Water Quality Assessments of Select Lakes within the Mississippi River (St. Cloud) Watershed

The Mississippi River (St. Cloud) watershed is located within the Upper Mississippi River Basin and includes portions of Benton, Meeker, Mille Lacs, Sherburne, Stearns, and Wright Counties.

Minnesota Pollution Control Agency

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Executive Summary

The Minnesota Pollution Control Agency (MPCA) conducts and supports lake monitoring for a variety of objectives. Staff within the MPCA's Lakes and Streams Monitoring Unit samples approximately 100 lakes per year, coordinate citizen volunteer monitoring through the Citizen Lake Monitoring Program (CLMP), and manage Surface Water Assessment Grants given to local groups to monitor lake and stream water quality. All water quality data from these activities are compared to state water quality standards to determine if a given lake is fully supporting or not supporting standards set for aquatic recreational use (e.g., swimming, wading, etc.). Lakes not supporting aquatic recreational use are termed "impaired" and are placed on a list biennially. This list is formally termed the 303(d) list (referencing the section within the federal Clean Water Act that requires us to assess for condition); it is also commonly called the "Impaired Waters List." A lake placed on the Impaired Waters List is required to be intensively researched through a Total Maximum Daily Load (TMDL) study to determine the source and extent of the pollution problem. The study also requires the development of a restoration plan. For unimpaired waters, a protection plan will be developed following the assessment process. It should be noted that a great deal of lake monitoring is also carried out by various other MPCA staff and local groups who are undertaking TMDL studies or other, special projects. The purpose of this report is to detail the results of the MPCA's assessments of selected lakes within the Mississippi (St. Cloud) watershed.

This report details the assessment of lakes within the Mississippi (St. Cloud) Hydrologic Unit Code (HUC)-8 watershed. The Mississippi (St. Cloud) watershed is made up of 21 HUC-11 intensively monitored watersheds. A general description at the 8-digit HUC level is provided, followed by discussions for each 11-digit HUC that has one or more assessed lakes. A full list of the assessed lakes, including their morphometric characteristics and assessment results, within the Mississippi (St. Cloud) watershed is located in Appendices A and B.

Of the 79 Mississippi (St. Cloud) watershed lakes possessing assessment level data, 35 were determined to be non-supporting of recreational use. Of the 10 lakes that have insufficient data to complete an assessment, 8 indicate improving water conditions. The Mississippi (St. Cloud) watershed has 34 lakes that have been determined to be fully supporting of recreational use.

Several potential stressors for impaired lakes should be considered during the TMDL study. Typically, Mississippi (St. Cloud) lakes within catchment areas primarily consisting of undisturbed forested or rangeland land uses were determined to be fully supporting. In contrast, lakes that were already receiving high nutrient contributions from large catchment areas also appear to be influenced by a variety of anthropogenic activities. Basin morphology and internal nutrient contributions should also be taken into consideration. Shallower lakes already receiving higher levels of internal contribution typically become more susceptible to impairment when external nutrient levels become elevated.

Through the integral assistance of local environmental partner organizations (LEPO) and citizen input, the Watershed Restoration and Protection Project (WRAP) process will provide the overall water quality framework for strategies and methods for achieving water quality standards for the lakes within the Mississippi (St. Cloud) watershed within an overall watershed plan. The WRAP will integrate TMDLs for the restoration of non-supporting (impaired) lakes and lake protection needs for fully supporting lakes into an implementation plan for the watershed. To help achieve the overall water quality goals for the lakes within the watershed, the implementation plan will identify target areas for the implementation of best management practices.

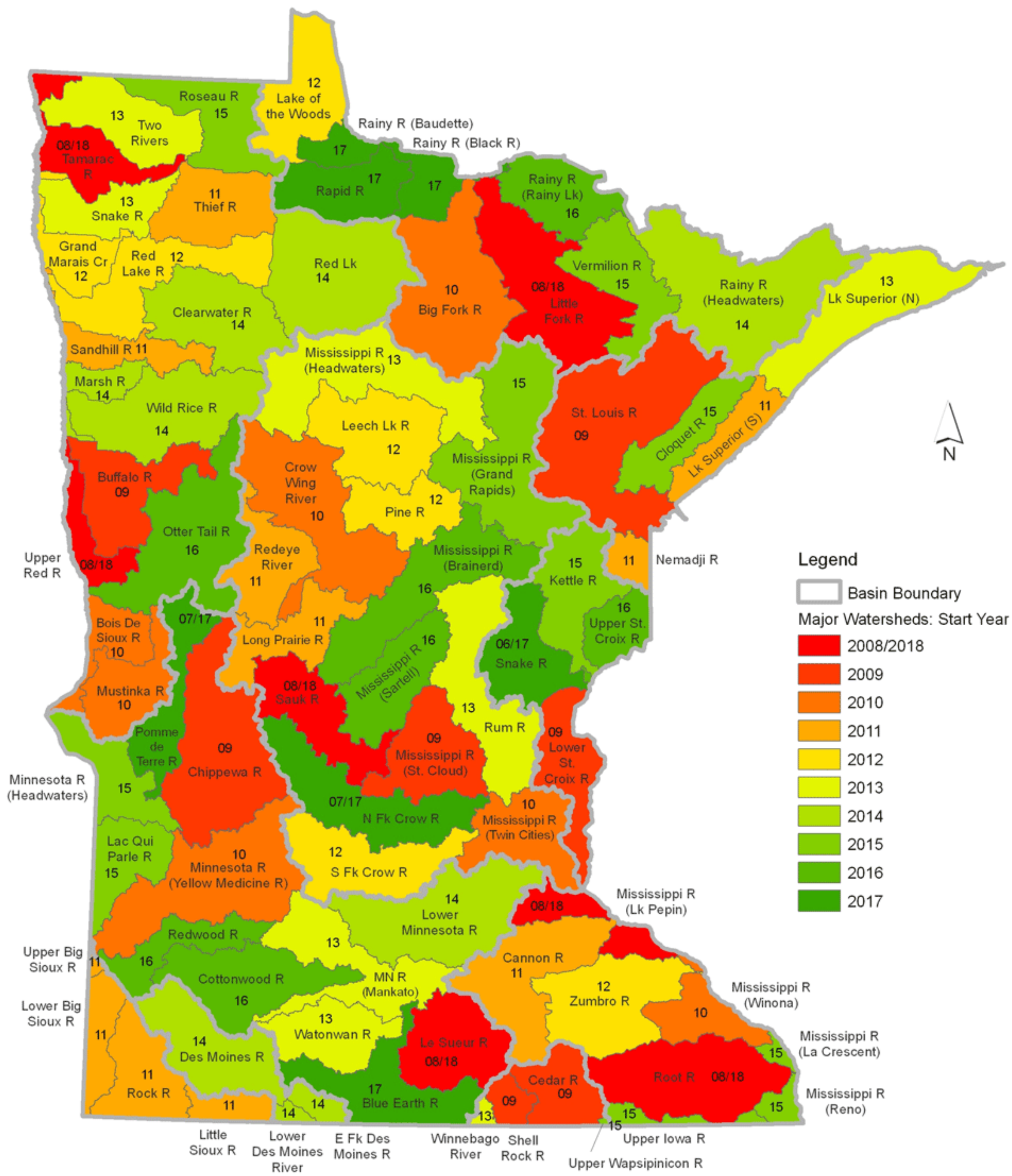
Introduction

The MPCA conducts and supports lake monitoring for a variety of objectives. One of our key responsibilities, per the federal Clean Water Act, is to monitor and assess Minnesota lakes to determine whether or not they are meeting state and federal water quality standards that have been set to ensure support of designated uses. This type of monitoring is commonly referred to as condition monitoring because the purpose is to determine the ambient, or background, condition of the water. Lake condition monitoring activities are usually focused on assessing the aquatic recreational use-support of lakes and identifying trends over time. While the MPCA conducts its own lake monitoring, local partners (soil and water conservation districts, watershed districts, etc.), and citizens play a critical role in helping us because their efforts greatly expand our overall capacity to conduct condition monitoring. To this end, the MPCA coordinates citizen volunteer lake monitoring through the CLMP, and manages Surface Water Assessment Grants given to local groups to monitor lake water quality. All of the water chemistry data from these activities are combined with our own lake monitoring data to assess the condition of Minnesota lakes. The MPCA also assesses lakes for aquatic consumption use-support, based on fish-tissue and water-column concentrations of toxic pollutants; however, that specialized fish sampling work is typically conducted by the Minnesota Department of Natural Resources (MDNR).

The primary organizing approach to MPCA's condition monitoring is the "major" watershed (8-digit HUC). There are 81 major watersheds in Minnesota, and the MPCA has established a schedule for intensively monitoring 6-8 of them annually (Figure 1). With this strategy, we will cycle through all 81 watersheds every 10 years. The MPCA began aligning its stream condition monitoring to this watershed approach in 2007. Lake monitoring was brought into this framework in 2009. The year 2017 will mark the final year of the first 10-year cycle. By intensively monitoring lakes and streams within a given watershed at the same time, the lake and stream data can be considered together to provide a comprehensive picture of water quality status and a determination can be made regarding how best to proceed with development of restoration and protection strategies.

Even when pooling MPCA, local group and citizen resources, we are not able to monitor all lakes in Minnesota. The primary focus of MPCA monitoring is lakes $\geq$500 acres in size ("large lakes"). These resources typically have public access points, they generally provide the greatest aquatic recreational opportunity to Minnesota's citizens, and they collectively represent 72 percent of the total lake area (greater than 10 acres) within Minnesota. Though our primary focus is on monitoring larger lakes, we are also committed to directly monitoring, or supporting the monitoring of, at least 25 percent of Minnesota's lakes between 100-499 acres ("small lakes"). In most years, we monitor a mix of large and small lakes, and provide grant funding to local groups to monitor lakes that fall in the 100-499 acre range. Currently, we are fully meeting the "large" lake goal, and with our local partners' help we are greatly exceeding the "small" lake monitoring goal.

Figure 1. Intensive watershed monitoring schedule



The overall purpose of this report is to provide information to the reader regarding lakes in the Mississippi (St. Cloud) watershed for which condition monitoring has been conducted, and whether or not these lakes are meeting water quality standards set for aquatic recreational use-support. Where available, we also provide long-term water quality trend information. Some technical terms and concepts are introduced in this report to provide context and help the reader understand factors affecting lake water quality. Additional detail on these concepts and terms can be found in the Guide to Lake Protection and Management: http://www.pca.state.mn.us/water/lakeprotection.html.

Methods of Data Collection and Analysis

Lake monitoring and data storage

The MPCA collects water quality data for lakes from May through September for a minimum of two years for condition monitoring. Data collected from June through September are used to assess the lake's condition, while May data are collected to observe lake conditions near the spring turnover and compare them with the remaining seasonal data. Lake surface samples are collected with an integrated sampler, a polyvinyl chloride (PVC) tube 2 meters (6.6 feet) in length with an inside diameter of 3.2 centimeters (1.24 inches). For lakes more than 4-5 meters (13-16 feet) deep, depth samples are also taken using a Kemmerer sampler. Where applicable, depth sample results are used to analyze the levels of internal nutrient contribution. The MPCA's sampling protocols are detailed in the MPCA Standard Operating Procedure for Lake Water Quality document, which can be found at: http://www.pca.state.mn.us/publications/wq-s1-16.pdf.

Samples collected by the MPCA are sent to the Minnesota Department of Health and analyzed using U.S. Environmental Protection Agency (EPA)-approved methods. Samples are analyzed for nutrients (total phosphorus (TP), total Kjeldahl nitrogen, and nitrite-nitrate), color, total suspended solids, total suspended volatile solids, pH, alkalinity, conductivity, chloride, hardness, sulfate, and chlorophyll-*a* (chl-*a*). Temperature and dissolved oxygen (DO) profiles and Secchi disk transparency measurements are also taken. Historical DO and temperature profiles are used for water column analysis in the absence of more recent data.

The CLMP began at the University of Minnesota in 1970, and was transferred to the MPCA in 1977. Through this program, volunteers monitor lakes statewide for transparency using a Secchi disk, which is used to supplement MPCA-collected data. This citizen-collected data has provided us with a rich long-term dataset for many lakes in Minnesota, and CLMP trends are calculated annually.

Data collected by the MPCA, and that submitted to the MPCA by external partners and citizens, are placed into the agency's environmental database, EQuIS. The MPCA makes these data available to the public through the Environment Data Access webpage: http://www.pca.state.mn.us/index.php/topics/environmental-data/eda-environmental-data-access/eda-surface-water-searches/eda-surface-water-data-home.html.

Remotely-sensed transparency

The MPCA and researchers from the University of Minnesota's Remote Sensing Laboratory have partnered on a project that paired citizen-collected Secchi transparency data with Landsat satellite images (primarily Thematic Mapper and Enhanced Thematic Mapper Plus) to determine the water clarity of Minnesota lakes. Through this project, a comprehensive water clarity database has been assembled for Minnesota lakes larger than eight hectare (ha) in surface area at five-year intervals over the period 1985–2005 (Olmanson et al. 2008). The data provide a reasonable estimate of transparency for Minnesota lakes, and comparisons with observed Secchi for the same time frame exhibit a correlation (R^2) on the order of 0.77-0.80 (Olmanson et al. 2008). In many of the intensive watersheds there are adequate observed data that can be used for the assessment process; however, in some remote watersheds with poor access (e.g., Boundary Waters Canoe Area Wilderness watersheds) there are minimal observed data and the remotely-sensed (RS) data provides the best basis for assessing lake condition and trends. Remotely-sensed measures for lakes may be found at http://www.dnr.state.mn.us/lakefind/index.html, and further information and reports on this approach may be found at: http://water.umn.edu/index.html.

Lake morphometry and mixing

Lake area, depth, and mixing have a significant influence on lake processes and water quality. Lake depths of 4.5 meters (15 feet) or less are often well suited for macrophyte (rooted plant) growth and this portion of the lake is referred to as the *littoral* area. Shallow lakes are often well-suited for macrophyte growth and it is not uncommon for emergent and submerged plants to be found across much of the lake. These plant beds are a natural part of the ecology of these lakes and are important to protect.

The size (area) of the lake as compared to the size of its catchment can be an important factor as well. Lakes with small catchment areas relative to their surface area often receive low water and nutrient loading and, absent significant sources of nutrients in their catchment, often have good water quality. In contrast, lakes that have large catchments relative to their surface area often receive high water and nutrient loading, which may result in poor water quality. Modeling, as described in the next section, can help predict the response of the lake.

Thermal stratification (formation of distinct temperature layers), in which deep lakes (maximum depths of nine meters or more) often stratify (form layers) during the summer months and are referred to as *dimictic* (Figure 2). These lakes fully mix or turn over twice per year; typically in spring and fall. Lakes with large surface area and shallow depth (maximum depths of five meters 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. The depth of the thermocline (zone of maximum change in temperature over the depth interval) can also be determined. In general, dimictic lakes have an upper, well-mixed layer (epilimnion) that 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 environment in the hypolimnion is conducive to phosphorus being released from the lake sediments. During stratification, dense colder hypolimnion waters are separated from the nutrient-hungry algae in the epilimnion. Intermittently (weakly) stratified polymictic lakes are mixed in high winds and during spring and fall. Mixing events allow the nutrient rich sediments to be re-suspended and are available to algae.

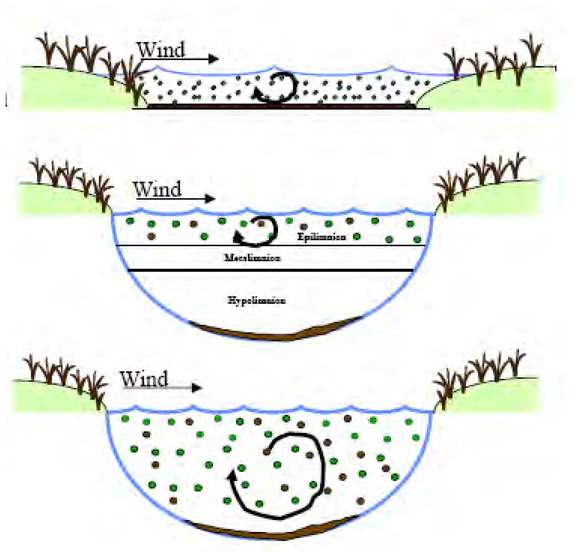
Minnesota's lake water quality standards differentiate between deep and shallow lakes. Shallow lakes are defined as those with maximum depths of 4.6 meters (15 feet) or less or where 80 percent or more of the lake is littoral (≤4.6 meters). As noted above, shallow lakes are often well-mixed and may have extensive growths of macrophytes. In contrast, deep lakes will often stratify during the summer and often have less surface area that can support macrophyte growth.

Figure 2. Lake stratification

Polymictic lake
Shallow, no layers,
Mixes continuously
Spring, summer and fall

Dimictic lake
Deep, form layers,
Mixes spring/fall

Intermittently stratified
Moderately deep
Mixes during high winds
Spring, summer, and fall



Data analysis and modeling

The MPCA applies a standard approach to data analysis of all lakes that we assess. The major steps are as follows:

1. DO and temperature data from the most recent one or two years are reviewed and may be charted as well. Profile data are used to determine whether the lake stratifies, the depth of thermocline, and the presence or absence of oxygen in the bottom waters. Charting profile data is essential for characterizing the lake and it aids in determining whether internal recycling of phosphorus may be a significant contributor to phosphorus loading during summer months. This evaluation also helps determine the proportion of the water column that may be available for fish habitation during the summer.

2. Total phosphorus, chl-*a* and Secchi transparency data from the two most recent summers are evaluated. In most instances, monthly data will be charted to look for correspondence among the TP, chl-*a* and Secchi measures (also referred to as trophic status measures). Charting the data allow us to note patterns that may indicate whether internal recycling and/or shifts in the biology of the lake (macrophyte growth/senescence, zooplankton cropping of algae, etc.) may be important factors in moderating the trophic status of the lake. Where appropriate, hypolimnetic TP data are analyzed, as well. These hypolimnetic measurements can often provide information on the extent of internal recycling from the sediments and whether the lake mixes periodically during the summer months – both of which are of value in a comprehensive assessment of lake condition.

One way to evaluate the trophic status of a lake and interpret the relationship between TP, chl-*a*, and Secchi disk transparency, is Carlson's Trophic State Index (TSI) (Carlson 1977). Comparisons of the individual TSI measures provides a basis for assessing the relationship among TP, chl-*a*, and Secchi. TSI values are calculated as follows:

Total Phosphorus TSI (TSIP) = 14.42 ln (TP) + 4.15

Chlorophyll-*a* TSI (TSIC) = 9.81 ln (chl-*a*) + 30.6

Secchi disk TSI (TSIS) = 60 – 14.41 ln (SD)

Total phosphorus and chl-*a* are measured in units of micrograms per liter (µg/L) and Secchi disk is in meters. TSI values range from 0 (ultra-oligotrophic) to 100 (hypereutrophic). In this index, each increase of 10 units represents a doubling of algal biomass. In most lakes, where phosphorus is the limiting nutrient, TSI values are in fairly close correspondence with each other. Individual assessments for each assessed lake may include TSI values and charts as needed to complement the overall assessment.

3. Long-term datasets of summer-mean TP, chl-*a* and Secchi data are assessed, where available. These data are typically charted and analyzed for trends. If a statistically-based CLMP trend analysis has been conducted by the CLMP coordinators that will be noted, as well. If a trend is determined and the investigator is aware of potential causes for the trend, the writer will also include this information.

4. 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 flow or amount of water that enters the lake. To analyze the most recent water quality of lakes within the watershed, the Minnesota Lake Eutrophication Analysis Procedures (MINLEAP) model (Wilson and Walker, 1989) was used. 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 detail in Wilson and Walker (1989). For the analysis of lakes within the watershed, MINLEAP was applied as a basis for comparing the observed TP, chl-*a*, and Secchi values with those predicted by the model based on the lake depth and size and the size of the watershed.

Lake Assessment Process

The federal Clean Water Act requires states to adopt water quality standards to protect waters from pollution. The standards are set on a wide range of pollutants, including bacteria, nutrients, turbidity, and mercury, and they define how much of a pollutant can be in the water and still allow it to meet designated uses, such as drinking water, fishing and swimming, etc. A water body is “impaired” if it fails to meet one or more water quality standards.

Under Section 303(d) of the Clean Water Act, the state is required to asses all waters of the state to determine if they meet water quality standards. Waters that do not meet standards are added to the 303(d) Impaired Waters List and updated every even-numbered year. If a water resource is listed, an investigative study termed a TMDL is conducted to determine the sources and magnitude of the pollution problem, and to set pollutant reduction goals needed to restore the waters. The MPCA is responsible for monitoring surface waters, assessing condition of lakes and streams, creating the 303(d) Impaired Waters List, and conducting or overseeing TMDL studies in Minnesota.

In Minnesota, TP, chl-*a*, and Secchi transparency are used to determine if a lake meets aquatic recreational use standards (ARUS). Chlorophyll grows in response to nutrients (notably, phosphorus) and is a measure of algal growth in the lake. Excessive algal growth leads to diminished water clarity, and lower Secchi readings. Minnesota’s ecoregion-based lake eutrophication standards are listed in Table 1. The appropriate standards are based on which ecoregion the lake is located and whether the lake is considered deep or shallow. For a lake to be considered impaired (i.e., not supporting – NS – of water quality standards), it must exceed the causative variable (TP) and one or more of the response variables (chl-*a* and Secchi transparency). A full support designation (FS) indicates that the data do not exceed the causative variable (TP) and one or more of the response variables (chl-*a* and Secchi transparency). At least 8 measurements of TP, chl-*a*, and Secchi within the most recent 10 years (MPCA, 2010) spread over a minimum of two years are required for assessment. The MPCA will only consider data that have been submitted to EQuIS, the national repository for water quality data. Sometimes, a lake is designated as having insufficient information (IF) for assessment. This means that there are either not enough data points for one of the three parameters (TP, chl-*a*, Secchi) or that the dataset is robust enough, but the data themselves are hovering close to the water quality standards, making a clear assessment difficult.

Table 1. Minnesota lake eutrophication standards by ecoregion and lake type (Heiskary and Wilson, 2005) and 2010 303(d) assessment values

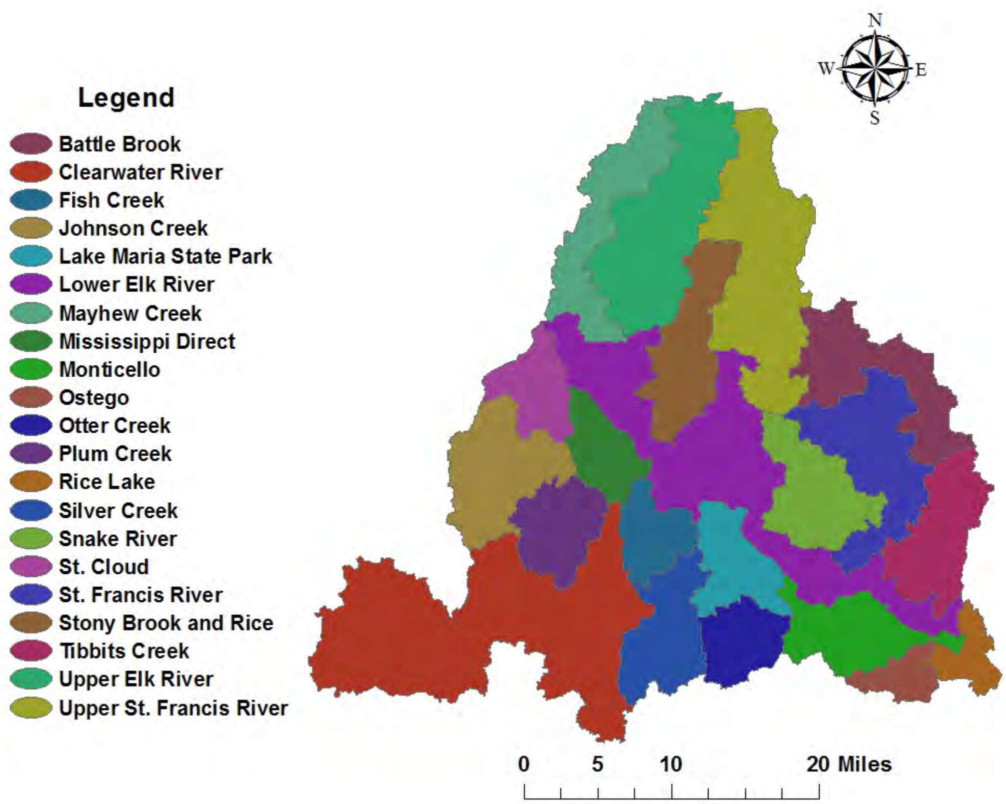
Ecoregion	TP	Chl-*a*	Secchi
	ppb	ppb	meters
NLF – Lake trout (Class 2A)	< 12	< 3	> 4.8
NLF – Stream trout (Class 2A)	< 20	< 6	> 2.5
NLF – Aquatic rec. use (Class 2B)	< 30	< 9	> 2.0
NCHF – Stream trout (Class 2a)	< 20	< 6	> 2.5
NCHF – Aquatic rec. use (Class 2b)	< 40	< 14	> 1.4
NCHF – Aquatic rec. use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

*The NCHF ecoregion standards were used for assessing lakes in the Mississippi (St. Cloud) watershed.

Mississippi (St. Cloud) Watershed

The MPCA is intensively monitoring all of Minnesota's 81 major watersheds on a 10-year rotational basis. The major watersheds in Minnesota are classified using a standardized numbering convention called Hydrologic Unit Codes (HUCs) developed by United States Geological Survey (USGS) in the mid-1970s. Hydrologic units are watershed boundaries organized in a nested hierarchy by size (Seaber, P.R., et al. 1987), wherein watersheds with larger HUC designations are nested within a watershed with a smaller HUC designation. Thus, each major watershed (HUC-8) is comprised of many, smaller contributing subwatersheds (11-digit HUC). The Mississippi (St. Cloud) watershed has 21 subwatersheds (Figure 3), of which 13 will be described in more detail within this report.

Figure 3. Subwatersheds within the Mississippi (St. Cloud) watershed



Watershed characteristics and land use

Minnesota is divided into seven regions, referred to as ecoregions, as defined by soils, land surface form, potential natural vegetation and land use (Omernik 1987). Because ecoregion characteristics such as soils, land surface form, natural vegetation and land use affect lake water quality, water quality standards are ecoregion-specific. 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. The Mississippi (St. Cloud) watershed lies within the North Central Hardwood Forest (NCHF) ecoregion (Figure 4). The North Central Hardwood Forest water quality standards will be used for summer-mean water quality comparisons. Additionally, the NCHF ecoregion will be used for model applications.

The Mississippi (St. Cloud) watershed covers a 289,861 hectare (717,479 acre) area in central Minnesota within the Upper Mississippi River Basin. The watershed drains to the southeast into the Lower Mississippi River approximately three miles southeast of Elk River, Minnesota. Watershed areas were estimated based on data from the National Landcover Dataset prepared by the United States Department of Agriculture Natural Resources Conservation Service (2006).

An overall land use comparison between the Mississippi (St. Cloud) watershed and typical values for the NCHF ecoregion are presented in Figure 5. A majority of the land use within the Mississippi (St. Cloud) watershed is made up of cultivated cropland. The central to east central portion of the HUC-8 watershed does have several areas where forest is dominant and the northern portion is made up of large areas of pasture and rangeland.

The distribution of land use throughout each of the subwatersheds within the Mississippi (St. Cloud) watershed also indicates a dominance of cultivated cropland. Figure 6 shows the variability among the subwatersheds. Additional discussion will be included within each of the subwatershed and lake catchment watershed portions of this report. The distribution of registered feedlots and surface discharging National Pollutant Discharge Elimination System permitted facilities are found in Figure 7.

Figure 4. Minnesota's EPA-mapped ecoregions and Mississippi (St. Cloud) watershed location

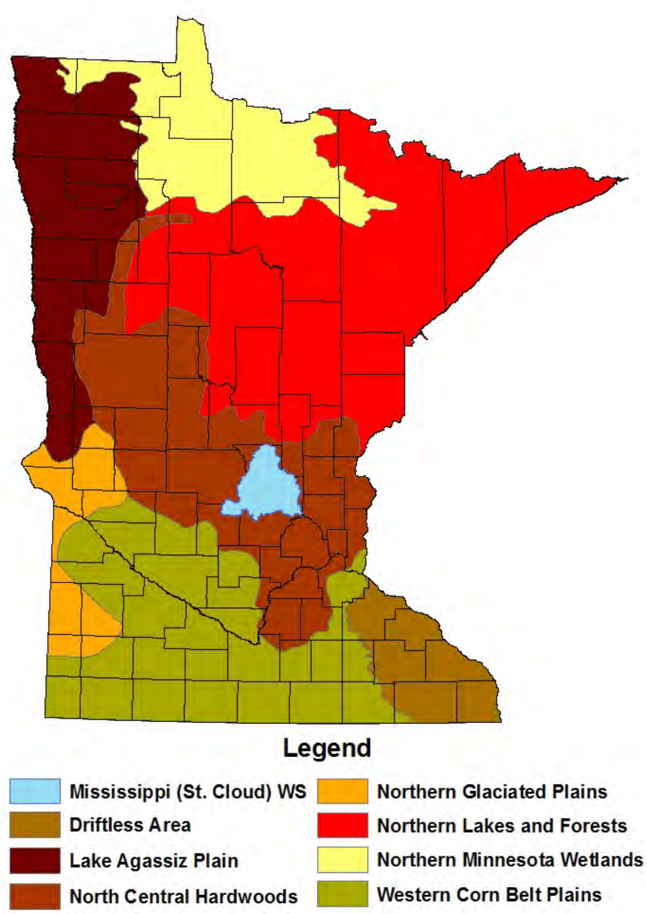


Figure 5. Land use distribution in the Mississippi (St. Cloud) watershed

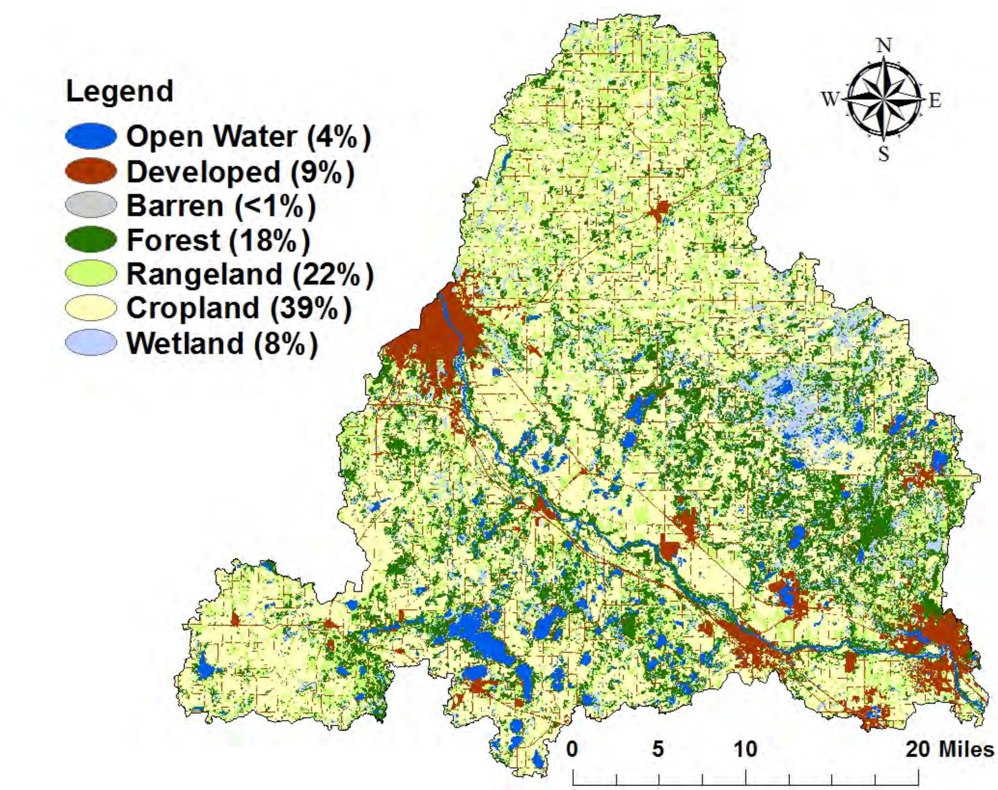


Figure 6. Land use in subwatersheds within the Mississippi (St. Cloud) watershed by HUC-11 subwatershed

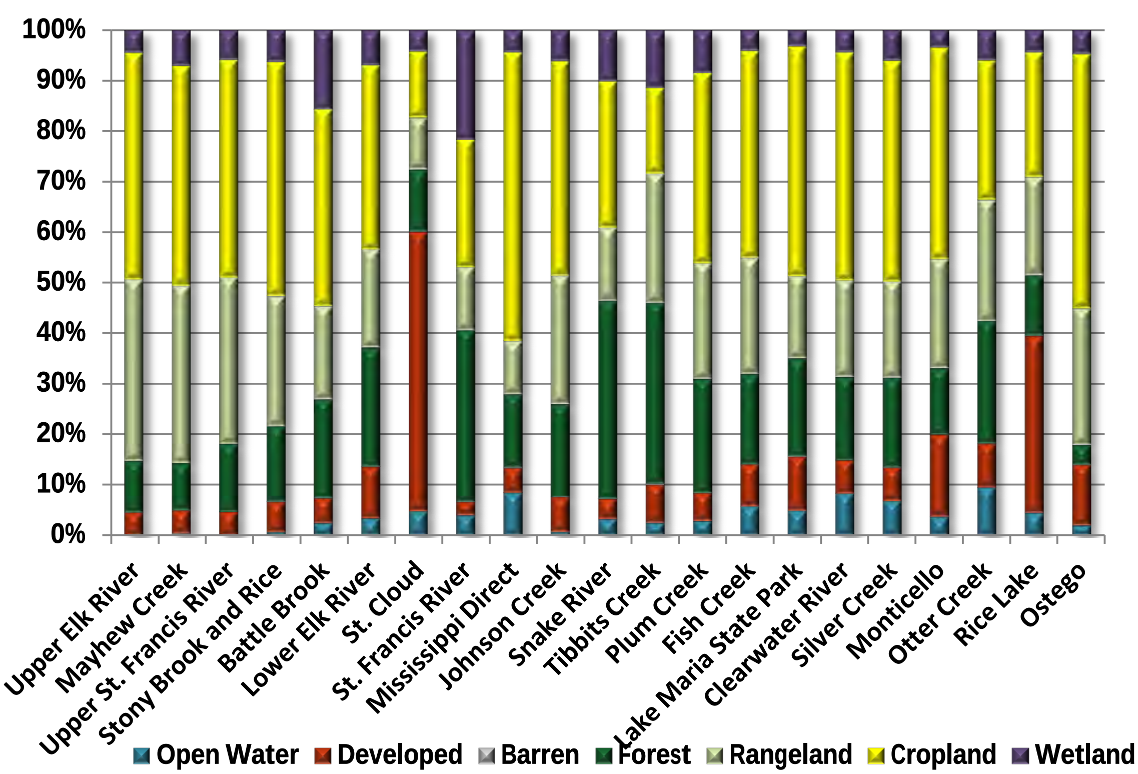
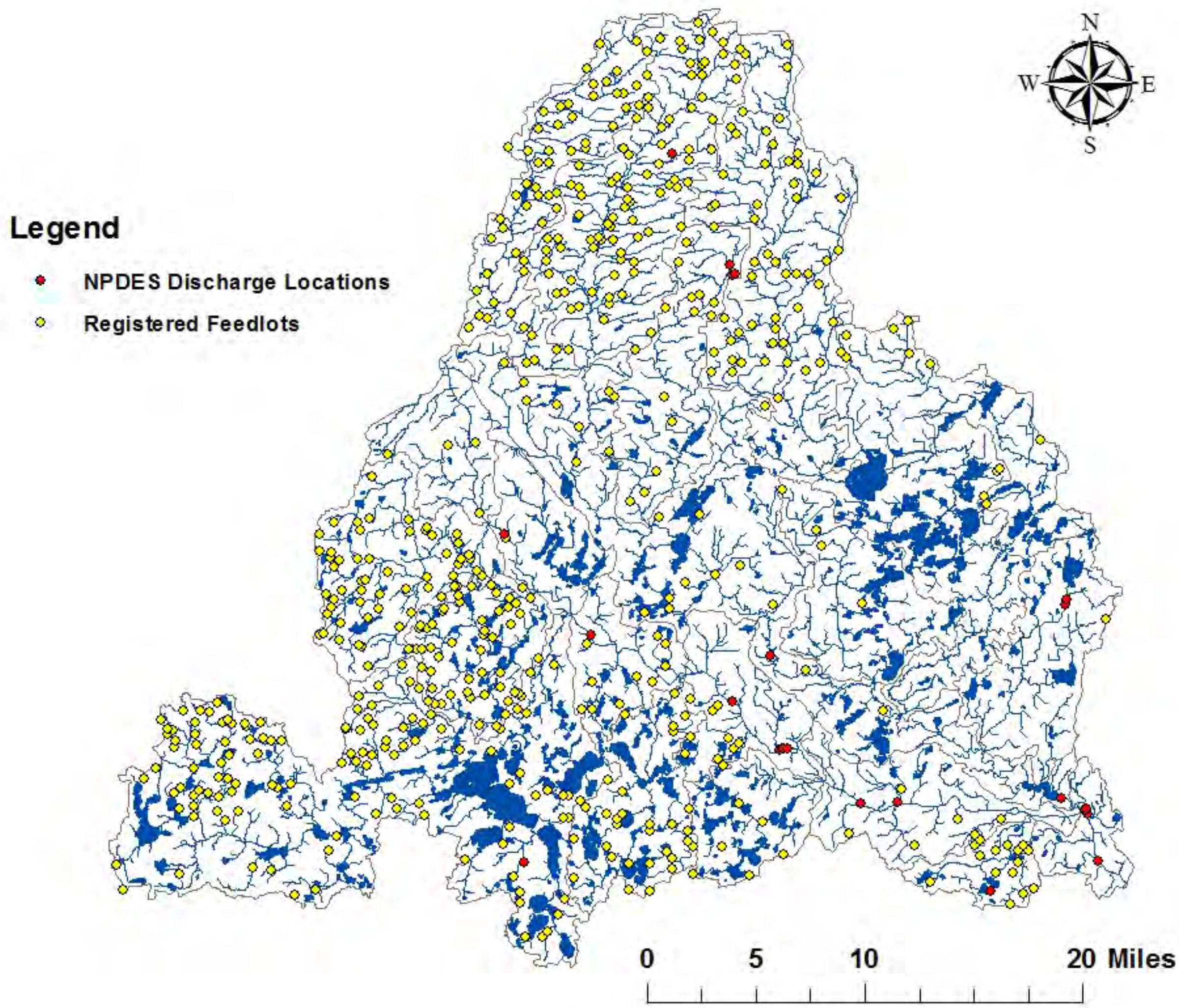


Figure 7. Permitted facilities within the Mississippi (St. Cloud) watershed

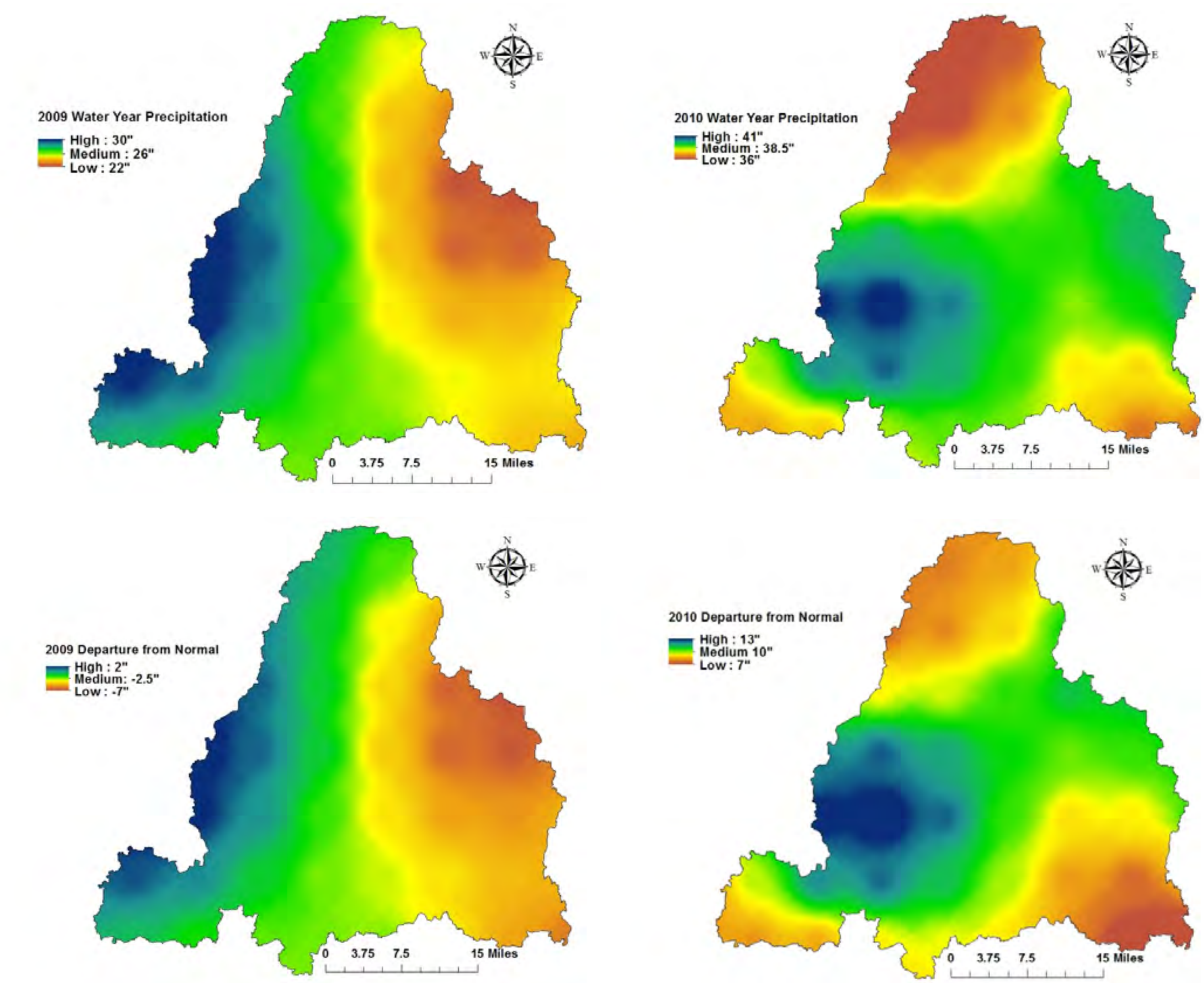


Precipitation and climate

Minnesota's climate is highly variable from year-to-year throughout the state as well as within each of Minnesota's 81 major watersheds. Precipitation is important to lake water budgets in the Mississippi River (St. Cloud) watershed. Stream inflow and groundwater recharge are major components to the water budget of lakes and are driven by annual precipitation amounts. How water moves through the watershed has the ability to influence in-lake water quality and lake levels. High intensity convective storms have the ability to precipitate several inches of water in a localized area within a short period of time.

State climatology precipitation records for the 2009 and 2010 water year (October 2009 through September 2010 and October 2010 through September 2011) indicated higher amounts in 2010. Median precipitation averages for 2009 were 0.3 meters (12.5 inches) below what was recorded in 2010 for the Mississippi (St. Cloud) watershed. Additionally, the 2009 water year precipitation departure from normal was 0.2 meters (7.5 inches) less than 2010 recorded levels (Figure 8). Water Year Precipitation and Water Year Departure from Normal maps indicate that the range of precipitation throughout the watershed can vary by as much as 0.5 meters (19 inches).

Figure 8. 2009 and 2010 Minnesota water year precipitation and departure from normal for the Mississippi (St. Cloud) watershed (State Climatological Office – DNR Waters)



Geology

A variety of soil types are found within the watershed but primarily consist of coarse- to medium-textured prairie and forest soils of east-central Minnesota and formed from the glacial outwash. Benton County soils are defined as light colored well drained with a gently rolling landscape with moderately long slopes. Significant differences are found in the portion of the watershed that lies within Sherburne County, northern Wright County, and eastern Stearns County. Soils in this area are darker with a mix of peat organic soils in northern Sherburne County and mineral soils with a nearly level landscape in southern Sherburne, northern Wright, and eastern Stearns Counties. Stoniness is commonly a problem in the Benton County area and droughty conditions and wind erosion occurs within Sherburne, Wright, and Stearns Counties (Arneman 1963).

Monitoring within the watershed

The Mississippi (St. Cloud) watershed is comprised of 21 HUC-11 minor watersheds (Figure 3). There are 13 HUC-11 subwatersheds that have lakes with sufficient monitoring data to allow for an assessment. A summary of the morphometric characteristics of these lakes is presented in Appendix B. Of the 176 lakes (> 10 acres) within the HUC-8 watershed, only 79 have been monitored (Table 2). Percent littoral area refers to that portion of the lake that is 4.5 meters (15 feet) or less in depth, which often represents the depth to which rooted plants may grow in the lake. Lakes with a high percentage of littoral area often have extensive rooted plant (macrophyte) beds. These plant beds are a natural part of the ecology of these lakes and are important to protect.

Lake distribution within the Mississippi (St. Cloud) watershed is heavier in the southern two thirds with the Benton County portion being fairly sparse. Significant lake resources include Clearwater, Elk, Mink, Maple, Sugar, Cedar, Clear, and Pleasant Lakes as well as the Briggs Chain of Lakes. One lake, George (73-0611-00), is classified as a non-protected manmade lake, but was assessed based on an abundance of sufficient data. Water clarity data were collected within the Melrose Deep Quarry (73-0701-00), also unprotected; however, due to incomplete data, an assessment was not completed. A moderate amount of assessable lake water quality data has been collected in the watershed, with most lakes having little or no historical water quality data collected. A majority of the protected lakes within the watershed are within the 4-40 hectare (10-99 acre) size range (Figure 9). A majority of the surface water data collection within the Mississippi (St. Cloud) watershed was coordinated by local partners paired with citizen monitoring volunteers.

Figure 9. Distribution of protected lakes within the Mississippi (St. Cloud) watershed by lake area

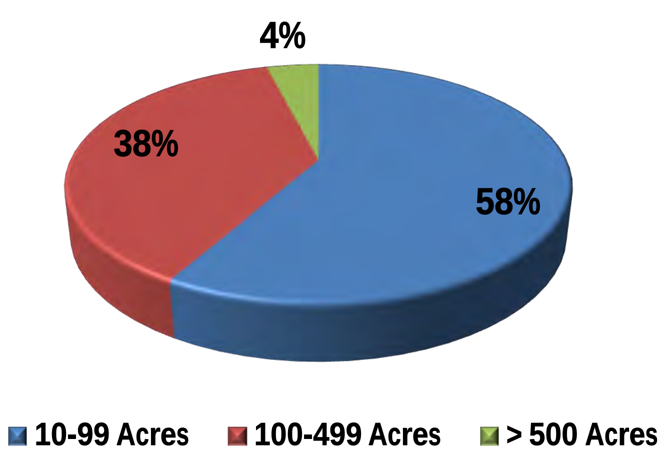


Table 2. Lake distribution by watershed

Subwatershed name	Area (acres)	Percent of watershed area	Number of lakes >4 ha (10 ac)	Sufficient data to assess	Insufficient data to assess	No water quality data
Upper Elk River	52,458	7.3	-	-	-	-
Mayhew Creek	34,002	4.7	1	1	-	-
Stony Brook and Rice	29,158	4.1	1	-	-	1
Lower Elk River	82,896	11.6	18	11	-	7
Snake River	28,112	3.9	14	1	1	13
Upper St. Francis River	63,444	8.8	2	-	-	9
Battle Brook	34,502	4.8	8	3	-	5
St. Francis River	38,653	5.4	26	-	-	26
Tibbits Creek	29,090	4.1	9	2	-	7
Mississippi Direct	15,890	2.2	7	3	-	4
St. Cloud*	17,118	2.4	1	-	1	-
Johnson Creek	33,326	4.6	1	1	-	-
Plum Creek**	20,958	2.9	6	5	-	1
Clearwater River	115,313	16.1	46	25	4	21
Fish Creek	15,489	2.2	3	1	-	2
Silver Creek	26,106	3.6	21	10	-	11
Lake Maria State Park	19,766	2.8	-	-	-	-
Otter Creek	16,893	2.4	13	5	3	5
Monticello	25,062	3.5	-	-	-	-
Ostego	9,271	1.3	3	2	-	1
Rice Lake	9,972	1.4	-	-	-	-

*Two lakes not classified as protected waters
**Three wetlands assessed as lakes due to basin characteristics

Subwatersheds of the Mississippi (St. Cloud) Watershed

Each major watershed can be broken down into smaller units known as subwatersheds (i.e., 11-digit Hydrologic Unit Code watersheds). While lakes can be assessed independent of subwatersheds, considering subwatershed factors sometimes comes into play when streams or major rivers flow into lakes or through chains of lakes. The subwatershed scale also allows us to more practically investigate pollution problems within a watershed, and effectively develop, manage, and implement effective TMDLs and protection strategies.

The Mississippi (St. Cloud) watershed is comprised of 21 subwatersheds. The Upper Elk River, Stony Brook and Rice, Upper St. Francis, St Francis, Lake Maria State Park, Monticello, and Rice Lake subwatersheds did not have lakes with sufficient data to assess. For that reason, lake assessment results within those subwatersheds will be excluded from the following discussion.

The NCHF ecoregion standards were used for assessing lakes in the Mississippi (St. Cloud) watershed. All average results presented in lake assessment discussions represent data from the most recent 10 years of water monitoring. The following subwatershed sections will proceed in hydrological order based on the HUC-11 ordering system. Each subwatershed discussion will include summaries of lakes with sufficient condition monitoring data to allow assessment and the ARUS result, MNLEAP modeling results at the HUC-11 scale, and a brief water quality narrative for each assessed lake. When available, trend information will also be discussed. MNLEAP modeling results for all assessed lakes can be found in Appendix C.

Mayhew Creek subwatershed

The Mayhew Creek (07010203020) HUC-11 watershed lies in the northwestern tip of the Mississippi (St. Cloud) watershed. This 13,737 hectare (34,002 acre) subwatershed represents 4.7 percent of the Mississippi (St. Cloud) watershed (Figure 10 and Table 2). Mayhew Creek pours into the Lower Elk River watershed approximately 5 miles east of St. Cloud, Minnesota. Based on 2003 National Pollutant Discharge Elimination System/State Disposal System (NPDES/SDS) registered feedlot data, there are no permitted discharge sites and 55 registered feedlots throughout the Mayhew Creek subwatershed (Figure 6).

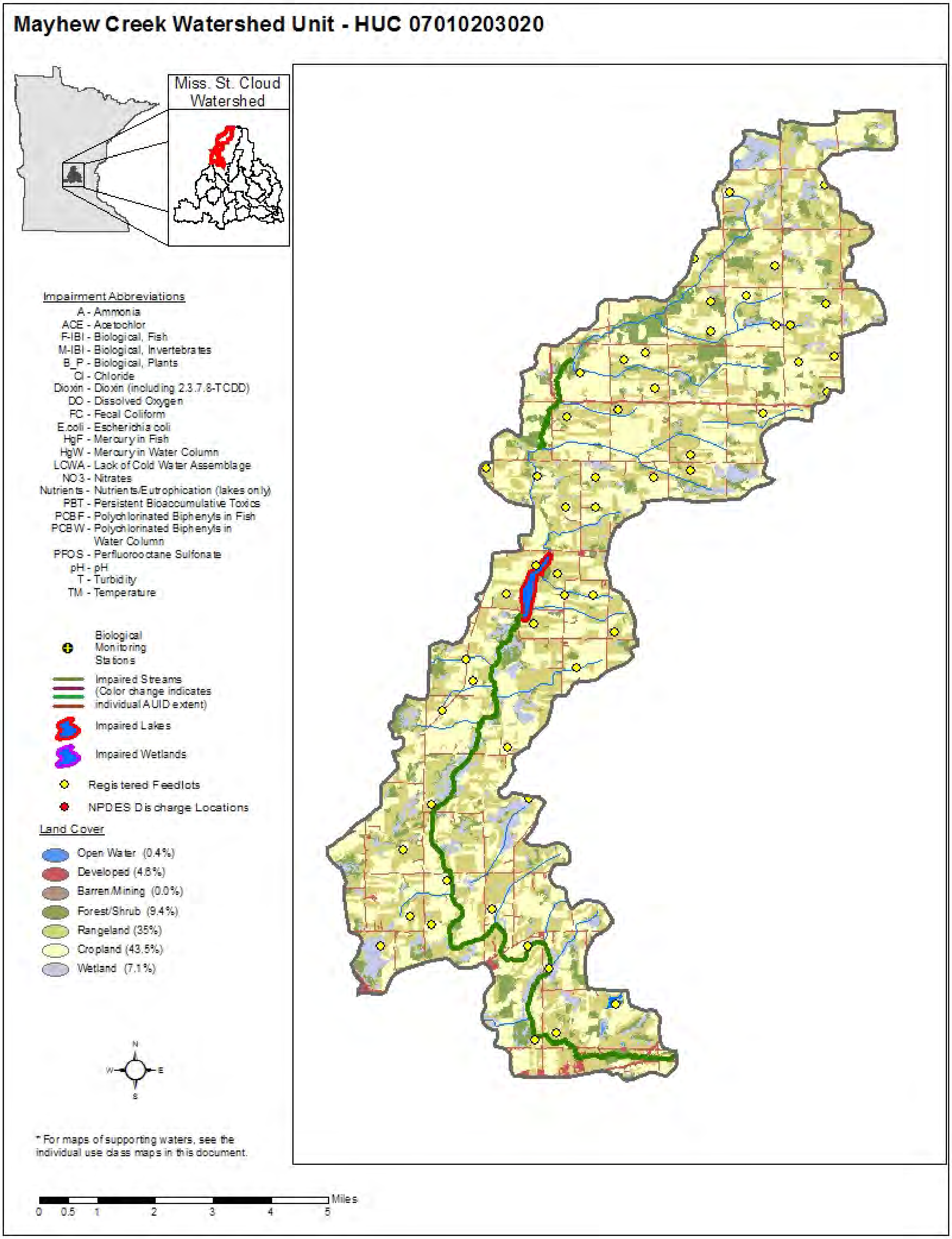
The Mayhew Creek subwatershed consists of only one lake greater than 4 hectares (10 acres) that was reviewed for aquatic recreation use (Table 3). Mayhew Lake lies central within the subwatershed and receives direct input from Mayhew Creek. Mayhew Lake was determined to be non-supporting for aquatic recreation use due to excess nutrient amounts. A review of the assessable data indicated a strong data set to determine the lakes impairment status. Land use within Mayhew Creek is consistent throughout with cropland and rangeland dominating (Figure 10). A more detailed description of Mayhew Lake will follow.

The MINLEAP model indicated that the observed TP for Mayhew Lake was significantly higher than the predicted value. This simply means that the observed TP was much higher than what was predicted for a lake of its size, depth, and watershed area in the NCHF ecoregion. The model predicted TP loading at 1,554 kilograms per year (kg/yr). This result is likely lower than the actual loading rate since the observed TP was higher than predicted. The areal water load to the lake was estimated at 20 meters per year (m/yr) and estimated water residence time is approximately 0.2 years. Background TP (Vighi & Chiaudani TP) was not calculated because alkalinity data was not available. The complete modeling results can be found in Appendix C.

Table 3. Summary of lake eutrophication assessment results for the Mayhew Creek subwatershed

Lake Name	DNR Lake ID	County	Lake Area	Maximum Depth	ARUS
Mayhew	05-0007	Benton	51	6.1	NS

Figure 10. Lake assessments and land use within Mayhew Creek subwatershed



Mayhew Lake 05-0007-00

Mayhew Lake is a small, relatively deep lake located approximately four and a half miles southeast of Rice, Minnesota. Mayhew Lake's watershed is large with an area of 7,999 hectares (19,799 acres) and a watershed to lake ratio of 156:1. Land use is dominated by cropland and rangeland with the cropland percentage being above the range of values expected for the NCHF ecoregion (Appendix D).

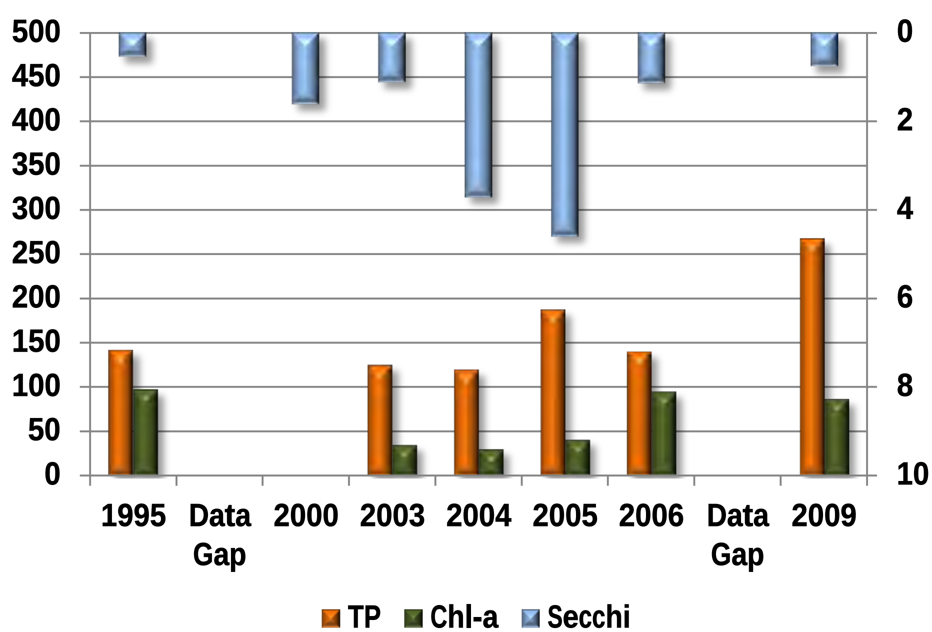
The average TP and chl-*a* values for Mayhew Lake were 171 µg/L and 50 µg/L respectively. Each was well above the water quality standard for lakes within the NCHF ecoregion. TP and chl-*a* data, collected in 2009, ranged from 134 µg/L to 394 µg/L and 31 µg/L to 204 µg/L respectively. Despite the high levels of TP and chl-*a*, the water clarity for Mayhew Lake was below the water quality standard with an average of two and a half meters (8.2 feet) (Appendix A).

Profile data, collected in 2009, indicates that a distinct thermocline formed between one and two meters (3.3 and 6.6 feet) from June through September with mixing occurring in the spring and fall. This suggests that Mayhew Lake typically stratifies during the summer months. Additionally, DO remained above 5 mg/L to a depth of three meters (9.8 feet) during the summer months.

Long-term water quality data for Mayhew Lake is sporadic and impaired conditions existed during each of the recorded years. Figure 11 indicates higher water clarity in 2004 and 2005; however, data collected since shows a decline in Secchi levels as well as an increase in TP.

Based on the chemical monitoring results and water clarity, Mayhew Lake was classified as a hypereutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Mayhew Lake was determined to be non-supporting of aquatic recreational use and was previously listed as an impaired water under the 2008 303(d) Impaired Waters List. Recent data supports this listing.

Figure 11. Mayhew Lake long-term water quality data



Lower Elk River subwatershed

The Lower Elk River (07010203040) HUC-11 watershed is central within the Mississippi (St. Cloud) watershed. This 33,490 hectare (82,896 acre) subwatershed represents 11.6 percent of the Mississippi (St. Cloud) watershed (Figure 12 and Table 2). Based on 2003 NPDES/SDS registered feedlot data, there are 2 permitted discharge sites and 19 registered feedlots throughout the Lower Elk River subwatershed (Figure 6).

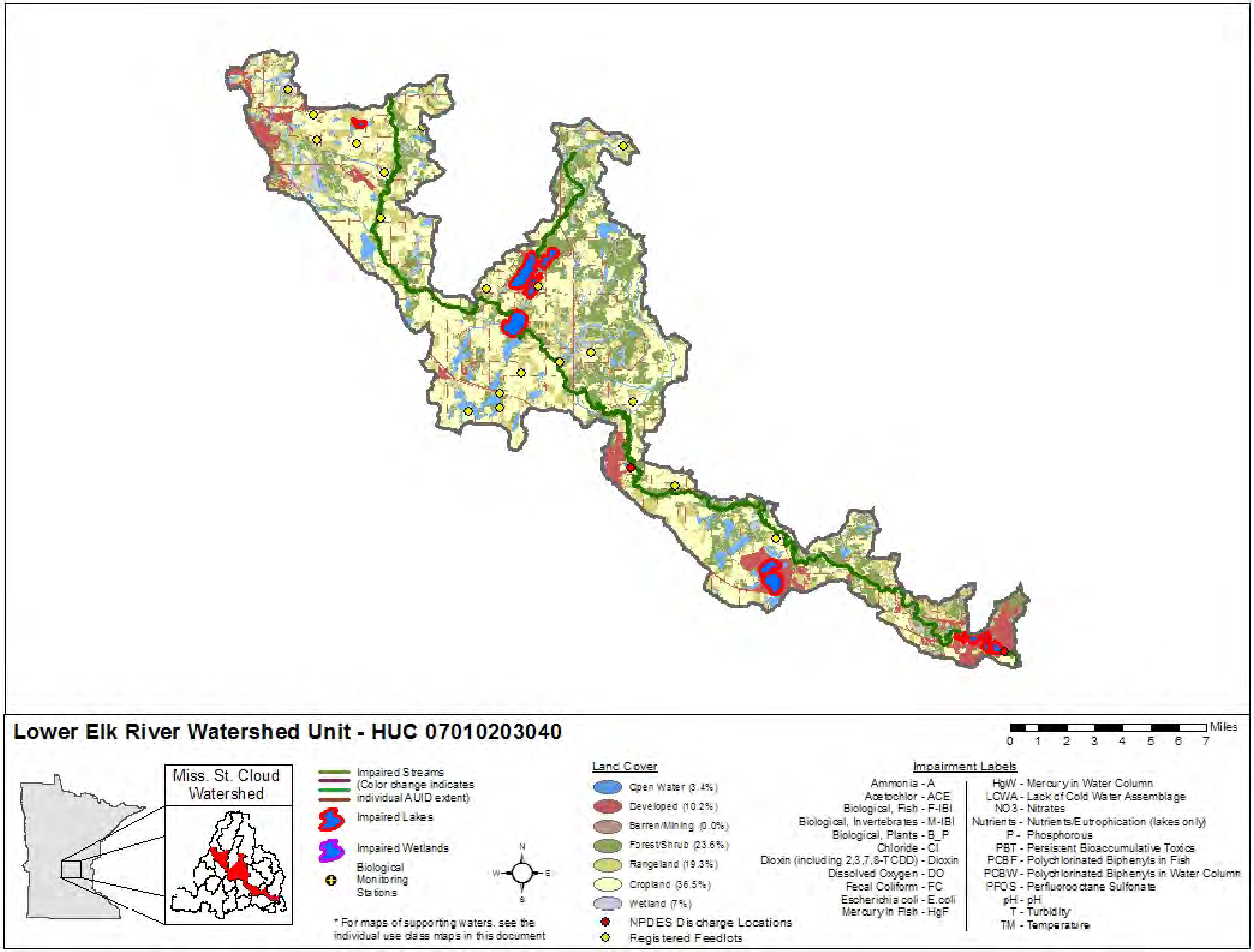
The Lower Elk River subwatershed consists of 18 lakes greater than 4 hectares (10 acres, of which 11 were reviewed for aquatic recreational use (Table 4). A majority of the lakes in this subwatershed are shallow basins and are evenly distributed throughout the Lower Elk River. Lakes that consisted of small catchment watersheds and received little contribution from the subwatershed, Mitchell, Big, Thompson, and Camp, were fully supporting for aquatic recreation use. Donovan and Julia were exceptions, each received minimal catchment contribution but both were listed as impaired for aquatic recreation use (excess nutrients). Additionally, the upper and lower basins of Orono, Elk, Briggs, and Rush were also determined to be impaired for aquatic recreation use (excess nutrients). Land use north of the Elk River appears to be a greater mixture of forest, rangeland, and cropland. South of the Elk River is more cropland dominant (Figure 12). All of the lakes determined to be impaired were listed in the 2008 assessment cycle. Data collected since has supported these listings.

The MNLEAP model indicated that the observed TP for Donovan, Elk, Briggs, and Rush Lakes was significantly higher than the predicted values. Upper and Lower Orono, Mitchell, Big, Thompson, Camp, Julia, and Rush Lakes observed TP was either lower than or relatively close to the predicted values. The model predicted a wide range of TP loading throughout the Lower Elk River coinciding with the variety of watershed areas and basin morphometry. These estimated load rates ranged from 68 kg/yr for Donovan Lake to 30,131 kg/yr for Upper and Lower Orono Lake. Loading rates at the subwatershed level can be visualized by observing that Donovan Lake lies near the headwaters while the two basins for Orono Lake are near the pour point and thus are susceptible to greater nutrient contributions from the watershed. Additionally, the areal load rates were higher for lakes with a larger catchment area (Upper and Lower Orono and Elk Lakes) when compared to lakes with smaller catchment areas (Big, Thompson, and Camp). Areal load rates ranged from 1 to 168 m/yr. The complete modeling results can be found in Appendix C.

Table 4. Summary of lake eutrophication assessment results for the Lower Elk River subwatershed

Lake Name	DNR Lake ID	County	Lake Area (Hectares)	Maximum Depth (Meters)	ARUS
Donovan	05-0004-00	Benton	22	2	NS
Upper Orono	71-0013-01	Sherburne	121	5	NS
Lower Orono	71-0013-02	Sherburne	-	-	NS
Mitchell	71-0081-00	Sherburne	156	10	FS
Big	71-0082-00	Sherburne	97	15	FS
Thompson	71-0096-00	Sherburne	40	7	FS
Camp	71-0123-00	Sherburne	34	10	FS
Elk	71-0141-00	Sherburne	142	2	NS
Julia	71-0145-00	Sherburne	55	4	NS
Briggs	71-0146-00	Sherburne	164	6	NS
Rush	71-0147-00	Sherburne	65	4	NS

Figure 12. Lake assessments and land use within Lower Elk River subwatershed



Donovan Lake 05-0004-02

Donovan Lake is a small, shallow lake located approximately three miles east of St. Cloud, Minnesota. Donovan Lake's watershed is small with an area of 321 hectares (794 acres) and a watershed to lake ratio of 15:1. Land use is dominated by cropland with the percentage being within the range of values expected for the NCHF ecoregion (Appendix D).

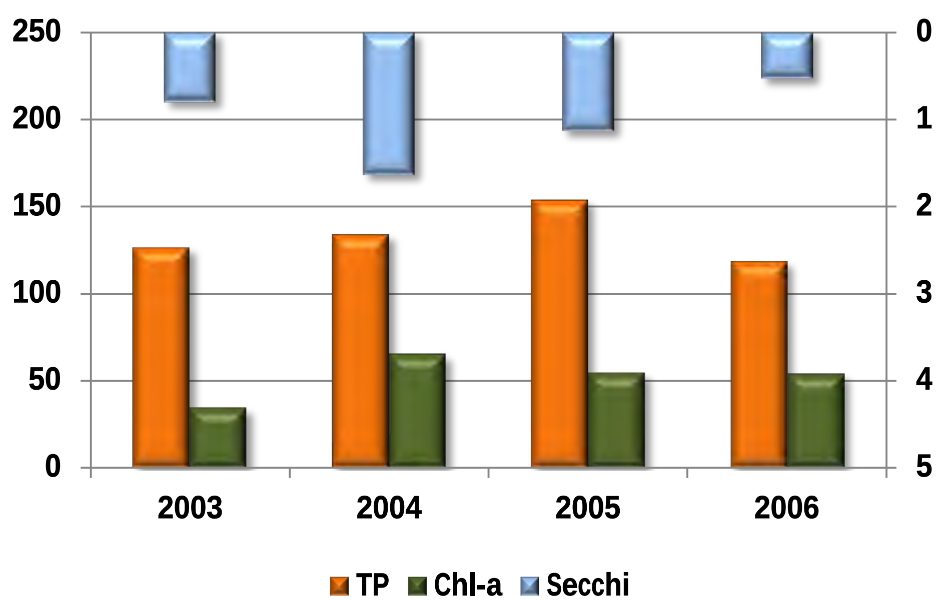
The average TP and chl-*a* values for Donovan Lake were 137 µg/L and 53 µg/L respectively. Each was well above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2006, ranged from 79 µg/L to 149 µg/L and 35 µg/L to 67 µg/L respectively. Despite the high levels of TP and chl-*a*, the water clarity for Donovan Lake was at the water quality standard for shallow lakes with an average of one meter (3.3 feet) (Appendix A).

Profile data, collected in 2006, indicates that Donovan Lake maintained a relatively consistent temperature from the surface to the lake bottom. This suggests that Donovan Lake typically remains mixed during the summer months. An incomplete DO data set was collected; thus, the oxygen content throughout the 2006 season cannot be accurately determined.

Long-term water quality data for Donovan Lake is limited and impaired conditions existed during each of the recorded years. Figure 13 indicates an increase in TP from 2003 to 2005 with levels dropping in 2006. Secchi results show a steady decline in water clarity. Additional data is required for a trend analysis.

Based on the chemical monitoring results and water clarity, Donovan Lake was classified as a hypereutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Donovan Lake was determined to be non-supporting of aquatic recreational use and was previously listed as an impaired water under the 2010 303(d) Impaired Waters List.

Figure 13. Donovan Lake long-term water quality data



Upper Orono Lake 71-0013-01

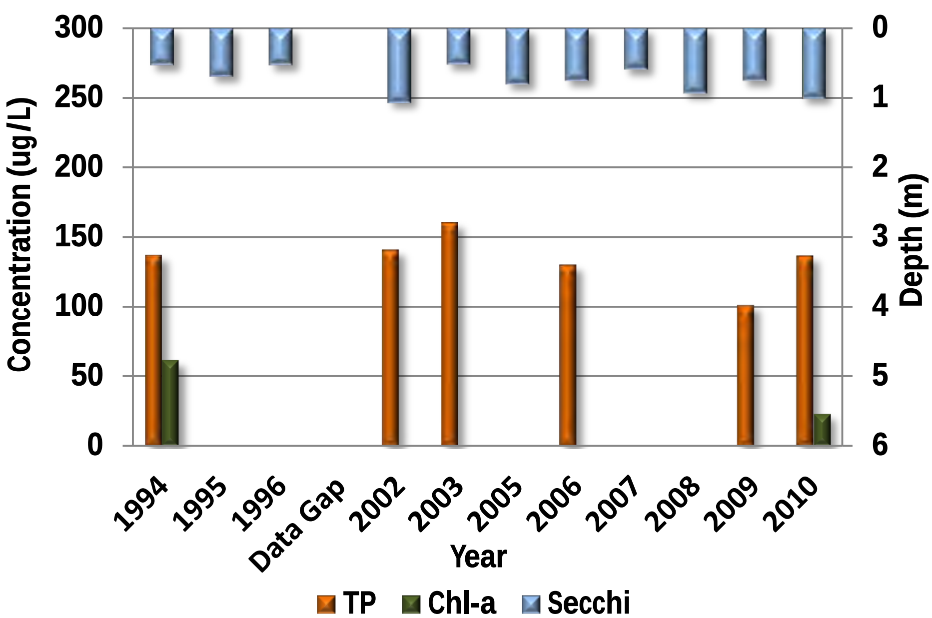
Upper Orono Lake is a moderately sized, relatively deep lake located just south of Elk River, Minnesota. Upper Orono Lake's watershed is very large with an area of 156,417 hectares (387,171 acres) and a watershed to lake ratio of 521:1. Land use is dominated by cropland with the percentage being within the expected range of values for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Upper Orono Lake were 132 µg/L and 23 µg/L respectively. Each was well above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 57 µg/L to 172 µg/L and 4 µg/L to 58 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Upper Orono Lake was above the water quality standard with an average of 0.8 meters (2.6 feet). Due to a lack of profile data, the lake mixing characteristics of Upper Orono Lake cannot be determined (Appendix A).

Long-term chemistry data for Upper Orono Lake is limited; however, Secchi data is fairly extensive. Figure 14 indicates a steady increase in TP levels, all of which exceed the nutrient water quality standard. Additionally, Secchi results do not indicate a significant trend of improvement or decline. Secchi data for each of the recorded years was in exceedence.

Based on the chemical monitoring results and water clarity, Upper Orono Lake was classified as a hypereutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Upper Orono Lake was determined to be non-supporting of aquatic recreational use and was previously listed as an impaired water under the 2008 303(d) Impaired Waters List. Recent data supports this listing.

Figure 14. Upper Orono Lake long-term water quality data



Lower Orono Lake 71-0013-02

Lower Orono Lake is a moderately sized, shallow lake located just south of Elk River, Minnesota. Lower Orono Lake's watershed is very large with an area of 156,417 hectares (387,171 acres) and a watershed to lake ratio of 521:1. Land use is dominated by cropland and the percentage is within the expected range of values for the NCHF ecoregion (Appendix D).

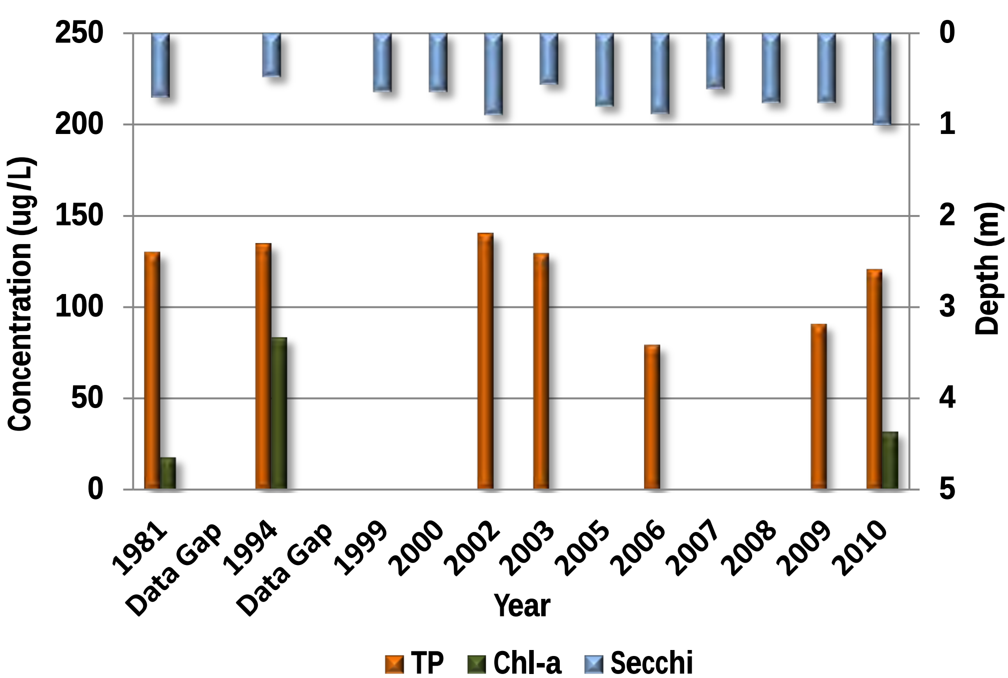
The average TP and chl-*a* values for Lower Orono Lake were 112 µg/L and 32 µg/L respectively. Each was well above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 5 µg/L to 163 µg/L and 1 µg/L to 74 µg/L respectively. Coinciding with the high levels of TP and chl-*a*, the water clarity for Lower Orono Lake was above the water quality standard with an average of 0.8 meters (2.6 feet) (Appendix A).

Historical profile data, collected in 1994, indicates that Lower Orono Lake remained mixed throughout the monitoring season. Additionally, DO remained above 5 mg/L from the surface to the bottom during each sampling event.

Long-term chemistry data for Lower Orono Lake is limited; however, Secchi data is fairly extensive. Figure 15 indicates a steady increase in TP levels, all of which exceed the nutrient standard. Additionally, Secchi results do not indicate a significant trend of improvement or decline. Secchi data for each of the recorded years was in exceedence.

Based on the chemical monitoring results and water clarity, Lower Orono Lake was classified as a hypereutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Lower Orono Lake was determined to be non-supporting of aquatic recreational use and was previously listed as an impaired water under the 2008 303(d) Impaired Waters List. Recent data supports this listing.

Figure 15. Lower Orono Lake long-term water quality data



Mitchell Lake 71-0081-00

Mitchell Lake is a small, deep lake located just north of Big Lake, Minnesota. Mitchell Lake's watershed is small with an area of 823 hectares (2,038 acres) and a watershed to lake ratio of 13:1. Land use is dominated by anthropogenic development and the percentage is well above the expected range for the NCHF ecoregion (Appendix D).

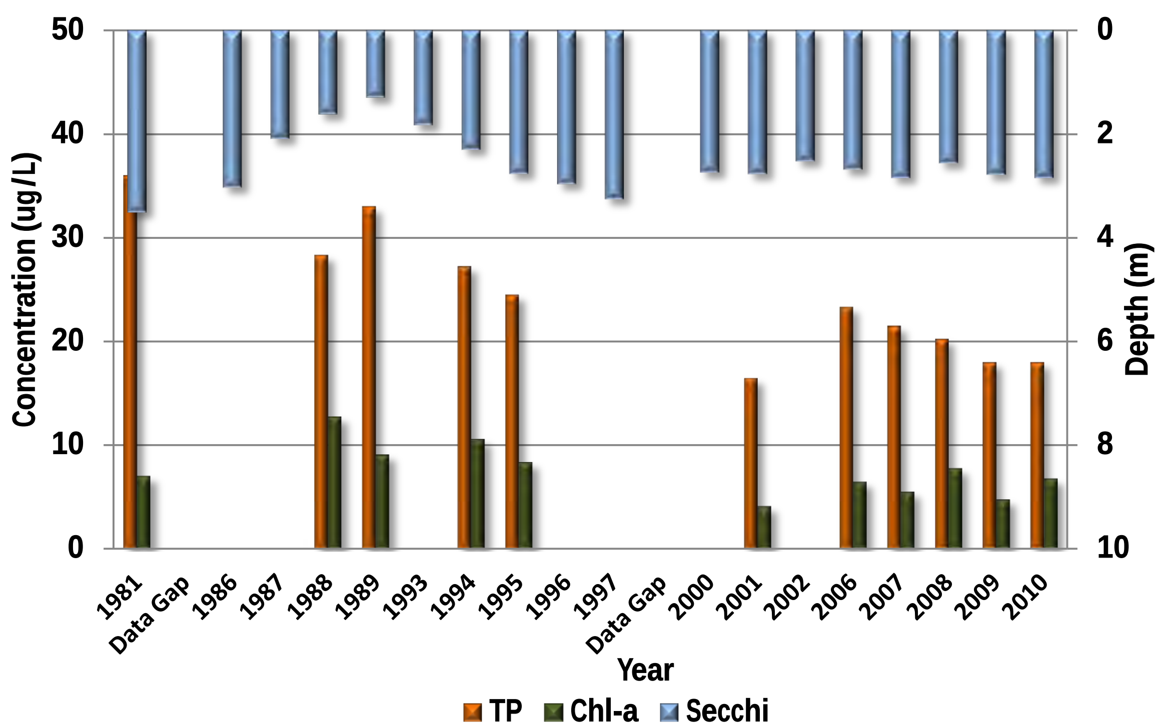
The average TP and chl-*a* values for Mitchell Lake were 19 µg/L and 6 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 15 µg/L to 23 µg/L and 4 µg/L to 9 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Mitchell Lake was below the water quality standard with an average of 2.7 meters (8.9 feet) (Appendix A).

Historical profile data, collected in 1995, indicates that a thermocline formed between 4 and 5 meters (13.1 and 16.4 feet) from June through August with mixing occurring in the spring and fall. This suggests that Mitchell Lake stratifies during the summer months. Additionally, DO remained above 5 mg/L to a depth of 6 meters (19.7 feet) during the summer months.

Long-term chemistry data for Mitchell Lake is fair; however, Secchi data is extensive. Figure 16 indicates a slight decline TP levels as well as increased water clarity. Trend data for Mitchell Lake does indicate an improvement in water quality.

Based on the chemical monitoring results and water clarity, Mitchell Lake was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Mitchell Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 16. Mitchell Lake long-term water quality data



Big Lake 71-0082-00

Big Lake is a moderately sized, deep lake located within the city of Big Lake, Minnesota. Big Lake's watershed is small with an area of 652 hectares (1,614 acres) and a watershed to lake ratio of 7:1. Land use is dominated by anthropogenic development and the percentage is above the expected range for the NCHF ecoregion (Appendix D).

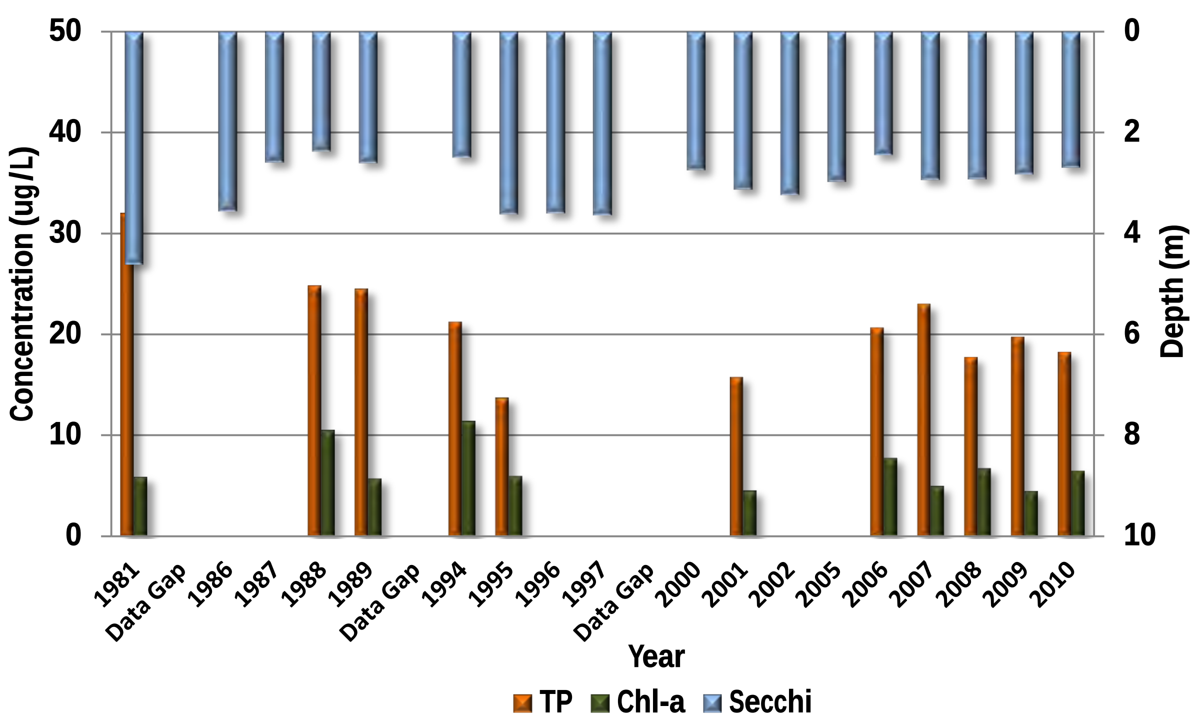
The average TP and chl-*a* values for Big Lake were 18 µg/L and 6 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 15 µg/L to 24 µg/L and 4 µg/L to 13 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Big Lake was below the water quality standard with an average of 2.9 meters (9.5 feet) (Appendix A).

Historical profile data, collected in 1995, indicates that a thermocline formed at depths varying from 4 to 7 meters (13.1 and 23 feet) during the summer months with and a deeper thermocline forming at a depth of 8 meters (26.2 feet) in the spring and fall. This suggests that Big Lake stratifies during the summer months. Additionally, DO remained above 5 mg/L to a depth of 6 meters (19.7 feet) during the summer months.

Long-term chemistry data for Big Lake is fair; however, Secchi data is extensive. Figure 17 indicates a slight decline of TP levels; however, water Clarity has also declined. Trend data for Big Lake does indicate an overall improvement in water quality.

Based on the chemical monitoring results and water clarity, Big Lake was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Big Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 17. Big Lake long-term water quality data



Thompson Lake 71-0096-00

Thompson Lake is a small, relatively deep lake located one mile northwest of Big Lake, Minnesota. Thompson Lake's watershed is small with an area of 415 hectares (1,028 acres) and a watershed to lake ratio of 10:1. Land use is dominated by forest and the percentage is above the expected range for the NCHF ecoregion (Appendix D).

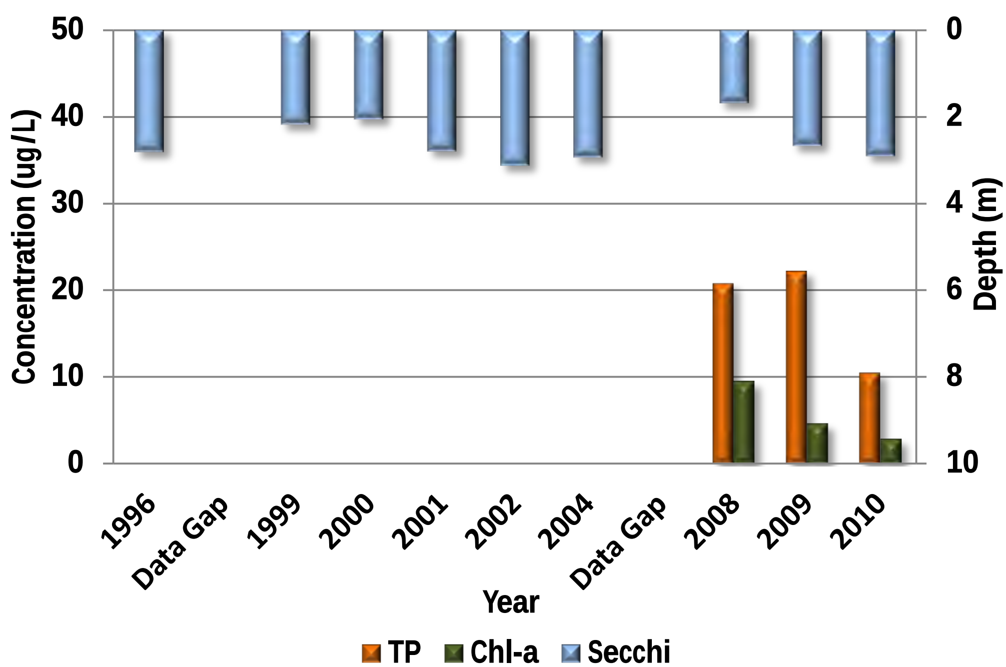
The average TP and chl-*a* values for Thompson Lake were 20 µg/L and 6 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2008 and 2009, ranged from 10 µg/L to 27 µg/L and 2 µg/L to 13 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Thompson Lake was below the water quality standard with an average of 2.7 meters (8.9 feet) (Appendix A).

Profile data, collected in 2009, indicates that a thermocline formed at a depth of 4 meters (13.1 feet) during the summer months. A shallower thermocline formed at a depth of 2 meters (6.6 feet) in the spring. This suggests that Thompson Lake stratifies during the summer months. Additionally, DO remained above 5 mg/L at depths ranging from 4 to 6 meters (13.1 and 19.7 feet) with the exception of July.

No long-term chemistry data for Thompson Lake exists; however, Secchi data is fair. Figure 18 does not indicate a trend for Thompson Lake. Water clarity has consistently been below the water quality standard.

Based on the chemical monitoring results and water clarity, Thompson Lake was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Thompson Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 18. Thompson Lake long-term water quality data



Camp Lake 71-0123-00

Camp Lake is a small, deep lake located one and a half miles east of Clear Lake, Minnesota. Camp Lake's watershed is small with an area of 347 hectares (858 acres) and a watershed to lake ratio of 10:1. Land use is dominated by cropland and the percentage is within the expected range for the NCHF ecoregion (Appendix D).

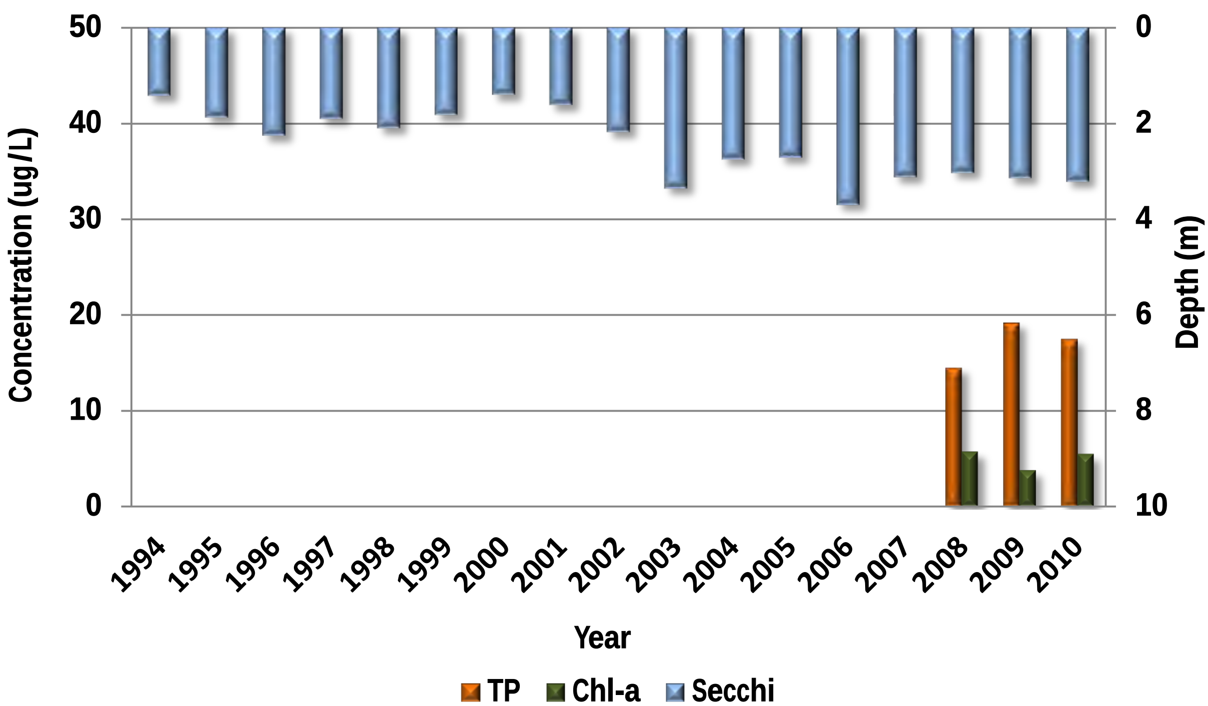
The average TP and chl-*a* values for Camp Lake were 17 µg/L and 5 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2008 and 2009, ranged from 10 µg/L to 23 µg/L and 3 µg/L to 7 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Camp Lake was below the water quality standard with an average of 2.9 meters (9.5 feet) (Appendix A).

Profile data, collected in 2009, indicates that a thermocline formed at a depth of 5 meters (16.4 feet) during the entire monitoring season. This suggests that Camp Lake stratifies during the summer months. Additionally, DO remained above 5 mg/L to a depth of approximately 5 meters (16.4 feet) throughout a majority of the monitoring season.

No long-term chemistry data for Camp Lake exists; however, a trend analysis can be completed for water clarity. Figure 19 does indicate a fairly consistent trend of improving water clarity for Camp Lake. Secchi results have never been below the water quality standard.

Based on the chemical monitoring results and water clarity, Camp Lake was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Camp Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 19. Camp Lake long-term water quality data



Elk Lake 71-0141-00

Elk Lake is a moderately sized, shallow lake located approximately two miles northeast of Clear Lake, Minnesota. Elk Lake's watershed is large with an area of 61,804 hectares (152,981 acres) and a watershed to lake ratio of 435:1. Land use is dominated by cropland and the percentage is within the expected range for the NCHF ecoregion (Appendix D).

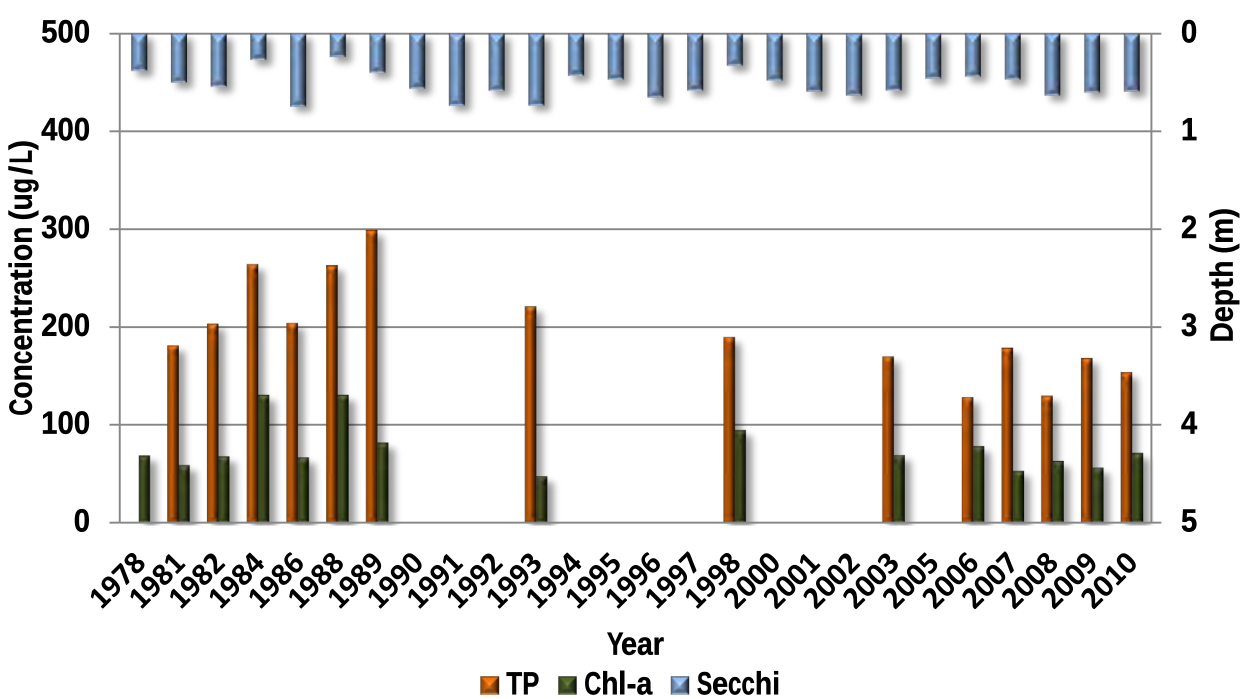
The average TP and chl-*a* values for Elk Lake were 155 µg/L and 66 µg/L respectively. Each was well above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 62 µg/L to 262 µg/L and 16 µg/L to 107 µg/L respectively. Coinciding with the high levels of TP and chl-*a*, the water clarity for Elk Lake was above the water quality standard with an average of 0.6 meters (2 feet) (Appendix A).

Profile data, collected in 2009, indicates that Elk Lake maintained a relatively consistent temperature from the surface to the lake bottom throughout a majority of the monitoring season. This suggests that Elk Lake does not form layers and continuously mixes during the summer months. Additionally, DO remained above 5 mg/L throughout the water column during each monitoring event.

Long-term chemistry data for Elk Lake is fair; however, Secchi data is extensive. Figure 20 indicates a decline in TP levels; however, water clarity does not yet indicate an improvement.

Based on the chemical monitoring results and water clarity, Elk Lake was classified as a hypertrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Elk Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2008 303(d) Impaired Waters List.

Figure 20. Elk Lake long-term water quality data



Julia Lake 71-0145-00

Julia Lake is a small, shallow lake located approximately three and a half miles northeast of Clear Lake, Minnesota. Julia Lake's watershed is small with an area of 783 hectares (1,938 acres) and a watershed to lake ratio of 14:1. Land use is dominated by cropland and forest with the cropland percentage being within the expected range and the forest percentage above the expected range for the NCHF ecoregion (Appendix D).

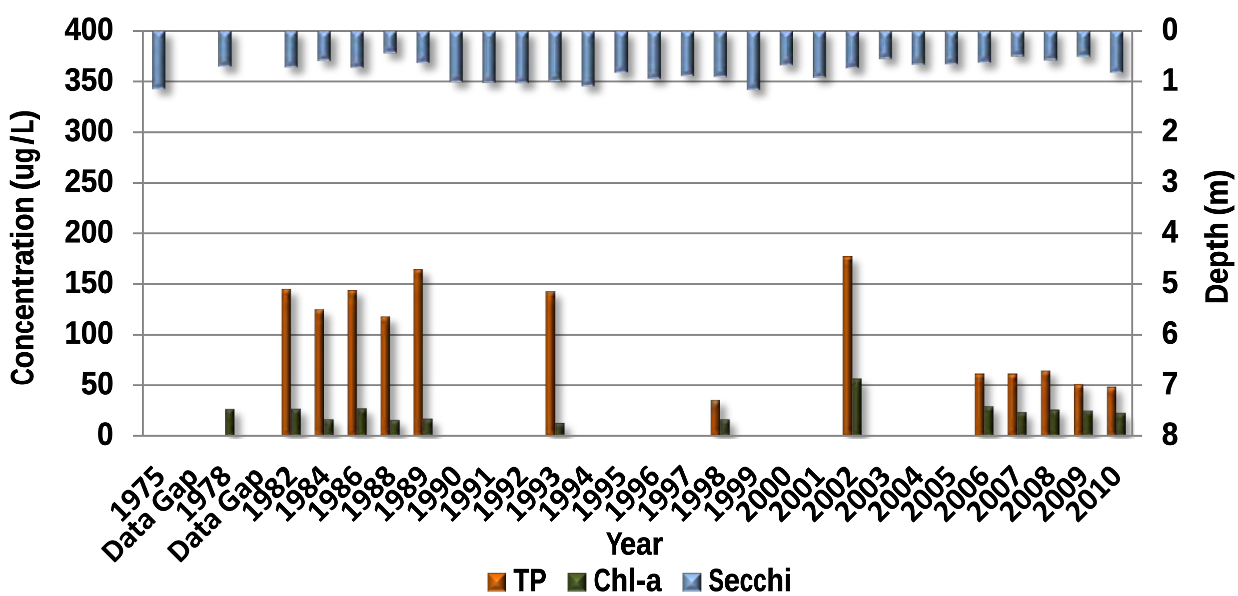
The average TP and chl-*a* values for Julia Lake were 66 µg/L and 27 µg/L respectively. Each was above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 37 µg/L to 70 µg/L and 9 µg/L to 36 µg/L respectively. Coinciding with the high levels of TP and chl-*a*, the water clarity for Julia Lake was above the water quality standard with an average of 0.7 meters (2.3 feet) (Appendix A).

Limited profile data, collected in 2008, indicates that Julia Lake maintained a relatively consistent temperature from the surface to the lake bottom with a weak thermocline forming at 3 meters. This suggests that Julia Lake forms a weak thermocline during calm periods but otherwise remains mixed. Additionally, DO remained above 5 mg/L throughout the water column in the spring and fall but became hypoxic towards the lake bottom in July.

Long-term chemistry data for Julia Lake is fair; however, Secchi data is extensive. Figure 21 indicates a significant decline in TP levels in the more recent years. Despite the drops in nutrient loading to Julia Lake, water clarity does not yet indicate an improvement.

Based on the chemical monitoring results and water clarity, Julia Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Julia Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2008 303(d) Impaired Waters List. Recent data supports this listing.

Figure 21. Julia Lake long-term water quality data



Briggs Lake 71-0146-00

Briggs Lake is a moderately sized, relatively deep lake located approximately three and a half miles northeast of Clear Lake, Minnesota. Briggs Lake's watershed is moderately sized with an area of 3,758 hectares (9,303 acres) and a watershed to lake ratio of 23:1. Land use is dominated by cropland and forest with the cropland percentage being within the expected range and the forest percentage above the expected range for the NCHF ecoregion (Appendix D).

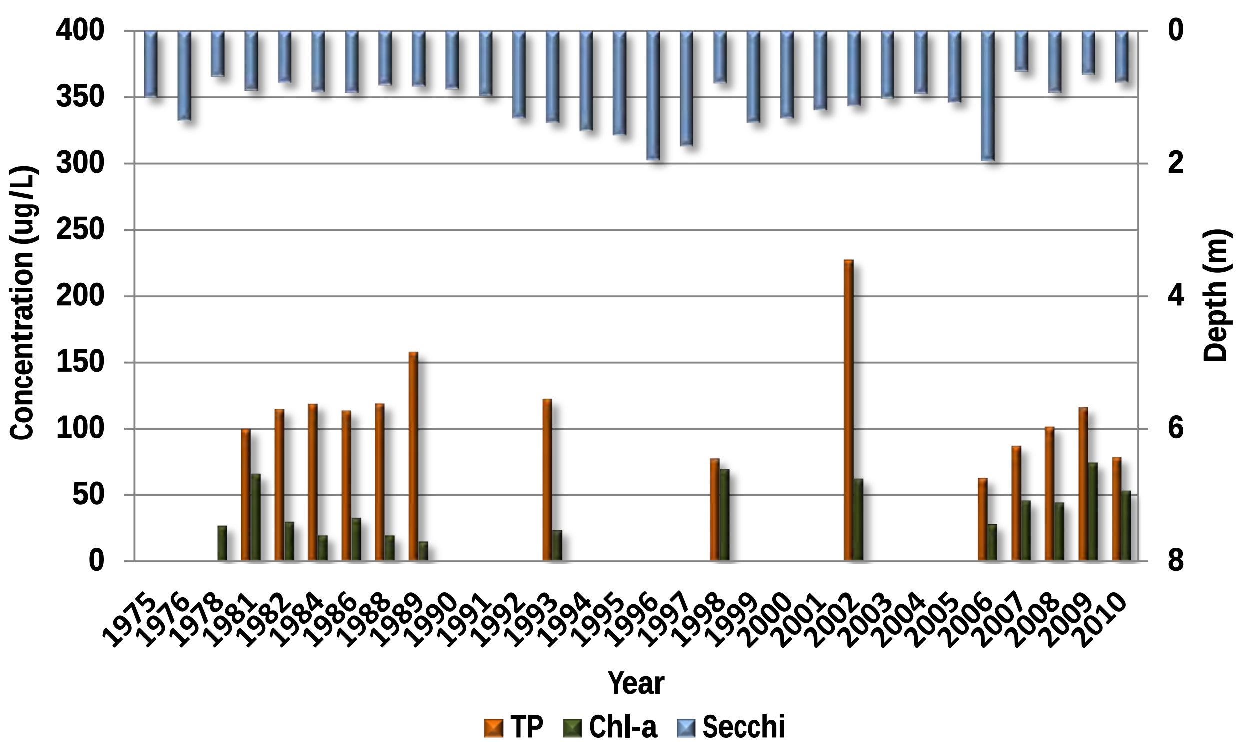
The average TP and chl-*a* values for Briggs Lake were 97 µg/L and 49 µg/L respectively. Each was well above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009, ranged from 51 µg/L to 140 µg/L and 5 µg/L to 95 µg/L respectively. Coinciding with the high levels of TP and chl-*a*, the water clarity for Briggs Lake was above the water quality standard with an average of one meter (3.3 feet) (Appendix A).

Limited profile data, collected in 2008, indicates that Briggs Lake maintained a relatively consistent temperature from the surface to the lake bottom. This suggests that Briggs Lake typically remains mixed during the summer months. Additionally, DO remained above 5 mg/L throughout the water column in the spring and fall but became hypoxic in July.

Long-term chemistry data for Briggs Lake is fair; however, Secchi data is extensive. Figure 22 indicates a slight decline in TP levels. Despite the drops in nutrient loading to Julia Lake water clarity does not indicate an improvement.

Based on the chemical monitoring results and water clarity, Briggs Lake was classified as a hypereutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Briggs Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2008 303(d) Impaired Waters List. Recent data supports this listing.

Figure 22. Briggs Lake long-term water quality data



Rush Lake 71-0147-00

Rush Lake is a small, shallow lake located approximately three miles northeast of Clear Lake, Minnesota. Rush Lake's watershed is moderate with an area of 4,085 hectares (10,111 acres) and a watershed to lake ratio of 63:1. Land use is dominated by cropland and forest with the cropland percentage being within the expected range and the forest percentage above the expected range for the NCHF ecoregion (Appendix D).

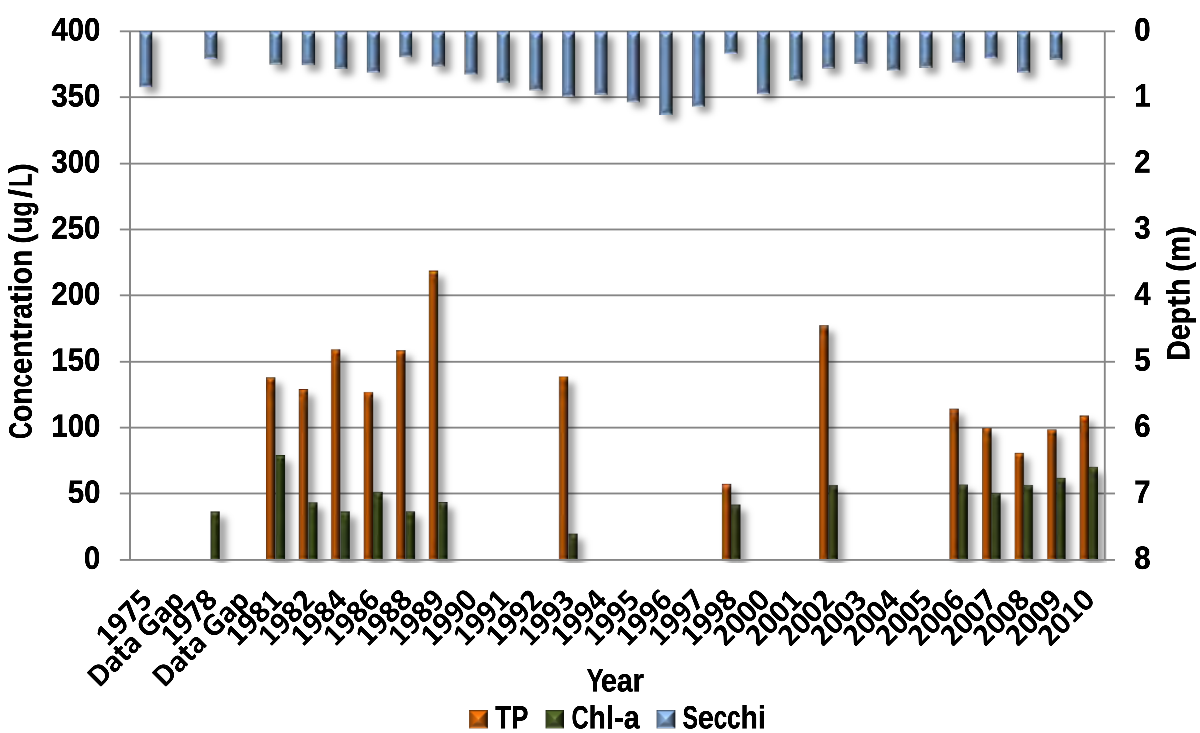
The average TP and chl-*a* values for Rush Lake were 104 µg/L and 59 µg/L respectively. Each was well above the water quality standard for shallow lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2010, ranged from 43 µg/L to 162 µg/L and 5 µg/L to 111 µg/L respectively. Coinciding with the high levels of TP and chl-*a*, the water clarity for Rush Lake was above the water quality standard with an average of 0.5 meters (1.6 feet) (Appendix A).

Limited profile data, collected in 2008, indicates that Rush Lake maintained a relatively consistent temperature from the surface to the lake bottom. This suggests that Rush Lake typically remains mixed during the summer months. Additionally, DO remained above 5 mg/L throughout the water column in the spring and fall but became hypoxic in July.

Long-term chemistry data for Rush Lake is fair; however, Secchi data is extensive. Figure 23 indicates a decline in TP levels. Despite the drops in nutrient loading to Rush Lake, water clarity does not indicate an improvement.

Based on the chemical monitoring results and water clarity, Rush Lake was classified as a hypereutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Rush Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2008 303(d) Impaired Waters List. Recent data supports this listing.

Figure 23. Rush Lake long-term water quality data



Snake River subwatershed

The Snake River (07010203050) HUC-11 watershed is in the east central portion of the Mississippi (St. Cloud) watershed. This 11,357 hectare (28,112 acre) subwatershed represents 3.9 percent of the Mississippi (St. Cloud) watershed (Figure 24 and Table 2). Based on 2003 NPDES/SDS registered feedlot data, there are no permitted discharge sites and four registered feedlots throughout the Snake River subwatershed (Figure 6).

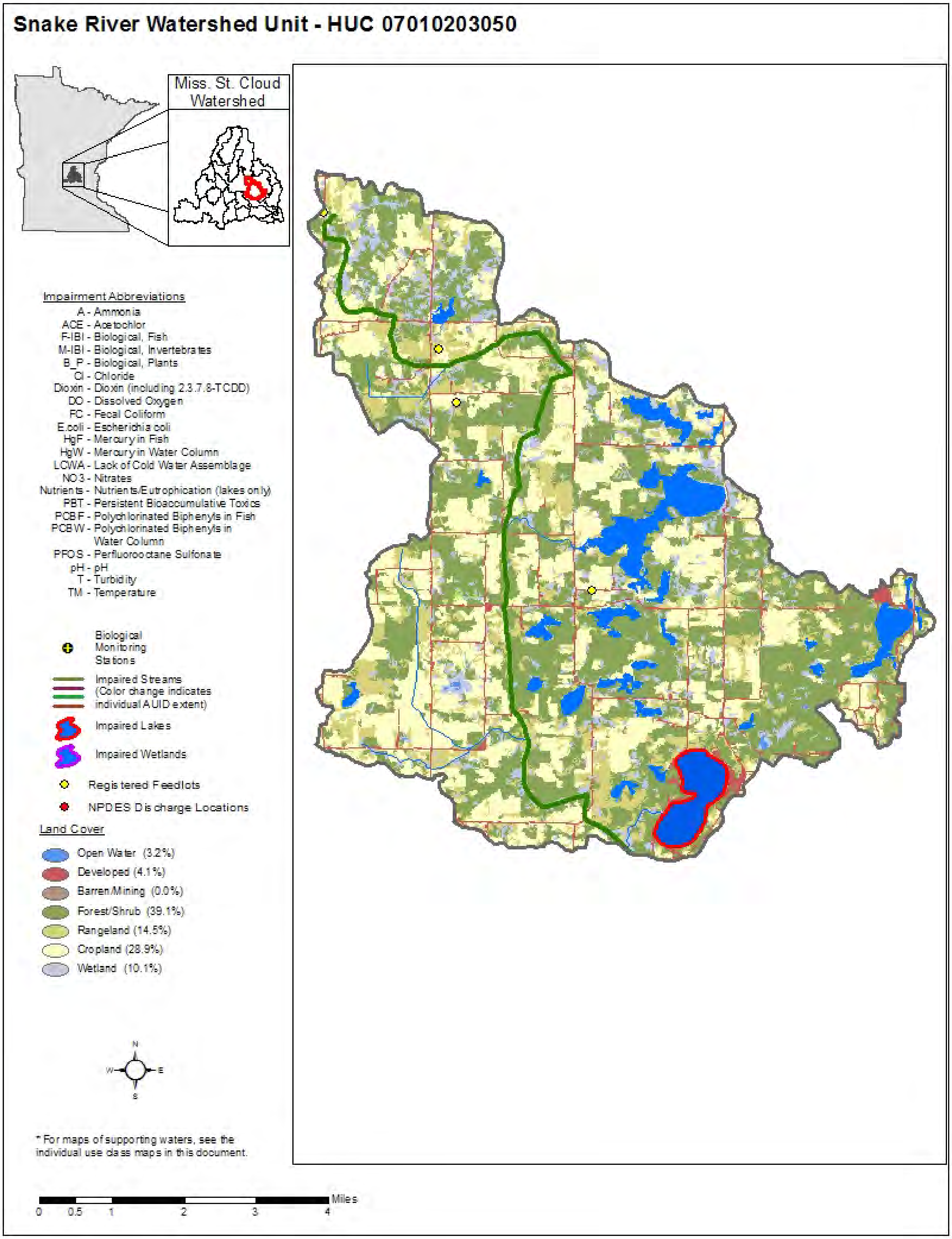
The Snake River subwatershed consists of 14 lakes greater than 4 hectares (10 acres), of which 2 were reviewed for aquatic recreation use (Table 5). A majority of the lakes in this subwatershed are small shallow basins and are primarily located in the eastern portion of the Snake River subwatershed. Eagle Lake, which received contribution from several tributaries and smaller bodies of water, was determined to be non-supporting for aquatic recreation use (excess nutrients). Additionally, Eagle Lake is likely subject to internal nutrient loading due to intermittent mixing during the summer months. Ann Lake, a smaller deeper lake with a smaller catchment area, was fully supporting of aquatic recreation use. A review of the assessable data indicated a strong data set to determine each of the lakes impairment status. While a majority of the land use within the Snake River subwatershed consisted of undisturbed forest (Figure 24), a reduction in external nutrient loading will still prove beneficial.

The MNLEAP model indicated that the observed TP for Eagle Lake was close to the predicted result while the observed TP for Ann was significantly lower than what is predicted. The model predicted a fairly small range of TP loading between the two lakes coinciding with the differences in watershed areas and basin morphometry. These estimated load rates ranged from 116 kg/yr for Ann Lake to 447 kg/yr for Eagle Lake. Additionally, areal load rates ranged from 1 to 2m/yr. Background TP (Vighi & Chiaudani TP) was not calculated because alkalinity data was not available. The complete modeling results can be found in Appendix C.

Table 5. Summary of lake eutrophication assessment results for the Snake River subwatershed

Lake Name	DNR Lake ID	County	Lake Area (Hectares)	Maximum Depth (Meters)	ARUS
Eagle	71-0067-00	Sherburne	172	5.5	NS
Ann	71-0069-00	Sherburne	91	7.9	FS

Figure 24. Lake assessments and land use within Snake River subwatershed



Eagle Lake 71-0067-00

Eagle Lake is a moderately sized, shallow lake located approximately two and a half miles north of Big Lake, Minnesota. Eagle Lake's watershed is small with an area of 2,056 hectares (5,088 acres) and a watershed to lake ratio of 12:1. Land use is dominated by forest and the percentage is above the expected range for the NCHF ecoregion (Appendix D).

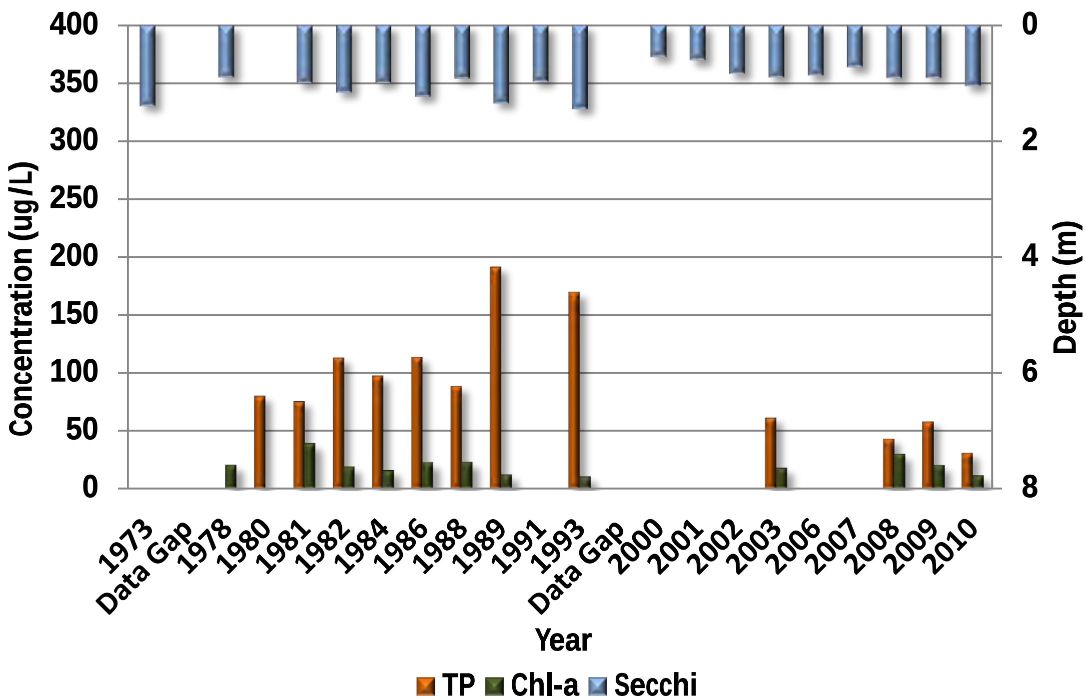
The average TP and chl-*a* values for Eagle Lake were 51 µg/L and 21 µg/L respectively. Each was below the water quality standard for shallow lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2008 and 2009, ranged from 12 µg/L to 74 µg/L and 12 µg/L to 42 µg/L respectively. Coinciding with the high levels of TP and chl-*a*, the water clarity for Eagle Lake was just above the water quality standard with an average of 0.9 meters (3 feet) (Appendix A).

Profile data, collected in 2008, indicates that Eagle Lake formed a weak thermocline at approximately 4 meters during the summer months. This suggests that Eagle Lake likely stratifies during calm periods but may mix under windy conditions. Additionally, DO remained above 5 mg/L to a depth of 4 to 5 meters (13.1 to 16.4 feet) throughout most of the monitoring season.

Long-term chemistry data for Eagle Lake is fair; however, Secchi data is extensive. Figure 25 indicates a decline in TP levels. Despite the drops in nutrient loading to Eagle Lake, water clarity does not indicate an improvement.

Based on the water clarity, Eagle Lake was classified as a hypereutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Eagle Lake was determined to be non-supporting for aquatic recreational use and was listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 25. Eagle Lake long-term water quality data



Ann Lake 71-0069-00

Ann Lake is a small, deep lake located approximately four and a half miles north of Big Lake, Minnesota. Ann Lake's watershed is small with an area of 461 hectares (1,141 acres) and a watershed to lake ratio of 5:1. Land use is dominated by forest and the percentage is above the expected range for the NCHF ecoregion (Appendix D).

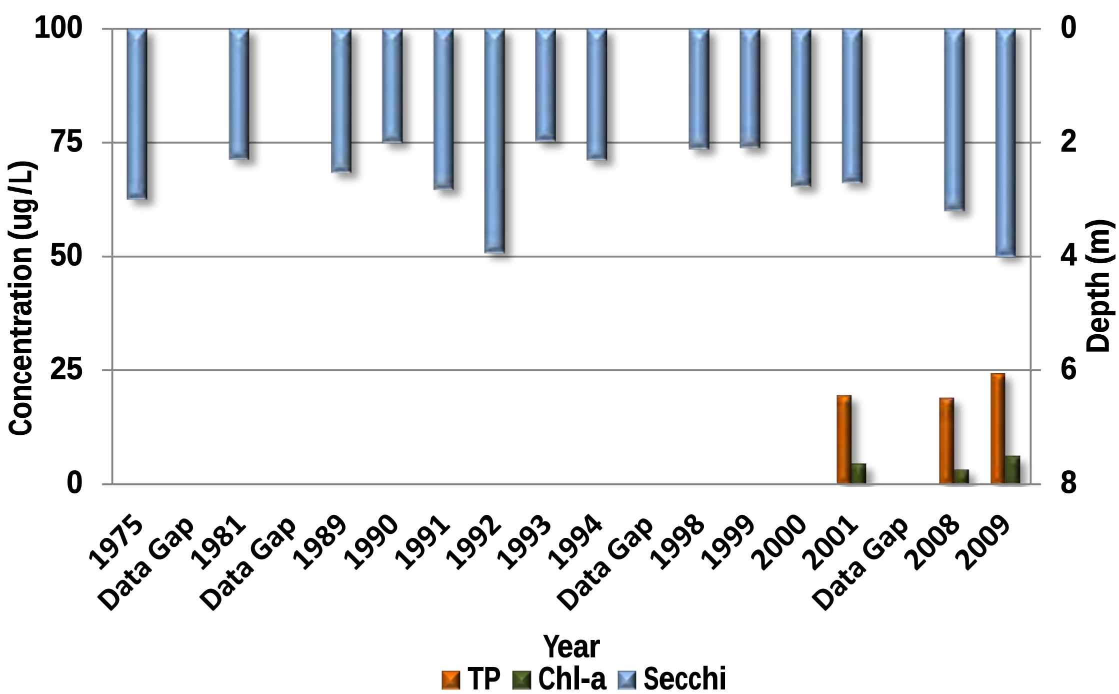
The average TP and chl-*a* values for Ann Lake were 21 µg/L and 5 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2001, ranged from 18 µg/L to 23 µg/L and 3 µg/L to 5 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Ann Lake was below the water quality standard with an average of 3 meters (9.9 feet) (Appendix A).

Limited profile data, collected in 2009, indicates that Ann Lake formed a weak thermocline at approximately 4 meters during the summer months. This suggests that Ann Lake likely stratifies during the summer months. Additionally, DO remained above 5 mg/L to a depth of 4 meters (13.1 feet) throughout the monitoring season.

No long-term chemistry data for Ann Lake exists. Secchi data is present; however, several long-term gaps are present. Figure 26 does indicate improvement in the water clarity for Ann Lake and Secchi results have consistently been below the water quality standard.

Based on the chemical monitoring results and water clarity, Ann Lake was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Ann Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 26. Ann Lake long-term water quality data



Battle Brook subwatershed

The Battle Brook (07010203070) HUC-11 watershed is on the east central border of the Mississippi (St. Cloud) watershed. This 13,939 hectare (34,502 acre) subwatershed represents 4.8 percent of the Mississippi (St. Cloud) watershed (Figure 27 and Table 2). Cropland is the major land use within this area (Figure 27). Based on 2003 NPDES/SDS registered feedlot data, there are no permitted discharge sites and eight registered feedlots throughout the subwatershed (Figure 6).

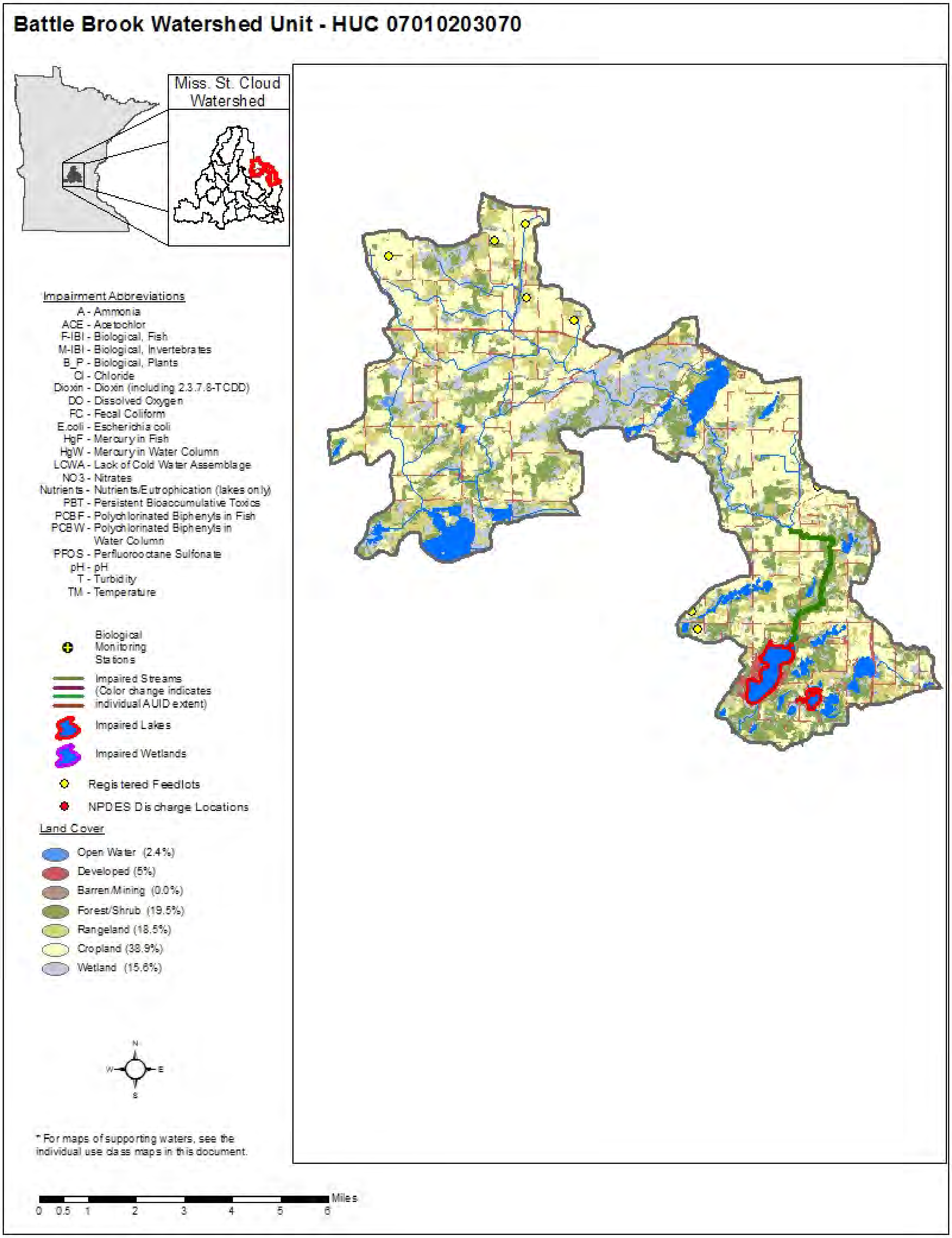
The Battle Brook subwatershed consists of eight lakes greater than 4 hectares (10 acres) of which three were reviewed for aquatic recreation use (Table 6). A majority of the lakes in this subwatershed are small shallow basins and are primarily located in the south eastern portion of the Battle Brook subwatershed near the pour point (Figure 27). Cantlin Lake, with the smallest contributing catchment watershed, was determined to be fully supporting of aquatic recreation use. Diann and Elk Lakes were determined to be non-supporting of aquatic recreation use (excess nutrients). Each lake receives a greater amount of external contribution with Elk Lake receiving the highest. Profile data for all three lakes indicate internal loading due to lake mixing is contributing to nutrient levels in addition to watershed runoff. Despite the high amount of internal nutrient contribution, a reduction in external loading will still prove beneficial.

The MNLEAP model results indicated that the observed TP was lower than the predicted values with the largest gap between results on Cantlin Lake. The model predicted a fair range of TP loading among the lakes coinciding with the variety of watershed areas and basin morphometry. These estimated load rates ranged from 127 kg/yr for Cantlin Lake to 2,027 kg/yr for Elk Lake. Additionally, the areal load rates were higher for a lake with a larger watershed area (Elk Lake) when compared to a lake with smaller watershed areas (Cantlin Lake). Areal load rates ranged from 1 to 10 m/yr. Alkalinity data was available for Elk Lake and calculated background TP was 26.1 µg/L. The complete modeling results can be found in Appendix C.

Table 6. Summary of lake eutrophication assessment results for the Battle Brook subwatershed

Lake Name	DNR Lake ID	County	Lake Area (Hectares)	Maximum Depth (Meters)	ARUS
Cantlin	71-0041-00	Sherburne	54	-	FS
Diann	71-0046-00	Sherburne	41	1.5	NS
Elk	71-0055-00	Sherburne	136	3.7	NS

Figure 27. Battle Brook subwatershed showing all chemistry assessments



Cantlin Lake 71-0041-00

Cantlin Lake is a small, shallow lake located approximately four and a half miles South of Princeton, Minnesota. Cantlin Lake's watershed is small with an area of 575 hectares (1,424 acres) and a watershed to lake ratio of 11:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

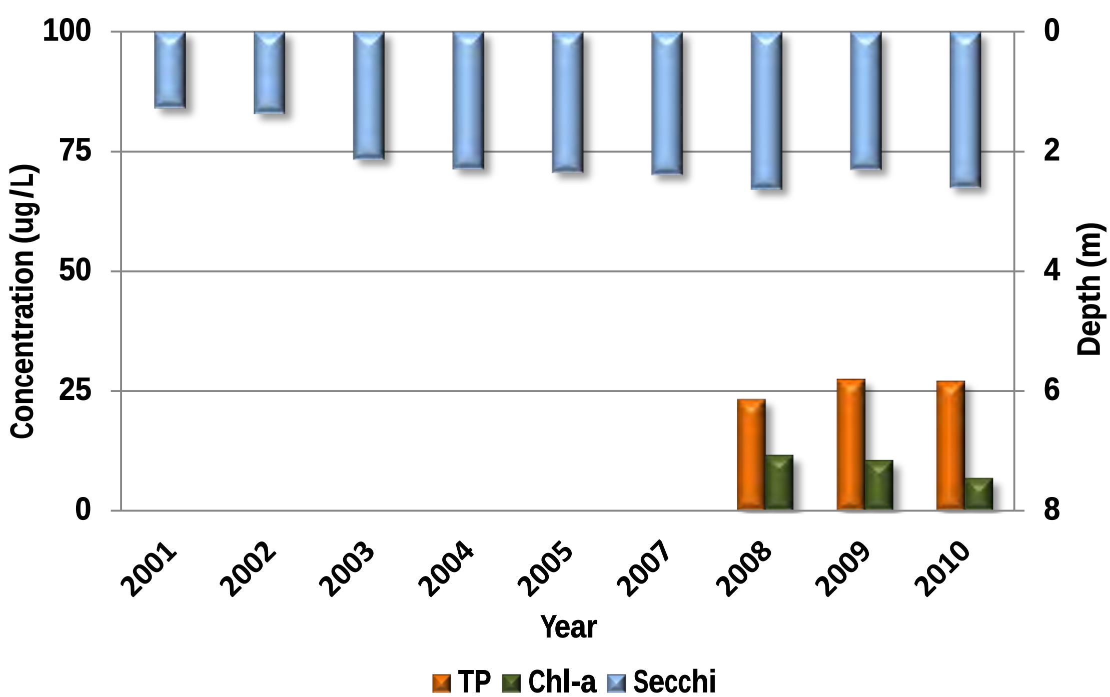
The average TP and chl-*a* values for Cantlin Lake were 26 µg/L and 10 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009, ranged from 23 µg/L to 34 µg/L and 3 µg/L to 18 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Cantlin Lake was below the water quality standard with an average of 2.2 meters (7.2 feet) (Appendix A).

Profile data, collected in 2009, indicates that Cantlin Lake remained continuously mixed during the summer months. Additionally, DO remained above 5 mg/L from the surface to the bottom throughout the entire monitoring season.

No long-term chemistry data for Cantlin Lake exists. A good Secchi data set is available for a trend analysis of water clarity. Figure 28 indicates an improvement in the water clarity for Cantlin Lake and Secchi results have consistently been below the water quality standard since 2002.

Based on the chemical monitoring results and water clarity, Cantlin Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Cantlin Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 28. Cantlin Lake long-term water quality data



Diann Lake 71-0046-00

Diann Lake is a small, shallow lake located approximately five miles South of Princeton, Minnesota. Diann Lake's watershed is small with an area of 1,182 hectares (2,926 acres) and a watershed to lake ratio of 29:1. Land use is dominated by cropland and forest with both percentages being within the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Diann Lake were 66 µg/L and 32 µg/L respectively. Each was above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2008, ranged from 72 µg/L to 83 µg/L and 24 µg/L to 53 µg/L respectively. Despite the high levels of TP and chl-*a*, the water clarity for Diann Lake was just above the water quality standard with an average of 1.1 meters (3.6 feet) (Appendix A). Trend data is not available for Diann Lake.

Profile data, collected in 2008, indicates that Diann Lake remained continuously mixed during the summer months. Additionally, DO remained above 5 mg/L from the surface to the bottom throughout most of the monitoring season.

Based on the chemical monitoring results and water clarity, Diann Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Diann Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2011 303(d) Impaired Waters List.

Elk Lake 71-0055-00

Elk Lake is a moderately sized, shallow lake located approximately five miles South of Princeton, Minnesota. Elk Lake's watershed is large with an area of 10,325 hectares (25,556 acres) and a watershed to lake ratio of 76:1. Land use is dominated by cropland with the percentage being within the range of values expected for the NCHF ecoregion (Appendix D).

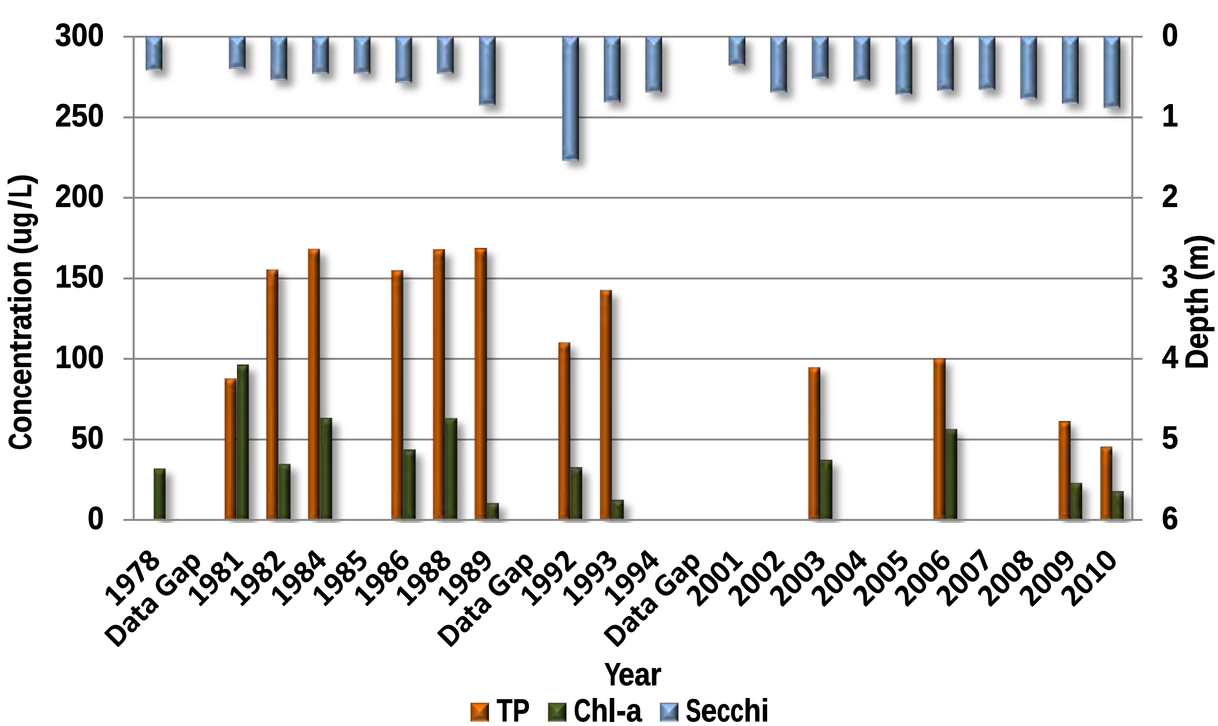
The average TP and chl-*a* values for Elk Lake were 73 µg/L and 31 µg/L respectively. Each was above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009, ranged from 31 µg/L to 80 µg/L and 8 µg/L to 30 µg/L respectively. Coinciding with the high levels of TP and chl-*a*, the water clarity for Elk Lake was above the water quality standard with an average of 0.7 meters (2.3 feet) (Appendix A).

Profile data, collected in 2009, indicates that Elk Lake remained continuously mixed during the summer months. Additionally, DO remained above 5 mg/L from the surface to the bottom throughout most of the monitoring season.

Long-term chemistry data for Elk Lake is fair; however, several gaps in the data are present. Secchi data for Elk Lake is extensive. Figure 29 indicates a decline in TP levels as well as improving water clarity. Despite these improvements, chemistry and Secchi results were still above the water quality standard.

Based on the chemical monitoring results and water clarity, Elk Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Elk Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 29. Elk Lake long-term water quality data



Tibbits Creek subwatershed

The Tibbits (07010203090) HUC-11 watershed is on the east central border of the Mississippi (St. Cloud) watershed. This 11,752 hectare (29,090 acre) subwatershed represents 4.1 percent of the Mississippi (St. Cloud) watershed (Figure 30 and Table 2). Forest/shrub is the major land use within this area (Figure 30). Based on 2003 NPDES/SDS registered feedlot data, there are two permitted discharge sites and one registered feedlot throughout the subwatershed (Figure 6).

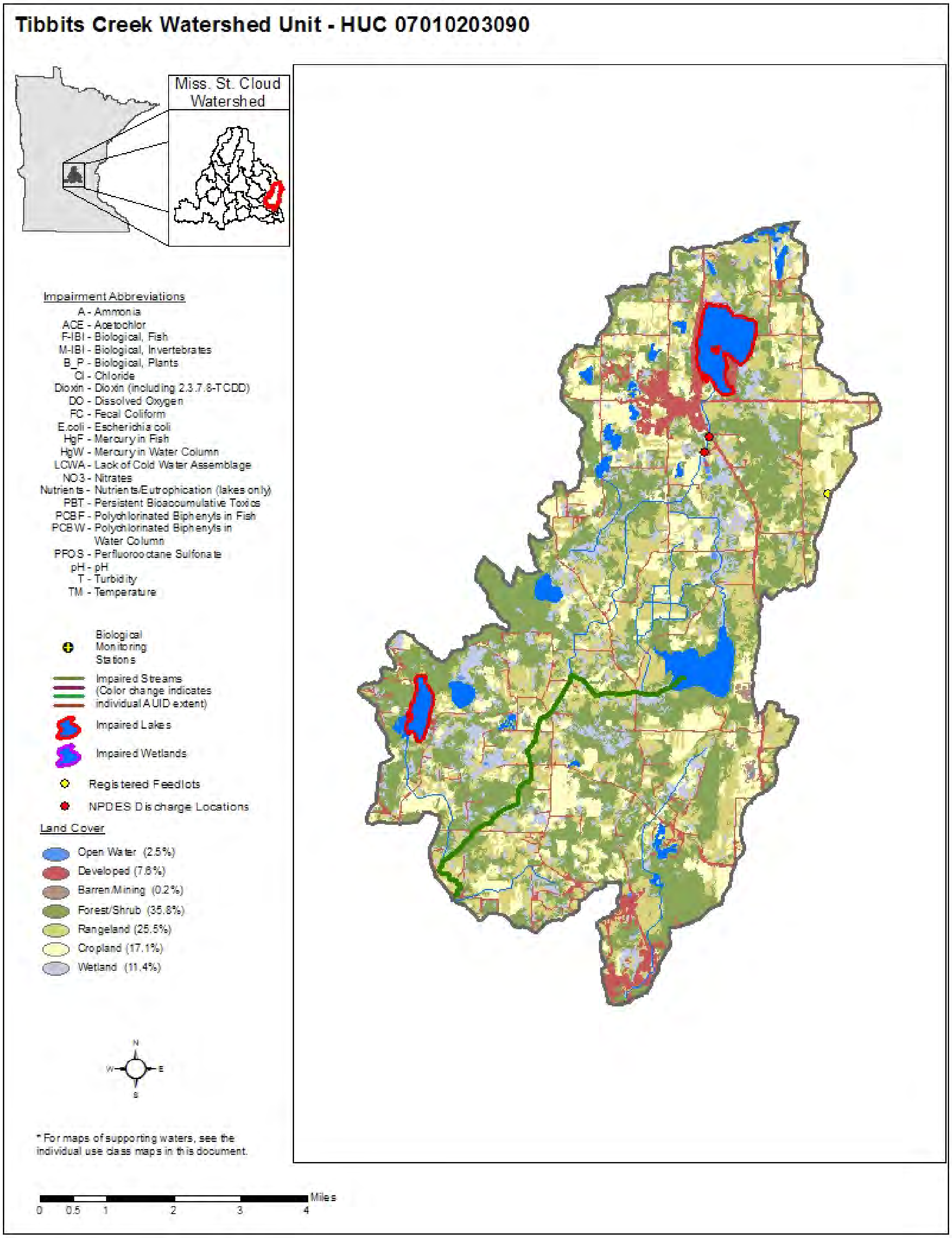
The Tibbits Creek subwatershed consists of nine lakes greater than 4 hectares (10 acres) of which two were reviewed for aquatic recreation use (Table 7). A majority of the lakes in this subwatershed are small shallow basins and are located throughout subwatershed (Figure 30). Fremont and Birch Lakes each have small contributing watersheds and both were determined to be non-supporting of aquatic recreation use (excess nutrients). Profile data for both lakes indicates internal loading due to lake mixing is contributing to nutrient levels in addition to watershed runoff. Despite the high amount of internal nutrient contribution, a reduction in external loading will still prove beneficial.

The MNLEAP model results indicated that the observed TP was significantly higher for Fremont Lake than the predicted values and the observed TP for Birch Lake was just below what was predicted. The model predicted similar TP loading rates for Fremont and Birch Lakes, 298 kg/yr and 350 kg/yr respectively. This coincides with the similarly sized watershed areas as well as basin morphometry. Additionally, the areal load rates were higher for a lake with a larger watershed area (Birch Lake) when compared to a lake with smaller watershed areas (Fremont Lake). Areal load rates ranged from 1 to 4 m/yr. Alkalinity data was available for Fremont Lake and calculated background TP was 27 µg/L. The complete modeling results can be found in Appendix C.

Table 7. Summary of lake eutrophication assessment results for the Tibbits Creek subwatershed

Lake Name	DNR Lake ID	County	Lake Area (Hectares)	Maximum Depth (Meters)	ARUS
Fremont	71-0016-00	Sherburne	188	3	NS
Birch	71-0057-00	Sherburne	60	5.5	NS

Figure 30. Lake assessments and land use within Tibbits Creek subwatershed



Fremont Lake 71-0016-00

Fremont Lake is a moderately sized, shallow lake located just north of Zimmerman, Minnesota. Fremont Lake's watershed is small with an area of 1,256 hectares (3,109 acres) and a watershed to lake ratio of 7:1. Land use is dominated by rangelands and the percentage is above the range of values expected for the NCHF ecoregion (Appendix D).

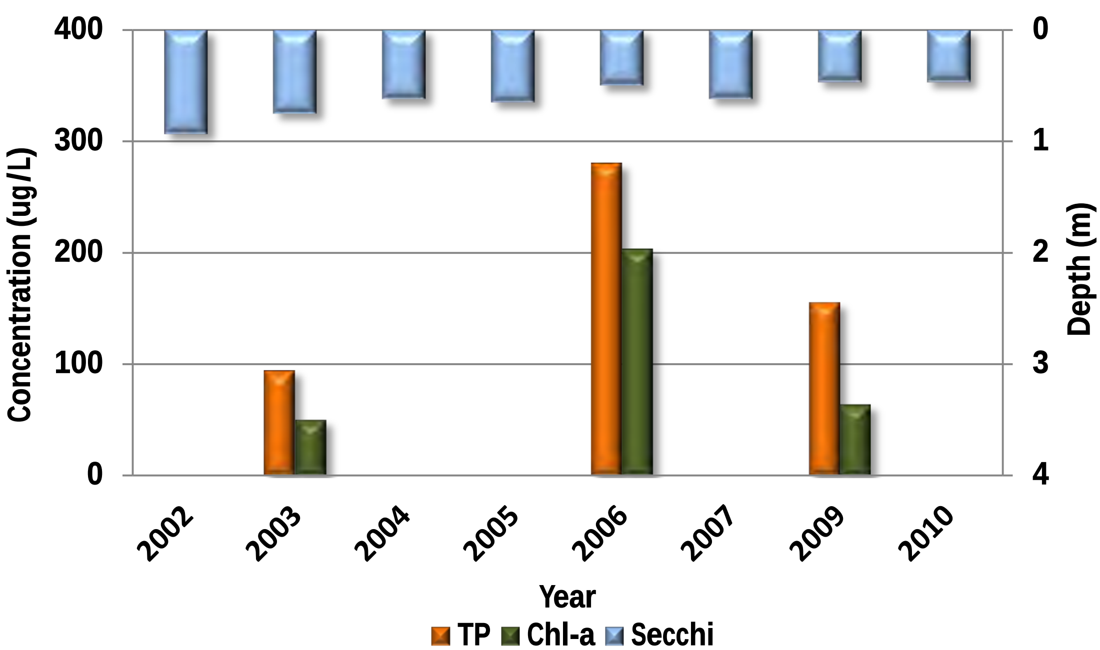
The average TP and chl-*a* values for Fremont Lake were 166 µg/L and 94 µg/L respectively. Each was well above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009, ranged from 64 µg/L to 218 µg/L and 6 µg/L to 102 µg/L respectively. Coinciding with the high levels of TP and chl-*a*, the water clarity for Fremont Lake was above the water quality standard with an average of 0.6 meters (2 feet) (Appendix A).

Profile data, collected in 2009, indicates that Fremont Lake remained continuously mixed during a majority of the summer months. A weak thermocline was observed in August of 2009. This suggests that Fremont Lake may form layers during calm weather periods. Additionally, DO remained above 5 mg/L from the surface to the bottom throughout most of the monitoring season.

Long-term chemistry data for Fremont Lake is sparse; however, enough Secchi data is available for a water clarity trend analysis. Figure 31 indicates declining water clarity. Additionally, Secchi results have been above the water quality standard for each of the monitoring years.

Based on the chemical monitoring results and water clarity, Fremont Lake was classified as a hypereutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Fremont Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 31. Fremont Lake long-term water quality data



Birch Lake 71-0057-00

Birch Lake is a small, relatively deep lake located three miles northeast of Big Lake, Minnesota. Birch Lake's watershed is small with an area of 1,726 hectares (4,272 acres) and a watershed to lake ratio of 29:1. Land use is dominated by wetlands and the percentage is well above the range of values expected for the NCHF ecoregion (Appendix D).

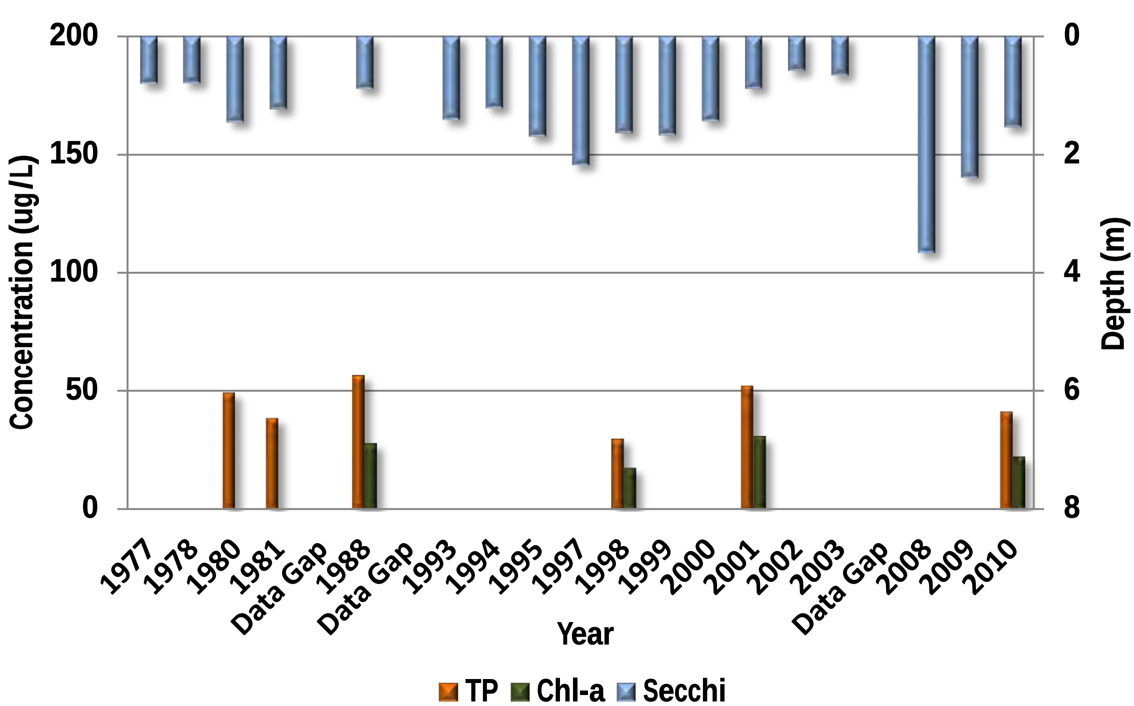
The average TP and chl-*a* values for Birch Lake were 48 µg/L and 28 µg/L respectively. Each was above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2010, ranged from 28 µg/L to 55 µg/L and 11 µg/L to 35 µg/L respectively. Coinciding with the high levels of TP and chl-*a*, the water clarity for Birch Lake was above the water quality standard with an average of one meter (3.3 feet) (Appendix A).

Limited profile data, collected in 1998, indicates that Birch Lake developed a weak thermocline at varying depths throughout the summer months. This suggests that Birch Lake may form layers during calm weather periods. Additional profile data is required to make a more accurate analysis. Also, DO levels fell below 5 mg/L at a depth varying from 3 to 4 meters (9.8 to 13.1 feet).

Long-term chemistry data for Birch Lake is poor and Secchi data for the last 10 years is sparse. Figure 32 indicates improving water clarity in recent sampling years. Total phosphorus levels do show a slight trend in improvement, but all values are above the water quality standard.

Based on the chemical monitoring results and water clarity, Birch Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Birch Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2006 303(d) Impaired Waters List. Recent data supports this listing.

Figure 32. Birch Lake long-term water quality data



Mississippi Direct subwatershed

The Mississippi Direct (07010203690) HUC-11 watershed is in the west central portion of the Mississippi (St. Cloud) watershed. This 6,420 hectare (15,890 acre) subwatershed represents 2.2 percent of the Mississippi (St. Cloud) watershed (Figure 33 and Table 2). Cropland is the major land use within this area (Figure 33). Based on 2003 NPDES/SDS registered feedlot data, there is one permitted discharge site and one registered feedlot throughout the subwatershed (Figure 6).

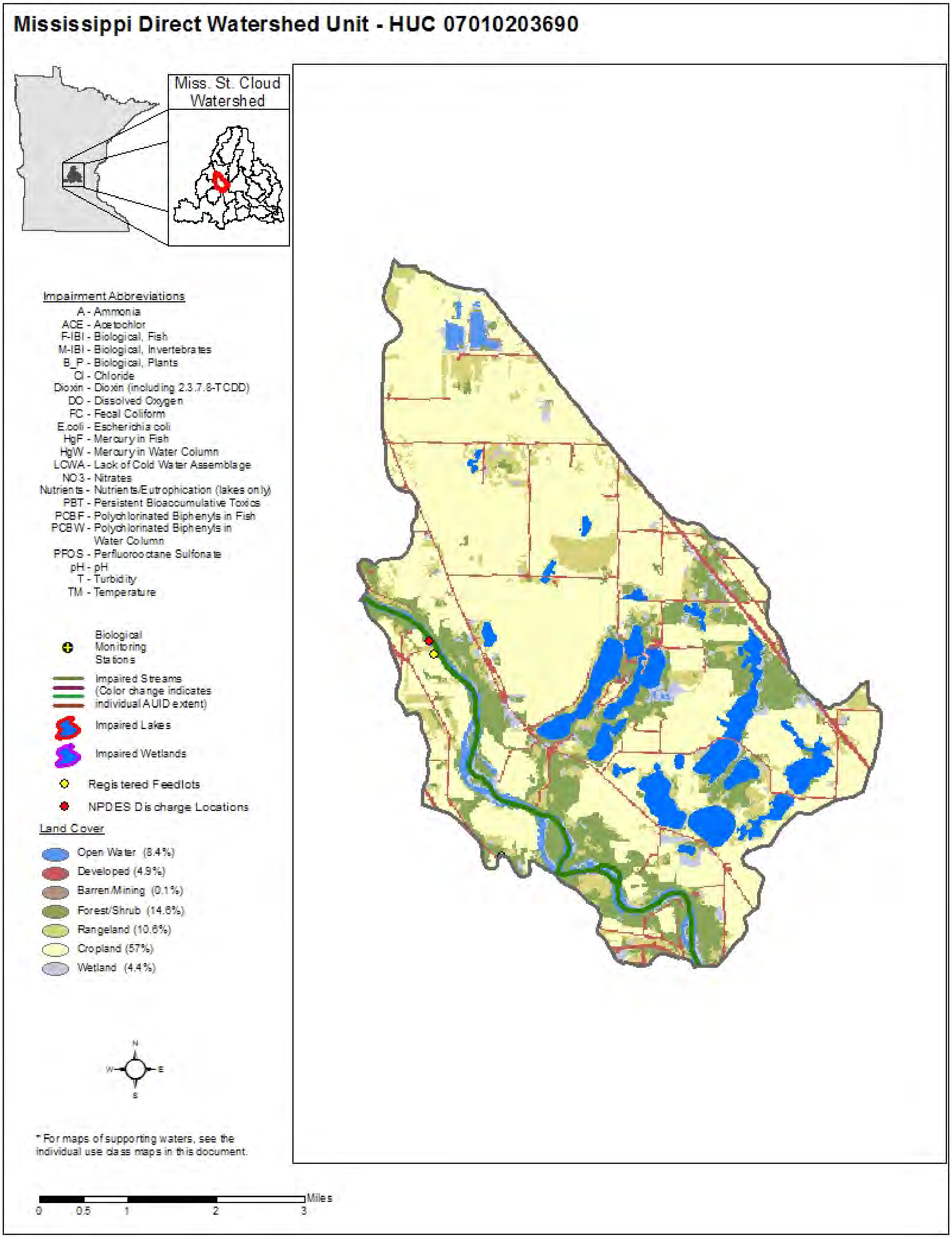
The Mississippi Direct subwatershed consists of seven lakes greater than 4 hectares (10 acres), of which three were reviewed for aquatic recreation use (Table 8). A majority of the lakes in the Mississippi Direct subwatershed are small, deep basins and are primarily located in the southern portion of the subwatershed north of the Mississippi River (Figure 33). Pickerel, Long, and Round Lakes each have moderately sized contributing watersheds but due to their depths likely receive little internal nutrient contribution. All three lakes were determined to be fully supporting of aquatic recreation use. Profile data for each of the lakes indicates that they are all stratifying thus resulting in a limited amount of nutrients being released from the bottom sediment.

The MNLEAP model results indicated that the observed TP was much lower than the predicted results for all three lakes. The model predicted a fairly similar range of TP loading rates among the lakes coinciding with the similar catchment watershed areas and basin morphometry. Estimated load rates ranged from 438 kg/yr for Long Lake to 568 kg/yr for Pickerel Lake. Additionally, the areal load rates were much higher for Round Lake than for the others. Areal load rates ranged from 4 to 19 m/yr. Background TP (Vighi & Chiaudani TP) was not calculated because alkalinity data was not available. The complete modeling results can be found in Appendix C.

Table 8. Summary of lake eutrophication assessment results for the Mississippi Direct subwatershed

Lake Name	DNR Lake ID	County	Lake Area (Hectares)	Maximum Depth (Meters)	ARUS
Pickerel	71-0158-00	Sherburne	73	6.4	FS
Long	71-0159-00	Sherburne	73	7.9	FS
Round	71-0167-00	Sherburne	16	13.1	FS

Figure 33. Mississippi Direct subwatershed showing all chemistry assessments



Pickerel Lake 71-0158-00

Pickerel Lake is a small, relatively deep lake located three miles northwest of Clearwater, Minnesota. Pickerel Lake's watershed is moderately sized with an area of 2,838 hectares (7,024 acres) and a watershed to lake ratio of 39:1. Land use is dominated by cropland and the percentage is above the range of values expected for the NCHF ecoregion (Appendix D).

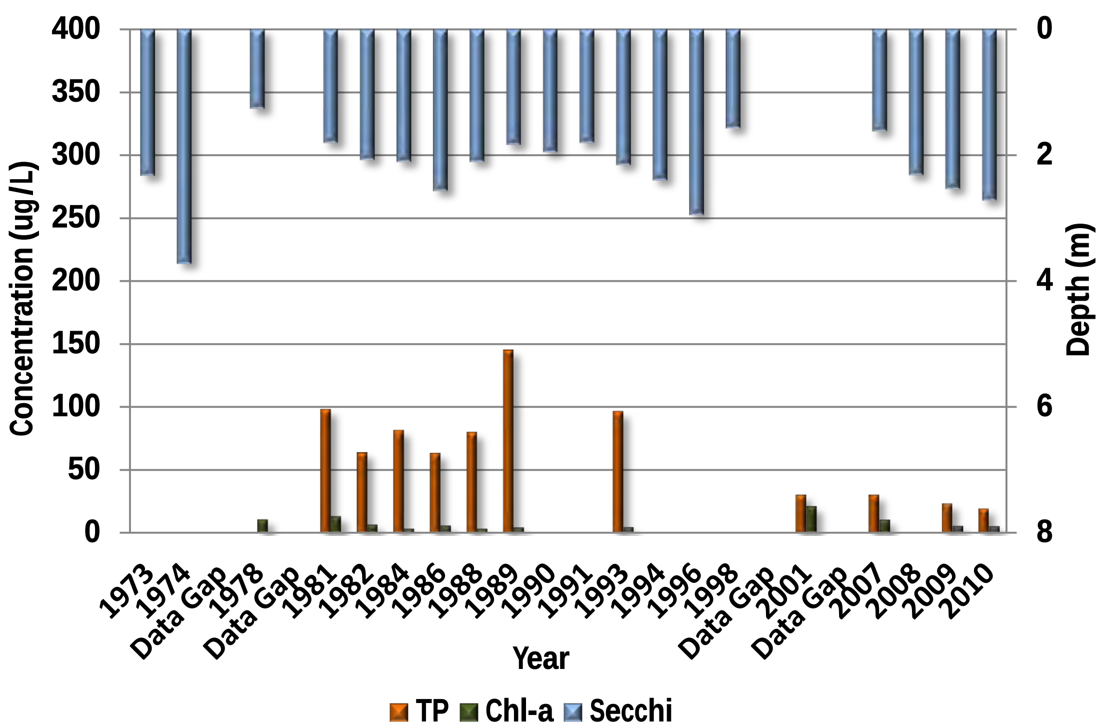
The average TP and chl-*a* values for Pickerel Lake were 26 µg/L and 10 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009, ranged from 19 µg/L to 29 µg/L and 4 µg/L to 7 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Pickerel Lake was below the water quality standard with an average of 2.4 meters (7.9 feet) (Appendix A).

Profile data, collected in 2009, indicates that Pickerel Lake developed a distinct thermocline near 4 meters (13.1 feet) throughout most of the summer and is stratified. Additionally, DO levels fell below 5 mg/L between 5 and 6 meters (16.4 to 19.7 feet).

Long-term chemistry and Secchi data for the last 10 years is sparse. Figure 34 indicates no trend in water clarity. Total phosphorus levels have reduced significantly since the 1980s an all values from recent years were below the water quality standard.

Based on the chemical monitoring results and water clarity, Pickerel Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Pickerel Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 34. Pickerel Lake long-term water quality data



Long Lake 71-0159-00

Long Lake is a small, relatively deep lake located two miles northwest of Clearwater, Minnesota. Long Lake's watershed is moderately sized with an area of 2,163 hectares (5,353 acres) and a watershed to lake ratio of 30:1. Land use is dominated by cropland and the percentage is well above the range of values expected for the NCHF ecoregion (Appendix D).

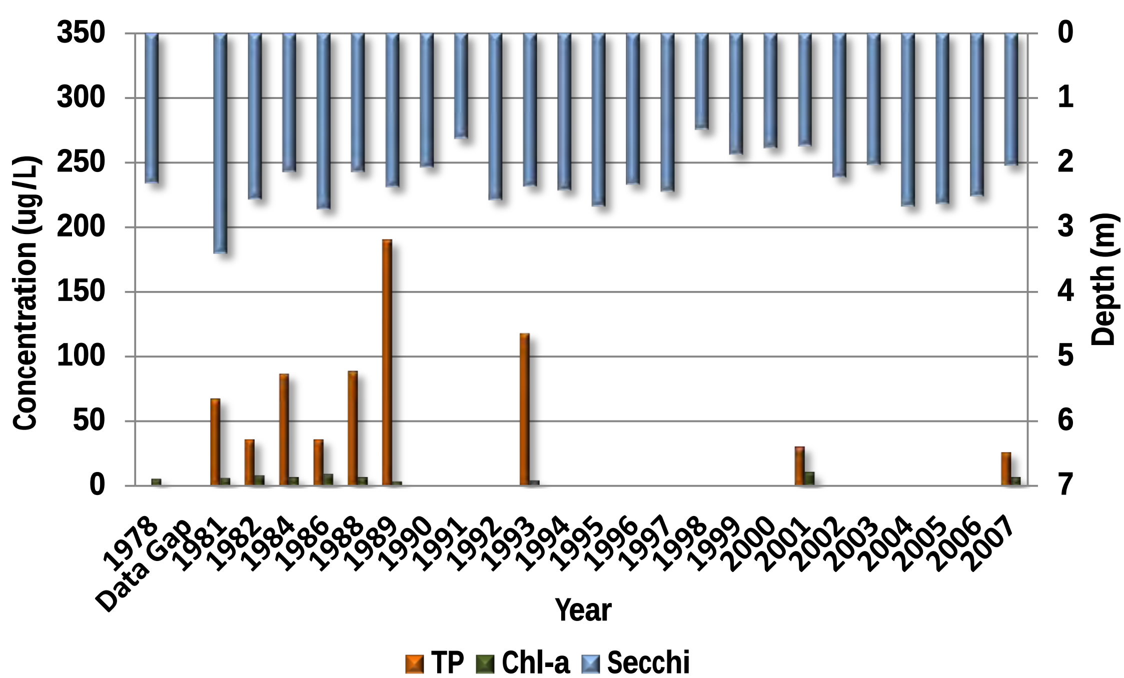
The average TP and chl-*a* values for Long Lake were 30 µg/L and 10 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2007, ranged from 18 µg/L to 23 µg/L and 4 µg/L to 9 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Long Lake was below the water quality standard with an average of 2.2 meters (7.2 feet) (Appendix A).

Limited profile data, collected in 2007, indicates that Long Lake developed a distinct thermocline around four meters (13.1 feet) throughout most of the summer and is stratified. Additionally, DO levels fell below 5 mg/L at a depth of 3 to 4 meters (9.8 to 13.1 feet).

Long-term chemistry data is sparse; however, Secchi data is quite extensive. Figure 35 indicates a slight trend towards reduced water clarity since the 1980s. Total phosphorus levels have reduced significantly and despite a reducing trend, Secchi averages for each year have been below the water quality standard.

Based on the chemical monitoring results and water clarity, Long Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Long Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 35. Long Lake long-term water quality data



Round Lake 71-0167-00

Round Lake is a small, deep lake located three miles northwest of Clearwater, Minnesota. Round Lake's watershed is moderately sized with an area of 2,282 hectares (5,648 acres) and a watershed to lake ratio of 11:1. Land use is dominated by cropland and the percentage is well above the range of values expected for the NCHF ecoregion (Appendix D).

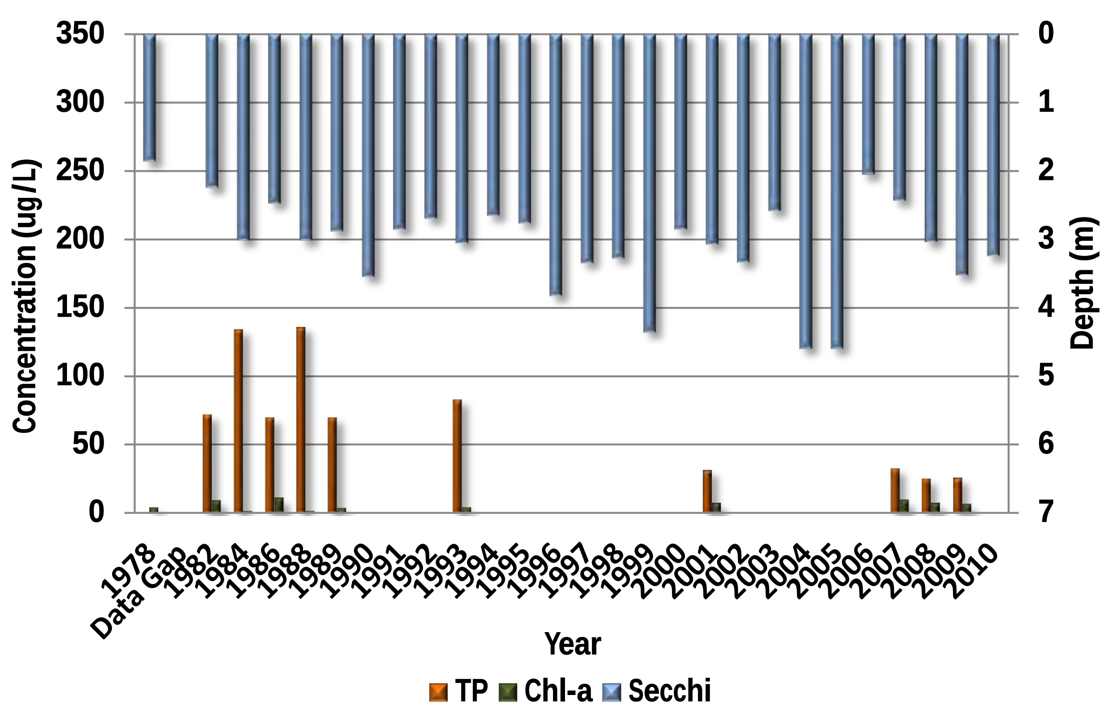
The average TP and chl-*a* values for Round Lake were 29 µg/L and 8 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2008, ranged from 10 µg/L to 48 µg/L and 2 µg/L to 11 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Round Lake was below the water quality standard with an average of 3.2 meters (10.5 feet) (Appendix A).

Profile data, collected in 2008, indicates that Round Lake developed a distinct thermocline at depths ranging from 2 to 5 meters (6.6 to 16.4 feet) throughout the entire summer and is stratified. Additionally, DO levels fell below 5 mg/L throughout the entire lake in early July and at a depth range of 3 to 7 meters (9.9 to 23 feet) during the remaining months.

Long-term chemistry data is sparse; however, Secchi data is quite extensive. Figure 36 indicates a trend towards improved water clarity. Total phosphorus levels have reduced significantly and Secchi averages for each year have been well below the water quality standard.

Based on the chemical monitoring results and water clarity, Round Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Round Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 36. Round Lake long-term water quality data



City of St. Cloud subwatershed

The St. Cloud (07010203700) HUC-11 watershed lies on the west central border of the Mississippi (St. Cloud) watershed. This 6,916 hectare (17,118 acre) subwatershed represents 2.4 percent of the Mississippi (St. Cloud) watershed (Figure 37 and Table 2). Anthropologic development is the major land use within this area (Figure 37). Based on 2003 NPDES/SDS registered feedlot data, there are no permitted discharge sites and four registered feedlots throughout the St. Cloud subwatershed (Figure 6).

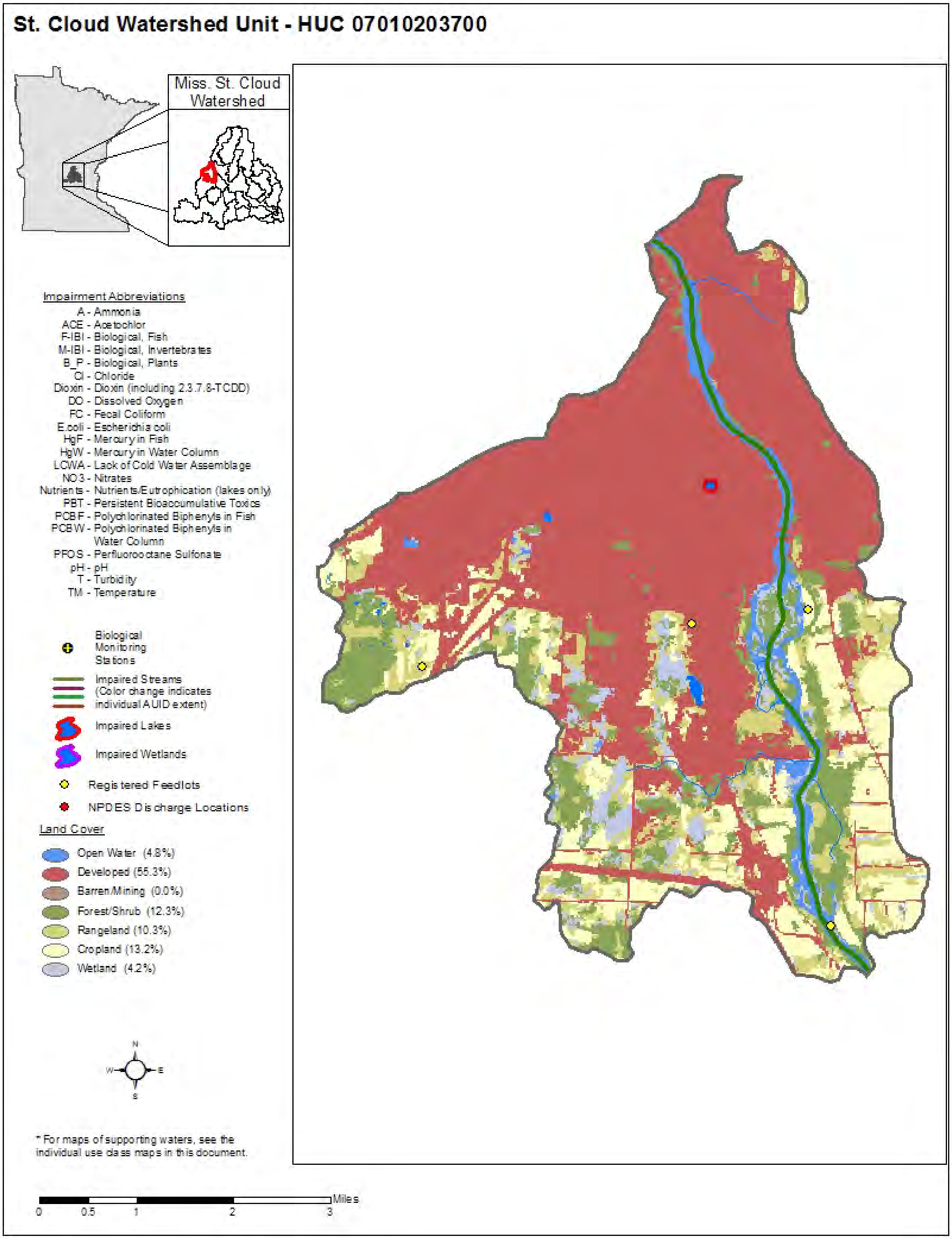
One lake within the city of St. Cloud subwatershed was reviewed for aquatic recreation use (Table 9). Lake George is not classified as a protected water body by the MDNR Division of Waters, but assessment level data was collected. Additionally, the Melrose Deep Quarry has had extensive water clarity observations recorded, but this is insufficient to complete an assessment. The Melrose Deep Quarry is also not classified as a protected water body by the MDNR Division of Waters. A majority of the water bodies within the city of St. Cloud subwatershed are non-protected, small, deep quarries primarily located in the western portion of the subwatershed (Figure 37). Lake George was determined to be non-supporting of recreational use (excess nutrients). The catchment watershed for Lake George primarily consists of anthropogenic development, but the lake itself receives no direct input from streams. Runoff from impervious surfaces may play a major role in the nutrient contribution of Lake George. Profile data is not available to determine the lakes mixing status.

The MINLEAP model indicated that the observed TP for Lake George was much lower than the predicted value. The model predicted TP loading at 651 kg/yr. The areal water load to the lake was estimated at 146 m/yr and estimated water residence time is approximately 0.1 years. Background TP (Vighi & Chiaudani TP) was not calculated because alkalinity data was not available. The complete modeling results can be found in Appendix C.

Table 9. Summary of lake eutrophication assessment results for the city of St. Cloud subwatershed

Lake Name	DNR Lake ID	County	Lake Area (Hectares)	Maximum Depth (Meters)	ARUS
George	73-0611-00	Stearns	3	10	NS
Melrose Deep Quarry	73-0701-00	Stearns	1	35	IF

Figure 37. Lake assessments and land use within the city of St. Cloud subwatershed



Lake George 73-0611-00

Lake George is a small, deep lake located near downtown St. Cloud, Minnesota. Lake George's watershed is moderately sized with an area of 1,073 hectares (8,358 acres) and a watershed to lake ratio of 1,045:1. Land use is dominated by anthropogenic development and the percentage is well above the range of values expected for the NCHF ecoregion (Appendix D). Additionally, Lake George receives no direct input from streams within the subwatershed.

The average TP and chl-*a* values for Lake George were 45 µg/L and 24 µg/L respectively. Each was above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 37 µg/L to 64 µg/L and 12 µg/L to 49 µg/L respectively. Despite high levels of TP and chl-*a*, the water clarity for Lake George was below than the water quality standard with an average of 1.8 meters (5.9 feet) (Appendix A). Due to a lack of profile data, the lake mixing characteristics of Lake George cannot be determined. Trend data is not available.

Based on the chemical monitoring results and water clarity, Lake George was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Lake George was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2011 303(d) Impaired Waters List.

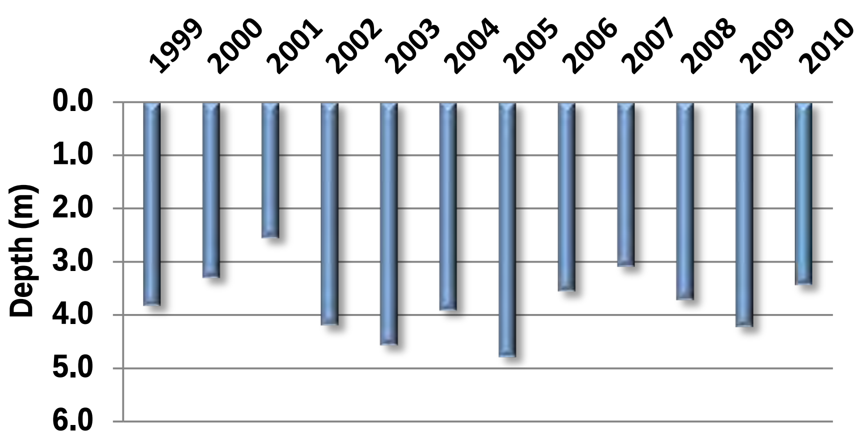
Melrose Deep Quarry 73-0701-00

Melrose Deep Quarry is a small, deep quarry lake located in the Quarry Park and Natural Reserve in Waite Park, Minnesota. Melrose Deep Quarry's watershed is moderately sized with an area of 1,073 hectares (8,358 acres) and a watershed to lake ratio of 4,179:1. Land use is dominated by anthropogenic development and the percentage is well above the range of values expected for the NCHF ecoregion (Appendix D). Additionally, the Melrose Deep Quarry receives no direct input from streams within the subwatershed.

Water chemistry and profile data has not been collected at the Melrose Deep Quarry; however, extensive water clarity data has been taken since 1999. The average Secchi transparency value for the quarry was 3.7 meters (12.1 feet) trending to a slight improvement in clarity over the span of the monitoring years (Figure 38).

Based on the water clarity, the Melrose Deep Quarry was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, the Melrose Deep Quarry was determined to have insufficient data to assess its aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 38. Melrose Deep Quarry transparency trend



Johnson Creek subwatershed

The Johnson Creek (07010203710) HUC-11 watershed lies on the west central border of the Mississippi (St. Cloud) watershed. This 13,463 hectare (33,326 acre) subwatershed represents 4.6 percent of the Mississippi (St. Cloud) watershed (Figure 39 and Table 2). Cropland is the major land use within this area (Figure 39). Based on 2003 NPDES/SDS registered feedlot data, there are no permitted discharge sites and 58 registered feedlots throughout the Johnson Creek subwatershed (Figure 6).

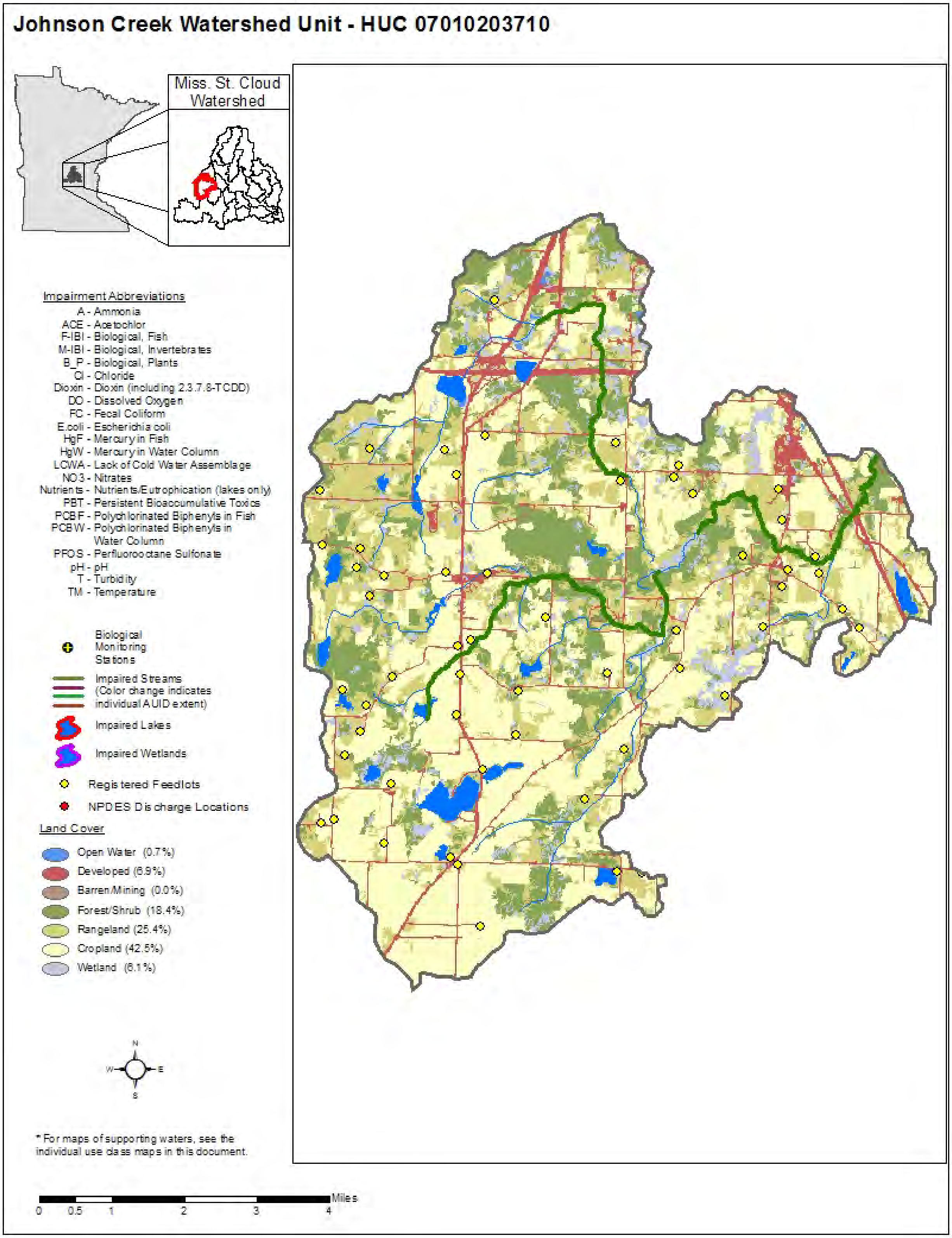
The Johnson Creek subwatershed consists of one lake greater than 4 hectares (10 acres) (Table10). Beaver Lake was assessed and determined to be fully supporting of aquatic recreation use (Table 10). Beaver Lake is located in the southern portion of the subwatershed and all other water bodies within Johnson Creek are classified as wetlands (Figure 39).

The MINLEAP model indicated that the observed TP for Beaver Lake was lower than the predicted value. The model predicted TP loading at 309 kg/yr. The areal water load to the lake was estimated at 3 m/yr and estimated water residence time is approximately 1 year. Background TP (Vighi & Chiaudani TP) was not calculated because alkalinity data was not available. The complete modeling results can be found in Appendix B.

Table 10. Summary of lake eutrophication assessment results for the Johnson Creek subwatershed

Lake Name	DNR Lake ID	County	Lake Area (Hectares)	Maximum Depth (Meters)	ARUS
Beaver	73-0023	Stearns	64	8.2	FS

Figure 39. Lake assessments and land use within Johnson Creek subwatershed



Beaver Lake 73-0023-00

Beaver Lake is a small, moderately deep lake located approximately seven miles south of St. Cloud, Minnesota. Beaver Lake's watershed is small relative to its surface water area with an area of 1,505 hectares (3,726 acres) and a watershed to lake ratio of 24:1. Land use is dominated by rangeland and the percentage is above the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Beaver Lake were 17 µg/L and 5 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2008 and 2009, ranged from 11 µg/L to 24 µg/L and 2 µg/L to 12 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Beaver Lake was below the water quality standard with an average of 3.9 meters (12.8 feet) (Appendix A). Due to a lack of profile data, the lake mixing characteristics of Beaver Lake cannot be determined. Trend data is not available.

Based on the chemical monitoring results and water clarity, Beaver Lake was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Beaver Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Plum Creek subwatershed

The Plum Creek (07010203720) HUC-11 watershed lies within the west central portion of the Mississippi (St. Cloud) watershed. This 8,467 hectare (20,958 acre) subwatershed represents 2.9 percent of the Mississippi (St. Cloud) watershed (Figure 40 and Table 2). Cropland is the major land use within this area (Figure 40). Based on 2003 NPDES/SDS registered feedlot data, there are no permitted discharge sites and 51 registered feedlots throughout the Plum Creek subwatershed (Figure 6).

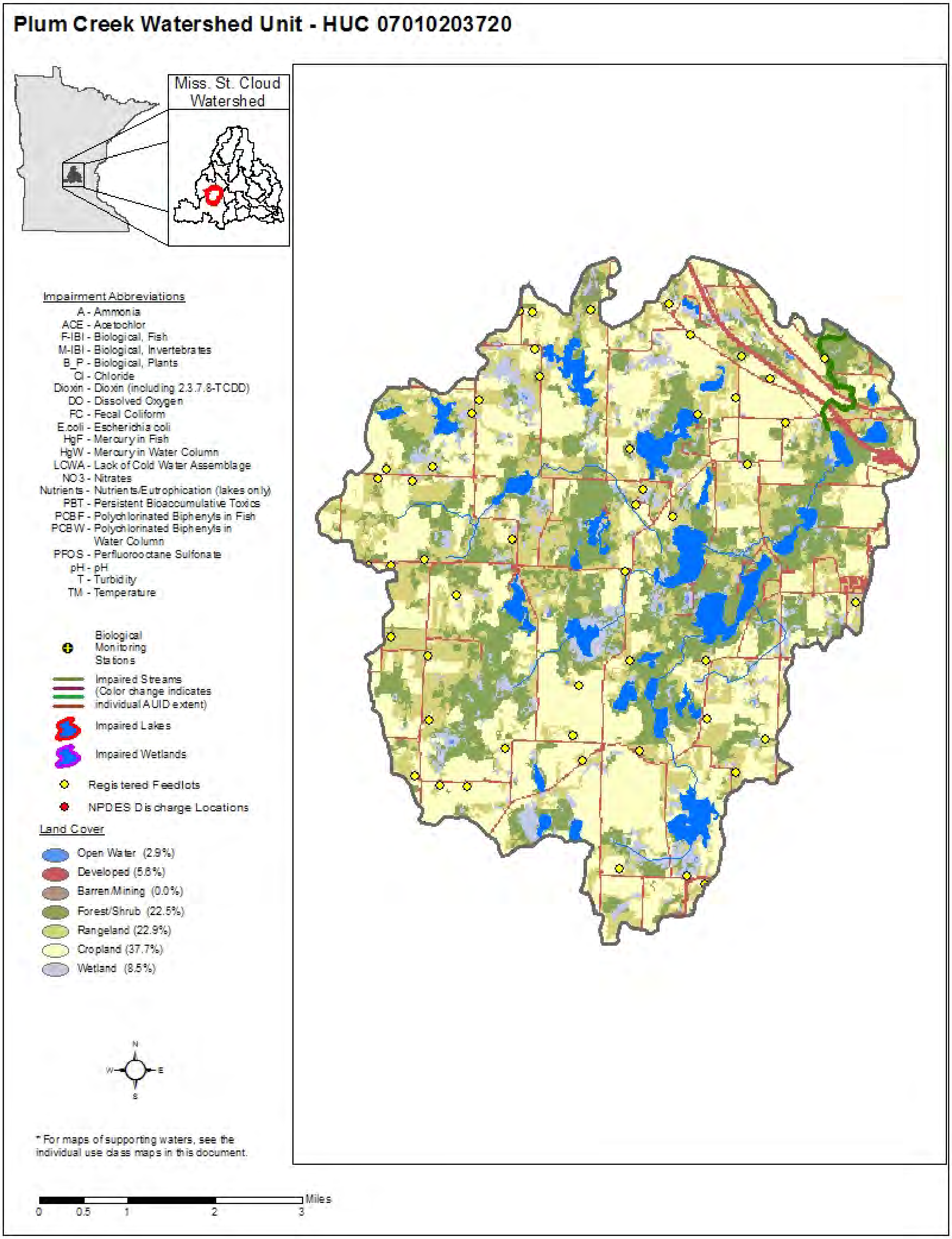
The Plum Creek subwatershed consists of six lakes greater than four hectares (10 acres) of which five were assessed for aquatic recreation use. Three additional lakes (Dallas, Feldges, and Quinn) are classified as wetlands by the MDNR Department of Waters but have basin characteristics more representative of a lake and were assessed as such (Table 11). Most lakes in the Plum Creek subwatershed are small, shallow to moderately deep basins and are located throughout the subwatershed (Figure 40). All eight lakes were determined to be fully supporting of aquatic recreational use. All of the lakes, with the exception of Bunt, are classified as deep lakes and all of the lakes had small to moderately sized contributing watersheds. Profile data was limited to only Crooked and Long Lakes. The results of each indicated stratification during the summer months. Despite the fully supporting assessment for Bunt, Maria, Feldges, and Dallas Lakes, each of these water bodies was determined to be eutrophic and a reduction in external loading will still prove beneficial.

The MNLEAP model indicated that the observed TP for all assessed lakes within the Plum Creek subwatershed was below what is predicted for lakes of their watershed and basin morphometric characteristics. The model predicted a fair range of TP loading throughout Plum Creek. These estimated load rates ranged from 71 kg/yr for Bunt Lake to 1,222 kg/yr for Warner Lake. Loading rates can be visualized by observing that Bunt Lake lies in an area receiving little watershed contribution while Warner Lake are near the pour point and is thus susceptible to higher nutrient contributions (Figure 40). Additionally, the areal load rates were higher for lakes with a larger watershed area (Dallas, Feldges, and Warner Lakes) when compared to lakes with smaller watershed areas (Bunt and Crooked Lakes). Areal load rates ranged from 1 m/yr to 86.2 m/yr. The complete modeling results can be found in Appendix C.

Table 11. Summary of lake eutrophication assessment results for the Plum Creek subwatershed

Lake Name	DNR Lake ID	County	Lake Area (Hectares)	Maximum Depth (Meters)	ARUS
Dallas	73-0001-00	Stearns	9	7	FS
Feldges	73-0002-00	Stearns	13	5	FS
Maria	73-0003-00	Stearns	39	5	FS
Long	73-0004-00	Stearns	25	12	FS
Crooked	73-0006-00	Stearns	45	11	FS
Quinn	73-0007-00	Stearns	8		FS
Bunt	73-0010-00	Stearns	40	2	FS
Warner	73-0011-00	Stearns	13	12	FS

Figure 40. Lake assessments and land use within Plum Creek subwatershed



Dallas Lake 73-0001-00

Dallas Lake is a small, moderately deep lake located approximately one and a half miles southwest of Clearwater, Minnesota. Dallas Lake's watershed is large with an area of 5,964 hectares (14,763 acres) and a watershed to lake ratio of 642:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Dallas Lake were 25 µg/L and 7 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 21 µg/L to 30 µg/L and 4 µg/L to 9 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Dallas Lake was below the water quality standard with an average of 3.3 meters (12.8 feet) (Appendix A). Due to a lack of profile data, the lake mixing characteristics of Dallas Lake cannot be determined. Trend data is not available.

Based on the chemical monitoring results and water clarity, Dallas Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Dallas Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Feldges Lake 73-0002-00

Feldges Lake is a small, moderately deep lake located approximately one and a half miles southwest of Clearwater, Minnesota. Feldges Lake's watershed is large with an area of 5,878 hectares (14,550 acres) and a watershed to lake ratio of 455:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Feldges Lake were 30 µg/L and 10 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 25 µg/L to 45 µg/L and 6 µg/L to 19 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Feldges Lake was below the water quality standard with an average of 2.5 meters (8.2 feet) (Appendix A). Due to a lack of profile data, the lake mixing characteristics of Feldges Lake cannot be determined. Trend data is not available.

Based on the chemical monitoring results and water clarity, Feldges Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Feldges Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Maria Lake 73-0003-00

Maria Lake is a small, moderately deep lake located approximately two miles southwest of Clearwater, Minnesota. Maria Lake's watershed is moderately sized with an area of 3,753 hectares (9,289 acres) and a watershed to lake ratio of 97:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Maria Lake were 32 µg/L and 13 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 21 µg/L to 63 µg/L and 8 µg/L to 37 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Maria Lake was below the water quality standard with an average of 2.3 meters (7.5 feet) (Appendix A). Due to a lack of profile data, the lake mixing characteristics of Maria Lake cannot be determined. Trend Data is not available.

Based on the chemical monitoring results and water clarity, Maria Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Maria Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Long Lake 73-0004-00

Long Lake is a small, deep lake located approximately two miles southwest of Clearwater, Minnesota. Long Lake's watershed is small with an area of 1,961 hectares (4,854 acres) and a watershed to lake ratio of 78:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

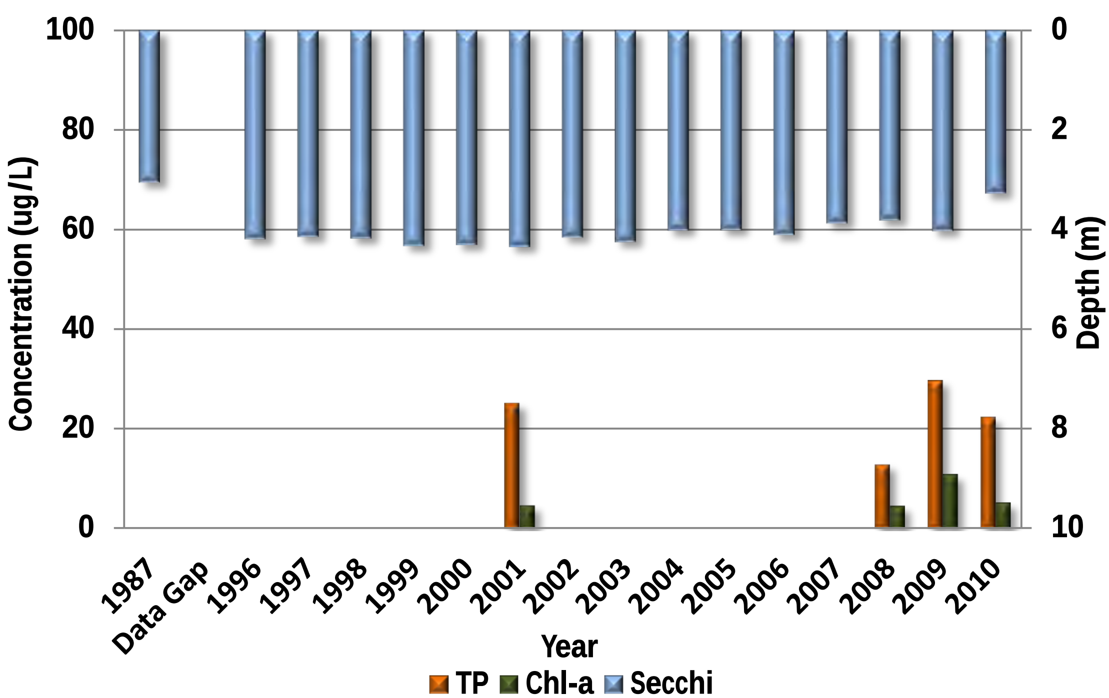
The average TP and chl-*a* values for Long Lake were 24 µg/L and 7 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 12 µg/L to 42 µg/L and 4 µg/L to 17 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Long Lake was below the water quality standard with an average of 3.9 meter (12.8 feet) (Appendix A).

Historical profile data, collected in 2001, shows a distinct thermocline forming between 2 and 3 meters (6.6 and 9.8 feet). This suggests that Long Lake remains stratified during the summer months. DO remained above 5 mg/L in June and September with hypoxic conditions developing below 5 meters (16.4 feet). In July and August, hypoxic conditions developed between 3 and 4 meters (9.8 and 13.1 feet).

Long-term chemistry data does not exist; however, Secchi data is fairly extensive. Figure 41 indicates a slight trend towards reduced water clarity. Despite this reduction, Secchi averages for each year have been below the water quality standard.

Based on the chemical monitoring results and water clarity, Long Lake was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Long Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 41. Long Lake long-term water quality data



Crooked Lake 73-0006-00

Crooked Lake is a small, deep lake located approximately three miles southwest of Clearwater, Minnesota. Crooked Lake's watershed is small with an area of 1,436 hectares (3,555 acres) and a watershed to lake ratio of 31:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

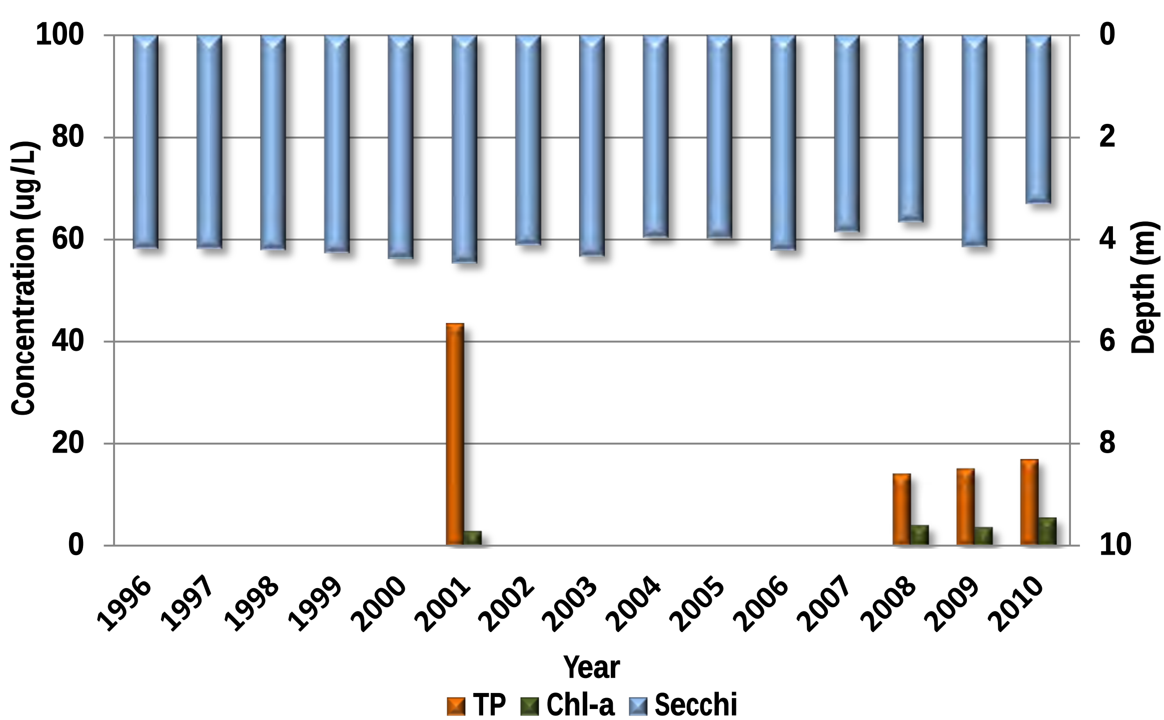
The average TP and chl-*a* values for Crooked Lake were 21 µg/L and 4 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 12 µg/L to 26 µg/L and 3 µg/L to 12 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Crooked Lake was below the water quality standard with an average of 3.9 meter (12.8 feet) (Appendix A).

Historical profile data, collected in 2001, shows a distinct thermocline forming between 2 and 3 meters (6.6 and 9.8 feet). This suggests that Crooked Lake stratifies during the summer months. Dissolved oxygen remained above 5 mg/L in June and September with hypoxic conditions developing below 5 meters (16.4 feet). In July and August, hypoxic conditions developed between 3 and 4 meters (9.8 and 13.1 feet).

Long-term chemistry data does not exist; however, Secchi data is fairly extensive. Figure 42 indicates a slight trend towards reduced water clarity. Despite this reduction, Secchi averages for each year have been below the water quality standard.

Based on the chemical monitoring results and water clarity, Crooked Lake was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Crooked Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 42. Crooked Lake long-term water quality data



Quinn Lake 73-0007-00

Quinn Lake is a small, deep lake located approximately three and a half miles southwest of Clearwater, Minnesota. Quinn Lake's watershed is small with an area of 1,131 hectares (2,799 acres) with a large watershed to lake ratio of 133:1. Land use is dominated by cropland and the percentage is just above the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Quinn Lake were 24 µg/L and 7 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 14 µg/L to 36 µg/L and 1 µg/L to 15 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Quinn Lake was below the water quality standard with an average of 4.1 meters (13.4 feet) (Appendix A). Due to a lack of profile data, the lake mixing characteristics of Quinn Lake cannot be determined. Trend data is not available.

Based on the chemical monitoring results and water clarity, Quinn Lake was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Quinn Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Bunt Lake 73-0010-00

Bunt Lake is a small, shallow lake located approximately three miles west of Clearwater, Minnesota. Bunt Lake's watershed is small relative to its surface water area with an area of 304 hectares (754 acres) and a watershed to lake ratio of 8:1. Land use is dominated by forest and cropland with the forest percentage being above the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Bunt Lake were 52 µg/L and 13 µg/L respectively. Each was below the water quality standard for shallow lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 22 µg/L to 131 µg/L and 4 µg/L to 31 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Bunt Lake was just below the water quality standard with an average of 1.2 meters (3.9 feet) (Appendix A). Due to a lack of profile data, the lake mixing characteristics of Bunt Lake cannot be determined. Trend data is not available.

Based on the chemical monitoring results and water clarity, Bunt Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Bunt Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Warner Lake 73-0011-00

Warner Lake is a small, deep lake located approximately one and a half miles west of Clearwater, Minnesota. Warner Lake's watershed is large with an area of 6,331 hectares (15,671 acres) and a watershed to lake ratio of 506:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Warner Lake were 21 µg/L and 16 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. TP and chl-*a* data, collected in 2009 and 2010, ranged from 14 µg/L to 30 µg/L and 11 µg/L to 23 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Warner Lake was just below the water quality standard with an average of 1.8 meters (5.9 feet) (Appendix A). Due to a lack of profile data, the lake mixing characteristics of Warner Lake cannot be determined. Trend data is not available.

Based on the chemical monitoring results and water clarity, Warner Lake was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Warner Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Clearwater River subwatershed

The Clearwater River (07010203730) HUC-11 watershed lies on the southwestern tip of the Mississippi (St. Cloud) watershed. This 46,586 hectare (115,313 acre) subwatershed represents 16 percent of the Mississippi (St. Cloud) watershed (Figure 43 and Table 2). Cropland is the major land use within this area (Figure 43). Based on 2003 NPDES/SDS registered feedlot data, there is one permitted discharge site and 125 registered feedlots throughout the Clearwater River subwatershed (Figure 6).

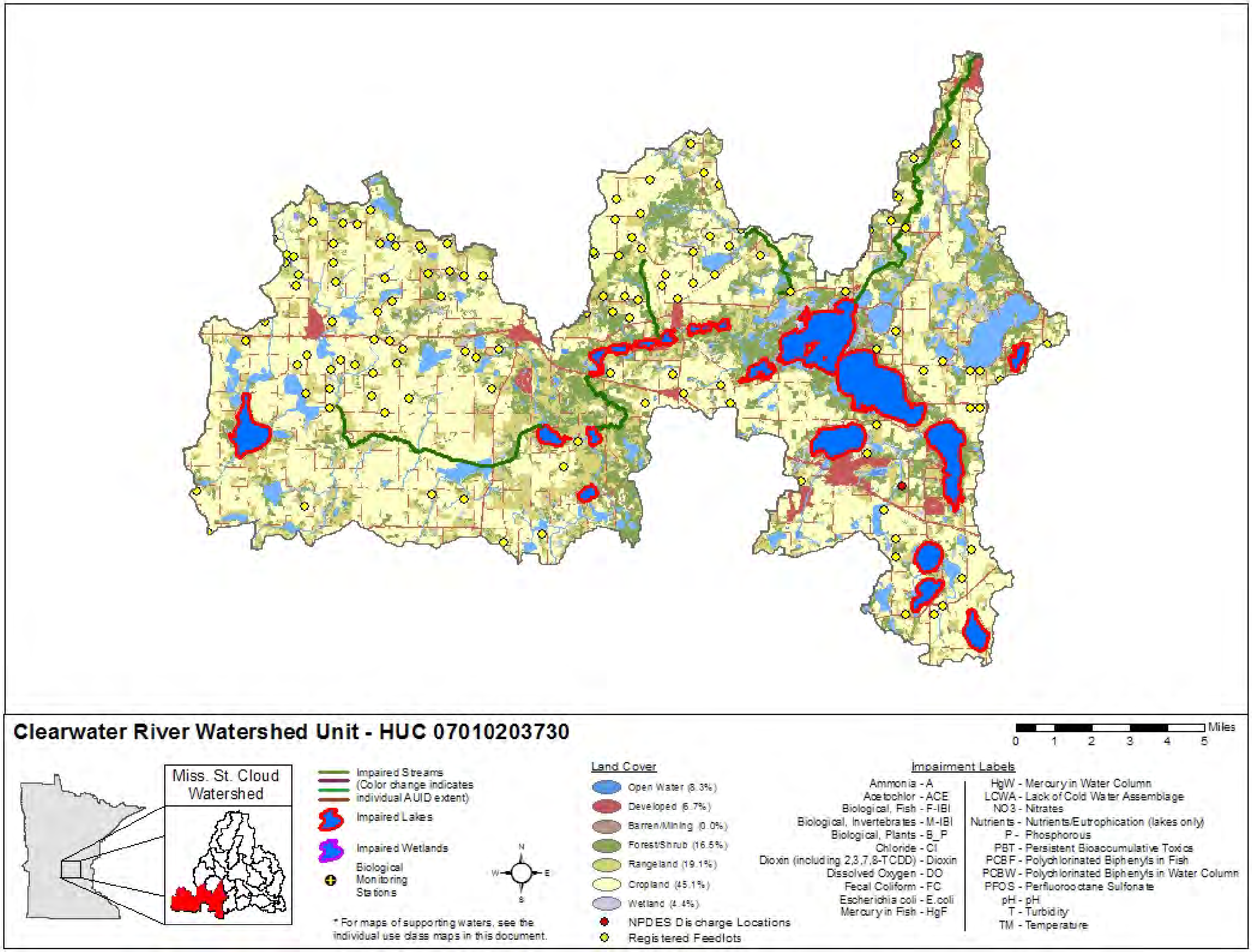
The Clearwater River subwatershed consists of 46 lakes greater than 4 hectares (10 acres), of which 25 were assessed for aquatic recreation use (Table 12). Lakes in the Clearwater River subwatershed vary in size from small basins to large chains of lakes and are located throughout the subwatershed (Figure 43). Of the 25 lakes that were assessed, 12 were determined to be non-supporting of aquatic recreational use (excess nutrients). In the case of Betty, Marie, Caroline, Louisa, Augusta, and Scott, large contributing watersheds are potentially increasing nutrient levels due to a high level of external loading. Profile data for Clear, Swartout, Albion, Henshaw, and Scott indicate periods of mixing, which likely causes internal nutrient release from the lake sediment into the water. Further investigation will be required to fully determine the source of nutrient contributions, but an overall reduction in external loading will still prove beneficial for all impaired waters.

The MNLEAP model indicated that the observed TP for Betty, Clear, Swartout, Albion, Henshaw, and Scott Lakes was significantly higher than the predicted values. The observed TP for Otter, Laura, Island, Nixon, Wiegand, Grass, and West Lakes was significantly below the predicted values. The model predicted a wide range of TP loading throughout the Clearwater River coinciding with the variety of watershed areas and basin morphometry. These estimated load rates ranged from 23 kg/yr for Little Mud Lake to 7,809 kg/yr for Wiegand Lake. Loading rates at the subwatershed level can be visualized by observing that Little Mud Lake lies near the headwaters while Wiegand Lake is located near the pour point and is thus susceptible to greater nutrient contributions from the watershed. Additionally, the areal load rates were higher for lakes with a larger watershed area (Grass and Wiegand Lakes) when compared to lakes with smaller watershed areas (Little Mud and Island Lakes). Areal load rates ranged from 1 m/yr to 115 m/yr. The complete modeling results can be found in Appendix C.

Table 12. Summary of lake eutrophication assessment results for the Clearwater River subwatershed

Lake Name	DNR Lake ID	County	Lake Area (Hectares)	Maximum Depth (Meters)	ARUS
Betty	47-0042-00	Meeker	74	8.8	NS
Clear	47-0095-00	Meeker	284	5.2	NS
Little Mud	47-0096-00	Meeker	17	12.8	NS
Marie	73-0014-00	Stearns	59	11	NS
Otter	73-0015-00	Stearns	51	15.5	FS
Laura	73-0020-00	Stearns	59	-	FS
Island	73-0042-00	Stearns	38	-	FS
Swartout	86-0208-00	Wright	139	3.4	NS
Albion	86-0212-00	Wright	133	-	NS
Henshaw	86-0213-00	Wright	112	-	NS
Indian	86-0223-00	Wright	55	9.5	NS
Cedar	86-0227-00	Wright	338	32.9	FS
Sugar	86-0233-00	Wright	463	21	FS
Bass	86-0234-00	Wright	95	10.4	FS
Nixon	86-0238-00	Wright	42	20.4	IF
Wiegand	86-0242-00	Wright	34	7.3	IF
Grass	86-0243-00	Wright	50	10.7	IF
Pleasant	86-0251-00	Wright	258	22.6	FS
Clearwater (East)	86-0252-01	Wright	-	22.3	FS
Clearwater (West)	86-0252-02	Wright	-	21.3	IF
Caroline	86-0281-00	Wright	56	13.6	NS
Louisa	86-0282-00	Wright	74	13.4	NS
Augusta	86-0284-00	Wright	75	25	NS
Scott	86-0297-00	Wright	41	7	NS
Union	86-0298-00	Wright	37	10.7	NS

Figure 43. Lake **assessments and land use within Clearwater River subwatershed**



Betty Lake 47-0042-00

Betty Lake is a relatively small, deep lake located approximately one mile southeast of Kimball, Minnesota. Betty Lake's watershed is large with an area of 17,693 hectares (43,794 acres) and a watershed to lake ratio of 241:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

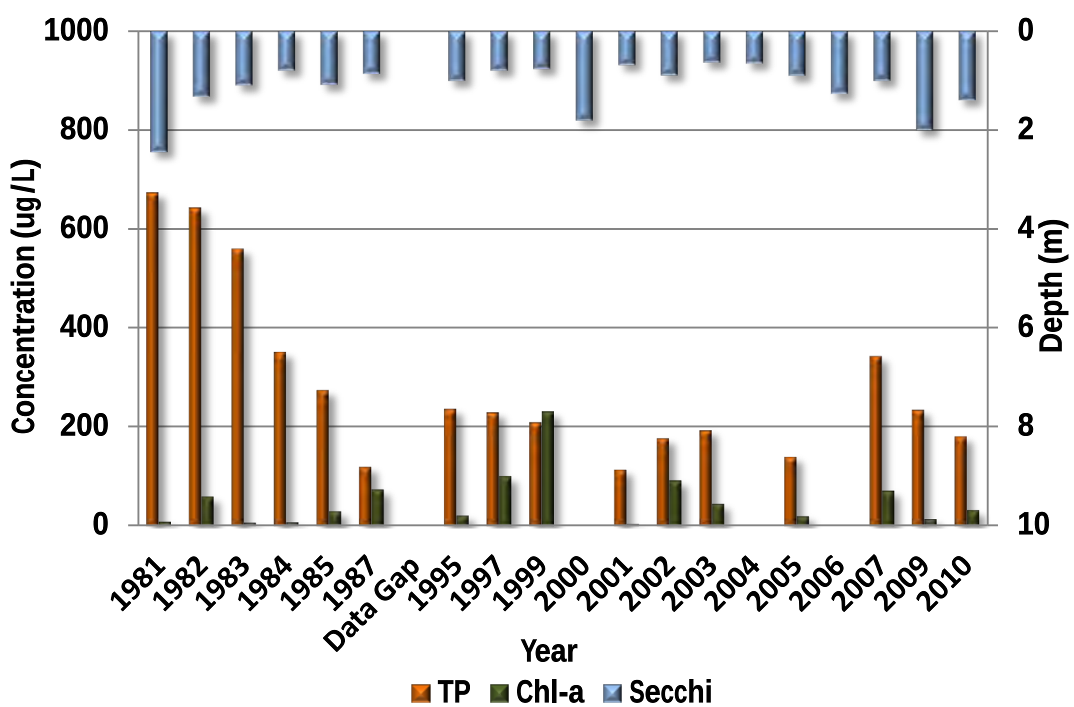
The average TP and chl-*a* values for Betty Lake were 172 µg/L and 57 µg/L respectively. Each was well above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 142 µg/L to 276 µg/L and 9 µg/L to 41 µg/L respectively. Coinciding with the high levels of TP and chl-*a*, the water clarity for Betty Lake was above the water quality standard with an average of 0.9 meters (3 feet) (Appendix A).

Profile data, collected in 2010, indicates that a distinct thermocline formed at a depth of approximately 2 meters (6.6 feet). This suggests that Betty Lake becomes stratified. Additionally, DO remained above 5 mg/L to a depth of 6 meters (19.7 feet) in the spring but became hypoxic at 1 to 3 meters (3.3 to 9.9 feet) in the summer.

Long-term chemistry data is fair and Secchi data is extensive. Figure 44 indicates a slight trend towards reduced water clarity. Chemistry trends indicate a distinct reduction in TP levels since the 1980s. Despite the reduction in nutrient levels, Secchi averages for each year have typically been above the water quality standard with the exception of 2009 and 2010.

Based on the chemical monitoring results and water clarity, Betty Lake was classified as a hypereutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Betty Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2008 303(d) Impaired Waters List. Additional data, collected since the initial listing, supports this impairment.

Figure 44. Betty Lake long-term water quality data



Clear Lake 47-0095-00

Clear Lake is a large, shallow lake located approximately one and a half miles southwest of Watkins, Minnesota. Clear Lake's watershed is moderately sized with an area of 2,619 hectares (6,482 acres) and a watershed to lake ratio of 9:1. Land use is dominated by cropland and the percentage is above the range of values expected for the NCHF ecoregion (Appendix D).

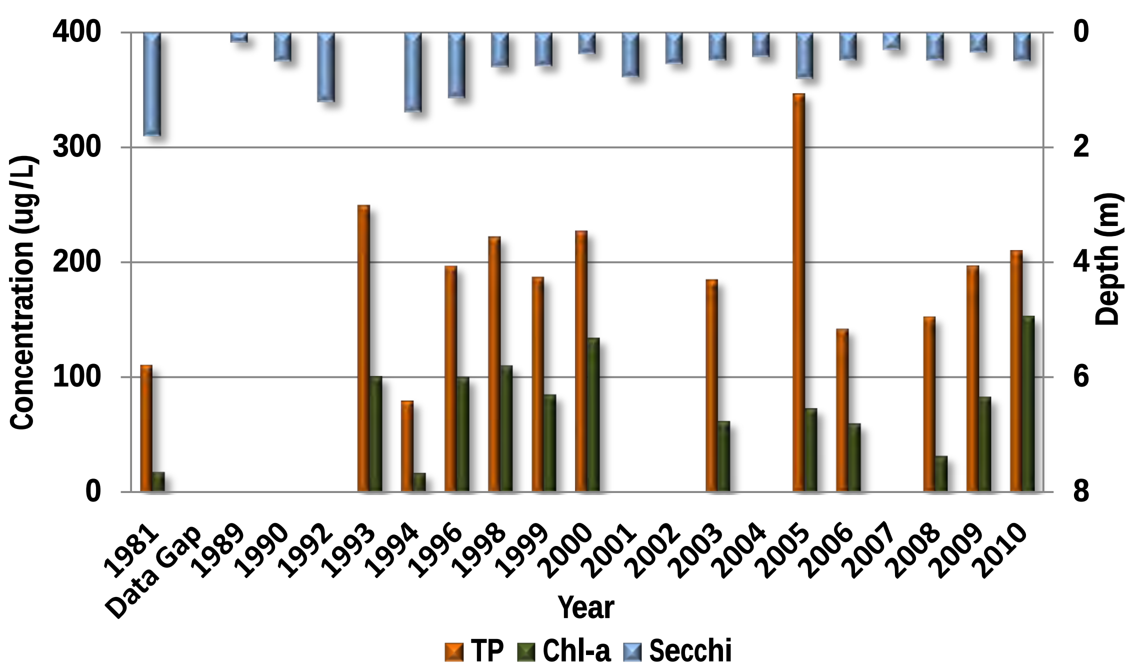
The average TP and chl-*a* values for Clear Lake were 185 µg/L and 90 µg/L respectively. Each was well above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 148 µg/L to 272 µg/L and 49 µg/L to 200 µg/L respectively. Coinciding with the high levels of TP and chl-*a*, the water clarity for Clear Lake was above the water quality standard with an average of 0.5 meters (1.6 feet) (Appendix A).

Profile data, collected in 2010, indicates that a thermocline formed between 4 and 5 meters (13.1 and 16.4 feet) in the spring, but the lake typically remains mixed during the rest of the season. This suggests that Clear Lake remains well mixed during the summer months but may form a thermocline during calm conditions. DO remained above 5 mg/L in June, August, and September with hypoxic conditions developing below 5 meters (16.4 feet). In July and August hypoxic conditions developed at 3 meters (9.8 feet).

Long-term chemistry data is fair and Secchi data is extensive. Figure 45 indicates a trend towards declining water clarity. Coinciding with the reduction in water clarity, chemistry trends indicate increasing levels of TP and chl-*a*.

Based on the chemical monitoring results and water clarity, Clear Lake was classified as a hypereutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Clear Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2008 303(d) Impaired Waters List.

Figure 45. Clear Lake long-term water quality data



Little Mud 47-0096-00

Little Mud Lake is a small, deep lake located approximately two and a half miles south of Watkins, Minnesota. Little Mud Lake's watershed is small with an area of 91 hectares (225 acres) and a watershed to lake ratio of 5:1. Land use is dominated by rangeland and the percentage is above the range of values expected for the NCHF ecoregion (Appendix D).

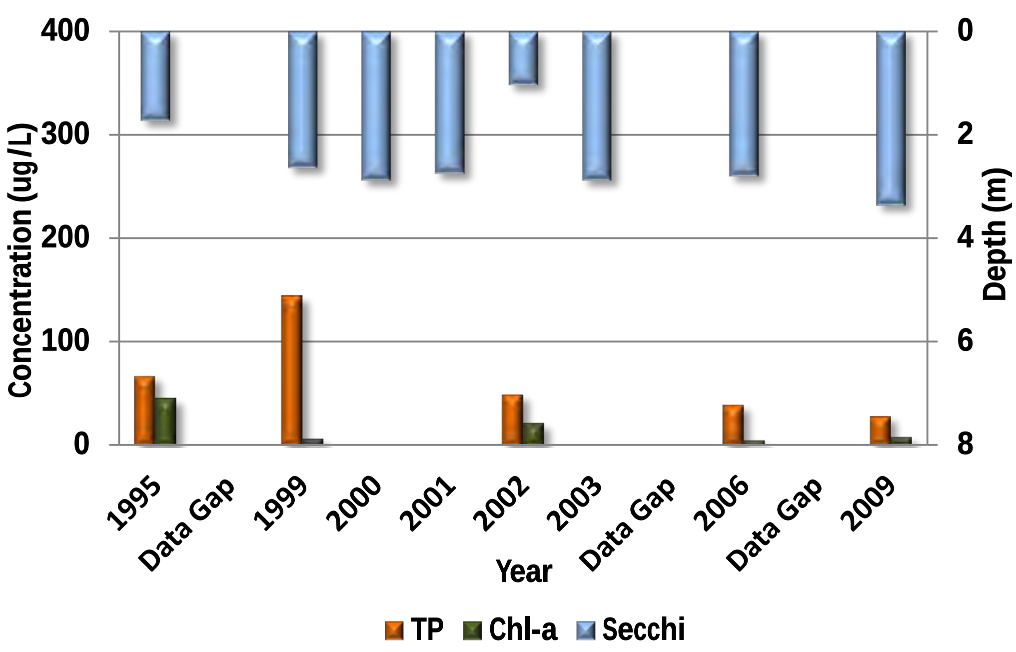
The average TP and chl-*a* values for Little Mud Lake were 49 µg/L and 21 µg/L respectively. Each was above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2002 and 2006, ranged from 25 µg/L to 66 µg/L and 3 µg/L to 27 µg/L respectively. Despite the high levels of TP and chl-*a*, the water clarity for Little Mud Lake was below the water quality standard with an average of 2.1 meters (6.9 feet) (Appendix A).

Profile data, collected in 2002, indicated that a thermocline formed at 3 meters (9.9 feet) for a majority of the season. This suggests that Little Mud Lake stratifies during the summer months. Additionally, DO remained above 5 mg/L at varying depths during the summer months with hypoxic conditions developing below.

Long-term chemistry data for Little Mud Lake is sparse. Available data, within Figure 46, indicates a trend towards an overall improvement in water quality. Coinciding with the increase in water clarity, chemistry trends indicate decreasing levels of TP and chl-*a*.

Based on the chemical monitoring results and water clarity, Little Mud Lake was classified as a eutrophic lake. Due to insufficient TP and chl-*a* results, Little Mud Lake was not assessed; however, existing results do lean towards non-supporting for aquatic recreational uses.

Figure 46. Little Mud Lake long-term water quality data



Marie Lake 73-0014-00

Marie Lake is a relatively small, deep lake located southwest of the Fairhaven, Minnesota city limits. Marie Lake's watershed is large with an area of 22,923 hectares (56,741 acres) and a watershed to lake ratio of 391:1. Land use is dominated by cropland and the percentage is just above the range of values expected for the NCHF ecoregion (Appendix D).

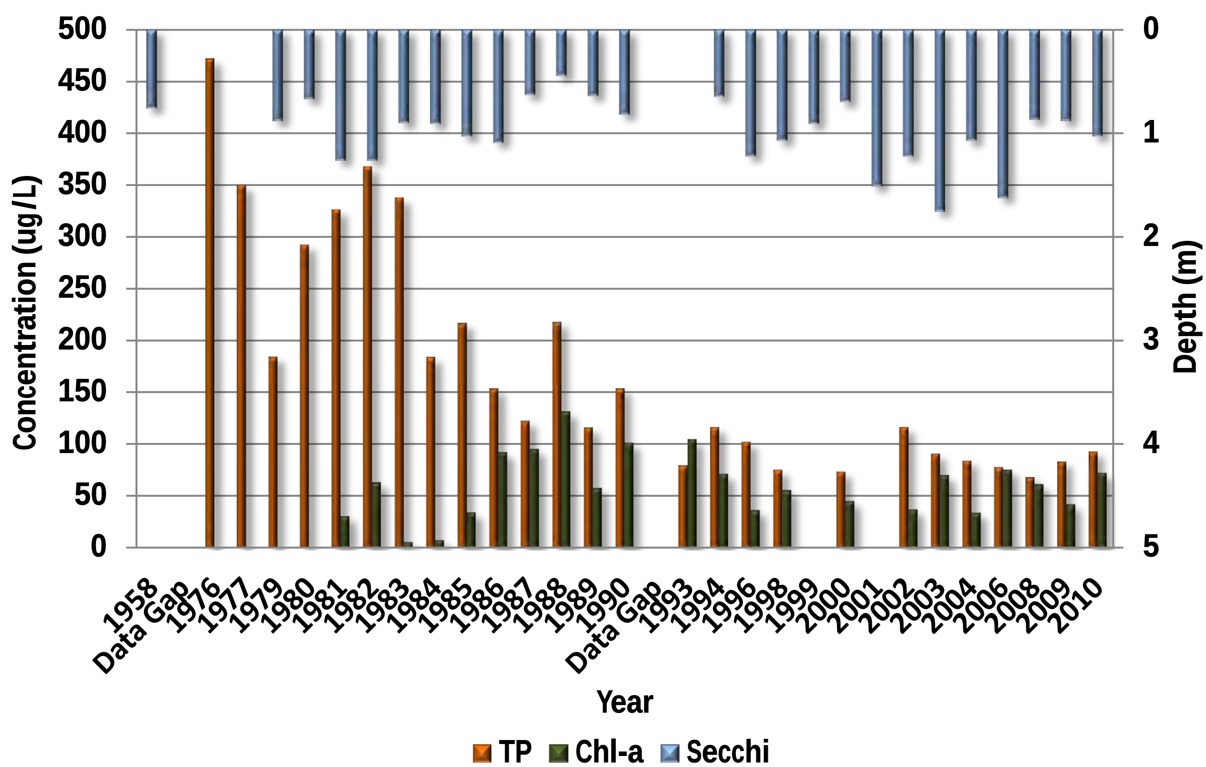
The average TP and chl-*a* values for Marie Lake were 108 µg/L and 48 µg/L respectively. Each was well above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 41 µg/L to 178 µg/L and 4 µg/L to 139 µg/L respectively. Despite the high levels of TP and chl-*a*, the water clarity for Marie Lake was just at the water quality standard with an average of 1 meter (3.3 feet) (Appendix A).

Profile data, collected in 2010, indicated that a thermocline formed between 1 and 2 meters (3.3 and 6.6 feet) throughout the season. This suggests that Marie Lake stratifies during the summer months. Dissolved oxygen typically dropped below 5 mg/L at a depth of 2 meters (6.6 feet) throughout most of the season.

Long-term chemistry data is fair and Secchi data is extensive. Figure 47 indicates a trend towards improving water clarity as well as lower levels of TP. Despite improving conditions all parameters still remain above the water quality standard.

Based on the chemical monitoring results and water clarity, Marie Lake was classified as a hypereutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Marie Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2008 303(d) Impaired Waters List.

Figure 47. Marie Lake long-term water quality data



Otter Lake 73-0015-00

Otter Lake is a small, deep lake located approximately two miles east of Fairhaven, Minnesota. Otter Lake's watershed is large with an area of 4,879 hectares (12,076 acres) and a watershed to lake ratio of 97:1. Land use is dominated by cropland and the percentage is just above the range of values expected for the NCHF ecoregion (Appendix D).

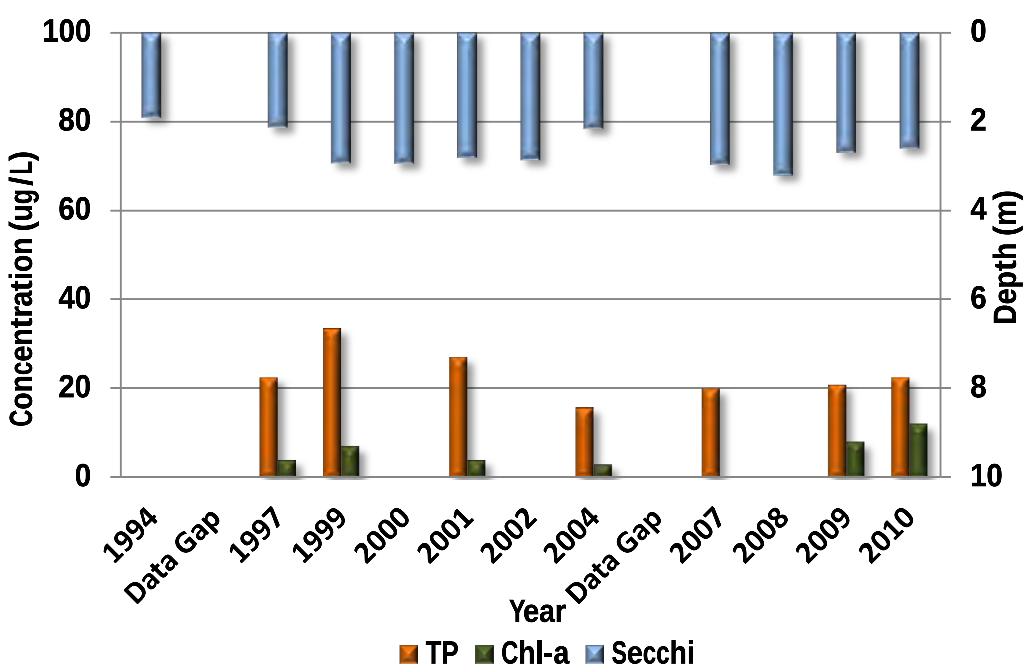
The average TP and chl-*a* values for Otter Lake were 22 µg/L and 9 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 18 µg/L to 24 µg/L and 4 µg/L to 14 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Otter Lake was below the water quality standard with an average of 2.8 meters (9.2 feet) (Appendix A).

Profile data, collected in 2009, indicated that a distinct thermocline formed between 2 and 4 meters (6.6 and 13.1 feet). This suggests that Otter Lake stratifies during the summer months. Dissolved oxygen remained above 5 mg/L to a depth of 4 meters (16.4 feet) with hypoxic/anoxic conditions occurring below.

Long-term chemistry and Secchi data is sparse. Figure 48 indicates a trend towards improving water clarity as well as lower levels of TP. All parameters were below the water quality standard for each year with available data.

Based on the chemical monitoring results and water clarity, Otter Lake was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Otter Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 48. Otter Lake long-term water quality data



Laura Lake 73-0020-00

Laura Lake is a small, shallow lake located approximately one mile northeast of Fairhaven, Minnesota. Laura Lake's watershed is small with an area of 1,073 hectares (2,400 acres) and a watershed to lake ratio of 16:1. Land use is dominated by cropland and the percentage is above the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Laura Lake were 20 µg/L and 4 µg/L respectively. Each was below the water quality standard for shallow lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 12 µg/L to 35 µg/L and 3 µg/L to 5 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Laura Lake was below the water quality standard with an average of 1.5 meters (4.9 feet) (Appendix A). Due to a lack of profile data, the lake mixing characteristics of Laura Lake cannot be determined. Trend data is not available.

Based on the chemical monitoring results and water clarity, Laura Lake was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Laura Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Island Lake 73-0042-00

Island Lake is a small, shallow lake located approximately three miles northwest of Kimball, Minnesota. Island Lake's watershed is small relative to its surface water area with an area of 134 hectares (332 acres) and a watershed to lake ratio of 4:1. Land use is dominated by forest and the percentage is well above the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Island Lake were 29 µg/L and 3 µg/L respectively. Each was below the water quality standard for shallow lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 15 µg/L to 39 µg/L and 1 µg/L to 6 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Island Lake was below the water quality standard with an average of 2.9 meters (9.5 feet) (Appendix A). Due to a lack of profile data, the lake mixing characteristics of Island Lake cannot be determined. Trend data is not available.

Based on the chemical monitoring results and water clarity, Island Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Island Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Swartout Lake 86-0208-00

Swartout Lake is a moderately sized, shallow lake located approximately two and a half miles southeast of Annandale, Minnesota. Swartout Lake's watershed is moderately sized with an area of 2,127 hectares (5,265 acres) and a watershed to lake ratio of 15:1. Land use is dominated by cropland and the percentage is just above the range of values expected for the NCHF ecoregion (Appendix D).

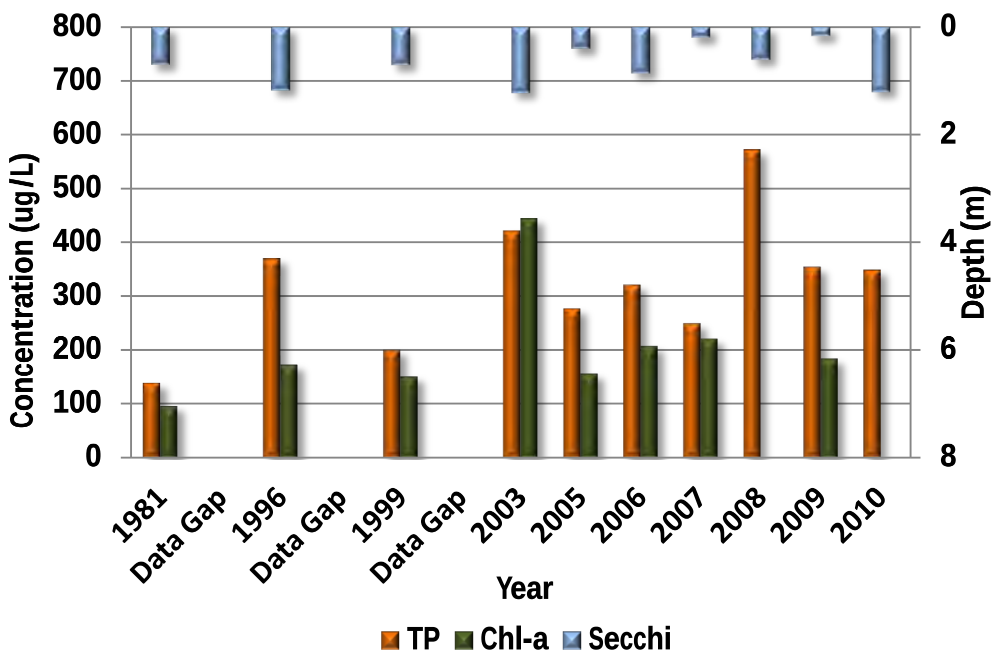
The average TP and chl-*a* values for Swartout Lake were 422 µg/L and 444 µg/L respectively. Each was well above the water quality standard for shallow lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 240 µg/L to 451 µg/L and 3 µg/L to 223 µg/L respectively. Despite the high levels of TP and chl-*a*, the water clarity for Swartout Lake was at the water quality standard with an average of 1 meter (3.3 feet) (Appendix A).

Profile data, collected in 2010, indicated that Swartout Lake remained continuously mixed during the summer months. Additionally, DO remained above 5 mg/L from the surface to approximately 2 meters (6.6 feet) in August and September. Hypoxic conditions existed throughout the water column in June and July.

Long-term chemistry and Secchi data is sparse. Figure 49 indicates a slight trend towards declining water clarity as well as increasing TP levels. All parameters were above the water quality standard for each year with available data.

Based on the chemical monitoring results and water clarity, Swartout Lake was classified as a hypereutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Swartout Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2008 303(d) Impaired Waters List.

Figure 49. Swartout Lake long-term water quality data



Albion Lake 86-0212-00

Albion Lake is a moderately sized, shallow lake located approximately three miles southwest of Maple Lake, Minnesota. Albion Lake's watershed is small with an area of 625 hectares (1,547 acres) and a watershed to lake ratio of 5:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

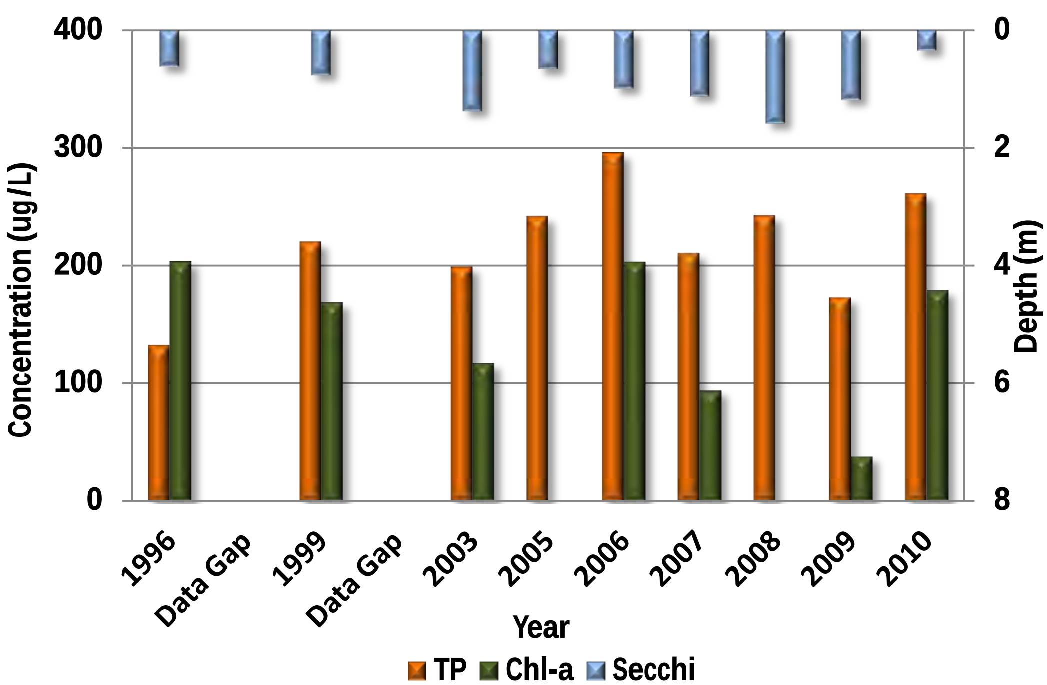
The average TP and chl-*a* values for Albion Lake were 199 µg/L and 117 µg/L respectively. Each was well above the water quality standard for shallow lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 142 µg/L to 484 µg/L and 5 µg/L to 443 µg/L respectively. Despite the high levels of TP and chl-*a*, the water clarity for Albion Lake was below the water quality standard with an average of 1.4 meters (4.6 feet) (Appendix A).

Profile data, collected in 2010, indicated that Albion Lake remained continuously mixed during the summer months. Additionally, Albion Lake became nearly anoxic at a depth of 1 meter (3.3 feet) throughout the summer months. Dissolved oxygen was above 5 mg/L throughout the entire water column in September.

Long-term chemistry and Secchi data is sparse. Figure 50 does indicate a slight trend towards improving water clarity; however, TP levels show an increasing trend. Albion Lake has a history of periodically improved water clarity but the nutrient data indicates an overall reduction in water quality.

Based on the chemical monitoring results and water clarity, Albion Lake was classified as a hypereutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Albion Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2008 303(d) Impaired Waters List.

Figure 50. Albion Lake long-term water quality data



Henshaw Lake 86-0213-00

Henshaw Lake is a moderately sized, shallow lake located approximately two miles southwest of Maple Lake, Minnesota. Henshaw Lake's watershed is small with an area of 443 hectares (1,096 acres) and a watershed to lake ratio of 4:1. Land use is dominated by cropland and the percentage is just above the range of values expected for the NCHF ecoregion (Appendix D).

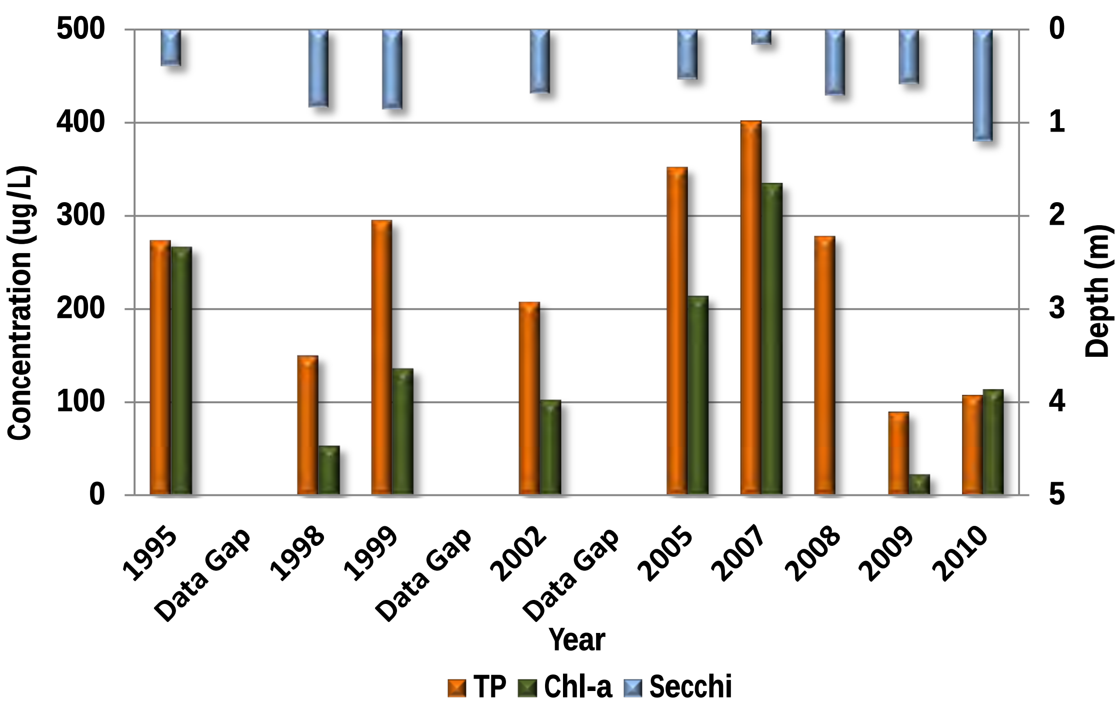
The average TP and chl-*a* values for Henshaw Lake were 208 µg/L and 103 µg/L respectively. Each was well above the water quality standard for shallow lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 74 µg/L to 141 µg/L and 15 µg/L to 214 µg/L respectively. Coinciding with the high levels of TP and chl-*a*, the water clarity for Henshaw Lake was above the water quality standard with an average of 0.7 meters (2.3 feet) (Appendix A).

Profile data, collected in 2010, indicates that Henshaw Lake remained continuously mixed during the summer months. Additionally, DO was above 5 mg/L throughout the entire water column during the entire monitoring year with the exception of July. Hypoxic conditions developed at 1 meter (3.3 feet) for that month.

Long-term chemistry and Secchi data is sparse. Figure 51 does indicate a slight trend towards improving water quality with an increase in water clarity and a reduction in TP; however, despite these improvements, chemistry and Secchi values were still above the water quality standard.

Based on the chemical monitoring results and water clarity, Henshaw Lake was classified as a hypereutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Henshaw Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2008 303(d) Impaired Waters List.

Figure 51. Henshaw Lake long-term water quality data



Indian Lake 86-0223-00

Indian Lake is a small, deep lake located approximately four miles northeast of Annandale, Minnesota. Indian Lake's watershed is moderately sized with an area of 2,182 hectares (5,401 acres) and a watershed to lake ratio of 40:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

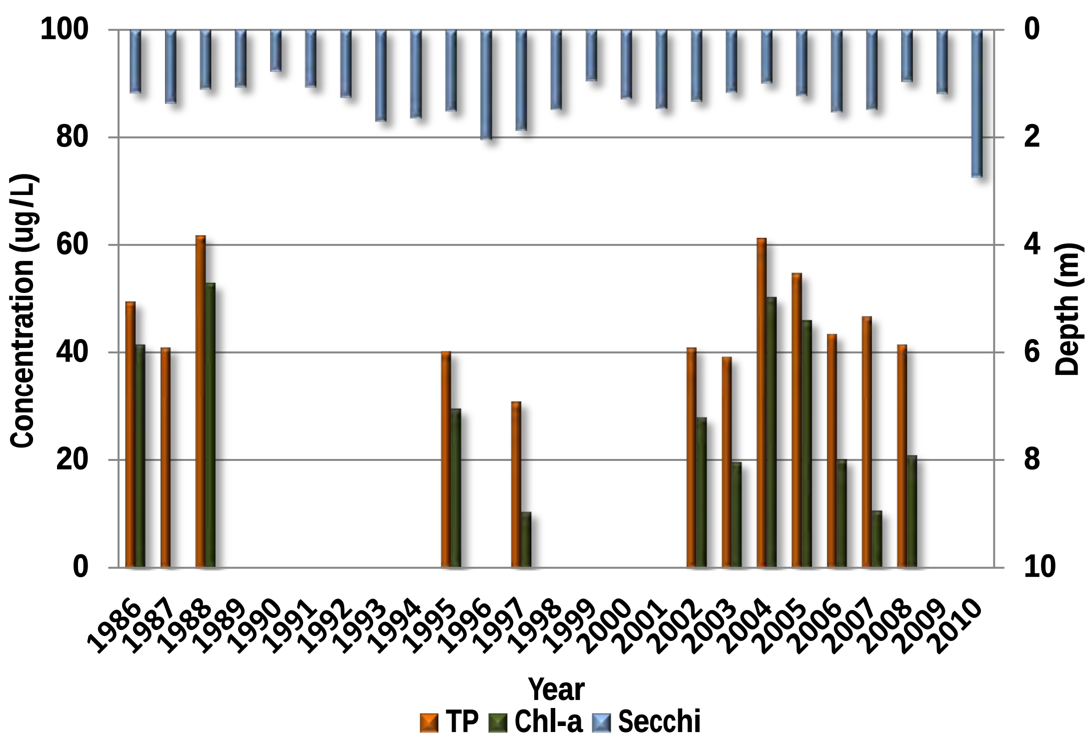
The average TP and chl-*a* values for Indian Lake were 47 µg/L and 28 µg/L respectively. Each was above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2008, ranged from 37 µg/L to 49 µg/L and 13 µg/L to 46 µg/L respectively. Coinciding with the high levels of TP and chl-*a*, the water clarity for Indian Lake was above the water quality standard with an average of 1.3 meters (4.3 feet) (Appendix A).

Historical profile data, collected in 1995, indicated that Indian Lake formed a distinct thermocline throughout the monitoring season at a depth of 4 meters (13.1 feet). This suggests that Indian Lake stratifies during the summer months. Additionally, DO was above 5 mg/L to a depth of 5 to 6 meters (16.4 to 19.7 feet) in the spring and fall but near anoxic conditions existed below 4 meters (13.1 feet) in the summer.

Long-term chemistry data is fair and Secchi data is extensive. Figure 52 indicates a slight trend towards improving water quality with an increase in water clarity and a reduction in TP; however, despite these improvements, chemistry and Secchi values were still above the water quality standard for a majority of the years.

Based on the chemical monitoring results and water clarity, Indian Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Indian Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2008 303(d) Impaired Waters List. Recent data supports this listing.

Figure 52. Indian Lake long-term water quality data



Cedar Lake 86-0227-00

Cedar Lake is a large, deep lake located approximately two miles east of Annandale, Minnesota. Cedar Lake's watershed is moderately sized with an area of 3,716 hectares (9,197 acres) and a watershed to lake ratio of 11:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

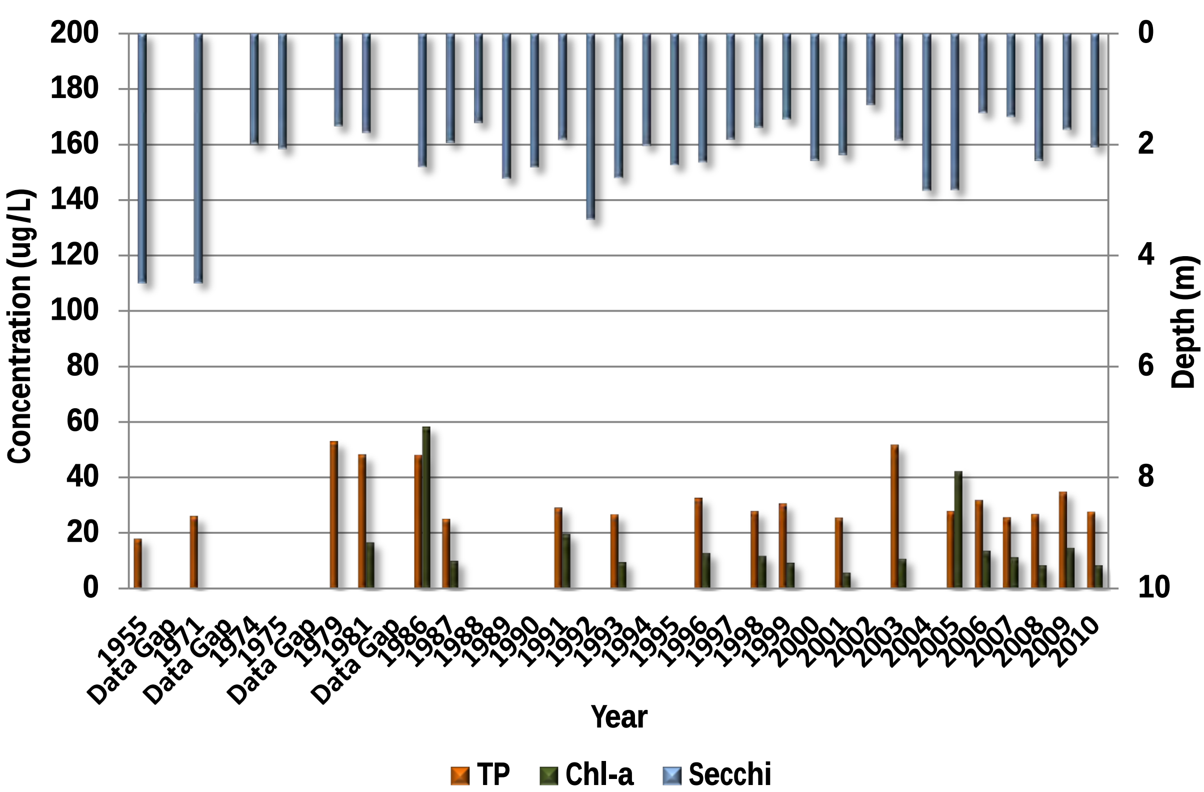
The average TP and chl-*a* values for Cedar Lake were 31 µg/L and 15 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 17 µg/L to 42 µg/L and 3 µg/L to 16 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Cedar Lake was below the water quality standard with an average of 2.1 meters (6.9 feet) (Appendix A).

Profile data, collected in 2010, indicates that Cedar Lake formed a distinct thermocline throughout the monitoring season at varying depths. This suggests that Cedar Lake stratifies during the summer months. Additionally, DO was above 5 mg/L to a depth of 11 meters (36 feet) a majority of the season with near anoxic conditions below this depth.

Long-term chemistry data is fair and Secchi data is extensive including data from the mid 1970s and 1950s. Despite Cedar Lake's status as fully supporting, Figure 53 indicates a trend towards declining water quality with an overall decrease in water clarity and slightly higher TP levels.

Based on the chemical monitoring results and water clarity, Cedar Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Cedar Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 53. Cedar Lake long-term water quality data



Sugar Lake 86-0233-00

Sugar Lake is a large, deep lake located approximately three miles northeast of Annandale, Minnesota. Sugar Lake's watershed is moderately sized with an area of 2,705 hectares (6,695 acres) and a watershed to lake ratio of 6:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

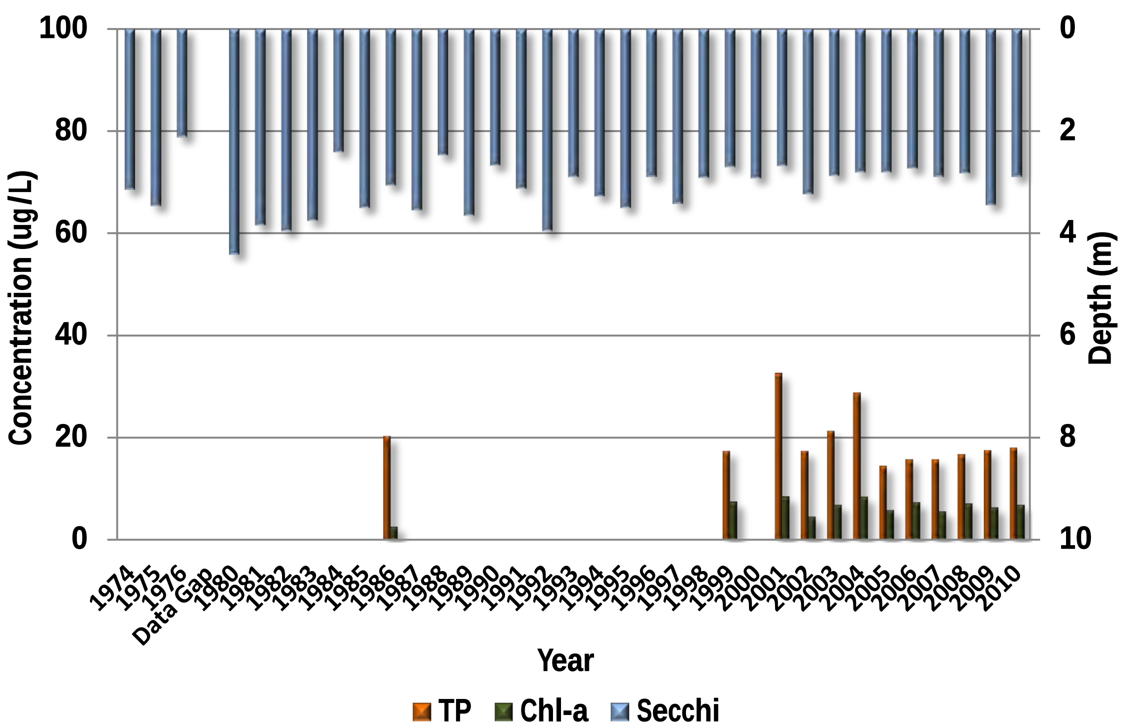
The average TP and chl-*a* values for Sugar Lake were 20 µg/L and 7 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 13 µg/L to 22 µg/L and 3 µg/L to 10 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Sugar Lake was below the water quality standard with an average of 3 meters (9.8 feet) (Appendix A).

Historical profile data, collected in 1999, indicates that Sugar Lake formed a distinct thermocline throughout the monitoring season at varying depths. This suggests that Sugar Lake stratifies during the summer months. Additionally, DO was above 5 mg/L to a minimal depth of 6 meters (19.7 feet) in June.

Long-term chemistry is adequate to complete a trend analysis and Secchi data is extensive. Despite Sugar Lake's status as fully supporting, Figure 54 indicates a trend towards declining water clarity. More recent TP values are lower than levels observed in earlier years.

Based on the chemical monitoring results and water clarity, Sugar Lake was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Sugar Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 54. Sugar Lake long-term water quality data



Bass Lake 86-0234-00

Bass Lake is a moderately sized, deep lake located approximately four miles north of Annandale, Minnesota. Bass Lake's watershed is small with an area of 384 hectares (951 acres) and a watershed to lake ratio of 4:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

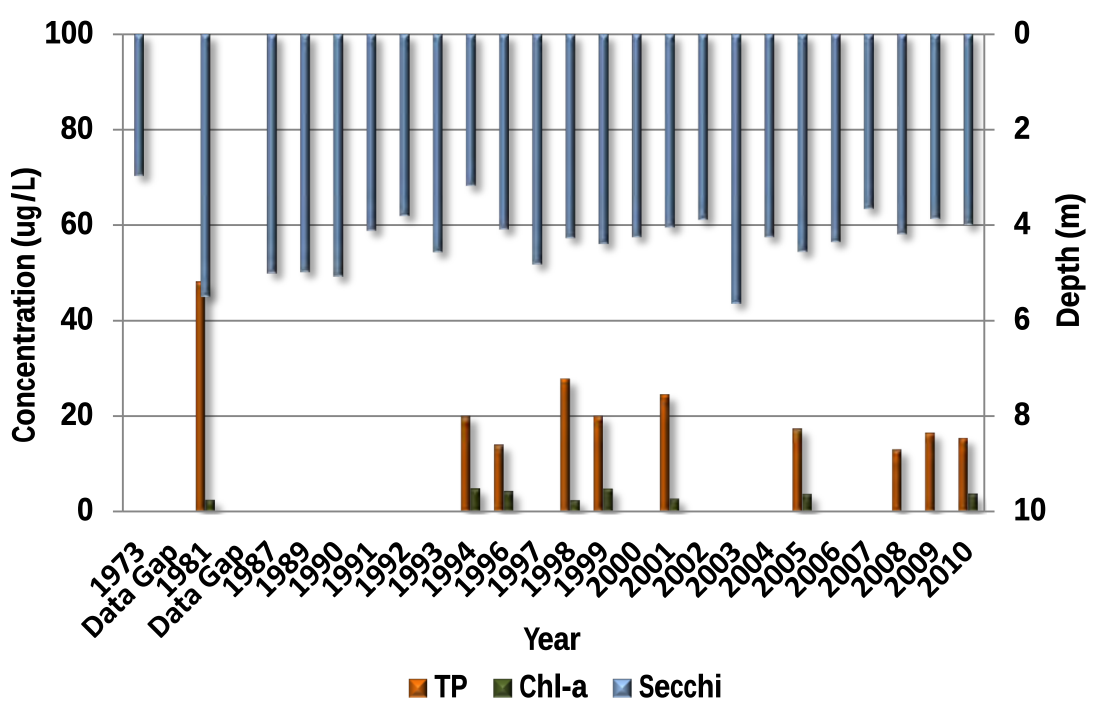
The average TP and chl-*a* values for Bass Lake were 18 µg/L and 3 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 11 µg/L to 22 µg/L and 3 µg/L to 6 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Bass Lake was below the water quality standard with an average of 4.3 meters (14.1 feet) (Appendix A).

Profile data, collected in 2005, indicates that Bass Lake formed a thermocline throughout the monitoring season at varying depths. This suggests that Bass Lake stratifies during the summer months. Additionally, DO data was limited but did indicate that levels remained above 5 mg/L throughout the entire water column in the spring and fall. Hypoxic conditions developed at a depth of 6 meters (19.7 feet) in July.

Long-term chemistry is sparse and Secchi data is extensive. Water clarity for Bass Lake maintains a consistent trend of high water quality. Figure 55 indicates a trend of declining TP levels. Averages for each year, since 1981, have all been below the water quality standard.

Based on the chemical monitoring results and water clarity, Bass Lake was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Bass Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 55. Bass Lake long-term water quality data



Nixon Lake 86-0238-00

Nixon Lake is a small, deep lake located approximately four miles south of Clearwater, Minnesota. Nixon Lake's watershed is small with an area of 634 hectares (1,570 acres) and a watershed to lake ratio of 15:1. Land use is dominated by forest and the percentage is above the range of values expected for the NCHF ecoregion (Appendix D).

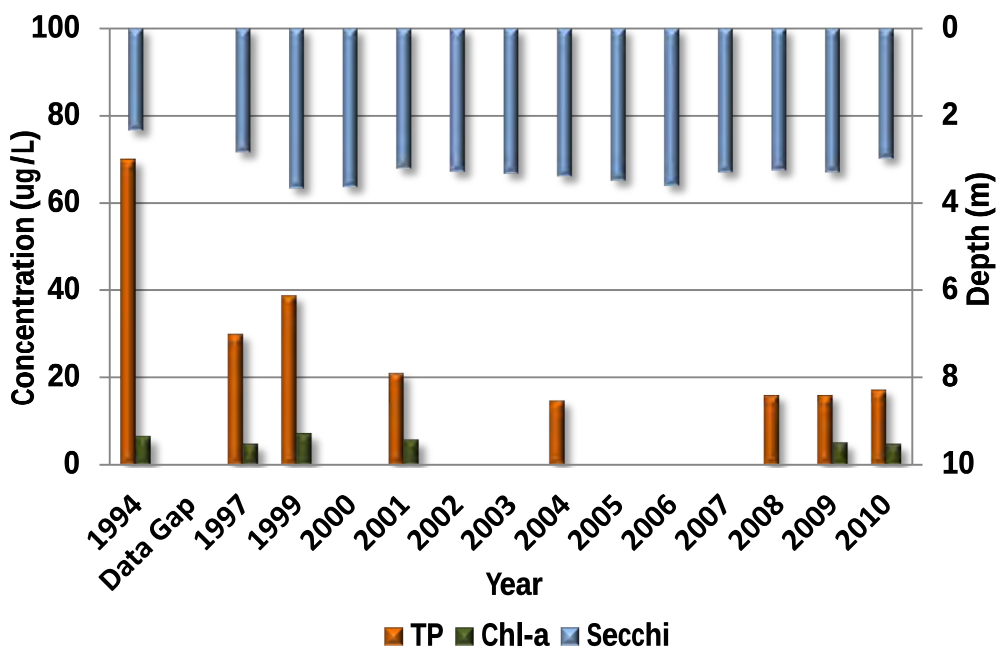
The average TP and chl-*a* values for Nixon Lake were 19 µg/L and 5 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 15 µg/L to 23 µg/L and 3 µg/L to 7 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Nixon Lake was below the water quality standard with an average of 3.3 meters (10.8 feet) (Appendix A).

Profile data, collected in 2009 and 2010, indicates that Nixon Lake formed a distinct thermocline between 3 and 4 meters (9.8 and 13.1 feet) during the summer months. This suggests that Nixon Lake stratifies during the summer months. Additionally, DO levels remained above 5 mg/L at varying depths. Hypoxic conditions developed as shallow as two meters (6.6 feet) in the peak of summer.

Long-term chemistry is sparse and Secchi data is adequate to complete a trend analysis. Water clarity for Nixon Lake maintains a consistent trend of high water quality. Figure 56 indicates a trend of declining TP levels. Averages for each year, with the exception of one high value reading in 1994, have all been below the water quality standard.

Based on the chemical monitoring results and water clarity, Nixon Lake was classified as a mesotrophic lake. Due to insufficient TP and chl-*a* results, Nixon Lake was not assessed; however, existing results do lean towards fully supporting aquatic recreational uses.

Figure 56. Nixon Lake long-term water quality data



Wiegand Lake 86-0242-00

Wiegand Lake is a small, deep lake located approximately four miles south of Clearwater, Minnesota. Wiegand Lake's watershed is large with an area of 40,533 hectares (100,328 acres) and a watershed to lake ratio of 1,180:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

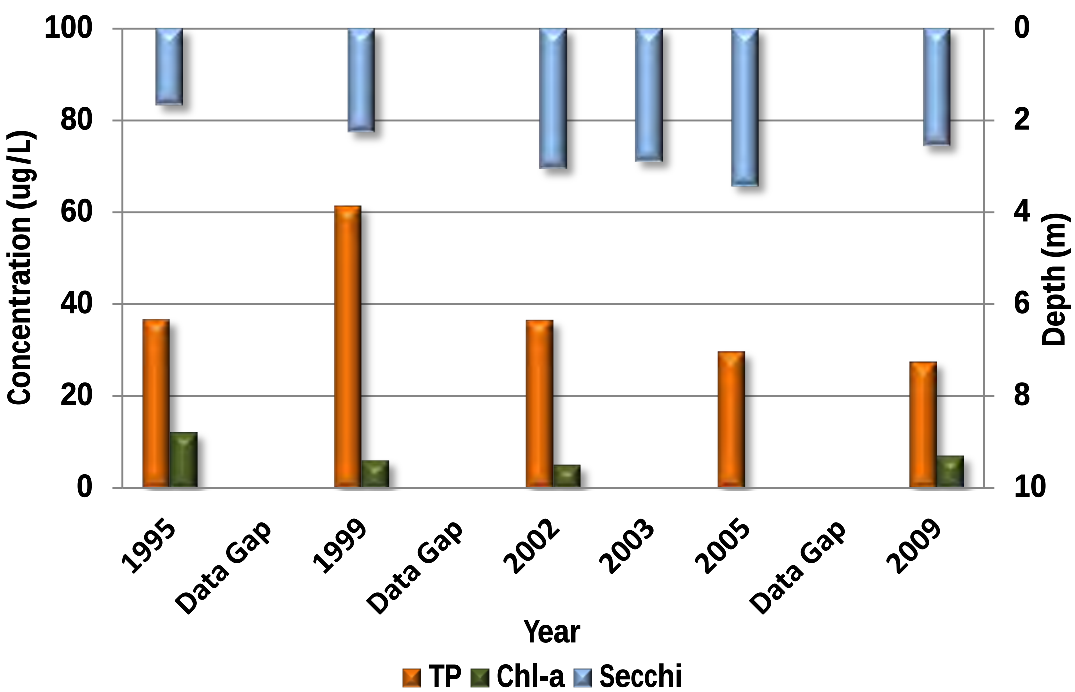
The average TP and chl-*a* values for Wiegand Lake were 37 µg/L and 5 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009, ranged from 21 µg/L to 32 µg/L and 3 µg/L to 10 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Wiegand Lake was below the water quality standard with an average of 2.9 meters (9.5 feet) (Appendix A).

Profile data, collected in 2009, indicates that Wiegand Lake formed a distinct thermocline during the summer months but was mixed in the fall. This suggests that Wiegand Lake stratifies during the summer months. Additionally, DO levels remained above 5 mg/L to a depth of 2 to 3 meters (6.6 to 9.9 feet) in the summer. Dissolved oxygen levels were above 5 mg/L throughout the water column in the fall.

Long-term chemistry and Secchi data is sparse and inadequate to complete a trend analysis. Available data (Figure 57) does indicate a trend of declining TP levels and improving water clarity.

Based on the chemical monitoring results and water clarity, Wiegand Lake was classified as a eutrophic lake. Due to insufficient TP and chl-*a* results, Wiegand Lake was not assessed; however, existing results do lean towards fully supporting for aquatic recreational uses.

Figure 57. Wiegand Lake long-term water quality data



Grass Lake 86-0243-00

Grass Lake is a small, deep lake located four miles north of Annandale, Minnesota. Grass Lake's watershed is large with an area of 39,878 hectares (98,709 acres) and a watershed to lake ratio of 803:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

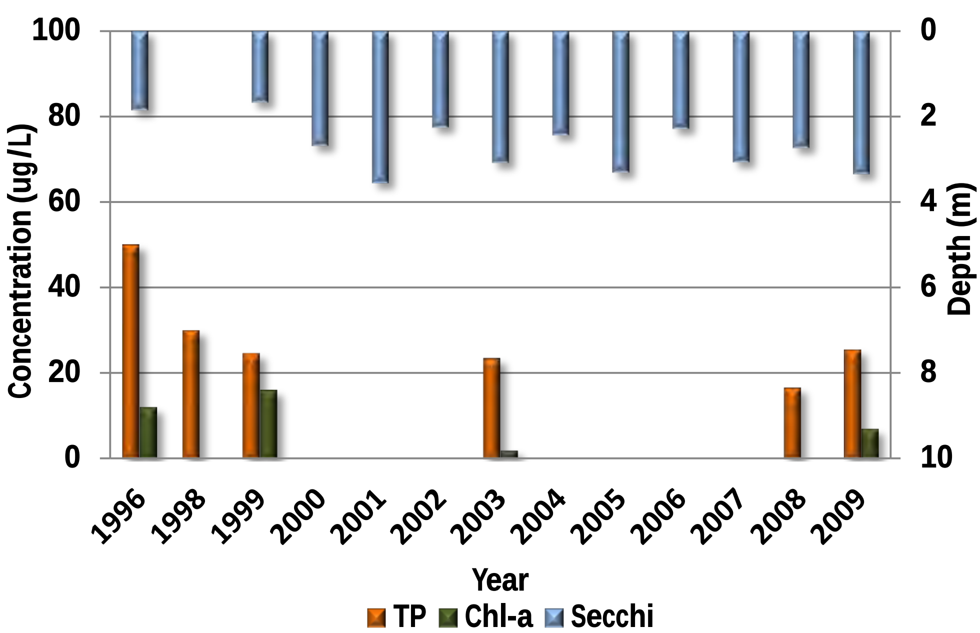
The average TP and chl-*a* values for Grass Lake were 24 µg/L and 2 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009, ranged from 19 µg/L to 32 µg/L and 3 µg/L to 14 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Grass Lake was below the water quality standard with an average of 3.1 meters (10.2 feet) (Appendix A).

Profile data, collected in 2009, indicates that Grass Lake formed a thermocline at a depth of 2 meters (6.6 feet) for most of the season and descended to a depth of 4 meters (13.1 feet) in August. This suggests that Grass Lake stratifies during the summer months. Additionally, DO levels typically remained above 5 mg/L to a depth of 4 meters (13.1 feet) for each month with anoxic conditions developing below.

Long-term chemistry is sparse and Secchi data is adequate to complete a trend analysis. Water clarity for Grass Lake indicates a slight trend towards improving conditions. Figure 58 indicates a trend of declining TP levels. Total phosphorus and Secchi averages for each year, since 1996, have all been below the water quality standard.

Based on the chemical monitoring results and water clarity, Grass Lake was classified as a mesotrophic lake. Due to insufficient TP and chl-*a* results, Grass Lake was not assessed; however, existing results do lean towards fully supporting for aquatic recreational uses.

Figure 58. Grass Lake long-term water quality data



Pleasant Lake 86-0251-00

Pleasant Lake is a large, deep lake located just north of Annandale, Minnesota. Pleasant Lake's watershed is small with an area of 1,273 hectares (3,151 acres) and a watershed to lake ratio of 5:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

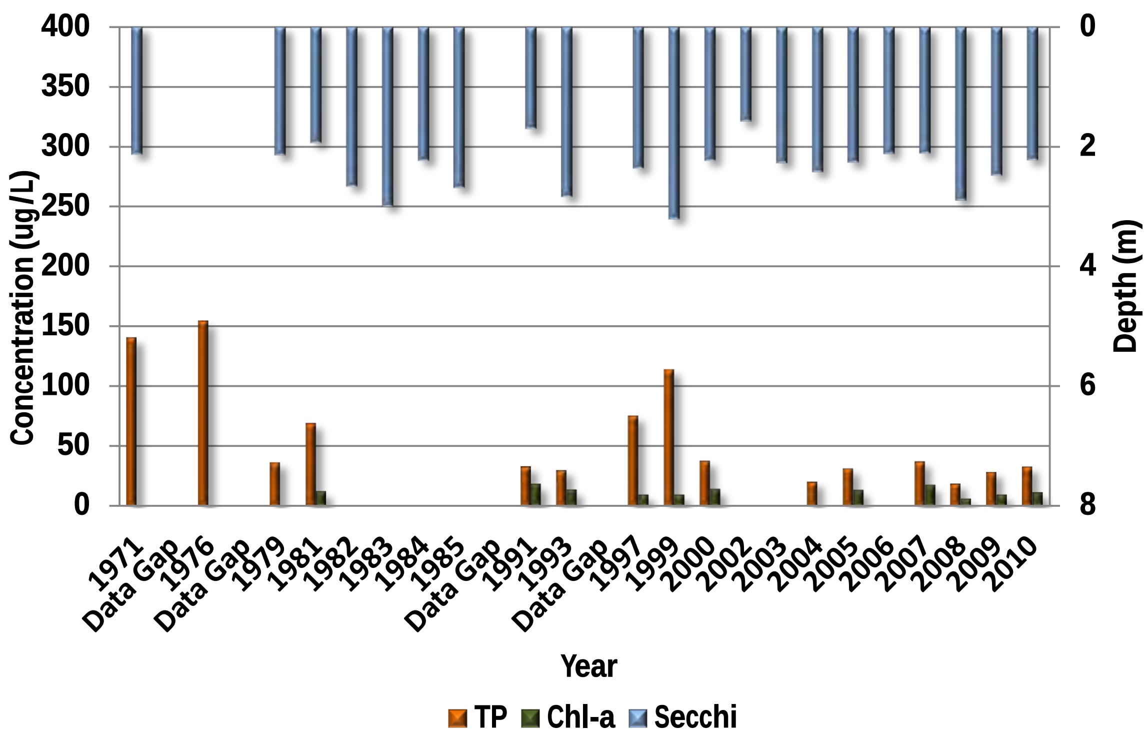
The average TP and chl-*a* values for Pleasant Lake were 29 µg/L and 12 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 13 µg/L to 77 µg/L and 3 µg/L to 92 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Pleasant Lake was below the water quality standard with an average of 2.4 meters (7.9 feet) (Appendix A).

Profile data, collected in 2010, indicates that Pleasant Lake formed a distinct thermocline in June and July at a depth of 3 to 5 meters (9.9 to 16.4 feet) but descended to a depth of 14 meters (45.9 feet) in September. This suggests that Pleasant Lake stratifies during the summer months. Additionally, DO levels typically remained above 5 mg/L to a depth of 5 to 7meters (16.4 to 23 feet) in the summer with anoxic conditions developing below.

Long-term chemistry data is sparse and Secchi data is adequate to complete a trend analysis. Water clarity for Pleasant Lake maintains a consistent trend of fully supporting conditions. Figure 59 indicates a trend of declining TP levels. Total phosphorus averages for each year, since 2000, have all been below the water quality standard.

Based on the chemical monitoring results and water clarity, Pleasant Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Pleasant Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 59. Pleasant Lake long-term water quality data



Clearwater Lake (East) 86-0252-01

Clearwater Lake (East) is a large, deep lake located one mile north of Annandale, Minnesota. The watershed for Clearwater Lake (East) is moderately sized with an area of 8,553 hectares (21,172 acres) and a watershed to lake ratio of 15:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

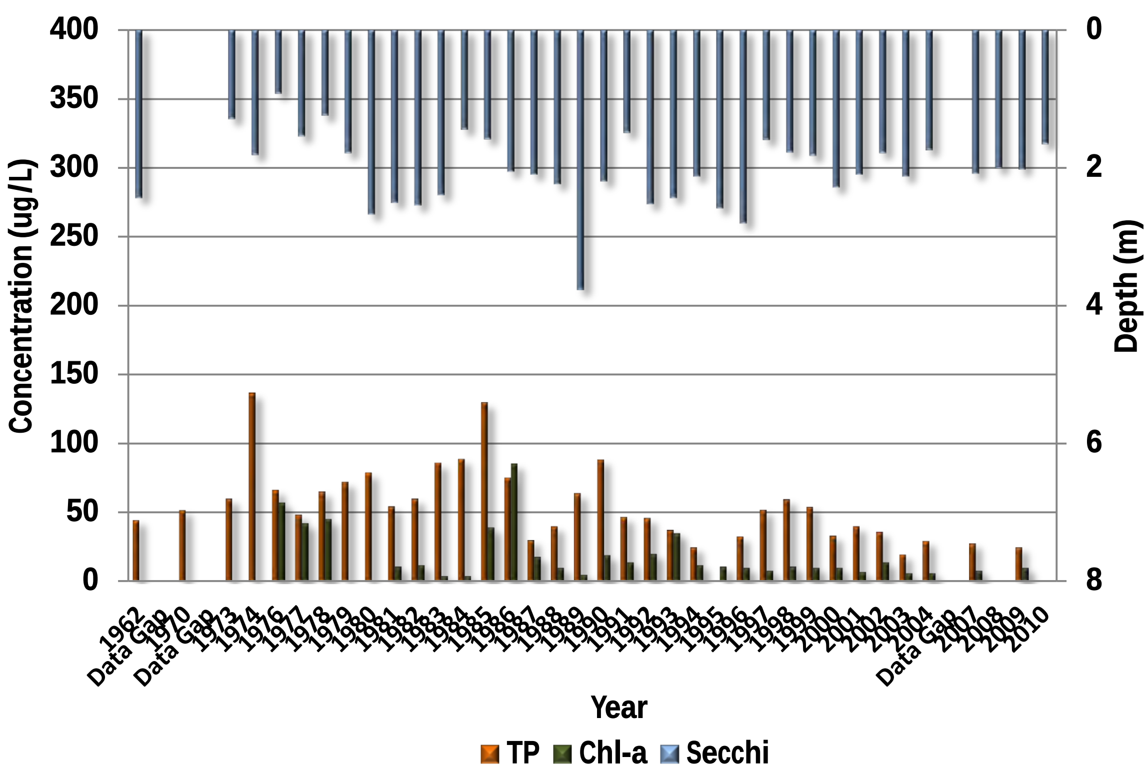
The average TP and chl-*a* values for Clearwater Lake (East) were 33 µg/L and 10 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009, ranged from 22 µg/L to 27 µg/L and 5 µg/L to 15 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Clearwater Lake (East) was below the water quality standard with an average of 1.9 meters (6.2 feet) (Appendix A).

Profile data, collected in 2009, indicates that Clearwater Lake (East) formed a distinct thermocline at a depth of 3 meters (9.9 feet) throughout the monitoring season. This suggests that Clearwater Lake (East) stratifies during the summer months. Additionally, DO levels above 5 mg/L varied throughout the season from a depth of 5 meters (16.4 feet) in July to 8 meters (26.2 feet) in August.

Long-term chemistry data is sparse and Secchi data is extensive. Figure 60 indicates that Secchi averages have improved and TP levels have declined. Total phosphorus averages for each year, since 1999, have all been at or below the water quality standard.

Based on the chemical monitoring results and water clarity, Clearwater Lake (East) was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Clearwater Lake (East) was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 60. Clearwater Lake (East) long-term water quality data



Clearwater Lake (West) 86-0252-02

Clearwater Lake (West) is a large, deep lake located one mile north of Annandale, Minnesota. Clearwater Lake's watershed is large with an area of 39,356 hectares (97,415 acres) and a watershed to lake ratio of 65:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

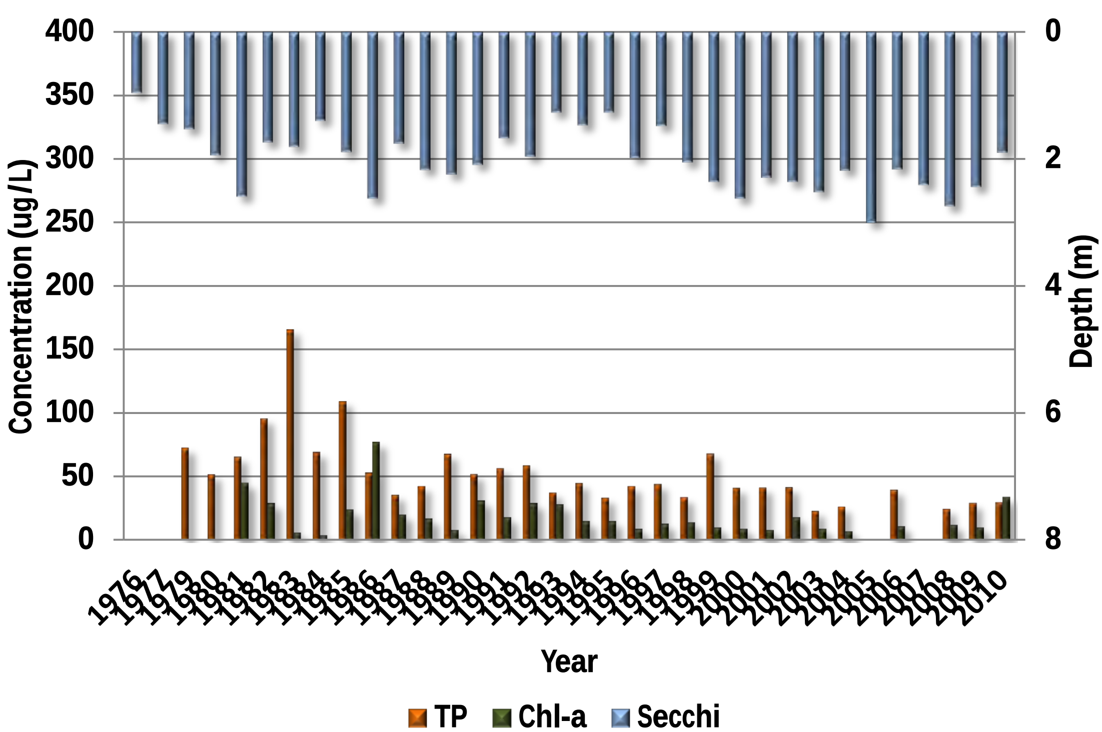
The average TP and chl-*a* values for Clearwater Lake (West) were 37 µg/L and 12 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 21 µg/L to 39 µg/L and 5 µg/L to 99 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Clearwater Lake (West) was below the water quality standard with an average of 2.5 meters (8.2 feet) (Appendix A).

Profile data, collected in 2010, indicates that Clearwater Lake (West) formed a thermocline at varying depths throughout the monitoring season. This suggests that Clearwater Lake (West) stratifies during the summer months. Additionally, DO levels above 5 mg/L varied throughout the season from a depth of 11 meters (36.1 feet) in September to 2 meters (6.6 feet) in August.

Long-term chemistry data is fair and Secchi data is extensive. Figure 61 indicates that Secchi averages have improved and TP levels have declined. Total phosphorus averages for each year, since 2003, have all been at or below the water quality standard.

Based on the chemical monitoring results and water clarity, Clearwater Lake (West) was classified as a eutrophic lake. Due to insufficient TP and chl-*a* results, Clearwater Lake (West) was not assessed; however, existing results do lean towards fully supporting aquatic recreational uses.

Figure 61. Clearwater Lake (West) long-term water quality data



Caroline Lake 86-0281-00

Caroline Lake is a small, deep lake located just south of Fairhaven, Minnesota. Caroline Lake's watershed is large with an area of 23,489 hectares (58,141 acres) and a watershed to lake ratio of 421:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

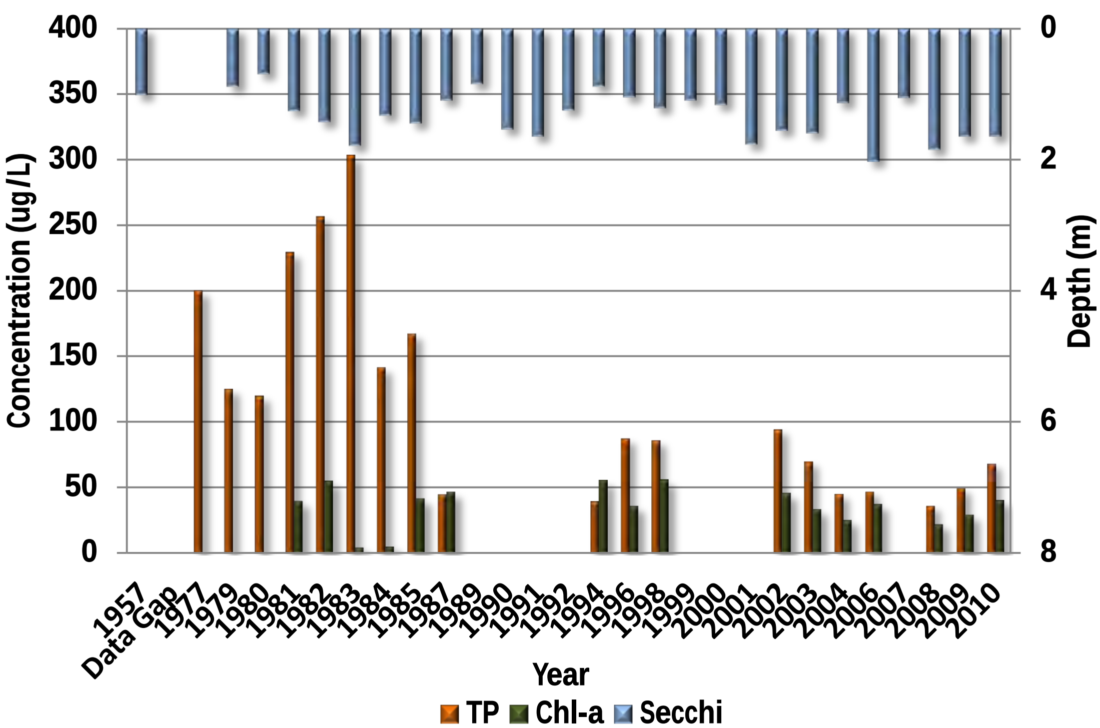
The average TP and chl-*a* values for Caroline Lake were 82 µg/L and 39 µg/L respectively. Each was above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 27 µg/L to 129 µg/L and 7 µg/L to 89 µg/L respectively. Despite the high levels of TP and chl-*a*, the water clarity for Caroline Lake was below the water quality standard with an average of 1.7 meters (5.6 feet) (Appendix A).

Profile data, collected in 2010, indicated that Caroline Lake typically formed a thermocline at a depth of 3 meters (9.9 feet) during the summer months. This suggests that Caroline Lake stratifies during the summer months. Additionally, DO levels dropped below 5 mg/L varied at a depth of 1 meter (3.3 feet) during the summer months as well.

Long-term chemistry data is fair and Secchi data is extensive. Figure 62 indicates that Secchi averages have improved and TP levels have declined. Despite these improvements, chemistry and Secchi values have historically been above the water quality standard.

Based on the chemical monitoring results and water clarity, Caroline Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Caroline Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2008 303(d) Impaired Waters List.

Figure 62. Caroline Lake long-term water quality data



Louisa Lake 86-0282-00

Louisa Lake is a small, deep lake located just south of Fairhaven, Minnesota. Louisa Lake's watershed is large with an area of 21,285 hectares (52,685 acres) and a watershed to lake ratio of 288:1. Land use is dominated by cropland and the percentage is just above the range of values expected for the NCHF ecoregion (Appendix D).

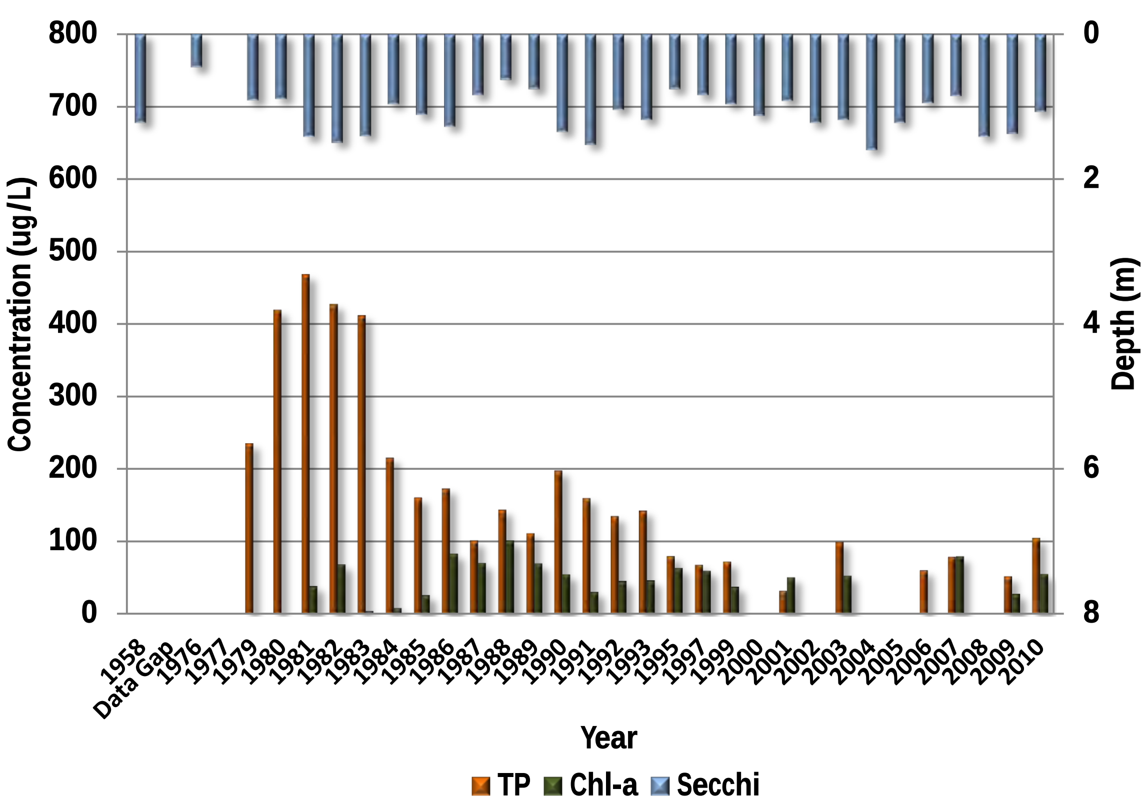
The average TP and chl-*a* values for Louisa Lake were 66 µg/L and 52 µg/L respectively. Each was above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 33 µg/L to 166 µg/L and 13 µg/L to 106 µg/L respectively. Coinciding with the high levels of TP and chl-*a*, the water clarity for Louisa Lake was above the water quality standard with an average of 1.2 meters (3.9 feet) (Appendix A).

Profile data, collected in 2010, indicated that Louisa Lake typically formed a thermocline at a depth of 2 meters (6.6 feet) during the summer months. This suggests that Louisa Lake stratifies during the summer months. Additionally, DO levels typically dropped below 5 mg/L at the same depth with anoxic conditions existing below during the summer months.

Long-term chemistry data is sparse for recent years and Secchi data is extensive. Figure 63 indicates that Secchi averages have improved and TP levels have declined. Despite these improvements, chemistry and Secchi values have historically been above the water quality standard.

Based on the chemical monitoring results and water clarity, Louisa Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Louisa Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2002 303(d) Impaired Waters List.

Figure 63. Louisa Lake long-term water quality data



Augusta Lake 86-0284-00

Augusta Lake is a small, deep lake located just south of Fairhaven, Minnesota. Augusta Lake's watershed is large with an area of 24,349 hectares (60,271 acres) and a watershed to lake ratio of 324:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

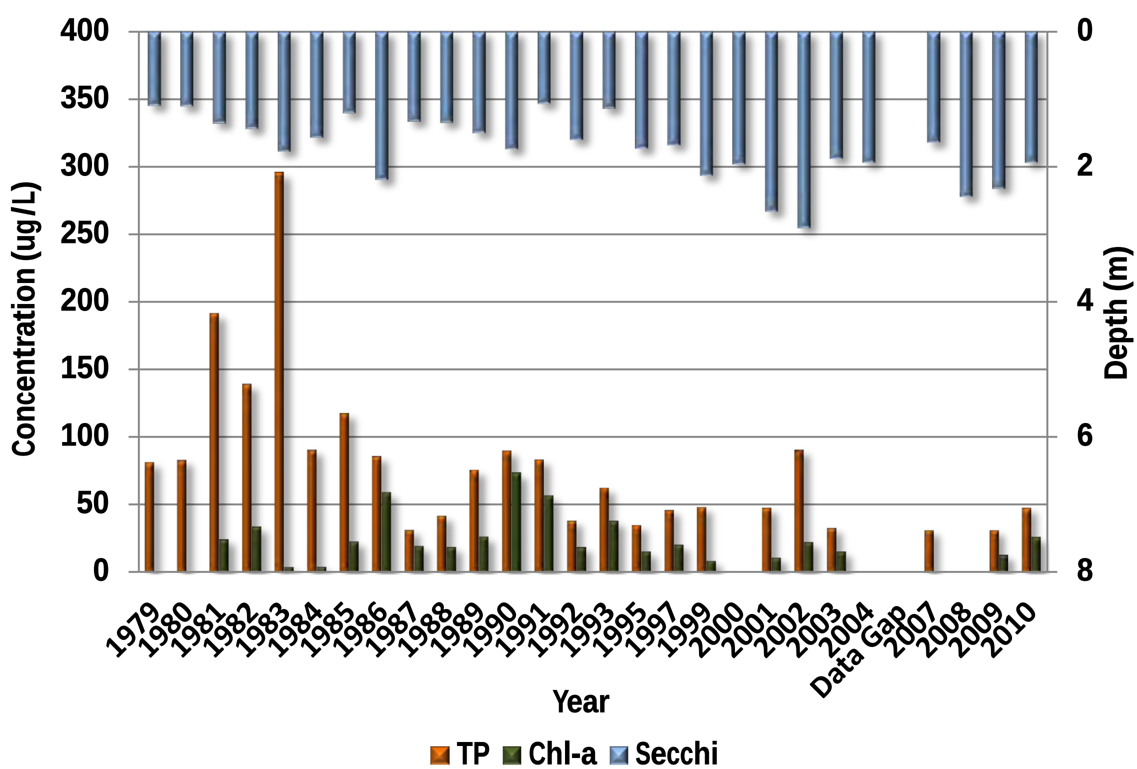
The average TP and chl-*a* values for Augusta Lake were 68 µg/L and 19 µg/L respectively. Each was above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 25 µg/L to 79 µg/L and 3 µg/L to 66 µg/L respectively. Despite the high levels of TP and chl-*a*, the water clarity for Augusta Lake was below the water quality standard with an average of 2.4 meters (7.9 feet) (Appendix A).

Profile data, collected in 2010, indicated that Augusta Lake typically formed a thermocline at a depth of 2 to 3 meters (6.6 to 9.9 feet) during the summer months. This layer dropped to a depth of 6 meters (19.7 feet) in September. This suggests that Augusta Lake stratifies during the summer months. Additionally, DO levels typically dropped below 5 mg/L between 4 and 5 meters (13.1 and 16.4 feet) for most of the season with the exception of July.

Long-term chemistry data is sparse for recent years and Secchi data is extensive. Figure 64 indicates that Secchi averages have improved and TP levels have declined. Despite these improvements, chemistry results from the past 10 years were still above the water quality standard.

Based on the chemical monitoring results and water clarity, Augusta Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Augusta Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2008 303(d) Impaired Waters List.

Figure 64. Augusta Lake long-term water quality data



Scott Lake 86-0297-00

Scott Lake is a small, deep lake located approximately two miles southwest of South Haven, Minnesota. Scott Lake's watershed is large with an area of 20,136 hectares (49,842 acres) and a watershed to lake ratio of 493:1. Land use is dominated by cropland and the percentage is just above the range of values expected for the NCHF ecoregion (Appendix D).

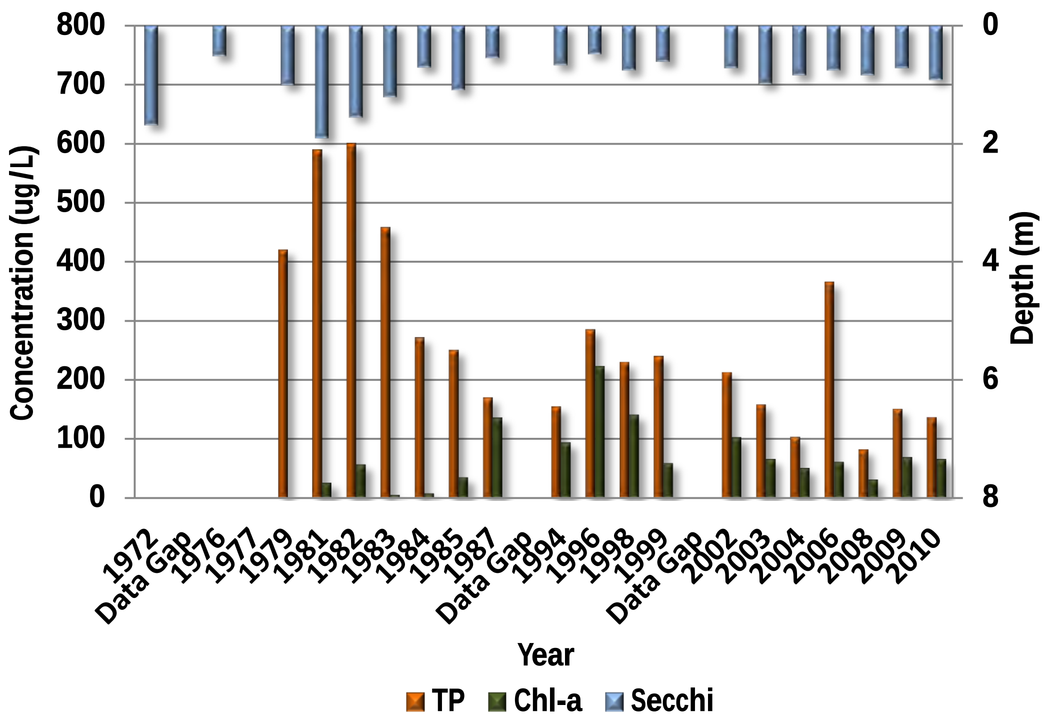
The average TP and chl-*a* values for Scott Lake were 185 µg/L and 84 µg/L respectively. Each was well above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2010, ranged from 85 µg/L to 185 µg/L and 30 µg/L to 122 µg/L respectively. Coinciding with the high levels of TP and chl-*a*, the water clarity for Scott Lake was above the water quality standard with an average of 0.8 meters (2.6 feet) (Appendix A).

Profile data, collected in 2010, indicated that Scott Lake did not form a thermocline from July through September with weak formation in June. This suggests that Scott Lake typically remains mixed but may develop layers during calm conditions. Additionally, DO levels commonly dropped below 5 mg/L from 1 to 3 meters (3.3 to 9.9 feet) from June through August. Dissolved oxygen remained above 5 mg/L throughout the entire water column in September.

Long-term chemistry and Secchi data is fair. Figure 65 indicates that despite declining TP levels, Secchi averages show a trend of declining water clarity. Trend data for Scott Lake has been historically above the water quality standard.

Based on the chemical monitoring results and water clarity, Scott Lake was classified as a hypereutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Scott Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2008 303(d) Impaired Waters List.

Figure 65. Scott Lake long-term water quality data



Union Lake 86-0298-00

Union Lake is a small, deep lake located approximately two and a half miles southwest of South Haven, Minnesota. Union Lake's watershed is small with an area of 1,820 hectares (4,505 acres) and a watershed to lake ratio of 50:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

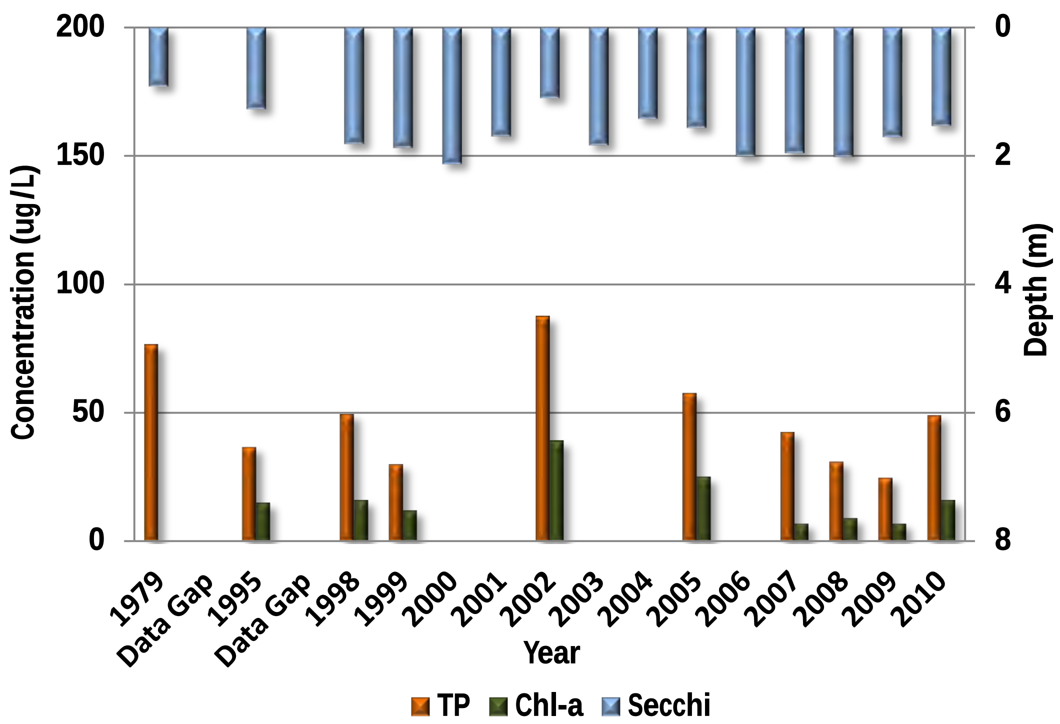
The average TP and chl-*a* values for Union Lake were 73 µg/L and 32 µg/L respectively. Each was above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 18 µg/L to 82 µg/L and 5 µg/L to 33 µg/L respectively. Despite the high levels of TP and chl-*a*, the water clarity for Union Lake was just below the water quality standard with an average of 1.7 meters (5.6 feet) (Appendix A).

Profile data, collected in 2010, indicated that Union Lake formed a thermocline at varying depths throughout the monitoring season. This suggests that Union Lake stratifies during the summer months. Additionally, DO levels dropped below 5 mg/L between 2 and 3 meters (6.6 to 9.9 feet) as well.

Long-term chemistry data is sparse and Secchi data is adequate to complete a trend analysis. Figure 66 indicates that TP values are declining and Secchi averages are improving.

Based on the chemical monitoring results and water clarity, Union Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Union Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 66. Union Lake long-term water quality data



Fish Creek subwatershed

The Fish Creek (07010203740) HUC-11 watershed lies central within the Mississippi (St. Cloud) watershed. This 6,258 hectare (15,489 acre) subwatershed represents 2.2 percent of the Mississippi (St. Cloud) watershed (Figure 67 and Table 2). Cropland is the major land use within this area (Figure 67). Based on 2003 NPDES/SDS registered feedlot data, there is one permitted discharge site and 11 registered feedlots throughout the Fish Creek subwatershed (Figure 6).

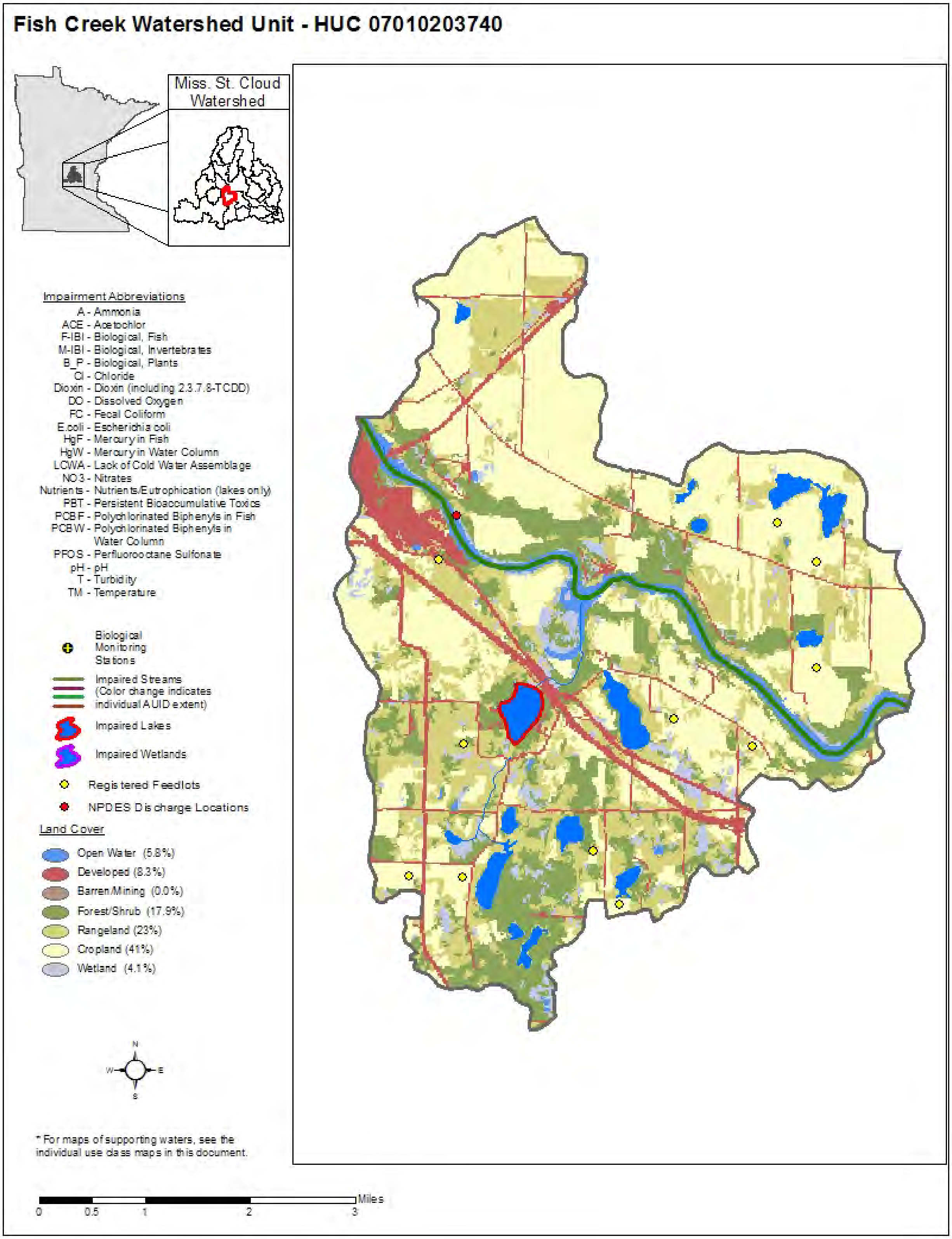
The Fish Creek subwatershed consists of three lakes greater than 4 hectares (10 acres). Of these three lakes, Fish Lake, was assessed and determined to be non-supporting of aquatic recreation use (Table 13). Rangeland use is dominating within the contributing watershed (Appendix D). Fish Lake is a small, deep lake that intermittently stratifies, which likely causes the internal release of nutrients from the lake sediment into the water. Further investigation will be required to fully determine the source of nutrient contributions, but an overall reduction in external loading will still prove beneficial.

The MINLEAP model indicated that the observed TP for Fish Lake was just below the predicted value. The model predicted TP loading at 355 kg/yr. The areal water load to the lake was estimated at 5.5 m/yr and estimated water residence time is approximately 0.7 years. Background TP (Vighi & Chiaudani TP) was not calculated because alkalinity data was not available. The complete modeling results can be found in Appendix C.

Table 13. Summary of lake eutrophication assessment results for the Fish Creek subwatershed

Lake Name	DNR Lake ID	County	Lake Area (Hectares)	Maximum Depth (Meters)	ARUS
Fish	86-0183-00	Wright	42	11.6	NS

Figure 67. Fish Creek subwatershed showing all lake assessments and land use



Fish Lake 86-0183-00

Fish Lake is a small, deep lake located approximately three miles southeast of Clearwater, Minnesota. Fish Lake's watershed is small with an area of 1,820 hectares (4,401 acres) and a watershed to lake ratio of 42:1. Land use is dominated by rangeland and the percentage is above the range of values expected for the NCHF ecoregion (Appendix D).

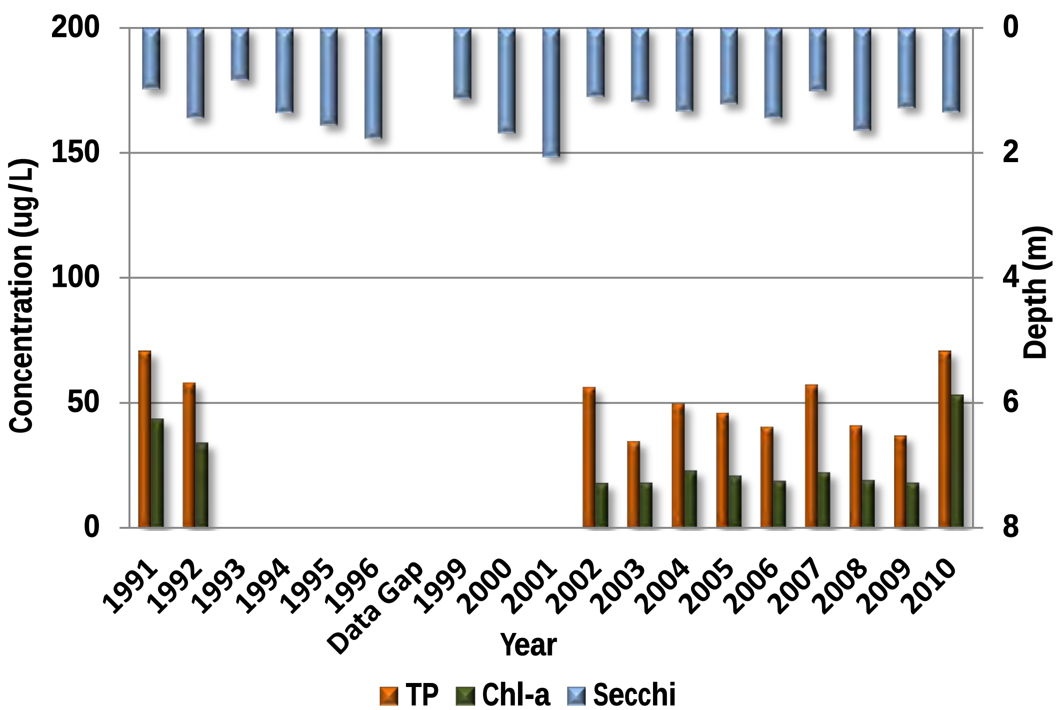
The average TP and chl-*a* values for Fish Lake were 48 µg/L and 24 µg/L respectively. Each was above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 26 µg/L to 93 µg/L and 14 µg/L to 78 µg/L respectively. Coinciding with the high levels of TP and chl-*a*, the water clarity for Fish Lake was above the water quality standard with an average of 1.3 meters (4.3 feet) (Appendix A).

Historic profile data, collected in 1992, indicated that Fish Lake formed a thermocline at varying depths throughout the spring and summer but became mixed in September. This suggests that Fish Lake stratifies during the summer months. Additionally, DO levels dropped below 5 mg/L at depths varying from 3meters (6.6 feet) in the summer to 7 meters (23 feet) in the spring.

Long-term chemistry data is adequate to complete a trend analysis and Secchi data is extensive. Figure 68 indicates little to no trend for TP values or Secchi results.

Based on the chemical monitoring results and water clarity, Fish Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Fish Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2008 303(d) Impaired Waters List. Recent data supports this listing.

Figure 68. Fish Lake long-term water quality data



Silver Creek subwatershed

The Silver Creek (07010203750) HUC-11 watershed lies along the south central border of the Mississippi (St. Cloud) watershed. This 10,547 hectare (26,106 acre) subwatershed represents 3.6 percent of the Mississippi (St. Cloud) watershed (Figure 69 and Table 2). Cropland is the major land use within this area (Figure 69). Based on 2003 NPDES/SDS registered feedlot data, there are no permitted discharge sites and 29 registered feedlots throughout the Silver Creek subwatershed (Figure 6).

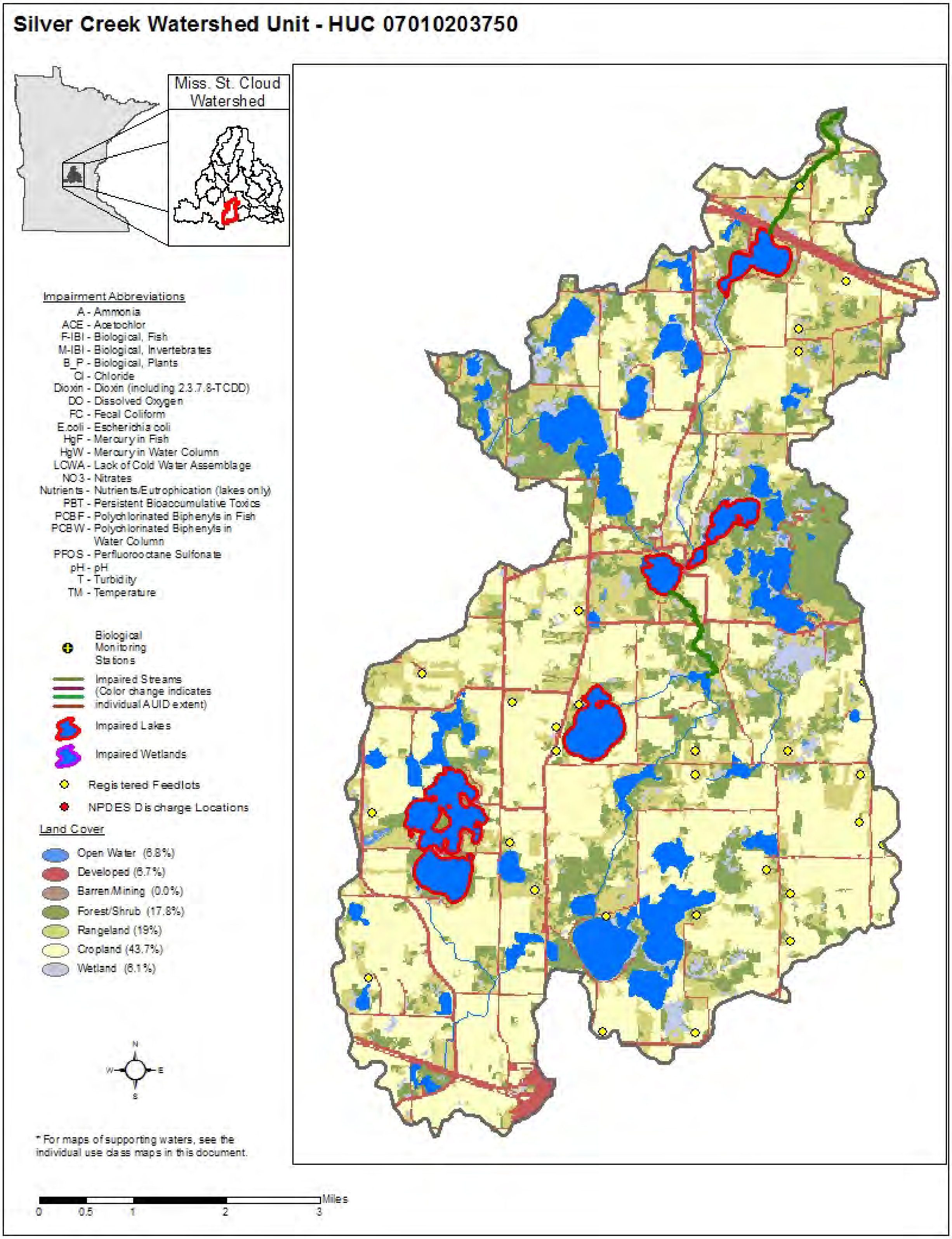
The Silver Creek subwatershed consists of 21 lakes greater than 4 hectares (10 acres), of which 10 were assessed for aquatic recreation use (Table 14). Lakes in the Silver Creek subwatershed vary in size from small to moderately sized basins and are located throughout the subwatershed (Figure 69). Of the 10 lakes that were assessed, seven were determined to be non-supporting of aquatic recreational use (excess nutrients). In the case of Little Mary South, Silver, and Locke Lakes, large contributing catchment watersheds are potentially increasing nutrient levels due to a high level of external loading. Profile data was not available to determine internal contribution; however, a disturbance of the sediment due to lake mixing is another potential nutrient source for the shallow lakes (Little Mary North and South and Millstone). The deeper impaired lakes (Silver, Locke, Mink, and Somers) are also likely receiving high levels of external nutrient contribution and further investigation will be required to fully determine the source of nutrient contributions. An overall reduction in external loading will prove beneficial for all impaired waters.

The MNLEAP model indicated that the observed TP for Little Mary North, Millstone, Mink, and Somers was significantly higher than the predicted values. Limestone Lake was the only lake within the Silver Creek subwatershed where was significantly below the predicted values. The remaining assessed lakes had model predictions that were near the actual TP levels. The model predicted a fair range of TP loading throughout Silver Creek coinciding with the variety of watershed areas and basin morphometry. These estimated load rates ranged from 35 kg/yr for Ember Lake to 2,510 kg/yr for Locke Lake. Loading rates at the subwatershed level can be visualized by observing that Ember Lake lies in an area receiving little watershed contribution while Locke Lake is located near the pour point and is thus susceptible to greater nutrient contributions. Additionally, the areal load rates were higher for lakes with a larger watershed area (Locke and Silver Lakes) when compared to lakes with smaller watershed areas (Millstone and Ember Lakes). Areal load rates ranged from 1 m/yr to 33 m/yr. The complete modeling results can be found in Appendix C.

Table 14. Summary of lake eutrophication assessment results for the Silver Creek subwatershed

Lake Name	DNR Lake ID	County	Lake Area (Hectares)	Maximum Depth (Meters)	ARUS
Little Mary South	86-0139-01	Wright	-	-	NS
Little Mary North	86-0139-02	Wright	-	-	NS
Silver	86-0140-00	Wright	36	12.8	NS
Millstone	86-0152-00	Wright	89	1.8	NS
Mary	86-0156-00	Wright	94	31.1	FS
Limestone	86-0163-00	Wright	151	10.4	FS
Locke	86-0168-00	Wright	61	14.9	NS
Ember	86-0171-00	Wright	27	12.5	FS
Mink	86-0229-00	Wright	123	9.8	NS
Somers	86-0230-00	Wright	63	5.5	NS

Figure 69. Silver Creek subwatershed showing all lake assessments and land use



Little Mary Lake 86-0139-01 (South Bay)

Little Mary Lake 86-0139-02 (North Bay)

Little Mary Lake is a small, shallow lake located approximately five miles southeast of Clearwater, Minnesota. The north and south bays receive input from differing watershed areas with the southern bay (11,251 hectares [27,849 acres]) receiving nearly six times the amount of watershed contribution than the northern bay (2,073 [5,132 acres]). Additionally, the land use for the north bay is dominated by forest while a majority of the land use in the south bay is cropland (Appendix D).

The average TP, chl-*a*, and Secchi values for Little Mary Lake were collected from each bay. The south bay had average TP and chl-*a* values of 107 µg/L and 56 µg/L respectively. The north bay had average TP and chl-*a* values of 163 µg/L and 80 µg/L respectively. The results from each bay were well above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus data, collected in 2009 and 2010, ranged from 74 µg/L to 140 µg/L for the south bay and 133 µg/L to 199 µg/L for the north. chl-*a* data, also collected in 2009 and 2010, ranged from 21 µg/L to 77 µg/L for the south bay and 60 µg/L to 125 µg/L for the north (Appendix A).

Coinciding with the high levels of TP and chl-*a*, the water clarity for each of the bays was above the water quality standard with an average of 0.8 meters (2.6 feet) for the south bay and 0.5 meters (1.6 feet) for the north bay. Due to a lack of profile data, the lake mixing characteristics of Little Mary Lake cannot be determined. Trend data is not available for either bay.

Based on the chemical monitoring results and water clarity, both bays of Little Mary Lake were classified as hypereutrophic. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, each bay of Little Mary Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2011 303(d) Impaired Waters List.

Silver Lake 86-0140-00

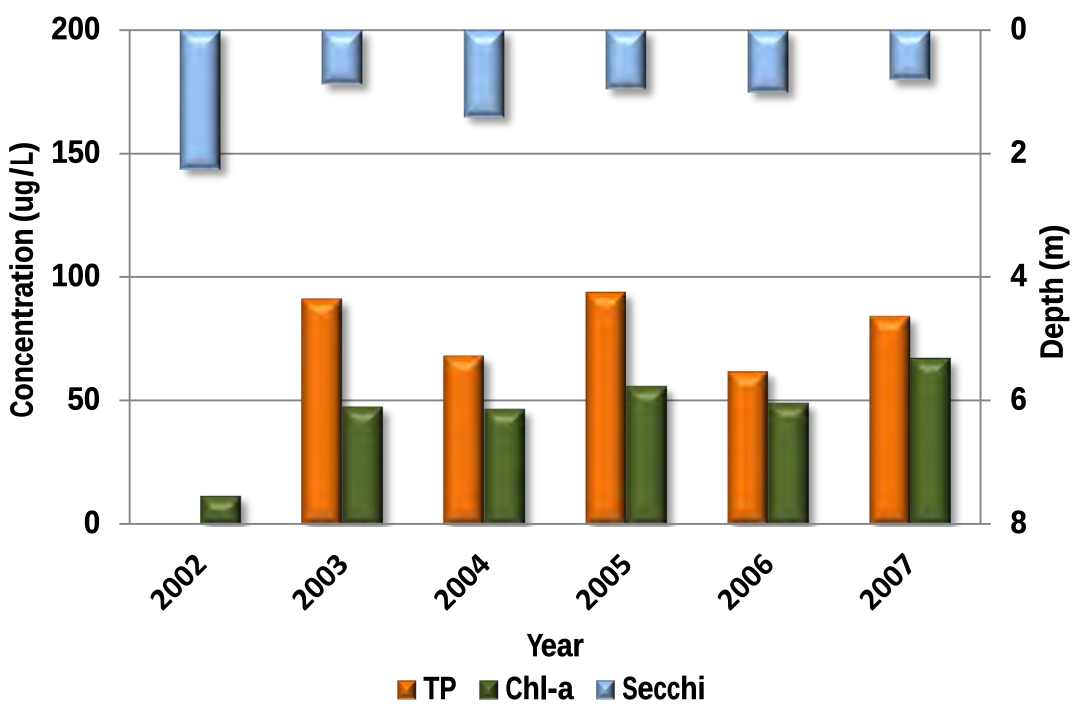
Silver Lake is a small, deep lake located approximately five miles north of Maple Lake, Minnesota. Silver Lake's watershed is moderately sized with an area of 9,081 hectares (22,478 acres) and a watershed to lake ratio of 253:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Silver Lake were 105 µg/L and 45 µg/L respectively. Each was above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2006 and 2007, ranged from 51 µg/L to 100 µg/L and 25 µg/L to 88 µg/L respectively. Coinciding with the high levels of TP and chl-*a*, the water clarity for Silver Lake was above the water quality standard with an average of 1.2 meters (3.9 feet) (Appendix A). Due to a lack of profile data, the lake mixing characteristics of Silver Lake cannot be determined.

Long-term chemistry and Secchi data is limited. Figure 70 indicates a slight decrease in TP levels all of which exceeded the nutrient standard. Additionally, Secchi results indicate a slight trend of declining averages. Secchi averages for a majority of the recorded years were above the water quality standard.

Based on the chemical monitoring results and water clarity, Silver Lake was classified as a hypereutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Silver Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2008 303(d) Impaired Waters List. Recent data supports this listing.

Figure 70. Silver Lake long-term water quality data



Millstone Lake 86-0152-00

Millstone Lake is a moderately sized, shallow lake located approximately three miles north of Maple Lake, Minnesota. Millstone Lake's watershed is small with an area of 285 hectares (706 acres) and a watershed to lake ratio of 3:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Millstone Lake were 357 µg/L and 119 µg/L respectively. Each was well above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 166 µg/L to 524 µg/L and 7 µg/L to 421 µg/L respectively. Despite the high levels of TP and chl-*a*, the water clarity for Millstone Lake was below the water quality standard with an average of 1.3 meters (4.3 feet) (Appendix A). Due to a lack of profile data, the lake mixing characteristics of Millstone Lake cannot be determined. Trend Data is not available.

Based on the chemical monitoring results and water clarity, Millstone Lake was classified as a hypereutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Millstone Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2011 303(d) Impaired Waters List.

Limestone Lake 86-0163-00

Limestone Lake is a moderately sized, deep lake located approximately two miles south of Hasty, Minnesota. Limestone Lake's watershed is moderately sized with an area of 3,321 hectares (8,221 acres) and a watershed to lake ratio of 22:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Limestone Lake were 24 µg/L and 10 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2008 and 2009, ranged from 14 µg/L to 30 µg/L and 6 µg/L to 15 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Limestone Lake was below the water quality standard with an average of 2.4 meters (7.9 feet) (Appendix A). Due to a lack of profile data, the lake mixing characteristics of Limestone Lake cannot be determined. Trend data is not available.

Based on the chemical monitoring results and water clarity, Limestone Lake was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Limestone Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Mary Lake 86-0156-00

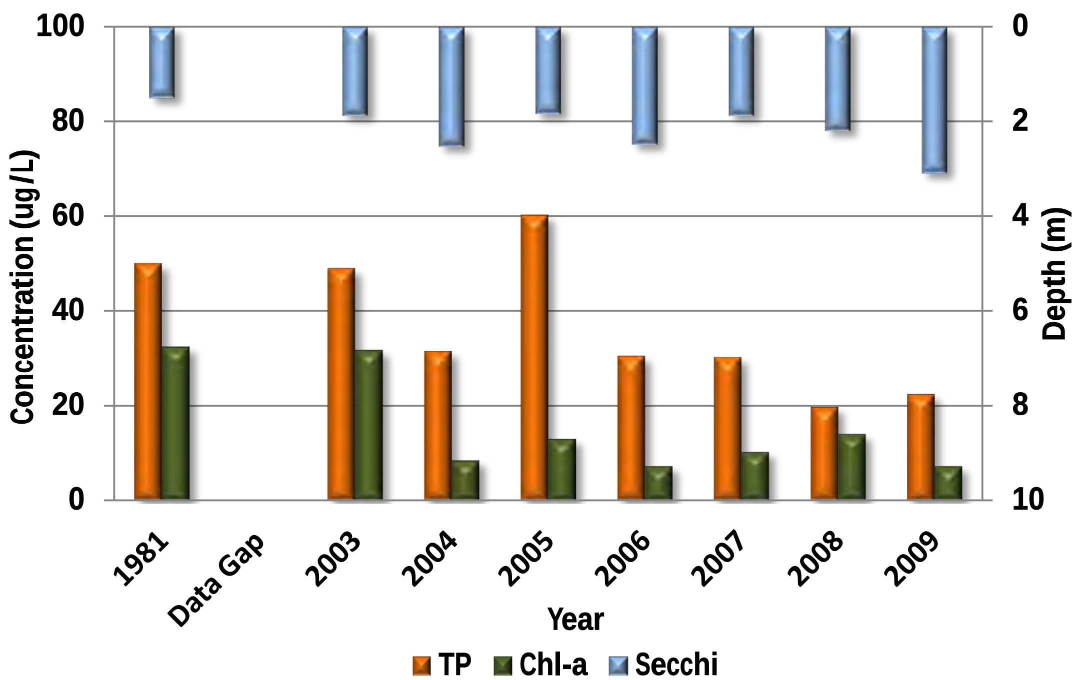
Mary Lake is a moderately sized, deep lake located approximately one mile north of Maple Lake, Minnesota. Mary Lake's watershed is moderately sized with an area of 1,546 hectares (3,826 acres) and a watershed to lake ratio of 16:1. Land use is dominated by cropland with the percentage being above the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Mary Lake were 35 µg/L and 13 µg/L respectively. Each was just below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2008 and 2009, ranged from 7 µg/L to 33 µg/L and 4 µg/L to 22 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Mary Lake was below the water quality standard with an average of 2.3 meters (7.5 feet) (Appendix A). Due to a lack of profile data, the lake mixing characteristics of Mary Lake cannot be determined.

Long-term chemistry and Secchi data is nearly adequate to complete a trend analysis. Available data (Figure 71) indicates a decrease in TP levels as well as an improvement in water clarity. Secchi averages for all of the recorded years were below the water quality standard.

Based on the chemical monitoring results and water clarity, Mary Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Mary Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 71. Mary Lake long-term water quality data



Locke Lake 86-0168-00

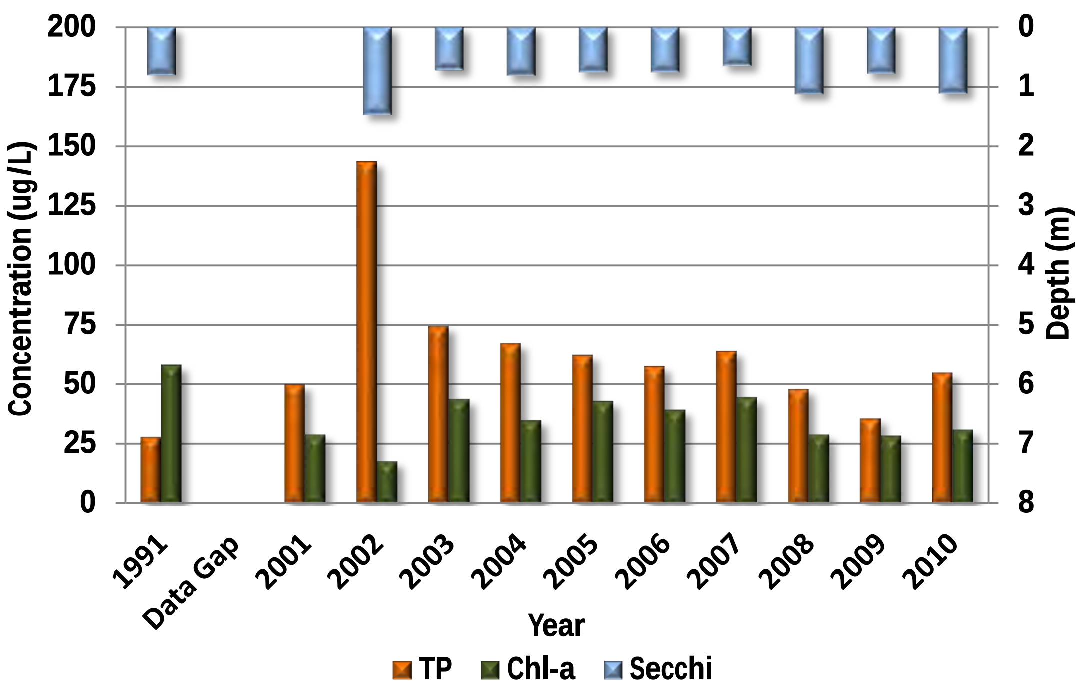
Locke Lake is a moderately sized, deep lake located approximately one half mile southeast of Hasty, Minnesota. Locke Lake's watershed is large with an area of 12,950 hectares (32,054 acres) and a watershed to lake ratio of 211:1. Land use is dominated by cropland with the percentage being within the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Locke Lake were 66 µg/L and 34 µg/L respectively. Each was above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 26 µg/L to 85 µg/L and 17 µg/L to 52 µg/L respectively. Coinciding with the high levels of TP and chl-*a*, the water clarity for Locke Lake was above the water quality standard with an average of 0.9 meters (3 feet) (Appendix A). Due to a lack of profile data, the lake mixing characteristics of Locke Lake cannot be determined.

Long-term chemistry and Secchi data is available to complete a trend analysis. Figure 72 indicates a decrease in TP levels; however, no apparent trend in water clarity is visible. Despite declining TP levels, nearly all of the yearly averages were above the water quality standard.

Based on the chemical monitoring results and water clarity, Locke Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Locke Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2006 303(d) Impaired Waters List. Recent data supports this listing.

Figure 72. Locke Lake long-term water quality data



Ember Lake 86-0171-00

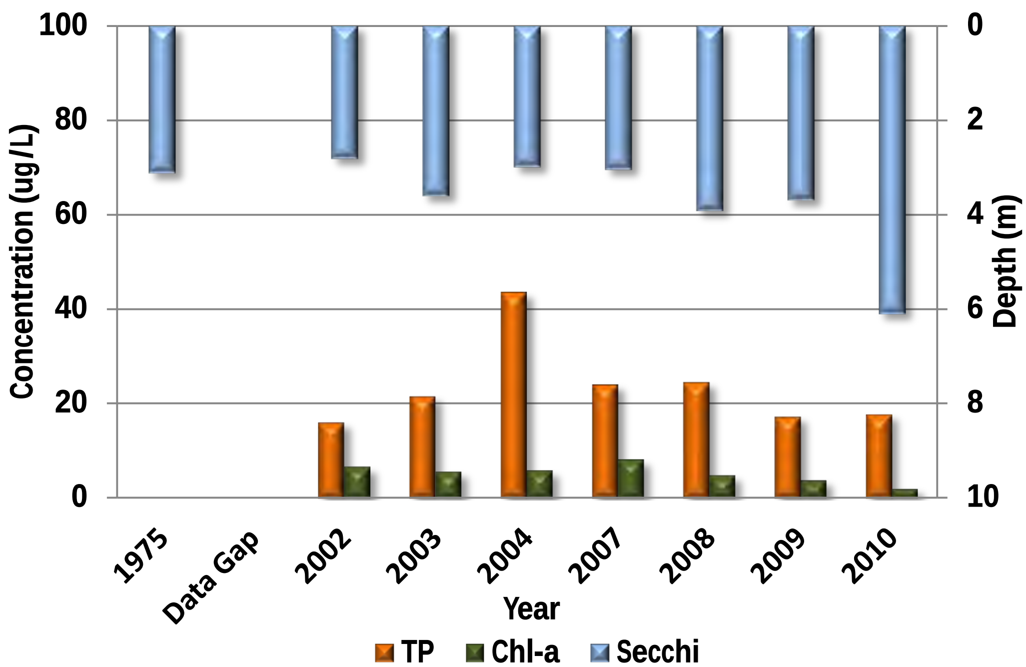
Ember Lake is a small, deep lake located approximately two miles south of Hasty, Minnesota. Ember Lake's watershed is small with an area of 139 hectares (345 acres) and a watershed to lake ratio of 5:1. Land use is dominated by cropland with the percentage being above the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Ember Lake were 24 µg/L and 5 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 11 µg/L to 22 µg/L and 1 µg/L to 5 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Ember Lake was below the water quality standard with an average of 3.7 meters (12.1 feet) (Appendix A). Due to a lack of profile data, the lake mixing characteristics of Ember Lake cannot be determined.

Long-term chemistry and Secchi data is nearly adequate to complete a trend analysis. Available data (Figure 73) indicates a decrease in TP levels as well as an improvement in water clarity. Secchi averages for all of the recorded years were below the water quality standard.

Based on the chemical monitoring results and water clarity, Ember Lake was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Ember Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 73. Ember Lake long-term water quality data



Mink Lake 86-0229-00

Mink Lake is a moderately sized, deep lake located approximately two miles north of Maple Lake, Minnesota. Mink Lake's watershed is small with an area of 1,042 hectares (2,580 acres) and a watershed to lake ratio of 8:1. Land use is dominated by cropland and the percentage is just above the range of values expected for the NCHF ecoregion (Appendix D).

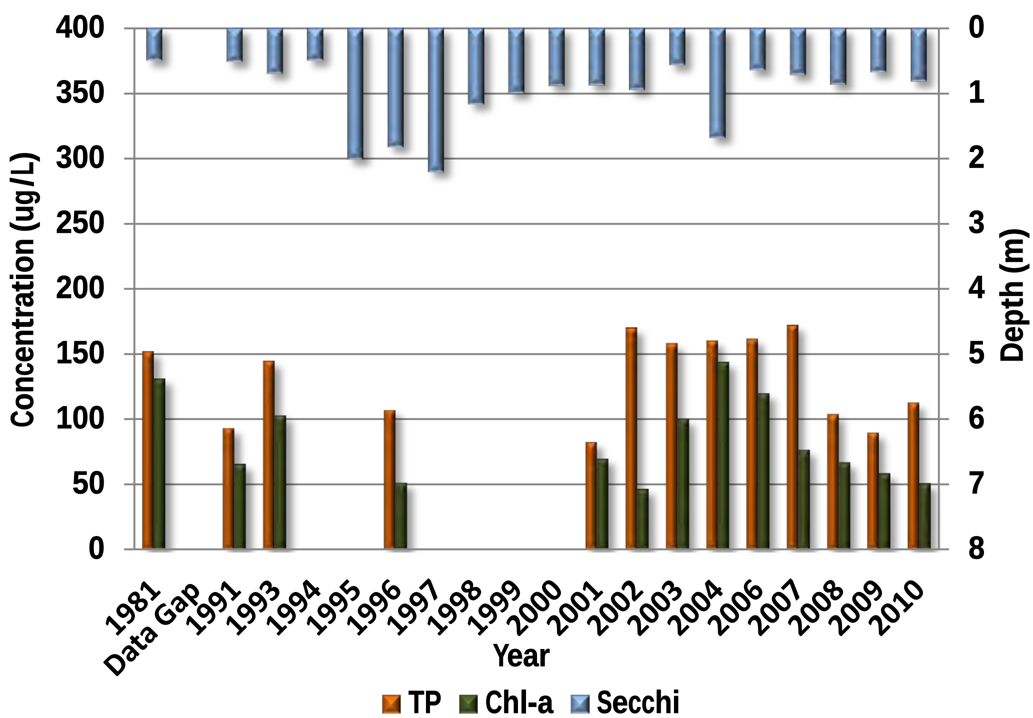
The average TP and chl-*a* values for Mink Lake were 134 µg/L and 81 µg/L respectively. Each was well above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 54 µg/L to 148 µg/L and 6 µg/L to 108 µg/L respectively. Coinciding with the high levels of TP and chl-*a*, the water clarity for Mink Lake was above the water quality standard with an average of 0.8 meters (2.6 feet) (Appendix A).

Historic profile data, collected in 1996, indicated that Mink Lake formed a thermocline at 6 meters (19.7) throughout the monitoring season, with the exception of July, where a layer formed at 3 meters (9.9 feet). This suggests that Mink Lake stratifies during the summer months. Additionally, DO levels dropped below 5 mg/L at a depth of 3 to 4 meters (9.9 to 13.1 feet) throughout most of the season with, often times, anoxic conditions existing below.

Long-term chemistry and Secchi data is available to complete a trend analysis. Figure 74 does not indicate an increase or decrease in TP levels; however, a slight decline in water clarity is visible. Total phosphorus averages for all years have been above the water quality standard. Additionally, nearly all of the Secchi averages have been above the water quality standard.

Based on the chemical monitoring results and water clarity, Mink Lake was classified as a hypereutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Mink Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2008 303(d) Impaired Waters List. Recent data supports this listing.

Figure 74. Mink Lake long-term water quality data



Somers Lake 86-0230-00

Somers Lake is a moderately sized, deep lake located approximately two miles north of Maple Lake, Minnesota. Somers Lake's watershed is small with an area of 1,165 hectares (2,883 acres) and a watershed to lake ratio of 18:1. Land use is dominated by cropland and the percentage is within the range of values expected for the NCHF (Appendix D).

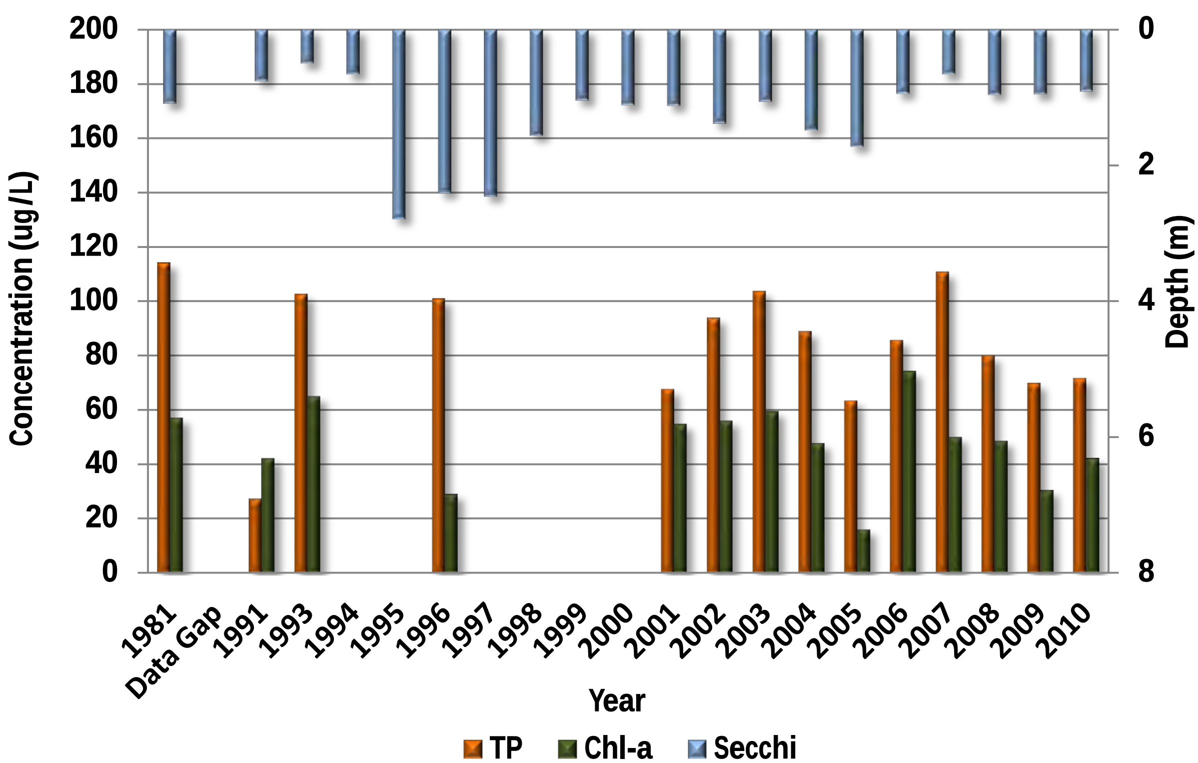
The average TP and chl-*a* values for Somers Lake were 84 µg/L and 49 µg/L respectively. Each was above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 45 µg/L to 93 µg/L and 16 µg/L to 64 µg/L respectively. Coinciding with the high levels of TP and chl-*a*, the water clarity for Somers Lake was above the water quality standard with an average of 1 meter (3.3 feet) (Appendix A).

Historic profile data, collected in 1996, indicated that Somers Lake formed a thermocline in May and July but was well mixed during other monitoring months. This suggests that Somers Lake may form a thermocline during calm periods but otherwise remains mixed. With the exception of June, DO levels dropped below 5 mg/L at varying depths with anoxic conditions developing below.

Long-term chemistry and Secchi data is available to complete a trend analysis. Figure 75 indicates a slight decline in TP levels; however, water clarity within Somers Lake is also declining. Total phosphorus averages for all years have been above the water quality standard.

Based on the chemical monitoring results and water clarity, Somers Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Somers Lake was determined to be non supporting of aquatic recreational use and was listed as an impaired water under the 2008 303(d) Impaired Waters List. Recent data supports this listing.

Figure 75. Sommers Lake long-term water quality data



Otter Creek subwatershed

The Otter Creek (07010203770) HUC-11 watershed lies along the south central border of the Mississippi (St. Cloud) watershed. This 6,825 hectare (16,893 acre) subwatershed represents 2.4 percent of the Mississippi (St. Cloud) watershed (Figure 76 and Table 2). Cropland is the major land use within this area (Figure 76). Based on 2003 NPDES/SDS registered feedlot data, there are no permitted discharge sites and eight registered feedlots throughout the Otter Creek subwatershed (Figure 6).

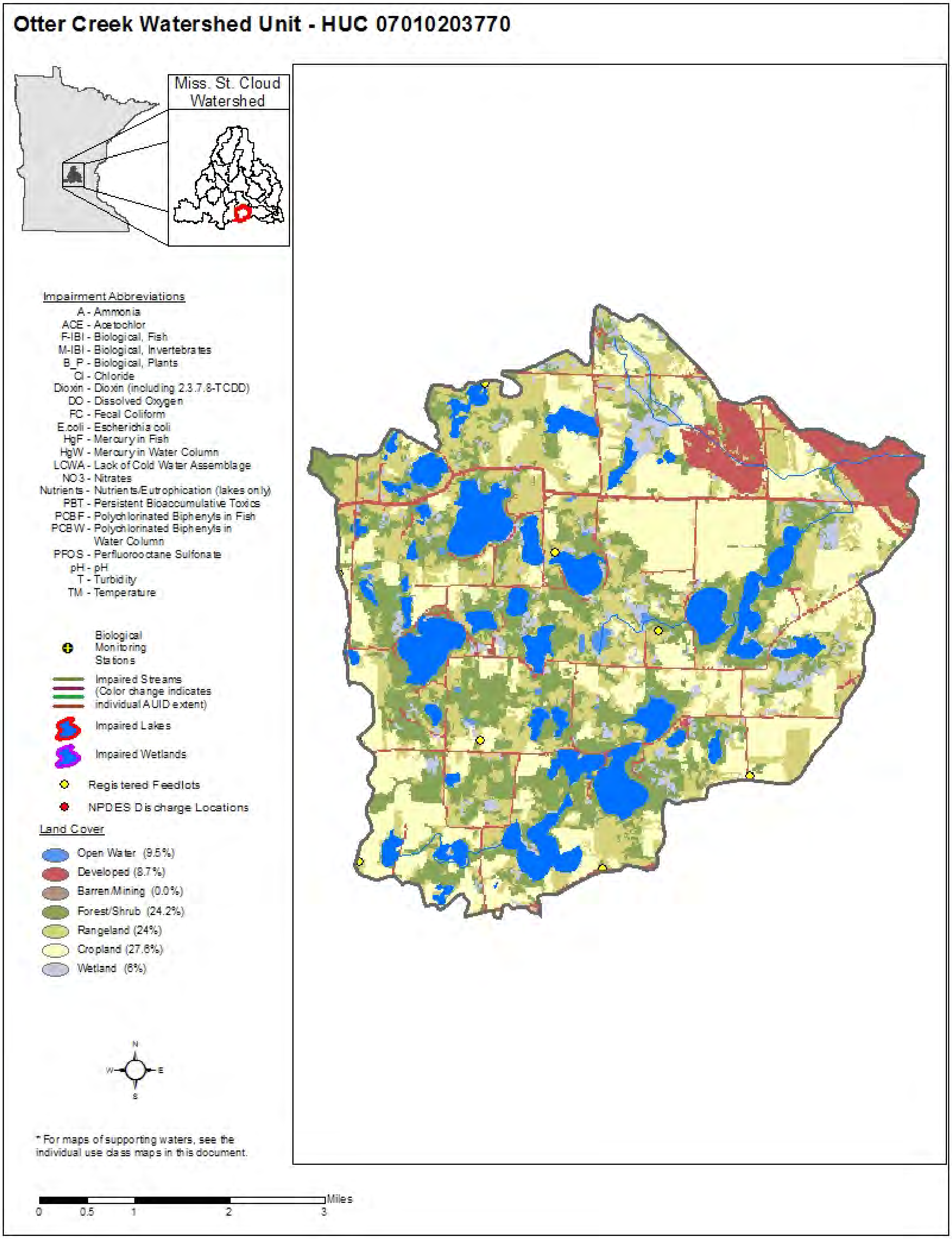
The Otter Creek subwatershed consists of 13 lakes greater than 4 hectares (10 acres), of which 5 were assessed for aquatic recreation use. Three additional lakes were assessed; however, the existing data was determined to be insufficient (Table 15). Lakes in the Otter Creek subwatershed vary in size from small to moderately sized basins and are located throughout the subwatershed (Figure 76). All five of the lakes that were assessed were determined to be supporting of aquatic recreational use. All of the lakes are classified as deep lakes and all of the lakes had small to moderately sized contributing watersheds dominated by forest use. Profile data was limited to only Cedar and Ida Lakes. The results of each indicated stratification during the summer months. Despite the fully supporting assessment for Bertram and Eagle Lakes, both of these water bodies were determined to be eutrophic. A reduction in external loading will still prove beneficial.

The MNLEAP model indicated that the observed TP for all assessed lakes within the Otter Creek subwatershed was below what is predicted for lakes of their watershed and basin morphometric characteristics. The model predicted a fair range of TP loading throughout Otter Creek. These estimated load rates ranged from 157 kg/yr for Eagle Lake to 940 kg/yr for Long Lake. Loading rates can be visualized by observing that Eagle Lake lies in an area receiving little watershed contribution while Long Lake has a much greater watershed area. Areal load rates were fairly low for all lakes within Otter Creek. Areal load rates ranged from 1 m/yr to 10 m/yr. The complete modeling results can be found in Appendix C.

Table 15. Summary of lake eutrophication assessment results for the Otter Creek subwatershed

Lake Name	DNR Lake ID	County	Lake Area (Hectares)	Maximum Depth (Meters)	ARUS
Birch	86-0066-00	Wright	42	15	FS
First	86-0067-00	Wright	6	18	IF
Mud	86-0068-00	Wright	12	20	IF
Long	86-0069-00	Wright	65	20	IF
Bertram	86-0070-00	Wright	55	7	FS
Cedar	86-0073-00	Wright	109	27	FS
Ida	86-0146-00	Wright	105	14	FS
Eagle	86-0148-00	Wright	80	21	FS

Figure 76. Otter Creek subwatershed showing all lake assessments and land use



Birch Lake 86-0066-00

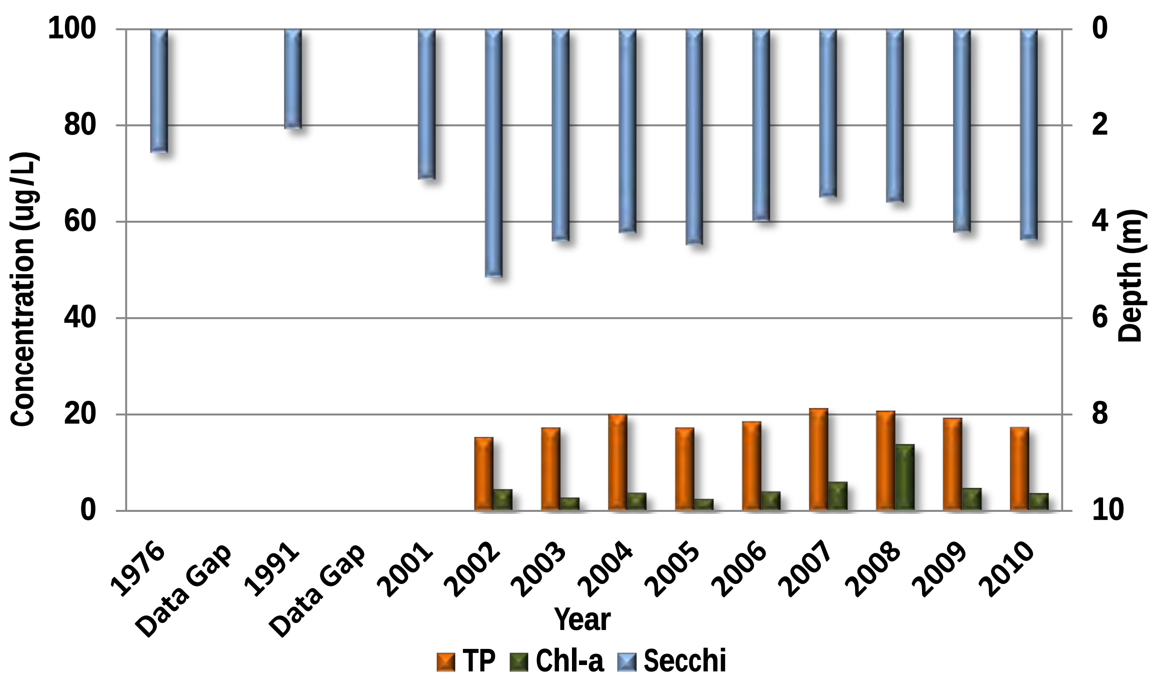
Birch Lake is a small, deep lake located approximately three and a half miles west of Monticello, Minnesota. Birch Lake's watershed is small with an area of 1,167 hectares (2,888 acres) and a watershed to lake ratio of 28:1. Land use is dominated by forest and rangeland and both percentages are above the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Birch Lake were 19 µg/L and 5 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 13 µg/L to 27 µg/L and 2 µg/L to 6 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Birch Lake was below the water quality standard with an average of 4.2 meters (13.8 feet) (Appendix A). Due to a lack of profile data, the lake mixing characteristics of Birch Lake cannot be determined.

Long-term chemistry and Secchi data is available to complete a trend analysis. Figure 77 indicates a slight increase in TP levels; however, water clarity within Somers Lake has improved since data was first collected. Total phosphorus and Secchi averages for all years have been below the water quality standard.

Based on the chemical monitoring results and water clarity, Birch Lake was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Birch Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 77. Birch Lake long-term water quality data



First Lake 86-0067-00

First Lake is a small, deep lake located one and a half miles west of Monticello, Minnesota. First Lake's watershed is moderately sized with an area of 4,924 hectares (12,187 acres) and a watershed to lake ratio of 871:1. Land use is dominated by forest and the percentage is above the range of values expected for the NCHF ecoregion (Appendix D).

Water chemistry and profile data has not been collected within First Lake and only one year of water clarity data has been collected. The average Secchi transparency value for First Lake was 1.8 meters (5.9 feet) (Appendix A). Trend data is not available.

Based on the water clarity, First Lake is classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, First Lake was determined to have insufficient data to assess its aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Mud Lake 86-0068-00

Mud Lake is a small, deep lake located one and a half miles west of Monticello, Minnesota. Mud Lake's watershed is moderately sized with an area of 4,785 hectares (11,843 acres) and a watershed to lake ratio of 408:1. Land use is dominated by forest and the percentage is above the range of values expected for the NCHF ecoregion (Appendix D).

Water chemistry and profile data has not been collected within Mud Lake and only one year of water clarity data has been collected. The average Secchi transparency value for Mud Lake was 1.7 meters (5.6 feet) for the 2008 monitoring season (Appendix A). Trend data is not available.

Based on the water clarity, Mud Lake is classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Mud Lake was determined to have insufficient data to assess its aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Long Lake 86-0069-00

Long Lake is a small, deep lake located approximately two miles southwest of Monticello, Minnesota. Long Lake's watershed is moderately sized with an area of 4,785 hectares (11,843 acres) and a watershed to lake ratio of 74:1. Land use is dominated by forest and the percentage is above the range of values expected for the NCHF ecoregion (Appendix D).

Long Lake was selected to be sampled as part of the National Lakes Assessment (NLA). The NLA was a statistically-based survey of the nation's lakes administered by the EPA in 2007. The resulting TP and chl-*a* values for Long Lake were 22 µg/L and 5 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Coinciding with the low levels of TP and chl-*a*, the water clarity for Long Lake was below the water quality standard with a value of 1.8 meters (5.9 feet) (Appendix A). Due to a lack of profile data, the lake mixing characteristics of Long Lake cannot be determined. Trend data is not available.

Based on the chemical monitoring results and water clarity, Long Lake was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Long Lake was determined to have insufficient data to assess its aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Bertram Lake 86-0070-00

Bertram Lake is a small, deep lake located approximately two miles southwest of Monticello, Minnesota. Bertram Lake's watershed is moderately sized with an area of 3,958 hectares (9,798 acres) and a watershed to lake ratio of 72:1. Land use is dominated by forest and the percentage is above the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Bertram Lake were 32 µg/L and 13 µg/L respectively. Each was just below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 19 µg/L to 66 µg/L and 6 µg/L to 32 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Bertram Lake was just below the water quality standard with an average of 1.5 meters (4.9 feet) (Appendix A). Due to a lack of profile data, the lake mixing characteristics of Bertram Lake cannot be determined. Trend data is not available.

Based on the chemical monitoring results and water clarity, Bertram Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Bertram Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Cedar Lake 86-0073-00

Cedar Lake is a moderately sized, deep lake located approximately three miles southwest of Monticello, Minnesota. Cedar Lake's watershed is small with an area of 1,146 hectares (2,836 acres) and a watershed to lake ratio of 10:1. Land use is dominated by forest and the percentage is above the range of values expected for the NCHF ecoregion (Appendix D).

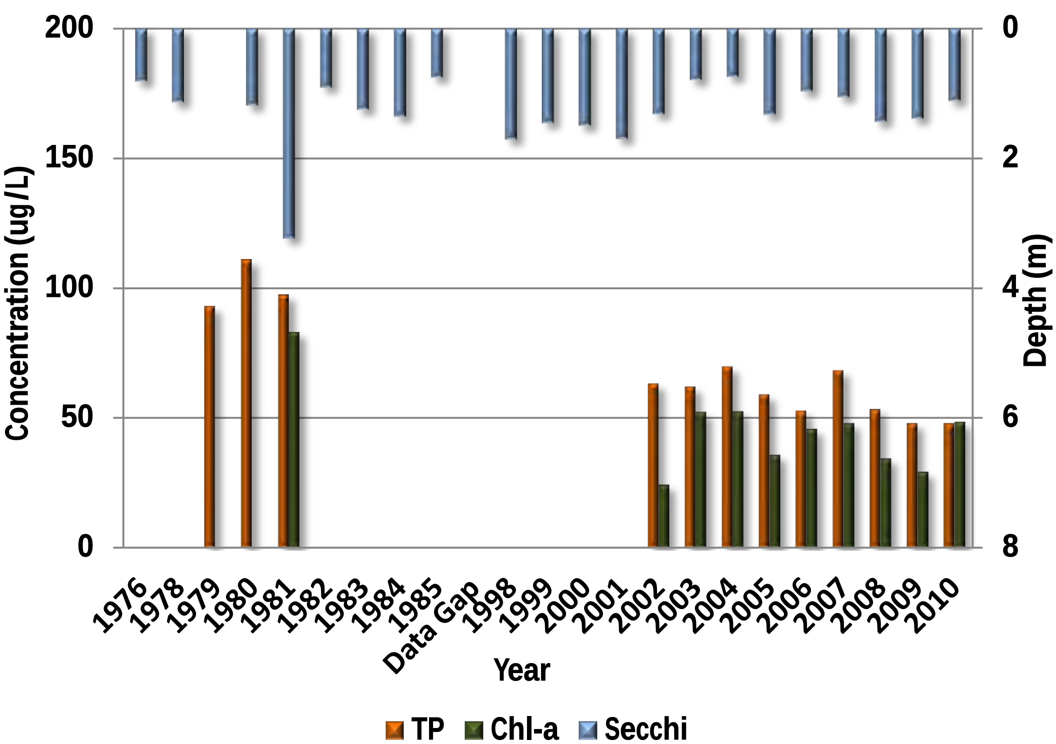
The average TP and chl-*a* values for Cedar Lake were 17 µg/L and 4 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 15 µg/L to 18 µg/L and 2 µg/L to 4 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Cedar Lake was below the water quality standard with an average of 5.1 meters (16.7 feet) (Appendix A).

Profile data, collected in 2003, indicated that Cedar Lake formed a shallow thermocline in June and July from 1 to 2 meters (3.3 to 6.6 feet). The thermocline layer dropped to a depth of 3 to 4 meters (9.9 to 13.1 feet) in August and September. This suggests that Cedar Lake stratifies during the summer months. Additionally, DO levels dropped below 5 mg/L at a depth of 5 meters (16.4 feet) in August and September.

Long-term chemistry data is available to complete a trend analysis and Secchi data is extensive. Figure 78 indicates decreasing levels in TP levels; however, water clarity has not improved. Total phosphorus and Secchi averages have been above the water quality standard a majority of the years.

Based on the chemical monitoring results and water clarity, Cedar Lake was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Cedar Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 78. Cedar Lake long-term water quality data



Ida Lake 86-0146-00

Ida Lake is a moderately sized, deep lake located approximately four miles west of Monticello, Minnesota. Ida Lake's watershed is small with an area of 941 hectares (2,330 acres) and a watershed to lake ratio of 9:1. Land use is dominated by forest and the percentage is above the range of values expected for the NCHF ecoregion (Appendix D).

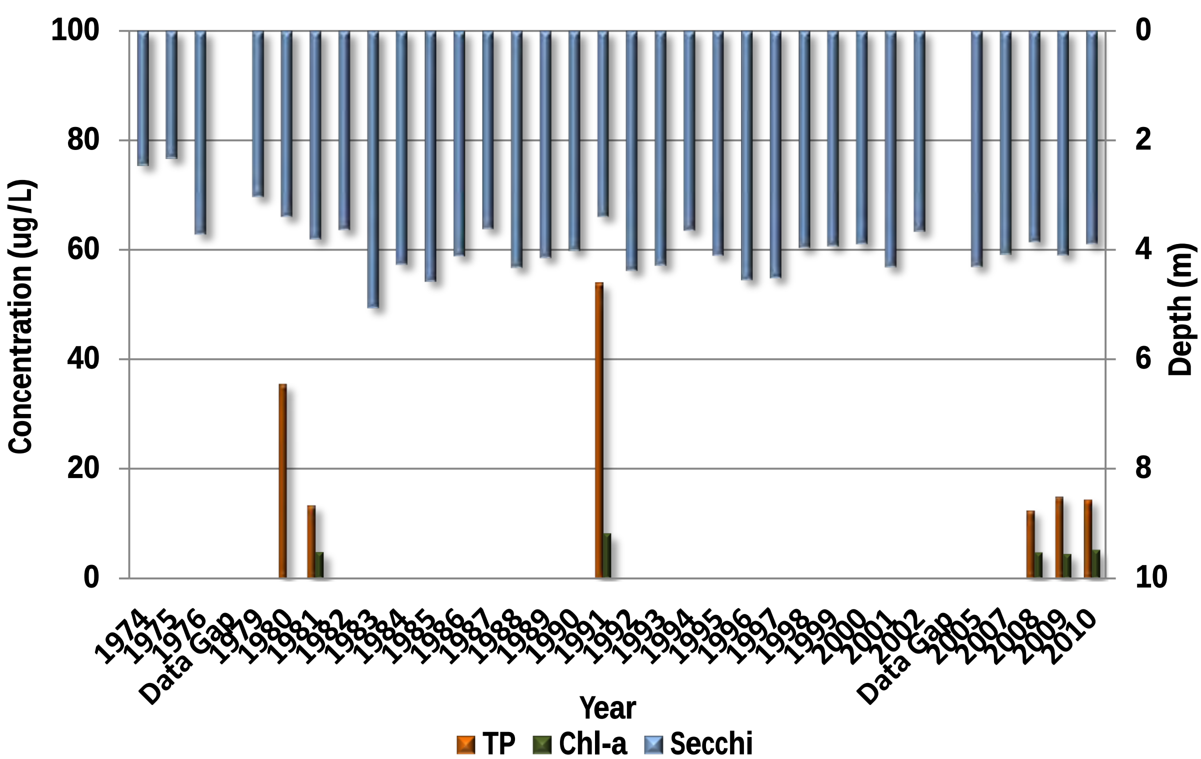
The average TP and chl-*a* values for Ida Lake were 14 µg/L and 5 µg/L respectively. Each was below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 12 µg/L to 20 µg/L and 3 µg/L to 10 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Ida Lake was below the water quality standard with an average of 4 meters (13.1 feet) (Appendix A).

Limited historical profile data, collected in 1991, indicated that Ida Lake typically formed a thermocline at 2 to 3 meters (6.6 to 9.9 feet) during the summer months. The thermocline layer dropped to a depth of 5 meters (16.4 feet) in September. This suggests that Ida Lake stratifies during the summer months. Additionally, DO levels dropped below 5 mg/L at a depth of 5 meters (16.4 feet) in August and September. Dissolved oxygen levels dropped below 5 mg/L at a depth of 9 meters (29.5 feet) in June.

Long-term chemistry data is not available and Secchi data is extensive. Available chemistry data (Figure 79) does indicate decreasing levels in TP levels. Secchi averages indicate an improvement in water clarity. These values have historically been well below the water quality standard.

Based on the chemical monitoring results and water clarity, Ida Lake was classified as a mesotrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Ida Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 79. Ida Lake long-term water quality data



Eagle Lake 86-0148-00

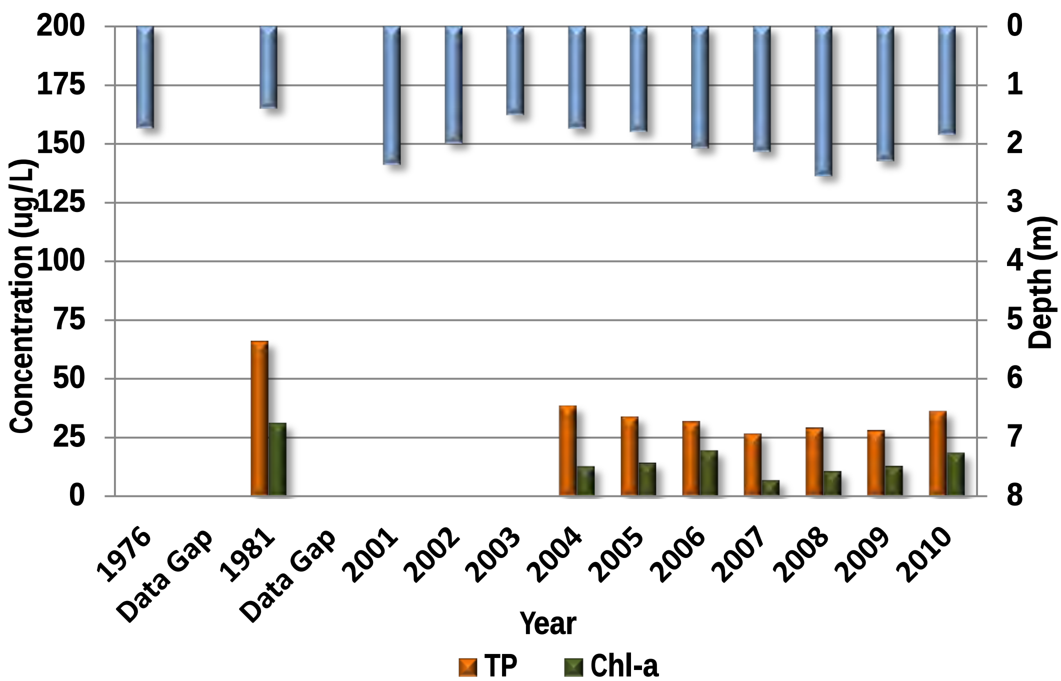
Eagle Lake is a moderately sized, deep lake located approximately five miles west of Monticello, Minnesota. Eagle Lake's watershed is small with an area of 693 hectares (1,716 acres) and a watershed to lake ratio of 9:1. Land use is dominated by forest and the percentage is above the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Eagle Lake were 32 µg/L and 14 µg/L respectively. Each was just below the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected in 2009 and 2010, ranged from 26 µg/L to 63 µg/L and 7 µg/L to 33 µg/L respectively. Coinciding with the low levels of TP and chl-*a*, the water clarity for Eagle Lake was below the water quality standard with an average of 2 meters (6.6 feet) (Appendix A). Due to a lack of profile data, the lake mixing characteristics of Eagle Lake cannot be determined.

Long-term chemistry data is nearly adequate and Secchi data is sufficient to complete a trend analysis. Available data (Figure 80) indicates a decrease in TP levels as well as an improvement in water clarity. Chemistry and Secchi averages for nearly all of the recorded years were below the water quality standard.

Based on the chemical monitoring results and water clarity, Eagle Lake was classified as a eutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Eagle Lake was determined to be fully supporting of aquatic recreational use and was not listed as an impaired water under the 2011 303(d) Impaired Waters List.

Figure 80. Eagle Lake long-term water quality data



Ostego subwatershed

The Ostego (07010203790) HUC-11 watershed lies along the south eastern border of the Mississippi (St. Cloud) watershed. This 3,745 hectare (9,271 acre) subwatershed represents 1.3 percent of the Mississippi (St. Cloud) watershed (Figure 81 and Table 2). Cropland is the major land use within this area (Figure 81). Based on 2003 NPDES/SDS registered feedlot data, there is one permitted discharge site and 12 registered feedlots throughout the Ostego subwatershed (Figure 6).

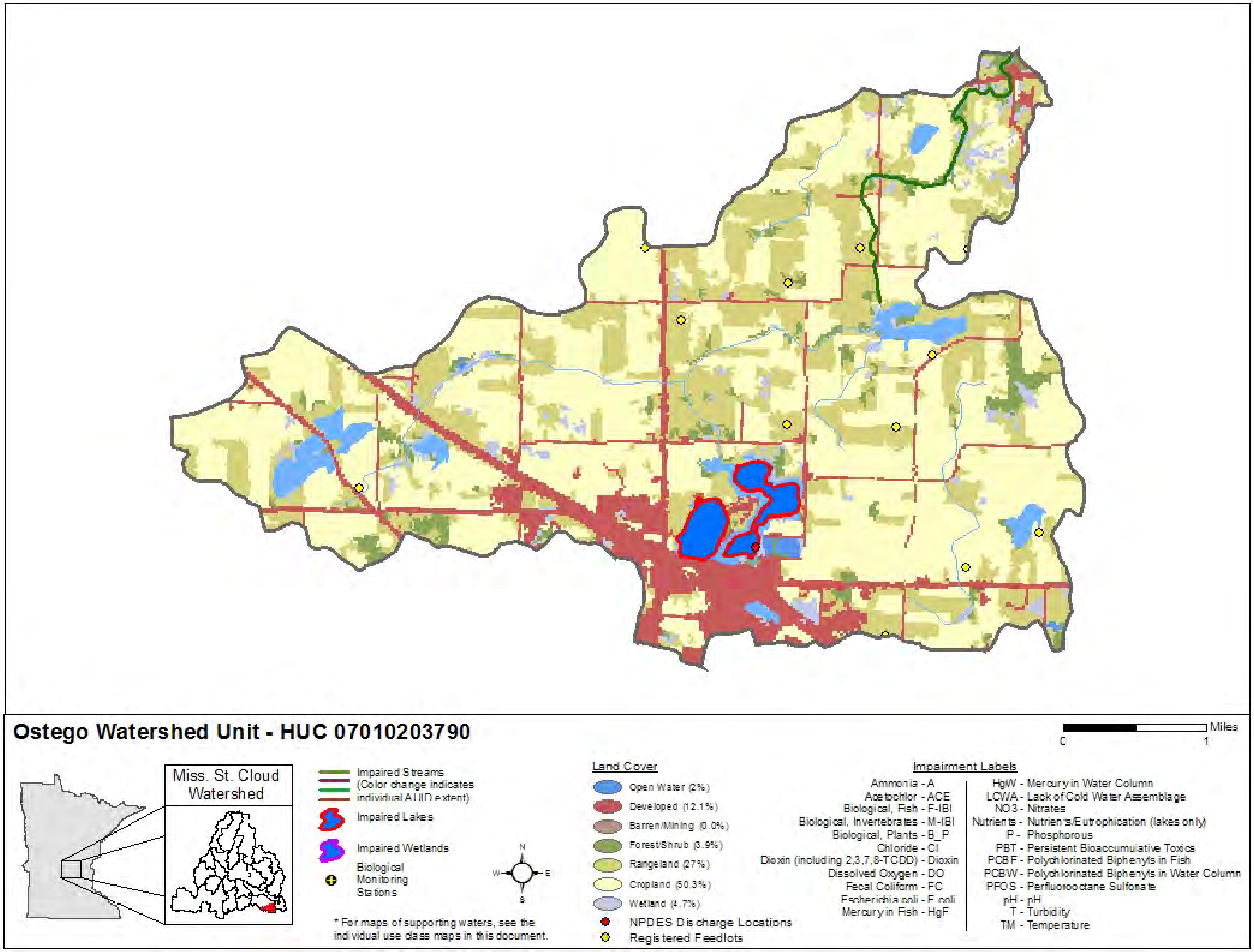
The Ostego subwatershed consists of three lakes greater than 4 hectares (10 acres), of which two were assessed for aquatic recreation use. Water quality data for School Lake and Hunters Lake (Mud) was obtained through a discharge permit from the city of Albertville. The morphometric characteristics of both lake basins were analyzed and they were each determined to be shallow lakes. Both lakes were assessed and determined to be non-supporting of aquatic recreation use (Table 16). Anthropogenic development is the dominating land use within the contributing watershed for both lakes (Figure 81). Profile data is not available for either lake to determine the mixing characteristics; however, based on their depth internal nutrient contribution due to lake mixing is likely. Further investigation will be required to fully determine the source of nutrient contributions, but an overall reduction in external loading will still prove beneficial.

The MNLEAP model results indicated that the observed TP was significantly higher for School and Hunters (Mud) Lakes than the predicted values. The model predicted similar TP loading rates for both School and Hunters (Mud) lakes, 143 kg/yr and 149 kg/yr respectively. Additionally, the areal load rates were similar for each lake. These rates ranged from 1 to 4 m/yr. Conditions related to the discharge permit were not factored into the modeling. The complete modeling results can be found in Appendix C.

Table 16. Summary of lake eutrophication assessment results for the Ostego subwatershed

Lake Name	DNR Lake ID	County	Lake Area (Hectares)	Maximum Depth (Meters)	ARUS
School	86-0025-00	Wright	31	-	NS
Hunters (Mud)	86-0026-00	Wright	52	-	NS

Figure 81. Ostego subwatershed showing all lake assessments and land use



School Lake 86-0025-00

School Lake is a small, shallow lake located within Albertville, Minnesota. School Lake's watershed is small with an area of 514 hectares (1,273 acres) and a watershed to lake ratio of 17:1. Land use is dominated by anthropogenic development and the percentage is above the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for School Lake were 261 µg/L and 15 µg/L respectively. Each was well above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected from 2001 to 2010, ranged from 60 µg/L to 539 µg/L and 8 µg/L to 467 µg/L respectively (Appendix A). Water quality data for School Lake was obtained through a discharge permit from the city of Albertville. Secchi and profile data is not available. The morphometric characteristics of School Lake were analyzed and it was determined that shallow lake standards should be applied. Trend data is not available.

Based on the chemical monitoring results, School Lake was classified as a hypereutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, School Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2011 303(d) Impaired Waters List.

Hunters (Mud) Lake 86-0026-00

Hunters (Mud) Lake is a small, shallow lake located within Albertville, Minnesota. Hunters (Mud) Lake's watershed is small with an area of 514 hectares (1,273 acres) and a watershed to lake ratio of 17:1. Land use is dominated by anthropogenic development and the percentage is above the range of values expected for the NCHF ecoregion (Appendix D).

The average TP and chl-*a* values for Hunters (Mud) Lake were 521 µg/L and 150 µg/L respectively. Each was well above the water quality standard for lakes within the NCHF ecoregion. Total phosphorus and chl-*a* data, collected from 2001 to 2010, ranged from 103 µg/L to 1,020 µg/L and 2 µg/L to 531 µg/L respectively (Appendix A). Water quality data for Hunters (Mud) Lake was obtained through a discharge permit from the city of Albertville. Secchi and profile data is not available. The morphometric characteristics of Hunters (Mud) Lake were analyzed and it was determined that shallow lake standards should be applied. Trend data is not available.

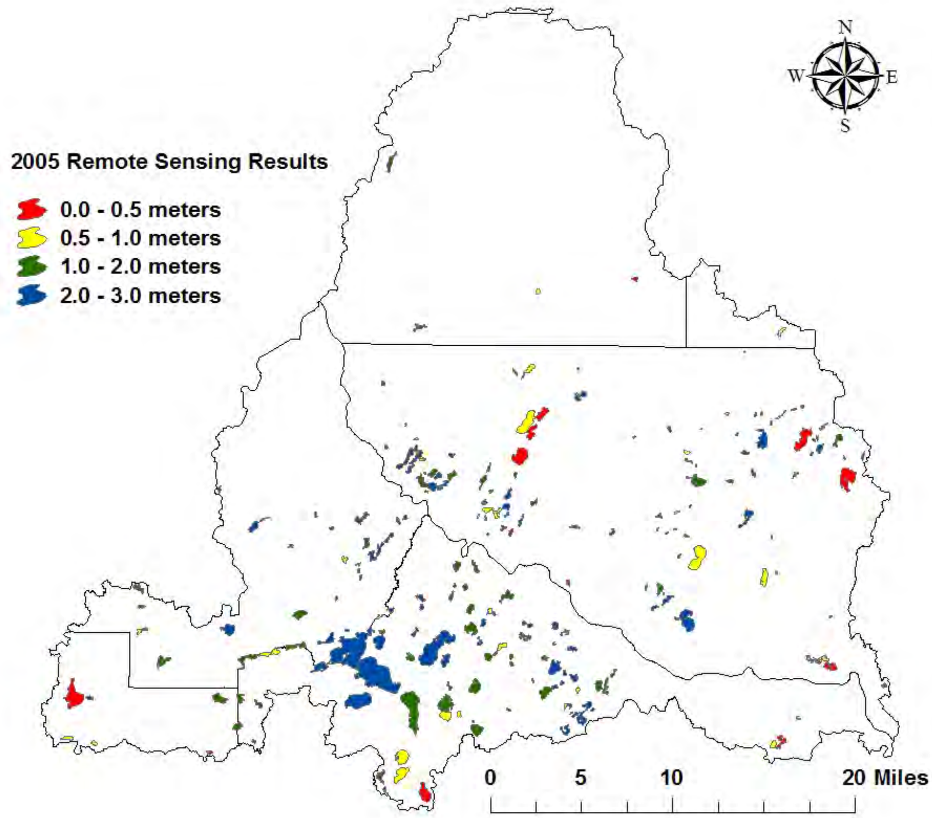
Based on the chemical monitoring results, Hunters (Mud) Lake was classified as a hypereutrophic lake. Additionally, based on the TP and chl-*a* standards for the support of aquatic recreation, Hunters (Mud) Lake was determined to be non-supporting of aquatic recreational use and was listed as an impaired water under the 2011 303(d) Impaired Waters List.

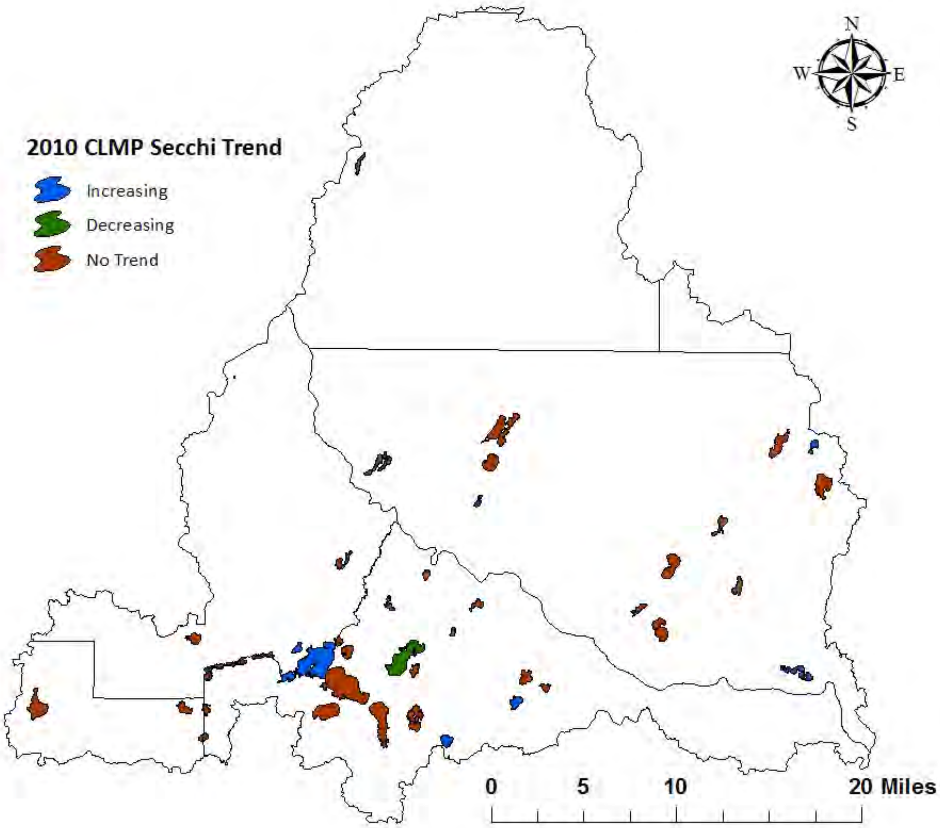
Citizen Lake Monitoring Program and Remote Sensing Trends

Where historic data exist, long-term water quality trends can be determined. Through the Citizen Lake Monitoring Program (CLMP), volunteers measure water clarity (i.e., transparency) using a Secchi disk. Since water transparency is an excellent indicator of water quality, this information can be used to help us understand water quality trends on lakes that are only periodically monitored for other water chemistry. Lakes must have at least eight years of data for trend analysis. There were 51 lakes in the watershed that met the minimum data requirements for Secchi trend analysis. Of those lakes, 10 indicate an improving water clarity trend and 1 indicates a declining trend in water clarity. There were 40 lakes that did not show a trend in clarity (Figure 82).

Where long-term water clarity data are lacking, we can also consider trends generated through Remote Sensing (RS) data, which have been proven to provide a reasonable estimate of transparency for Minnesota lakes. Based on the most recently available RS data (2005), presented in Figure 82, a majority of the lakes within the watershed have water clarity values between 0.5 meters and 2 meters in depth. There are 54 lakes with an inferred Secchi greater than 2.0 meters, and 40 have inferred Secchi less than 0.5 meters. The lakes in the regions of reduced anthropogenic influence and higher forested land uses within the HUC-11s appear to have the greater clarity, while the lakes in the more developed lands have reduced Secchi, similar to what was observed with the water quality data.

Figure 82. Mississippi (St. Cloud) watershed remotely sensed transparency and CLMP trends





Mississippi (St. Cloud) Watershed Summary

The Mississippi (St. Cloud) watershed has diverse characteristics, all of which have an impact on the numerous lakes within its borders. Various land uses, basin morphologies, geographic properties, and catchment areas all have an effect on the recreational use support of these lakes. Of the 79 lakes with sufficient assessment data, 34 were determined to be fully supporting for recreational use, while 35 were impaired. Available data were insufficient to complete an assessment of the remaining 10; however, 8 of these lakes did indicate supporting conditions.

The larger deeper lakes located within the Plum Creek, Otter Creek, and Clearwater River watersheds commonly indicated supporting conditions. Additionally, these deeper basins became stratified during the summer months allowing for a limited release of phosphorous from the lake sediment thus reducing internal contribution. Numerous recreationally supporting lakes typically had smaller catchment watersheds and lake to watershed ratios leading to a reduced external nutrient contribution potential. This was observed in the previously mentioned HUC-11 subwatersheds as well as in the Silver Creek, Lower Elk River, Snake River, and Battle Brook subwatersheds. A higher percentage of forested land use will also help to mitigate external nutrient contribution to the lakes and streams when compared to areas of disturbed soils.

Lakes within the Mississippi (St. Cloud) watershed that were non-supporting for aquatic recreation are commonly characterized as small and shallow. During the spring and fall turnover and periods of high winds, these lakes receive additional internal nutrient contribution as phosphorous is released from disturbed lake sediment. Additionally, many of these waters typically have larger watershed to lake ratios and are located near the bottom of large catchment areas. Also within these areas, greater anthropogenic disturbance can be seen from both urban development and cropland land use. Nutrient impairments within the Mississippi (St. Cloud) watershed were not limited to small and shallow lakes. The Louisa chain of lakes within the Clearwater River subwatershed is an example of deep lakes downstream from an area characterized by heavily disturbed land use.

Reducing levels of TP will be required in order to reduce the occurrence of algal blooms for lakes within the Mississippi River (St. Cloud) watershed. Alternatively, should in-lake TP concentrations increase, the potential for nuisance algal blooms will also increase. It is important to limit as much external (watershed) phosphorus loading to the lakes as possible to improve or maintain the current concentrations. Additionally, the watersheds for each of these lakes will need to be addressed through a TMDL study to determine the source and extent of pollution problems.

In conjunction with the intensive watershed monitoring (IWM) cycle, which began in this watershed in 2009, a Watershed Restoration and Protection Project (WRAP) were initiated by the MPCA in 2010. Through the integral assistance of local environmental partner organizations (LEPO) and citizen input, the WRAP process will provide the overall water quality framework for strategies and methods for achieving water quality standards for the lakes within the Mississippi (St. Cloud) watershed within an overall watershed plan. The WRAP will integrate TMDLs for the restoration of non-supporting (impaired) lakes and lake protection needs for fully supporting lakes into an implementation plan for the watershed. To help achieve the overall water quality goals for the lakes within the watershed, the implementation plan will identify target areas for the implementation of best management practices. Upon the completion of the WRAP process in 2013/2014, through the guidance of LEPO, an implementation phase will commence based on the implementation plan recommendations. This watershed will be subsequently re-evaluated in 2019, during the next IWM cycle for effectiveness through a reassessment of the surface water resources.

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Appendix A

Available water quality information for assessed lakes within the Mississippi (St. Cloud) watershed

Lake ID	Lake Name	ARUS	Trophic Status	Mean TP	Mean Chl-a	Mean Secchi	CLMP Trend	RS Trend
				ug/L	ug/L	Meters		
05-0004-02	Donovan	NS	HE	137	53	1.0	-	-
05-0007-00	Mayhew	NS	HE	171	50	2.5	NT	-
47-0042-00	Betty	NS	HE	172	57	0.9	NT	-
47-0095-00	Clear	NS	HE	185	62	0.5	NT	Decreasing
47-0096-00	Little Mud	IF	E	49	21	2.1	-	-
71-0013-01	Upper Orono	NS	HE	132	23	0.8	Increasing	-
71-0013-02	Lower Orono	NS	HE	112	32	0.8	Increasing	-
71-0016-00	Fremont	NS	HE	166	94	0.6	NT	-
71-0041-00	Cantlin	FS	E	26	10	2.2	Increasing	-
71-0046-00	Diann	NS	E	66	32	1.1	-	Decreasing
71-0055-00	Elk	NS	E	73	31	0.7	NT	-
71-0057-00	Birch	NS	E	48	28	1.0	NT	Decreasing
71-0067-00	Eagle	IF	E	51	21	0.9	NT	Decreasing
71-0069-00	Ann	FS	M	21	5	3.0	NT	-
71-0081-00	Mitchell	FS	M	19	6	2.7	NT	-
71-0082-00	Big	FS	M	18	6	2.9	NT	-
71-0096-00	Thompson	FS	M	20	6	2.7	NT	-
71-0123-00	Camp	FS	M	17	5	2.9	Increasing	Increasing
71-0141-00	Elk	NS	HE	155	66	0.6	NT	Decreasing
71-0145-00	Julia	NS	E	65	27	0.7	NT	-
71-0146-00	Briggs	NS	HE	97	49	1.0	NT	-
71-0147-00	Rush	NS	HE	104	59	0.5	NT	-
71-0158-00	Pickerel	FS	E	26	10	2.4	NT	-
71-0159-00	Long	FS	E	30	10	2.2	NT	-
71-0167-00	Round	FS	E	29	8	3.2	Increasing	-

Lake ID	Lake Name	ARUS	Trophic Status	Mean TP	Mean Chl-a	Mean Secchi	CLMP Trend	RS Trend
				ug/L	ug/L	Meters		
73-0001-00	Dallas	FS	E	25	7	3.3	-	-
73-0002-00	Feldges	FS	E	30	10	2.5	-	-
73-0003-00	Maria	FS	E	32	13	2.3	-	-
73-0004-00	Long	FS	M	24	7	3.9	NT	-
73-0006-00	Crooked	FS	M	21	4	3.9	NT	-
73-0007-00	Quinn	FS	M	24	7	4.1	-	-
73-0010-00	Bunt	NS	E	52	13	1.2	-	-
73-0011-00	Warner	FS	M	21	16	1.8	-	-
73-0014-00	Marie	NS	HE	108	48	1.5	NT	-
73-0015-00	Otter	FS	M	22	9	2.8	Increasing	-
73-0020-00	Laura	FS	M	20	4	1.5	-	-
73-0023-00	Beaver	FS	M	17	5	3.9	-	-
73-0042-00	Island	FS	E	29	3	3.0	-	-
73-0611-00	George	PS	E	45	24	1.8	-	-
73-0701-00	Melrose Deep Quarry	IF	M	-	-	3.7	NT	-
86-0025-00	School	NS	HE	261	105	-	-	-
86-0026-00	Hunters (Mud)	NS	HE	521	150	-	-	-
86-0066-00	Birch	FS	M	19	5	4.2	NT	-
86-0067-00	First	IF	E	-	-	1.8	-	-
86-0068-00	Mud	IF	E	-	-	1.7	-	-
86-0069-00	Long	IF	M	22	5	1.8	-	-
86-0070-00	Bertram	FS	E	32	13	1.5	-	-
86-0073-00	Cedar	FS	M	17	4	5.1	-	-
86-0139-01	Little Mary South	NS	HE	107	56	0.8	-	-
86-0139-02	Little Mary North	NS	HE	163	80	0.5	-	-
86-0140-00	Silver	NS	HE	105	45	1.2	-	-
86-0146-00	Ida	FS	M	14	5	4.0	NT	-
86-0148-00	Eagle	FS	E	32	14	2.0	Increasing	-

Lake ID	Lake Name	ARUS	Trophic Status	Mean TP	Mean Chl-a	Mean Secchi	CLMP Trend	RS Trend
				ug/L	ug/L	Meters		
86-0152-00	Millstone	NS	HE	357	119	1.3	-	-
86-0156-00	Mary	FS	E	35	13	2.3	Increasing	-
86-0163-00	Limestone	FS	M	24	10	2.4	-	-
86-0168-00	Locke	NS	E	66	34	0.9	NT	-
86-0171-00	Ember	FS	M	24	5	3.7	NT	-
86-0183-00	Fish	NS	E	48	24	1.3	NT	-
86-0208-00	Swartout	NS	HE	422	444	1.0	-	Decreasing
86-0212-00	Albion	NS	HE	199	117	1.4	-	-
86-0213-00	Henshaw	NS	HE	208	103	0.7	-	-
86-0223-00	Indian	NS	E	47	28	1.3	NT	-
86-0227-00	Cedar	FS	E	31	15	2.1	NT	-
86-0229-00	Mink	NS	HE	134	81	0.8	NT	-
86-0230-00	Somers	NS	E	84	49	1.0	NT	-
86-0233-00	Sugar	FS	M	20	7	2.9	Decreasing	-
86-0234-00	Bass	FS	M	18	3	4.3	NT	-
86-0238-00	Nixon	IF	M	19	5	3.3	NT	-
86-0242-00	Wiegand	IF	E	37	5	3.0	-	-
86-0243-00	Grass	IF	M	24	2	3.1	NT	-
86-0251-00	Pleasant	FS	E	29	12	2.4	NT	-
86-0252-01	Clearwater East	FS	E	33	10	1.9	NT	-
86-0252-02	Clearwater West	IF	E	37	12	2.5	Increasing	-
86-0281-00	Caroline	NS	E	82	39	1.7	NT	-
86-0282-00	Louisa	NS	E	66	52	1.2	NT	-
86-0284-00	Augusta	NS	E	68	19	2.4	Increasing	-
86-0297-00	Scott	NS	HE	185	84	0.8	NT	-
86-0298-00	Union	NS	E	73	32	1.7	NT	-

FS= full support NS = non- support IF = insufficient data for assessment HE = hypereutrophic E = eutrophic M = mesotrophic O = oligotrophic

NT = no trend

Appendix B

Morphometric characteristics for all assessed lakes within the Mississippi (St. Cloud) watershed

Lake ID	Lake Name	County	Ecoregion	Subwatershed	Lake Area	WS Area	Max Depth	Avg. Depth	Littoral	Mixing Characteristics
					Hectares	Hectares	Meters	Meters	%	
05-0004-02	Donovan	Benton	NCHF	Lower Elk River	22	321	1.5	0.9	100	Polymictic
05-0007-00	Mayhew	Benton	NCHF	Mayhew Creek	51	7,999	6.1	4.0	50	Dimictic
47-0042-00	Betty	Meeker	NCHF	Clearwater River	74	17,693	8.8	3.6	61	Dimictic
47-0095-00	Clear	Meeker	NCHF	Clearwater River	284	2,619	5.2	2.5	89	Intermittent
47-0096-00	Little Mud	Meeker	NCHF	Clearwater River	17	91	12.8	3.6	68	Dimictic
71-0013-01	Upper Orono	Sherburne	NCHF	Lower Elk River	121	156,417	5.2	1.5	-	-
71-0013-02	Lower Orono	Sherburne	NCHF	Lower Elk River	121	156,417	5.2	1.5	-	Polymictic
71-0016-00	Fremont	Sherburne	NCHF	Tibbits Creek	188	1,256	3.0	1.6	100	Intermittent
71-0041-00	Cantlin	Sherburne	NCHF	Battle Brook	54	575	-	-	-	Polymictic
71-0046-00	Diann	Sherburne	NCHF	Battle Brook	41	1,182	1.5	1.0	100	Polymictic
71-0055-00	Elk	Sherburne	NCHF	Battle Brook	136	10,325	3.7	2.2	100	Polymictic
71-0057-00	Birch	Sherburne	NCHF	Tibbits Creek	60	1,726	5.5	3.1	78	Intermittent
71-0067-00	Eagle	Sherburne	NCHF	Snake River	172	2,056	5.5	3.2	87	Intermittent
71-0069-00	Ann	Sherburne	NCHF	Snake River	91	461	7.9	2.0	75	Dimictic
71-0081-00	Mitchell	Sherburne	NCHF	Lower Elk River	63	823	10.1	4.8	65	Dimictic
71-0082-00	Big	Sherburne	NCHF	Lower Elk River	97	652	14.6	5.1	44	Dimictic
71-0096-00	Thompson	Sherburne	NCHF	Lower Elk River	40	415	6.7	9.7	66	Dimictic
71-0123-00	Camp	Sherburne	NCHF	Lower Elk River	34	347	10.4	9.9	70	Dimictic
71-0141-00	Elk	Sherburne	NCHF	Lower Elk River	142	61,804	2.4	1.6	100	Polymictic
71-0145-00	Julia	Sherburne	NCHF	Lower Elk River	55	783	3.7	2.4	100	Intermittent
71-0146-00	Briggs	Sherburne	NCHF	Lower Elk River	164	3,758	6.1	3.9	56	Polymictic
71-0147-00	Rush	Sherburne	NCHF	Lower Elk River	65	4,085	3.7	1.7	100	Polymictic
71-0158-00	Pickerel	Sherburne	NCHF	Mississippi Direct	73	2,838	6.4	1.8	87	Dimictic
71-0159-00	Long	Sherburne	NCHF	Mississippi Direct	73	2,163	7.9	3.1	79	Dimictic

Lake ID	Lake Name	County	Ecoregion	Subwatershed	Lake Area	WS Area	Max Depth	Avg. Depth	Littoral	Mixing Characteristics
					Hectares	Hectares	Meters	Meters	%	
71-0167-00	Round	Sherburne	NCHF	Mississippi Direct	16	2,282	13.1	12.3	62	Dimictic
73-0001-00	Dallas	Stearns	NCHF	Plum Creek	9	5,964	6.7	8.1	78	-
73-0002-00	Feldges	Stearns	NCHF	Plum Creek	13	5,878	5.2	5.6	91	-
73-0003-00	Maria	Stearns	NCHF	Plum Creek	39	3,753	5.5	2.3	97	-
73-0004-00	Long	Stearns	NCHF	Plum Creek	25	1,961	11.6	3.9	53	Dimictic
73-0006-00	Crooked	Stearns	NCHF	Plum Creek	45	1,436	10.7	4.1	55	Dimictic
73-0007-00	Quinn	Stearns	NCHF	Plum Creek	8	1,131	-	-	-	-
73-0010-00	Bunt	Stearns	NCHF	Plum Creek	40	305	1.8	0.9	100	-
73-0011-00	Warner	Stearns	NCHF	Plum Creek	13	6,331	11.6	3.7	100	-
73-0014-00	Marie	Stearns	NCHF	Clearwater River	59	22,923	11.0	2.2	84	Dimictic
73-0015-00	Otter	Stearns	NCHF	Clearwater River	51	4,879	15.5	7.2	33	Dimictic
73-0020-00	Laura	Stearns	NCHF	Clearwater River	59	970	-	-	-	-
73-0023-00	Beaver	Stearns	NCHF	Johnson Creek	64	1,505	8.2	4.0	32	-
73-0042-00	Island	Stearns	NCHF	Clearwater River	38	134	-	-	-	-
73-0611-00	George	Stearns	NCHF	St. Cloud	3	3,377	9.8	14.9	43	-
73-0701-00	Melrose Deep Quarry	Stearns	NCHF	St. Cloud	1	3,377	-	-	-	-
86-0025-00	School	Wright	NCHF	Ostego	31	693	1.5	4.0	100	-
86-0026-00	Hunters (Mud)	Wright	NCHF	Ostego	52	693	1.2	3.0	100	-
86-0066-00	Birch	Wright	NCHF	Otter Creek	42	1,167	15.9	16.4	49	-
86-0067-00	First	Wright	NCHF	Otter Creek	6	4,924	10.7	11.5	60	-
86-0068-00	Mud	Wright	NCHF	Otter Creek	12	4,785	11.3	9.7	67	-
86-0069-00	Long	Wright	NCHF	Otter Creek	65	4,785	10.1	11.4	67	-
86-0070-00	Bertram	Wright	NCHF	Otter Creek	55	3,958	12.8	5.9	23	-
86-0073-00	Cedar	Wright	NCHF	Otter Creek	109	1,146	14.3	1.8	89	Dimictic
86-0139-01	Little Mary South	Wright	NCHF	Silver Creek	73	11,251	-	-	-	-
86-0139-02	Little Mary North	Wright	NCHF	Silver Creek	73	2,073	-	-	-	-
86-0140-00	Silver	Wright	NCHF	Silver Creek	36	9,081	12.8	5.1	39	-
86-0146-00	Ida	Wright	NCHF	Otter Creek	105	941	18.3	5.6	47	Dimictic

Lake ID	Lake Name	County	Ecoregion	Subwatershed	Lake Area	WS Area	Max Depth	Avg. Depth	Littoral	Mixing Characteristics
					Hectares	Hectares	Meters	Meters	%	
86-0148-00	Eagle	Wright	NCHF	Otter Creek	80	693	11.6	4.4	69	-
86-0152-00	Millstone	Wright	NCHF	Silver Creek	89	285	1.8	1.3	-	-
86-0156-00	Mary	Wright	NCHF	Silver Creek	94	1,546	31.1	10.7	39	-
86-0163-00	Limestone	Wright	NCHF	Silver Creek	151	3,321	10.4	3.7	54	-
86-0168-00	Locke	Wright	NCHF	Silver Creek	61	12,950	14.9	5.5	43	-
86-0171-00	Ember	Wright	NCHF	Silver Creek	27	139	12.5	12.1	42	-
86-0183-00	Fish	Wright	NCHF	Fish Creek	42	1,778	11.6	4.0	59	Dimictic
86-0208-00	Swartout	Wright	NCHF	Clearwater River	139	2,127	3.4	1.5	100	Polymictic
86-0212-00	Albion	Wright	NCHF	Clearwater River	133	625	-	-	-	Polymictic
86-0213-00	Henshaw	Wright	NCHF	Clearwater River	112	443	-	-	-	Polymictic
86-0223-00	Indian	Wright	NCHF	Clearwater River	55	2,182	9.5	5.1	45	Dimictic
86-0227-00	Cedar	Wright	NCHF	Clearwater River	338	3,716	32.9	29.5	38	Dimictic
86-0229-00	Mink	Wright	NCHF	Silver Creek	123	1,042	9.8	1.9	91	Dimictic
86-0230-00	Somers	Wright	NCHF	Silver Creek	63	1,165	5.5	2.9	79	Intermittent
86-0233-00	Sugar	Wright	NCHF	Clearwater River	463	2,705	21.0	7.6	35	Dimictic
86-0234-00	Bass	Wright	NCHF	Clearwater River	95	384	10.4	5.1	45	Dimictic
86-0238-00	Nixon	Wright	NCHF	Clearwater River	42	634	20.4	4.1	59	Dimictic
86-0242-00	Wiegand	Wright	NCHF	Clearwater River	34	40,533	7.3	8.1	83	Dimictic
86-0243-00	Grass	Wright	NCHF	Clearwater River	50	39,878	10.7	3.0	68	Dimictic
86-0251-00	Pleasant	Wright	NCHF	Clearwater River	258	1,273	22.6	4.9	51	Dimictic
86-0252-01	Clearwater East	Wright	NCHF	Clearwater River	670	8,553	22.3	6.8	-	Dimictic
86-0252-02	Clearwater West	Wright	NCHF	Clearwater River	606	39,356	21.3	4.9	-	Dimictic
86-0281-00	Caroline	Wright	NCHF	Clearwater River	56	23,489	13.6	4.6	50	Dimictic
86-0282-00	Louisa	Wright	NCHF	Clearwater River	74	21,285	13.4	3.2	63	Dimictic
86-0284-00	Augusta	Wright	NCHF	Clearwater River	75	24,349	25.0	7.6	27	Dimictic
86-0297-00	Scott	Wright	NCHF	Clearwater River	41	20,136	7.0	2.9	65	Intermittent
86-0298-00	Union	Wright	NCHF	Clearwater River	37	1,820	10.7	5.6	31	Dimictic

Appendix C

MINLEAP modeling results for all assessed lakes within the Mississippi (St. Cloud) watershed

Lake ID	Obs TP	MINLEAP TP	Obs Chl-a	MINLEAP Chl-a	Obs Secchi	MINLEAP Secchi	Average TP Inflow	TP Load	Background TP	P Retention	Outflow	Residence Time	Areal Load
	ug/L	ug/L	ug/L	ug/L	m	m	ug/L	kg/yr	ug/L	%	hm3/yr	years	m/yr
05-0004-02	137	77	53	37	1.0	0.9	160	68	-	0.5	0.4	0.5	1.9
05-0007-00	171	90	50	47	2.5	0.8	149	1,554	-	0.4	10.4	0.2	20.4
47-0042-00	172	99	57	54	0.9	0.7	149	3,426	-	0.3	23	0.1	31.1
47-0095-00	185	48	62	19	0.5	1.4	167	589	-	0.7	3.5	2	1.24
47-0096-00	49	35	21	12	2.1	1.8	181	23	-	0.8	0.1	4.9	0.7
71-0013-01	132	132	23	82	0.8	0.6	148	30,131	-	0.1	203.4	0	168.1
71-0013-02	112	132	32	82	0.8	0.6	148	30,131	-	0.1	203.4	0	168.1
71-0016-00	166	52	94	21	0.6	1.3	175	298	27	0.7	1.7	1.8	0.9
71-0041-00	26	71	10	34	2.2	1	165	127	-	0.6	0.8	0.6	1.42
71-0046-00	66	86	32	44	1.1	0.8	154	240	-	0.4	1.6	0.3	3.8
71-0055-00	73	88	31	46	0.7	0.8	150	2,027	26	0.4	13.5	0.2	9.9
71-0057-00	48	63	28	28	1.0	1.1	154	350	-	0.6	2.3	0.8	3.8
71-0067-00	51	47	21	19	0.9	1.4	163	447	-	0.7	2.7	2	1.6
71-0069-00	21	44	5	17	3.0	1.5	182	116	-	0.8	0.6	2.9	0.7
71-0081-00	19	42	6	15	2.7	1.6	162	177	22	0.7	1.1	2.8	1.7
71-0082-00	18	32	6	11	2.9	1.9	174	155	22	0.8	0.9	5.6	0.9
71-0096-00	20	28	6	9	2.7	2.2	165	92	-	0.8	0.6	7	1.4
71-0123-00	17	28	5	9	2.9	2.2	166	77	-	0.8	0.5	7.2	1.4
71-0141-00	155	121	66	72	0.6	0.6	148	11,934	-	0.2	80.4	0	56.6
71-0145-00	65	56	27	23	0.7	1.2	161	167	-	0.7	1.04	1.3	1.9
71-0146-00	97	54	49	22	1.0	1.2	156	772	-	0.7	4.9	1.3	3
71-0147-00	104	89	59	47	0.5	0.8	151	805	88	0.4	5.3	0.2	8.2
71-0158-00	26	79	10	39	2.4	0.9	153	568	-	0.5	3.7	0.4	5.1

Lake ID	Obs TP	MINLEAP TP	Obs Chl-a	MINLEAP Chl-a	Obs Secchi	MINLEAP Secchi	Average TP Inflow	TP Load	Background TP	P Retention	Outflow	Residence Time	Areal Load
	ug/L	ug/L	ug/L	ug/L	m	m	ug/L	kg/yr	ug/L	%	hm3/yr	years	m/yr
71-0159-00	30	63	10	28	2.2	1.1	154	438	-	0.6	2.8	0.8	3.9
71-0167-00	29	65	8	30	3.2	1.1	149	444	-	0.6	2.9	0.7	18.6
73-0001-00	25	103	7	57	3.3	0.7	148	1,150	-	0.3	7.8	0.1	86.2
73-0002-00	30	103	10	57	2.5	0.7	148	1,135	-	0.3	7.7	0.1	58.8
73-0003-00	32	91	13	48	2.3	0.8	150	734	-	0.4	4.9	0.2	12.6
73-0004-00	24	77	7	38	3.9	0.9	150	385	-	0.5	2.6	0.4	10.2
73-0006-00	21	59	4	25	3.9	1.2	154	290	-	0.6	1.9	1	4.2
73-0007-00	24	114	7	66	4.1	0.4	149	220	-	0.2	1.5	0	18.4
73-0010-00	52	66	13	30	1.2	1	171	71	-	0.6	0.4	0.9	1
73-0011-00	21	110	16	64	1.8	0.7	148	1,222	-	0.3	8.2	0.1	63.4
73-0014-00	108	115	48	67	1.5	0.6	148	4,428	-	0.2	29.8	0	50.6
73-0015-00	22	68	9	32	2.8	1	150	954	-	0.5	6.4	0.6	12.5
73-0020-00	20	79	4	39	1.5	0.9	159	204	-	0.5	1.3	0.4	2.2
73-0023-00	17	54	5	22	3.9	1.2	156	309	-	0.7	2	1.3	3.1
73-0042-00	29	56	3	24	3.0	1.2	196	37	-	0.7	0.2	1.8	0.5
73-0611-00	45	101	24	56	1.8	0.7	148	651	-	0.3	4.4	0.1	146.4
86-0025-00	261	78	105	38	-	0.9	156	143		0.5	0.9	0.4	3
86-0026-00	521	75	150	36	-	0.9	162	149	-	0.5	0.9	0.5	1.8
86-0066-00	19	33	5	11	4.2	1.9	155	237	-	0.8	1.5	4.5	3.7
86-0069-00	22	55	5	23	1.8	1.2	150	940	20	0.6	6.3	1.2	9.8
86-0070-00	32	67	13	31	1.5	1	151	778	-	0.6	5.2	0.6	9.4
86-0073-00	17	57	4	24	5.1	1.2	165	253	29	0.7	1.5	1.3	1.4
86-0139-01	107	115	56	67	0.8	0.6	149	2,187	-	0.2	14.7	0	20.1
86-0139-02	163	88	80	46	0.5	0.8	154	421	-	0.4	2.7	0.2	3.7
86-0140-00	105	94	45	50	1.2	0.8	149	1,758	-	0.4	11.8	0.2	32.8
86-0146-00	14	34	5	12	4.0	1.8	168	213	-	0.8	1.3	4.6	1.2
86-0148-00	32	38	14	13	2.0	1.7	169	157	-	0.8	0.9	3.8	1.2
86-0152-00	357	47	119	18	1.3	1.4	201	82	-	0.8	0.4	2.8	0.5

Lake ID	Obs TP	MINLEAP TP	Obs Chl-a	MINLEAP Chl-a	Obs Secchi	MINLEAP Secchi	Average TP Inflow	TP Load	Background TP	P Retention	Outflow	Residence Time	Areal Load
	ug/L	ug/L	ug/L	ug/L	m	m	ug/L	kg/yr	ug/L	%	hm3/yr	years	m/yr
86-0156-00	35	32	13	11	2.3	1.9	159	326	-	0.8	2.1	4.9	2.2
86-0163-00	24	54	10	23	2.4	1.2	156	684	-	0.7	4.4	1.3	2.9
86-0168-00	66	89	34	47	0.9	0.8	149	2,510	-	0.4	16.9	0.2	27.6
86-0171-00	24	20	5	5	3.7	2.9	182	35	-	0.9	0.2	17.1	0.7
86-0183-00	48	65	24	29	1.3	1.1	152	355		0.6	2.3	0.7	5.5
86-0208-00	422	66	444	30	1.0	1	160	451	-	0.6	2.8	0.7	2
86-0212-00	199	59	117	26	1.4	1.1	185	160	-	0.7	0.9	1.4	0.7
86-0213-00	208	57	103	24	0.7	1.2	191	119	-	0.7	0.6	1.6	0.6
86-0223-00	47	59	28	25	1.3	1.2	153	436	-	0.6	2.9	1	5.2
86-0227-00	31	17	15	4	2.1	3.3	164	816	-	0.9	5	20.1	1.5
86-0229-00	134	52	81	21	0.8	1.3	169	237	-	0.7	1.4	1.7	1.1
86-0230-00	84	56	49	24	1.0	1.2	158	243	-	0.6	1.5	1.2	2.4
86-0233-00	20	26	7	8	2.9	2.3	178	659	-	0.9	3.7	9.5	0.8
86-0234-00	18	28	3	8	4.3	2.2	191	102	23.4	0.9	0.5	9	0.6
86-0238-00	19	46	5	18	3.3	1.4	160	135		0.7	0.8	2	2
86-0242-00	37	112	5	65	3.0	0.7	148	7,809	-	0.2	52.7	0.1	115
86-0243-00	24	120	2	72	3.1	0.6	148	7,688	-	0.2	51.9	0	103.7
86-0251-00	29	30	12	9	2.4	2.1	183	322	23.9	0.8	1.8	7.2	0.7
86-0252-01	33	36	10	12	1.9	1.8	162	1,847	-	0.8	11.4	4	1.7
86-0252-02	37	69	12	32	2.5	1	151	7,754	-	0.5	51.4	0.6	8.5
86-0281-00	82	105	39	59	1.7	0.7	148	4,536	-	0.3	30.6	0.1	54.6
86-0282-00	66	105	52	59	1.2	0.7	149	4,117	-	0.3	27.7	0.1	37.4
86-0284-00	68	91	19	48	2.4	0.8	149	4,707	-	0.4	31.7	0.2	42.2
86-0297-00	185	114	84	67	0.8	0.7	148	3,886	-	0.2	26.2	0	63.9
86-0298-00	73	61	32	27	1.7	1.1	152	361	27	0.6	2.4	0.9	6.4

Appendix D

Land use for lake catchment areas within the Mississippi (St. Cloud) watershed

Lake ID	Lake Name	Subwatershed	Forest	Open Water	Wetland	Rangeland	Cropland	Developed
			%	%	%	%	%	%
05-0004-02	Donovan	Lower Elk River	7	12	4	28	38	11
05-0007-00	Mayhew	Mayhew Creek	9	<1	5	40	41	5
47-0042-00	Betty	Clearwater River	9	3	3	21	58	6
47-0095-00	Clear	Clearwater River	9	9	3	18	56	5
47-0096-00	Little Mud	Clearwater River	22	15	4	28	24	7
71-0013-01	Upper Orono	Lower Elk River	20	2	10	24	37	6
71-0013-02	Lower Orono	Lower Elk River	20	2	10	24	37	6
71-0016-00	Fremont	Tibbits Creek	17	16	7	37	15	7
71-0041-00	Cantlin	Battle Brook	16	13	9	22	32	7
71-0046-00	Diann	Battle Brook	26	11	11	20	26	7
71-0055-00	Elk	Battle Brook	18	3	16	16	41	6
71-0057-00	Birch	Tibbits Creek	22	4	65	3	4	2
71-0067-00	Eagle	Snake River	46	10	7	12	20	5
71-0069-00	Ann	Snake River	41	9	10	11	18	10
71-0081-00	Mitchell	Lower Elk River	4	24	4	9	20	39
71-0082-00	Big	Lower Elk River	5	20	4	11	25	34
71-0096-00	Thompson	Lower Elk River	34	14	8	17	21	6
71-0123-00	Camp	Lower Elk River	14	11	6	23	34	12
71-0141-00	Elk	Lower Elk River	13	1	6	29	44	6
71-0145-00	Julia	Lower Elk River	34	8	7	9	35	7
71-0146-00	Briggs	Lower Elk River	31	7	9	14	33	6
71-0147-00	Rush	Lower Elk River	30	8	9	13	34	6
71-0158-00	Pickerel	Mississippi Direct	7	6	3	10	68	6
71-0159-00	Long	Mississippi Direct	3	5	1	10	76	5
71-0167-00	Round	Mississippi Direct	4	6	2	10	73	5

Lake ID	Lake Name	Subwatershed	Forest	Open Water	Wetland	Rangeland	Cropland	Developed
			%	%	%	%	%	%
73-0001-00	Dallas	Plum Creek	25	4	9	23	35	4
73-0002-00	Feldges	Plum Creek	24	4	9	23	36	4
73-0003-00	Maria	Plum Creek	26	3	9	26	32	4
73-0004-00	Long	Plum Creek	19	4	10	18	44	5
73-0006-00	Crooked	Plum Creek	19	4	10	17	46	4
73-0007-00	Quinn	Plum Creek	13	1	11	18	52	5
73-0010-00	Bunt	Plum Creek	28	13	10	18	27	4
73-0011-00	Warner	Plum Creek	25	4	9	23	35	4
73-0014-00	Marie	Clearwater River	14	3	3	23	51	6
73-0015-00	Otter	Clearwater River	21	2	5	14	53	4
73-0020-00	Laura	Clearwater River	14	4	4	12	60	6
73-0023-00	Beaver	Johnson Creek	3	3	3	50	38	3
73-0042-00	Island	Clearwater River	37	29	1	17	16	<1
73-0611-00	George	St. Cloud	7	4	2	5	4	79
73-0701-00	Melrose Deep Quarry	St. Cloud	7	4	2	5	4	79
86-0025-00	School	Ostego	<1	5	2	5	33	55
86-0026-00	Hunters (Mud)	Ostego	1	10	5	6	28	51
86-0066-00	Birch	Otter Creek	31	16	5	31	11	6
86-0067-00	First	Otter Creek	30	13	6	24	23	5
86-0068-00	Mud	Otter Creek	30	13	6	24	23	5
86-0069-00	Long	Otter Creek	30	13	6	24	23	5
86-0070-00	Bertram	Otter Creek	32	14	5	24	19	5
86-0073-00	Cedar	Otter Creek	34	13	5	21	24	3
86-0139-01	Little Mary South	Silver Creek	20	10	6	18	40	6
86-0139-02	Little Mary North	Silver Creek	33	6	10	21	27	4
86-0140-00	Silver	Silver Creek	17	11	6	17	43	6
86-0146-00	Ida	Otter Creek	37	15	4	29	10	6
86-0148-00	Eagle	Otter Creek	36	13	3	15	28	5
86-0152-00	Millstone	Silver Creek	8	29	<1	11	43	8

Lake ID	Lake Name	Subwatershed	Forest	Open Water	Wetland	Rangeland	Cropland	Developed
			%	%	%	%	%	%
86-0156-00	Mary	Silver Creek	12	7	8	13	56	4
86-0163-00	Limestone	Silver Creek	22	18	9	18	28	6
86-0168-00	Locke	Silver Creek	19	10	6	18	41	6
86-0171-00	Ember	Silver Creek	5	16	3	10	58	7
86-0183-00	Fish	Fish Creek	28	7	6	31	22	6
86-0208-00	Swartout	Clearwater River	8	18	3	14	51	6
86-0212-00	Albion	Clearwater River	14	24	5	15	36	7
86-0213-00	Henshaw	Clearwater River	4	25	2	13	52	3
86-0223-00	Indian	Clearwater River	23	24	1	10	35	7
86-0227-00	Cedar	Clearwater River	12	19	4	15	43	8
86-0229-00	Mink	Silver Creek	9	11	5	15	52	7
86-0230-00	Somers	Silver Creek	10	15	5	15	49	7
86-0233-00	Sugar	Clearwater River	18	19	8	18	31	6
86-0234-00	Bass	Clearwater River	12	23	7	12	36	9
86-0238-00	Nixon	Clearwater River	34	6	11	15	31	3
86-0242-00	Wiegand	Clearwater River	16	8	4	18	47	7
86-0243-00	Grass	Clearwater River	16	8	4	18	47	7
86-0251-00	Pleasant	Clearwater River	9	19	6	10	36	20
86-0252-01	Clearwater East	Clearwater River	14	19	5	12	40	10
86-0252-02	Clearwater West	Clearwater River	16	8	4	18	47	7
86-0281-00	Caroline	Clearwater River	15	3	3	23	50	6
86-0282-00	Louisa	Clearwater River	13	3	3	23	52	6
86-0284-00	Augusta	Clearwater River	15	3	3	22	50	6
86-0297-00	Scott	Clearwater River	12	3	3	23	53	6
86-0298-00	Union	Clearwater River	20	3	5	25	40	6