# A Water Quality Assessment of Select Lakes within the Kawishiwi River Watershed

Rainy River Basin
Cook, Lake and St. Louis Counties, Minnesota

Minnesota Pollution Control Agency

Water Monitoring Section

Lakes and Streams Monitoring Unit

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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 sample approximately 100 lakes per year, coordinate citizen volunteer monitoring through the Citizen Lake Monitoring Program, and manage Surface Water Assessment Grants given to local groups to monitor lake and stream water quality. Watershed-based monitoring emphasizes large lakes (500 acres or greater) whenever possible. 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 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.

This report details the assessment of lakes within the Kawishiwi River watershed, using data within the 2000-2009 assessment cycle. The Kawishiwi River watershed is located in northeast Minnesota within Saint Louis, Lake, and Cook Counties, forming part of the Rainy River basin headwaters. The watershed drains 3,185 square kilometers (1,230 square miles) of coniferous and deciduous forest and interconnected lakes, streams, and wetlands. The Kawishiwi River originates in Lake and Cook Counties in the heart of the scenic Boundary Waters Canoe Area Wilderness (BWCAW) and generally flows west to its confluence with Fall Lake at the town of Winton, Minnesota. The Kawishiwi River watershed is made up of ten Hydrologic Unit Code (HUC)-11 sub-watersheds. A general description at the eight-digit HUC level is provided, followed by discussions for each 11-digit HUC. A full list of the assessed lakes, including their morphometric characteristics, is located in Appendix A. To analyze the most recent water quality of lakes within the Kawishiwi River watershed, the Minnesota Lake Eutrophication Analysis Procedures (MINLEAP) model was used; model estimates are located in Appendix B.

The Kawishiwi River watershed has abundant surface water resources, including over 430 lakes. Because most of the watershed is within remote parts of the Superior National Forest (including the BWCAW), water quality data are lacking on most lakes, and only eight lakes have sufficient water quality data for formal assessments. Most of the assessed lakes are large and part of the Kawishiwi River channel. Monitoring was conducted by the MPCA and trained volunteers from the White Iron Chain of Lakes Association. A total of 139 lakes within the BWCAW were assessed as fully supporting based on estimates of remotely-sensed transparency from the interpretation of satellite imagery. The assessed lakes of the Kawishiwi River watershed are all meeting MPCA's Northern Lakes and Forest eutrophication criteria. Assessed lakes have low Secchi transparency originating from natural bog staining from the surrounding watersheds. Reduced transparency is not in response to elevated chlorophyll-a (i.e. algal) concentrations. The large lakes within the Kawishiwi River channel (Birch, White Iron, Farm, Garden, and Fall) are mesotrophic and have very similar total phosphorus concentrations ranging from 17-24 micrograms per liter (µg/L). The lakes drain very large forested watersheds with very rapid residence times (~ 30 - 45 days). Water quality did not vary significantly on an annual basis, and conditions are naturally reflective of the forest and wetlands which dominate land cover in the Superior National Forest and BWCAW. Bearhead Lake has lower nutrient concentrations, because it is a seepage lake draining a very small forested headwater watershed. Chlorophyll-a (Chl-a) concentrations are also comparable among the assessed lakes, ranging from 4.8 -7.5 µg/L; well below concentrations that produce algal blooms. Several lakes have long-term Secchi transparency datasets. Clarity is generally stable and likely affected by variability in Kawishiwi River streamflows and lake levels. Water quality data from Shagawa and Burntside Lakes (technically outside of the watershed) also are summarized because they are significant and prominent water resources with long-term datasets, and are part of the Fall Lake watershed. Water quality in Shagawa has markedly improved since the 1970s, when the city of Ely's wastewater treatment plant was upgraded to remove phosphorus. Several lakes in the Kawishiwi watershed remain impaired for mercury in fish-tissue; the state-wide TMDL has been approved by the U.S. Environmental Protection Agency (EPA).

# Intensive Watershed Monitoring Approach

## Introduction

The Minnesota Pollution Control Agency (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 lakes in Minnesota to determine whether or not these lakes support their designated uses. This type of monitoring is commonly referred to as condition monitoring. While the MPCA conducts its own lake monitoring, local partners (soil and water conservation districts -SWCDs, 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 monitoring through the Citizen Lake Monitoring Program (CLMP), and manages Surface Water Assessment Grants given to local groups to monitor lake water quality. All of the data from these activities are combined with our own lake monitoring data to assess the condition of Minnesota lakes. Lake condition monitoring activities are focused on assessing the recreational use-support of lakes and identifying trends over time. The MPCA also assesses lakes for aquatic consumption use-support, based on fish-tissue and water-column concentrations of toxic pollutants.

The primary organizing approach to MPCA's condition monitoring is the "major" watershed (eight-digit hydrologic unit code). There are 81 major watersheds in Minnesota, and the MPCA has established a schedule for intensively monitoring six-eight of them annually. With this strategy, the MPCA and its partners will cycle through all 81 watersheds every ten 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 ten-year cycle. The watershed approach provides a unifying focus on the water resources within a watershed as the starting point for water quality assessment, planning, and results measures. 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 ≥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 these lakes collectively represent 72 percent of the total lake area (greater than ten 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 10-499 acre range. Currently, we are fully meeting the "large" lake goal, and we are greatly exceeding the "small" lake monitoring goal.

MPCA lake monitoring activities were not yet in sync with the watershed approach in 2008; the year MPCA started intensive monitoring of lakes in the Kawishiwi River watershed to assess their condition. MPCA's monitoring of large lakes within the Kawishiwi River watershed was concluded in 2009. This report was prepared in 2010 because of this recent monitoring by the MPCA and our partners, even though the Rainy River Headwaters major watershed (which the Kawishiwi is a major part of) is scheduled to be intensely monitored in 2014. This report will be amended once the 2014 data have been assessed.

This report will describe all available lake data collected within the past ten years by partner agencies, grantees, and citizen volunteers found in STORET for the Kawishiwi River watershed. Trophic status, thermal stratification, temporal trends, model-predicted phosphorus and assessment status is noted for all lakes with sufficient data. Further detail on concepts and terms in this report can be found in the Guide to Lake Protection and Management: (http://www.pca.state.mn.us/water/lakeprotection.html).

# Methods of Data Collection and Analysis

## Lake monitoring and data storage

The MPCA collects water quality data for lakes from May through September for each of the applicable years. Data collected from June through September is used to assess the lake's condition while May data is collected to observe lake conditions near the spring turn over and compare this with the remaining seasonal data. Lake surface samples were collected with an integrated sampler, a polyvinyl chloride (PVC) tube two meters (6.6 feet) in length with an inside diameter of 3.2 centimeters (1.24 inches). Depth total phosphorous (TP) samples were collected with a Kemmerer sampler. A summary of data follows (Appendix B).

For lakes sampled by the MPCA, sampling procedures were employed as described 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 were sent to the Minnesota Department of Health using EPA approved methods for laboratory analysis. Samples were analyzed for nutrients, color, solids, pH, alkalinity, conductivity, and chlorophyll-a (Chl-a). Temperature and dissolved oxygen (DO) profiles and Secchi disk transparency measurements were also taken. Historical DO and temperature profiles were used for water column analysis in the absence of more recent data.

Data collected by MPCA and submitted to MPCA by external partners is placed in the EPA data warehouse, STORET. The MPCA makes this 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). Individual lake summaries are also available via the MPCA webpage at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/lake-water-quality/lake-water-quality-data-search.html.

The White Iron Chain of Lakes Association (WICOLA) is a group of citizen stewards working with many partners to monitor, maintain, and improve the Kawishiwi River system and the unique lakes encompassed in its watershed. MPCA started partnering with WICOLA in 2005 with the development and implementation of the Kawishiwi Watershed Monitoring Plan. The Plan called for using the agency's advanced Citizen Lake Monitoring Program (CLMP) protocols for volunteer monitoring. From 2005 to present WICOLA volunteers sampled area lakes under MPCA supervision, and samples were analyzed by RMB Laboratory. Additionally, from 2006-2008 MPCA staff sampled several area streams and lake tributaries to supplement the cooperative lake monitoring. WICOLA was recently awarded a grant from MPCA to support expanded monitoring, stressor identification and ultimately to develop a comprehensive watershed protection plan for the Kawishiwi Watershed. This report will provide the baseline water quality information used to guide the upcoming watershed plan.

## Remote sensed transparency

A 20-year comprehensive water clarity database assembled from Landsat imagery, primarily Thematic Mapper and Enhanced Thematic Mapper Plus, for Minnesota lakes larger than eight hectares (ha; 20 acres) in surface area contains data on more than 10,500 lakes at five-year intervals over the period 1985–2005 (Olmanson et al. 2008). The data has been proven to provide a reasonable estimate of transparency for Minnesota lakes and comparisons with observed Secchi for the same timeframe exhibit a correlation ($R^2$) on the order of 0.77-0.80 (Olmanson et al. 2008). In many of the intensive watersheds there is adequate observed data that can be used for the assessment process; however, in some remote watersheds where access to lakes is poor (e.g. Boundary Waters Canoe Area Wilderness- BWCAW - watersheds), where there are minimal observed data, and remotely-sensed (RS) Secchi data indicate excellent water clarity, RS data may be used for assessing lake condition and trends. RS 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 .

Kawishiwi River watershed lakes that are entirely within the BWCAW have been assessed for aquatic recreational purposes solely using RS data, as described in MPCA guidance (MPCA, 2010):

> "On lakes wholly within the BWCAW Wilderness, remote sensing inferred Secchi transparency will be used to determine full support of aquatic recreation use. Transparency at five year intervals over the past 25 years will be reviewed and those that are above the more stringent thresholds (20 percent) on all dates will be considered to be fully supporting".

This more stringent remotely-sensed secchi transparency (SD) criterion for BWCAW lakes is 2.4 meters. Northeast Minnesota is the most difficult part of the state for remote sensing (L. Olmanson, University of Minnesota, personal communication, September 2010). Specifically, the northeast had few lakes (only 13) with sufficient data available for calibration modeling (in 2008), and clear lakes are often affected by haze originating from Lake Superior. The natural bog-staining common in many area lakes, which reduces transparency, can also be problematic for remote sensing predictions of SD. Nonetheless, the Kawishiwi RS dataset is the most comprehensive data available, allows for comparisons on the sub-watershed scale, and provides the MPCA a conservative method to assess for aquatic recreation use.

## 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 submergent 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 watershed can be an important factor as well; whereby lakes with small watershed areas relative to their surface area often receive low water and nutrient loading and absent significant sources of nutrients in their watershed, often have good water quality. In contrast, lakes that have large watersheds 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 1). 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 standards differentiate among 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 1. Lake stratification schematic**

**Polymictic Lake**

Shallow, no layers,

Mixes continuously

Spring, Summer & Fall

**Dimictic Lake**

Deep, form layers,

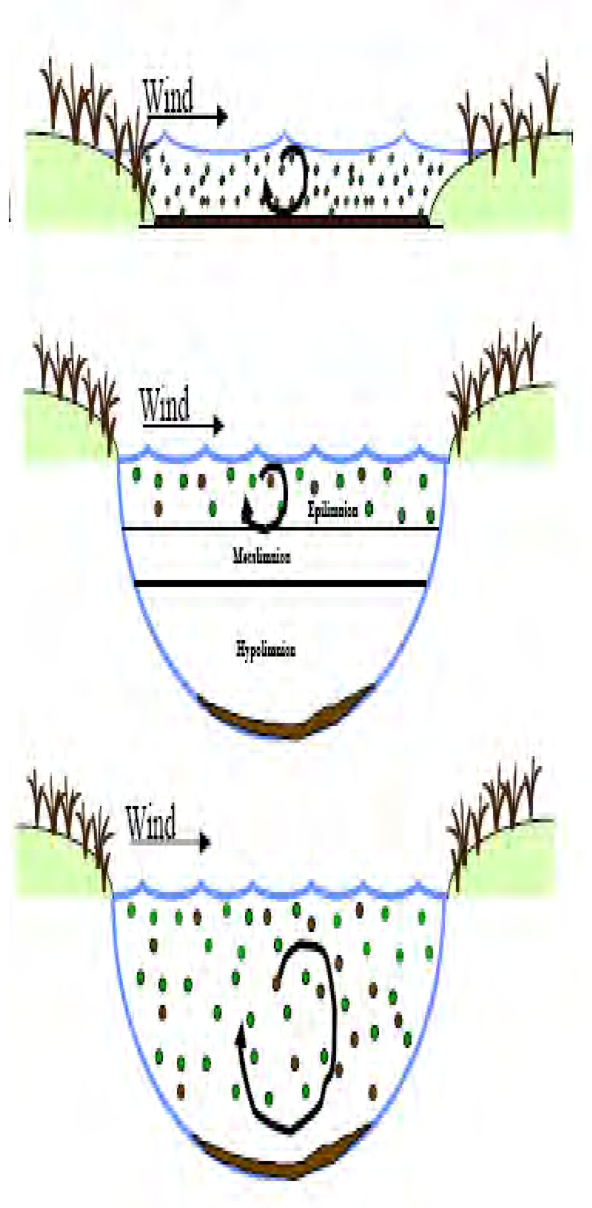
Mixes Spring/Fall

**Intermittently Stratified**

Moderately deep

Mixes during high winds

Spring, Summer, & Fall



## Data analysis and modeling

A standard approach to data analysis is applied to all fully assessed lakes. The major steps are as follows:

Dissolved oxygen and temperature data from the most recent one or two years is reviewed and may be charted as well. Profile data are used to determine whether the lake stratifies, depth of thermocline and presence or absence of oxygen in the bottom waters. This step is essential for characterizing the lake and 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.

Total phosphorus (TP), Chl-a and SD 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 also allows for patterns to be observed that may help 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)

TP 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 ten 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.

Long term trends based on available summer-mean TP, Chl-a, and Secchi are assessed when possible. These data are typically charted and analyzed for trends. If statistically-based CLMP trend analysis was conducted that will be noted as well. If a trend is noted and the investigator is aware of potential causes for the trend, that will be noted as well.

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 Kawishiwi River watershed, the 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 Kawishiwi River 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. Individual results for each of the assessed lakes will be discussed in the lake summary portion of the HUC-11 watershed sections within this report. Complete MINLEAP results can be found in Appendix B.

In addition to fully assessed lakes there are often numerous lakes that do not have sufficient data for assessment. In these instances existing data (TP, Chl-a and SD) will be summarized and noted in summary tables. In some instances no data other than remote sensed Secchi may be available. This data will be summarized or noted as appropriate. In most instances there will be little or no discussion of lakes that are not fully assessed; however summary data will be compiled so that more comprehensive characterizations of lake condition at the HUC-11 and HUC-8 scales can be made.

# 303(d) Assessment

The federal Clean Water Act requires states to adopt water quality standards to protect waters from pollution. These standards 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. The standards are set on a wide range of pollutants, including bacteria, nutrients, turbidity and mercury. 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.

TP, Chl-a, and Secchi transparency are used to determine if a lake meets aquatic recreational use standards. Minnesota's ecoregion-based eutrophication standards are listed in Table 1. For a lake to be assessed as impaired, it must exceed the causative variable (TP) and one or more of the response variables: chlorophyll-a and Secchi transparency. The Northern Lakes and Forests (NLF) Class 2B ecoregion standards were used for assessing lakes in the Kawishiwi watershed. The appropriate standards are based on which ecoregion the lake is located in and whether the lake is considered deep or shallow. Individual assessments for each of the lakes will be discussed in the lake summary portion of the HUC-11 watershed sections within this report.

**Table 1: Minnesota lake eutrophication standards by ecoregion and lake type**

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

This report summarizes water quality information for the following Kawishiwi watershed water resources:

Several large lakes greater than 500 acres: Birch, Bear Island, Burntside, Shagawa, Fall, Farm, South Farm, and Garden Lakes.

Bearhead and White Iron Lakes, part of the Minnesota Department of Natural Resource's (MDNR's) Sentinel Lake program - http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/lake-water-quality/sentinel-lakes.html.

A detailed water quality, fishery, and aquatic plant assessment report on White Iron is complete and is available from the Web site above. Much of the background information for this report was taken from that report. The Bearhead Lake Sentinel Report is projected for completion in 2011.

Stream monitoring of the North and South Kawishiwi River, and select tributaries, done in support of large lake monitoring (including historical condition monitoring by the U.S. Geological Survey and MPCA).

A summary of the most recent (2005) remote sensing estimates of water clarity of all lakes within the Kawishiwi River watershed, discussed on the HUC-11 watershed scale.

The large and Sentinel lakes were monitored by MPCA in 2008 and 2009. White Iron and the lakes of the Garden Lake Reservoir were sampled as part of the cooperative monitoring program between the MPCA and WICOLA volunteers.

# Environmental Setting, History, and Distribution of Lakes

The Kawishiwi River watershed is located in northeast Minnesota (Figure 2) within Saint Louis, Lake, and Cook Counties, forming part of the Rainy River basin headwaters. The watershed drains 3,185 $km^2$ (1,230 $mi^2$) of coniferous and deciduous forest and interconnected lakes, streams, and wetlands. The Kawishiwi River originates in Lake and Cook Counties in the heart of the scenic BWCAW and generally flows west to its confluence with Fall Lake at the town of Winton, Minnesota. Major tributaries to the Kawishiwi include the Stony and Isabella Rivers. The Kawishiwi flows westerly through several large lakes (Figure 3), until it naturally splits into a north and south branch. The south Branch flows into the Birch Lake Reservoir, immediately upstream of White Iron Lake. A dam at the outlet of Birch Lake controls lake levels on Birch Lake, and influences water levels in the South Kawishiwi River and White Iron Lake. The north Branch flows into Farm Lake, immediately downstream of White Iron Lake (Figure 3). The branches converge in the Garden Lake Reservoir (composed of Garden, Farm, and South Farm Lakes) and the Kawishiwi River eventually flows into Fall Lake via the Winton hydroelectric dam. From its source in Kawishiwi Lake to its mouth in Fall Lake, the Kawishiwi River flows through 18 lakes; these lakes comprise more than 33 miles of the total river length of 75 miles (Ericson et. al, 1976).

**Figure 2. Minnesota's Level III ecoregions and the Kawishiwi River watershed (US EPA).**

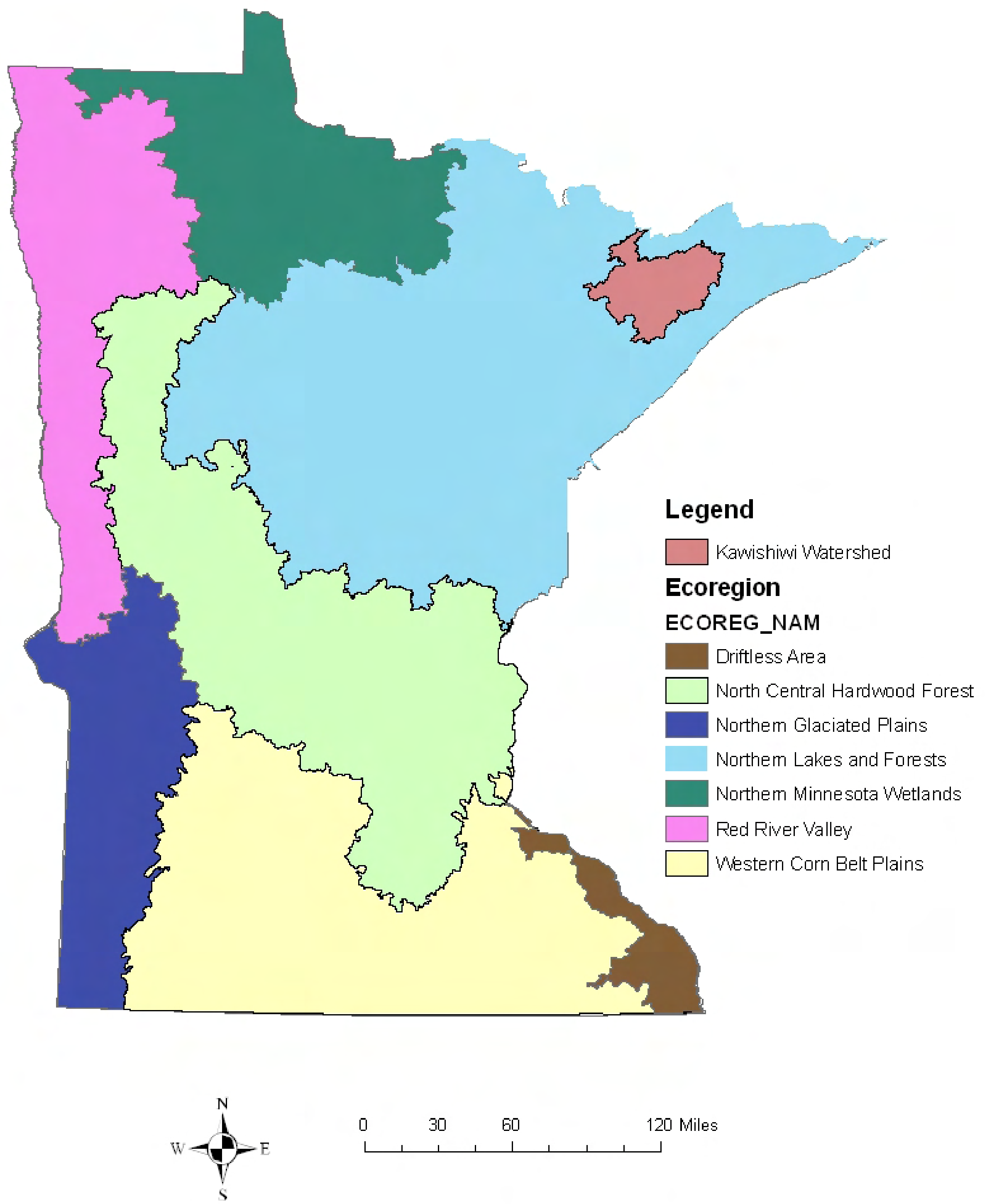
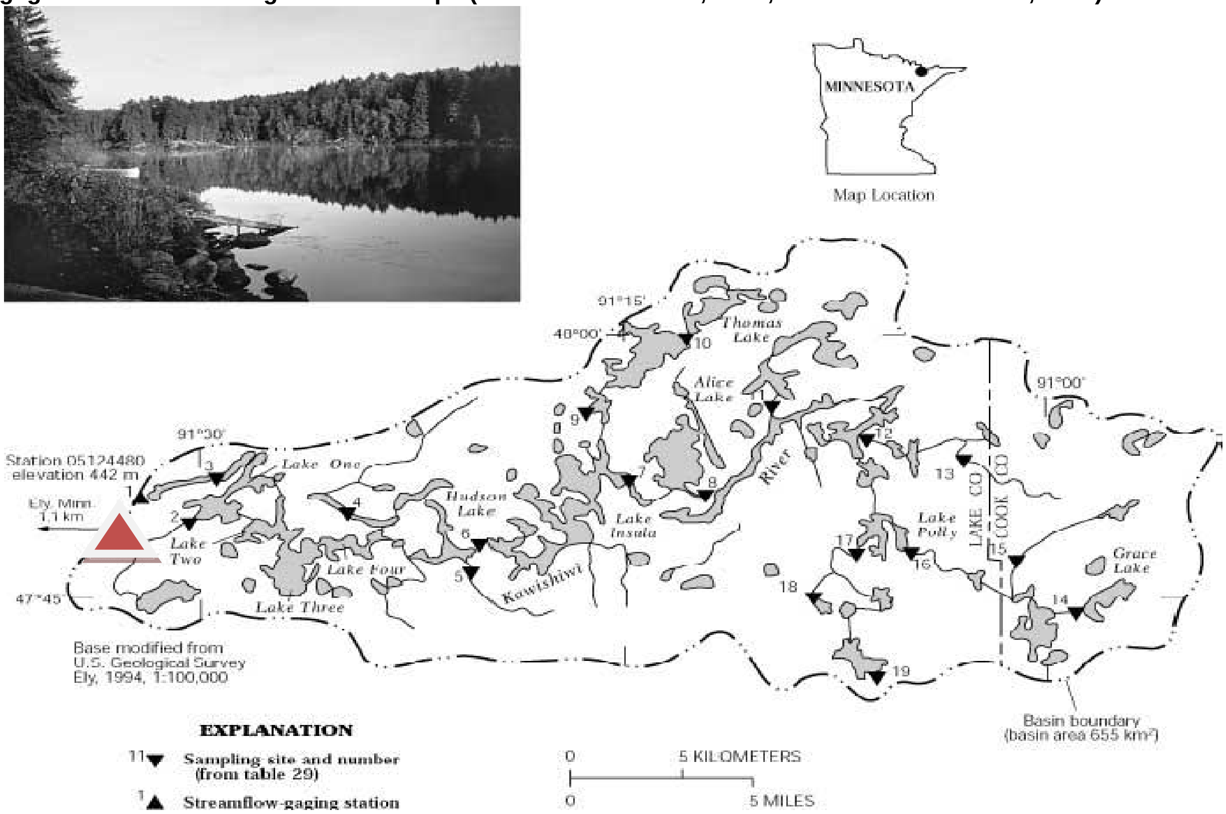
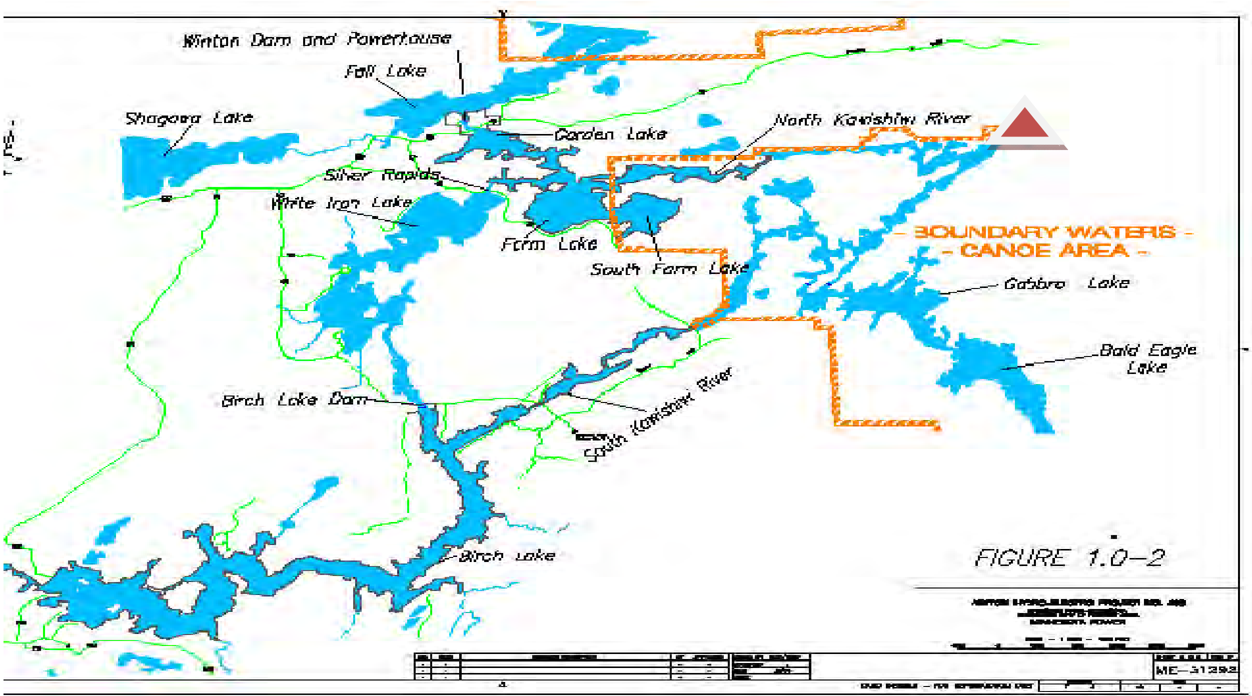


**Figure 3. The Upper Kawishiwi River watershed, and lower portions of the South Kawishiwi watershed- USGS gage noted as red triangle on both maps (from Mast and Turk, 1999; and Minnesota Power, 2001)**



The hydrology of the Kawishiwi River watershed is relatively complex and is influenced by hydroelectric facilities both upstream and downstream of White Iron Lake operated under Federal license by Minnesota Power (MP; Figure 3). MP is required to operate the Birch and Garden Lake reservoirs within elevation ranges that balance hydropower generation, recreational uses, aesthetics, and the natural flow of water within the basin.

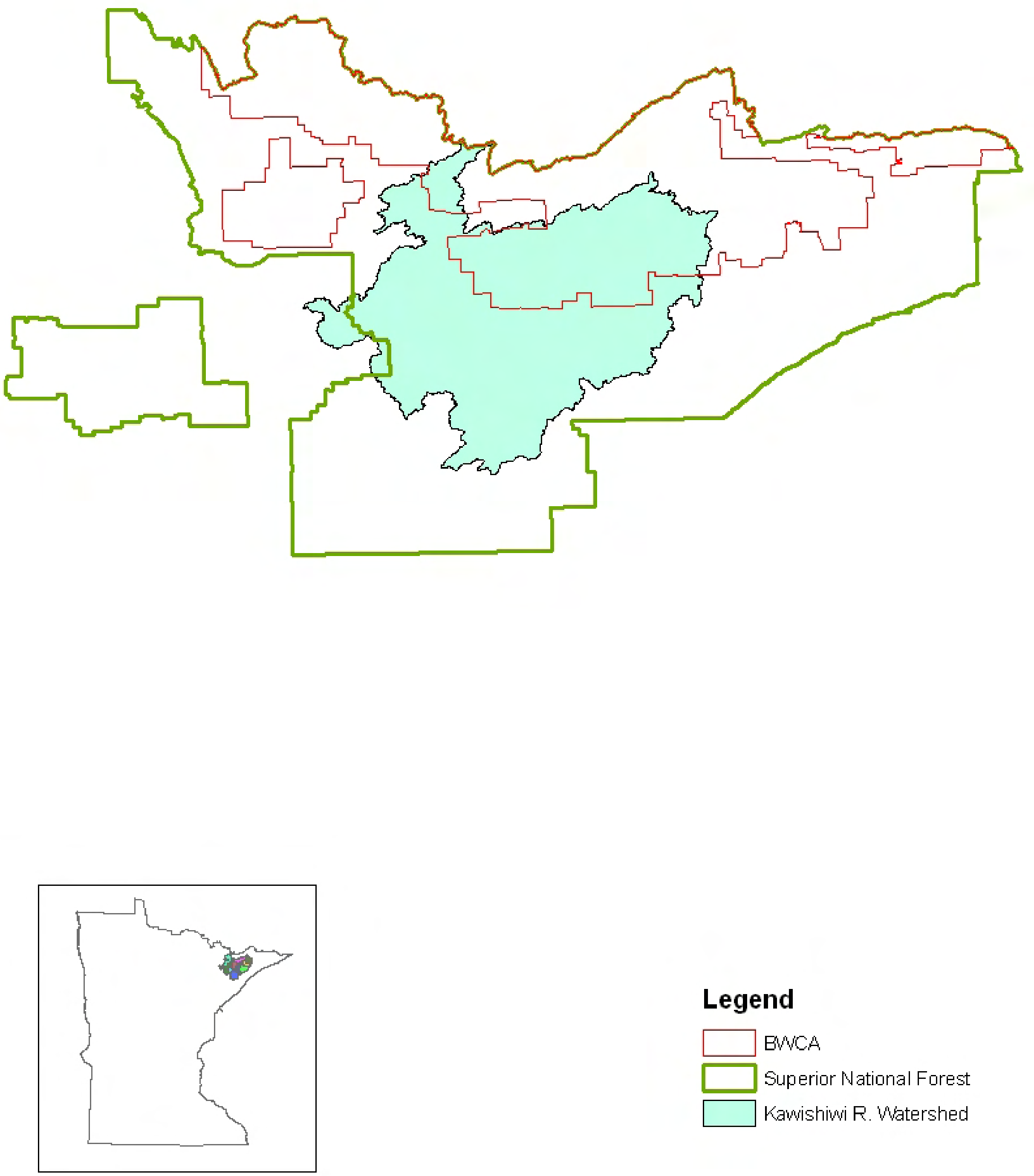
Soils within the watershed are primarily bouldery sandy till and glacial fluvial sand and gravel; soil thickness varies greatly and depends on bedrock topography, being thickest in the southwest portion of the basin (Dunka River) and thinnest in the northern portion where bedrock is at or near the surface (Olcott and Siegel, 1978). Vegetation is represented by the extreme southern part of the boreal forest zone (Pettyman, 1978). Upland areas are dominated by jack pine, aspen, and birch; the once common red and white pine are only in isolated, scatted stands because of the past effects of logging and fire (Mast and Turk, 1999).

Major industries in the watershed include tourism and forest products harvesting. The watershed is remote and sparsely populated since all but the extreme southwestern portion is within Superior National Forest; a large portion is further within the BWCAW (Figure 4). The BWCAW covers 1.3 million acres and is the most heavily used wilderness area in the county, with approximately 200,000 visitors annually (United States Department of Agriculture Forest Service, 2004). The two largest communities in the vicinity, Ely and Babbitt, are just outside the boundaries of the Kawishiwi River watershed. Agricultural and developed land uses are very low, and make up 0.3 and 0.4 percent of the entire watershed, respectfully. Nearly all (99 percent) of land cover within the watershed is a mix of forest, wetlands, and open water.

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). 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 Kawishiwi River watershed lies within the Northern Lakes and Forest (NLF) ecoregion (Figure 2). The NLF ecoregion is defined as follows (Omernik, 1987)

> "The Northern Lakes and Forests is a region of nutrient poor glacial soils, coniferous and northern hardwood forests, undulating till plains, morainal hills, broad lacustrine basins, and extensive sandy outwash plains. Soils in this ecoregion are thicker than in those to the north and generally lack the arability of soils in adjacent ecoregions to the south. The numerous lakes that dot the landscape are clearer and less productive than those in ecoregions to the south"

**Figure 4. Superior National Forest and Kawishiwi River watershed boudaries.**



The following is a compilation of pertinent historical information from the Kawishiwi River watershed. It is provided as ancillary information to help interpret the lake assessment results (compiled by MDNR for the White Iron Lake Sentinel Lake Report; Anderson et. al, 2010).

1900 to 1917 Logging on Kawishiwi River. Dams are built to impound water for moving logs at: 1) the site of the current Winton Hydroelectric dam at the outlet of Garden Lake, 2) the site of the current Birch Lake Hydroelectric reservoir dam, raising the water level about five feet, 3) the first narrows on the South Kawishiwi River below the point where the north and south forks divide. The purpose of the last dam was to divert flow to the North Kawishiwi River while logging was being done there. There are few remnants of this dam and no apparent restriction of flow remains. A dam is built at the head of Murphy Rapids on the North Kawishiwi to divert flow to the South Kawishiwi River while logging was being done there. Some of this dam still remains, restricting flow down the North Kawishiwi River.

1920s to 1923 Winton Hydroelectric facility is completed. The logging dam at the outlet of Garden Lake is rebuilt to its current configuration, resulting in a Garden Reservoir pool elevation about 1.5 feet (ft) lower than White Iron Lake, logging dams are rebuilt at the at the Birch Lake outlet, and on the North Kawishiwi River (Murphy Rapids) to divert and impound water. Additional dams are built at Gabbro Lake (a tributary to the South Kawishiwi River) to create an additional storage reservoir.

1940s Gabbro Lake Dam operations are abandoned; dams are left in place to deteriorate.

1950s Record floods on White Iron Lake (and other area lakes) in 1950. On May 17, the flow at the Winton Dam was 15,153 cubic feet per second (the normal flow for May is 2,500 cubic feet per second). White Iron Lake rose eight feet. The west bridge approach at Silver Rapids was washed out. A 10 foot culvert was subsequently added to alleviate future flooding, a measure that helped little. Eventually a used, longer steel bridge was placed over the rapids, and the culvert and the rock and gravel added in 1927 were removed. The first fisheries lake survey was conducted in 1958. No bass were captured. Shoreline development included 96 cottages and six resorts.

1970s Winton Hydroelectric Dam relicensing process. Many complaints are received about spring flooding on White Iron Lake with water level rises up to six feet. The MDNR is concerned that spring draw-downs of water of up to three feet in the Garden Lake Reservoir to alleviate flooding in White Iron Lake during the spring snow melt are negatively affecting walleye reproduction by exposing their spawning areas. A proposal is made to remove the remnants of the old North Kawishiwi River Dam at Murphy Rapids and to rebuild part of the South Kawishiwi River Dam to divert flow to Garden Lake Reservoir via the North Kawishiwi River, thus bypassing Birch Lake and White Iron Lake and alleviating flooding in those lakes, and negating the need to draw-down Garden Reservoir. This proposal is opposed by the U.S. Forest Service on legal grounds. The present bridge at Silver Rapids was built. The channel was dredged of old debris and abutments.

1980s Shoreline development on White Iron included 135 homes and cottages and six resorts with 52 cabins based on a 1982 inventory. The first largemouth bass are captured in a fisheries investigation.

1990s White Iron Chain of Lakes Association (WICOLA) is formed in 1993. Annual water testing begins. Lake Assessment Program Report, a cooperative study between WICOLA and the MPCA, is published in 1996. White Iron Lake added to impaired waters list for mercury in fish tissue in 1998.

2000s Shoreline development on White Iron includes 197 homes and cottages and four resorts with 42 cabins and 11 motel units based on 2001 inventory. MPCA and WICOLA initiate cooperative lake monitoring program in 2005.

## Distribution of lakes

The Kawishiwi River is a large portion of one of Minnesota's 81 major watersheds- the Rainy River headwaters. The Kawishiwi makes up about half of the 6,506 $km^2$ (2,512 $mi^2$) Rainy River headwaters watershed. Each major watershed has its own Hydrologic Unit Code (HUC-8) for catalog purposes. Nested within each HUC-8 are smaller contributing sub-watersheds, termed HUC-11 watersheds. The Kawishiwi River watershed is composed of ten HUC-11 sub-watersheds (Figure 5), ranging in size from 214 to 512 $km^2$ (83 to 198 $mi^2$). Lake distribution varies among the HUC-11 watersheds (Table 2). Land-cover at the Kawishiwi watershed scale and in all HUC-11 sub-watersheds are similar and dominated by forest, open water (i.e. lakes), and wetlands (Figure 6). As stated previously, agriculture and urban land use are very low.

A brief description of each HUC-11 watershed and notable large lakes within each follows:

- Upper Kawishiwi River – watershed headwaters, lake-dominated area almost entirely within the BWCAW. Notable large lakes include Polly, Phoebe, and Kawishiwi.
- Perent River- Tributary to the Isabella River; flows from Perent Lake to Isabella Lake. Notable lakes include Perent and Coffee.
- Island River – Tributary to the Isabella River, also includes the Dumbbell River watershed. Flows into Isabella River just downstream of Isabella Lake. Notable lakes include Silver Island, Windy, and Dumbbell.
- Inga-Isabella River – Little Isabella River, and Inga and Mitawan Creek watersheds. Flows north to Isabella River. Notable lakes include Bog, Mitawan, and Grouse.
- Isabella River – Major tributary to the S. Kawishiwi River. Flows into Bald Eagle Lake and also includes the Snake River. Notable lakes include Bald Eagle, Isabella, and Gabbro.
- Upper Stony River – Southern border of the watershed originates in a large wetland complex and has relatively few lakes. This HUC-11 also includes Greenwood and Sand Rivers. Notable lakes include Greenwood, Sand, and McDougal.
- Stony River – Lower portions of the Stony River, flows southwest to Birch Lake. Notable lakes include Slate and Swallow.
- South Fork Kawishiwi River – Includes the Birch Lake and Dunka River watersheds. Relatively few lakes. Notable lakes include Bearhead, Birch, and Clear.
- Middle Kawishiwi River – Lake dominated watershed primarily in the BWCAW, includes the Kawishiwi River watershed upstream of North / South split. Notable lakes include Insula, Alice, and One – Four.
- Lower Kawishiwi River – Includes the Bear Island River watershed and all waters downstream of Birch Lake to the Fall Lake outlet. Notable lakes include White Iron, Bear Island, and Garden Lake Reservoir.

**Table 2. Lake distributions in the Kawishiwi HUC-11 watersheds**

| HUC-11 Watershed Name | Area $km^2$ ($mi^2$) | Total Lakes | All P Lakes [1] | Lakes <4 ha (<10 ac.) | Lakes 4 - 40 ha (10 - 100 ac.) | Lakes 40 – 202 ha (100-500 ac.) | Lakes > 202 ha (>500 ac.) | FS [2] | NS [3] | Insufficient Data [4] |
|---|---|---|---|---|---|---|---|---|---|---|
| Upper Kawishiwi | 264 (102) | 92 | 92 | 24 | 56 | 11 | 1 | 23 | | 9 |
| Perent River | 217 (84) | 53 | 53 | 15 | 32 | 5 | 1 | 16 | | |
| Island River | 385 (149) | 75 | 66 | 25 | 41 | 8 | 1 | 1 | | 1 |
| Inga-Isabella River | 246 (95) | 32 | 30 | 11 | 17 | 4 | 0 | 3 | | 2 |
| Isabella River | 276 (106) | 45 | 42 | 10 | 25 | 6 | 4 | 16 | | 3 |
| Upper Stony River | 402 (155) | 27 | 25 | 2 | 17 | 7 | 1 | | | |
| Stony River | 224 (86) | 47 | 35 | 18 | 24 | 5 | 0 | | | 2 |
| South Fork Kawishiwi River | 472 (182) | 34 | 25 | 10 | 21 | 1 | 2 | 4 | | 2 |
| Middle Kawishiwi River | 348 (134) | 103 | 102 | 9 | 74 | 13 | 7 | 69 | | 4 |
| Lower Kawishiwi River [5] | 515 (199) | 57 | 51 | 7 | 26 | 15 | 9 | 12 | | 6 |

1. Lakes identified as protected waters by MDNR
2. Full Support, FS, number of lakes meeting MPCA nutrient criteria; lakes entirely within BWCAW are assessed FS if all years RS SD are > 2.4 M.
3. Not Support, NS, number of lakes not meeting MPCA nutrient criteria
4. Number of lakes with insufficient data available for a water quality assessment
5. Includes Fall, Newton, and Basswood Lakes, but excludes Shagawa Lake and all other upstream lakes that flow into Fall Lake downstream (west) of Winton Dam

The Kawishiwi watershed has a total of 434 lakes greater than 4 ha (10 acres) in size (Tables 2-4). Birch is the watershed's largest lake covering 2,959 ha (7,314 acres). Lakes make up a significant portion of the watershed's total area (9.3 percent) and are prominent on the landscape. The Upper and Middle Kawishiwi River have the most lakes (Table 2), while the more wetland dominated Stony River watershed has the least. Morphometric summary data for all lakes within the Kawishiwi River watershed are listed in Appendix A.

Given the remote and wilderness setting of the majority of the watershed, most lakes (373 out of 434 or 86 percent) lack historical water quality data (Table 4). For the subset of lakes with data, most is limited to Secchi transparency measurements taken by citizen volunteers such as WICOLA and the Northern Tier High

Adventure Boy Scout Camp. Just eight lakes in the watershed have sufficient data for a 303(d) water quality assessment. This is defined by the MPCA as at least eight paired TP, Chl-a, and SD transparency measurements within the most recent 10 years (MPCA, 2010). These lakes are shown in Figure 7, and are limited to large, prominent lakes with high recreational use. This report will also discuss water quality conditions in Shagawa and Burntside Lakes. Shagawa is one of the most studied lakes in Minnesota because it receives treated wastewater effluent from the city of Ely and historically experienced severe algal blooms. Shagawa Lake and the Burntside Lake watershed further upstream, are significant tributaries to Fall Lake via the Shagawa River - which enters Fall Lake downstream of the Kawishiwi River watershed outlet at the Winton Dam (Figure 3).

**Table 3. Lakes within the Kawishiwi watershed summarized by acreage class**

| Lake Class (Size Range in Hectares) | Number of Lakes |
|---|---|
| < 4 | 131 |
| 4 - 40 | 333 |
| 40- 202 | 75 |
| > 202 | 26 |

**Table 4. Kawishiwi River watershed lake summary**

| | |
|---|---|
| Total drainage area | 3,346 $km^2$ |
| Number of HUC-11 watersheds | 10 |
| Lake area as percentage of total watershed | 9.3 % |
| Total number of lakes | 565 |
| Number of lakes over 4 hectares (10 acres) | 434 |
| Number of lakes with assessment level data | 146 [1] |
| Number of BWCAW lakes assessed with SD only | 139 |
| Number of lakes with insufficent data | 29 |
| Number of lakes with no water qualty data in STORET [2] | 373 |

1. Lakes en tirely within the BWCAW are assessed FS if all years RS data show SD > 2.4 M; 8 lakes outside BWCAW have sufficient data for an assessment
2. Excluding RS data; only those lakes with manually collected samples or Secchi transparency

**Figure 5. Kawishiwi River HUC-11 watersheds**

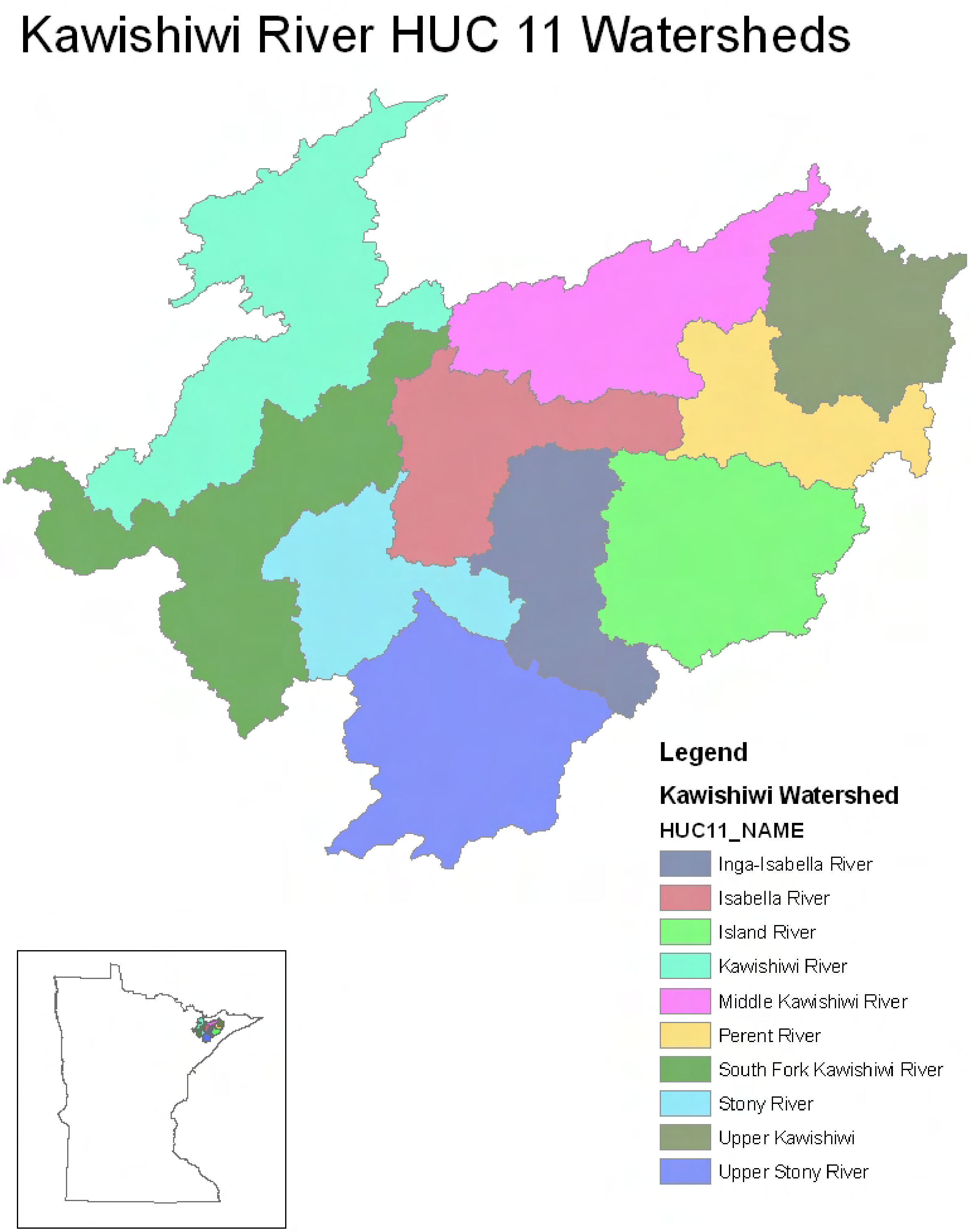


**Figure 6. Landuse within Kawishiwi River HUC-11 watersheds**

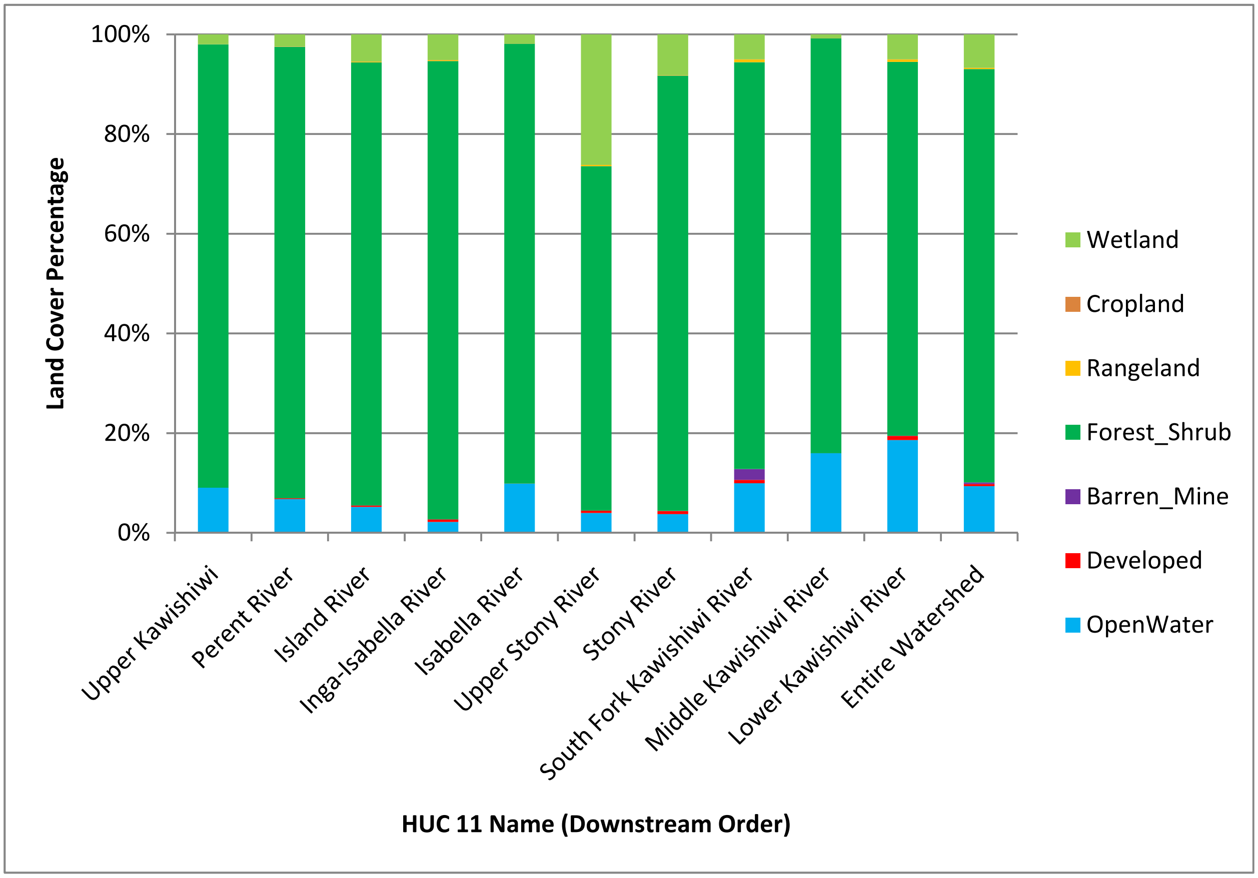
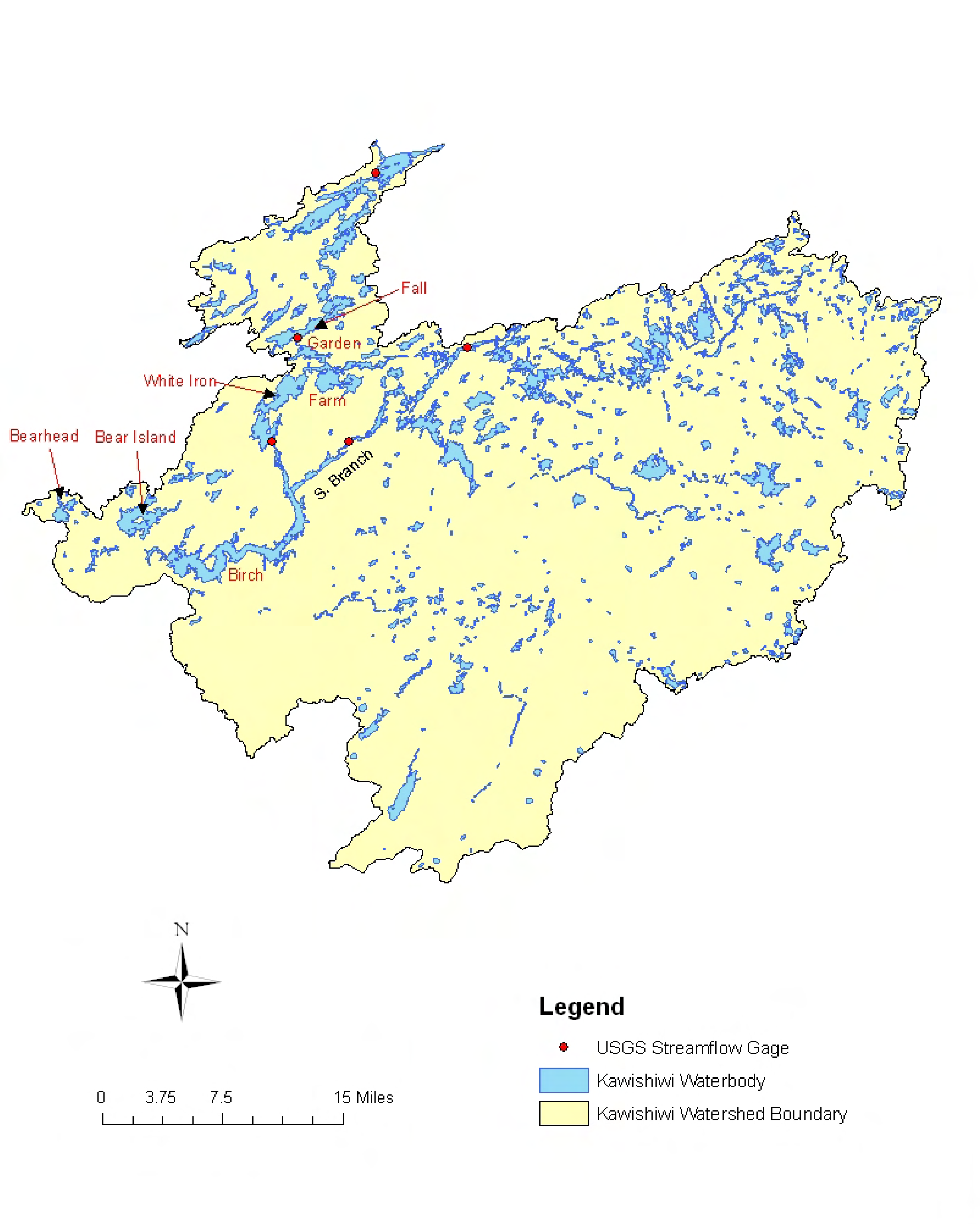


**Figure 7. Assessed lakes within the Kawishiwi River watershed**



# Summary of Climate and Hydrological Data

Annual average precipitation for the Kawishiwi watershed is approximately 76 centimeters (cm; 30 inches). Precipitation records for the 2008 water year (October 2007 through September 2008) showed conditions were much wetter than average, with a large portion of the watershed 15.25-25.5 cm (6-10 inches) above normal (Figure 8). The 2009 water year was near normal (Figure 8).

Rain gage records from the watershed outlet at Winton show two 2.5 cm (1 inch) plus rain events during the 2008 field season and one during 2009 (Figures 9 and 10). Large rain events will increase runoff into lakes and may influence in-lake water quality and lake levels. Drought conditions occurred during the late summer of 2007, with near record low flows on area streams. Heavy rains fell that fall, including 25.5 cm (10 inches) of rain at Winton in September, nearly triple the normal amount.

**Figure 8. 2008 and 2009 water year precipitation departure from normal**

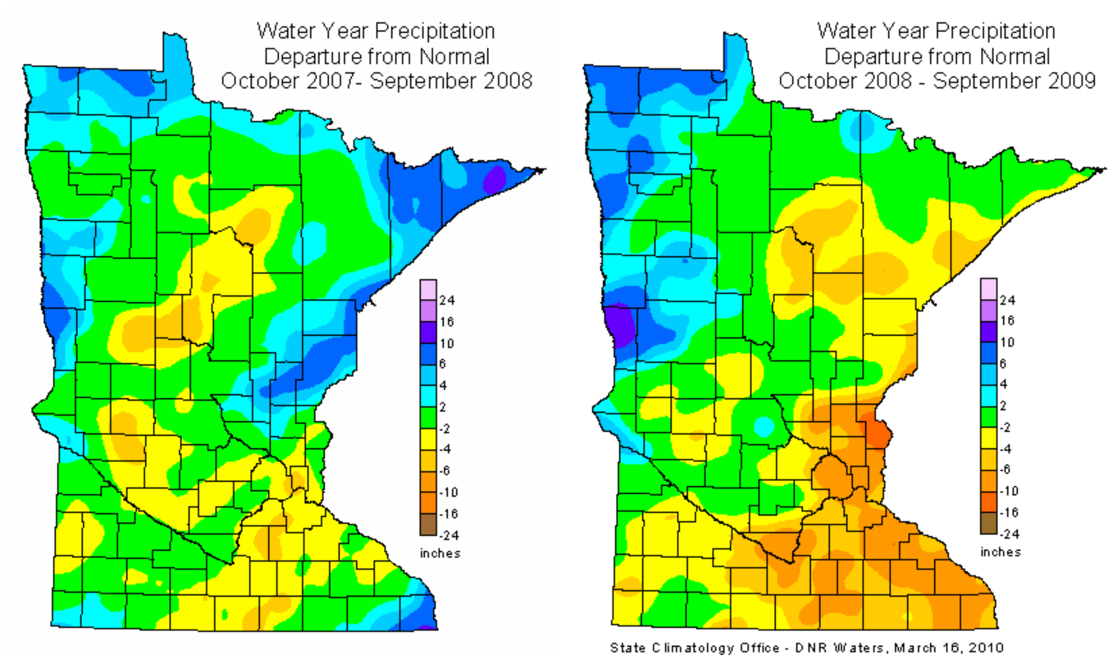


**Figure 9. 2008 monitoring season rainfall based on records for Winton, MN. State Climatology Office Data**

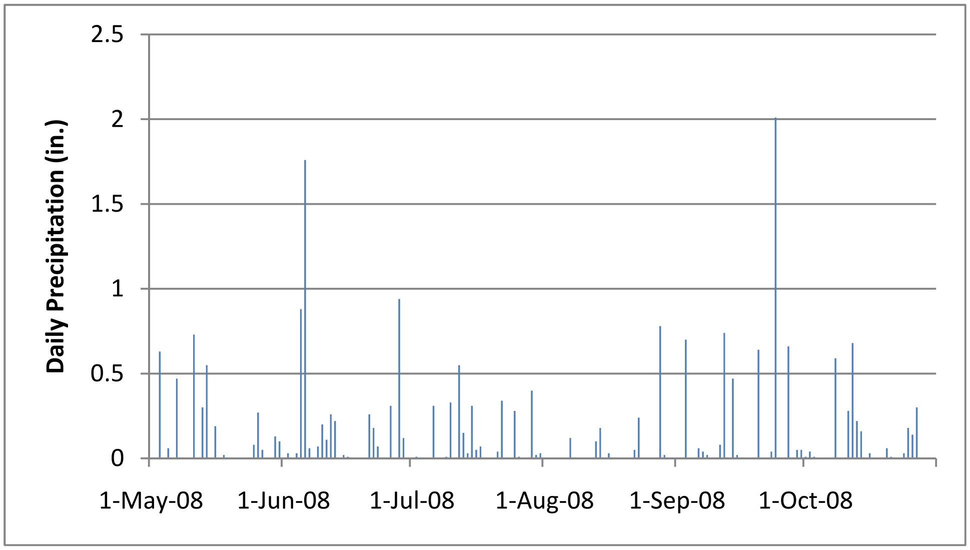
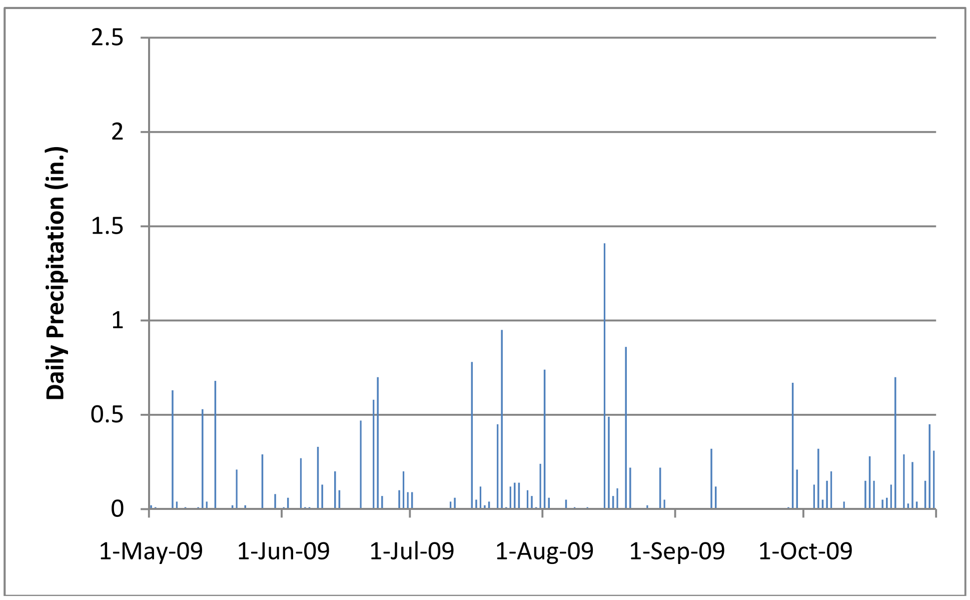
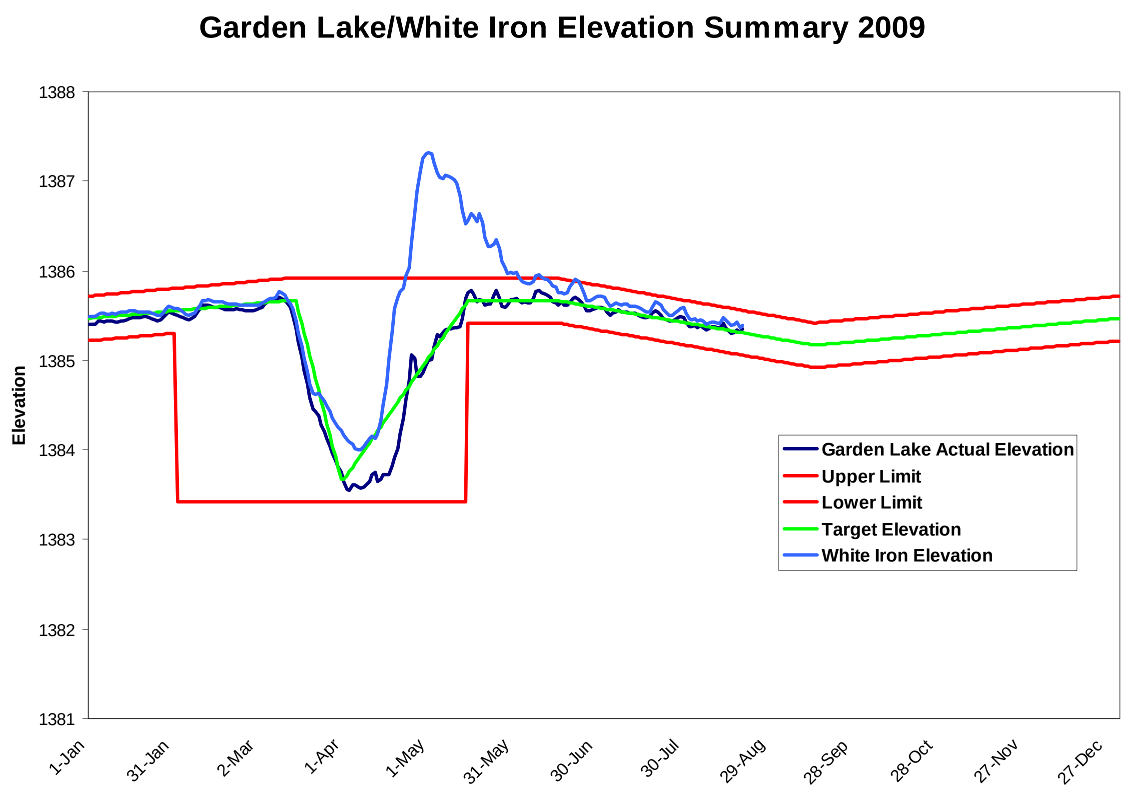



**Figure 10. 2009 monitoring season rainfall based on records for Winton, MN. State Climatology Office Data**



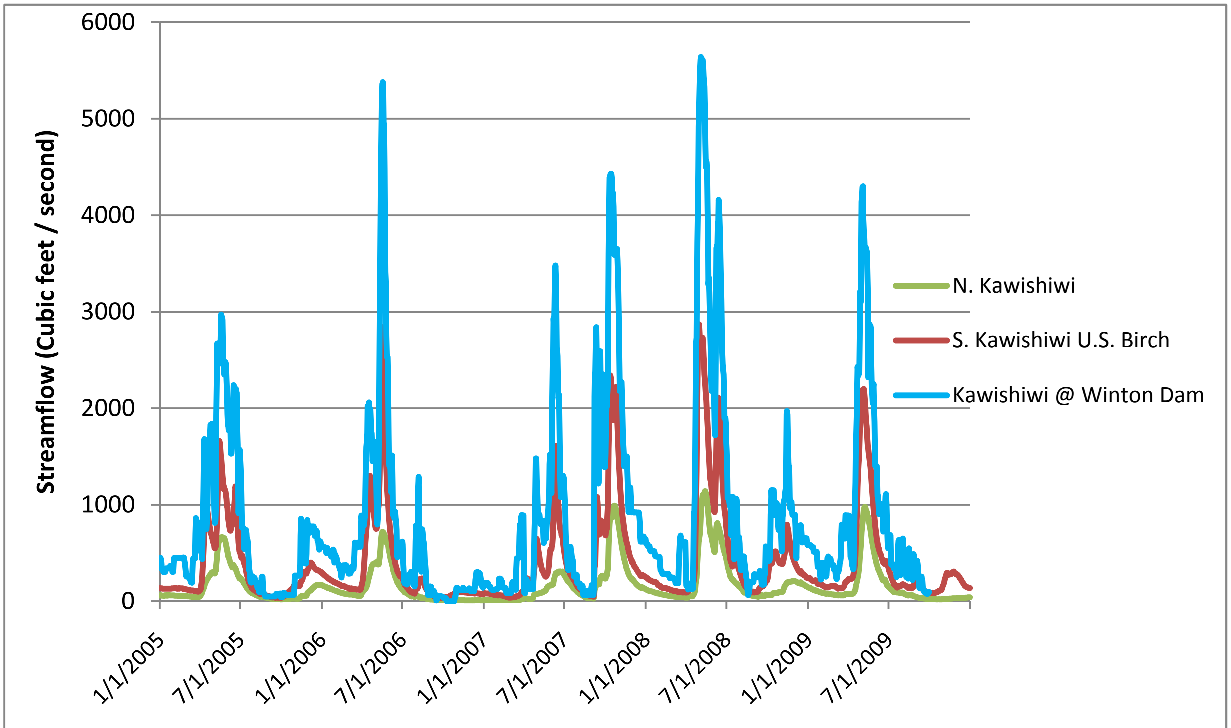
Lake level monitoring is limited in the Kawishiwi watershed. The most complete records are from Birch Lake and the White Iron chain because hydrological monitoring is a necessity for hydropower operations. White Iron Lake and the Garden Lake Reservoir are essentially at the same pool elevation at low lake levels; at higher flows (i.e. during spring runoff) the water levels are higher on White Iron due to a natural constriction that limits flow into the Garden Lake Reservoir. Levels are drawn down in the fall and winter for hydropower generation and to alleviate spring flooding on White Iron Lake. Both these occurrences can be seen in Minnesota Power's 2009 elevation data (Figure 11).

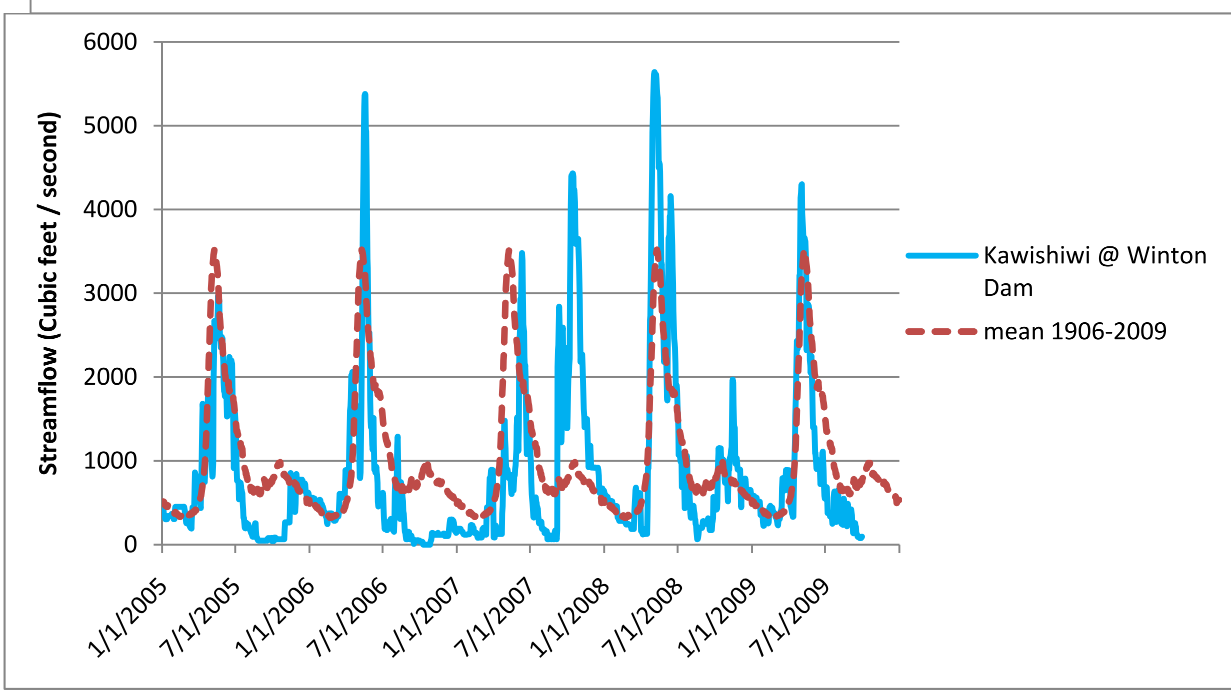
**Figure 11. White Iron and Garden Lake 2009 water level data and elevation ranges (courtesy of Minnesota Power)**




Currently, there are four U.S. Geological Survey (USGS) streamflow gauges in the watershed (Figure 12). The longest record is from the Kawishiwi River outlet at Winton Dam operated jointly by MP and the USGS (monitoring started in 1906 and has been continuous since 1923). The North Kawishiwi gage has been in operation since 1966. This gage is above the split into a North and South branch (Figure 3) and is therefore, unaffected by hydro operations and is a good integrator of climate conditions in the upper watershed. The two gages on the South Branch are located upstream and downstream of Birch Lake (Figure 7) and were reinstituted in the last decade. The flows of the North and South Branch are additive and approximately equate flow at the Winton outlet (Figure 12). The most recent five years of streamflow data at the Winton gage and the long term average are shown in Figure 12. As discussed previously, the high flows during the fall of 2007 and spring of 2008, and near normal flows in 2009 are evident.

**Figure 12. Streamflows at the 3 USGS Kawishiwi River gages; including 2005-2009 flows and long-term means at the Winton gage (USGS data).**



# Results

## Upper Kawishiwi River HUC-11 Watershed

The Upper Kawishiwi River watershed drains 264 $km^2$ (102 $mi^2$) in Cook and Lake Counties and forms the headwaters of the Kawishiwi River. It is one of the more lake-rich sub-watersheds with 68 lakes greater than 4 ha (10 acres) in size. Nearly the entire watershed is within the BWCAW. Prominent large lakes include Polly, Phoebe, and Kawishiwi.

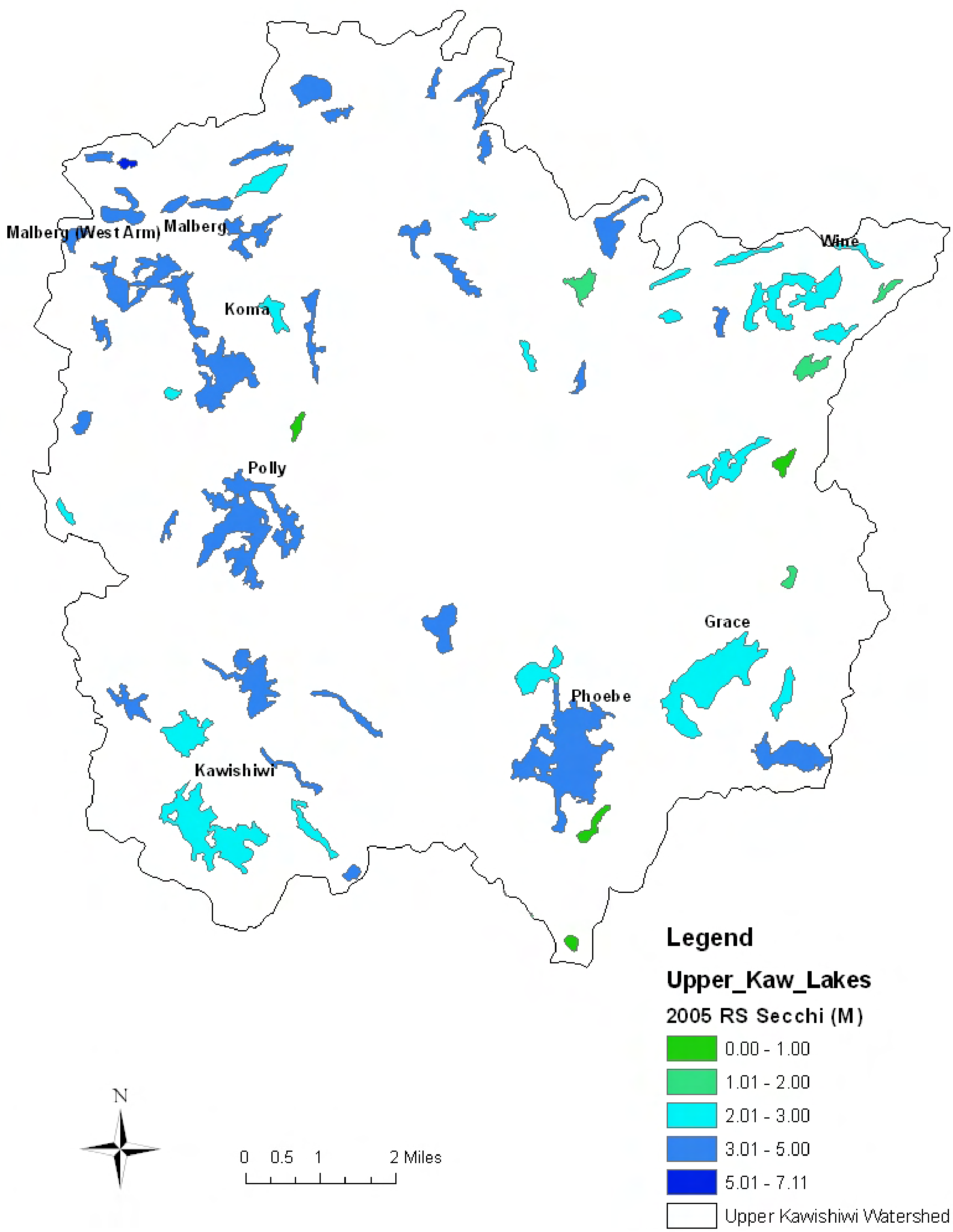
Given the remote location of this watershed, no lakes have assessment level data or sufficient SD data for trend determination. A total of 19 lakes have some historical water quality data collected in the assessment cycle but it's limited to a few SD readings per lake. Therefore, RS SD were used to infer water clarity, including trends from 1985-2005 on the HUC-11 scale. Nearly all (49 of 51) lakes with RS SD exhibited no trends in transparency, likely due to the influence of the BWCAW and the relative lack of human-induced changes in the watershed. The mean RS SD value was 3.0 meters (m), which is similar to the mean monitored SD value (2.5 m; Table 5). The two lakes with declining RS trends, Single and Poet, are small lakes south of Phoebe Lake. Their declining trends are the result of an abrupt decline in 2005 RS SD. This may be due to poor imagery that year; the 2005 value on both lakes was < 1.0 m, versus a 1985-2000 mean of > 2.5 m. A total of 23 lakes within the BWCAW were assessed as fully supporting (FS) based on the RS dataset, using the more stringent NLF criterion (2.4 m) on all years from 1985-2005. These lakes are listed in Appendix A. The 2005 RS SD ranged from 0.7 m on Poet Lake to 7.1 m on Scotch Lake. Transparency on most lakes was greater than 2.0 m (Figure 13). Since most of this watershed is within the BWCAW, few lakes had declining SD trends, and the 2005 RS mean transparency exceeded the criterion, it is reasonable to conclude that water clarity in the Upper Kawishiwi is excellent, relatively stable, and reflective of natural watershed conditions.

**Table 5. Upper Kawishiwi HUC-11 RS Secchi assessment and trend summary**

| Number of Lakes with RS SD | 2005 HUC-11 Mean RS SD (M) | 2000-2009 HUC-11 Mean Monitored SD (M) [1] | Number of BWCAW lakes assessed fully supporting | Number of Lakes with improving SD | Number of Lakes with declining SD | Number of Lakes with No Trend |
|---|---|---|---|---|---|---|
| 51 | 3.0 | 2.5 | 23 | 0 | 2 | 49 |

1. 19 lakes have SD in STORET data from 2000-2009

**Figure 13. 2005 RS Secchi for lakes in the Upper Kawishiwi River HUC-11 watershed**



## Perent River HUC-11 Watershed

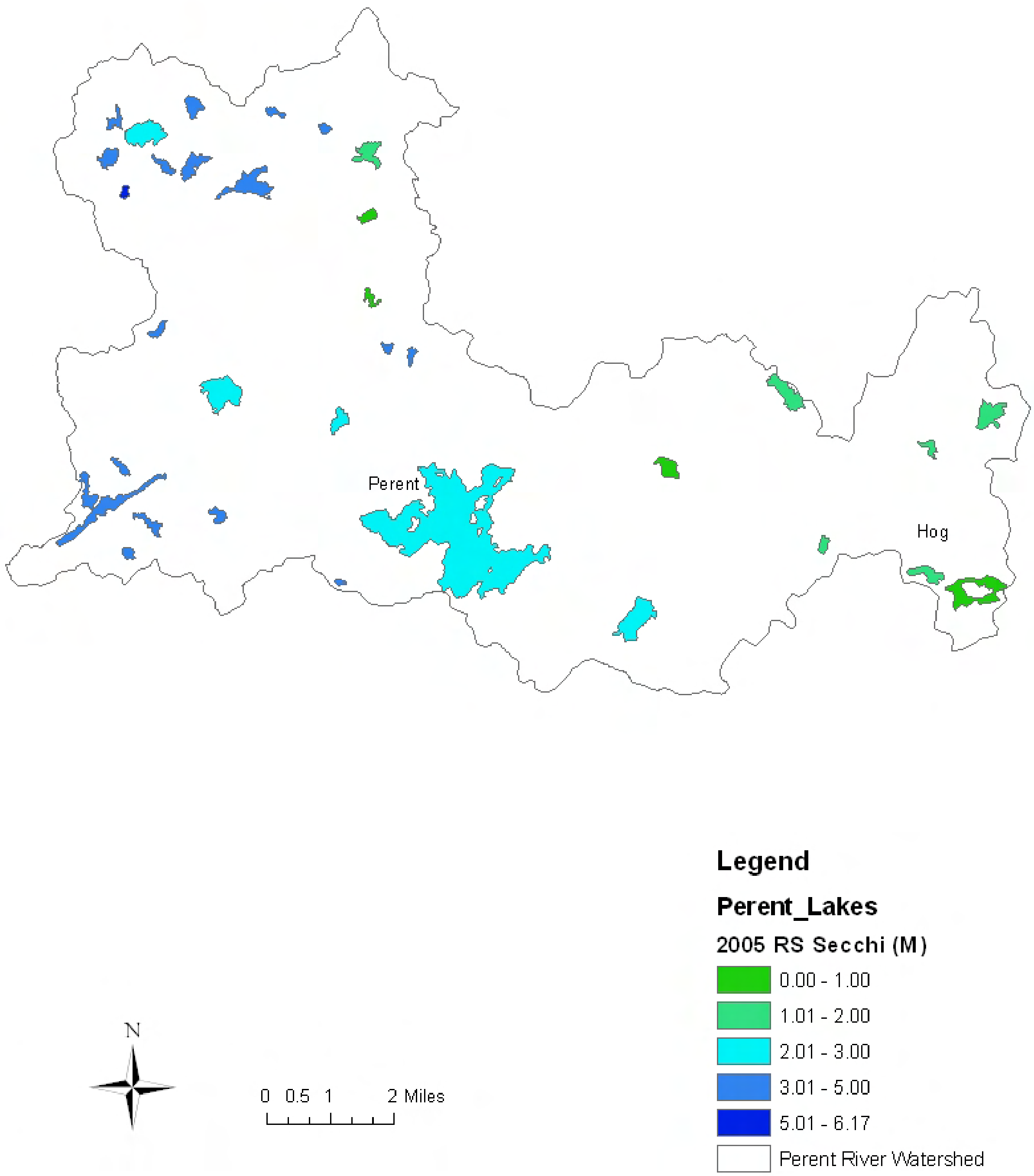
The Perent River watershed drains 217 $km^2$ (84 $mi^2$) in Cook and Lake County, is a main tributary to the Isabella River watershed, and flows west to Isabella Lake. The western half of the watershed is within the BWCAW. Most lakes in the watershed are small and relatively shallow, only six of the 38 lakes are greater than 40 ha (100 acres). Prominent lakes in the watershed include Perent, Hog, and Coffee, with Perent being the largest at 647 ha (1,600 acres). Given the remote location of this watershed, no lakes have assessment level data or sufficient SD data for trend determinations. Historical water quality data collected in the assessment cycle are very sparse, limited to one SD measurement on Perent Lake in 2006. Therefore, RS data are the only data available to make conclusions on the HUC-11 scale.

A total of 27 lakes were assessed using RS SD. Most of the lakes (25 of 27) have no detectable trends in RS transparency, with 16 assessed as fully supporting using the 2.4 m SD criterion (Table 6). These lakes are listed in Appendix A. The two lakes with declining trends are Cook and Hog Lakes. Both are shallow, bog stained flowages, characteristics that can be problematic for RS predictions. The 2005 RS SD ranged from 0.9 m on Bill Lake to 4.5 m on Placid Lake. The mean RS value in the HUC-11 was 2.9 m. RS transparency tended to be lower in the headwaters (southeast) and improve in the small lakes near the watershed outlet (northwest; Figure 14). Since part of this watershed is within the BWCAW, few lakes had declining SD trends, and the 2005 RS mean transparency exceeded the criterion, it is reasonable to conclude that water clarity in the Perent River watershed is excellent, relatively stable, and reflective of watershed conditions.

**Table 6. Perent River HUC-11 RS Secchi assessment and trend summary**

| Number of Lakes with RS SD | 2005 Mean RS SD (M) | Number of BWCAW lakes assessed fully supporting | Number of Lakes with improving SD | Number of Lakes with declining SD | Number of Lakes with No Trend |
|---|---|---|---|---|---|
| 27 | 2.9 | 16 | 0 | 2 | 25 |

**Figure 14. 2005 RS Secchi for lakes in the Perent River HUC-11 watershed**



## Island River HUC-11 Watershed

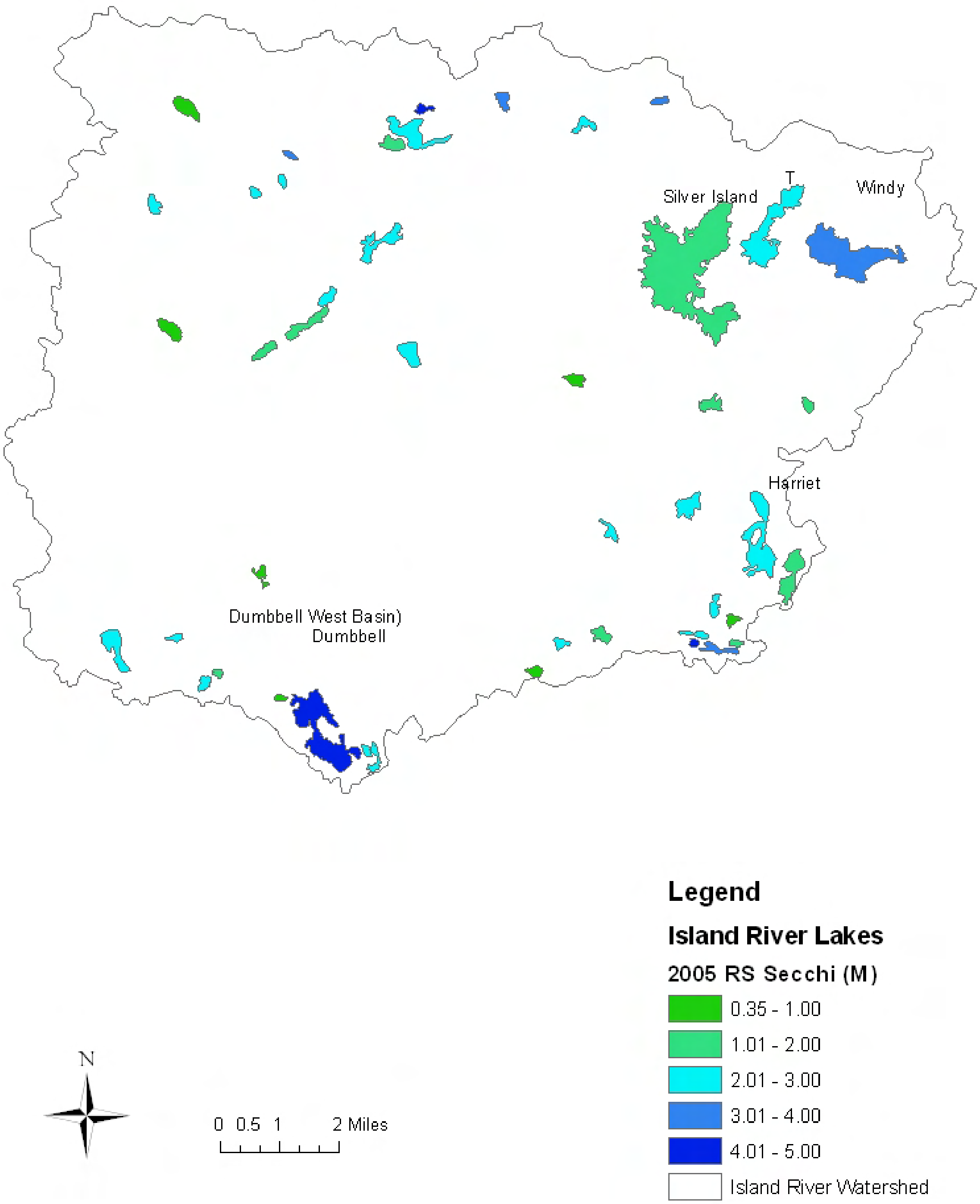
The Island River watershed drains 385 $km^2$ (149 $mi^2$) in Lake County and is a major tributary to the Isabella River. It forms the southeastern boundary of the Kawishiwi watershed, flowing west to the Isabella River immediately downstream of Isabella Lake. It contains 50 lakes greater than 4 ha (10 acres), with most being on the perimeter of the watershed. Notable large lakes that receive high levels of recreational use include Silver Island, Dumbbell, and Windy. Lakeshore development is minimal and limited to Superior National Forest campgrounds on several lakes. The far northern portion of the watershed is within the BWCAW, although the entire watershed is within a remote portion of Superior National Forest. No water quality data were collected on any lakes during the assessment cycle.

A total of 40 lakes have RS transparency data (Table 7, Figure 15). The one lake within the BWCAW was assessed and was determined to be fully supporting (Sumpet Lake). Most (37 of 40) lakes had no trend in RS transparency. The three lakes with declining trends (Mound, Charity, and Scott) are all small, shallow, bog stained lakes; where the 2005 RS estimate was much lower than previous years. The 2005 RS transparency ranged from 0.5 m on Green Wing Lake to 5.0 m on Small Lake (an overestimate because Small lake is only 1.2 m deep). The mean RS value in the HUC-11 was 2.2 m, slightly below those in other Kawishiwi headwaters HUC-11 sub-watersheds. Since most of the watershed is within a remote portion of the Superior National Forest or the BWCAW, and few lakes had declining SD trends, it is reasonable to conclude that water clarity in the Island River watershed is good, relatively stable, and reflective of watershed conditions.

**Table 7. Island River HUC-11 RS Secchi assessment and trend summary**

| Number of Lakes with RS SD | 2005 Mean RS SD (M) | Number of BWCAW lakes assessed Full Supporting | Number of Lakes with improving SD | Number of Lakes with declining SD | Number of Lakes with No Trend |
|---|---|---|---|---|---|
| 40 | 2.2 | 1 | 0 | 3 | 37 |

**Figure 15. 2005 RS Secchi for lakes in the Island River HUC-11 watershed**



## Inga-Isabella River HUC-11 Watershed

The Inga-Isabella River watershed drains 246 $km^2$ (95 $mi^2$) in Lake County and is composed of the Little Isabella River, and the Mitawan and Inga Creek watersheds. The watershed flows north into the Isabella River immediately upstream of Bald Eagle Lake, and has comparably few lakes. Only 21 lakes are greater than 4 ha (10 acres). The northern portion of the watershed is within the BWCAW, the remainder of the watershed is within Superior National Forest. The Inga-Isabella watershed has the highest percentage of forested land (92 percent) among the Kawishiwi's subwatersheds. Lakeshore development is minimal, and is limited to isolated private parcels on a few lakes (Grouse, Mitawan, and Gegoka).

Water quality data are limited to just two lakes, Grouse and Rat Lakes. Rat Lake, a widening in the Little Isabella River, had just one SD measurement collected during the assessment cycle. Grouse Lake has an extensive CLMP SD record, with annual monitoring since 1988, and therefore has sufficient data for trend determination. Data are shown in Figure 16; the long-term mean transparency is 1.8 m. Annual variability is minimal, and no temporal trend was detected. These results are indicative of the stable landuse and minimal lakeshore development in the vicinity.

RS SD data and trends were estimated on 19 lakes (Figure 17). The watershed's three lakes within the BWCAW were assessed and determined to be fully supporting (Bog, Brush, and John). RS trends were not detected on any lakes (Table 8). Mean 2005 RS transparency in the watershed was 2.5 m, it ranged from 1.3 m on Inga Lake to 3.8 m on Brush Lake. Since part of this watershed is within the BWCAW, few lakes had declining SD trends, and the 2005 RS mean transparency exceeded the BWCAW criterion, it is reasonable to conclude that water clarity in the Perent River watershed is excellent, relatively stable, and reflective of watershed conditions.

**Figure 16. Grouse Lake summer-mean Secchi trends. Standard error bars noted in red**

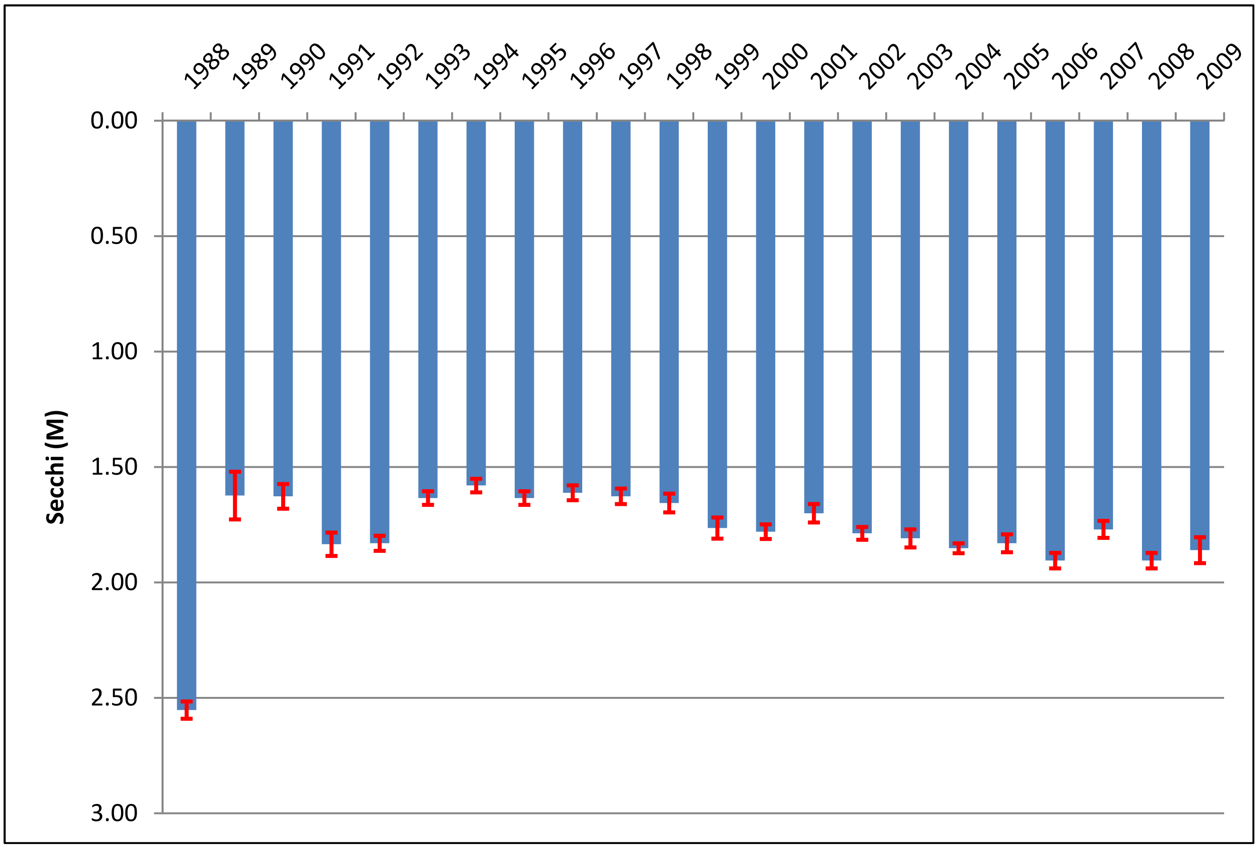
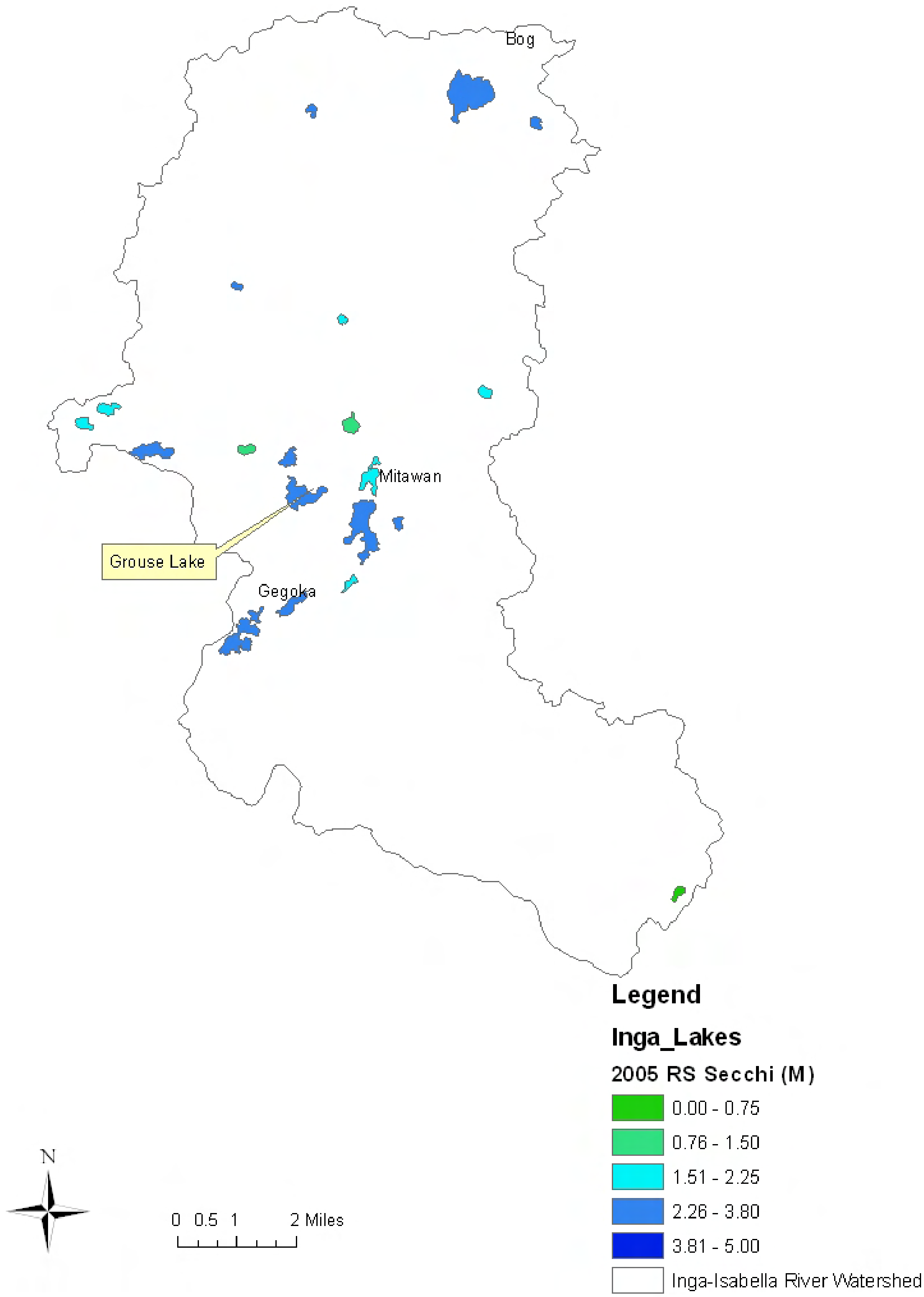



**Table 8. Inga-Isabella River HUC-11 RS assessment and trend summary**

| Number of Lakes with RS SD | 2005 Mean RS SD (M) | Number of BWCAW lakes assessed FS | Number of Lakes with improving SD | Number of Lakes with declining SD | Number of Lakes with No Trend |
|---|---|---|---|---|---|
| 19 | 2.5 | 3 | 0 | 0 | 19 |

**Figure 17. 2005 RS Secchi for lakes in the Inga-Isabella River HUC-11 watershed**



## Isabella River HUC-11 Watershed

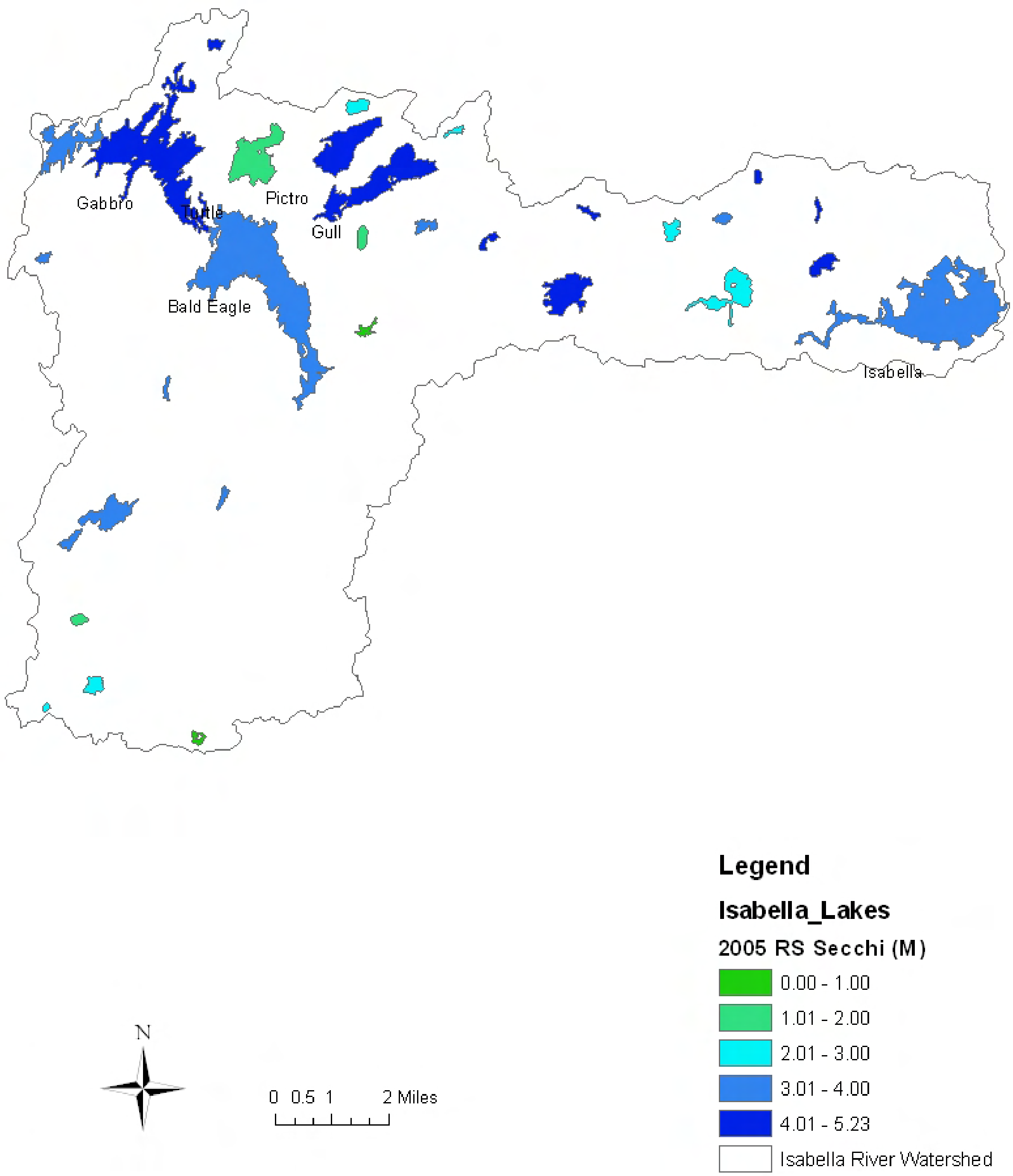
The Isabella River watershed drains 274 $km^2$ (106 $mi^2$) in central Lake County. The Isabella River is the largest tributary to the Kawishiwi River, and flows into Bald Eagle Lake. The HUC-11 watershed is defined as the Isabella River from its source in Isabella Lake to its confluence with Bald Eagle Lake (it also includes the Snake River sub-watershed). Major tributaries to the Isabella River include the Little Isabella, Island, and Perent Rivers. The northern 2/3 of the watershed is within the BWCAW; Isabella Lake is a popular entry point into the BWCAW.

The watershed has 35 lakes greater than 4 ha (10 acres). Prominent large lakes include Isabella, Bald Eagle, and Gabbro (all are greater than 1,000 acres). Water quality data are sparse in the watershed, limited to a few SD measurements on seven lakes. RS transparency data and trends were estimated on 27 lakes (Table 9, Figure 18). The watershed's 16 BWCAW lakes were assessed and all determined to be fully supporting (see Appendix A). RS trends were not detected on any lakes (Table 9). Mean 2005 RS transparency in the watershed was 3.5 m, it ranged from 1.7 m on Baird Lake to 5.2 m on Pietro Lake. Since most of this watershed is within the BWCAW, no lakes had declining SD trends, and the 2005 RS mean transparency exceeded the  criterion, it is reasonable to conclude that water clarity in the Isabella River watershed is excellent, relatively stable, and reflective of watershed conditions.

**Table 9. Isabella River HUC-11 RS assessment and trend summary**

| Number of Lakes with RS SD | 2005 Inferred Mean SD (M) | Number of BWCAW lakes assessed FS | Number of Lakes with improving SD | Number of Lakes with declining SD | Number of Lakes with No Trend |
|---|---|---|---|---|---|
| 27 | 3.5 | 16 | 0 | 0 | 27 |

**Figure 18. 2005 RS Secchi for lakes in the Isabella River HUC-11 watershed**



## Upper Stony River HUC-11 Watershed

The Upper Stony River drains 401 $km^2$ (155 $mi^2$) in Lake County and forms the southern boundary of the Kawishiwi watershed. It includes the headwaters of the Stony River and its main tributaries, the Greenwood and Sand Rivers – which both originate in large lakes. The watershed's headwaters are within a large wetland complex. Lakes in the watershed are shallow, heavily bog stained, and have significant macrophyte growth in mid-summer (Al Anderson, MDNR Finland Area Fisheries Manager, personal communication). There are relatively few lakes in this watershed, and the watershed has a high percentage of wetlands (26 percent, Figure 6). Along the watershed's perimeter, isolated seepage lakes are present in low-lying wetland areas (Figure 19). The watershed is within a remote part of Superior National Forest. Most lakes are undeveloped, except Sand and North McDougal, which has some development along its southern shore including a Superior National Forest campground.

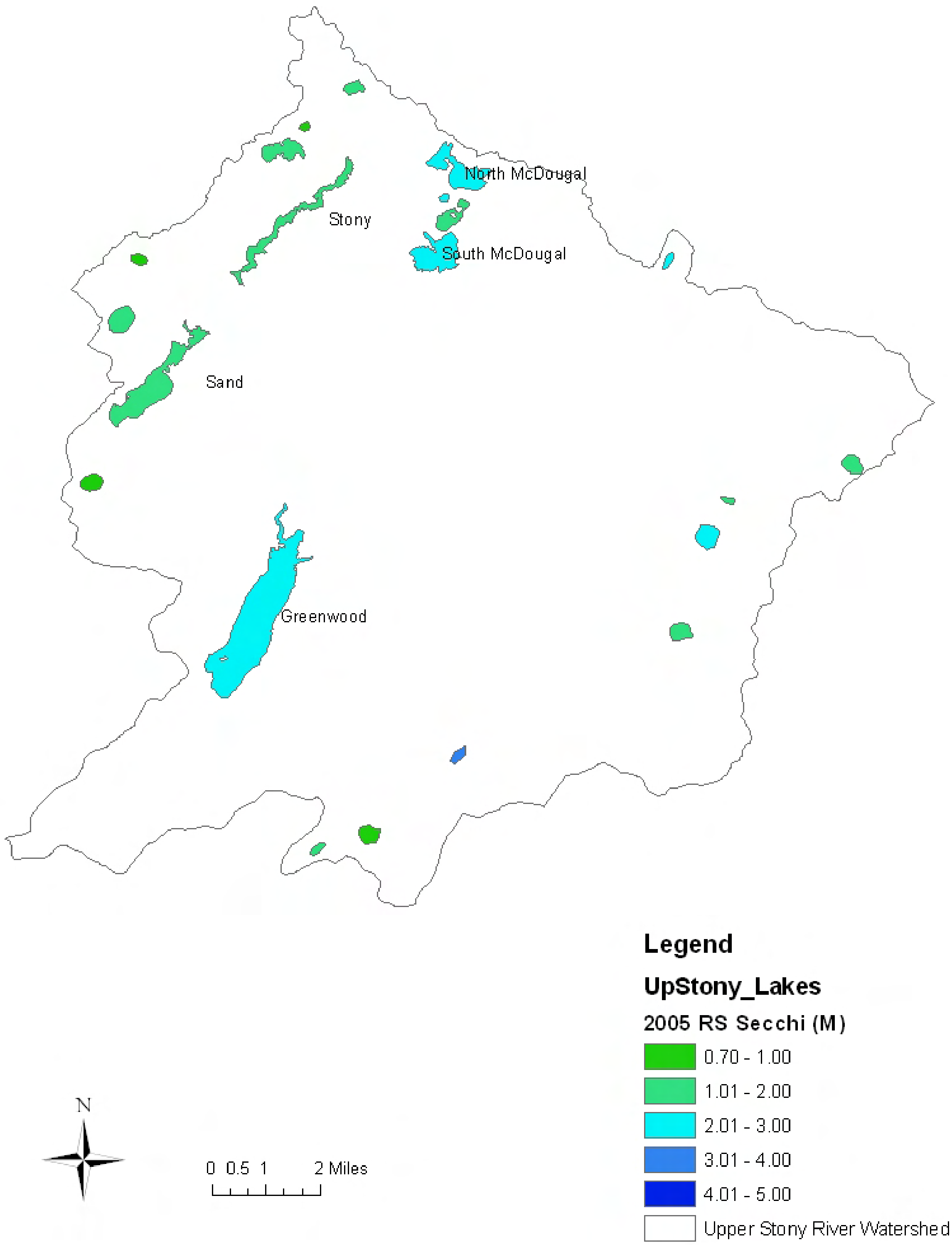
The watershed contains 25 lakes greater than 4 ha (10 acres). No historical water quality data were collected on any lakes within the assessment cycle. Because the watershed is outside the BWCAW, no lakes were assessed. RS Secchi data and trends were estimated on 21 lakes (Table 10). Sixteen lakes have no trends in transparency, and five had declining trends (Driller, Fools, Cougar, Spruce, and Sand). These lakes are all seepage lakes surrounded by large wetland complexes, and likely heavily bog stained. Mean 2005 RS transparency in the watershed was 1.8 m - the lowest average among Kawishiwi sub-watersheds. The 2005 RS transparency ranged from 0.7 m on Little Wampus Lake to 2.9 m on N. McDougal Lake. Given the influence of the area's wetlands, lakes have low transparency. Lower transparency is not a response to high chlorophyll (i.e. algae) concentrations. This natural staining originates from tannin compounds drained from wetlands and forests within the watersheds.

**Table 10. Upper Stony River RS SD assessment and trend summary**

| Number of Lakes with RS SD | 2005 Inferred Mean SD (M) | Number of BWCAW lakes assessed FS | Number of Lakes with improving SD | Number of Lakes with declining SD | Number of Lakes with No Trend |
|---|---|---|---|---|---|
| 21 | 1.8 | N/A [1] | 0 | 5 | 16 |

1. This HUC-11 watershed is outside of the BWCAW

**Figure 19. 2005 RS Secchi for lakes in the Upper Stony River HUC-11 watershed**



## Stony River HUC-11 Watershed

The Stony River watershed drains 222 $km^2$ (86 $mi^2$) in Lake County and is defined as the lower portion of the Stony River watershed from the outlet of Stony Lake downstream to the confluence with Birch Lake. The watershed has 29 lakes greater than 4 ha (10 acres), although most (24) are less than 40 ha (100 acres). The majority of lakes are located in the eastern portion of the watershed, with few west of Highway 1. The watershed is entirely within Superior National Forest, and like all Kawishiwi sub-watersheds, land cover is dominated by forests, wetlands, and open water.

Historical water quality data are limited in the Stony River watershed. Just one lake (Dunnigan) has data collected in the assessment cycle. Dunnigan (38-0664) is located on the northern border of the watershed adjacent to Highway 1. The lake is a long term acid rain study lake and has been routinely sampled once per year by the MPCA and Superior National Forest since the early 1980s. Although there are not enough data for a formal assessment, data are briefly discussed since it is the most intensively monitored lake in the watershed. The SD, TP and Chl-a data are shown in Figures 20 and 21. No trends were detected in the SD record. The long term mean is approximately 3.0 m; no conclusions on the annual variability can be made because samples were only collected once per year. TP and Chl-a concentrations were relatively stable (Figure 21), and averaged 16 and 4.4 µg/L respectfully (well below NLF eutrophication criteria).

**Figure 20. Secchi trends in Dunnigan Lake**

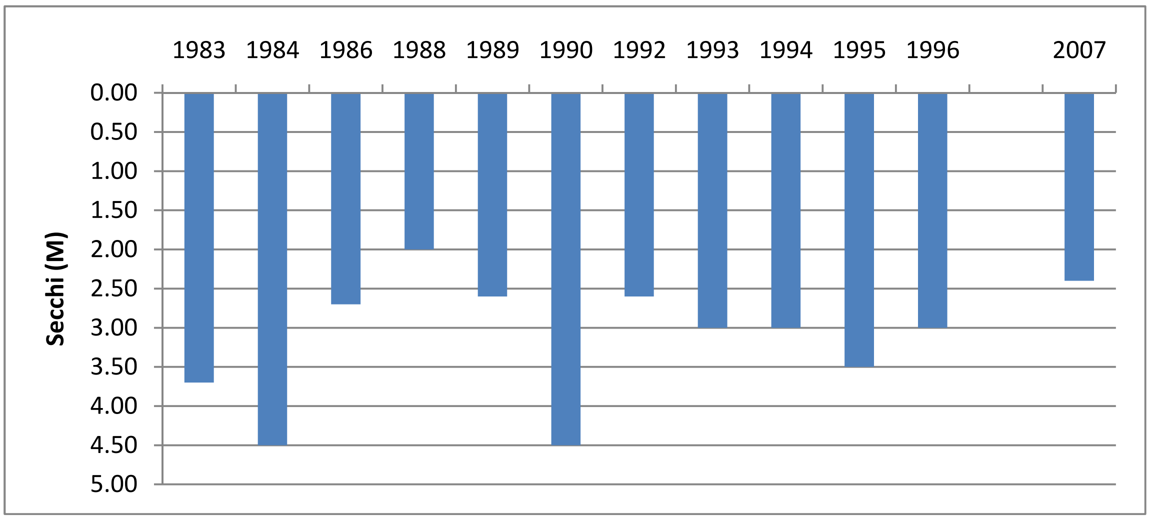
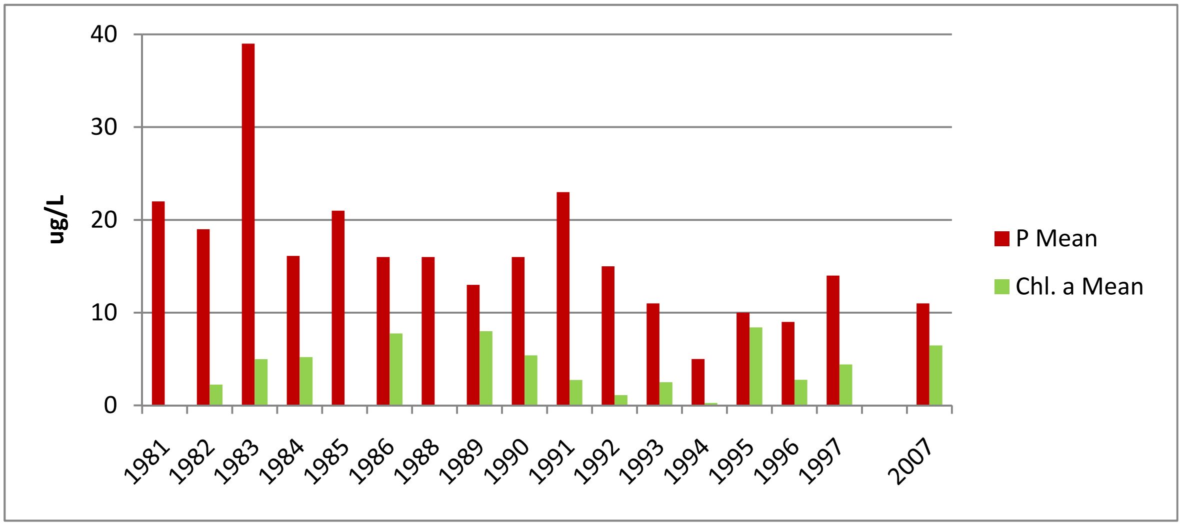


**Figure 21. TP and Chl-a trends in Dunnigan Lake**



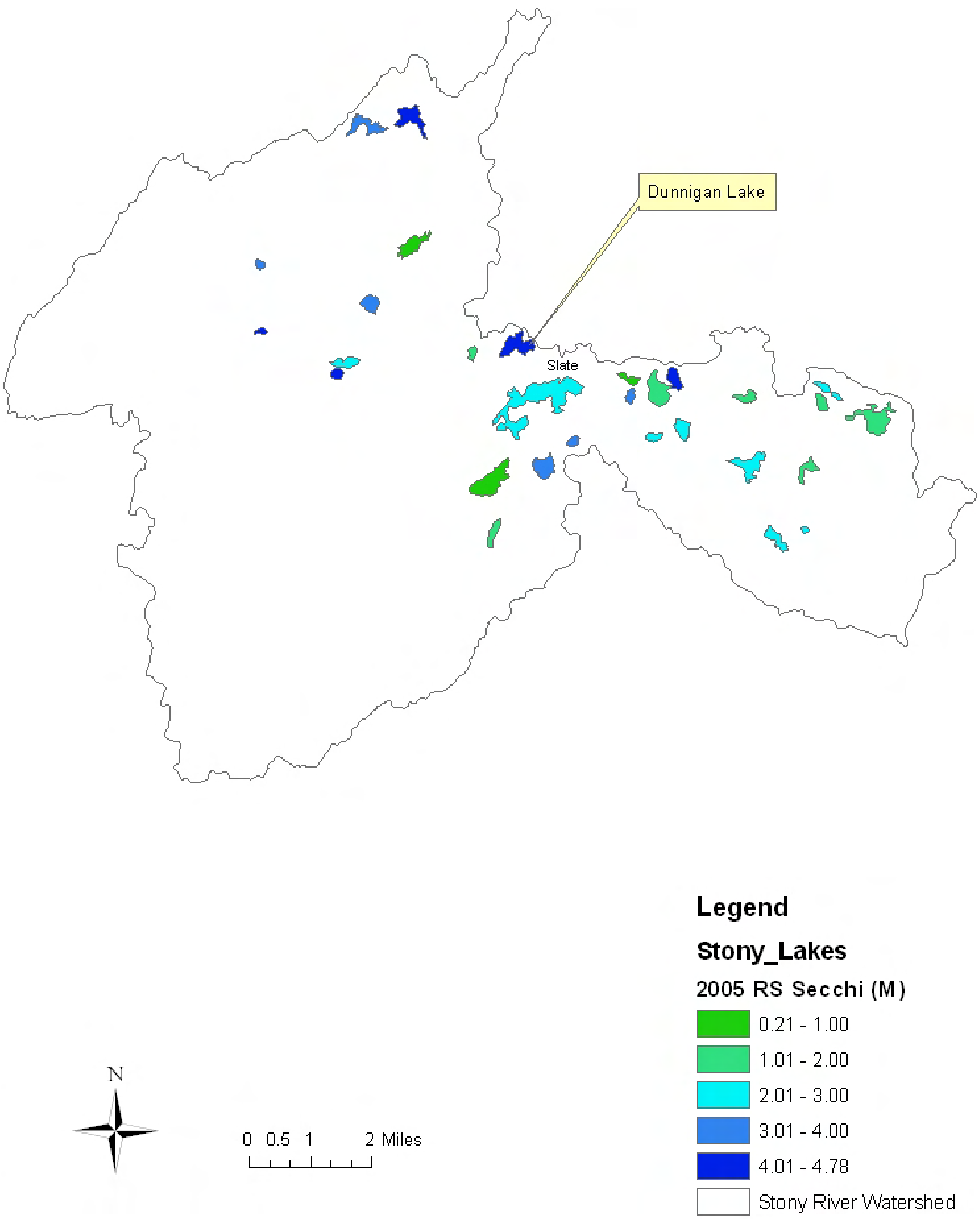

RS transparency data and trends were estimated on 25 lakes (Table 11, Figure 22). A total of 23 lakes had no trends in transparency. The two lakes with declining trends (Beaver Hut and Gypsy) are remote, undeveloped, and classified by the MDNR as Designated Stream Trout Lakes. The declining trends are due to an abrupt decline in 2005 RS transparency, which is probably influenced by poor imagery that year. It's unlikely that actual transparencies were 1.1 m on Gypsy and 0.2 m on Beaver Hut Lake; MDNR staff have measured SD transparency near 2.0 m on both lakes during routine fishery surveys. Mean 2005 RS transparency in the watershed was 2.5 m, and ranged from 0.2 m on Beaver Hut Lake to 4.8 m on Pear Lake. Since few lakes had declining SD trends, and the 2005 RS mean transparency exceeded the criterion, it is reasonable to conclude that water clarity in the Stony River watershed is excellent, relatively stable, and reflective of watershed conditions.

**Table 11. Stony River HUC-11 RS SD assessment and trend summary**

| Number of Lakes with RS SD | 2005 Inferred Mean SD (M) | Number of BWCAW lakes assessed FS | Number of Lakes with improving SD | Number of Lakes with declining SD | Number of Lakes with No Trend |
|---|---|---|---|---|---|
| 25 | 2.5 | N/A [1] | 0 | 2 | 23 |

1. This HUC-11 watershed is outside of the BWCAW

**Figure 22. 2005 RS Secchi for lakes in the Stony River HUC-11 watershed**



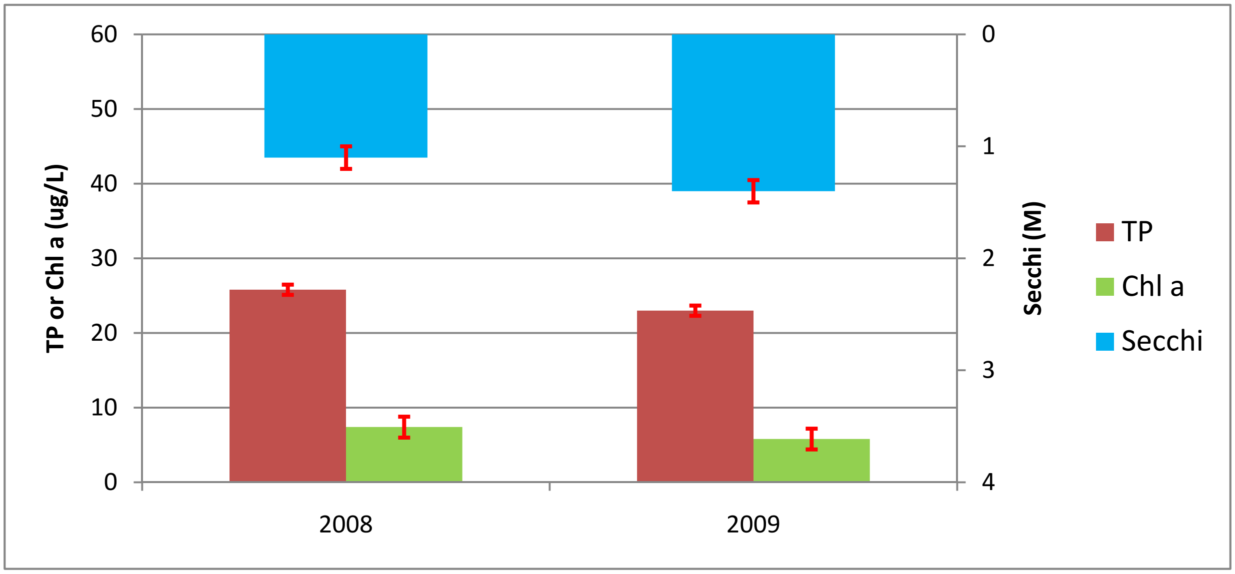
## South Fork Kawishiwi River HUC-11 Watershed

The South Fork Kawishiwi River HUC-11 watershed drains a total of 471 $km^2$ (182 $mi^2$), from the start of the South Kawishiwi River to the Birch Lake outlet. The upstream portion of the South Kawishiwi watershed is within the BWCAW. The watershed has 24 lakes greater than 4 ha (10 acres); most are small and located adjacent to the South Kawishiwi River or west of Birch Lake. Birch Lake (69-0003), located three miles east of Babbitt, is the principal lake in the watershed. It covers over 2,954 ha (7,300 acres) and has a very large watershed area (2,167 $km^2$ or 837 $mi^2$). Other large lakes in the watershed include Bearhead and Clear.

Two lakes in the HUC-11 have assessment level data, Birch and Bearhead. Both were sampled by the MPCA in 2008 and 2009. Birch is one of the region's most popular recreational lakes. The South Kawishiwi is the largest tributary to the lake. Three smaller tributaries, the Stony, Dunka, and Birch Rivers, drain large wetland areas with few lakes. The Dunka River drains 150 $km^2$ (58 $mi^2$) and is included in this HUC-11; the Stony drains 370 $km^2$ (143 $mi^2$) and is upstream of the South Kawishiwi HUC-11 watershed. Compared to other large lakes in the Kawishiwi watershed, Birch has a high density of lakeshore development- including several resorts, a Superior National Forest campground and several dispersed lakeshore campsites, the city of Babbitt's swimming beach and recreation area, and several homes and cabins near Babbitt and the Dunka Bay area. However, large portions of the lake, particularly the northern and eastern shores, remain undeveloped and within Superior National Forest. Lake levels are controlled by a Minnesota Power (MP) dam at the outlet on Minnesota Highway 1 (Figure 3). Birch is a shallow impounded lake; large portions of the lake are 5-7 m deep, the mean depth is approximately 3.9 m (12.8 feet).

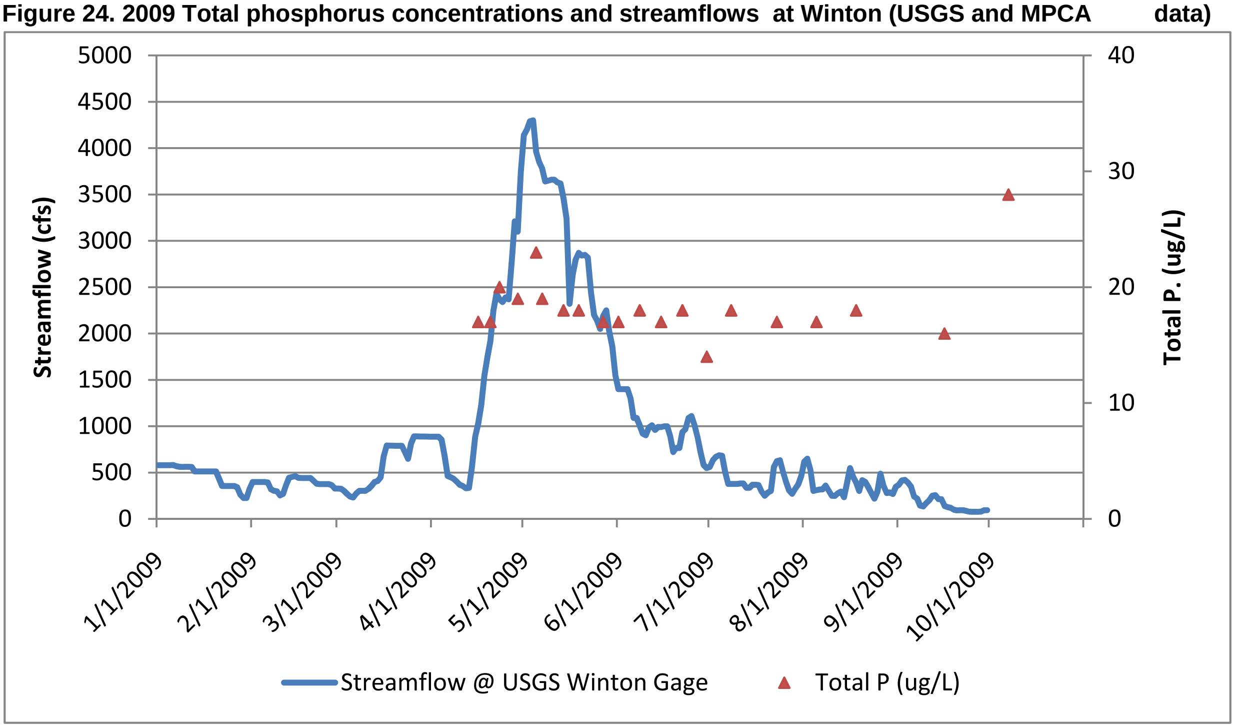
Birch was sampled at two sites, one in the south basin near Birch point, and one in the north basin between the campground and the South Kawishiwi inlet. Depth at both sites was approximately 7 m (23 feet). Average TP, Chl-a, and SD data from 2008 and 2009 are shown in Figure 23. These data represent the mean of epilimnetic samples from two sites (water quality conditions were very similar between the two sites). Data were also similar among years with low variability (standard errors). SD transparency averaged about 1.3 m. This low transparency is heavily influenced by natural bog staining originating from the lake's wetland-dominated watershed, and is not in response to high chlorophyll (algae) concentrations. Color values in Birch averaged 90 platinum-cobalt units; indicating heavily stained water (placing Birch in approximately the 97th percentile of MPCA's monitored lakes). TP and SD did not vary significantly throughout the season. Chl-a concentrations peaked in August at approximately 10 µg/L. Chl-a concentrations greater than 20 µg/L will typically be perceived as a nuisance bloom in northern Minnesota lakes (Heiskary and Walker, 1988). Water temperatures peaked in mid-summer near 20 C (68 F) in both years and there was no significant difference among the two sites. The lake did not thermally stratify. Birch consistently maintained epilimnetic oxygen concentrations greater than 5 mg/L, levels needed to support healthy cool and warm water fisheries.

**Figure 23. Birch Lake 2008 and 2009 TP, Chl-a, and SD data**




Birch is a polymictic lake and is heavily influenced by the hydrology and water quality of its main tributary - the South Kawishiwi River. Birch has a short residence time (estimated at 0.2 years or ~ 70 days) because it has a large watershed to lake area ratio and relatively small volume. Most polymictic lakes in Minnesota have widely fluctuating epilimnetic TP concentrations (Heiskary and Wilson, 2005). Birch is somewhat unique in this regard, due to the influence of the Kawishiwi River. Figure 24 shows streamflow values at the USGS Winton gage and recent TP samples collected throughout the 2009 field season near the Kawishiwi River Winton outlet. TP concentrations consistently ranged from 15-20 µg/L - independent of discharge. This is likely due to the influence of the relatively unimpacted forested watersheds upstream, and the numerous on-channel lakes which attenuate phosphorus.

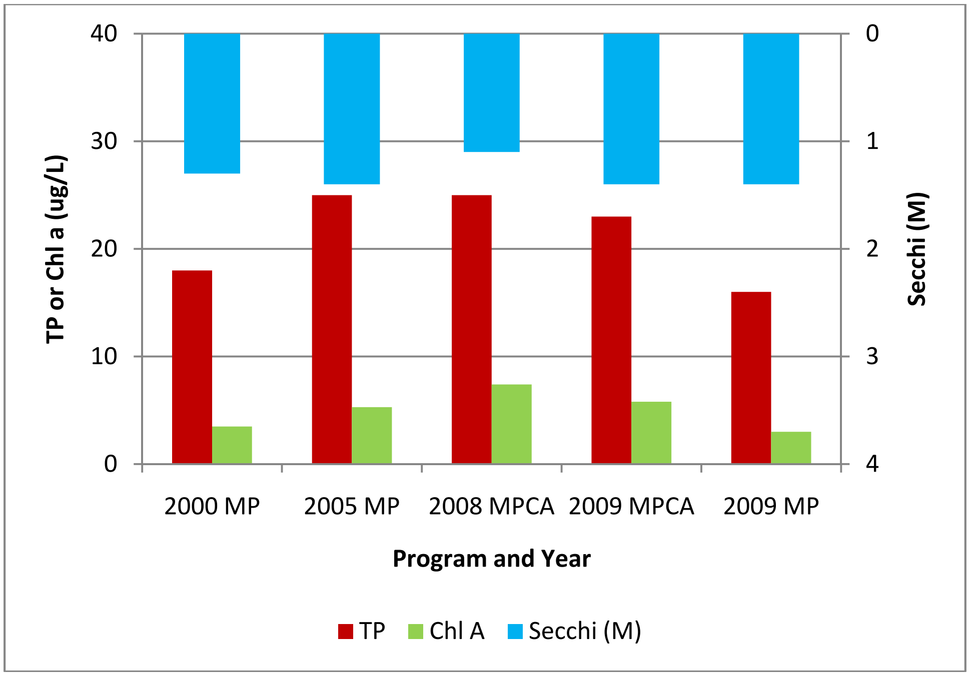
**Figure 24. 2009 Total phosphorus concentrations and streamflows at Winton (USGS and MPCA data)**



The MINLEAP model was utilized for Birch Lake based on the average of 2008 and 2009 TP, Chl-a, and SD values. The model compares observed data with those predicted by the model based on lake area, depth and watershed area. Complete modeling results can be found in Appendix B. MINLEAP's predicted TP and Chl-a values were very close to observed. Model-predicted SD exceeded observed, primarily because the model does not account for light limitation from the bog-stain. MINLEAP predicted a P loading rate of 15,100 kilograms per year (kg/yr), again reflecting the influence of the lake's large watershed.

Birch Lake was monitored seasonally (spring, summer, and fall) in 2000, 2005, and 2009 by MP as a requirement of their federal hydropower license. Combining MP and MPCA data allow for the examination of eutrophication trends within the assessment cycle (Figure 25). TP, Chl-a, and SD slightly varied each year but were not statically different.

**Figure 25. TP, Chl-a, and SD trends in Birch Lake**




Based on the 2008 and 2009 monitoring results, Birch Lake is classified as a mesotrophic lake.

Additionally, based on the TP, Chl-a, and Secchi transparency assessment standards, Birch Lake was determined to be fully supporting of aquatic recreational use, and meeting eutrophication criteria (Table 12). As discussed previously, the low SD transparency is due to natural bog staining from the surrounding watersheds, and not in response to elevated Chl-a concentrations.

**Table 12. NLF ecoregion eutrophication criteria, and assessment cycle mean values for Birch Lake**

| Ecoregion | TP µg/L | Chl-*a* µg/L | Secchi meters |
|---|---|---|---|
| NLF – Aquatic Rec. Use (Class 2B) | < 30 | < 9 | > 2.0 |
| Birch Lake (69-0003) | 24 | 6.6 | 1.2 |

Bearhead Lake (69-0254) is the other assessed lake in this HUC-11 watershed. Bearhead is a Sentinel lake, and currently is intensively monitored by MDNR and MPCA. A detailed report is due out in 2011. A brief summary of current water quality conditions is presented here, since it is one of the few assessed lakes in the Kawishiwi River watershed. Bearhead Lake is located approximately 10 miles east of Tower. It covers 272 ha (674 acres) and is on the northwestern border of the watershed. Bearhead is a seepage lake (lacking surface inlets or outlets), and makes up the headwaters of the Birch Lake watershed. Bearhead has a very small watershed, estimated at 562 ha (1,389 acres) and it is nearly all forested land. The lake and its watershed are entirely within Bearhead Lake State Park. Lakeshore development is minimal and limited to the state park campground and associated recreation areas in the northwest part of the lake. The lake was sampled monthly from May – October at the point of maximum depth (14 m) adjacent to the swimming beach.

Average TP, Chl-a, and SD data from 2008 and 2009 are shown in Figure 26. All three parameters did not vary significantly among years. TP and Chl-a averaged 14 and 7.5 µg/L respectively. SD transparency averaged 3.0 m, and was slightly higher in 2009. TP concentrations were fairly consistent in all months. Chl-a peaked in mid-summer or early fall, which is normal for dimictic mesotrophic lakes within the NLF ecoregion.

Bearhead was thermally stratified by mid-summer in both years. Spring and summer 2008 oxygen and temperature data are shown in Figure 27. The thermocline developed at 6 m in August; while May temperatures were consistent around 7 C (44 F) from the surface to the bottom. Conditions were similar in 2009.

**Figure 26. Bearhead Lake 2008-2009 TP, Chl-a, and SD data**

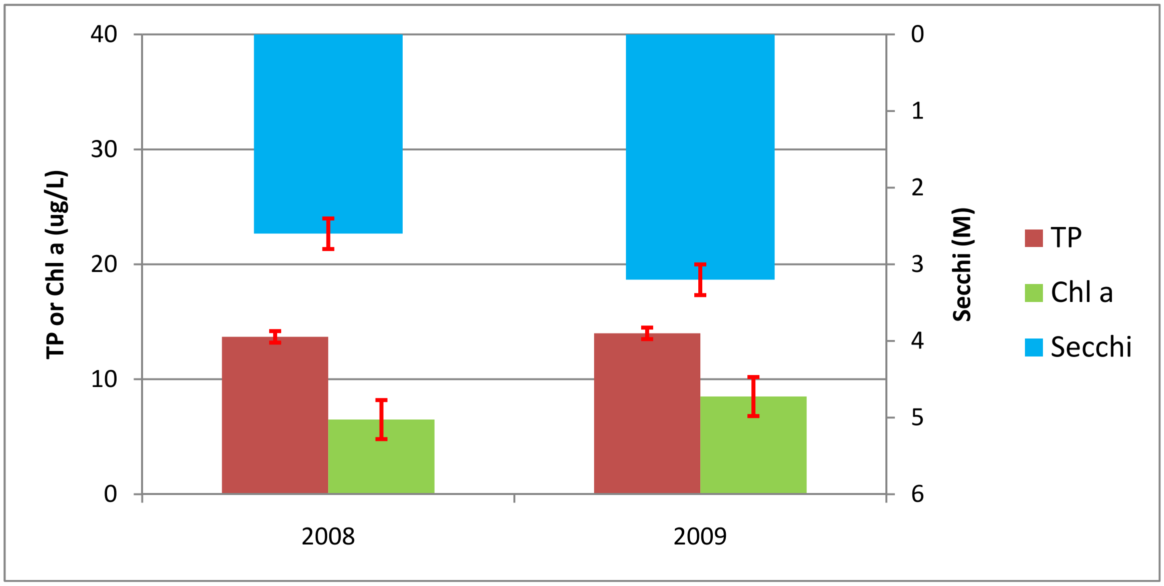
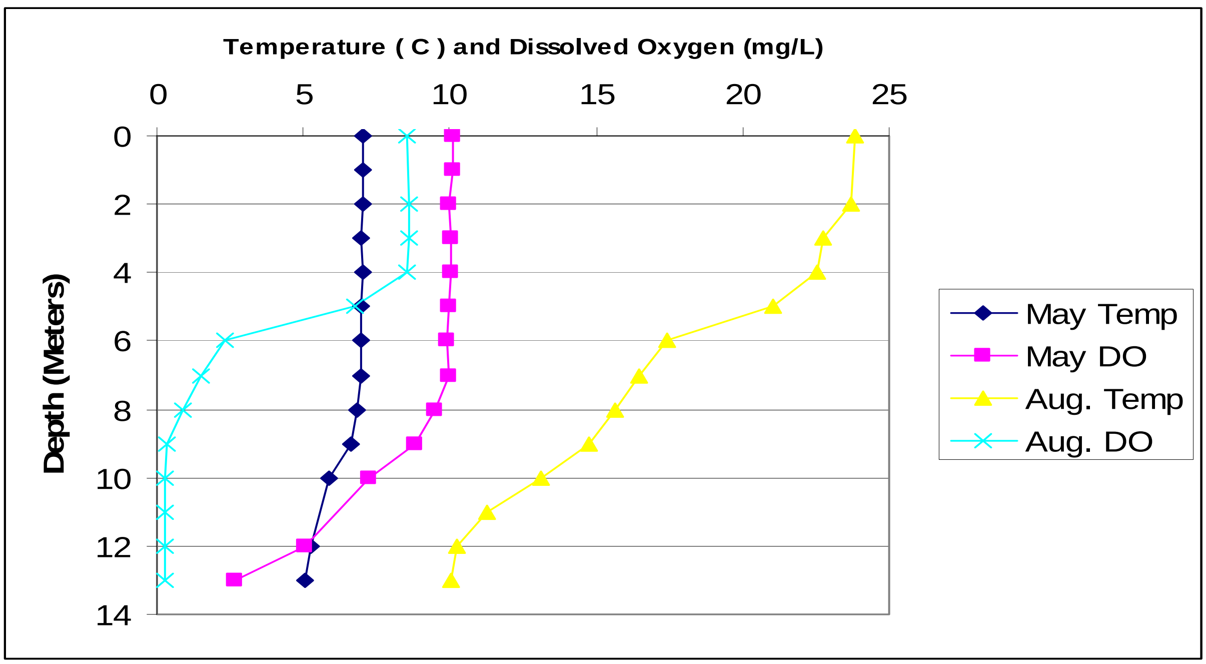



**Figure 27. Bearhead Lake May and August 2008 temperature and dissolved oxygen profiles**



The MINLEAP model was utilized for Bearhead Lake with "observed" based on the average of 2008 and 2009 TP, chl-a, and SD values. Complete modeling results can be found in Appendix B. MINLEAP's predicted TP was identical to observed; however, observed Chl-a and SD values were higher than predicted, but not statistically different. At this point, we do not have an explanation for the difference between observed and predicted Chl-a and Secchi but this will be addressed in the Sentinel report. Accurately modeling P and water budgets for seepage lakes can be difficult; however, it appears MINLEAP provides reasonable estimates for Bearhead. MINLEAP predicted a residence time on the order of six years, and a P loading rate of 80 kg/yr- quite low but reflective of Bearhead's small, and relatively pristine forested watershed.

Based on 2008 and 2009 monitoring results, Bearhead Lake is classified as a mesotrophic lake. Additionally, based on the TP, Chl-a, and Secchi transparency assessment standards, Bearhead Lake was determined to be fully supporting of aquatic recreational use, and meeting all assessment criteria (Table 13). In summary, based on recent monitoring, Bearhead has excellent and stable water quality.

**Table 13. NLF ecoregion eutrophication criteria, and assessment cycle mean values for Bearhead Lake**

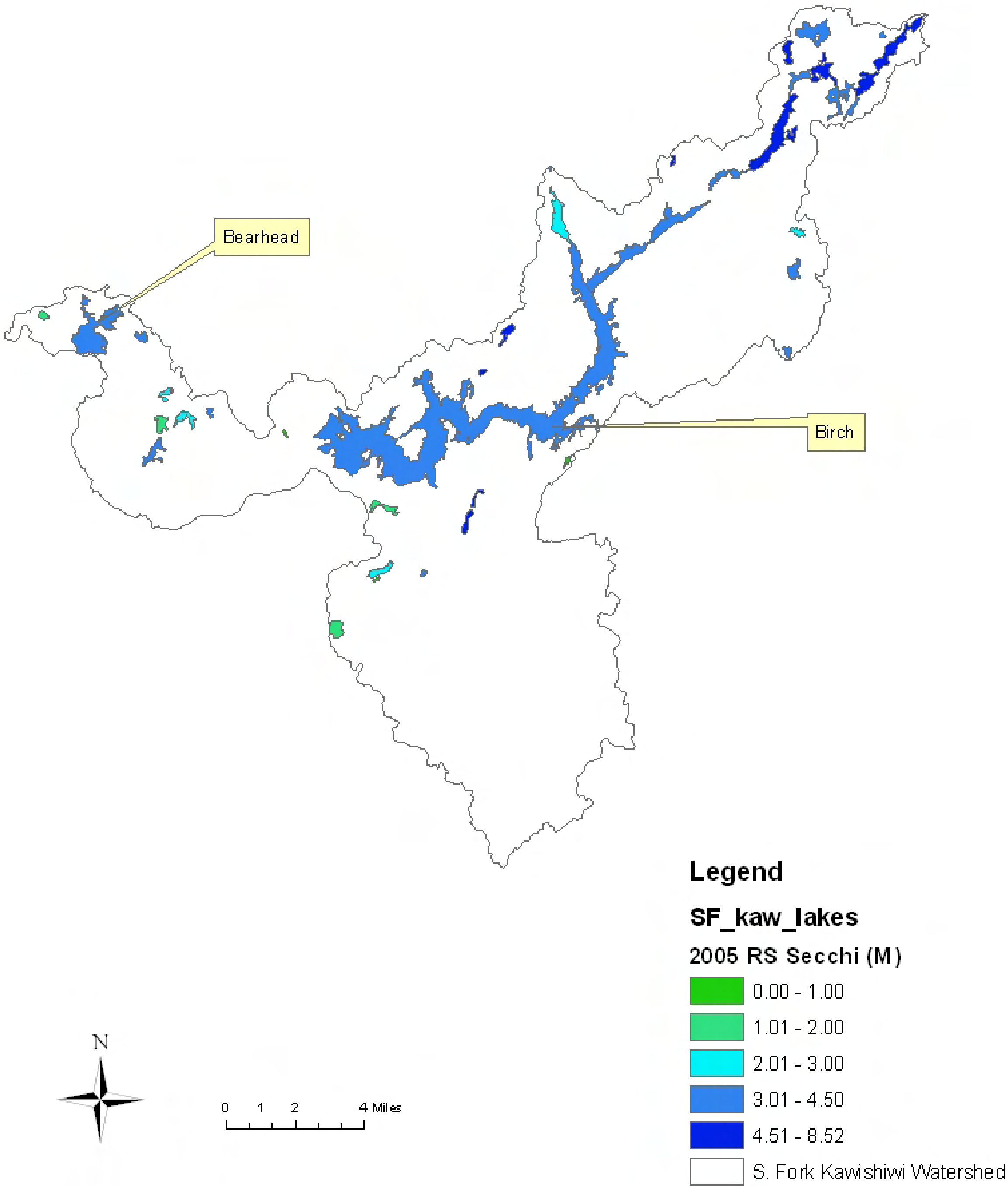
| Ecoregion | TP µg/L | Chl-*a* µg/L | Secchi meters |
|---|---|---|---|
| **NLF – Aquatic Rec. Use (Class 2B)** | **< 30** | **< 9** | **> 2.0** |
| Bearhead Lake (69-0254) | 14 | 7.5 | 2.9 |

RS transparency was estimated on 21 lakes with the HUC-11 watershed (Figure 28, Table 14). No lakes had statistically significant improving or declining trends. A total of four lakes within the BWCAW were assessed as fully supporting. RS SD was over-estimated on Birch and those lakes adjacent to the South Kawishiwi River because of the natural bog staining. The mean RS SD on Birch from 1985-2005 was 3.4 m., while the monitored mean in the assessment cycle was 1.2 m, a substantial difference. The watershed's 2005 mean RS SD was 3.4 m, and ranged from 1.1 m on Arthur Lake to 5.6 m on Crocket Lake. Overall, it is likely that most lakes in the watershed have excellent water clarity given the watershed characteristics discussed above.

**Table 14. South Fork Kawishiwi River RS Secchi assessment and trend summary**

| Number of Lakes with RS SD | 2005 Inferred Mean SD (M) | Number of BWCAW lakes assessed FS | Number of Lakes with improving SD | Number of Lakes with declining SD | Number of Lakes with No Trend |
|---|---|---|---|---|---|
| 21 | 3.4 | 4 | 0 | 0 | 21 |

**Figure 28. 2005 RS Secchi for lakes in the South Fork Kawishiwi River HUC-11 watershed (assessed lakes labeled in yellow)**



## Middle Fork Kawishiwi River HUC-11 Watershed

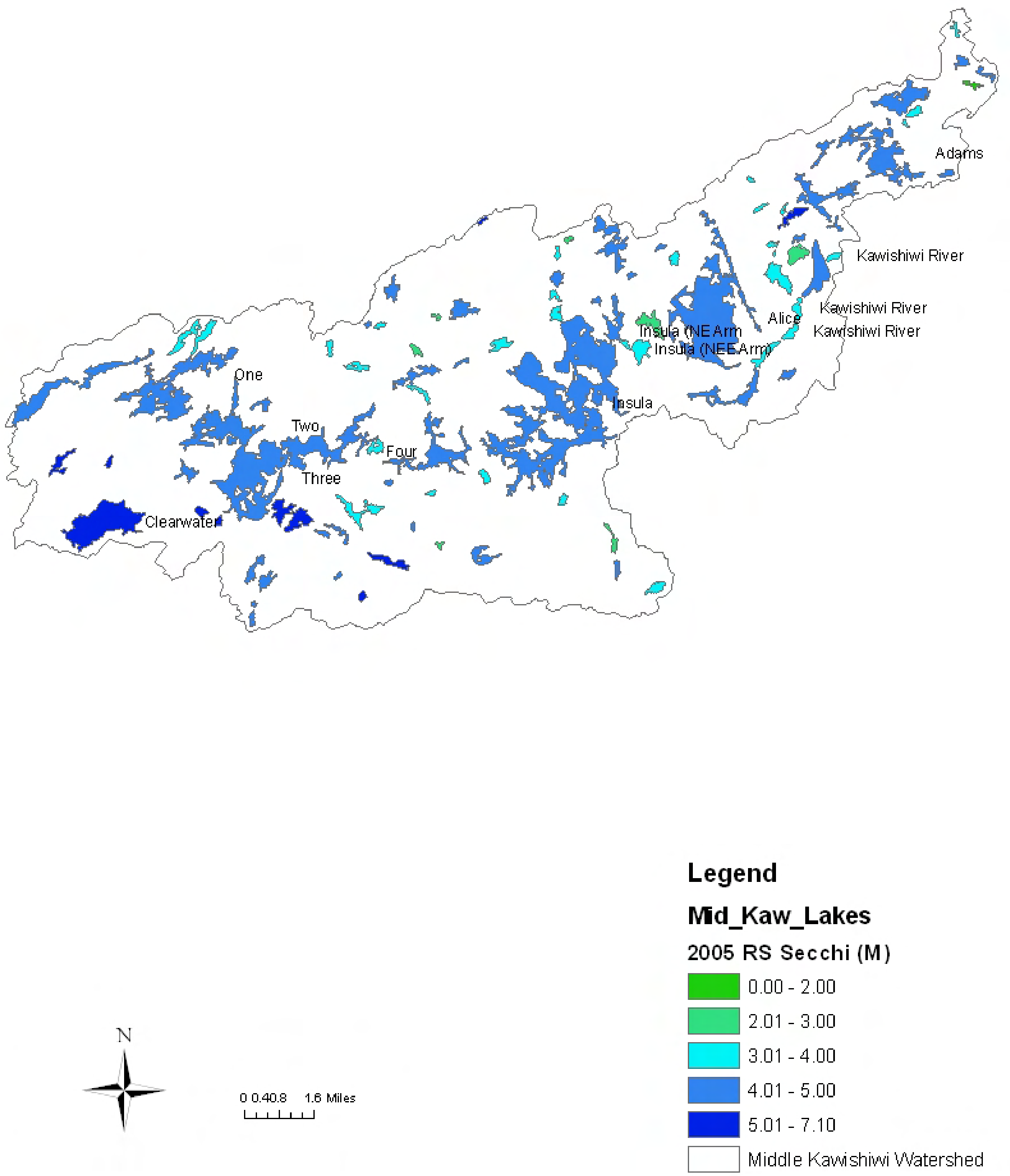
The Middle Fork Kawishiwi River watershed drains 347 $km^2$ (134 $mi^2$) through a lake-dominated region of the BWCAW. This portion of the Kawishiwi is defined from Adams Lake to the River's north-south split downstream of Lake One. The River flows through several large on-channel lakes in this HUC-11 watershed, examples include Insula and Alice (Figure 3, Figure 29). The lower portion of the watershed is a heavily used part of the BWCAW.

The watershed contains 94 lakes greater than 4 ha (10 acres), 80 of these have RS transparency data. Lake monitoring data are sparse, and limited to a few SD measurements on several lakes. No lakes have assessment level data or sufficient CLMP SD data for trends. Based on RS data, water clarity is excellent (highest among all HUC-11 watersheds) and stable, with 69 lakes assessed as FS based on the BWCAW SD criterion (2.4 m), and no lakes exhibiting trends in RS SD (Table 15). 2005 RS Secchi ranged from 2.3 m on Sable Lake to 7.1 m on Clearwater Lake. The HUC-11 RS Secchi results were expected given the influence of the BWCAW.

**Table 15. Middle Fork Kawishiwi River RS assessment and trend summary**

| Number of Lakes with RS SD | 2005 Inferred Mean SD (M) | Number of BWCAW lakes assessed FS | Number of Lakes with improving SD | Number of Lakes with declining SD | Number of Lakes with No Trend |
|---|---|---|---|---|---|
| 80 | 4.2 | 69 | 0 | 0 | 80 |

**Figure 29. 2005 RS Secchi for lakes in the Middle Kawishiwi River HUC-11 watershed**



## Lower Kawishiwi River HUC-11 Watershed

The Lower Kawishiwi River HUC-11 watershed encompasses the area from the Birch Lake outlet to Basswood Lake, although the Kawishiwi River watershed technically ends at the Winton hydroelectric dam when the River enters Fall Lake. The Lower Kawishiwi includes the White Iron Lake watershed - which drains the South Kawishiwi River, and the Farm Lake watershed- which drains the North Fork Kawishiwi watershed. White Iron and Farm Lakes converge into Garden Lake. The River then flows a short distance from the Garden Lake outlet to the Winton Dam and into Fall Lake (Figure 3, Figure 30). Several large lakes in this watershed have assessment level data- including Bear Island, White Iron, Farm, Garden, and Fall. Water quality data from Shagawa and Burntside Lakes (technically outside of the watershed) also are summarized because they are significant and prominent water resources with long term datasets, and are part of the Fall Lake watershed.

The Lower Kawishiwi River drains 512 $km^2$ (198 $mi^2$) and contains 50 lakes greater than 4 ha (10 acres). The landscape is dominated by large lakes including nine greater than 202 ha (500 acres). Several of the large lakes receive high amounts of recreational use due to their proximity to the city of Ely. Lakeshore development- seasonal cabins, year round homes, and resorts - is comparatively high on the large lakes within the White Iron Chain, Shagawa, Fall, and Burntside. Shagawa Lake is the receiving water for Ely's treated wastewater, and as such is one of the most intensely studied lakes in Minnesota (see below). Burntside, the area's largest lake, covers 2,910 ha (7,191 acres) and portions of the lake border the BWCAW. The lake's outlet, the Burntside River, flows into Shagawa Lake.

Bear Island Lake covers 938 ha (2,319 acres) and is located about 15 miles southwest of Ely. It has a relatively large watershed covering 70 $km^2$ (27 $mi^2$) principally draining forests and wetlands. The lake's outlet, the Bear Island River, flows northeast into White Iron Lake. Portions of the southern shore are highly developed, the northern shore is primarily undeveloped and under state or federal management. The lake was monitored by MPCA staff in 2008 and 2009. One site was sampled, located west of Bear Island at the lake's maximum depth (18 m). Summer mean TP, Chl-a, and SD values for 2008 and 2009 are shown in Figure 31. Water quality conditions were similar both years. Chl-a concentrations were slightly higher in 2009, due to relatively high concentrations (10 and 12 µg/L) in July and September. However, no algal blooms were identified either year. Water clarity is moderately influenced by natural bog staining; clarity averaged 1.7 and 2.1 m in 2008 and 2009 respectively. The lake was thermally stratified by June both years; during stratification hypolimnetic TP concentrations were higher than those in the epilimnion, which is normal.

**Figure 30.** **Flow path within the Lower Kawishiwi River watershed (assessed & intensely monitoring lakes labeled in red)**

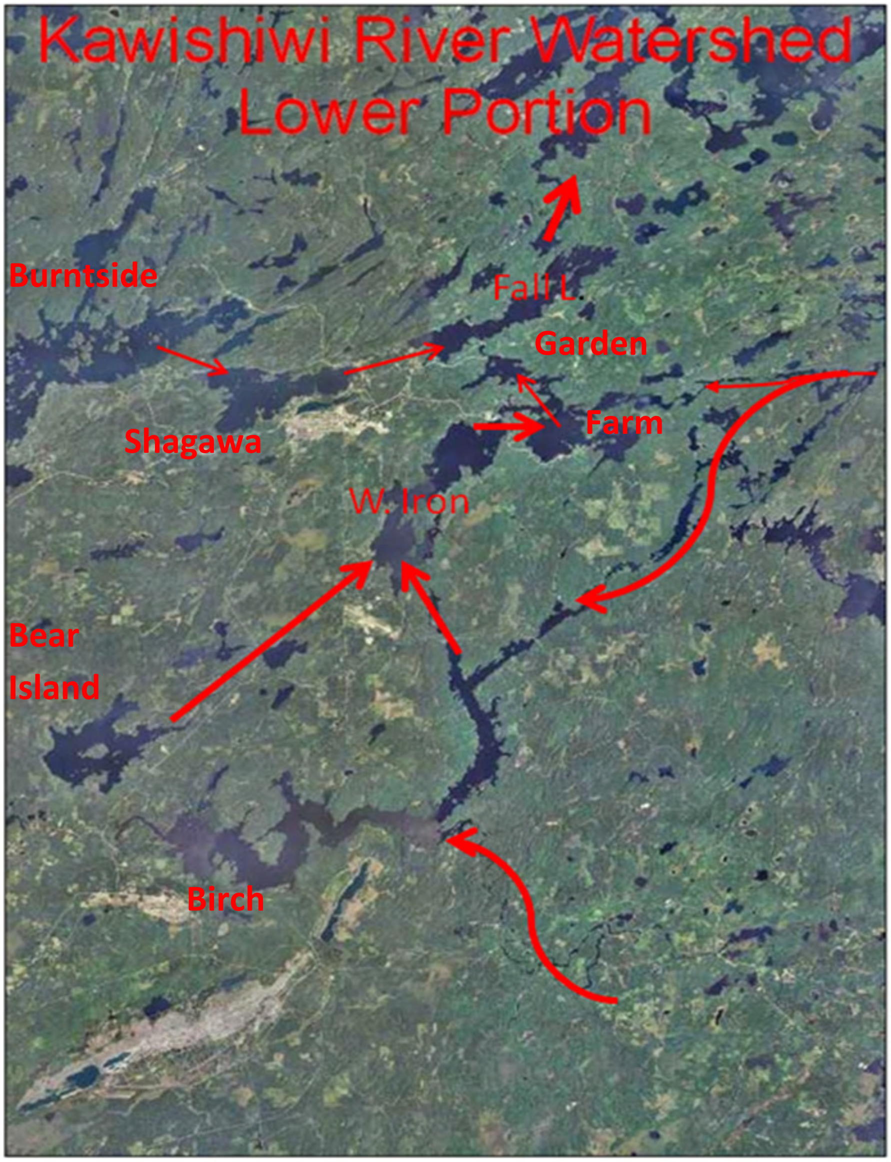
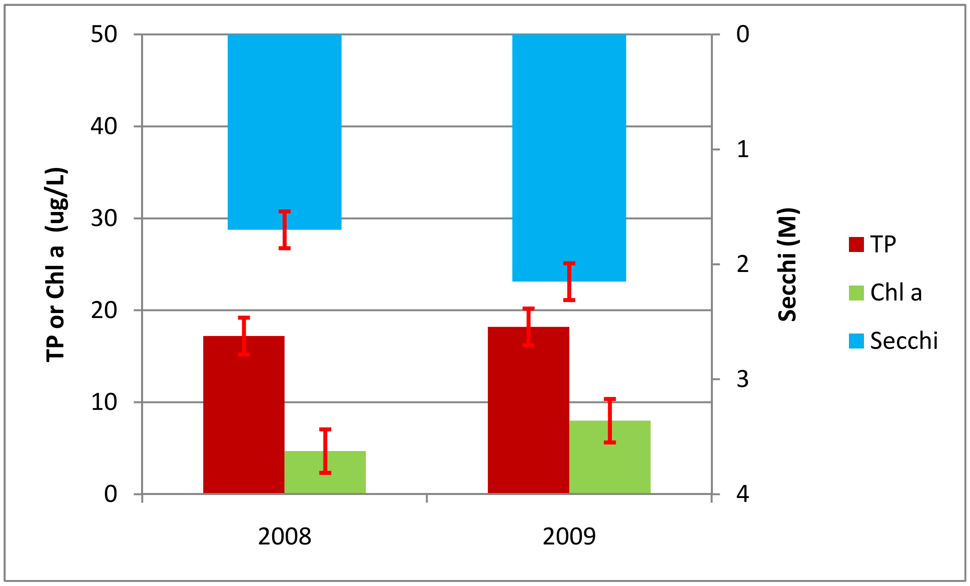


**Figure 31. Bear Island Lake 2008 and 2009 TP, Chl-a, and SD data**




The MINLEAP model was utilized for Bear Island Lake on the average of 2008 and 2009 TP, Chl-a, and SD values. Complete modeling results can be found in Appendix B. MINLEAP's predicted TP and Chl-values were lower than observed, but are not statistically different. SD values were over-predicted by the model. MINLEAP does not account for the bog-stained water observed in the lake. MINLEAP predicted a P loading rate of 559 kg/yr, and a residence time on the order of four-five years.

**Table 16. NLF ecoregion eutrophication criteria and assessment cycle mean values for Bear Island Lake**

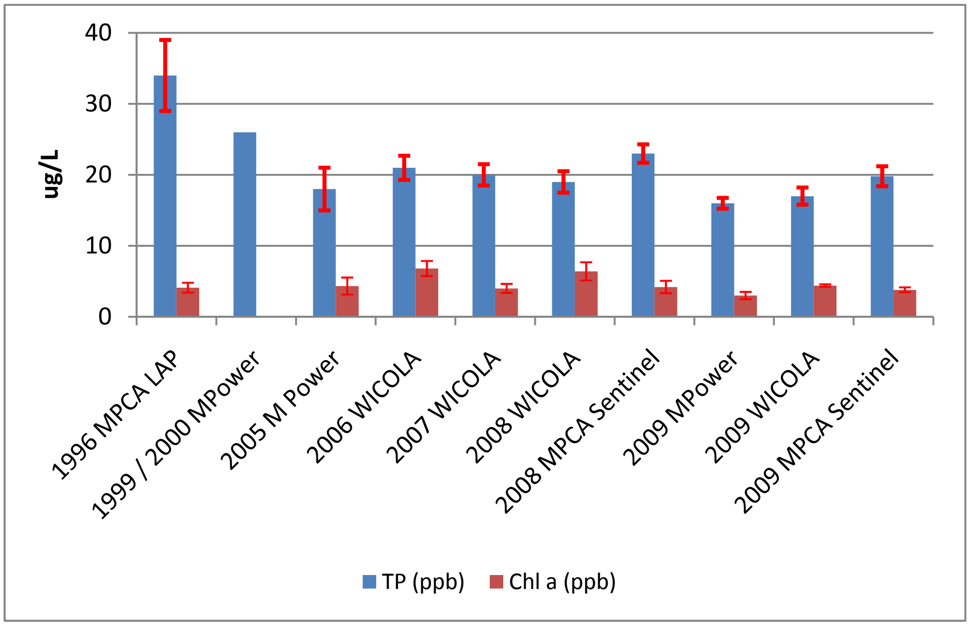
| **Ecoregion** | **TP**<br>**µg/L** | **Chl-*a***<br>**µg/L** | **Secchi**<br>**meters** |
|---|---|---|---|
| **NLF – Aquatic Rec. Use (Class 2B)** | **< 30** | **< 9** | **> 2.0** |
| Bear Island Lake (69-0115) | 17 | 6.3 | 1.9 |

Based on 2008 and 2009 monitoring results, Bear Island Lake is classified as a mesotrophic lake. Additionally, based on the TP, Chl-a, and Secchi transparency assessment standards, Bear Island Lake was determined to be fully supporting of aquatic recreational use, and meeting eutrophication criteria (Table 16). As discussed previously, the low SD transparency is due to natural bog staining from the surrounding watersheds, and not in response to elevated Chl-a concentrations.

White Iron Lake covers 1,310 ha (3,238 acres) and is located near the center of the Lower Kawishiwi watershed. White Iron has been monitored historically by the MPCA, WICOLA, Superior National Forest, MDNR, and MP. A detailed Sentinel lake report on White Iron can be found here. http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/lakes/lake-water-quality/sentinel-lakes.html.

A summary of those findings are included in this report for contextual purposes. Intensive water quality monitoring (TP and Chl-a sampling) occurred in 1995-96, and from 2005-2009 (WICOLA, MPCA, and Minnesota Power data). TP and Chl-a results are summarized in Figure 32. These data show stable concentrations of TP and Chl-a in White Iron. Summer-mean TP and Chl-a are consistently near 20 and 5 µg/L respectively, and standard errors are low. These data point to stable water quality over the last few years, with perhaps a slight decline in TP since the 1990s. The Secchi dataset on White Iron is very strong with 20 - 40+ measurements taken annually since 1994. WICOLA volunteers should be commended for their volunteer monitoring efforts. The long-term mean is approximately 1.6 m and trends show an overall improvement in transparency. Transparency cycles were previously documented and are thought to be influenced by natural variability, climate change, water levels, reservoir operations, and related causes.

**Figure 32. Trends in TP and Chl-a concentrations in White Iron Lake**




The recent monitoring conducted by WICOLA volunteers allows water quality comparisons between White Iron and the other downstream lakes in the chain (Farm, South Farm, and Garden). These three lakes are essentially at the same reservoir elevation, and water levels are heavily influenced by Kawishiwi River streamflows and hydropower management at the Winton Dam. The lakes have a very large watershed (3,154 $km^2$ or 1,218 $mi^2$), which results in a rapid resident time, estimated at 30-50 days. Farm, South Farm, and Garden have similar morphology, with max depths in their largest basins near 10-15 m, and navigable channels connecting the lakes. The North Kawishiwi River enters into the northern portion of Farm Lake (Figure 30). South Farm Lake flows into and is located east of Farm Lake, and is isolated from the North Kawishiwi River. Garden Lake, covering 256 ha (635 acres), is the most downstream lake in the reservoir system. It is deeper and smaller than the other lakes in the chain.

WICOLA has collected transparency data since 1994 on the White Iron chain of lakes. In 2005, they expanded monitoring efforts to include water quality sampling (TP, Chl-a, and sonde profiles), under a partnership with the MPCA. Monitoring began on Garden Lake and was expanded to White Iron and Farm in 2006. TP and Chl-a data collected by WICOLA in White Iron, Farm, and Garden Lakes is shown in Figures 33 and 34. TP and Chl-a concentrations have been quite consistent among years and within lakes, ranging from 15-20 and 4-7 µg/L respectively. The relatively stable water quality was maintained despite variability in climate and runoff conditions. For example, some years were near normal (2005 & 2009), others much drier (2006) and wetter (2007) than average.

In 1996 WICOLA partnered with the MPCA to conduct a lake assessment on White Iron, Farm, and Garden. TP and Chl-a concentrations in 1996 (not shown, see MPCA, 1996) were slightly higher, but not significantly different, than the more recent data.

**Figure 33. Recent TP trends in White Iron, Farm, and Garden Lakes (WICOLA data)**

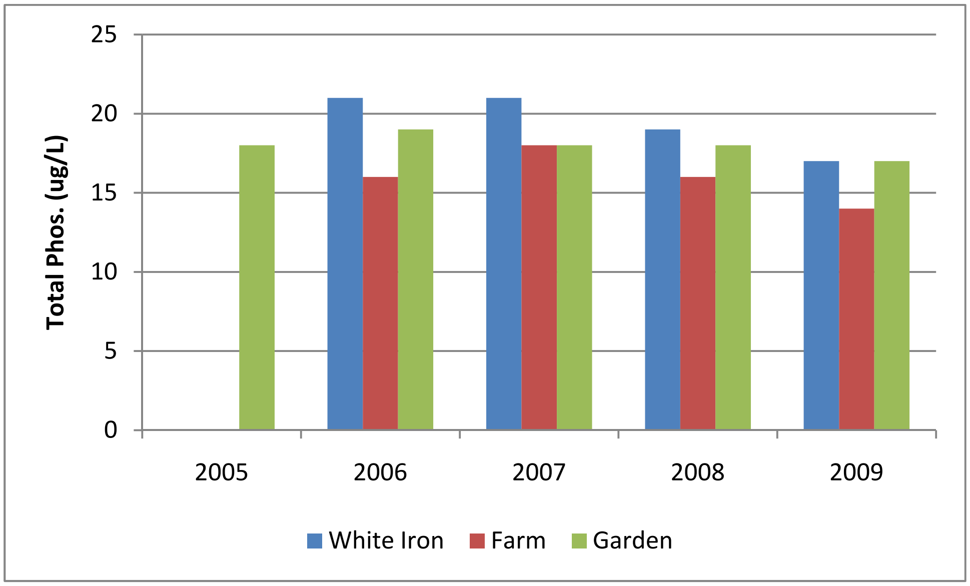
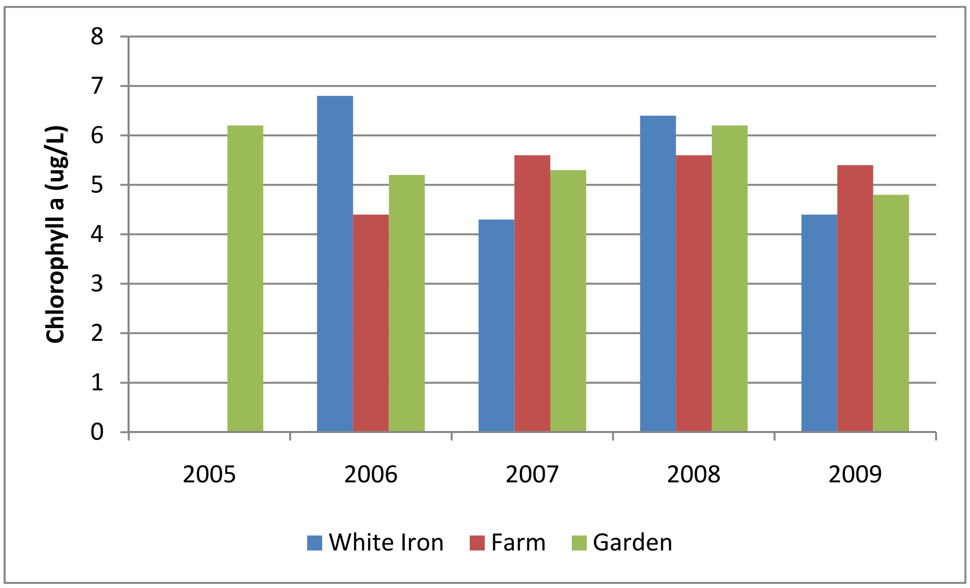
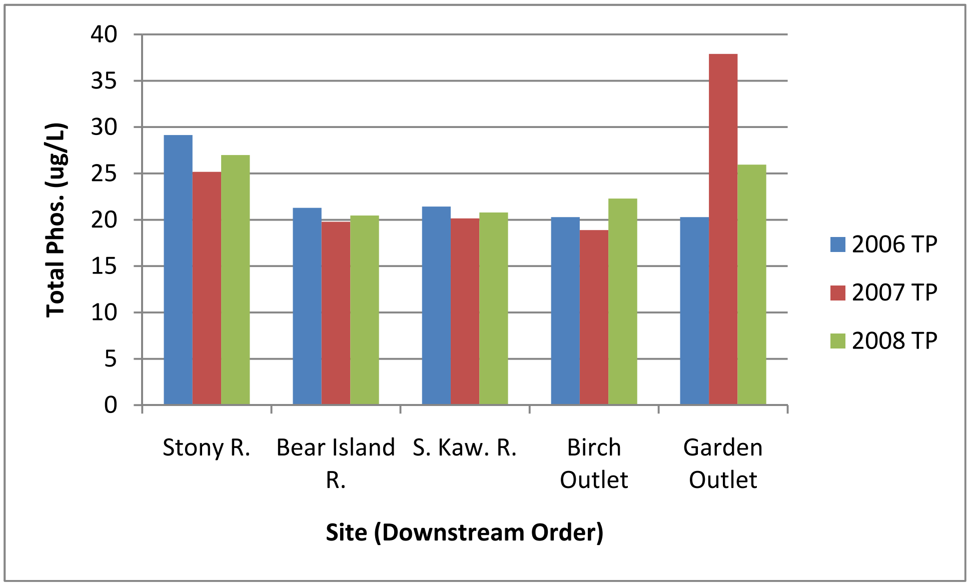



**Figure 34. Recent Chl-a trends in White Iron, Farm, and Garden Lakes (WICOLA data)**




To supplement the lake monitoring, MPCA staff sampled water quality in the Kawishiwi River and other smaller tributaries to the chain of lakes. Monitoring was conducted twice per month from May - September from 2006 to 2008. Stony River is a tributary to Birch (upstream of White Iron), and Bear Island is a tributary to White Iron. The South Kawishiwi River upstream and downstream of Birch Lake and the Kawishiwi at the Garden Lake outlet were also sampled. These data are shown in Figure 35. Similar to the in-lake concentrations, tributary TP concentrations were also quite stable near 20 µg/L. Elevated concentrations in Garden in 2007 are due to one outlier (187 µg/L). TP concentrations were slightly elevated in the Stony River. This portion of the Stony, just downstream from Slate Lake, is heavily influenced by wetlands and natural bog staining.

**Figure 35. TP concentrations in large streams in the lower Kawishiwi River watershed (MPCA data)**

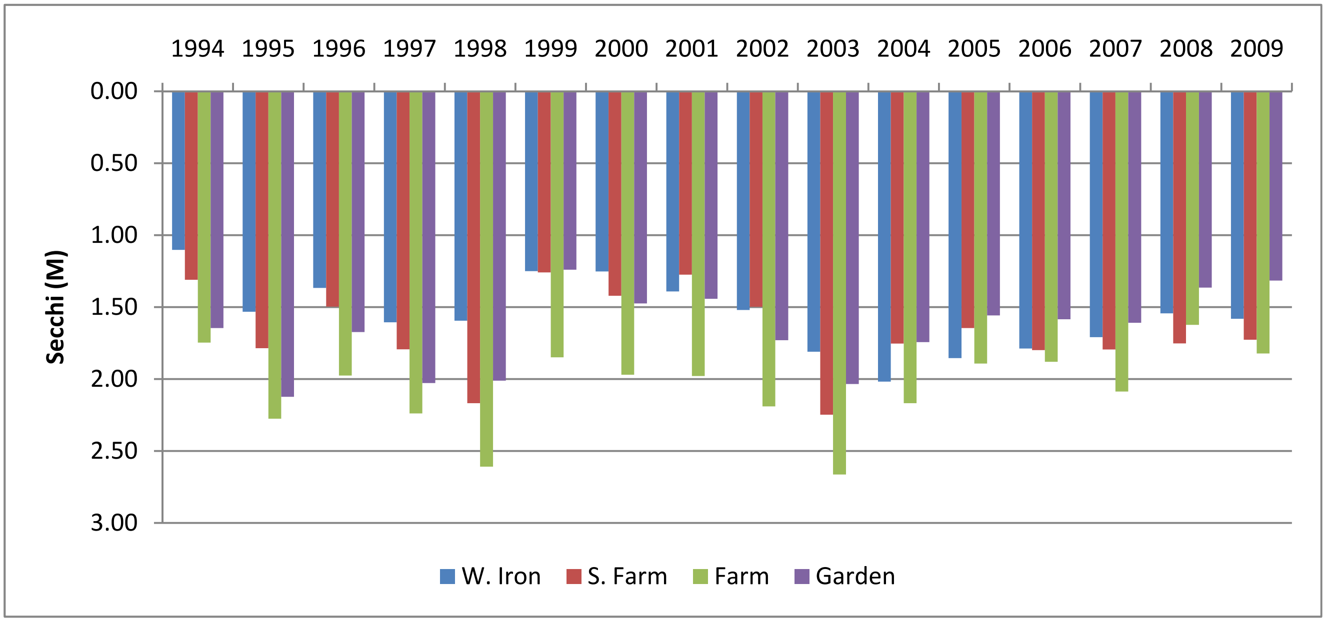



Historical data collected from two of the watershed's long-term stream monitoring stations, the USGS' North Kawishiwi streamflow gage and the MPCA Milestone River Monitoring site at the South Kawishiwi River/ Birch Lake Outlet were compared to the recent tributary monitoring. The geometric mean TP concentration at the USGS site (1970-1995) was 16 µg/L, versus 26 µg/L at the Milestone site (1967 – 2005). These values are similar to concentrations in area lakes and reflect influences of their perspective watersheds and sampling locations. The North Kawishiwi site is more riverine in nature, and downstream of several bedrock lake basins within the BWCAW. The slightly higher TP concentrations coming out of Birch Lake reflect the influence of the Lake's wetland dominated watershed (increased color and dissolved organics), and in-lake processes immediately upstream of the sampling site. Long-term trends at the Milestone site show statistically significant ($p < .01$) declines in both TP and total suspended solid concentrations from 1967-2008 (Dave Christopherson, MPCA). The cause of this trend needs to be further investigated. It may be related to improved analytical techniques, or increased monitoring in the last decade, since it's reasonable to assume land use has remained stable in this time frame.

The long-term SD dataset from the White Iron chain of lakes is shown in Figure 36. Data have been collected since 1994 on all lakes, sufficient for trend determinations. WICOLA volunteers should be commended for their monitoring efforts. A statistically significant decline in transparency was detected in Farm and Garden, while no trends were found in South Farm. The decline on Farm and Garden was minimal, estimated at 0.3 m (one foot) per decade. The cause of the decline needs further study; given the stability in both Chl-a concentrations (well below those levels that cause mild blooms in the NLF ecoregion) and watershed land-cover. SD trends on South Farm are stable, likely because the lake is within the BWCAW. Continued long-term SD monitoring is essential to determine if these trends are due to natural variability, climate change, water levels and river flows, reservoir operations, or other causes.

Transparency is slightly higher on Farm compared to other lakes in the White Iron chain (Figure 36), although all lakes have low transparency due to natural bog staining. The North Fork of the Kawishiwi River enters Farm Lake, and heavily influences transparency. Upstream lakes in this watershed have clearer water and less bog-staining. The 1996 MPCA lake assessment found color averaged ~ 100 Pt-co units in White Iron and Garden, while only 60 on Farm. Additionally, upstream lakes in the North Kawishiwi Watershed, such as One, Two, and Three Lakes have measured transparencies near 3 m. Large lakes within the South Kawishiwi drainage have monitored transparencies between 1.5 to 2.0 m.

**Figure 36. CLMP Secchi trends within the White Iron chain of lakes**




Mid-summer DO and temperature profiles indicate that Farm and White Iron are polymictic. During periods of warm, calm weather stratification can occur, but given the lake's very short residence times and large fetches, polymictic conditions are most likely to be observed. Garden is the deepest lake in the reservoir system (max. depth = 16.7 m); it was stratified mid-summer with a developed thermocline at approximately 7 m. All three lakes were well oxygenated in the epilimnion. Surface concentrations exceeded 5 milligrams per liter (mg/L), levels needed to sustain warm and cool water fisheries, and concentrations only fell below 5 mg/L within 0-2 m of the lake bottom.

The MINLEAP model was utilized separately for White Iron and the Garden Lake Reservoir. For White Iron the average of 2008-09 MPCA Sentinel lake data were used as model inputs. For the Garden Lake Reservoir, the average of WICOLA's 2005-2009 data from Farm, South Farm, and Garden were used as model inputs. For White Iron, TP inflows were set at 25 µg/L based on MPCA monitoring data from Birch Lake. TP inflows on the Garden Lake Reservoir were also set at 25 µg/L based on data collected on the North and South Branch of the Kawishiwi River. Complete modeling results can be found in Appendix B.

For White Iron, MINLEAP's predicted TP and Chl-a values were very close to observed. SD values were over-predicted by the model (observed = 1.5 m; predicted = 2.8 m), but not statistically different. MINLEAP does not account for the bog-stained water observed in the lake, and was not designed to model conditions in lakes with very short residence times. MINLEAP predicted a P loading rate of 14,061 kg/yr, and a residence time of 0.1 years (~ 40 days) reflecting the influence of the lake's large watershed.

For the Garden Lake Reservoir, MINLEAP's predicted TP and Chl-a values were also close to observed and SD values were over-predicted by the model, but not statistically different. MINLEAP predicted a P loading rate of 18,290 kg/yr. This value approximates the TP load for the entire Kawishiwi watershed, because the Kawishiwi River only travels an additional 0.8 km (0.5 miles) downstream of Garden Lake to the watershed's outlet at the Winton Dam. Estimated residence times are slightly lower than White Iron (~ 30 days) because the Reservoir's watershed is approximately 30 percent larger and its area is 25 percent smaller than White Iron's (mean depths are similar).

Based off the 2000 - 2009 monitoring results White Iron, Farm, and Garden are classified as mesotrophic lakes. Additionally, based on the TP, Chl-a, and Secchi transparency assessment standards, the lakes were determined to be fully supporting of aquatic recreational use, and meeting eutrophication criteria (Table 17). As discussed previously, the low SD transparency is due to natural bog staining from the surrounding watersheds, and not in response to elevated Chl-a concentrations. In summary, water quality within the White

Iron Chain of Lakes can be considered good, meeting eutrophication criteria, relatively stable and similar among lakes, and reflective of the Kawishiwi River's land cover and hydrology.

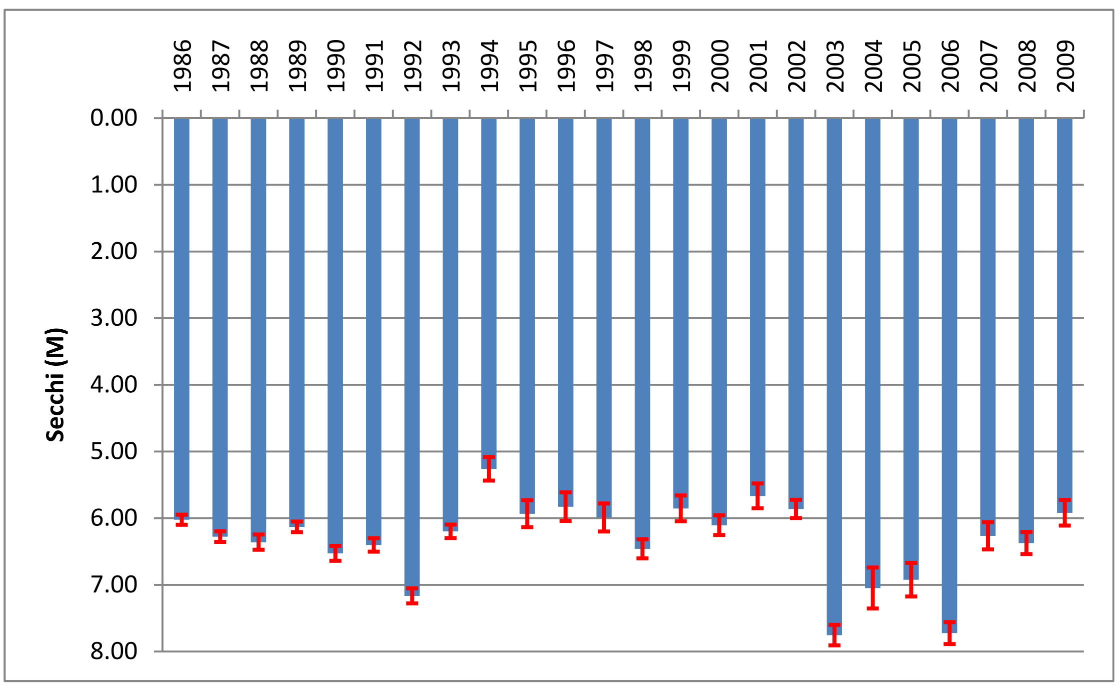
**Table 17. NLF ecoregion eutrophication criteria and assessment cycle mean values for White Iron, Farm, and Garden Lakes**

| | TP µg/L | Chl-*a* µg/L | Secchi meters |
|---|---|---|---|
| **NLF – Aquatic Rec. Use (Class 2B)** | **< 30** | **< 9** | **> 2.0** |
| White Iron Lake (69-0004) | 20 | 5.2 | 1.6 |
| Farm Lake (38-0779) | 17 | 4.8 | 2.0 |
| Garden Lake (38-0782) | 18 | 6.1 | 1.6 |

Burntside Lake covers 2,910 ha (7,191 acres), and is located five miles northwest of the city Ely. The lake drains 11,904 ha (29,416 acres) of primarily forested land. It is a prominent lake in the vicinity for several reasons: it serves as the drinking water source for Ely, borders the BWCAW and is classified by the State of Minnesota as an Outstanding Resource Value Water, and is a popular recreational lake. Most of the development is along the southern shore. Burntside is a deep oligotrophic lake that has a natural cold water fishery (lake trout). The lake's maximum and mean depths are 48 m (157 ft) and 13.7 m (45 ft) respectively. The lake is characterized by steep bedrock shorelines, and numerous islands. Its outlet, the Burnside River, is a significant tributary to Shagawa Lake.

Burntside was not sampled in the current assessment cycle; however, there is a long-term SD record with measurements taken since 1986 by CLMP and Burnside Lake Association volunteers. The MPCA collected water quality samples in 1994 as part of a lake assessment (with the Association), and in 1986 and 1988 (Burntside was a NLF ecoregion reference lake). Long-term SD data are shown in Figure 37. Long-term summer-mean transparency is 6.3 m. No trends in transparency were detected, and annual variability is low. The long-term (1986,1988, 1994) mean TP and Chl-a concentrations are 11 and 2 µg/L, respectively, indicating oligotrophic conditions.

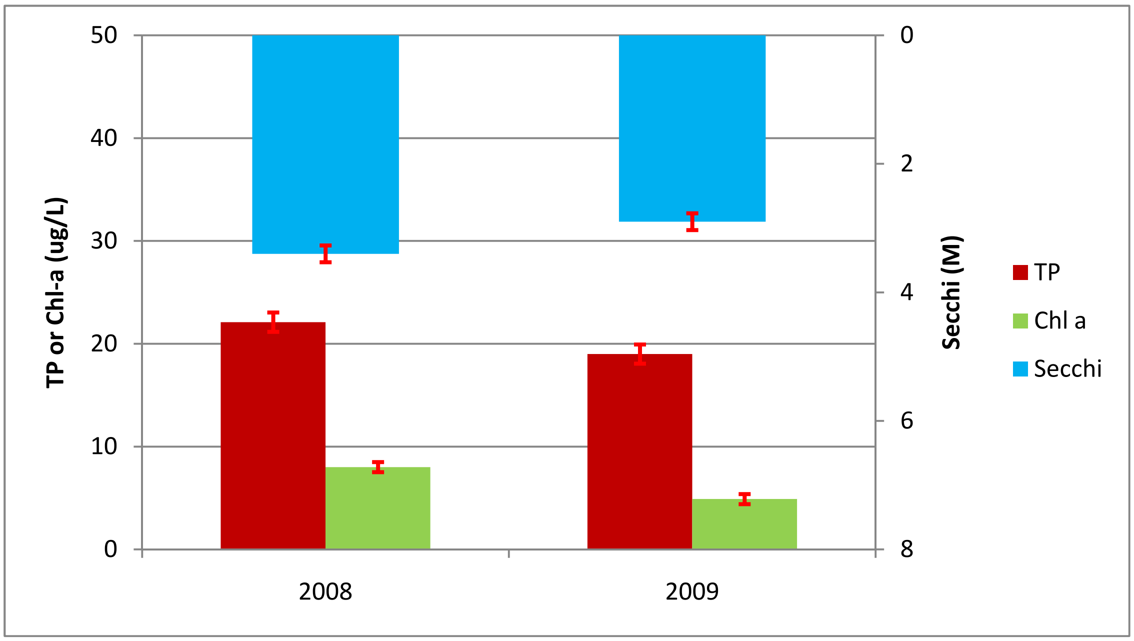
**Figure 37. Burntside Lake CLMP Secchi trends**



Shagawa Lake covers 936 ha (2,314 acres) and is located at the city of Ely. Shagawa is moderately deep - with maximum and mean depths of 14.6 m (48 feet) and 5.6 m (18.5 feet) respectively. The Shagawa River exits on Shagawa's eastern shore and flows east to Fall Lake. Ely discharges its treated wastewater into Shagawa. The MPCA completed a Lake Assessment study on Shagawa Lake in 1988 in conjunction with the Lake Association. MPCA and the Association continued monitoring the lake in the 1990's in order to track water quality trends as a result of tertiary treatment of Ely's wastewater in the 1970's (MPCA, 1999).

The MPCA monitored the lake in 2008 and 2009, sampling the two long term stations in the center and eastern basins (depth ~ 14 m or 45 feet). TP, Chl-a, and SD data are shown in Figure 38. They represent the mean values from the two sites, since variability between the sites was minimal. TP and SD data were similar among years. Chl-a concentrations were slightly higher in 2008, due to the influence of one sample likely taken during a mild bloom in August (14.9 µg/L). The maximum 2009 concentration was only 5.5 µg/L. Annual variability, as measured by the standard error, was much lower in 2009 (0.2 µg/L), versus 1.7 µg/L in 2008.

**Figure 38. 2008 and 2009 TP, Chl-a, and SD data for Shagawa Lake**




Shagawa has an extensive historical water quality dataset. The lake has been monitored since the 1960s to study the impact of Ely's wastewater discharge to the lake. The EPA conducted intensive lake monitoring in the early 1970s to track the lake's response to improvements to Ely's wastewater treatment plant in 1973 - when the plant was upgraded to remove phosphorus (see Larsen et. al, 1975, and Schults et. al., 1976). The long term TP, Chl-a, and SD data are shown in Figure 39. The gradual decline in TP and Chl-a, and resulting increase in SD transparency (~ 1.5 m) are evident. The upgrade to the wastewater treatment plant resulted in a 70 percent reduction in TP load to Shagawa during 1973-74 (Larsen et. al., 1975). Before the wastewater upgrade, it was estimated that the plant accounted for 81 percent of the lake's TP load from 1967-1972 (Larsen et. al., 1975). In 2009, the TP contribution from the wastewater plant was down to 98 kg (with an annual average TP *concentration* of 110 µg/L; MPCA Delta database). As such, wastewater's contribution was estimated at just 5.7 percent of the lake's total TP load (Table 18), reflecting further improvements to wastewater treatment and the lake's continued recovery from cultural eutrophication.

**Table 18. Treated wastewater's contribution to Shagawa Lake's TP load before and after upgrades (Larsen, et. al., 1975; and MPCA data)**

| Year | Ely's wastewater load (kg) | Estimated total lake TP Load (kg) | Percent contribution from treated wastewater |
|---|---|---|---|
| 1967-1972 average | 5,380 | 6,690 | 81 |
| 1973 | 543 | 2,139 | 25 |
| 2009 | 98 [1] | 1,600 [2] | 5.7 |

1. Calculated from the MPCA Delta database from an average measured daily wastewater load of 0.268 kg/day (0.11 mg/L)

2. Estimated from MINLEAP model using an average TP inflow of 25 ug/L

Seasonal TP and Chl-a concentrations from the early 1970's in Shagawa and adjacent Burntside Lake are shown in Figure 40 (Larsen, et. al., 1975). The elevated concentrations in Shagawa, peaking in late summer, are clearly evident. Chl-a concentrations peaked near 50 µg/L in the 1970's; in the 1990's annual maximum values still were near 40 µg/L. By 2008-09, peak Chl-a was down to 14 µg/L. Nuisance blooms were evident based on the Chl-a concentrations and observations recorded during the historical monitoring (MPCA, 1969; Larsen et. al, 1975; Schults et. al., 1976). Late summer peak TP concentrations in Shagawa were still quite elevated shortly after the wastewater upgrade (~ 80 µg/L). After the upgrade, the lake entered into a period of TP washout, and the increase in TP concentrations was attributed to an increase in ortho-phosphorus released from the lake sediments (Larsen, et. al, 1975). This internal load of P released from a reservoir within the sediment can significantly delay water quality improvements. TP and Chl-a concentrations in 1972 from nearby (upstream) oligotrophic Burntside lake were consistent near 10 and 2 µg/L respectively (Figure 40); these concentrations were similar to those measured in the lake by MPCA in the 1980's and 1990's.

The MINLEAP model was utilized on Shagawa based using the average of the 2008-09 MPCA data as model input. TP inflows were set (i.e. estimated) at 25 µg/L, using the authors' best professional judgment. This value balances the contribution from the oligotrophic Burntside Lake (concentrations likely near 10 ug/L) which provides 70 percent of Shagawa's inflow (Larsen, et. al., 1975), with higher TP concentrations entering Shagawa from urban sources (stormwater, lakeshore developments, and treated wastewater). MINLEAP's predicted TP and Chl-values were lower than observed, but not statistically different. MINLEAP predicted a P loading rate of 1,606 kg/year, and a residence time of 0.9 years which are similar to those measured by the EPA in the 1970's. Complete modeling results can be found in Appendix B.

Based on 2008 - 2009 monitoring results Shagawa is classified as a mesotrophic lake. Additionally, based on the TP, Chl-a, and Secchi transparency assessment standards, the lake was determined to be fully supporting of aquatic recreational use, and meeting all eutrophication criteria (Table 19). As discussed above, significant improvements in wastewater treatment have dramatically improved water quality since the 1970s.

**Figure 39. Trends in TP and Chl-a concentrations in Shagawa Lake**

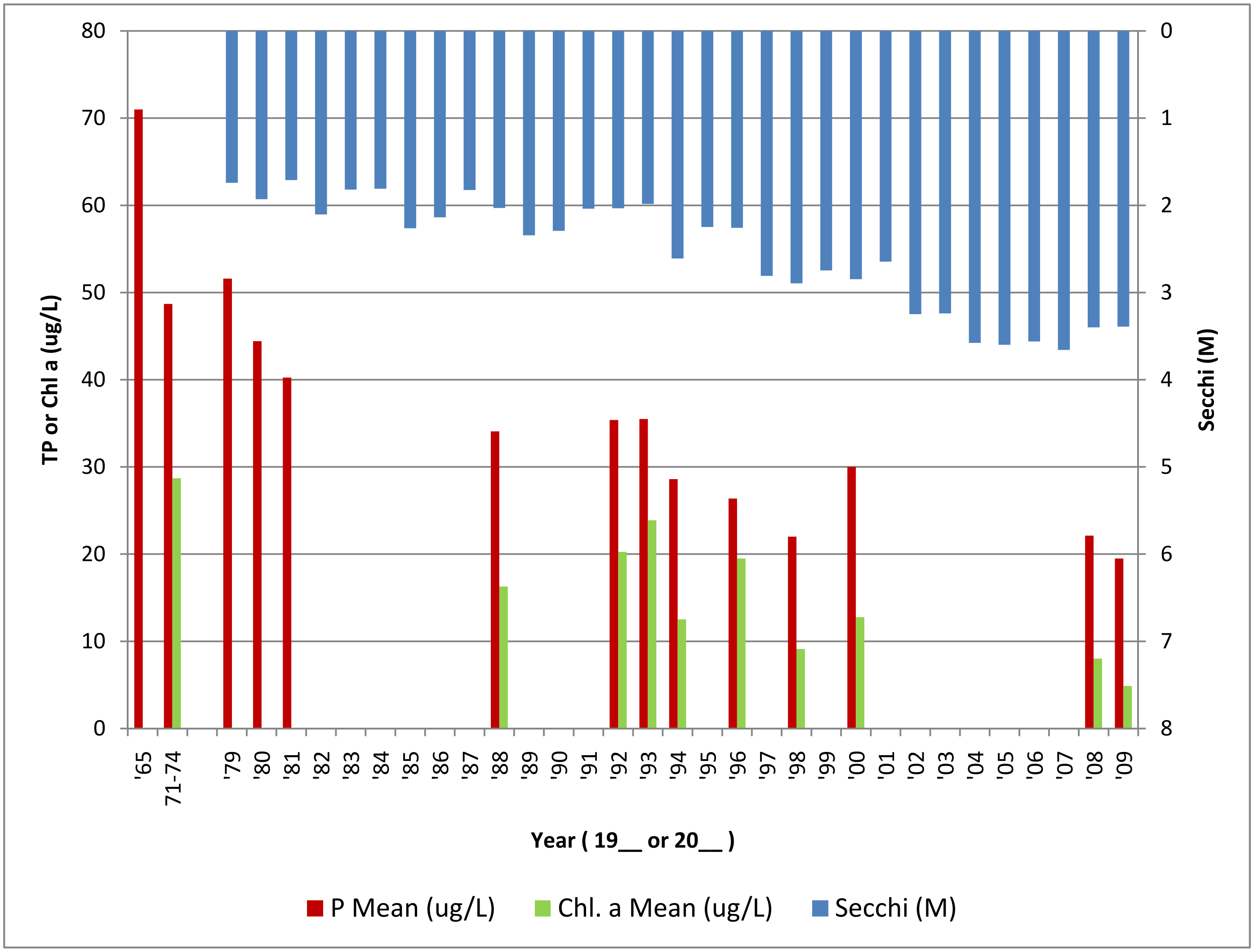
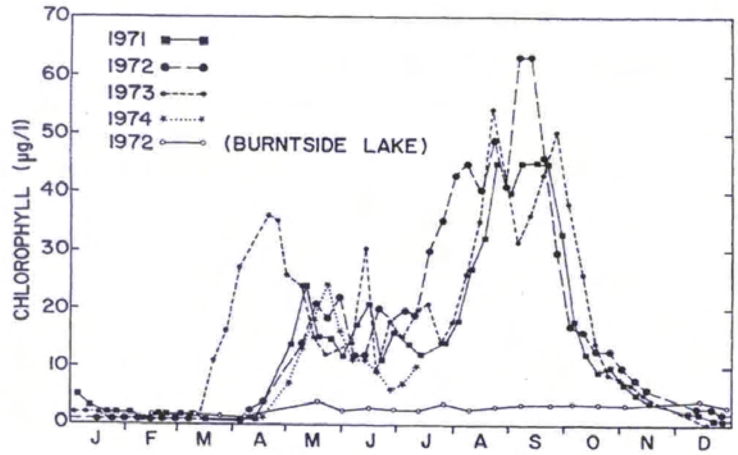


**Figure 40. Historical concentrations of TP and Chl-a in Shagawa and Burntside Lakes (from Larsen et. al., 1975)**



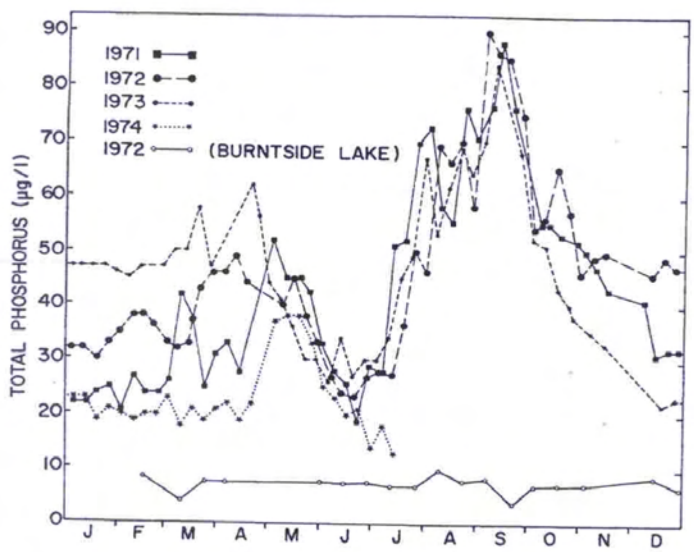



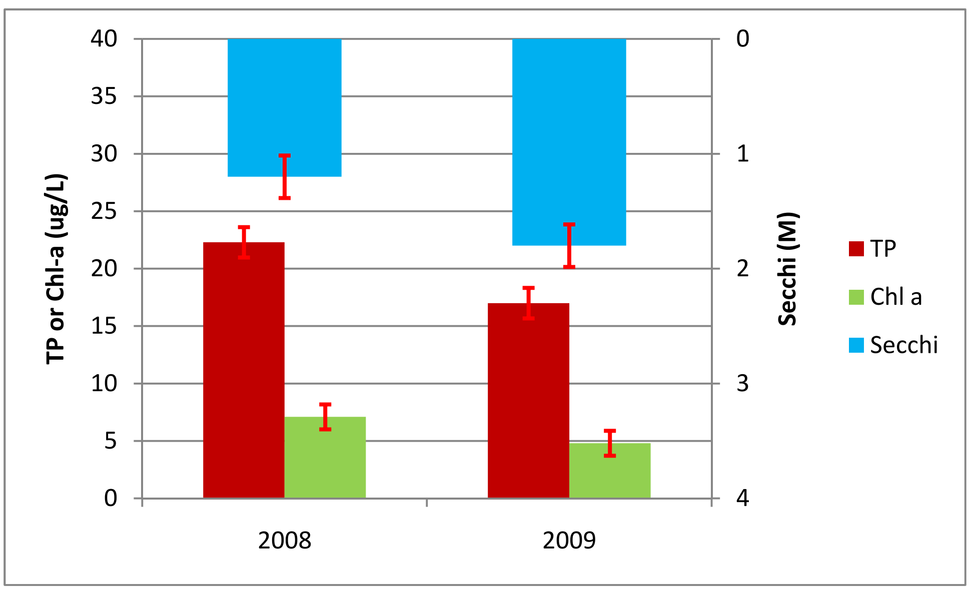
**Table 19. NLF ecoregion eutrophication criteria and assessment cycle mean values for Shagawa Lake**

| Ecoregion | TP<br>µg/L | Chl-*a*<br>µg/L | Secchi<br>meters |
|---|---|---|---|
| **NLF – Aquatic Rec. Use (Class 2B)** | **< 30** | **< 9** | **> 2.0** |
| Shagawa Lake (69-0069) | 21 | 6.4 | 3.2 |

Fall Lake (38-0811), located at the community of Winton east of Ely, is the outlet of the Kawishiwi River watershed. It drains a very large watershed (3,491 $km^2$ or 1,348 $mi^2$). The Kawishiwi is the lake's major inlet, providing approximately 90 percent of the flow into the lake; other inlets include the Shagawa River and Fall Creek. Lake levels are controlled by dams at both the major inlet (Kawishiwi River at Winton) and outlet (Newton Falls dam). Fall is one of the largest lakes in the watershed, covering 913 ha (2,258 acres). It has a large fetch and few islands, and is relatively shallow with a mean depth of 4 m (13 feet) and a maximum depth of 9.7 m (32 feet). Fall is heavily used as a recreational lake. The northeastern portion is within the BWCAW, and a very popular Superior National Forest campground is located on the southern shore near the wilderness boundary. Lakeshore development is relatively high- particularly the residences and resorts around the community of Winton at the western end of the lake.

Fall Lake was sampled by MPCA staff in 2008 and 2009. One site was monitored, located in the center of the basin at a depth of 9 m (30 feet). Figure 41 shows the 2008 and 2009 TP, Chl-a, and SD data. TP, and Chl-a concentrations were slightly higher (and SD slightly lower) in 2008 but not statistically different. Water quality in Fall is very similar to the upstream lakes within the White Iron Chain. Chl-a concentrations and SD transparency were low, heavily influenced by the bog-stained Kawishiwi River. Fall is a polymictic lake, and was only marginally stratified during mid-summer.

**Figure 41. 2008 and 2009 TP, Chl-a, and SD data on Fall Lake**




The MINLEAP model was utilized on Fall Lake by using the average of the 2008-09 MPCA data as model inputs. TP inflows were set at 30 µg/L, which was slightly higher than levels found in upstream lakes. MINLEAP's predicted TP, and Chl-a values were slightly higher than observed, but not statistically different. The model predicted a P loading rate of 24,227 kg/yr, reflective of the lake's very large watershed. Residence time is very rapid, estimated at 0.1 years (~ 20 - 30 days). Complete modeling results can be found in Appendix B.

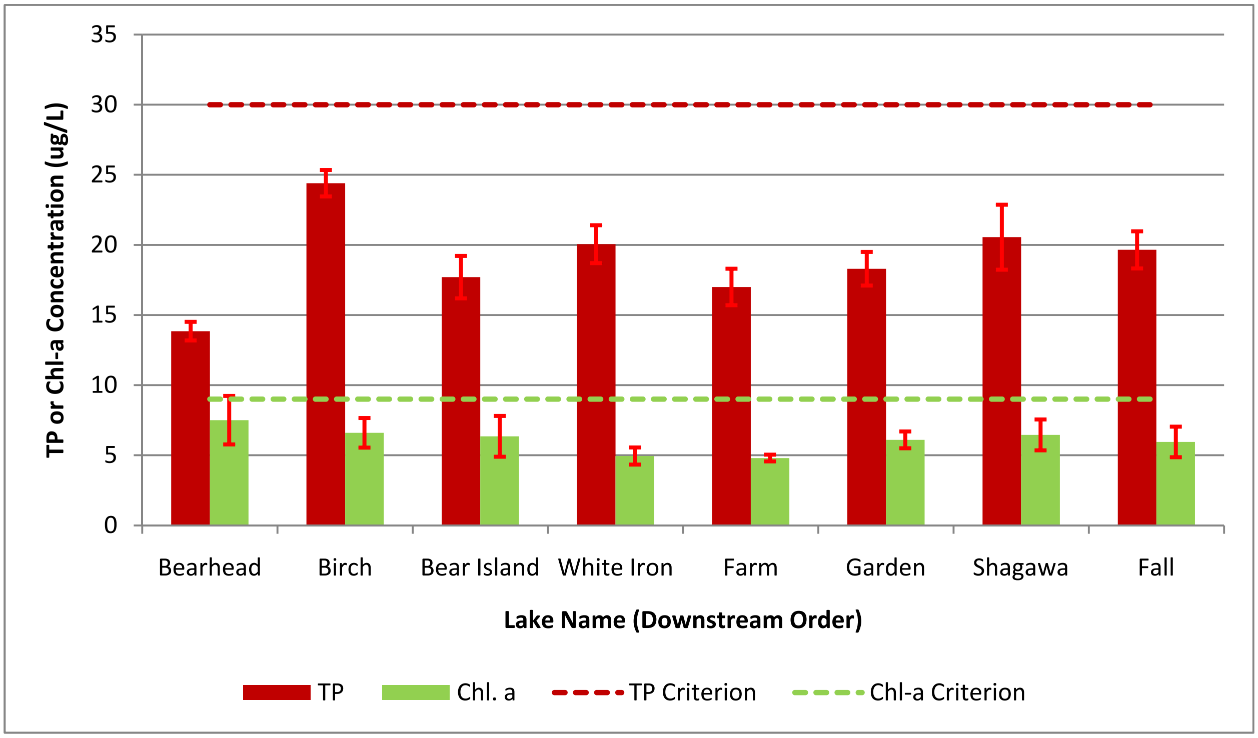
Based on 2008 and 2009 monitoring results, Fall Lake is classified as a mesotrophic lake. Additionally, based on the TP and Chl-a standards, Fall Lake was determined to be fully supporting of aquatic recreational use, and meeting eutrophication criteria (Table 20). As discussed previously, the low SD transparency is due to natural bog staining from the surrounding watersheds, and not in response to elevated Chl-a concentrations.

**Table 20. NLF ecoregion eutrophication criteria and assessment cycle mean values for Fall Lake**

| Ecoregion | TP µg/L | Chl-*a* µg/L | Secchi meters |
|---|---|---|---|
| **NLF – Aquatic Rec. Use (Class 2B)** | **< 30** | **< 9** | **> 2.0** |
| Fall Lake (38-0811) | 20 | 5.9 | 1.5 |

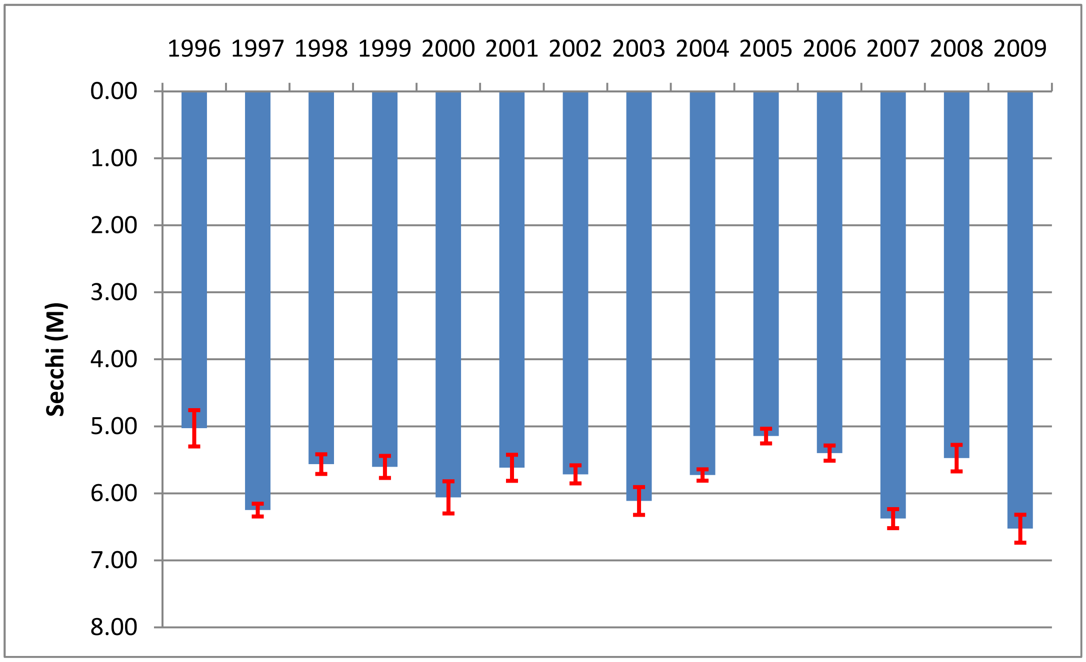
In summary, the recently monitored lakes of the Kawishiwi River watershed are all meeting MPCA's NLF eutrophication criteria (Figure 42). The low SD transparency is due to natural bog staining from the surrounding watersheds, and is not in response to elevated Chl-a concentrations. The large lakes within the Kawishiwi River channel are mesotrophic and have very similar TP concentrations ranging from 17-24 µg/L. The lakes drain very large forested watersheds with very rapid residence times (~ 30 - 45 days). Water quality did not vary significantly on an annual basis, and conditions are naturally reflective of the forest and wetlands which dominate land cover in the Superior National Forest and the BWCAW. Bearhead Lake has lower nutrient concentrations, because it is a seepage lake draining a very small forested headwater watershed. Chl-a concentrations are also comparable, ranging from 4.8 -7.5 µg/L; well below concentrations that produce nuisance algal blooms. Several lakes have long term SD datasets; clarity is generally stable and likely affected by variability in Kawishiwi River streamflows.

**Figure 42. Assessment cycle mean TP and Chl-a concentrations and NLF eutrophication criteria for the assessed lakes in the Kawishiwi River watershed**




One lake in this HUC-11 watershed has sufficient CLMP data for determining trends in transparency. Little Long Lake (69-0066) covers 128 ha (318 acres) and is located southeast of Burntside Lake off the Echo Trail. The lake is moderately deep, with a maximum depth of 13.7 m (45 feet). It has a very small watershed (approximately 141 ha or 349 acres); the outlet flows into Bass Lake and eventually into Basswood Lake. A portion of the southern lakeshore is developed, including several residences and one resort. Transparency data have been routinely collected since 1996. The long term mean is 5.7 m, and transparency is stable (Figure 43). Transparency is higher in Little Long compared to the assessed lakes within the Kawishiwi watershed, because it has a deeper basin, much smaller watershed, and is not affected by bog staining.

**Figure 43. Little Long Lake CLMP Secchi trends**




Based on the 2005 RS data, water clarity in the Lower Kawishiwi is stable, with 41 of 42 lakes having no trends (Table 21). The seven lakes within the BWCAW were all assessed as fully supporting; one lake exhibited a declining trend in RS SD (One Pine). One Pine Lake is a shallow flowage within the Bear Island River and is influenced by bog stain. 2005 RS transparency ranged from 1.1 m on One Pine Lake to 7.0 m on Sandpit Lake. When comparing the monitored versus RS estimated SD for the watershed's assessed lakes, the RS transparency data were higher (Figure 44). It is likely the satellite overestimated clarity due to interference from natural bog staining.

**Table 21. Lower Kawishiwi HUC-11 2005 RS assessment and trend summary**

| Number of Lakes with RS SD | 2005 Inferred Mean SD (M) | Number of BWCAW lakes assessed FS | Number of Lakes with improving SD | Number of Lakes with declining SD | Number of Lakes with No Trend |
|---|---|---|---|---|---|
| 42 | 3.9 | 7 | 0 | 1 | 41 |

## Mercury

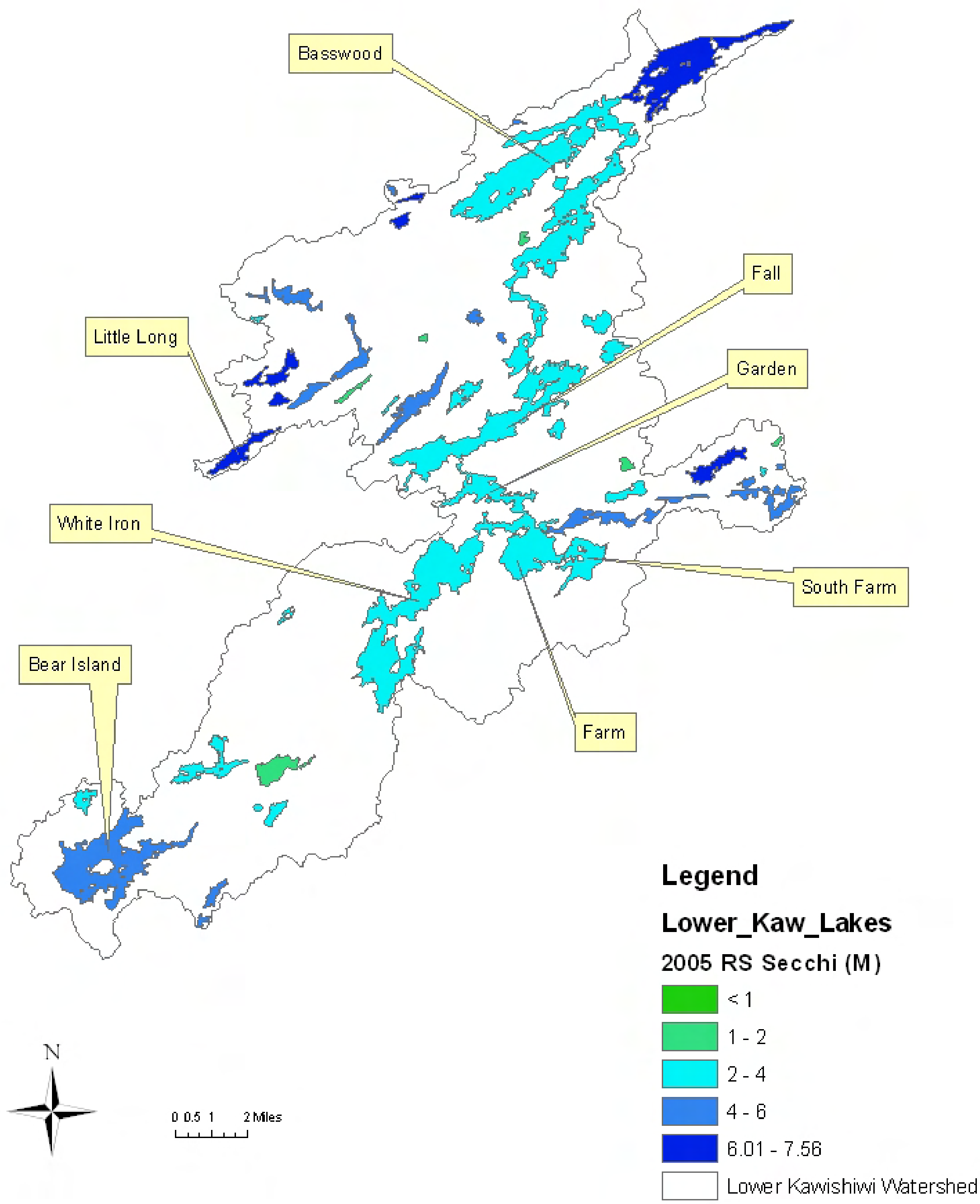
To this point the emphasis has been on assessing the condition of the Kawishiwi River watershed lakes relative to aquatic recreational use support with an emphasis on eutrophication. As is the case in a majority of watersheds across Minnesota, the accumulation of mercury in fish tissue is a major cause of water quality impairment.

This mercury impairment will not be addressed in any detail in this report but it is important to note that several lakes in the Kawishiwi River watershed are listed as impaired for mercury in fish tissue. That impairment was addressed through a statewide mercury TMDL, available here: http://www.pca.state.mn.us/water/tmdl/tmdl-mercuryplan.html.

# Summary

In conclusion, a combination of observed lake water quality data collected by the MPCA and our cooperators, and remotely-sensed Secchi transparency data point to good water quality throughout the Kawishiwi River watershed. Lakes with sufficient data are meeting eutrophication criteria and aquatic recreational use standards for the Northern Lakes and Forests ecoregion. Assessed lakes have low Secchi transparency originating from natural bog staining from the surrounding watersheds. The numerous lakes entirely within the BWCAW were assessed as fully supporting based on a more stringent remotely-sensed Secchi criterion. Water quality did not vary significantly on an annual basis, and conditions are naturally reflective of the forests and wetlands which dominate land-cover in the Superior National Forest and the BWCAW.

**Figure 44. 2005 RS Secchi for lakes in the Lower Kawishiwi River HUC-11 watershed; assessed or monitored lakes noted in yellow**



# References

Anderson, J., D. Thompson, R. Valley, and J. Butcher. 2010. Sentinel Lake Assessment Report, White Iron Lake, St. Louis County, Minnesota. Minnesota Pollution Control Agency, Minnesota Department of Natural Resources, and Superior National Forest, 43 p.

Carlson, R.E. 1977. A Trophic State Index for Lakes. Limnology and Oceanography 22:361-369.

Ericson, D.W., G.F. Lindholm, and J.O. Helgesen, 1976. Water Resources of the Rainy Lake Watershed, Northeastern Minnesota. U.S. Geological Survey Hydrologic Atlas HA-556

Heiskary, S.A. and W.W. Walker Jr. 1988. Developing Phosphorus Criteria for Minnesota Lakes. Lake and Reservoir Management 4(1): 1-9.

Heiskary, S.A. and C.B. Wilson, 2005. Minnesota lake water quality assessment report: Developing nutrient criteria, 3rd edition. Minnesota Pollution Control Agency, 176 p.

Heiskary, S.A. and C.B. Wilson. 2008. Minnesota's approach to lake nutrient criteria development. Lake and Reserv. Manage. 24:282-297.

Larsen, D.P., K.W. Malueg, D.W. Schults, and R.M. Brice, 1975. Response of eutrophic Shagawa Lake, Minnesota, USA, to point-source phosphorus reduction. U.S. Environmental Protection Agency, Eutrophication and lake restoration branch, 20 p.

Mast, M.A. and Turk, J.T., 1999. Environmental characteristics and water quality of Hydrologic Benchmark Network stations in the Midwestern United States, 1963-1995: US Geological Survey Circular 1173-B, 130 p.

Minnesota Power , 2001. Preliminary draft environmental assessment for the Winton Hydroelectric Project, FERC Project No. 469. ftp://ftp.mnpower.com/mp/winton/environment_draft.pdf

MPCA, 1969, Report on investigation of pollution of the northern border waters from the mouth of the Pigeon River at Lake Superior Westward through the Boundary Waters Cane Area and lower lakes to the outlet of Rainy Lake, August – September 1965; MPCA Division of Water Quality

MPCA, 1994. Burntside Lake Assessment Report.

MPCA, 1996. White Iron, Farm, and Garden Lakes Assessment Report.

MPCA, 1999. Reference lake and trend monitoring summary for St. Louis County Minnesota (Shagawa, Elbow, and Prairie) .

MPCA, 2010. Guidance manual for assessing the quality of Minnesota surface waters for determination of impairment: 305(b) report and 303(d) list. 2010 assessment cycle. 104 p.

Olcott, P.G., and D.I. Siegel. 1978. Physiography and superficial geology of the copper-nickel study region, northeastern Minnesota. US Geological Survey Open File Report 78-51, 22 p.

Olmanson, L.G., M.E. Bauer, and P.L. Brezonik, 2008. A 20 year Landsat water clarity census of Minnesota's 10,000 lakes. Remote Sensing of Environment 112(11)4086-4097.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. Annals of the Asso. Amer. Geogr. 77(1):118-125.

Pettyman, D.H., 1978. Soil survey of Kawishiwi area, Minnesota parts of Lake and Cook counties in Superior National Forest: US Department of Agriculture Soil Conservation Service, 35 p.

Schults, D.W., K.W. Malueg, and P.D. Smith, 1976. Limnological comparison of culturally eutrophic Shagawa Lake and adjacent oligotrophic Burntside Lake, Minnesota. American Midland Naturalist 96:160-178.

USDA, Forest Service. Land and Resource Management Plan, Superior National Forest, 2004. http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsm91_050597.pdf

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

# Appendix A

## Morphometric characteristics for all lakes within the Kawishiwi River watershed

| Lake ID | Lake Name | County | HUC-11 Name | Trophic Status (O=oligotrophic M=mesotrophic E=eutrophic) | Lake Area (acres) | Max Depth (feet) | % Littoral | Assessment Status |
|---|---|---|---|---|---|---|---|---|
| 38-0089 | Rail | LAKE | Upper Kawishiwi | | 11 | | | |
| 38-0077 | Bag | LAKE | Upper Kawishiwi | | 11 | | | |
| 38-0150 | Panhandle | LAKE | Upper Kawishiwi | E | 11 | 20 | 89 | **Insufficient Data** |
| 38-0107 | Fable | LAKE | Upper Kawishiwi | | 11 | | | |
| 38-0872 | Unnamed | LAKE | Upper Kawishiwi | | 11 | | | |
| 16-0697 | Snort | COOK | Upper Kawishiwi | | 11 | | | |
| 38-0092 | Scotch | LAKE | Upper Kawishiwi | | 12 | | | **Full Support** |
| 38-0006 | Edge | LAKE | Upper Kawishiwi | | 12 | | | |
| 16-0703 | Longleg | COOK | Upper Kawishiwi | | 12 | | | |
| 16-0682 | Nibble | COOK | Upper Kawishiwi | | 12 | | | |
| 16-0685 | Mug | COOK | Upper Kawishiwi | | 13 | | | |
| 16-0695 | Stew | COOK | Upper Kawishiwi | | 13 | | | |
| 38-0159 | Unnamed | LAKE | Upper Kawishiwi | | 13 | | | |
| 16-0680 | Needle | COOK | Upper Kawishiwi | | 15 | | | |
| 38-0097 | Bowstring | LAKE | Upper Kawishiwi | | 15 | | | |
| 38-0100 | Fantail | LAKE | Upper Kawishiwi | | 16 | | | **Full Support** |
| 16-0669 | Magic | COOK | Upper Kawishiwi | | 16 | | | |
| 38-0345 | Puffer | LAKE | Upper Kawishiwi | | 17 | | | |
| 16-0712 | Wager | COOK | Upper Kawishiwi | | 17 | | | |
| 16-0668 | Single | COOK | Upper Kawishiwi | | 18 | | | |
| 38-0148 | Peron | LAKE | Upper Kawishiwi | | 18 | | | |
| 38-0157 | Anit | LAKE | Upper Kawishiwi | M | 18 | 19 | 72 | **Insufficient Data** |
| 38-0082 | Sundown | LAKE | Upper Kawishiwi | | 19 | | | |
| 16-0694 | Oketo | COOK | Upper Kawishiwi | | 19 | | | |
| 16-0709 | Romp | COOK | Upper Kawishiwi | | 19 | | | |
| 38-0105 | Wolverine | LAKE | Upper Kawishiwi | | 20 | | | **Full Support** |
| 16-0689 | Zenith | COOK | Upper Kawishiwi | M | 20 | | | **Insufficient Data** |
| 38-0093 | Caveman | LAKE | Upper Kawishiwi | | 23 | | | **Full Support** |
| 16-0681 | Louse | COOK | Upper Kawishiwi | | 24 | | | |

| Lake ID | Lake Name | County | HUC-11 Name | Trophic Status (O=oligotrophic M=mesotrophic E=eutrophic) | Lake Area (acres) | Max Depth (feet) | % Littoral | Assessment Status |
|---|---|---|---|---|---|---|---|---|
| 38-0076 | Stringer | LAKE | Upper Kawishiwi | | 24 | | | |
| 38-0106 | Kickshaw | LAKE | Upper Kawishiwi | | 24 | | | **Full Support** |
| 16-0698 | Wapata | COOK | Upper Kawishiwi | | 27 | | | |
| 16-0696 | Whopper | COOK | Upper Kawishiwi | | 28 | | | |
| 38-0005 | Blue Wing | LAKE | Upper Kawishiwi | | 28 | | | |
| 16-0684 | Alcove | COOK | Upper Kawishiwi | | 29 | | | |
| 38-0158 | Kivandeba | LAKE | Upper Kawishiwi | | 29 | | | **Full Support** |
| 38-0222 | Bugo | LAKE | Upper Kawishiwi | M | 30 | | | **Insufficient Data** |
| 16-0687 | Duck | COOK | Upper Kawishiwi | | 31 | | 100 | |
| 16-0683 | Pow | COOK | Upper Kawishiwi | | 38 | | | |
| 16-0660 | Poet | COOK | Upper Kawishiwi | | 38 | | | |
| 38-0088 | Saddle | LAKE | Upper Kawishiwi | | 39 | | | **Full Support** |
| 38-0099 | Record | LAKE | Upper Kawishiwi | | 42 | | | |
| 38-0108 | Kivaniva | LAKE | Upper Kawishiwi | M | 45 | 49 | 81 | **Full Support** |
| 38-0094 | Frond | LAKE | Upper Kawishiwi | M | 45 | | | **Full Support** |
| 16-0679 | Bug | COOK | Upper Kawishiwi | | 47 | | | |
| 16-0658 | Ella | COOK | Upper Kawishiwi | E | 52 | 6 | 100 | **Insufficient Data** |
| 16-0692 | Frederick | COOK | Upper Kawishiwi | | 53 | | 100 | |
| 38-0079 | Watonwan | LAKE | Upper Kawishiwi | | 58 | 25 | 80 | |
| 16-0693 | Pie | COOK | Upper Kawishiwi | | 59 | | | |
| 38-0096 | Trail | LAKE | Upper Kawishiwi | | 60 | | | **Full Support** |
| 38-0008 | John Ek | LAKE | Upper Kawishiwi | | 64 | | | **Full Support** |
| 38-0095 | Boze | LAKE | Upper Kawishiwi | | 66 | | | **Full Support** |
| 38-0073 | Baskatong | LAKE | Upper Kawishiwi | | 69 | | 100 | **Full Support** |
| 16-0807 | Knight | COOK | Upper Kawishiwi | | 94 | 6 | 100 | |
| 38-0151 | Pan | LAKE | Upper Kawishiwi | M | 94 | 59 | 48 | **Full Support** |
| 38-0069 | Hazel | LAKE | Upper Kawishiwi | E | 96 | | 100 | **Insufficient Data** |
| 16-0677 | Dent | COOK | Upper Kawishiwi | | 102 | | | **Full Support** |
| 16-0701 | Barto | COOK | Upper Kawishiwi | | 106 | 40 | | **Full Support** |
| 38-0074 | Square | LAKE | Upper Kawishiwi | M | 127 | | 100 | **Insufficient Data** |
| 38-0070 | Kawasachong | LAKE | Upper Kawishiwi | M | 161 | 11 | 100 | **Full Support** |
| 16-0659 | Beth | COOK | Upper Kawishiwi | M | 171 | 22 | 59 | **Full Support** |
| 38-0098 | Koma | LAKE | Upper Kawishiwi | M | 253 | 14 | 100 | **Full Support** |
| 16-0686 | Wine | COOK | Upper Kawishiwi | | 264 | 55 | 50 | |

| Lake ID | Lake Name | County | HUC-11 Name | Trophic Status (O=oligotrophic M=mesotrophic E=eutrophic) | Lake Area (acres) | Max Depth (feet) | % Littoral | Assessment Status |
|---|---|---|---|---|---|---|---|---|
| 38-0080 | Kawishiwi | LAKE | Upper Kawishiwi | M | 389 | 12 | 100 | **Insufficient Data** |
| 38-0090 | Malberg | LAKE | Upper Kawishiwi | M | 415 | 33 | 78 | **Full Support** |
| 16-0657 | Grace | COOK | Upper Kawishiwi | M | 442 | 16 | 77 | **Full Support** |
| 38-0104 | Polly | LAKE | Upper Kawishiwi | E | 485 | 21 | 80 | **Full Support** |
| 16-0808 | Phoebe | COOK | Upper Kawishiwi | M | 611 | 25 | 62 | **Full Support** |
| 38-0302 | Clevise | LAKE | Perent River | | 10 | | | **Full Support** |
| 38-0278 | Unnamed | LAKE | Perent River | | 10 | | | |
| 38-0276 | Unnamed | LAKE | Perent River | | 11 | | | |
| 38-0296 | Unnamed | LAKE | Perent River | | 12 | | | |
| 38-0314 | Azure | LAKE | Perent River | | 12 | | | |
| 38-0350 | Yoke | LAKE | Perent River | | 13 | | | **Full Support** |
| 38-0349 | Screamer | LAKE | Perent River | | 13 | | | **Full Support** |
| 38-0312 | Fungus | LAKE | Perent River | | 14 | | | **Full Support** |
| 38-0295 | Unnamed | LAKE | Perent River | | 14 | | | |
| 38-0279 | Placid | LAKE | Perent River | | 15 | | | **Full Support** |
| 38-0221 | Chickadee | LAKE | Perent River | | 16 | | | **Full Support** |
| 38-0275 | Unnamed | LAKE | Perent River | | 16 | | | |
| 38-0294 | Unnamed | LAKE | Perent River | | 16 | | | |
| 38-0317 | Unnamed | LAKE | Perent River | | 16 | | | |
| 38-0307 | Whittler | LAKE | Perent River | | 17 | | | |
| 38-0316 | Harica | LAKE | Perent River | | 19 | | | **Full Support** |
| 38-0308 | Powwow | LAKE | Perent River | | 20 | | 72 | **Full Support** |
| 38-0297 | Snusbox | LAKE | Perent River | | 21 | | | **Full Support** |
| 38-0305 | Andek | LAKE | Perent River | | 22 | | | |
| 16-0667 | Vyre | COOK | Perent River | | 24 | | 100 | |
| 38-0844 | Unnamed | LAKE | Perent River | | 26 | | | **Full Support** |
| 38-0315 | Boga | LAKE | Perent River | | 31 | | | **Full Support** |
| 38-0298 | Pompous | LAKE | Perent River | | 31 | | | **Full Support** |
| 38-0348 | Lethe | LAKE | Perent River | | 35 | | | **Full Support** |
| 38-0320 | Promise | LAKE | Perent River | | 38 | | | **Full Support** |
| 38-0313 | Tomahawk | LAKE | Perent River | | 44 | | | |
| 16-0647 | Big Snow | COOK | Perent River | | 46 | | | |
| 38-0085 | Bill | LAKE | Perent River | | 55 | | | |
| 38-0299 | Jupiter | LAKE | Perent River | | 60 | | | |

| Lake ID | Lake Name | County | HUC-11 Name | Trophic Status (O=oligotrophic M=mesotrophic E=eutrophic) | Lake Area (acres) | Max Depth (feet) | % Littoral | Assessment Status |
|---|---|---|---|---|---|---|---|---|
| 38-0301 | South Hope | LAKE | Perent River | | 80 | | 100 | |
| 16-0666 | Dollar | COOK | Perent River | | 81 | | | |
| 38-0004 | Cook | LAKE | Perent River | | 89 | | | |
| 38-0300 | Maniwaki | LAKE | Perent River | | 104 | 10 | 100 | **Full Support** |
| 38-0319 | Hope | LAKE | Perent River | | 114 | 8 | 100 | |
| 16-0653 | Hog | COOK | Perent River | | 126 | 7 | | |
| 38-0064 | Coffee | LAKE | Perent River | | 130 | 11 | 100 | |
| 38-0311 | Ferne | LAKE | Perent River | | 138 | 8 | 100 | |
| 38-0220 | Perent | LAKE | Perent River | E | 1604 | 38 | 76 | **Full Support** |
| 38-0270 | Dumbbell | LAKE | Island River | | 10 | | | |
| 38-0422 | Shoofly | LAKE | Island River | | 11 | 23 | 62 | |
| 38-0288 | Unnamed | LAKE | Island River | | 11 | | 0 | |
| 38-0429 | Spear | LAKE | Island River | | 11 | | 100 | |
| 38-0286 | Unnamed | LAKE | Island River | | 11 | | | |
| 38-0394 | Lois | LAKE | Island River | | 12 | | | |
| 38-0043 | Outlaw | LAKE | Island River | | 13 | | | |
| 38-0287 | Unnamed | LAKE | Island River | | 13 | | | |
| 38-0437 | Bine | LAKE | Island River | | 14 | | 100 | |
| 38-0059 | Mound | LAKE | Island River | | 15 | 8 | | |
| 38-0433 | Bushel | LAKE | Island River | | 15 | | | |
| 38-0445 | Nine A.M. | LAKE | Island River | | 15 | | 100 | |
| 38-0062 | Fool Hen | LAKE | Island River | | 15 | | | |
| 38-0218 | Elixir | LAKE | Island River | | 16 | 8 | 100 | |
| 38-0265 | Folly | LAKE | Island River | | 17 | | | |
| 38-0447 | Lunch | LAKE | Island River | | 19 | | | |
| 38-0431 | Trappers | LAKE | Island River | | 19 | 12 | 100 | |
| 38-0281 | Small | LAKE | Island River | | 20 | | | |
| 38-0272 | Katydid | LAKE | Island River | | 21 | | 100 | |
| 38-0055 | Charity | LAKE | Island River | | 22 | 10 | 100 | |
| 38-0428 | Frank | LAKE | Island River | | 24 | | 100 | |
| 38-0267 | Scanlon | LAKE | Island River | | 25 | | | |
| 38-0271 | Scott | LAKE | Island River | | 25 | | 100 | |
| 38-0283 | Sumpet | LAKE | Island River | | 31 | | | **Full Support** |
| 38-0446 | Sapphire | LAKE | Island River | | 32 | | | |

| Lake ID | Lake Name | County | HUC-11 Name | Trophic Status (O=oligotrophic M=mesotrophic E=eutrophic) | Lake Area (acres) | Max Depth (feet) | % Littoral | Assessment Status |
|---|---|---|---|---|---|---|---|---|
| 38-0285 | Swamp | LAKE | Island River | | 32 | | | |
| 38-0264 | Green Wing | LAKE | Island River | | 35 | | | |
| 38-0057 | Hogback | LAKE | Island River | | 38 | 43 | 60 | |
| 38-0056 | Fulton | LAKE | Island River | | 39 | 20 | 71 | |
| 38-0058 | Scarp | LAKE | Island River | | 41 | 15 | 93 | |
| 38-0293 | Bunny | LAKE | Island River | | 41 | 6 | 100 | |
| 38-0290 | Comfort | LAKE | Island River | | 43 | | | |
| 38-0441 | Jack | LAKE | Island River | | 44 | | | |
| 38-0440 | Redskin | LAKE | Island River | | 44 | | | |
| 38-0269 | Homestead | LAKE | Island River | | 45 | 5 | 100 | |
| 38-0042 | Wye | LAKE | Island River | | 53 | 10 | 100 | |
| 38-0448 | Helen | LAKE | Island River | | 61 | | 100 | |
| 38-0842 | Island River | LAKE | Island River | | 72 | | | |
| 38-0273 | Plum | LAKE | Island River | | 73 | | | |
| 38-0049 | Wanless | LAKE | Island River | | 76 | 16 | 99 | |
| 38-0395 | Sylvania | LAKE | Island River | | 77 | 5 | 100 | |
| 38-0292 | Section 29 | LAKE | Island River | | 100 | 20 | 81 | |
| 38-0432 | Eighteen | LAKE | Island River | | 104 | 8 | 100 | |
| 38-0050 | Sister | LAKE | Island River | | 124 | 15 | | |
| 38-0289 | Island River | LAKE | Island River | | 141 | | | |
| 38-0048 | Harriet | LAKE | Island River | | 259 | 34 | 74 | |
| 38-0066 | T | LAKE | Island River | | 291 | 11 | 100 | |
| 38-0393 | Dumbbell | LAKE | Island River | | 414 | 40 | 46 | |
| 38-0068 | Windy | LAKE | Island River | M | 460 | 39 | 44 | **Insufficient Data** |
| 38-0219 | Silver Island | LAKE | Island River | | 1231 | 15 | 100 | |
| 38-0578 | Sphagnum | LAKE | Inga-Isabella River | | 11 | | | |
| 38-0576 | Edward | LAKE | Inga-Isabella River | | 13 | | | |
| 38-0577 | Little Bear | LAKE | Inga-Isabella River | | 13 | | | |
| 38-0574 | John | LAKE | Inga-Isabella River | | 17 | | | **Full Support** |
| 38-0560 | Victor | LAKE | Inga-Isabella River | | 17 | 6 | | |
| 38-0572 | Fishfry | LAKE | Inga-Isabella River | | 18 | | | |
| 38-0570 | Steamhaul | LAKE | Inga-Isabella River | | 20 | 17 | 98 | |
| 38-0444 | Brush | LAKE | Inga-Isabella River | | 23 | | | **Full Support** |
| 38-0635 | Grass | LAKE | Inga-Isabella River | | 24 | 9 | 100 | |

| Lake ID | Lake Name | County | HUC-11 Name | Trophic Status (O=oligotrophic M=mesotrophic E=eutrophic) | Lake Area (acres) | Max Depth (feet) | % Littoral | Assessment Status |
|---|---|---|---|---|---|---|---|---|
| 38-0424 | Lena | LAKE | Inga-Isabella River | | 24 | | 100 | |
| 38-0555 | Ova | LAKE | Inga-Isabella River | | 26 | | 100 | |
| 38-0550 | Surprise | LAKE | Inga-Isabella River | | 35 | 9 | 100 | |
| 38-0556 | Cat | LAKE | Inga-Isabella River | | 41 | 24 | 86 | |
| 38-0549 | Inga | LAKE | Inga-Isabella River | | 42 | 6 | 100 | |
| 38-0568 | Flat Horn | LAKE | Inga-Isabella River | | 51 | 10 | 100 | |
| 38-0559 | Kitigan | LAKE | Inga-Isabella River | | 69 | 7 | 100 | |
| 38-0552 | Dragon | LAKE | Inga-Isabella River | | 89 | 14 | 100 | |
| 38-0557 | Grouse | LAKE | Inga-Isabella River | E | 121 | 10 | 100 | **Insufficient Data** |
| 38-0573 | Gegoka | LAKE | Inga-Isabella River | | 140 | 7 | 100 | |
| 38-0561 | Mitawan | LAKE | Inga-Isabella River | | 186 | 27 | 57 | |
| 38-0443 | Bog | LAKE | Inga-Isabella River | | 253 | 16 | 93 | **Full Support** |
| 38-0689 | Gesend Pond | LAKE | Isabella River | | 10 | | | |
| 38-0688 | Norway | LAKE | Isabella River | | 11 | | 89 | |
| 38-0597 | Campfire | LAKE | Isabella River | | 11 | | | |
| 38-0458 | Wager | LAKE | Isabella River | | 13 | | 100 | |
| 38-0595 | Unnamed | LAKE | Isabella River | | 14 | | | |
| 38-0661 | Robin | LAKE | Isabella River | | 17 | | | |
| 38-0464 | Flapper | LAKE | Isabella River | | 17 | | | |
| 38-0598 | Myth | LAKE | Isabella River | | 17 | | | |
| 38-0456 | Hump | LAKE | Isabella River | | 19 | | | **Full Support** |
| 38-0585 | Kayoskh | LAKE | Isabella River | | 22 | | | **Full Support** |
| 38-0690 | Unnamed (Tonic) | LAKE | Isabella River | | 23 | | | |
| 38-0594 | Cargo | LAKE | Isabella River | | 23 | | | **Full Support** |
| 38-0461 | Fallen Arch | LAKE | Isabella River | | 23 | | 100 | **Full Support** |
| 38-0705 | Nickel | LAKE | Isabella River | | 23 | 9 | 100 | |
| 38-0700 | Cortes | LAKE | Isabella River | | 28 | | | **Full Support** |
| 38-0694 | Baird | LAKE | Isabella River | | 31 | | 100 | |
| 38-0593 | Superstition | LAKE | Isabella River | | 32 | | | **Full Support** |
| 38-0592 | Phospor | LAKE | Isabella River | | 34 | | | **Full Support** |
| 38-0591 | Pangi | LAKE | Isabella River | | 35 | | | |
| 38-0460 | Marathon | LAKE | Isabella River | | 35 | | 100 | **Full Support** |
| 38-0843 | Unnamed | LAKE | Isabella River | | 47 | | | |
| 38-0459 | Diana | LAKE | Isabella River | | 48 | | | **Full Support** |

| Lake ID | Lake Name | County | HUC-11 Name | Trophic Status (O=oligotrophic M=mesotrophic E=eutrophic) | Lake Area (acres) | Max Depth (feet) | % Littoral | Assessment Status |
|---|---|---|---|---|---|---|---|---|
| 38-0583 | Camdre | LAKE | Isabella River | | 50 | | 100 | |
| 38-0687 | Shamrock | LAKE | Isabella River | | 54 | 10 | 100 | |
| 38-0463 | Pelt | LAKE | Isabella River | | 77 | | | **Full Support** |
| 38-0703 | Little Gabbro | LAKE | Isabella River | E | 189 | 26 | 76 | **Full Support** |
| 38-0465 | Rice | LAKE | Isabella River | | 206 | 3 | | |
| 38-0691 | August | LAKE | Isabella River | E | 223 | 19 | 96 | **Insufficient Data** |
| 38-0596 | Quadga | LAKE | Isabella River | | 249 | 30 | 64 | **Full Support** |
| 38-0584 | Pietro | LAKE | Isabella River | M | 337 | 31 | 23 | **Full Support** |
| 38-0704 | Turtle | LAKE | Isabella River | E | 344 | 9 | 100 | **Insufficient Data** |
| 38-0590 | Gull | LAKE | Isabella River | M | 501 | 31 | 72 | **Full Support** |
| 38-0701 | Gabbro | LAKE | Isabella River | | 1044 | 50 | 51 | **Full Support** |
| 38-0396 | Isabella | LAKE | Isabella River | M | 1078 | 18 | 77 | **Insufficient Data** |
| 38-0637 | Bald Eagle | LAKE | Isabella River | M | 1252 | 36 | 76 | **Full Support** |
| 38-0655 | Railroad | LAKE | Upper Stony River | | 10 | 4 | | |
| 38-0657 | Fourth McDougal | LAKE | Upper Stony River | | 13 | | 58 | |
| 38-0546 | Unnamed | LAKE | Upper Stony River | | 15 | | | |
| 38-0548 | Wilbar | LAKE | Upper Stony River | | 16 | | | |
| 38-0684 | Little Wampus | LAKE | Upper Stony River | | 18 | | 100 | |
| 38-0547 | Fishtrap | LAKE | Upper Stony River | | 23 | | | |
| 38-0683 | Unnamed | LAKE | Upper Stony River | | 25 | | | |
| 38-0652 | Driller | LAKE | Upper Stony River | | 29 | 6 | 100 | |
| 38-0761 | Fools | LAKE | Upper Stony River | | 31 | 11 | 100 | |
| 38-0654 | Source | LAKE | Upper Stony River | | 33 | | | |
| 38-0824 | Unnamed | LAKE | Upper Stony River | | 35 | | | |
| 38-0679 | Campers | LAKE | Upper Stony River | | 48 | | 100 | |
| 38-0767 | Cougar | LAKE | Upper Stony River | | 67 | | | |
| 38-0420 | Osier | LAKE | Upper Stony River | | 71 | | | |
| 38-0544 | Spruce | LAKE | Upper Stony River | | 75 | | | |
| 38-0653 | Phantom | LAKE | Upper Stony River | | 75 | | | |
| 38-0543 | Rota | LAKE | Upper Stony River | | 95 | | | |
| 38-0658 | Middle McDougal | LAKE | Upper Stony River | | 101 | 5 | 100 | |
| 38-0762 | Bonga | LAKE | Upper Stony River | | 116 | | 100 | |
| 38-0685 | Wampus | LAKE | Upper Stony River | | 138 | 6 | | |
| 38-0660 | Stony | LAKE | Upper Stony River | | 250 | 4 | | |

| Lake ID | Lake Name | County | HUC-11 Name | Trophic Status (O=oligotrophic M=mesotrophic E=eutrophic) | Lake Area (acres) | Max Depth (feet) | % Littoral | Assessment Status |
|---|---|---|---|---|---|---|---|---|
| 38-0686 | North McDougal | LAKE | Upper Stony River | | 259 | 10 | 100 | |
| 38-0659 | South McDougal | LAKE | Upper Stony River | | 273 | 5 | 100 | |
| 38-0735 | Sand | LAKE | Upper Stony River | | 481 | 10 | | |
| 38-0656 | Greenwood | LAKE | Upper Stony River | | 1318 | 5 | | |
| 38-0769 | Unnamed (Pear) | LAKE | Stony River | | 10 | | | |
| 38-0563 | Unnamed | LAKE | Stony River | | 11 | | | |
| 38-0772 | Jackpot | LAKE | Stony River | | 12 | | | |
| 38-0680 | Moccasin | LAKE | Stony River | | 13 | | | |
| 38-0776 | Unnamed (Sue) | LAKE | Stony River | | 14 | | | |
| 38-0682 | Luster | LAKE | Stony River | | 15 | | | |
| 38-0665 | Gypsy | LAKE | Stony River | | 15 | 21 | 99 | |
| 38-0672 | Alsike | LAKE | Stony River | | 18 | | | |
| 38-0667 | Gunsten | LAKE | Stony River | | 19 | | | |
| 38-0673 | Highlife | LAKE | Stony River | | 20 | 22 | 95 | |
| 38-0771 | Fran | LAKE | Stony River | | 21 | | 70 | |
| 38-0551 | Beetle | LAKE | Stony River | | 25 | 26 | 85 | |
| 38-0553 | Hide | LAKE | Stony River | | 25 | 9 | 100 | |
| 38-0676 | Pitcha | LAKE | Stony River | | 28 | | 100 | |
| 38-0564 | Planted | LAKE | Stony River | | 29 | | | |
| 38-0669 | Chipmunk | LAKE | Stony River | | 29 | | | |
| 38-0681 | Wadop | LAKE | Stony River | | 38 | 9 | 100 | |
| 38-0773 | Denley | LAKE | Stony River | | 41 | | | |
| 38-0671 | Two Deer | LAKE | Stony River | | 43 | | 100 | |
| 38-0770 | Chow | LAKE | Stony River | | 44 | 11 | 100 | |
| 38-0737 | Beaver Hut | LAKE | Stony River | | 55 | 19 | | |
| 38-0674 | East Chub | LAKE | Stony River | | 63 | 8 | 100 | |
| 38-0670 | Pike | LAKE | Stony River | | 75 | 10 | 100 | |
| 38-0664 | Dunnigan | LAKE | Stony River | O | 83 | 15 | 100 | **Insufficient Data** |
| 38-0675 | West Chub | LAKE | Stony River | | 115 | 12 | 100 | |
| 38-0736 | Harris | LAKE | Stony River | | 117 | 13 | 100 | |
| 38-0554 | Gander | LAKE | Stony River | | 118 | 5 | 100 | |
| 38-0668 | Swallow | LAKE | Stony River | | 149 | 4 | 88 | |
| 38-0666 | Slate | LAKE | Stony River | M | 321 | 12 | 100 | **Insufficient Data** |
| 69-0272 | Unnamed | ST. | South Fork | | 11 | | | |

| Lake ID | Lake Name | County | HUC-11 Name | Trophic Status (O=oligotrophic M=mesotrophic E=eutrophic) | Lake Area (acres) | Max Depth (feet) | % Littoral | Assessment Status |
|---|---|---|---|---|---|---|---|---|
| | | LOUIS | Kawishiwi River | | | | | |
| 38-0723 | Astray | LAKE | South Fork Kawishiwi River | | 13 | | | **Full Support** |
| 69-0155 | Cold | ST LOUIS | South Fork Kawishiwi River | | 13 | 17 | | |
| 69-0261 | Square | ST. LOUIS | South Fork Kawishiwi River | | 15 | | | |
| 38-0777 | Crocket | LAKE | South Fork Kawishiwi River | | 18 | | | |
| 69-0057 | Kangas | ST. LOUIS | South Fork Kawishiwi River | | 21 | | | |
| 69-0156 | Sock | ST. LOUIS | South Fork Kawishiwi River | | 24 | 19 | 95 | |
| 38-0702 | Bruin | LAKE | South Fork Kawishiwi River | | 34 | | | **Full Support** |
| 69-0255 | Horseshoe | ST. LOUIS | South Fork Kawishiwi River | | 35 | 2 | | |
| 38-0692 | Heart | LAKE | South Fork Kawishiwi River | | 36 | | 100 | |
| 69-0153 | Spruce | ST. LOUIS | South Fork Kawishiwi River | | 39 | | | |
| 38-0706 | Omaday | LAKE | South Fork Kawishiwi River | | 40 | 7 | 100 | |
| 69-0215 | Blueberry | ST. LOUIS | South Fork Kawishiwi River | | 47 | | | |
| 69-0056 | Little | ST. LOUIS | South Fork Kawishiwi River | | 66 | 24 | 83 | |
| 69-0154 | Arthur | ST. LOUIS | South Fork Kawishiwi River | E | 71 | 19 | 73 | **Insufficient Data** |
| 69-0157 | Joseph | ST. LOUIS | South Fork Kawishiwi River | | 75 | 33 | 88 | |
| 38-0699 | Bogberry | LAKE | South Fork Kawishiwi River | | 78 | | | |
| 69-0053 | Argo | ST. LOUIS | South Fork Kawishiwi River | | 83 | | | |

| Lake ID | Lake Name | County | HUC-11 Name | Trophic Status (O=oligotrophic M=mesotrophic E=eutrophic) | Lake Area (acres) | Max Depth (feet) | % Littoral | Assessment Status |
|---|---|---|---|---|---|---|---|---|
| 38-0707 | Eskwagama | LAKE | South Fork Kawishiwi River | | 89 | | 100 | **Full Support** |
| 69-1348 | Tailings Pond | ST. LOUIS | South Fork Kawishiwi River | | 94 | | | |
| 69-0158 | Isaac | ST. LOUIS | South Fork Kawishiwi River | | 98 | 54 | 65 | |
| 38-0722 | Clear | LAKE | South Fork Kawishiwi River | | 253 | 19 | 100 | |
| 69-0254 | Bearhead | ST LOUIS | South Fork Kawishiwi River | M | 649 | 46 | 55 | **Full Support** |
| 69-0003 | Birch | ST LOUIS | South Fork Kawishiwi River | M | 7315 | 25 | 19 | **Insufficient Data** |
| 38-0601 | Unnamed | LAKE | Middle Kawishiwi River | | 10 | | 69 | |
| 38-0467 | Unnamed | LAKE | Middle Kawishiwi River | | 10 | | | **Full Support** |
| 38-0471 | Drumstick | LAKE | Middle Kawishiwi River | | 10 | | | |
| 38-0374 | Unnamed | LAKE | Middle Kawishiwi River | | 11 | | | |
| 38-0327 | Kaapoo | LAKE | Middle Kawishiwi River | | 11 | | | **Full Support** |
| 38-0152 | Unnamed | LAKE | Middle Kawishiwi River | | 12 | 28 | 69 | **Full Support** |
| 38-0325 | Blissfull | LAKE | Middle Kawishiwi River | | 12 | | | |
| 38-0487 | Unnamed | LAKE | Middle Kawishiwi River | | 12 | | | |
| 38-0841 | Unnamed | LAKE | Middle Kawishiwi River | | 12 | | | |
| 38-0607 | Unnamed | LAKE | Middle Kawishiwi River | | 12 | | | |
| 38-0335 | Recline | LAKE | Middle Kawishiwi River | | 12 | | | **Full Support** |
| 38-0119 | Siren | LAKE | Middle Kawishiwi | | 12 | | | **Full Support** |

| Lake ID | Lake Name | County | HUC-11 Name | Trophic Status (O=oligotrophic M=mesotrophic E=eutrophic) | Lake Area (acres) | Max Depth (feet) | % Littoral | Assessment Status |
|---|---|---|---|---|---|---|---|---|
| | | | River | | | | | |
| 38-0342 | Unnamed | LAKE | Middle Kawishiwi River | | 13 | | | |
| 38-0339 | Ham | LAKE | Middle Kawishiwi River | | 13 | | | **Full Support** |
| 38-0454 | Hush | LAKE | Middle Kawishiwi River | | 13 | | | **Full Support** |
| 38-0850 | Unnamed | LAKE | Middle Kawishiwi River | | 13 | | | |
| 38-0155 | Cowan | LAKE | Middle Kawishiwi River | | 13 | | | |
| 38-0468 | Sable | LAKE | Middle Kawishiwi River | | 13 | | | |
| 38-0337 | Unnamed | LAKE | Middle Kawishiwi River | | 13 | | | |
| 38-0450 | Zitkala | LAKE | Middle Kawishiwi River | | 14 | | | **Full Support** |
| 38-0479 | Blinker | LAKE | Middle Kawishiwi River | | 14 | | | |
| 38-0486 | Brunch | LAKE | Middle Kawishiwi River | | 14 | | | |
| 38-0331 | Club | LAKE | Middle Kawishiwi River | | 14 | | | |
| 38-0481 | Quartz | LAKE | Middle Kawishiwi River | | 14 | | | **Full Support** |
| 38-0451 | Briddle | LAKE | Middle Kawishiwi River | | 15 | | | **Full Support** |
| 38-0303 | Arrow - 1 | LAKE | Middle Kawishiwi River | | 15 | | | |
| 38-0142 | Porridge | LAKE | Middle Kawishiwi River | | 15 | | | |
| 38-0485 | Drag | LAKE | Middle Kawishiwi River | | 16 | | | **Full Support** |
| 38-0469 | Coon | LAKE | Middle Kawishiwi River | | 16 | | | |

| Lake ID | Lake Name | County | HUC-11 Name | Trophic Status (O=oligotrophic M=mesotrophic E=eutrophic) | Lake Area (acres) | Max Depth (feet) | % Littoral | Assessment Status |
|---|---|---|---|---|---|---|---|---|
| 38-0845 | Unnamed | LAKE | Middle Kawishiwi River | | 16 | | | **Full Support** |
| 38-0611 | Carefree | LAKE | Middle Kawishiwi River | | 18 | | | |
| 38-0470 | Beam | LAKE | Middle Kawishiwi River | | 18 | | | **Full Support** |
| 38-0612 | Weasel | LAKE | Middle Kawishiwi River | | 18 | | | **Full Support** |
| 38-0587 | Brewis | LAKE | Middle Kawishiwi River | | 19 | | | **Full Support** |
| 38-0581 | Spinnan | LAKE | Middle Kawishiwi River | | 20 | | | **Full Support** |
| 38-0476 | Fast | LAKE | Middle Kawishiwi River | | 22 | | | **Full Support** |
| 38-0323 | Whiz | LAKE | Middle Kawishiwi River | | 22 | | | **Full Support** |
| 38-0449 | Tornado | LAKE | Middle Kawishiwi River | | 22 | | 100 | |
| 38-0321 | Unnamed | LAKE | Middle Kawishiwi River | M | 22 | | | **Full Support** |
| 38-0457 | Pioneer | LAKE | Middle Kawishiwi River | | 22 | | | **Full Support** |
| 38-0156 | Humpback | LAKE | Middle Kawishiwi River | | 23 | | | **Full Support** |
| 38-0328 | Unnamed | LAKE | Middle Kawishiwi River | | 25 | | 100 | **Full Support** |
| 38-0527 | Delta | LAKE | Middle Kawishiwi River | | 26 | 7 | | **Full Support** |
| 38-0154 | Treasure | LAKE | Middle Kawishiwi River | | 26 | | 44 | **Full Support** |
| 38-0310 | Arrow - 3 | LAKE | Middle Kawishiwi River | | 26 | | 100 | **Full Support** |
| 38-0329 | Cacabic | LAKE | Middle Kawishiwi River | E | 27 | | | **Full Support** |
| 38-0480 | Hood | LAKE | Middle Kawishiwi | | 27 | | | **Full Support** |

| Lake ID | Lake Name | County | HUC-11 Name | Trophic Status (O=oligotrophic M=mesotrophic E=eutrophic) | Lake Area (acres) | Max Depth (feet) | % Littoral | Assessment Status |
|---|---|---|---|---|---|---|---|---|
| | | | River | | | | | |
| 38-0132 | Fee | LAKE | Middle Kawishiwi River | M | 29 | | | **Full Support** |
| 38-0466 | Termulo | LAKE | Middle Kawishiwi River | | 29 | | 66 | |
| 38-0525 | Harbor | LAKE | Middle Kawishiwi River | | 30 | | | **Full Support** |
| 38-0582 | Holiday | LAKE | Middle Kawishiwi River | | 30 | | | **Full Support** |
| 38-0332 | Struggle | LAKE | Middle Kawishiwi River | | 31 | | | **Full Support** |
| 38-0344 | Assawan | LAKE | Middle Kawishiwi River | | 32 | | | **Full Support** |
| 38-0304 | Arrow - 2 | LAKE | Middle Kawishiwi River | | 32 | | 100 | |
| 38-0589 | Mirror | LAKE | Middle Kawishiwi River | | 34 | | | **Full Support** |
| 38-0131 | Vee | LAKE | Middle Kawishiwi River | | 35 | | | **Full Support** |
| 38-0141 | Jug | LAKE | Middle Kawishiwi River | | 35 | | 100 | |
| 38-0610 | Rifle | LAKE | Middle Kawishiwi River | M | 39 | | | **Full Support** |
| 38-0375 | Smite | LAKE | Middle Kawishiwi River | | 41 | | 82 | **Full Support** |
| 38-0482 | Slowfoot | LAKE | Middle Kawishiwi River | | 42 | | | **Full Support** |
| 38-0309 | Calamity | LAKE | Middle Kawishiwi River | | 45 | | | **Full Support** |
| 38-0475 | Jut | LAKE | Middle Kawishiwi River | | 47 | | | **Full Support** |
| 38-0639 | Pagami | LAKE | Middle Kawishiwi River | | 47 | 7 | 100 | **Full Support** |
| 38-0477 | Cache | LAKE | Middle Kawishiwi River | | 48 | | 100 | **Full Support** |

| Lake ID | Lake Name | County | HUC-11 Name | Trophic Status (O=oligotrophic M=mesotrophic E=eutrophic) | Lake Area (acres) | Max Depth (feet) | % Littoral | Assessment Status |
|---|---|---|---|---|---|---|---|---|
| 38-0588 | Path | LAKE | Middle Kawishiwi River | | 52 | | | **Full Support** |
| 38-0613 | Rock Island | LAKE | Middle Kawishiwi River | E | 55 | | | **Full Support** |
| 38-0478 | Museum | LAKE | Middle Kawishiwi River | | 58 | | | **Full Support** |
| 38-0473 | Benezie | LAKE | Middle Kawishiwi River | | 59 | | | **Full Support** |
| 38-0586 | Rock of Ages | LAKE | Middle Kawishiwi River | | 65 | | | **Full Support** |
| 38-0453 | South Wilder | LAKE | Middle Kawishiwi River | | 65 | 35 | 45 | **Full Support** |
| 38-0322 | Fisher | LAKE | Middle Kawishiwi River | | 68 | | 47 | **Full Support** |
| 38-0455 | Pose | LAKE | Middle Kawishiwi River | | 80 | | 100 | **Full Support** |
| 38-0324 | Bow | LAKE | Middle Kawishiwi River | | 82 | | 100 | |
| 38-0474 | Starlight | LAKE | Middle Kawishiwi River | | 98 | | | **Full Support** |
| 38-0452 | North Wilder | LAKE | Middle Kawishiwi River | | 101 | | 89 | **Full Support** |
| 38-0340 | Carol | LAKE | Middle Kawishiwi River | E | 102 | | | **Insufficient Data** |
| 38-0483 | Fire | LAKE | Middle Kawishiwi River | | 108 | 30 | 70 | **Full Support** |
| 38-0338 | River | LAKE | Middle Kawishiwi River | | 109 | | | **Full Support** |
| 38-0336 | Amber | LAKE | Middle Kawishiwi River | | 123 | 27 | 55 | |
| 38-0343 | Fishdance | LAKE | Middle Kawishiwi River | | 160 | 50 | 51 | **Full Support** |
| 38-0881 | Unnamed | LAKE | Middle Kawishiwi River | | 199 | | | **Full Support** |
| 38-0580 | Horseshoe | LAKE | Middle Kawishiwi | E | 203 | 40 | 67 | **Full Support** |

| Lake ID | Lake Name | County | HUC-11 Name | Trophic Status (O=oligotrophic M=mesotrophic E=eutrophic) | Lake Area (acres) | Max Depth (feet) | % Littoral | Assessment Status |
|---|---|---|---|---|---|---|---|---|
| | | | River | | | | | |
| 38-0334 | Kiana | LAKE | Middle Kawishiwi River | O | 208 | 56 | 39 | **Full Support** |
| 38-0223 | Beaver | LAKE | Middle Kawishiwi River | M | 218 | 76 | 40 | **Full Support** |
| 38-0140 | Boulder | LAKE | Middle Kawishiwi River | M | 263 | 54 | 47 | **Full Support** |
| 38-0484 | Hudson | LAKE | Middle Kawishiwi River | M | 409 | 35 | 59 | **Full Support** |
| 38-0153 | Adams | LAKE | Middle Kawishiwi River | M | 489 | 84 | 26 | **Full Support** |
| 38-0608 | Two | LAKE | Middle Kawishiwi River | M | 543 | 35 | 33 | **Insufficient Data** |
| 38-0638 | Clearwater | LAKE | Middle Kawishiwi River | O | 637 | 46 | 27 | **Full Support** |
| 38-0528 | Four | LAKE | Middle Kawishiwi River | M | 678 | 25 | 78 | **Full Support** |
| 38-0605 | One | LAKE | Middle Kawishiwi River | M | 891 | 57 | 52 | **Full Support** |
| 38-0600 | Three | LAKE | Middle Kawishiwi River | M | 921 | 37 | 43 | **Insufficient Data** |
| 38-0330 | Alice | LAKE | Middle Kawishiwi River | M | 1485 | 53 | 28 | **Full Support** |
| 38-0397 | Insula | LAKE | Middle Kawishiwi River | M | 3025 | 63 | 38 | **Full Support** |
| 38-0739 | Pea Soup | LAKE | Kawishiwi River | | 12 | | | |
| 69-1040 | Little Dry | ST. LOUIS | Kawishiwi River | | 15 | | 73 | |
| 69-0086 | Little Sletten | ST LOUIS | Kawishiwi River | | 17 | 30 | 41 | |
| 38-0805 | Unnamed | LAKE | Kawishiwi River | | 20 | | | **Full Support** |
| 69-0055 | Canary | ST. LOUIS | Kawishiwi River | | 21 | | | |
| 38-0855 | Hawks Nest | LAKE | Kawishiwi River | | 22 | | | |
| 38-0790 | Bright | LAKE | Kawishiwi River | | 23 | | | |

| Lake ID | Lake Name | County | HUC-11 Name | Trophic Status (O=oligotrophic M=mesotrophic E=eutrophic) | Lake Area (acres) | Max Depth (feet) | % Littoral | Assessment Status |
|---|---|---|---|---|---|---|---|---|
| 38-0717 | Kamimela | LAKE | Kawishiwi River | | 23 | 18 | | |
| 69-0084 | Sletten | ST LOUIS | Kawishiwi River | | 23 | 40 | 67 | |
| 38-0719 | Uranus | LAKE | Kawishiwi River | | 23 | | | **Full Support** |
| 69-0005 | Alruss | ST. LOUIS | Kawishiwi River | E | 27 | | 47 | **Insufficient Data** |
| 38-0791 | Thirty Three | LAKE | Kawishiwi River | | 27 | | | **Full Support** |
| 69-0067 | Picketts | ST. LOUIS | Kawishiwi River | | 28 | | | |
| 69-0083 | Tee | ST. LOUIS | Kawishiwi River | | 38 | | 43 | |
| 38-0787 | Azion | LAKE | Kawishiwi River | | 43 | | | |
| 69-0059 | Whisper | ST. LOUIS | Kawishiwi River | | 45 | 25 | 87 | |
| 38-0720 | Conchu | LAKE | Kawishiwi River | | 48 | | 49 | **Full Support** |
| 38-0786 | Sandpit | LAKE | Kawishiwi River | O | 59 | 53 | 29 | **Insufficient Data** |
| 69-0060 | Mud | ST. LOUIS | Kawishiwi River | | 62 | 4 | | |
| 38-0740 | Kempton | LAKE | Kawishiwi River | | 70 | | | |
| 69-0062 | Hobo | ST. LOUIS | Kawishiwi River | | 73 | 15 | 100 | |
| 38-0789 | Camp | LAKE | Kawishiwi River | | 77 | | | **Full Support** |
| 38-0812 | Range | LAKE | Kawishiwi River | | 80 | 19 | 67 | |
| 69-0064 | Dry | ST. LOUIS | Kawishiwi River | | 85 | 45 | 21 | |
| 38-0781 | Stub | LAKE | Kawishiwi River | | 88 | 20 | 73 | |
| 69-0058 | Perch | ST LOUIS | Kawishiwi River | | 98 | 13 | 100 | |
| 69-0054 | Blueberry | ST. LOUIS | Kawishiwi River | | 124 | 6 | | |
| 69-0159 | Muckwa | ST. LOUIS | Kawishiwi River | | 147 | 9 | 100 | |
| 69-0063 | Bass | ST LOUIS | Kawishiwi River | | 164 | 35 | 41 | |
| 38-0742 | Mud | LAKE | Kawishiwi River | | 177 | 17 | 88 | **Full Support** |
| 38-0741 | Pickerel | LAKE | Kawishiwi River | | 181 | 13 | 100 | |
| 38-0788 | Muskeg | LAKE | Kawishiwi River | | 193 | 7 | 100 | **Full Support** |

| Lake ID | Lake Name | County | HUC-11 Name | Trophic Status (O=oligotrophic M=mesotrophic E=eutrophic) | Lake Area (acres) | Max Depth (feet) | % Littoral | Assessment Status |
|---|---|---|---|---|---|---|---|---|
| 38-0780 | Browns | LAKE | Kawishiwi River | | 207 | 20 | | |
| 69-0082 | Grassy | ST LOUIS | Kawishiwi River | | 245 | 15 | | |
| 69-0071 | High | ST LOUIS | Kawishiwi River | | 274 | 66 | 36 | |
| 69-0070 | Low | ST. LOUIS | Kawishiwi River | | 288 | 40 | 52 | |
| 69-0066 | Little Long | ST LOUIS | Kawishiwi River | O | 319 | 45 | 23 | **Insufficient Data** |
| 38-0718 | Greenstone | LAKE | Kawishiwi River | | 329 | 72 | 38 | |
| 69-0061 | One Pine | ST LOUIS | Kawishiwi River | | 352 | 13 | 100 | |
| 69-0117 | Johnson | ST LOUIS | Kawishiwi River | | 447 | 18 | 99 | |
| 38-0810 | Cedar | LAKE | Kawishiwi River | | 460 | 42 | 34 | |
| 38-0784 | Newton | LAKE | Kawishiwi River | | 517 | 47 | 72 | |
| 38-0738 | North Branch Kawishiwi | LAKE | Kawishiwi River | M | 547 | 55 | | **Full Support** |
| 38-0778 | South Farm | LAKE | Kawishiwi River | E | 562 | 30 | 58 | **Insufficient Data** |
| 38-0782 | Garden | LAKE | Kawishiwi River | M | 636 | 55 | 36 | **Full Support** |
| 38-0779 | Farm | LAKE | Kawishiwi River | M | 1283 | 56 | 35 | **Full Support** |
| 38-0811 | Fall | LAKE | Kawishiwi River | M | 2234 | 32 | 54 | **Insufficient Data** |
| 69-0115 | Bear Island | ST LOUIS | Kawishiwi River | M | 2320 | 70 | 37 | **Insufficient Data** |
| 69-0004 | White Iron | ST LOUIS | Kawishiwi River | M | 3151 | 47 | 47 | **Full Support** |
| 38-0645 | Basswood | LAKE | Kawishiwi River | M | 14051 | 111 | 21 | **Full Support** |

# Appendix B

## Lake chemistry and MINLEAP results for assessed lakes

| Lake ID | Lake Name | TP Mean | TP MINLEAP | Chl –a Mean | Chl-a MINLEAP | Secchi Mean | Secchi MINLEAP | Average TP Inflow [4] | TP Load | Chiadudani/ Vighi [2] | Phos. Retention | Outflow | Residence Time | Areal Load |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ug/L | ug/L | ug/L | ug/L | meters | meters | ug/L | kg/yr | ug/L | % | hm3/yr | years | m/yr |
| 69-0254 | Bearhead [1] | 14 | 14 | 7.5 | 3 | 2.9 | 4.1 | 48 | 80 | 12 | 72 | 1.65 | 6.1 | 0.6 |
| 69-0115 | Bear Island | 18 | 12 | 6.3 | 2.6 | 1.9 | 4.4 | 37 | 559 | 10 | 67 | 15 | 4.8 | 1.6 |
| 69-0003 | Birch | 24 | 23 | 6.6 | 6.4 | 1.3 | 2.6 | 31 | 15,139 | 11 | 25 | 496 | 0.2 | 21.8 |
| 69-0004 | White Iron | 22 | 21 | 4 | 5.5 | 1.5 | 2.8 | 25 | 14,061 | 10 | 18 | 556 | 0.1 | 42.4 |
| 38-0782 | Garden Lake Reservoir [3] | 17 | 22 | 5.5 | 5.9 | 1.7 | 2.7 | 25 | 18,290 | 11 | 14 | 726 | 0.1 | 72.4 |
| 69-0069 | Shagawa | 21 | 16 | 6.4 | 3.8 | 3.2 | 3.6 | 53 | 1,606 | 12. | 41 | 59 | 0.9 | 6.3 |
| 38-0811 | Fall | 20 | 26 | 5.9 | 7.7 | 1.5 | 2.3 | 30 | 24,227 | 11 | 13 | 804 | 0.1 | 88.0 |

1. watershed areas are estimated for this headwater, seepage lake
2. estimated background TP based on lake alkalinity and mean depth
3. Garden, Farm, and South Farm combined for modeling purposes
4. TP inflow set at 30 ug/L except for Shagawa and White Iron (25 ug/L)