic bag**: Site ID and Date (MM/DD/YY)

Clean Hands: Put on clean glove. *Do not touch anything that may contaminate your gloves!*

Dirty Hands: Open the outer bag and hold it open so the Clean Hands person can reach inside.

Clean Hands: *Do not touch the outer bag!* Open the inner bag. Remove the bottle, preferably leaving the inner bag in the outer bag. If the inner bag is pulled out when retrieving the bottle, place the inner bag back in the outer bag before sampling. Remove the cap, submerge the sample bottle, and allow the bottle to partially fill with water. Screw the cap on the bottle, shake the bottle several times, and empty the rinsate away from the site. After two more rinsings, hold the bottle under water and fill bottle (i.e., when no more bubbles appear). Replace the cap of the bottle. Replace bottle in the inner bag, close the inner seal most of the way, and squeeze the inner bag to expel most of the air; then complete the seal.

Dirty Hands: Close the outer bag seal most of the way, squeeze the bag to expel most of the air, and then complete the seal. Immediately place the double-bagged bottle in the cooler to minimize exposure to sunlight.

Shipping and Preservation

Samples must be kept on ice or in a refrigerator until preserved. Samples must be preserved within 48 hours of sample collection. Therefore, if shipping to lab without preservative, ship samples in cooler with ice or frozen blue-pack, and ship overnight express no later than 24 hours after sampling.

Appendix 2. Water Quality Data for 2006. Complete record including profiles in Environmental Data Access at: http://www.pca.state.mn.us/data/edaWater/index.cfm

Data sorted by lake, date, site and depth

Field			m	m		us/cm
Site Name	Date	Site	D	SD	pH	Cond
Greenwood	5/24/2006	102	0	3.7	7.4	25
Greenwood	6/13/2006	102	0	4.9	7.7	15
Greenwood	7/11/2006	102	0	6.3	7.8	23
Greenwood	8/22/2006	102	0	4.6	7.7	24
Greenwood	9/13/2006	102	0	4.6	7.1	24
Field Duplicate	9/13/2006	102	0			
Greenwood	5/24/2006	102	23			
Greenwood	8/22/2006	102	26			
Greenwood	9/13/2006	102	27			
Greenwood	7/11/2006	102	28			
Greenwood	5/24/2006	104	0	3.4		
Greenwood	6/13/2006	104	0			
Greenwood	7/11/2006	104	0	6.1	7.7	23
Greenwood	8/22/2006	104	0	4.6	7.8	24
Devil Track	5/24/2006	201	0	2.2	7.2	45
Devil Track	6/13/2006	201	0	2.7	7.9	31
Devil Track	7/11/2006	201	0	3.0	7.9	43
Field Duplicate	7/11/2006	201	0	3.0	7.9	43
Devil Track	8/22/2006	201	0	3.0	7.8	45
Devil Track	9/12/2006	201	0	3.0	7.3	47
Devil Track	8/22/2006	201	13			
Devil Track	9/12/2006	201	13			
Devil Track	7/11/2006	201	13.5			
Field Duplicate	7/11/2006	201	13.5			
Devil Track	5/24/2006	201	14			
Devil Track	5/24/2006	204	0	2.2	7.3	45
Devil Track	6/13/2006	204	0	2.8	7.5	29
Devil Track	7/11/2006	204	0	2.4	7.9	43
Devil Track	8/22/2006	204	0	2.7	7.7	45
Devil Track	9/12/2006	204	0	3.0	7.4	47
Wilson Lake	5/24/2006	103	0	4.6	7.5	43
Wilson Lake	6/13/2006	103	0	6.4	7.1	82
Wilson Lake	7/11/2006	103	0	4.0	8.3	42
Wilson Lake	8/22/2006	103	0	4.3	7.9	44
Wilson Lake	9/11/2006	103	0	4.0	7.6	45
Wilson Lake	7/11/2006	103	14			
Wilson Lake	8/22/2006	103	14			
Wilson Lake	5/24/2006	103	15			
Wilson Lake	6/13/2006	103	15			
Wilson Lake	9/11/2006	103	15			
Moose Lake	5/23/2006	101	0	3.8	N/A	107
Moose Lake	6/12/2006	101	0	4.9	7.0	81
Moose Lake	7/10/2006	101	0	3.8	8.5	105
Moose Lake	8/21/2006	101	0		8.4	105
Moose Lake	9/11/2006	101	0	4.0	8.1	107
Moose Lake	7/10/2006	101	18.5			

Moose Lake	8/21/2006	101	18.5			
Moose Lake	5/23/2006	101	19			
Moose Lake	6/12/2006	101	19			
Moose Lake	5/23/2006	102	0	3.7	N/A	107
Moose Lake	6/12/2006	102	0	4.8	6.9	9
Moose Lake	7/10/2006	102	0	4.0	8.3	104
Moose Lake	8/21/2006	102	0	4.3	8.4	104
Moose Lake	9/11/2006	102	0	4.3	8.0	107
Field Duplicate	9/11/2006	102	0			
Moose Lake	9/11/2006	102	16			
Field Duplicate	9/11/2006	102	16			
Trout Lake	6/12/2006	101	0	5.4	7.9	30
Trout Lake	7/10/2006	101	0	4.6	8.4	26
Field Duplicate	7/10/2006	101	0	4.6	8.4	26
Trout Lake	8/21/2006	101	0	4.3	8.1	27
Trout Lake	9/11/2006	101	0	3.7	7.1	28
Trout Lake	6/12/2006	101	26			
Trout Lake	7/10/2006	101	26			
Field Duplicate	7/10/2006	101	26			
Trout Lake	8/21/2006	101	26			
Trout Lake	9/11/2006	101	26			
Trout Lake	5/23/2006	102	0	5.5	6.9	27
Trout Lake	6/12/2006	102	0	5.5	6.9	24
Trout Lake	7/10/2006	102	0	4.5	7.9	27
Trout Lake	8/21/2006	102	0	3.7	7.9	27
Trout Lake	9/11/2006	102	0	3.7	7.4	28
Trout Lake	5/23/2006	102	10.5			

Lab

			m	ug/L	mg/L	ug/L		mg/L		PCU	mg/L			
Site Name	Date	Site	D	TP	TKN	Chl-a	Pheo	TSS	TSV	Col	Alk.	Cl	TOC	SO4
Greenwood	5/24/2006	102	0	9	0.41	4.2	0.9	1.6	1.2	10	<10	<1		
Greenwood	6/13/2006	102	0	6	0.33	1.4	<.16	1	1	10	<10	<1		
Greenwood	7/11/2006	102	0	7	0.35	1.5	<.21	1.2	<1	10	< 10	<1		
Greenwood	8/22/2006	102	0	7	0.42	3.4	0.5	1.2	1.2	10	<10	<1		
Greenwood	9/13/2006	102	0	6	0.37	3.2	0.7	2.4	1.2	5	<10	<1		
Field Dup	9/13/2006	102	0			3.0	0.3							
Greenwood	5/24/2006	102	23	10										
Greenwood	8/22/2006	102	26	16										
Greenwood	9/13/2006	102	27	19										
Greenwood	7/11/2006	102	28	18										
Greenwood	5/24/2006	104	0	9	0.47	2.8	0.9	2.4	1.6	10	<10	<1		
Greenwood	6/13/2006	104	0	9		1.2	0.2							
Greenwood	7/11/2006	104	0	7		1.5	<.21							
Greenwood	8/22/2006	104	0	10		3.2	0.7							
Devil Track	5/24/2006	201	0	14	0.43	2.4	0.7	<1	<1	50	15	1.3		
Devil Track	6/13/2006	201	0	13	0.44	2.7	0.4	<1	<1	50	21	1.3	7.9	3.1
Devil Track	7/11/2006	201	0	13	0.37	5.1	1.1	2	1.6	50	20	1.1		
Field Dup	7/11/2006	201	0	12	0.43	5.3	1.0	2	1.2	50	16	1.1		
Devil Track	8/22/2006	201	0	23	0.47	5.3	0.7	6.8	<1	40	17	1.3	7.7	3.3
Devil Track	9/12/2006	201	0	16	0.33	4.1	1.0	2.4	1.2	40	20	1.2	6.7	3.3
Devil Track	8/22/2006	201	13	15										
Devil Track	9/12/2006	201	13	15										
Devil Track	7/11/2006	201	14	14										
Field Dup	7/11/2006	201	14	16										
Devil Track	5/24/2006	201	14	12										
Devil Track	5/24/2006	204	0	12	0.49	3.2	0.3	1.2	<1	50	17	1.2		
Devil Track	6/13/2006	204	0	13		2.6	0.5							
Devil Track	7/11/2006	204	0	20		7.6	1.0							
Devil Track	8/22/2006	204	0	13		4.8	0.9							
Devil Track	9/12/2006	204	0	21		5.2	2.1							
Wilson Lake	5/24/2006	103	0	13	0.4	1.7	<.16	<1	<1	10	17	<1		
Wilson Lake	6/13/2006	103	0	9	0.33	1.5	0.3	1.2	<1	10	21	<1	4.9	3.5
Wilson Lake	7/11/2006	103	0	11	0.35	3.1	0.6	1.6	1.2	10	16	<1		
Wilson Lake	8/22/2006	103	0	12	0.42	3.4	0.7	<1	<1	5	17	<1	4.8	3.7
Wilson Lake	9/11/2006	103	0	14	0.35	5.1	0.7	2.4	1.2	5	23	<1	4.2	3.6
Wilson Lake	7/11/2006	103	14	18										
Wilson Lake	8/22/2006	103	14	56										
Wilson Lake	5/24/2006	103	15	13										
Wilson Lake	6/13/2006	103	15	17										
Wilson Lake	9/11/2006	103	15	87										
Moose Lake	5/23/2006	101	0	17	0.42	2.0	0.3	<1	<1	20	51	1.8		
Moose Lake	6/12/2006	101	0	12	0.41	1.9	0.2	1.2	1.2	20	54	1.9		
Moose Lake	7/10/2006	101	0	12	0.39	2.4	<.22	1.2	1.2	20	54	1.5		
Moose Lake	8/21/2006	101	0	11	0.41	2.8	<.37	<1	<1	10	55	1.7		
Moose Lake	9/11/2006	101	0	12		3.1	0.4							
Moose Lake	7/10/2006	101	19	18										
Moose Lake	8/21/2006	101	19	21										
Moose Lake	5/23/2006	101	19	15										
Moose Lake	6/12/2006	101	19	17										
Moose Lake	5/23/2006	102	0	13	0.44	2.0	0.2	1.6	1.2	20	52	1.7		
Moose Lake	6/12/2006	102	0	19		1.4	0.3							

Moose Lake	7/10/2006	102	0	10		2.2	0.2					
Moose Lake	8/21/2006	102	0	13		2.3	<.34					
Moose Lake	9/11/2006	102	0	9	0.41	3.1	0.3	1.2	1.2	10	53	1.6
Field Dup	9/11/2006	102	0	11	0.42							
Moose Lake	9/11/2006	102	16	19								
Field Dup	9/11/2006	102	16	19								
Trout Lake	6/12/2006	101	0	11	0.47	1.3	0.2	<1	<1	10	<10	<1
Trout Lake	7/10/2006	101	0	11	0.38	2.6	0.4	1.6	1.2	5	<10	<1
Field Dup	7/10/2006	101	0	11	0.36	2.5	0.4	2	1.6	10	<10	<1
Trout Lake	8/21/2006	101	0	12	0.35	3.4	0.6	1.2	1.2	5	<10	<1
Trout Lake	9/11/2006	101	0	9	0.33	2.8	0.4	2	1.6	5	11	<1
Trout Lake	6/12/2006	101	26	12								
Trout Lake	7/10/2006	101	26	13								
Field Dup	7/10/2006	101	26	14								
Trout Lake	8/21/2006	101	26	12								
Trout Lake	9/11/2006	101	26	11								
Trout Lake	5/23/2006	102	0	9	0.33	1.5	0.3	1.2	1.2	10	<10	<1
Trout Lake	6/12/2006	102	0	9		1.4	<.16					
Trout Lake	7/10/2006	102	0	10		2.3	0.3					
Trout Lake	8/21/2006	102	0	11		3.7	0.6					
Trout Lake	9/11/2006	102	0	9		3.1	0.5					
Trout Lake	5/23/2006	102	11	11								