

Nest Lake Assessment Report

2008 Water Quality Update



Minnesota Pollution Control Agency

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Executive Summary

Nest Lake is a 990-acre lake in Kandiyohi County within the North Fork Crow River watershed. Nest Lake is approximately 1 mile northwest of Spicer, MN and is located in the North Central Hardwood Forest Ecoregion (NCHF). The lake has a maximum depth of 40 ft and 525 littoral acres. Two public accesses are located around the lake. The main tributary to Nest Lake is the Middle Fork of the Crow River; Nest Lake outlets into Green Lake. The total watershed for Nest Lake is 121.5 square miles.

This report is a review of recent work completed through the Middle Fork Crow River Lakes Partnership, the Middle Fork Crow River Watershed District, area volunteers, and the Minnesota Pollution Control Agency. A diagnostic study of the entire watershed was completed in 2002, with follow up monitoring occurring from 2004 to present. References will be made to existing reports for additional data; this report will discuss the trophic state of Nest Lake based on all available summer (June to September) data available in STORET (U.S. Environmental Protection Agency's national water quality data repository) through 2008.

A number of water quality models were used to estimate the water quality of Nest Lake based on morphometry and watershed characteristics. These models provide a means to compare the measured water quality of the lake relative to the predicted water quality. The modeling application Minnesota Lake Eutrophication Analysis Procedure (MINLEAP) predicted a summer-mean total phosphorus concentration of 37 µg/L (micrograms per liter) using NCHF ecoregion inputs; mean values of 2000 through 2008 data exceeded the predicted values. BATHTUB calculated the majority of total phosphorus entering Nest Lake (50% to 80%) is from external sources, primarily the Middle Fork Crow River, while 10 to 30% is from internal cycling of phosphorus from the bottom sediments (Wilson et. al, 2006). The result of modeling and diatom inferred total phosphorus levels prior to European settlement suggest reducing total phosphorus levels below 25 µg/L.

Current data exceeds the Minnesota lake eutrophication standards adopted into rule in 2008 (Table 4). This will likely lead to a nonsupport designation for aquatic recreation use (swimming and wading) on Nest Lake during the 2010 Impaired Waters assessment.

Lake Assessment Program: Nest Lake 2008

Introduction

Nest Lake was sampled in 2000, 2004, and 2005 by the Middle Fork Crow River Lakes Partnership, 2006 by the Middle Fork Crow River Watershed District, 2007 by the Minnesota Pollution Control Agency (MPCA), and 2007-2008 by local volunteers. This report was compiled at the request of the Middle Fork Crow River Watershed District. Data analyzed will include all available data in STORET. Further detail on concepts and terms in this report can be found in the Guide to Lake Protection and Management (<http://www.pca.state.mn.us/water/lakeprotection.html>).

Background

Watershed, soils, and land use

Nest Lake is a 990-acre lake in Kandiyohi County within the North Fork Crow River watershed. Nest Lake is approximately 1 mile northwest of Spicer, MN and is located in the Northern Central Hardwood Forest Ecoregion. The lake has a maximum depth of 40 feet, a mean depth of 15 feet and 525 littoral acres. The total watershed for Nest Lake is 121.5 square miles with much of that lying to the north of the lake (Figure 1). Two public accesses are located around the lake. The main tributary to Nest Lake is the Middle Fork of the Crow River; Nest Lake outlets into Green Lake.

Soils in the area around Nest Lake are of the Koronis-Hawick-Sunburg group; Central Iowa and Minnesota Till Prairies. These are moist prairie soils.

Land use for the Nest Lake watershed is dominated by agricultural/cultivated use (45%) and grassland/pasture (19%). Water/wetlands and forests each make up approximately 15% of the land use (Figure 1).

Figure 1. Nest Lake Watershed and Land Use

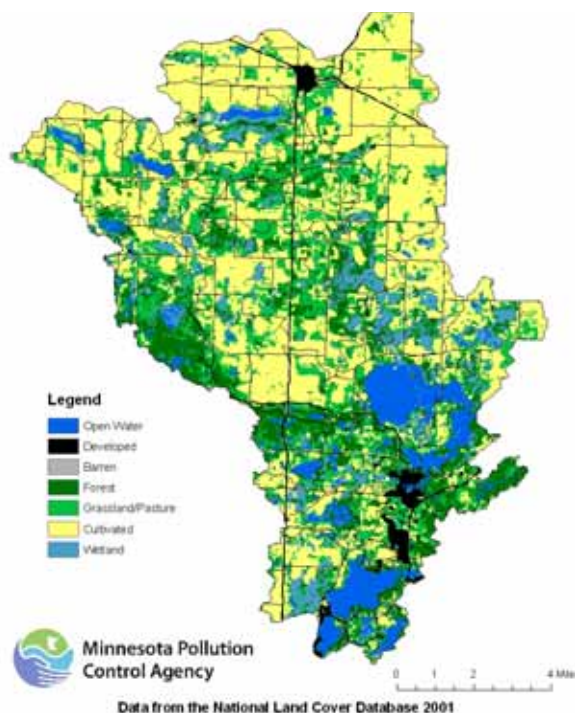
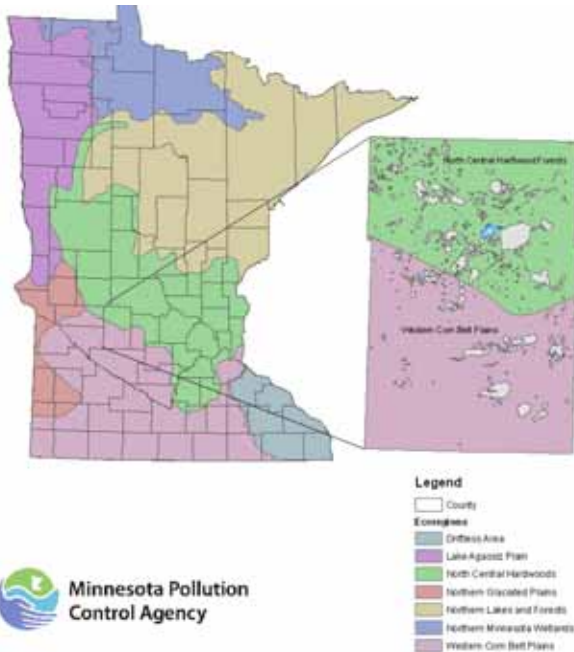


Figure 2. Minnesota Ecoregions



Ecoregions

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. Nest Lake is located in the North Central Hardwood Forest (NCHF) ecoregion (Figure 2).

Climate

Based on state climatology records, precipitation averages 30 inches (0.8 m) annually in this part of the state (Figure 3). Recent years have been drier than the normal expected precipitation (Table 1). Typical evaporation and runoff values for lakes in the NCHF ecoregion are 0.71 meters per year (m/yr) of evaporation and 0.13 m/yr of runoff.

Stratification

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* (Figure 4). These lakes fully 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*. Lakes, with moderate depths, may stratify intermittently during calm periods, but mix during heavy winds and during spring and fall. 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 dimictic lakes have an 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. This low oxygen environments in the hypolimnion are conducive to total phosphorus (TP) being released from

Figure 3. Normal Annual Precipitation

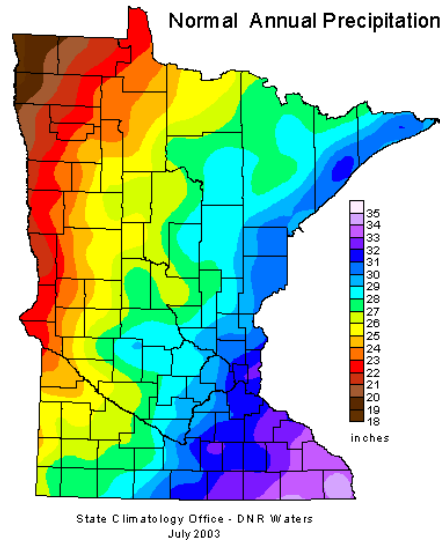


Table 1. Average Rainfall in Inches at New

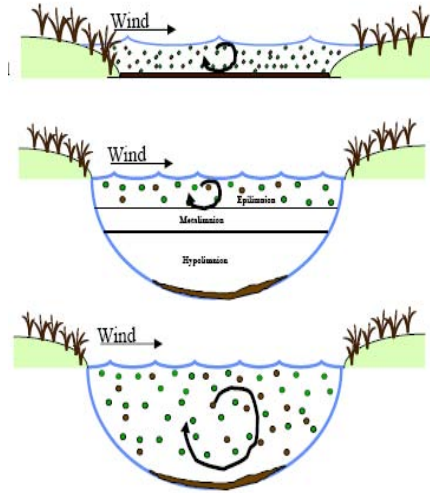
Year	Annual	Growing Season
		(May - September)
2004	32.8	26.3
2005	41.8	23.3
2006	25.3	16.5
2007	27.7	12.5
2008	21.9	14.1

*based on data through October 2008

the lake sediments. During stratification dense colder hypolimnion waters are separated from the nutrient hungry algae in the epilimnion. Intermittent (weakly) stratified polymictic lakes are mixed in high winds and during spring and fall. Mixing events allow for the nutrient rich sediments to be re-suspended and available to algae. Most of the fish in the lake are usually found in the epilimnion or near the thermocline. Nest Lake, based on historical temperature profiles, appears to be polymictic. While the lake is deep, it does have a large fetch (4 kilometers) and is susceptible to wind mixing.

Figure 4. Lake Stratification

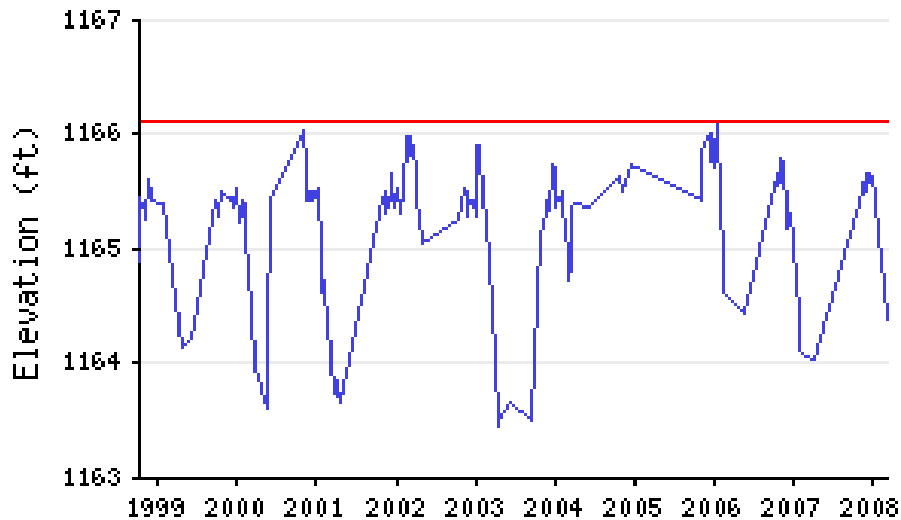
- Polymictic Lake**
Shallow, no layers,
Mixes continuously
Spring, Summer & Fall
- Dimictic Lake**
Deep, form layers,
Mixes Spring/Fall
- Intermittently Stratified**
Moderately deep
Mixes during high winds
Spring, Summer, & Fall



Lake Level

A summary of lake level information was drawn from the Department of Natural Resources (DNR) web site. Lake level data have been collected on Nest Lake from December 1940 to August 2008. The highest recorded level was 1166.7 feet in June 1986 and the lowest record was 1162.7 in November 1976. The lake level has ranged 3.96 feet, since 1940. A hydrograph of the last 10 years indicates fluctuating water levels (Figure 5).

Figure 5. Nest Lake Level Hydrograph



Status of the Fishery

A summary of fisheries information was drawn from the DNR web site. Nest Lake was most recently surveyed for fish population in July 2003. Largemouth and smallmouth bass collected were large-sized, with moderate numbers of largemouth and high numbers of smallmouth bass. Black crappies were found in high numbers with the fish smaller than average. Bluegill, walleye, and northerns were all average-sized with moderate numbers of fish found. Yellow perch were found in low numbers, but the fish were average-sized. Muskellunge have been found in Nest Lake, likely the result of accidental introduction. Walleye are actively managed in the lake, with fry and fingerlings stocked routinely. In 2007, as part of the National Lake Assessment Program (NLAP), the DNR sampled Nest Lake for data necessary to calculate an index of biotic integrity (IBI) – essentially a measure of the health of the fishery. While the state-wide IBI is still under development, the data did show that Nest Lake had 22 species of fish, resulting in a score of 84. This mid-range score would identify the lake as having a “normal fish community” (Proulx, 2008).

Aquatic Plant Survey

A near-shore survey of aquatic plant communities was completed in August 2007 as part of NLAP. Ten randomly-selected, evenly spaced sites were visited and visually assessed, and plant specimens were collected and identified. Twenty-two plant species were identified (Neuman, 2008). A previous DNR standard lake survey found nearly 40 different species of plants. Nest Lake shoreline is mostly developed with limited natural vegetation. However, there were two sites with predominantly undisturbed shoreline and one location with heavily disturbed shoreline (Figure 6). It should be noted that Nest Lake is infested with curly-leaf pondweed (*Potamogeton Crispus*), an exotic invasive species most often prevalent in May and June.

Figure 6. Nest Lake Near-Shore Habitat Assessment

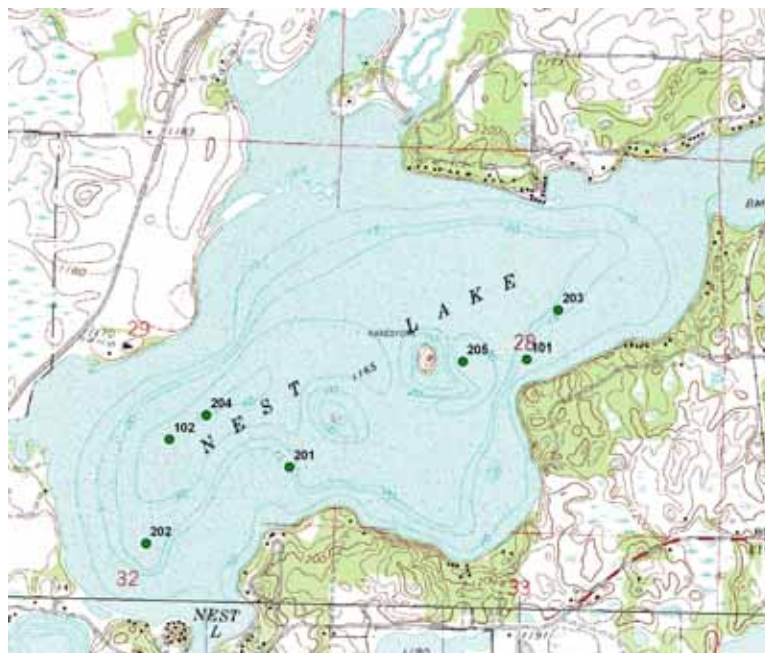


Results

Methods

Data have been collected on Nest Lake for many years by many different groups over the May to September monitoring window. Most recently data have been collected monthly by lake association volunteers at Site 205 (Figure 7; 2007, 2008) and analyzed by RMB Environmental Laboratories in Detroit Lakes. In 2007, MPCA staff sampled the lake as part of NLAP. Data collection involved a one time sampling event which analyzed samples for a wide variety of parameters, including nutrients, pesticides, and metals (sediment). A variety of laboratories were used for the NLAP project; data discussed in this report have been analyzed by the Minnesota Department of Health Laboratory. In 2000 and 2004-2006 samples were collected through monitoring activities by the Middle Fork Crow River Watershed District. These samples were collected twice monthly at sites 204 and 205 and analyzed by ERA Laboratories in Duluth, MN. All data were analyzed using U.S. Environmental Protection Agency (EPA) approved methods.

Figure 7. Established Sites on Nest Lake



Samples were primarily analyzed for total phosphorus and chlorophyll-a. Secchi disk transparency was also collected during sampling events. All data for this report was stored in STORET, EPA’s national water quality data bank.

In-lake Conditions

Dissolved oxygen and temperature. Profiles were taken at one-meter intervals at sites 205 or 101 in 1976, 1978, 1979, 1992, and 2007. A comparison of the mid-summer profiles is found in Figure 8. Nest Lake is thermally well-mixed on most dates, but will stratify intermittently (e.g. July 12, 1978; Figure 8). The dissolved oxygen (DO) typically drops below 5 milligrams per liter (mg/L) (necessary to support game fish) below a depth of 4 to 6 meters (Figure 8). Under these low oxygen conditions, total phosphorus can often be released from the sediments, creating an internal cycling of nutrients that promote algal growth.

Figure 8. Nest Lake Mid-Summer Temperature and Dissolved Oxygen Profiles

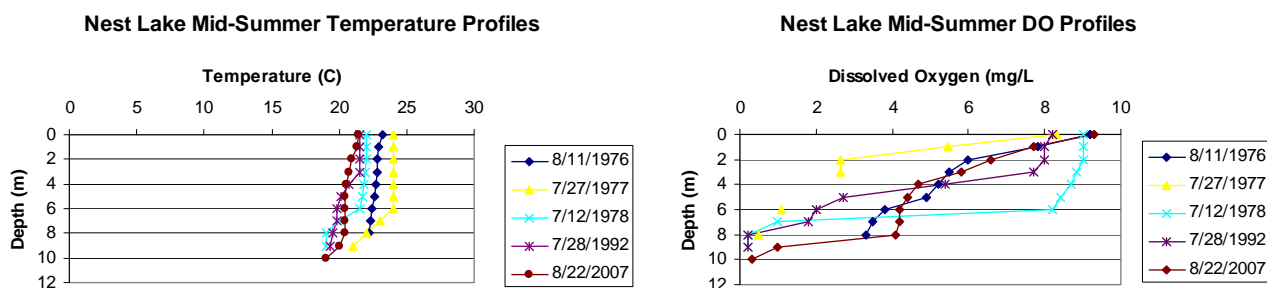
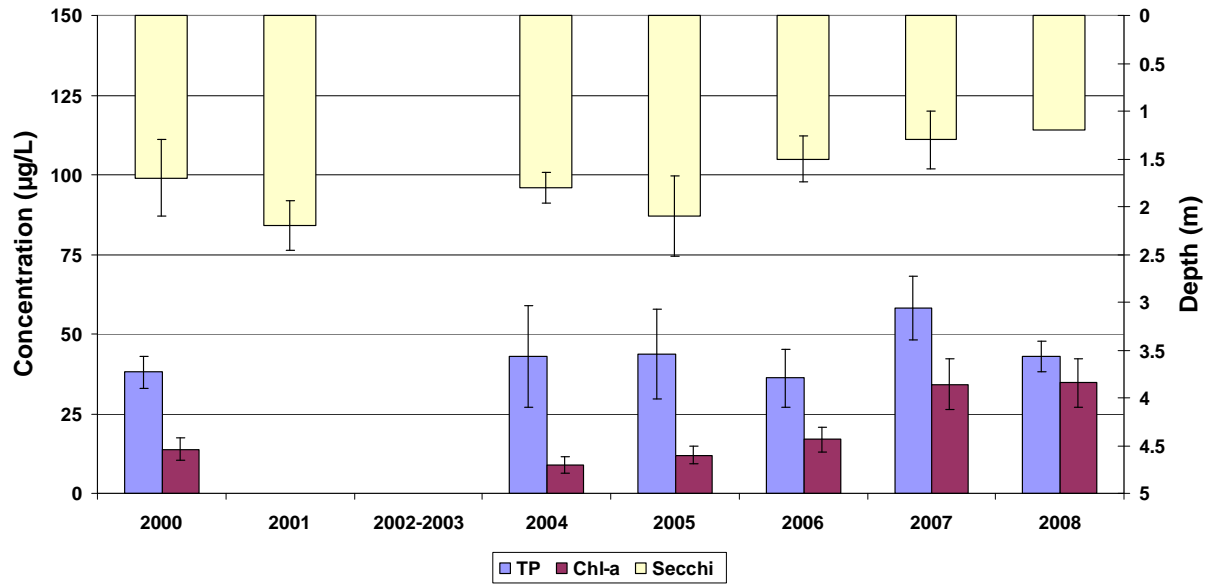


Figure 9 includes standard error bars; if no bars exist; only a single sample was taken for that year. The graph includes data collected from June to September each year; the actively growing season for lakes. For lakes with data on multiple sites, the data were averaged and a whole lake value was depicted (Figure 9 and Table 2).

Figure 9. Nest Lake 2000 to 2008 Summer-Mean Trophic State Parameters



Total Phosphorus. Total phosphorus (TP) is the driving nutrient for plant growth in fresh waters. Since 2000, phosphorus concentrations have ranged from 36 µg/L to 58 µg/L in the surface waters of Nest Lake (Figure 9). These values are on the high end, but generally within the expected range found in NCHF ecoregion reference lakes. TP patterns were consistent over these years, with concentrations increasing across the summer months, typically peaking in September. With polymictic conditions, there is often frequent nutrient exchange between the bottom sediments and the water column. This peak in TP often occurs when rainfall and flows are at their lowest, which further suggests the influence of internal cycling of nutrients.

Chlorophyll-a. Chlorophyll-a, a pigment found in algae, is used to estimate the amount of algal production in a lake. In 2000 and 2004-2006, chlorophyll-a values were well within the expected range of reference lakes in the NCHF ecoregion (Figure 9). In 2007 and 2008, however, the chlorophyll-a values greatly exceeded the expected range (Table 2). Of note is that 2007 and 2008 were both years of lower rainfall during the growing season than the previous years (Table 1); algae prosper during long stretches of warm, sunny days.

Phytoplankton (algae) composition. Nest Lake was sampled for algal composition during the NLAP sampling event in August of 2007. Typically over a season, there is a transition between algal dominance of diatoms to a blue-green algae dominated assemblage. Samples were collected at mid-lake and at one near shore site for the NLAP program. The mid-lake site had 95% blue-green algae and 5% dinoflagellates; the near shore site was comprised only of blue-greens.

Secchi disk transparency. Transparency is generally a function of the amount of algae in the water. Suspended sediments or color (due to dissolved organic material) may also reduce water transparency. While color was low in Nest Lake (5 Pt-Co Units), the total suspended solids and total suspended inorganic solids were well above ecoregion reference lake expected values (data only available for August 2007). Like chlorophyll-a, Secchi transparency values fell within the expected ranges for 2004 through 2006 and then were lower (worse) for 2007 and 2008 (Table 2). This drop in transparency is consistent with the elevated chlorophyll-a concentrations, as algae limit light penetration into the water column. Seasonal patterns of Secchi transparency were similar to those of phosphorus and chlorophyll-a, with transparency often peaking in May or June and declining through August or September each year.

Other parameters. Data on other parameters, such as chloride, alkalinity, and suspended solids were only available from a one time sampling event in August 2007. Based on that one-time measurement, all of the parameters except nitrite + nitrate nitrogen and color exceeded the expected ranges for reference lakes in the NCHF ecoregion. Chloride, total suspended solids, and total suspended inorganic solids were significantly higher than would be expected. Elevated chloride levels are often the result of road-salt application on roads in the watershed.

Table 2. Ecoregion Reference Lake Data Summary Compared to Recent Nest Lake Summer-Mean Averages

Parameter	2000	2004	2005	2006	2007	2008	NCHF
Number of reference lakes							35
Total Phosphorus (µg/L)	38	43	44	36	58	43	23 – 50
Chlorophyll mean (µg/L)	13.8	8.8	12.0	16.9	34.2	34.8	5 – 22
Secchi Disk (meters)	1.7	1.8	2.1	1.5	1.3	1.2	1.5 – 3.2
Total Kjeldahl Nitrogen (mg/L)					1.6		< 0.6 – 1.2
Nitrite + Nitrate-N (mg/L)					<0.05		< 0.01
Alkalinity (mg/L)					160		75 – 150
Color (Pt-Co U)					5		10 - 20
Chloride (mg/L)					17		4 – 10
Total Suspended Solids (mg/L)					11		2 - 6
Total Suspended Inorganic Solids (mg/L)					9.2		1 - 2
TN:TP ratio					36:1		25:1 - 35:1
TSI	55	54	54	56	62	61	

Trophic Status. One way to evaluate the trophic status of a lake and to interpret the relationship between total phosphorus, chlorophyll-a, and Secchi disk transparency 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:

$$\text{Total Phosphorus TSI (TSIP)} = 14.42 \ln (\text{TP}) + 4.15$$

$$\text{Chlorophyll-a TSI (TSIC)} = 9.81 \ln (\text{Chl-a}) + 30.6$$

$$\text{Secchi disk TSI (TSIS)} = 60 - 14.41 \ln (\text{SD})$$

TP and chlorophyll-a are in µg/l and Secchi disk 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 trophic parameters in Nest Lake and respective TSIs are presented in Figure 11. Based on these values, Nest Lake’s current trophic condition would be considered *eutrophic*. Individual TSI values for TP and chlorophyll-a agree quite well with each other; the TSI for Secchi is slightly lower than expected. As a result, relying on Secchi disk transparency alone would likely underestimate the trophic status of the lake. TSI values for individual years can be found in Table 2.

Tributary sampling. As part of the diagnostic study in 2000 and the follow up monitoring in 2004 and 2005, stream sampling for chemistry and flow was conducted. Data from this section is taken from the Middle Fork of the Crow River Kandiyohi County, Minnesota 2004 Update of the 2002 Diagnostic Study (Wilson, et. al 2005) and Middle Fork of the Crow River Lakes Partnership 2005 Monitoring Report (Wilson, et. al 2006).

Total phosphorus flow weighted means were calculated for the entire watershed. The Middle Fork Crow River was monitored just upstream and downstream of Nest Lake. Flow measurements were collected by the Department of Natural Resources and water samples were collected by project volunteers. Coming into Nest Lake the flow weighted means for 2000, 2004, and 2005 were 60, 44, and 56 µg/L TP; at the outlet of the lake, the flow weighted means were calculated at 37, 34, and 32 µg/L TP. Flows for 2004 were near the long term average for the river, while 2005 was well above average flows. The decline in phosphorus from the inlet to the outlet indicates that Nest Lake acts as a sink for phosphorus. This is the result of physical sedimentation of suspended sediment and algal uptake of TP and sedimentation of algae. Suspended sediment and phosphorus adsorbed on the sediment are deposited in the lake. Water exiting the lake has less suspended sediment and phosphorus as a result. This will likely provide a benefit to downstream lakes, such as Green Lake, but will provide a constant source for phosphorus for Nest Lake and contribute to the internal loading in the system.

Water Quality Trends. Nest Lake has a long history of water quality monitoring for total phosphorus, chlorophyll-a, and Secchi depth. All parameters have been quite varied over the historical record; 1977 was an exceptionally bad year for phosphorus; samples were from two dates in mid-summer with two sites sampled per trip. Recent (2000 – 2008) phosphorus and chlorophyll-a levels appear to be improved from the 70s and 80s; however, since 2004, chlorophyll-a has been on the rise (Figure 10). Based on the most recent trend analysis for Secchi transparency, Nest Lake does not show a statistically significant trend of declining or improving transparency. However, the last two sampling seasons have had lower transparency than previous years.

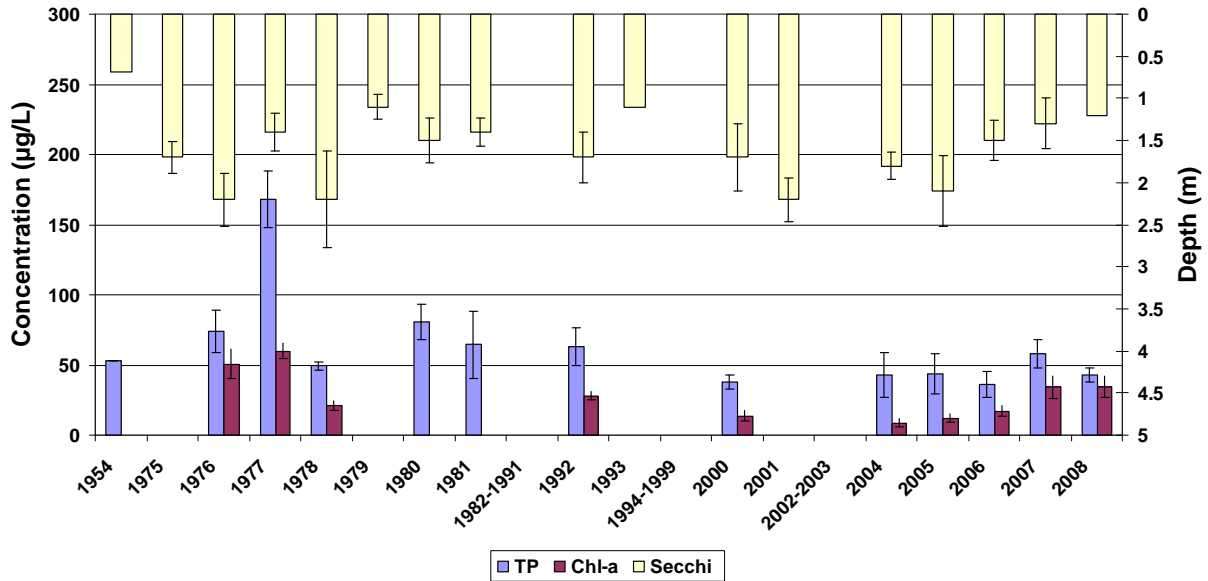
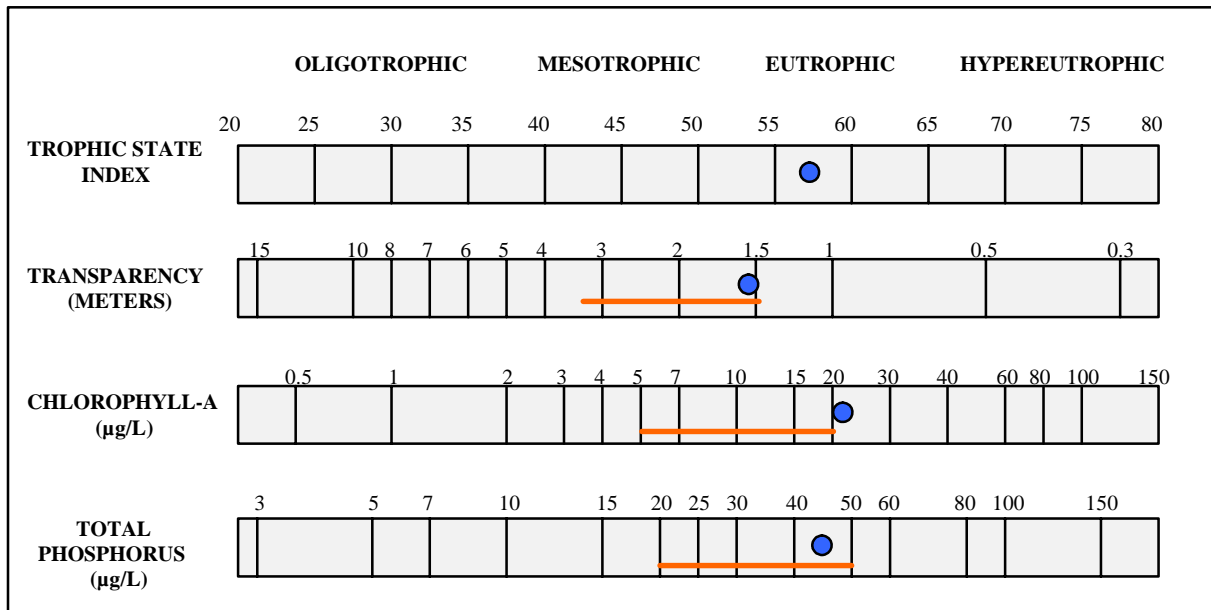


Figure 10. Long-Term Summer-Mean Trophic State Parameters

**FIGURE 11. Carlson's Trophic State Index for Nest Lake
R.E. Carlson**

- TSI < 30** Classical Oligotrophy: Clear water, oxygen throughout the year in the hypolimnion, salmonid fisheries in deep lakes.
- TSI 30 - 40** Deeper lakes still exhibit classical oligotrophy, but some shallower lakes will become anoxic in the hypolimnion during the summer.
- TSI 40 - 50** Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.
- TSI 50 - 60** Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimnia during the summer, macrophyte problems evident, warm-water fisheries only.
- TSI 60 - 70** Dominance of blue-green algae, algal scums probable, extensive macrophyte problems.
- TSI 70 - 80** Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypereutrophic.
- TSI > 80** Algal scums, summer fish kills, few macrophytes, dominance of rough fish.



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

NCHF Ecoregion Range: ————— Nest : ●

Modeling and Phosphorus Loading

Numerous 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. These models can also be used for estimating changes in the quality of the lake as a result of altering nutrient inputs to the lake or altering the amount of water that flows into the lake.

As part of the follow-up diagnostic monitoring that occurred in 2004 and 2005, BATHTUB (Walker, 1985 and 1986) was run on the Nest Lake watershed (Wilson et al 2005, Wilson et al 2006). BATHTUB is an empirical model that was developed by the Army Corps of Engineers to deal with more complex data sets, including tributary and upstream lake data to determine a detailed water and nutrient budget. Based on BATHTUB modeling (Wilson et al, 2006), it was determined that water flowing into and out of Nest Lake at a rate of 48 cubic feet per second (cfs), resulting in a 0.3 to 0.5 year residence time (amount of time it would take to fill the empty lake basin). Based on watershed load monitoring and lake monitoring data, an estimated 80% of the phosphorus in Nest Lake was coming from the Middle Fork Crow River. Approximately 8% was determined to be from internal loading (lake sediments) and approximately 7% from septic systems. The remaining 5% was attributed to precipitation and a small, unmonitored tributary to the lake. These values were calculated during 2005, which was a very wet year. Values for 2004, with more average amounts of precipitation, put phosphorus sources from the river at 49%, internal loading at 36%, with the remainder coming from other small tributaries, precipitation, and failing septic systems. Based on these modeling efforts, it is estimated that the lake retains 40% to 50% of the total phosphorus entering the system (Wilson, et. al, 2005).

To analyze the water quality data recently collected on Nest Lake, MINLEAP (Wilson and Walker, 1989) was used. MINLEAP (Minnesota Lake Eutrophication Analysis Procedure) was developed by MPCA staff based on an analysis of data collected from ecoregion reference lakes. It was intended to be used as a screening tool for estimating lake conditions with minimal input data. MINLEAP was run for Nest Lake and model results were compared to recent data (Table 3). The model was calibrated to match inflowing stream TP concentrations measured during the diagnostic and follow up monitoring efforts. Model predictions are comparable to the lower values observed in recent years (2000 and 2006). Estimated background phosphorus was predicted for 2007 only, with a predicted TP level of 24.4 µg/L.

Table 3. Observed Summer-Mean Compared to MINLEAP Predicted Outputs

Parameter	2000	2004	2005	2006	2007	2008	MINLEAP Prediction
Total Phosphorus (µg/L)	38	43	44	36	58	43	37
Chlorophyll mean (µg/L)	13.8	8.8	12.0	16.9	34.2	34.8	13
Secchi Disk (meters)	1.7	1.8	2.1	1.5	1.3	1.2	1.7

Another way to place lake condition in perspective is to compare modern-day TP concentrations to historic, specifically pre-European conditions (1750 – 1800 time period). One technique for estimating pre-European conditions or changes over time involves the collection of a sediment core from the bottom of the lake. The core is sectioned and the various sections are “dated” by means of various techniques. Diatom fossils in cores can be used to estimate the trophic status of the lake as their environmental requirements are well known (i.e. range phosphorus concentrations). Lakes from across Minnesota's four main lake ecoregions were sampled and pre-European trophic status and trends were developed (Heiskary and Swain, 2002). Nest Lake was not a part of this study, but several nearby lakes in Kandiyohi County were included. Thirty deep, NCHF lakes were analyzed and the resulting range in total phosphorus was 20 to 30 µg/L in pre-European times.

Goal Setting

Eutrophication standards are now in place for assessing the aquatic recreation use support for lakes in Minnesota. For deep lakes in the NCHF ecoregion to be considered supporting aquatic recreation use, the following must be met: TP < 40 µg/L, chlorophyll-a < 14 µg/L, and Secchi disk transparency > 1.4 meters. To be deemed impaired, total phosphorus and either chlorophyll-a or Secchi depth must exceed the standards. Based on data that will be used in the 2010 assessment cycle, Nest Lake would exceed the phosphorus and

chlorophyll-a standards. As a result, it is likely that Nest Lake will be listed as impaired on the 2010 Impaired Waters list.

Table 4. Minnesota Lake Eutrophication Standards

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

For Nest Lake it would be desirable to reduce in-lake total phosphorus levels. Based on modeling done in previous studies and this report and the pre-European diatom-inferred total phosphorus of deep lakes in the NCHF, achieving an in-lake TP on the order of 25-35 µg/L would be recommended. Due to periodic internal recycling of nutrients, there may be a need to address internal as well as external sources of phosphorus.

Recommendations

Numerous recommendations were provided by Wilson et. al (2006) following 3 years of monitoring in the watershed. These recommendations included: examining and upgrading failing septic systems, protecting riparian areas (river and lakeshore), promoting/implementing conservation projects on both agricultural and urban land, and identifying and correcting sources of phosphorus to the Middle Fork Crow River upstream of Nest Lake. In addition, continued citizen transparency monitoring using Secchi disks (lake) and transparency tube (streams) would allow for long-term trends to be tracked.

References

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Glossary

Acid Rain: Rain with a higher than normal acid range (low pH) often caused by polluted air mixing with cloud moisture.

Algal Bloom: An unusual or excessive abundance of algae.

Alkalinity: Capacity of a lake to neutralize acid.

Bioaccumulation: Build-up of toxic substances in fish flesh. Toxic effects may be passed on to humans eating the fish.

Biomanipulation: Adjusting the fish species composition in a lake as a restoration technique.

Dimictic: Lakes which thermally stratify and mix (turnover) once in spring and fall.

Ecoregion: Areas of relative homogeneity. EPA ecoregions have been defined for Minnesota based on land use, soils, landform, and potential natural vegetation.

Ecosystem: A community of interaction among animals, plants, and microorganisms, and the physical and chemical environment in which they live.

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.

Eutrophication: The aging process by which lakes are fertilized with nutrients. Natural eutrophication will very gradually change the character of a lake. Cultural eutrophication is the accelerated aging of a lake as a result of human activities.

Eutrophic Lake: A nutrient-rich lake – usually shallow, “green” and with limited oxygen in the bottom layer of water.

Fall Turnover: Cooling surface waters, activated by wind action, sink to mix with lower levels of water. As in spring turnover, all water is now at the same temperature.

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.

Lake Management: A process that involves study, assessment of problems, and decisions on how to maintain a lake as a thriving ecosystem.

Lake Restoration: Actions directed toward improving the quality of a lake.

Lake Stewardship: An attitude that recognizes the vulnerability of lakes and the need for citizens, both individually and collectively, to assume responsibility for their care.

Limnetic Community: The area of open water in a lake providing the habitat for phytoplankton, zooplankton and fish.

Littoral Community: The shallow areas around a lake’s shoreline, dominated by aquatic plants. The plants produce oxygen and provide food and shelter for animal life.

Mesotrophic Lake: Midway in nutrient levels between the eutrophic and oligotrophic lakes

Nonpoint Source: Polluted runoff – nutrients and pollution sources not discharged from a single point: e.g. runoff from agricultural fields or feedlots.

Oligotrophic Lake: A relatively nutrient- poor lake, it is clear and deep with bottom waters high in dissolved oxygen.

pH Scale: A measure of acidity.

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

Phytoplankton: Algae – the base of the lake’s food chain, it also produces oxygen.

Point Sources: Specific sources of nutrient or polluted discharge to a lake: e.g. stormwater outlets.

Polymictic: A lake which does not thermally stratify in the summer. Polymictic lakes mix periodically throughout summer via wind and wave action.

Profundal Community: The area below the limnetic zone where light does not penetrate. This area roughly corresponds to the hypolimnion layer of water and is home to organisms that break down or consume organic matter.

Respiration: Oxygen consumption

Secchi Disk: A device measuring the depth of light penetration in water.

Sedimentation: The addition of soils to lakes, a part of the natural aging process, makes lakes shallower. The process can be greatly accelerated by human activities.

Spring Turnover: After ice melts in spring, warming surface water sinks to mix with deeper water. At this time of year, all water is the same temperature.

Thermocline: During summertime, the middle layer of lake water. Lying below the epilimnion, this water rapidly loses warmth.

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

Turbidity: Particles in solution (e.g. soil or algae) which scatter light and reduce transparency.

Water Density: Water is most dense at 39 degrees F (4 degrees C) and expands (becomes less dense) at both higher and lower temperatures.

Watershed: The surrounding land area that drains into a lake, river or river system.

Zooplankton: Microscopic animals

Abbreviations and Units

DATE= yr-mo-da
SITE= sampling site ID,
TP= total phosphorus in mg/L (decimal) or μ /L as whole number
TKN= total Kjeldahl nitrogen in mg/L
N2N3= nitrite+nitrate N in mg/L
NH4= ammonia-N in mg/L
TNTP=TN:TP ratio
PH= pH in SU (F=field, L or _=lab)
ALK= alkalinity in mg/L (lab)
TSS= total suspended solids in mg/L
TSV= total suspended volatile solids in mg/L
CON= conductivity in umhos/cm (F=field, L=lab)
CL= chloride in mg/L
DO= dissolved oxygen in mg/L
TEMP= temperature in degrees centigrade
SD= Secchi disk in meters (SDF=feet)
CHLA= chlorophyll-a in μ /L
TSI= Carlson's TSI (P=TP, S=Secchi, C=Chla)
PHEO= pheophytin in μ g/L
PHYS= physical appearance rating (classes=1 to 5)
REC= recreational suitability rating (classes=1 to 5)

Nest Lake Data

Date	Site	Chl-a (ug/L)	Secchi (m)	TP (ug/L)
6/14/2000	3901	5.6	3.6	20
6/29/2000	3901	11.4	2.4	22
7/13/2000	3901	8.9	1.3	43
7/26/2000	3901	9.7	1.2	47
8/15/2000	3901	10.6	1.1	34
8/29/2000	3901	17.9	1.2	49
9/12/2000	3901	32.8	0.9	49
6/22/2004	205	4	1.68	37
7/7/2004	205	7	1.52	23
7/20/2004	205	22	1.83	32
8/3/2004	205	15	1.52	34
8/17/2004	205	2	1.22	54
8/31/2004	205	4	1.68	59
9/14/2004	205	2	2.74	70
6/7/2005	205	1	4.88	26
6/21/2005	205	4	3.35	22
7/5/2005	205	8	2.13	36
7/19/2005	205	15	1.68	43
8/2/2005	205	11	1.37	39
8/16/2005	205	4	1.22	59
8/30/2005	205	25	1.37	54
9/14/2005	205	20	1.37	62
9/27/2005	205	20	1.37	52
6/13/2006	205	5	3.05	28
6/27/2006	205	5	1.98	28
7/11/2006	205	12	1.37	30
7/25/2006	205	16	1.07	32
8/8/2006	205	16	1.07	41
8/22/2006	205	17	1.22	33
9/5/2006	205	29	1.22	44
9/19/2006	205	35	1.22	53
5/20/2007	205	20	2.1	31
6/18/2007	205	16	2.1	31
7/22/2007	205	26	1.2	39
8/22/2007	106	44	0.6	70
9/16/2007	205	59	0.8	63
6/22/2008	205	12		31
7/20/2008	205	42		44
8/14/2008	205	43		43
9/21/2008	205	42	1.2	55