Battle Lake 31-0197-00 ITASCA COUNTY

Lake Water Quality

Summary

Battle Lake is located 20 miles northeast of Big Fork, MN in Itasca County. It is a somewhat small lake covering 243 acres (Table 1).

Battle Lake has two inlets and one outlet, which classify it as a drainage lake. Water enters Battle Lake from nearby lakes and exits the lake on the west side through Pickerel and Deer Lakes into the Big Fork River.

Water quality data have been collected on Battle Lake from 1993-2014 (Tables 2 & 3). These data show that the lake is mesotrophic (TSI = 45) with mostly clear water conditions most of the summer and excellent recreational opportunities.

Table 1. Battle Lake location and key physical characteristics.

Location Data		Physical Characteristics	
MN Lake ID:	31-0197-00	Surface area (acres):	243.3
County:	Itasca	Littoral area (acres):	243.3
Ecoregion:	Northern Lakes and Forests	% Littoral area:	72.1
Major Drainage Basin:	Big Fork R.	Max depth (ft), (m):	15.0, 4.5
Latitude/Longitude:	47.827972/ -93.340243	Inlets:	2
Invasive Species:	None (as of 2014)	Outlets:	1
		Public Accesses:	0

Table 2. Availability of primary data types for Battle Lake.

Data Availability

Transparency data		Good data set from 2003-2014.
Chemical data		Minimal data from 2003, 2008-2009.
Inlet/Outlet data		No stream data available.

Recommendations **For recommendations refer to page 19.**

Lake Map

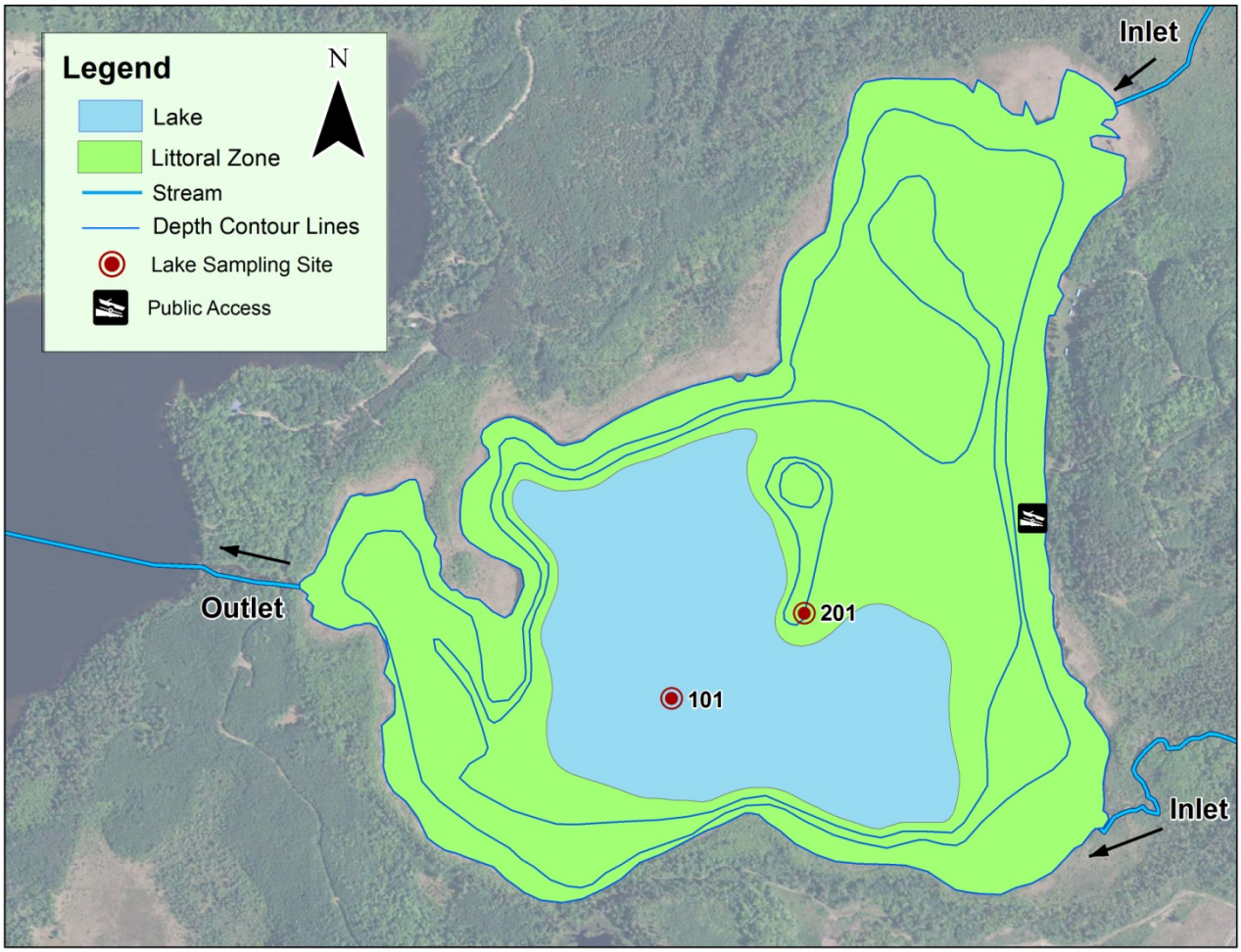


Figure 1. Map of Battle Lake with 2010 aerial imagery and illustrations of lake depth contour lines, sample site locations, inlets and outlets, and public access points. The light green areas in the lake illustrate the littoral zone, where the sunlight can usually reach the lake bottom, allowing aquatic plants to grow.

Table 3. Monitoring programs and associated monitoring sites. Monitoring programs include the Citizen Lake Monitoring Program (CLMP), Lake Assessment Projects (LAP), and Itasca County Lakes Inventory (ICLI).

Lake Site	Depth (ft)	Monitoring Programs
101	15	LAP: 2003
201	10	CLMP: 2003-2014; ICLI: 2008-2009

Average Water Quality Statistics

The information below describes available chemical data for Battle Lake through 2014 (Table 4). Data for total phosphorus, chlorophyll *a*, and Secchi depth are from the primary site 201.

Minnesota is divided into 7 ecoregions based on land use, vegetation, precipitation and geology. The MPCA has developed a way to determine the "average range" of water quality expected for lakes in each ecoregion. For more information on ecoregions and expected water quality ranges, see page 11. Battle Lake is in the Northern Lakes and Forests Ecoregion.

Table 4. Water quality means compared to ecoregion ranges and impaired waters standard.

Parameter	Mean	Ecoregion Range[1]	Impaired Waters Standard[2]	Interpretation
Total phosphorus (ug/L)	13.6	14 – 27	> 30	Results are within the expected range for the Northern Lakes and Forests Ecoregion.
[3]Chlorophyll *a* (ug/L)	4.7	4 – 10	> 9	
Chlorophyll *a* max (ug/L)	11.5	< 15		
Secchi depth (ft)	8.3	8 – 15	< 6.5	
Dissolved oxygen	*See page 8*			Dissolved oxygen depth profiles show that the lake mixes all summer.
Total Kjeldahl Nitrogen (mg/L)	NA	<0.4 – 0.75		No data available.
Alkalinity (mg/L)	143.0	40 – 140		Indicates a low sensitivity to acid rain and a good buffering capacity.
Color (Pt-Co Units)	10.4	10 – 35		Indicates clear water with little to no tannins (brown stain).
pH	8.2	7.2 – 8.3		Within the expected range for the ecoregion. Lake water pH less than 6.5 can affect fish spawning and the solubility of metals in the water.
Chloride (mg/L)	NA	0.6 – 1.2		No data available.
Total Suspended Solids (mg/L)	2.4	<1 – 2		Indicates low suspended solids and clear water.
Conductivity (umhos/cm)	NA	50 – 250		No data available.
TN:TP Ratio	NA	25:1 - 35:1		No nitrogen data available.

[1]The ecoregion range is the 25th-75th percentile of summer means from ecoregion reference lakes
[2]For further information regarding the Impaired Waters Assessment program, refer to http://www.pca.state.mn.us/water/tmdl/index.html
[3]Chlorophyll *a* measurements have been corrected for pheophytin
Units: 1 mg/L (ppm) = 1,000 ug/L (ppb)

Water Quality Characteristics - Historical Means and Ranges

Table 5. Water quality means and ranges for primary sites.

Parameters	Primary Site 201
Total Phosphorus Mean (ug/L):	**13.6**
Total Phosphorus Min:	10.0
Total Phosphorus Max:	24.0
Number of Observations:	9
Chlorophyll *a* Mean (ug/L):	**4.7**
Chlorophyll-a Min:	1.8
Chlorophyll-a Max:	11.5
Number of Observations:	9
Secchi Depth Mean (ft):	**8.3**
Secchi Depth Min:	4.6
Secchi Depth Max:	12.1
Number of Observations:	122

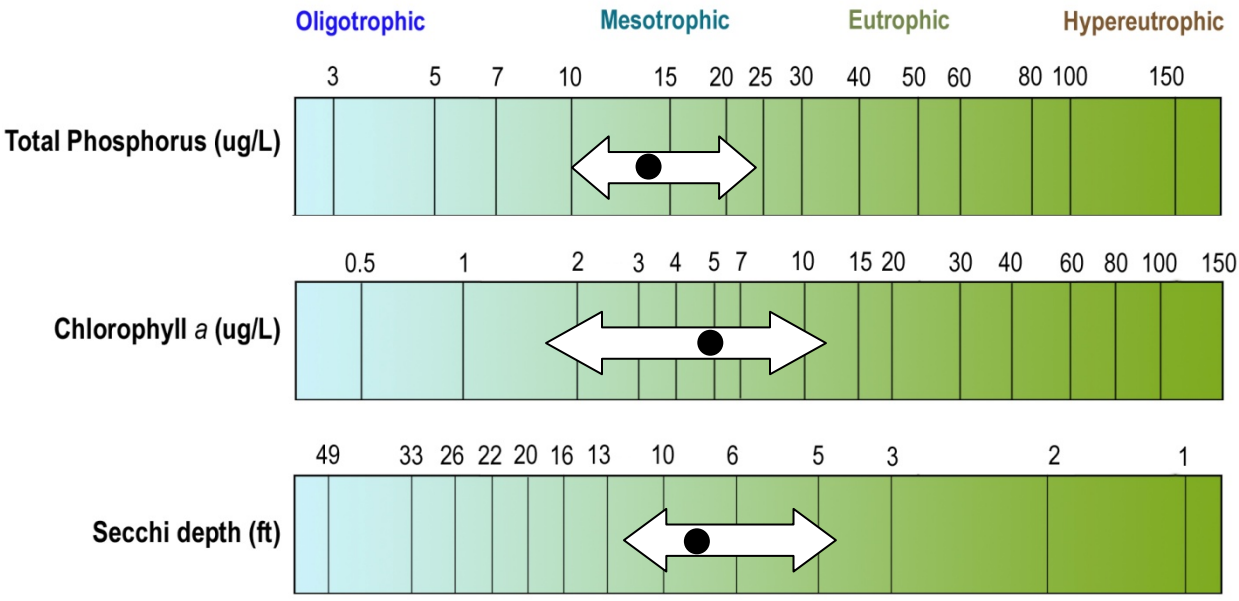


Figure 2. Battle Lake total phosphorus, chlorophyll a and transparency historical ranges. The arrow represents the range and the black dot represents the historical mean (Primary Site 201). Figure adapted after Moore and Thornton, [Ed.]. 1988. Lake and Reservoir Restoration Guidance Manual. (Doc. No. EPA 440/5-88-002)

Transparency (Secchi Depth)

Transparency is how easily light can pass through a substance. In lakes it is how deep sunlight penetrates through the water. Plants and algae need sunlight to grow, so they are only able to grow in areas of lakes where the sun penetrates. Water transparency depends on the amount of particles in the water. An increase in particulates results in a decrease in transparency. The transparency varies year to year due to changes in weather, precipitation, lake use, flooding, temperature, lake levels, etc.

The annual mean transparency in Battle Lake ranges from 6.4 to 10.3 feet (Figure 3). The annual means have been lower than the long-term mean since 2011. For trend analysis, see page 10. Transparency monitoring should be continued annually at site 201 in order to track water quality changes.

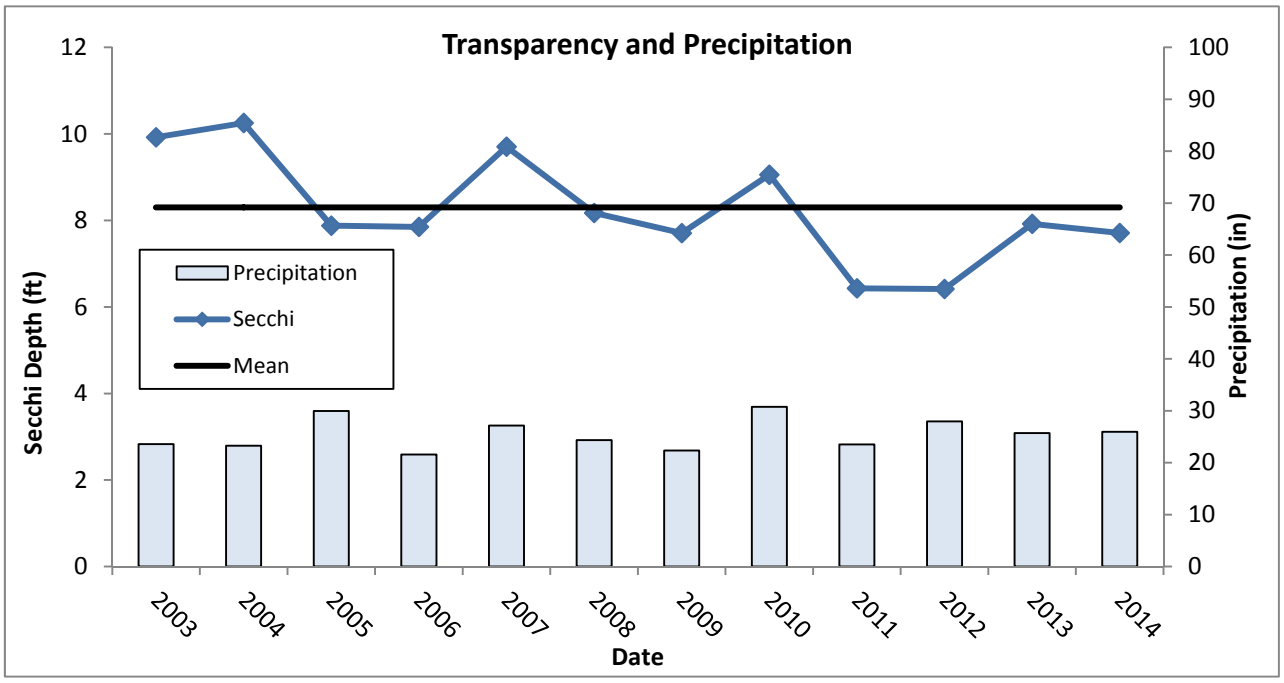


Figure 3. Annual mean transparency compared to long-term mean transparency.

Battle Lake transparency ranges from 4.6 to 12.1 ft at the primary site (201). Figure 4 shows the seasonal transparency dynamics. The maximum Secchi reading is usually obtained in early summer. Battle Lake transparency is high in May and June, and then declines through August. The transparency then rebounds in October after fall turnover. This transparency dynamic is typical of a Minnesota lake. The dynamics have to do with algae and zooplankton population dynamics, and lake turnover.

It is important for lake residents to understand the seasonal transparency dynamics in their lake so that they are not worried about why their transparency is lower in August than it is in June. It is typical for a lake to vary in transparency throughout the summer.

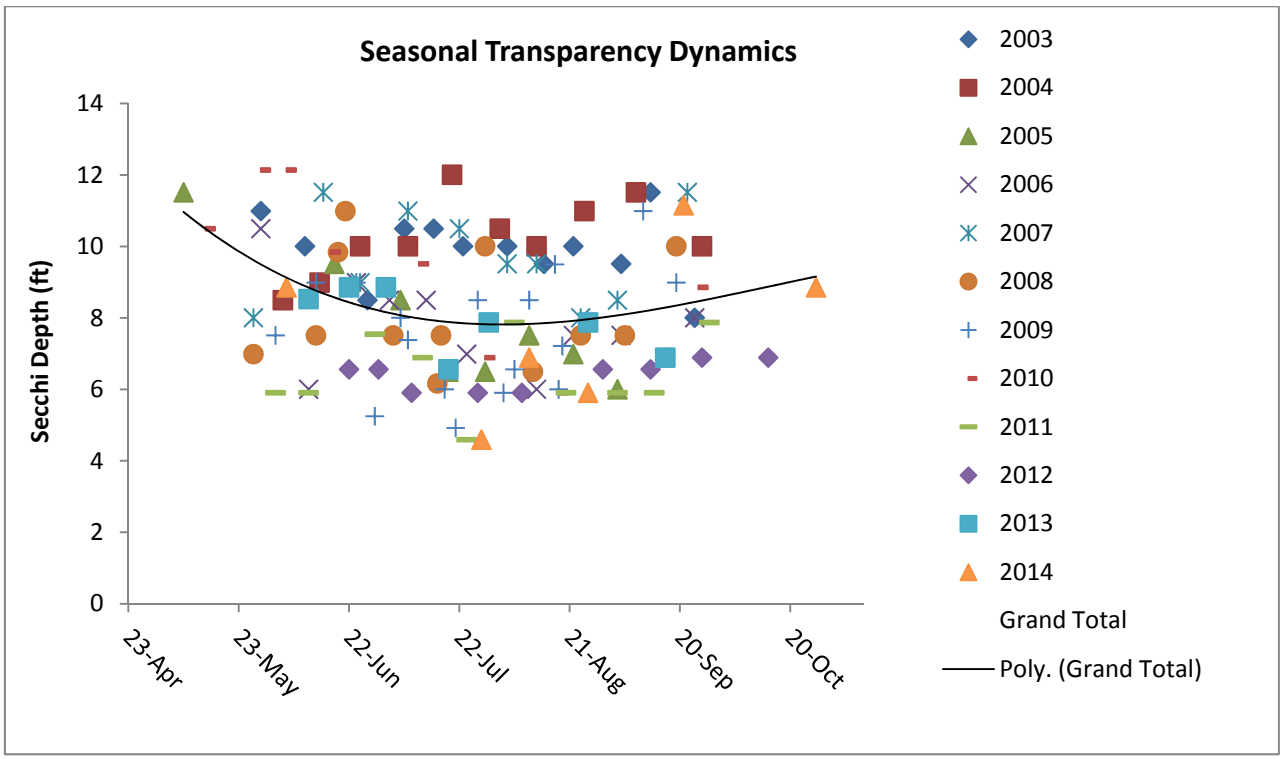


Figure 4. Seasonal transparency dynamics and year to year comparison (Primary Site 201). The black line represents the pattern in the data.

User Perceptions

When volunteers collect Secchi depth readings, they record their perceptions of the water based on the physical appearance and the recreational suitability. These perceptions can be compared to water quality parameters to see how the lake "user" would experience the lake at that time. Looking at transparency data, as the Secchi depth decreases the perception of the lake's physical appearance rating decreases. Battle Lake was rated as being "not quite crystal clear" 63% of the time by samplers at site 201 between 2003 and 2014 (Figure 5).

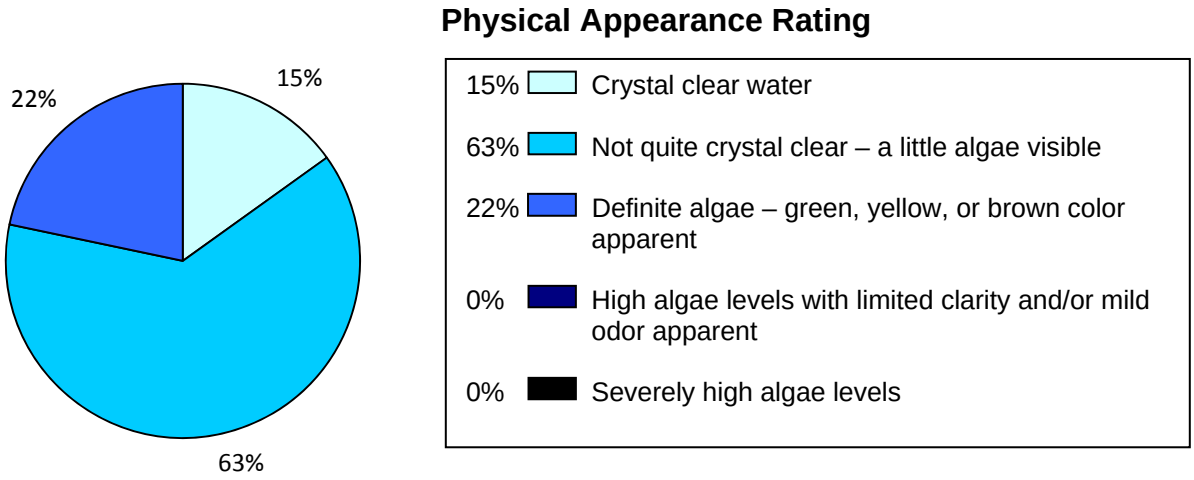


Figure 5. Battle Lake physical appearance ratings by samplers.

As the Secchi depth decreases, the perception of recreational suitability of the lake decreases. Battle Lake was rated as having "very minor aesthetic problems" 42% of the time from 2003 to 2014 (Figure 6).

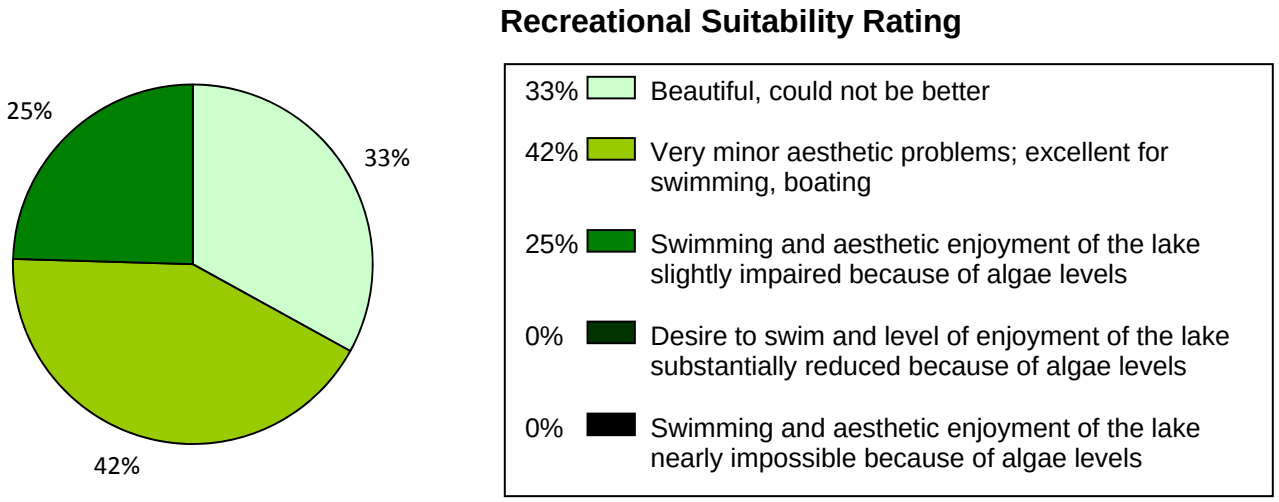


Figure 6. Recreational suitability rating, as rated by the volunteer monitor.

Total Phosphorus

Battle Lake is phosphorus limited, which means that algae and aquatic plant growth is dependent upon available phosphorus.

Total phosphorus was evaluated in Battle Lake in 2003, 2008-2009. The data do not indicate much seasonal variability. The majority of the data points fall into the mesotrophic range (Figure 7).

There are a couple higher phosphorus points in mid-summer, which could be due to the lake turning over after a wind event.

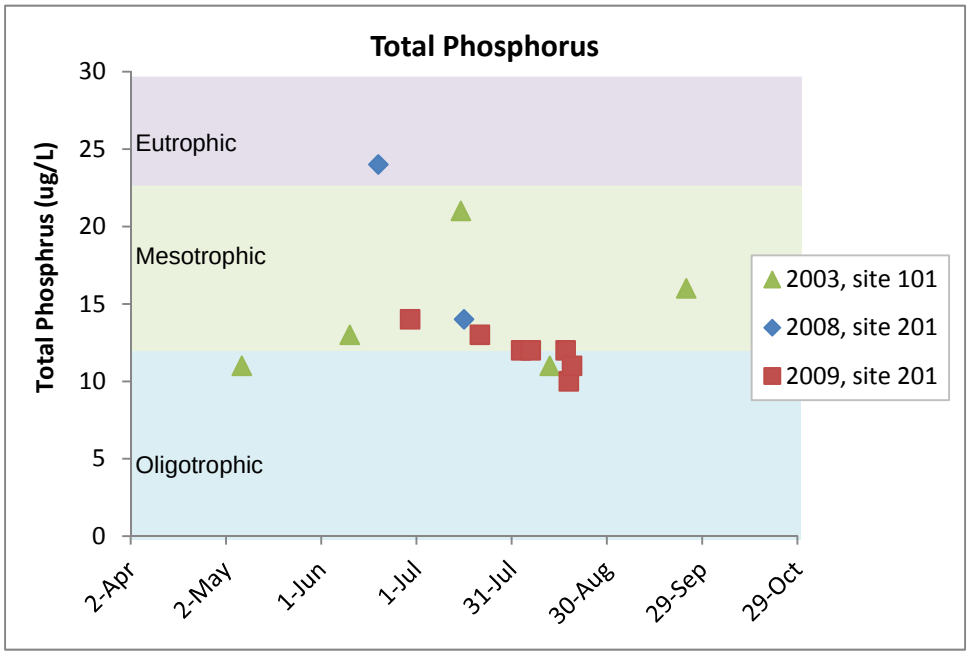


Figure 7. Historical total phosphorus concentrations (ug/L) for Battle Lake site 201.

Phosphorus should continue to be monitored to track any future changes in water quality.

Chlorophyll *a*

Chlorophyll *a* is the pigment that makes plants and algae green. Chlorophyll *a* is tested in lakes to determine the algae concentration or how "green" the water is.

Chlorophyll *a* concentrations greater than 10 ug/L are perceived as a mild algae bloom, while concentrations greater than 20 ug/L are perceived as a nuisance.

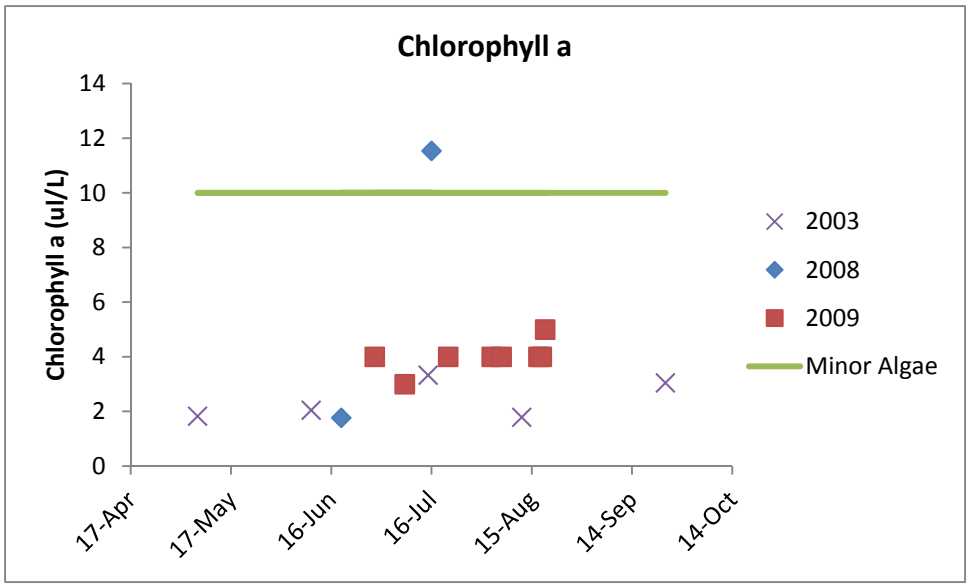
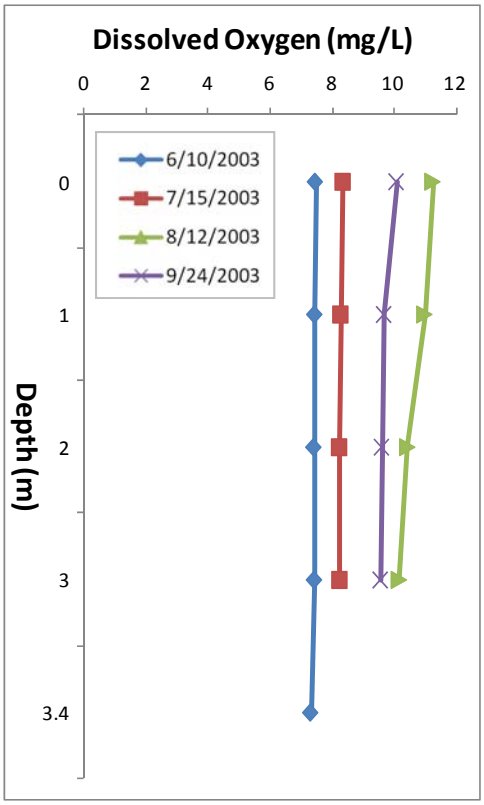


Figure 8. Chlorophyll *a* concentrations (ug/L) for Battle Lake at site 202.

Chlorophyll *a* was evaluated in Battle Lake in 2003, 2008-2009 (Figure 8). Chlorophyll *a* concentrations went above 10 ug/L only once, indicating very clear water most years. There was not much variation over the years monitored and chlorophyll *a* concentrations remained relatively steady over the summer.

Dissolved Oxygen



Dissolved Oxygen (DO) is the amount of oxygen dissolved in lake water. Oxygen is necessary for all living organisms to survive except for some bacteria. Living organisms breathe in oxygen that is dissolved in the water. Dissolved oxygen levels of <5 mg/L are typically avoided by game fisheries.

Battle Lake is a shallow lake, with a maximum depth of 15 feet. Dissolved oxygen profiles from data collected in 2003 show that the lake is mixed all summer (Figure 9). In a shallow lake, the water column never completely stratifies. Any windy day can mix up the water column causing phosphorus from the anoxic lake bottom to re-suspend into the water. This phenomenon is known as internal loading.

Figure 9. Dissolved oxygen profile for Battle Lake.

Trophic State Index (TSI)

TSI is a standard measure or means for calculating the trophic status or productivity of a lake. More specifically, it is the total weight of living algae (algae biomass) in a waterbody at a specific location and time. Three variables, chlorophyll a, Secchi depth, and total phosphorus, independently estimate algal biomass.

Phosphorus (nutrients), chlorophyll *a* (algae concentration) and Secchi depth (transparency) are related. As phosphorus increases, there is more food available for algae, resulting in increased algal concentrations. When algal concentrations increase, the water becomes less transparent and the Secchi depth decreases. If all three TSI numbers are within a few points of each other, they are strongly related. If they are different, there are other dynamics influencing the lake's productivity, and TSI mean should not be reported for the lake.

The mean TSI for Battle Lake falls into the mesotrophic range (Figure 10). There is good agreement between the TSI for phosphorus, chlorophyll *a* and transparency, indicating that these variables are strongly related (Table 6).

Mesotrophic lakes (TSI 40-50) are characterized by moderately clear water most of the summer. "Meso" means middle or mid; therefore, mesotrophic means a medium amount of productivity. Mesotrophic lakes are commonly found in central Minnesota and have clear water with algal blooms in late summer (Table 7). They are also good for walleye fishing.

Table 6. Trophic State Index for site 202.

Trophic State Index	Site 201
TSI Total Phosphorus	42
TSI Chlorophyll-a	46
TSI Secchi	47
TSI Mean	45
Trophic State:	Mesotrophic

Numbers represent the mean TSI for each parameter.

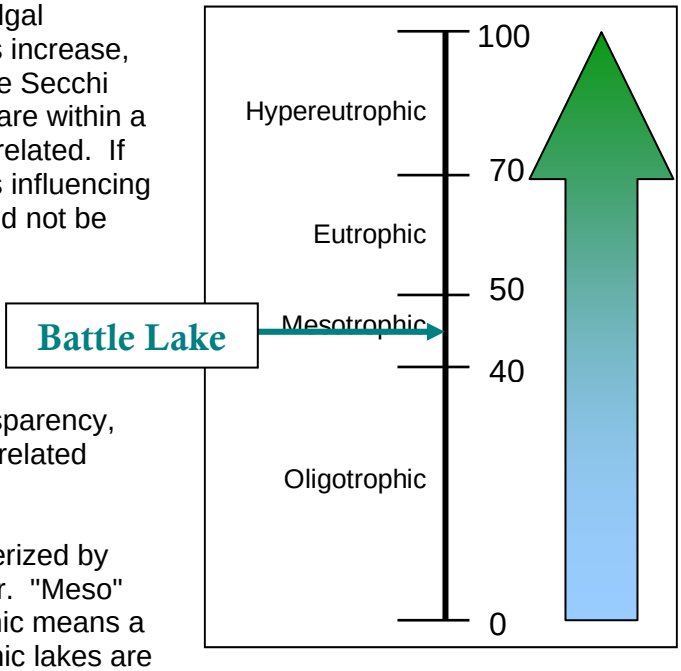


Figure 10. Trophic state index chart with corresponding trophic status.

Table 7. Trophic state index attributes and their corresponding fisheries and recreation characteristics.

TSI	Attributes	Fisheries & Recreation
<30	Oligotrophy: Clear water, oxygen throughout the year at the bottom of the lake, very deep cold water.	Trout fisheries dominate
30-40	Bottom of shallower lakes may become anoxic (no oxygen).	Trout fisheries in deep lakes only. Walleye, Cisco present.
40-50	Mesotrophy: Water moderately clear most of the summer. May be "greener" in late summer.	No oxygen at the bottom of the lake results in loss of trout. Walleye may predominate.
50-60	Eutrophy: Algae and aquatic plant problems possible. "Green" water most of the year.	Warm-water fisheries only. Bass may dominate.
60-70	Blue-green algae dominate, algal scums and aquatic plant problems.	Dense algae and aquatic plants. Low water clarity may discourage swimming and boating.
70-80	Hypereutrophy: Dense algae and aquatic plants.	Water is not suitable for recreation.
>80	Algal scums, few aquatic plants	Rough fish (carp) dominate; summer fish kills possible

Source: Carlson, R.E. 1997. A trophic state index for lakes. *Limnology and Oceanography*. 22:361-369.

Trend Analysis

For detecting trends, a minimum of 8-10 years of data with 4 or more readings per season are recommended. Minimum confidence accepted by the MPCA is 90%. This means that there is a 90% chance that the data are showing a true trend and a 10% chance that the trend is a random result of the data. Only short-term trends can be determined with just a few years of data, because there can be different wet years and dry years, water levels, weather, etc, that affect the water quality naturally.

Battle Lake had enough data to perform a trend analysis on transparency (Table 8). The data was analyzed using the Mann Kendall Trend Analysis.

Table 8. Trend analysis for site 202.

Lake Site	Parameter	Date Range	Trend	Probability
201	Total Phosphorus	2008-2009	Insufficient data	--
201	Chlorophyll *a*	2008-2009	Insufficient data	--
201	Transparency	2003-2014	Declining	95%

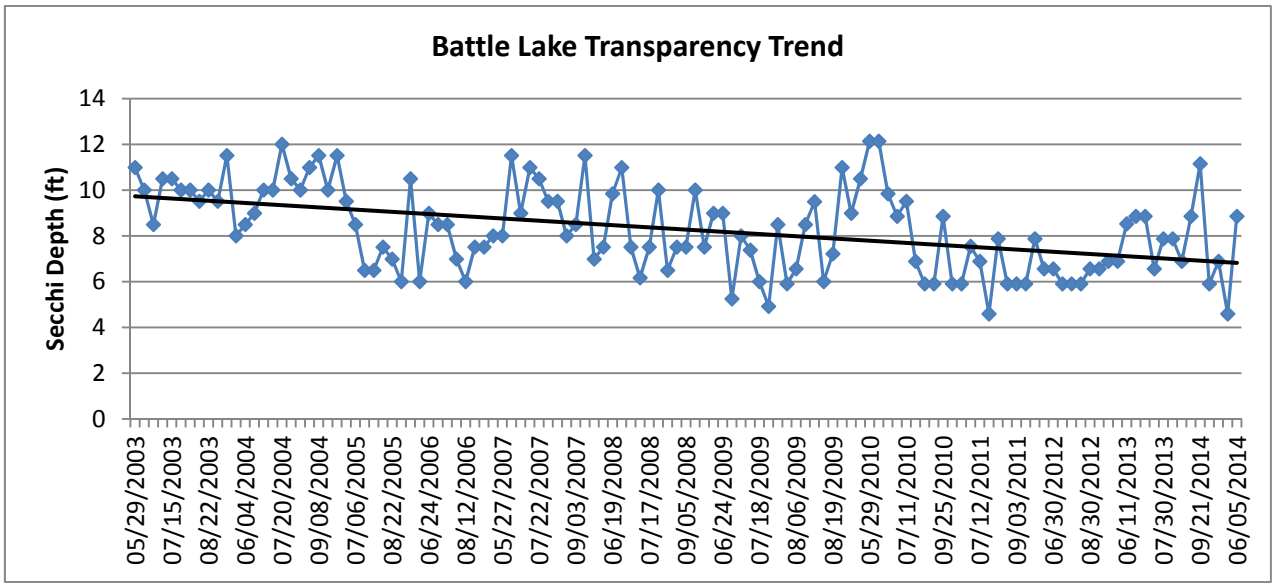


Figure 11. Transparency (feet) trend for site 201 from 1994-2014.

Battle Lake shows evidence of a declining transparency trend (Figure 11). The yearly minimum and maximum transparencies are declining, showing more algae blooms. Transparency monitoring should continue so that this trend can be tracked in future years.

Ecoregion Comparisons

Minnesota is divided into 7 ecoregions based on land use, vegetation, precipitation and geology (Figure 12). The MPCA has developed a way to determine the "average range" of water quality expected for lakes in each ecoregion. From 1985-1988, the MPCA evaluated the lake water quality for reference lakes. These reference lakes are not considered pristine, but are considered to have little human impact and therefore are representative of the typical lakes within the ecoregion. The "average range" refers to the 25th - 75th percentile range for data within each ecoregion. For the purpose of this graphical representation, the means of the reference lake data sets were used.

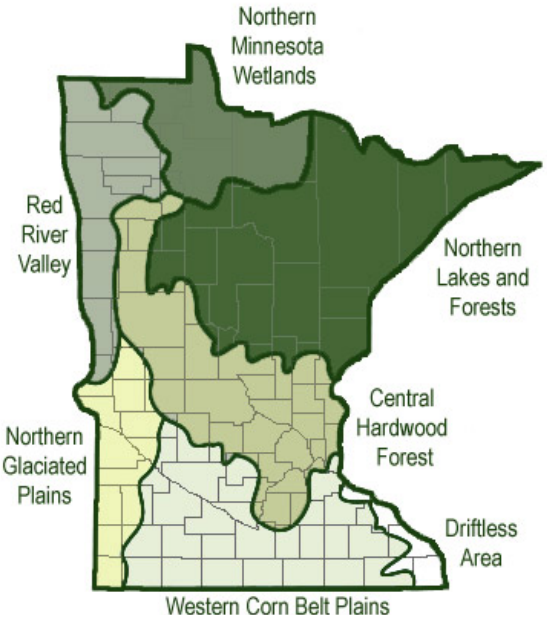
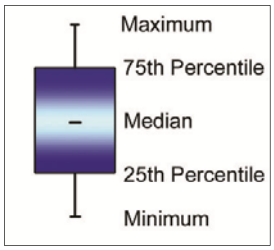


Figure 12. Minnesota Ecoregions.

Battle Lake is in the Northern Lakes and Forest Ecoregion. The mean total phosphorus, chlorophyll *a* and transparency (Secchi depth) for Battle Lake are within the ecoregion ranges (Figure 13).



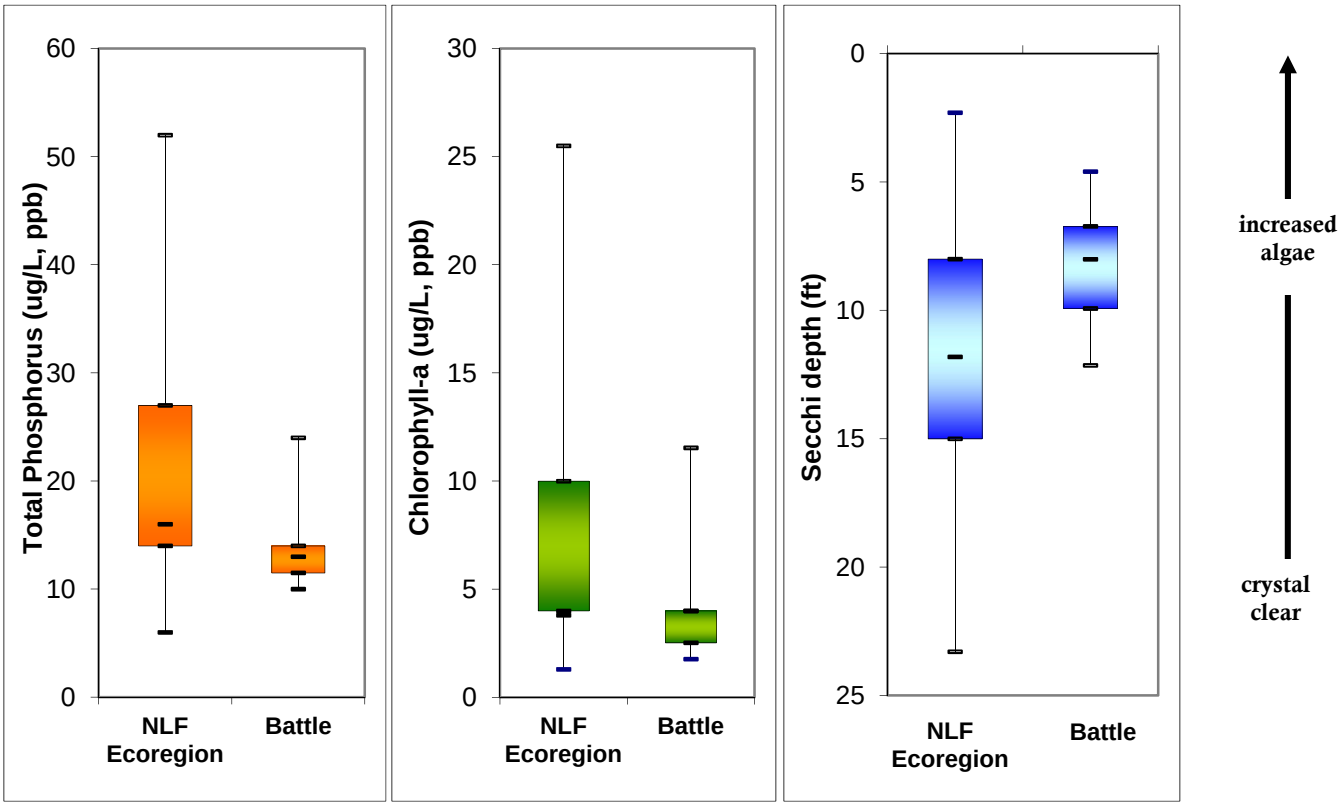


Figure 13. Battle Lake ranges compared to Northern Lakes and Forest Ecoregion ranges. The Battle Lake total phosphorus and chlorophyll *a* ranges are from 14 data points collected in May-September of 2003, 2008-2009. The Battle Lake Secchi depth range is from 122 data points collected in May-September of 1993-2014.

Lakeshed Data and Interpretations

Lakeshed

Understanding a lakeshed requires an understanding of basic hydrology. A watershed is defined as all land and water surface area that contribute excess water to a defined point. The MN DNR has delineated three basic scales of watersheds (from large to small): 1) basins, 2) major watersheds, and 3) minor watersheds.

The Big Fork River Major Watershed is one of the watersheds that make up the Rainy River Basin, which drains north to Hudson's Bay (Figure 14). Battle Lake is located in minor watershed 77019 (Figure 15).

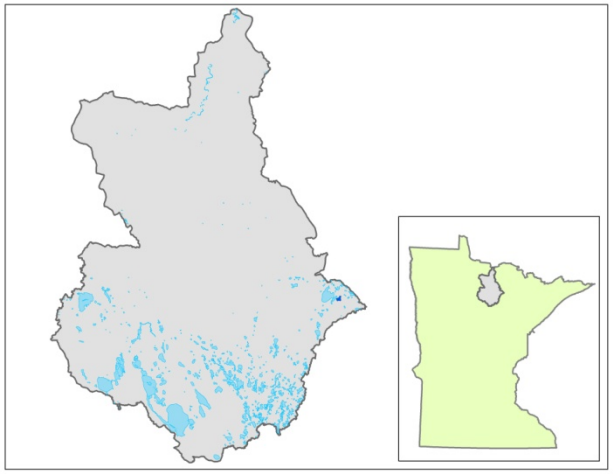


Figure 14. Major Watershed.

Figure 15. Minor Watershed.

The MN DNR also has evaluated catchments for each individual lake with greater than 100 acres surface area. These lakesheds (catchments) are the "building blocks" for the larger scale watersheds. Battle Lake falls within lakeshed 7701903 (Figure 16). Though very useful for displaying the land and water that contribute directly to a lake, lakesheds are not always true watersheds because they may not show the water flowing into a lake from upstream streams or rivers. While some lakes may have only one or two upstream lakesheds draining into them, others

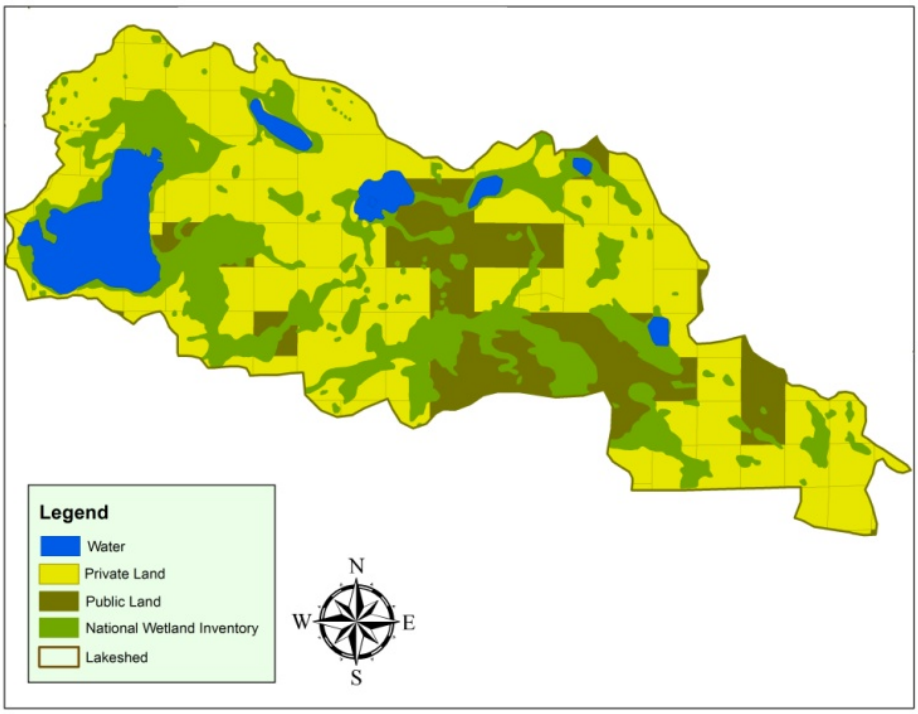


Figure 16. Battle Lake lakeshed (6002001) with land ownership, lakes, wetlands, and rivers illustrated.

may be connected to a large number of lakesheds, reflecting a larger drainage area via stream or river networks. For further discussion of Battle Lake's watershed, containing all the lakesheds upstream of the Battle Lake lakeshed, see page 17. The data interpretation of the Battle Lake lakeshed includes only the immediate lakeshed as this area is the land surface that flows directly into Battle Lake.

The lakeshed vitals table identifies where to focus organizational and management efforts for each lake (Table 9). Criteria were developed using limnological concepts to determine the effect to lake water quality.

KEY

Possibly detrimental to the lake
Warrants attention
Beneficial to the lake

Table 9. Battle Lake lakeshed vitals table.

Lakeshed Vitals		**Rating**
Lake Area	243.32 acres	descriptive
Littoral Zone Area	175.37 acres	descriptive
Lake Max Depth	14.9 feet	descriptive
Lake Mean Depth	8.11 feet	descriptive
Water Residence Time	NA	NA
Miles of Stream	5.17 miles	descriptive
Inlets	2	
Outlets	1	
Major Watershed	77 - Big Fork R.	descriptive
Minor Watershed	77019	descriptive
Lakeshed	7701903	descriptive
Ecoregion	Northern Lakes and Forests	descriptive
Total Lakeshed to Lake Area Ratio (total lakeshed includes lake area)	18:1	
Standard Watershed to Lake Basin Ratio (standard watershed includes lake areas)	22:1	
Wetland Coverage (NWI)	24.7%	
Aquatic Invasive Species	None	
Public Drainage Ditches	0	
Public Lake Accesses	0	
Miles of Shoreline	3.51	descriptive
Shoreline Development Index	1.61	
Public Land to Private Land Ratio	1:2.9	
Development Classification	Recreational Development	
Miles of Road	10.41 miles	descriptive
Municipalities in lakeshed	None	
Forestry Practices	Some in 2013, see Figure 21.	
Feedlots	0	
Sewage Management	Individual waste treatment systems (septic systems and holding tanks)	
Lake Management Plan	None	
Lake Vegetation Survey/Plan	DNR, 2002	

Land Cover / Land Use

The activities that occur on the land within the lakeshed can greatly impact a lake. Land use planning helps ensure the use of land resources in an organized fashion so that the needs of the present and future generations can be best addressed. The basic purpose of land use planning is to ensure that each area of land will be used in a manner that provides maximum social benefits without degradation of the land resource.

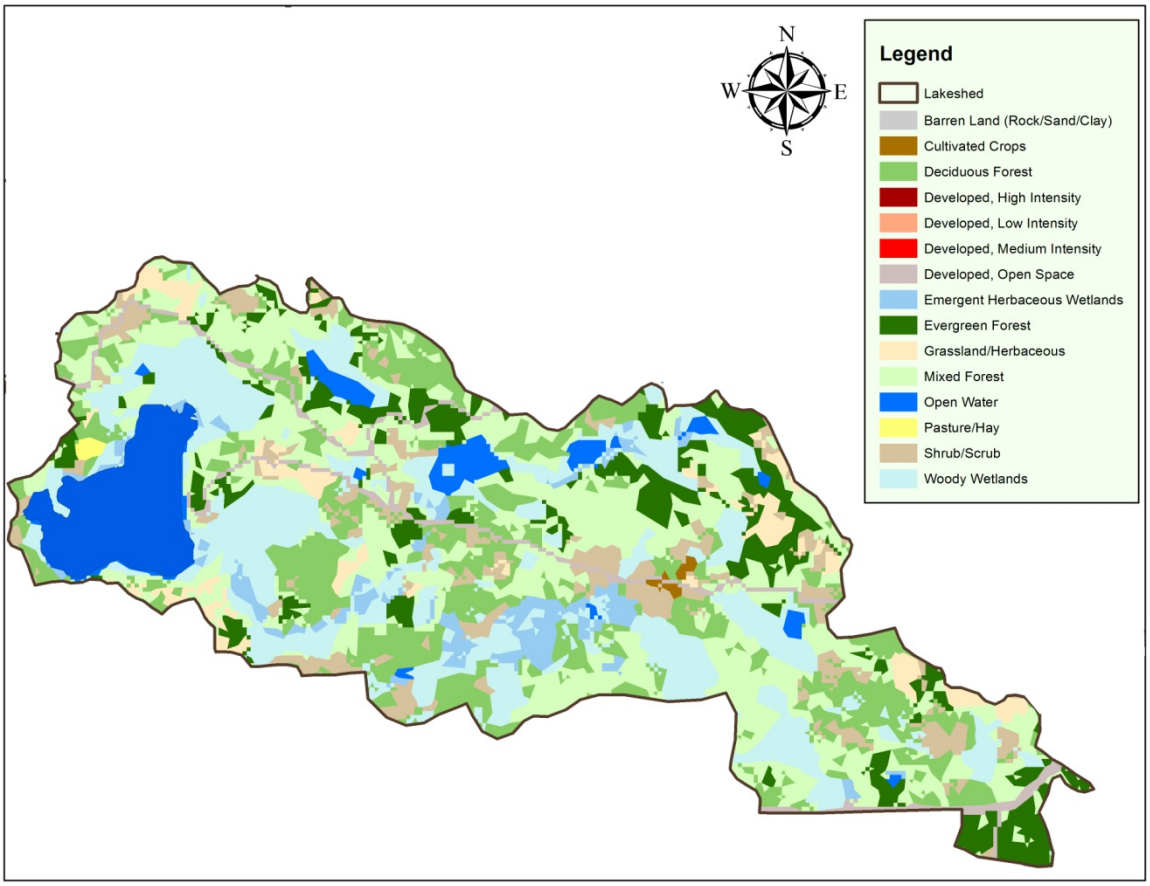


Figure 17. Battle Lake lakeshed (7701903) land cover (NLCD 2011).

Changes in land use, and ultimately land cover, impact the hydrology of a lakeshed. Land cover is also directly related to the land's ability to absorb and store water rather than cause it to flow overland (gathering nutrients and sediment as it moves) towards the lowest point, typically the lake. Impervious intensity describes the land's inability to absorb water, the higher the % impervious intensity the more area that water cannot penetrate in to the soils. Monitoring the changes in land use can assist in future planning procedures to address the needs of future generations.

Phosphorus export, which is the main cause of lake eutrophication, depends on the type of land cover occurring in the lakeshed. Figure 17 depicts the land cover in Battle Lake 's lakeshed.

The National Land Cover Dataset (NLCD) has records from 2001 and 2011. Table 10 describes Battle Lake's lakeshed land cover statistics and percent change from 2001 to 2011. Overall, the mixed forest and shrub/scrub decreased, while deciduous forest and grassland increased (Table 10). There was negligible change in the urban and impervious cover from 1990-2000 (Table 11).

Table 10. Battle Lake's lakeshed land cover statistics and % change from 2001 to 2011 (Data Source: NLCD).

Land Cover	2001 Acres	Percent	2011 Acres	Percent	% Change 2001 to 2011
Cultivated Crops	8.35	0.20	8.62	0.21	0.0065
Deciduous Forest	492.77	11.86	715.13	17.21	5.3493
Developed Open Space	108.25	2.61	111.18	2.68	0.0699
Emergent Herbaceous Wetlands	192.19	4.63	160.78	3.87	-0.7568
Evergreen Forest	416.53	10.03	395.84	9.53	-0.4998
Grassland/Herbaceous	9.23	0.22	158.92	3.82	3.6028
Mixed Forest	1217.88	29.32	1090.50	26.25	-3.0712
Open Water	336.87	8.11	325.11	7.82	-0.2846
Pasture/Hay	7.03	0.17	7.04	0.17	0.0004
Shrub/Scrub	539.62	12.99	308.10	7.42	-5.5746
Woody Wetlands	825.49	19.87	873.77	21.03	1.1581
Total Area	4155				

Table 11. Battle Lake development area and % change from 1990-2000 (Data Source: UMN Landsat).

Category	1990 Acres	Percent	2000 Acres	Percent	% Change 1990 to 2000
Total Impervious Area	9	0.24	13	0.34	0.1
Urban Acreage	110	2.65	110	2.65	0

Demographics

Battle Lake is classified as a Recreational Development lake. Recreational Development lakes usually have between 60 and 225 acres of water per mile of shoreline, between 3 and 25 dwellings per mile of shoreline, and are more than 15 feet deep.

The Minnesota Department of Administration Geographic and Demographic Analysis Division extrapolated future population in 5-year increments out to 2035. Compared to Itasca County as a whole, Carpenter Township has a higher growth projection (Figure 18).
(source: http://www.demography.state.mn.us)

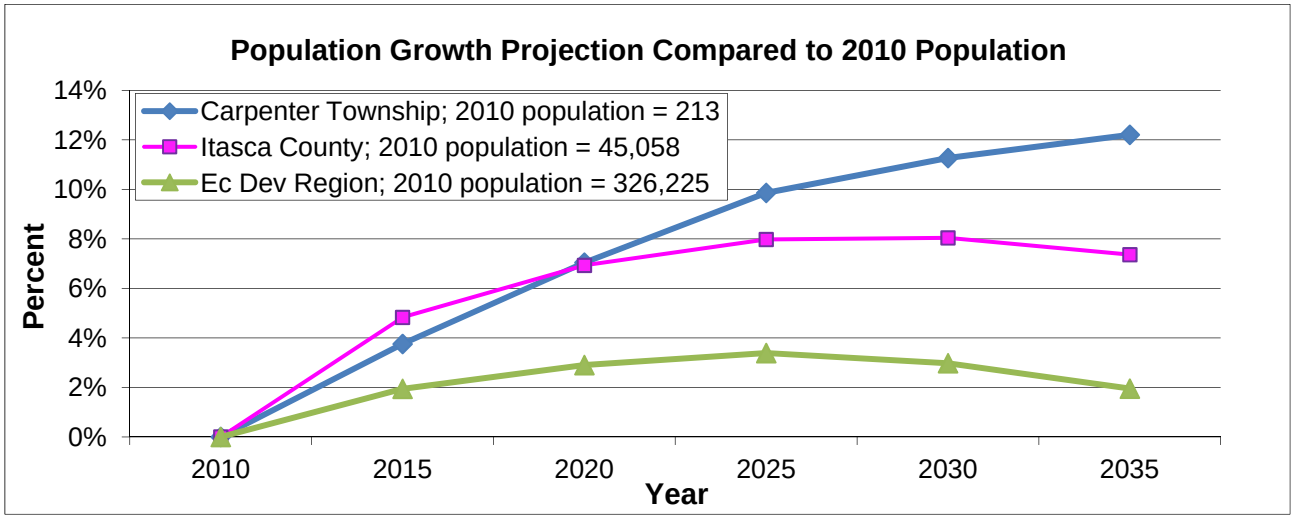


Figure 18. Population growth projection for adjacent townships and Itasca County.

Lakeshed Water Quality Protection Strategy

Each lakeshed has a different makeup of public and private lands. Looking in more detail at the makeup of these lands can give insight on where to focus protection efforts. The protected lands (easements, wetlands, public land) are the future water quality infrastructure for the lake. Developed land and agriculture have the highest phosphorus runoff coefficients, so this land should be minimized for water quality protection.

The majority of the land within Battle Lake's lakeshed is privately owned forest (Table 12). This land can be the focus of development and protection efforts in the lakeshed.

Table 12. Land ownership, land use/land cover, estimated phosphorus loading, and ideas for protection and restoration in the lakeshed (Sources: County parcel data and the 2011 National Land Cover Dataset).

	Private (68.6)					8.0	Public (23.4)		
	Developed	**Agriculture**	**Forested Uplands**	**Other**	**Wetlands**	**Open Water**	**County**	**State**	**Federal**
Land Use (%)	2.5%	0.4%	46.1%	3.5%	16.2%	8.0%	0%	22.5%	0.9%
Runoff Coefficient Lbs of phosphorus/acre/year	0.45 – 1.5	0.26 – 0.9	0.09		0.09		0.09	0.09	0.09
Estimated Phosphorus Loading Acreage x runoff coefficient	46 –154	4 –14	172		1.5		0.018	84.168	3.348
Description	Focused on Shoreland	Cropland	Focus of develop-ment and protection efforts	Open, pasture, grass-land, shrub-land	Protected				
Restoration and Protection Options	Shoreline restoration	Restore wetlands; CRP	Forest stewardship planning, 3rd party certification, SFIA, local woodland cooperatives		Protected by Wetland Conservation Act		County Tax Forfeit Lands	State Forest	National Forest

DNR Fisheries approach for lake protection and restoration

Credit: Peter Jacobson and Michael Duval, Minnesota DNR Fisheries

In an effort to prioritize protection and restoration efforts of fishery lakes, the MN DNR has developed a ranking system by separating lakes into two categories, those needing protection and those needing restoration. Modeling by the DNR Fisheries Research Unit suggests that total phosphorus concentrations increase significantly over natural concentrations in lakes that have watershed with disturbance greater than 25%. Therefore, lakes with watersheds that have less than 25% disturbance need protection and lakes with more than 25% disturbance need restoration (Table 13). Watershed disturbance was defined as having urban, agricultural and mining land uses. Watershed protection is defined as publicly owned land or conservation easement.

Table 13. Suggested approaches for watershed protection and restoration of DNR-managed fish lakes in Minnesota.

Watershed Disturbance (%)	Watershed Protected (%)	Management Type	Comments
< 25%	> 75%	Vigilance	Sufficiently protected -- Water quality supports healthy and diverse native fish communities. Keep public lands protected.
	< 75%	Protection	Excellent candidates for protection -- Water quality can be maintained in a range that supports healthy and diverse native fish communities. Disturbed lands should be limited to less than 25%.
25-60%	n/a	Full Restoration	Realistic chance for full restoration of water quality and improve quality of fish communities. Disturbed land percentage should be reduced and BMPs implemented.
> 60%	n/a	Partial Restoration	Restoration will be very expensive and probably will not achieve water quality conditions necessary to sustain healthy fish communities. Restoration opportunities must be critically evaluated to assure feasible positive outcomes.

The next step was to prioritize lakes within each of these management categories. DNR Fisheries identified high value fishery lakes, such as cisco refuge lakes. Ciscos (*Coregonus artedi)* can be an early indicator of eutrophication in a lake because they require cold hypolimnetic temperatures and high dissolved oxygen levels. These watersheds with low disturbance and high value fishery lakes are excellent candidates for priority protection measures, especially those that are related to forestry and minimizing the effects of landscape disturbance. Forest stewardship planning, harvest coordination to reduce hydrology impacts and forest conservation easements are some potential tools that can protect these high value resources for the long term.

Battle Lake's lakeshed is classified with having 81% of the watershed protected and 2% of the watershed disturbed (Figure 19). Therefore, this lakeshed should have a vigilance focus. Goals for the lake should be to keep the public lands protected. Battle Lake has one other lakeshed flowing into it (Figure 20).

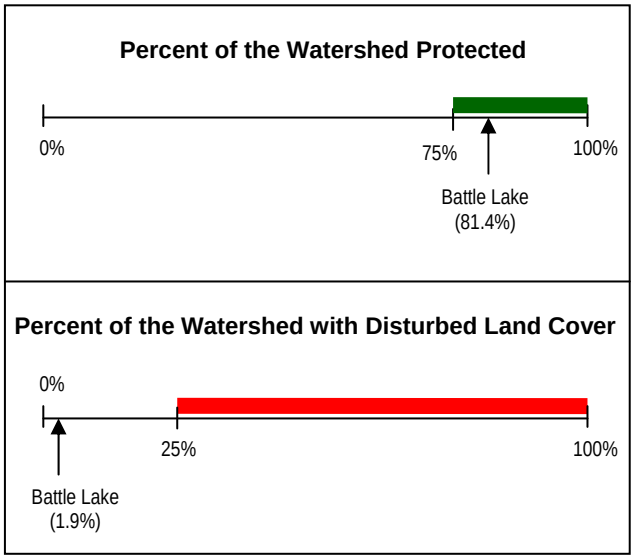


Figure 19. Battle Lake's lakeshed percentage of watershed protected and disturbed.

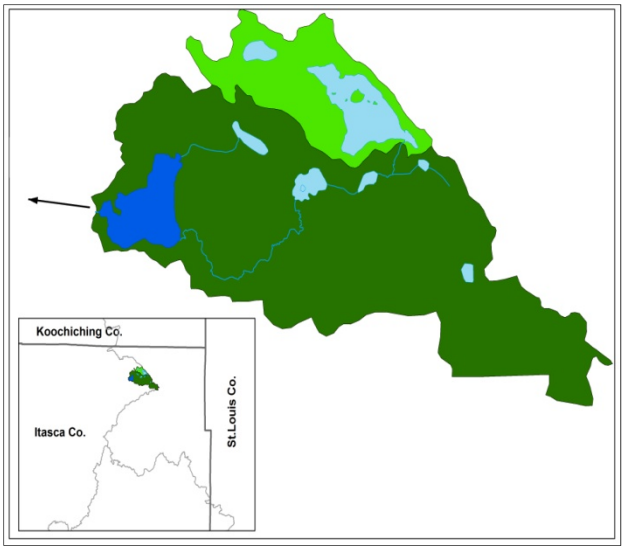


Figure 20. Lakesheds that contribute water to the Battle Lake lakeshed. Color-coded based on management focus (Table 13).

Status of the Fishery (DNR, as of 07/12/2010)

Battle Lake is a 199 acre lake located east of Effie, MN in the Bigfork River watershed. The lake has a maximum depth of 15 feet and is part of a navigable chain of lakes including Pickerel and Deer Lakes. The lake has limited development, and the primary access is through a shallow channel from Pickerel Lake. Battle Lake is managed primarily for bluegill, while northern pike and walleye are considered secondary species. All three lakes in the chain have a conservation regulation (10 fish daily bag limit) for sunfish and a slot length limit (17-26 inch protected) for walleye.

The bluegill trap-net catch rate in 2010 was 9.1/net, above the management plan goal of 3.0/net but within the expected range for similar lakes. The two highest historical catch rates for bluegill have occurred in the two most recent assessments. A trend of increased bluegill abundance has been noted in many area lakes in recent years. Bluegill size structure in Battle Lake has declined over the same period. Sampled bluegill in 2010 ranged from 3.0 to 8.4 inches, with a mean length of 6.2 inches. This compares to mean lengths of 6.8 inches in 2004 and 8.4 inches in 1998. Bluegill were not aged in this assessment, but results from the two most recent spring trap-net assessments (2005, 2009) showed growth similar to the lake class average. Additional spring assessments are planned to further evaluate the effectiveness of the conservation regulation.

The gill-net catch for northern pike was 12.3/net, above the expected range and the highest on record for Battle Lake. Catch rates in most recent assessments have exceeded the lake class median and management plan goal of 7.0/net. Sampled pike in 2010 ranged from 13.0 to 27.7 inches with a mean length of 21.0 inches. Ages 1 through 5 were represented in the sample. Mean length-at-age was similar to the statewide average for ages 1 and 2, and above the statewide average for ages 3 through 5. Northern pike reached 23.7 inches in four years.

The walleye gill-net catch was 1.3/net, below the lake class expected range but similar to previous assessments. Net catches for walleye have only exceeded the management plan goal of 2.0/net in two of the nine assessments since 1960. Sampled walleye ranged from 16.3 to 22.2 inches, with a mean length of 19.0 inches. Ages 5, 7 and 9 were represented in the sample, all which correspond to years of fry stocking. Mean back-calculated length at age was similar to the statewide average for all ages. Walleye reached 16.7 inches in five years.

The 2010 black crappie gill-net catch was a historical high at 7.2/net. The two highest catch rates for crappie have occurred in the last two surveys. Gill-net and trap-net catches were generally below 1.0/net in most previous assessments. The 2010 trap-net catch remained near the long-term average at 0.4/net. Black crappie size structure was moderate. Crappie from gill nets ranged from 4.6 to 10.9 inches, with a mean length of 8.9 inches. Recruitment appeared consistent, with ages 2 through 7 represented in the sample. Mean length-at-age was similar to the statewide average. Black crappie took five years to reach 9.3 inches.

The gill-net catch for yellow perch was below the expected range at 2.7/net. The two lowest net catches for yellow perch have occurred in the two most recent assessments, and are likely related to the higher abundance of northern pike. Although catches in past surveys have been as high as 51.3/net, historical catch rates have generally been less than 10.0/net. Size structure of yellow perch was poor, with only one perch over 8 inches in the sample.

Other species sampled in test nets included brown bullhead, largemouth bass, rock bass, pumpkinseed, hybrid sunfish and white sucker. Near-shore IBI (Index of Biotic Integrity) sampling with a small-mesh seine and back-pack electrofishing was conducted in 2010 in an attempt to capture smaller fishes not normally encountered with standard sampling gear. Additional species

captured in near-shore sampling included bluntnose minnow, blacknose shiner, golden shiner, and Johnny darter.

See the link below for specific information on gillnet surveys, stocking information, and fish consumption guidelines. http://www.dnr.state.mn.us/lakefind/showreport.html?downum=31019700

Key Findings / Recommendations

Monitoring Recommendations
Transparency monitoring at site 201 should be continued annually. It is important to continue transparency monitoring weekly or at least bimonthly every year to enable year-to-year comparisons and trend analyses. Total Phosphorus and chlorophyll *a* monitoring should continue, as the budget allows, to track trends in water quality.

Battle Lake is showing a declining trend in transparency, and since there is little development around the lake the nutrient source could be in the watershed. If the inlets are suspected as nutrient sources to the lake they could be monitored for phosphorus and nitrogen.

Overall Summary
Battle Lake is a mesotrophic lake (TSI = 45) with evidence of a declining trend in water clarity. The total phosphorus, chlorophyll *a* and transparency ranges are within the ecoregion ranges.

Only two percent (2%) of the Battle Lake lakeshed is disturbed by development and agriculture (Figure 19). The threshold of disturbance where water quality tends to decline is 25%. Battle Lake is well under this threshold. More than three quarters (81%) of the lakeshed is protected by public lands or wetlands, which protects that land from development (Figure 19).

The lake has a declining trend in clarity, but it is unclear what could be causing this trend because there appear to be no imminent threats to the lake. Battle Lake is a shallow lake (max depth 15 feet), which can be a bit more dynamic in conditions. The lakeshed is well-protected and there is very little development, so the trend could be due to watershed nutrient sources or it could be occurring naturally due to the precipitation, groundwater and climate patterns of the last decade.

There is a small amount of forestry occurring in the lakeshed, but it is not along the lakeshore or the stream inlets (Figure 21). Therefore, it is not likely causing much of an impact to water quality.

Priority Impacts to the Lake
A potential impact to Battle Lake's water quality would be the expansion of residential housing development in the lakeshed; however, most of the shoreline of Battle Lake is wetlands and unable to be developed.

The inlets should be examined for erosion and potential nutrient sources to the lake.

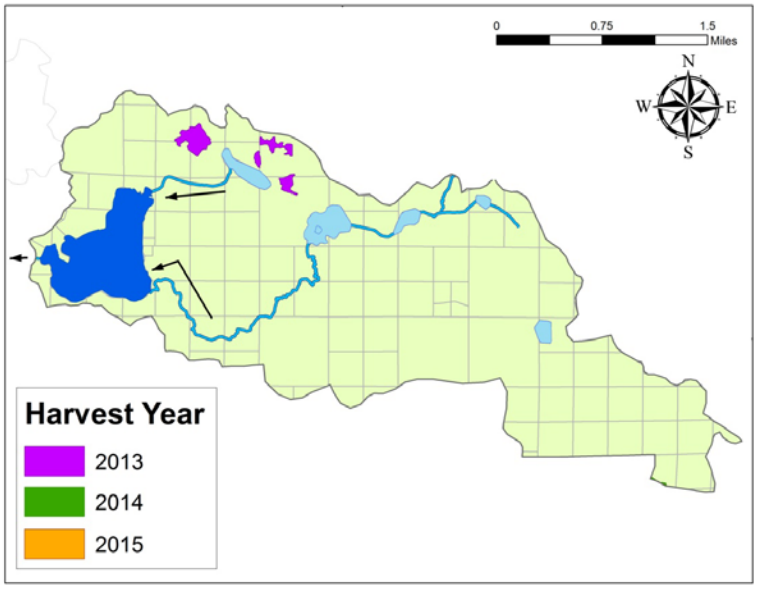


Figure 21. County forestry occurring on county lands (source: Itasca County).

Best Management Practices Recommendations
The management focus for Battle Lake should be to continue to protect the current water quality and lakeshed.

Because the lake has a declining trend in transparency (Figure 11), visually inspect the inlets of the lake for potential runoff sources. If runoff or erosion is suspected, contact the Itasca SWCD for help with wetland restoration, shoreline restoration, rain gardens, grassed waterways, filter strips and other best management practices to address overland flow and erosion.

Project Implementation
The best management practices above can be implemented by a variety of entities. Some possibilities are listed below.

Individual property owners
- Shoreline restoration
- Rain gardens
- Aquatic plant bed protection (only remove a small area for swimming)
- Conservation easements

Lake Associations
- Lake condition monitoring
- Ground truthing – visual inspection upstream on stream inlets
- Watershed runoff mapping by a consultant
- Shoreline inventory study by a consultant
- Conservation easements

Soil and Water Conservation District (SWCD) and Natural Resources Conservation Service (NRCS)
- Shoreline restoration
- Stream buffers
- Wetland restoration
- Work with farmers to
    - Restore wetlands
    - Implement conservation farming practices
    - Land retirement programs such as Conservation Reserve Program

Organizational contacts and reference sites

Itasca County Environmental Services Department	124 NE 4th St., Grand Rapids, MN 55744 (218) 327-2857 https://www.co.itasca.mn.us
Itasca Soil and Water Conservation District	1889 East Highway 2, Grand Rapids, MN 55744 (218) 828-6197 http://www.itascaswcd.org
DNR Fisheries Office	1201 East Highway 2, Grand Rapids, MN 55744 (218) 327-4430 http://www.dnr.state.mn.us/areas/fisheries/grandrapids/index.html
Regional Minnesota Pollution Control Agency Office	525 Lake Avenue South, Duluth, MN 55802 (218) 723-4660 http://www.pca.state.mn.us
Regional Board of Soil and Water Resources Office	1601 Minnesota Drive, Brainerd, MN 56401 (218) 828-2383 http://www.bwsr.state.mn.us