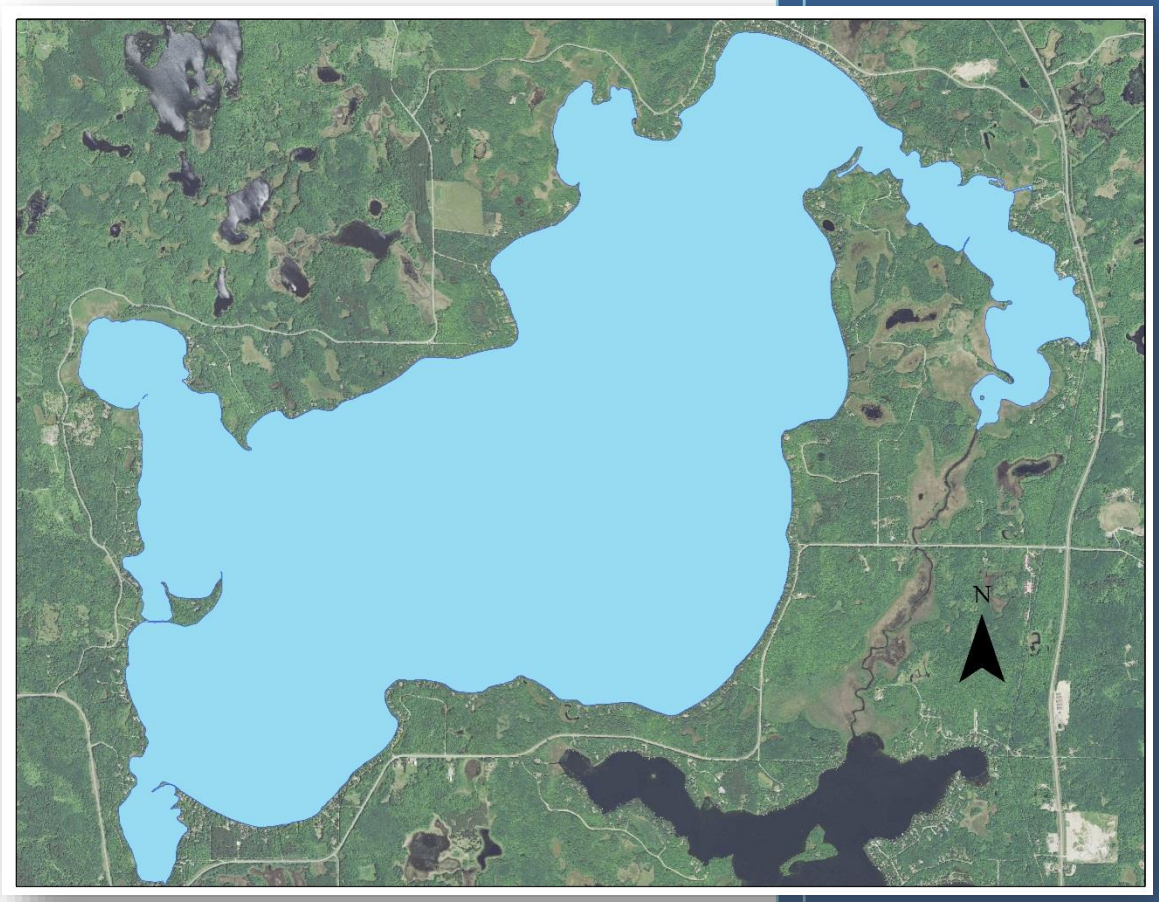
2020

Ten Mile Lake 11-0413-00



Year End Report

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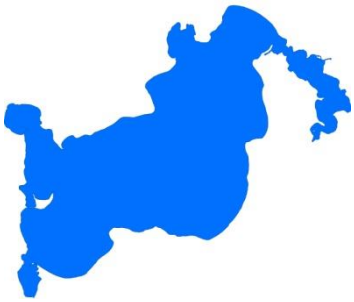
Layout and Description of the Project



Ten Mile Lake is made up of six separate basins (Figure 1). They are Long Bay, Flower Pot Bay, Lundstrom's Bay, Robinson's Bay, Kenfield Bay, and the Main Basin.

The terrestrial watershed of Ten Mile Lake is relatively small: 3 miles to the north, 2.5 miles west, 0.5 miles east, and 7.8 miles south west.

The MPCA reported (1991 Hydraulic Assessment) that Ten Mile Lake receives approximately 50% of its water from groundwater. The area where groundwater flows into Ten Mile Lake begins with the east shore of Long Bay, continues around the north shore, through Flower Pot Bay, around the northwest shore, through Lundstrom's Bay, down the west shore line and Robinson's Bay, around the west side of Kenfield Bay, and to the east end of the Chub Lake flowage.

The area where groundwater flows out of the lake begins at the east end of the Chub Lake flowage, goes around the east side of the lake, to the Boy River outlet at Hwy 6. This flowage is from Ten Mile Lake south to Birch Lake. There is probably a continuous flow from the east side of Ten Mile Lake to the Boy River through the marshes.

This monitoring project was started in 1994 with the intention of developing a body of data that could be used to manage Ten Mile Lake in the future. It was also intended to identify environmental problems both on the lake and within the flowage. Samples for laboratory analysis are collected over the deepest depression in each of the basins to be tested. The sampling sites were designated and located by the Minnesota Pollution Control Agency. In addition to the lake sampling, there is also a set of ten watershed samples collected at selected culverts around the lake. This sampling is done with the May sampling on Ten Mile Lake.

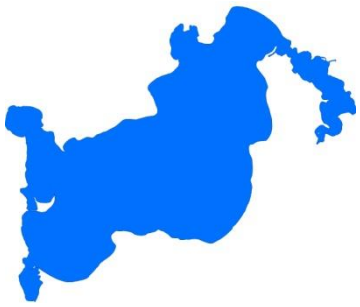
There are six sampling sites (Figure 1). In the past, three sites - the Main Basin, Kenfield Bay, and Long Bay - were designated as primary sites and were sampled in mid-May, mid-July, and mid-September. Of those, the Main Basin and Long Bay were also tested for water clarity by Secchi disc measurement. Three secondary sites - Flower Pot Bay, Lundstrom's Bay, and Robinson's Bay- were chosen as rotational or alternate sites, where samples are drawn for laboratory examination. Starting in 2015, all six sites were monitored each month in the summer.

The analysis started in 1994 for total phosphorus, total nitrogen, Chlorophyll-a, and Pheophytin-a. The chemical parameters were tested on a monthly basis from May through September until 2002 when the sampling was reduced to May, July, and September.

Lakes go through a life process from birth to death, where the birth of a lake results from filling a hole in the earth with water, and the death is the formation of a bog or meadow. The nutrient input to the lake is a result of activities going on in the watershed, the size of the watershed, wind-blown deposits and the quality of the water reaching the lake via precipitation, groundwater and flowing streams. Reducing nutrient inputs extends a lakes lifespan by slowing the natural aging process.

In northern Minnesota, the process of making lakes was reinstated by fairly recent glacial excavation, which ended about 8,000 to 10,000 years ago, and lake basins were filled by melting glacial ice. Watersheds were formed and lake basins were connected by streams and rivers. Bacteria, algae, plants, invertebrates, and vertebrates, which include the fish species, moved down and up the streams and into the new aquatic environments.

Introduction



Ten Mile Lake is located between the cities of Hackensack and Walker in Cass County, Minnesota. The lake has a surface area of 5,047 acres, making it one of the largest lakes in the state. It is also one of the deepest lakes in Minnesota, with a maximum depth of 208 feet and a mean depth of 53 feet.

Ten Mile Lake has no inlets and one outlet, which classifies it as a groundwater drainage lake. It is the headwaters of the Boy River which flows south from Ten Mile and then east and north through a chain of 15 or 16 lakes before emptying into the east side of Leech Lake. The Leech Lake River then exits Leech Lake and joins the Mississippi.

Water quality data have been collected on Ten Mile Lake since 1974. These data show that the lake is oligo-mesotrophic (page 17). Oligo-mesotrophic lakes are deep with clear water all summer and are excellent for recreation.

The Ten Mile Lake Association was first formed in 1946. The association has been involved in numerous activities including water quality monitoring, education, lake management planning, and conservation easements. It is also a member of the Association of Cass County Lakes (ACCL).

Table 1. Ten Mile Lake location and key physical characteristics

Location Data	
MN Lake ID:	11-0413-00
County:	Cass
Ecoregion:	Northern Lakes and Forests
Major Drainage Basin:	Upper Mississippi River
Latitude/Longitude:	46.95833333/-94.58361111
Invasive Species:	Chinese Mystery Snail, Banded Mystery Snail, Purple Loosestrife, zebra mussels

Physical Characteristics	
Surface area:	5,047 acres
Littoral area:	1,316 acres
% Littoral area:	26%
Max depth	208 ft, 63.4 m
Inlets:	0
Outlets:	1 (Boy River)
Public Accesses:	1

Table 2. Availability of primary data types for Ten Mile Lake.

Data Availability

Transparency data		Excellent data source from 1979-2020.
Chemical data		Excellent data source from 1994-2020.

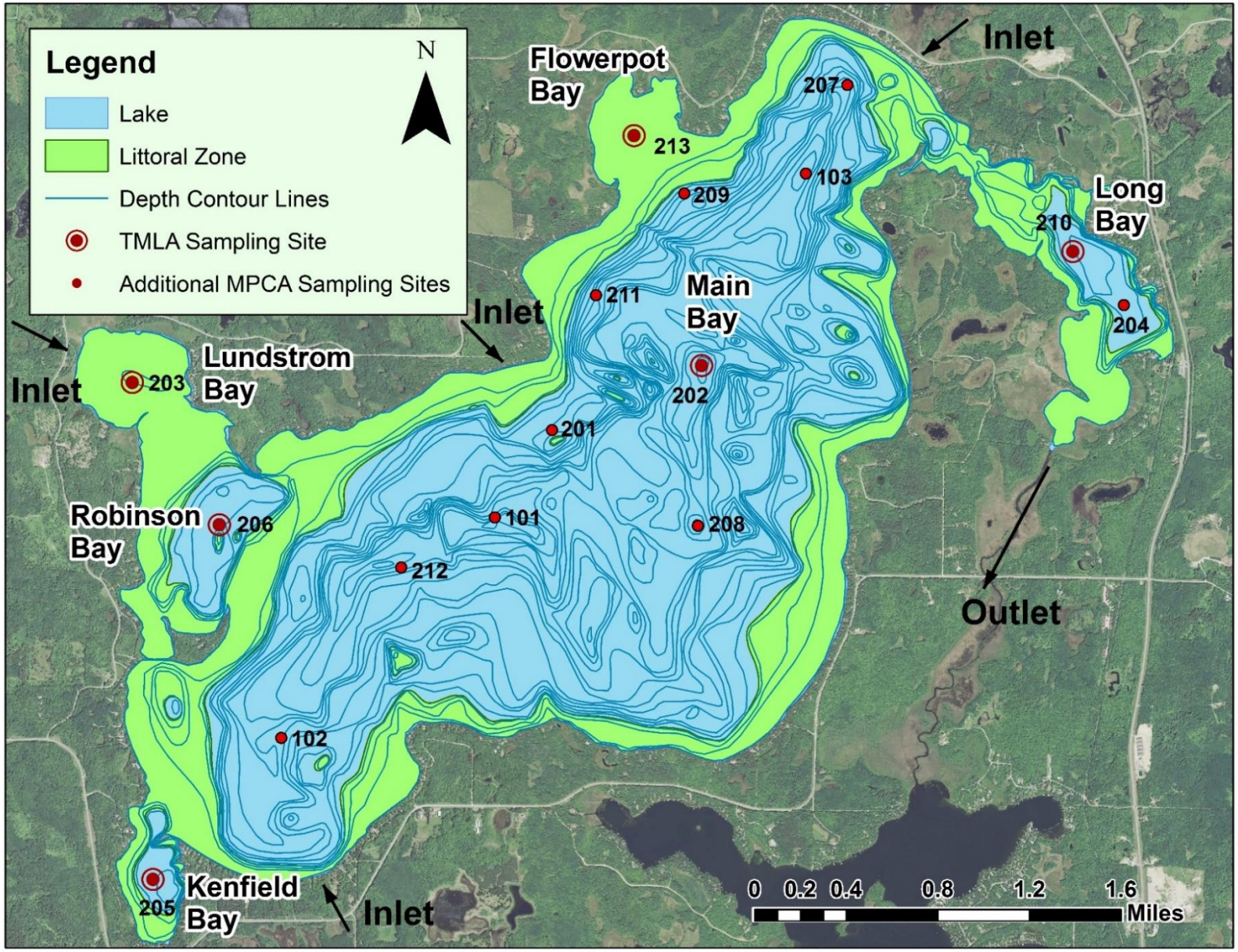


Figure 1. Map of Ten Mile Lake with 2010 aerial imagery and illustrations of lake depth contour lines, sample site locations, inlets and outlets, and public access points. The light green areas in the lake illustrate the littoral zone, where the sunlight can usually reach the lake bottom, allowing aquatic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

Water Quality Monitoring Program History

Ten Mile Lake has been monitored by many different organizations over the years. The Ten Mile Lake Association has been monitoring the lake since 1974. This is some of the earliest water quality data collected by citizens in the state of Minnesota.

In 2008, the Minnesota Department of Natural Resources (DNR) started their Sentinel Lakes Program, now called SLICE (Sustaining Lakes in a Changing Environment). This program was set up to monitor a sample of Minnesota lakes that are representative of the state's most common aquatic environments. Information gathered will be used to develop management approaches that can mitigate or minimize negative impacts caused by conventional "high-impact" residential development and agriculture, aquatic plant removal, invasive species and climate change. Ten Mile Lake is one of the selected SLICE sample lakes due to its deep cold water characteristics. The DNR hopes to continue this monitoring program into the future to document lake changes. To read more about the SLICE program, visit: http://www.dnr.state.mn.us/fisheries/slice/index.html.

Table 3. Monitoring programs and associated monitoring sites. Monitoring programs include the Citizen Lake Monitoring Program (CLMP), Minnesota Pollution Control Agency (MPCA), DNR Sentinel Lakes Program (SLICE), Ten Mile Lake Association (TMLA), Whitefish Property Owners Association (WAPOA), Outdoor Corps (OC).

Lake Site	Depth (ft)	Monitoring Programs
101	150	MPCA: 1989, 1991
102	90	MPCA: 1989, 1991; SLICE: 2008-2017
103	126	MPCA: 1991
201	40	CLMP: 1974-1975, SLICE 2016
202* Primary site	208	CLMP: 1979-1991, 1994-2015; MPCA: 1979-1981; SLICE: 2008-2020 TMLA: 1974, 1987-2004, 2016-2020
203	10	MPCA: 1979; TMLA: 1988, 1990-1991, 1995, 1998, 2001, 2004, 2007, 2010, 2013, 2015-2020
204	35	CLMP: 1980-1991, 1994-2015; MPCA: 1980-1981; TMLA: 1974, 1987-1991, 1994-2004, 2016
205	35	CLMP: 2003; OC: 2003; TMLA: 1974, 1988-1991, 1994-2004, 2016-2020; WAPOA: 2001-2002
206	45	CLMP: 2003; OC: 2003; WAPOA: 2001-2002 TMLA: 1988-1989, 1991, 1996, 1999, 2002-205, 2016-2020
207	40	CLMP: 2003
208	98	SLICE: 2008-2011
209	40	TMLA: 1994, 1997, 2000, 2003
210	42	OC: 2003; WAPOA: 2001-2002; TMLA: 1980-2020
211	100	OC: 2003
212	140	SLICE: 2010
213	10	TMLA: 1994, 1997, 2000, 2003, 2006, 2008, 2011, 2014-2020

Average Water Quality Statistics

The information below describes available chemical data for Ten Mile Lake through 2020 (Table 4). Data for total phosphorus, chlorophyll *a*, and Secchi depth are from the primary site 202.

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 19. Ten Mile Lake is in the Northern Lakes and Forests Ecoregion.

Table 4. Water quality means compared to ecoregion ranges and impaired waters standard (primary site)

Parameter	Mean at primary site	Ecoregion Range[1]	Impaired Waters Standard[2]	Interpretation
Total phosphorus (ug/L)	11.8	14 – 27	> 30	Results are better than the expected range for the Northern Lakes and Forests Ecoregion.
[3]Chlorophyll *a* (ug/L)	1.96	< 10	> 9	
Chlorophyll *a* max (ug/L)	5.3	< 15		
Secchi depth (ft)	19.2	8 – 15	< 6.5	
Dissolved oxygen	*See page 15*			Dissolved oxygen depth profiles show that the lake is dimictic (mixes in spring and fall).
Ammonia Nitrogen	0.05			Indicates safe levels for fish.
Total Kjeldahl Nitrogen (mg/L)	0.39	<0.4 – 0.75		Indicates insufficient nitrogen to support summer nitrogen-induced algae blooms.
Inorganic Nitrogen (NO2+NO3)	0.17	<0.01		Indicates insufficient nitrogen to support summer nitrogen-induced algae blooms.
Alkalinity (mg/L)	110	40 – 140		Indicates a low sensitivity to acid rain and a good buffering capacity.
Calcium	25	NA		Indicates a hard water lake that is suitable to zebra mussels.
Color (Pt-Co Units)	5.9	10 – 35		Indicates clear water with little to no tannins (brown stain).
pH	7.9	7.2 – 8.3		Indicates a hard water lake. Lake water pH less than 6.5 can affect fish spawning and the solubility of metals in the water.
Chloride (mg/L)	1.5	0.6 – 1.2		Indicates runoff from roads and parking areas. Still low level.
Total Suspended Solids (mg/L)	3.0	<1 – 2		This indicates low a low-level suspended solid.
Specific Conductance (umhos/cm)	210.5	50 – 250		Within the expected range for the ecoregion.
TN:TP Ratio	30:1	25:1 - 35:1		Shows the lake is phosphorus limited.

[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 202 Main Bay	Site 205 Kenfield Bay	Site 206 Robinson Bay	Site 210 Long Bay	Site 203 Lundstrom Bay	Site 213 Flowerpot Bay
Total Phosphorus Mean (ug/L):	**12.2**	**11.8**	**8.9**	**11.9**	**18.7**	**7.7**
Total Phosphorus Min:	3	6.0	5.0	6.0	8.0	6.0
Total Phosphorus Max:	50.0	45	26.0	19.0	36.0	14.0
Number of Observations:	236	77	41	30	50	30
Chlorophyll *a* Mean (ug/L):	**2.28**	**1.8**	**2.4**	**2.5**	**2.0**	**2.0**
Chlorophyll-a Min:	<1	<1	<1	1.0	<1	1.0
Chlorophyll-a Max:	8.9	8.0	6.2	4.0	4.0	3.0
Number of Observations:	144	74	40	29	45	28
Secchi Depth Mean (ft):	**19.2**	**16.2**	**18.6**	**17.1**	**-**	**-**
Secchi Depth Min:	10.5	11.7	13.0	10.7	-	-
Secchi Depth Max:	27.0	20.5	23.0	23.7	-	-
Number of Observations:	638	29	25	23	0	0

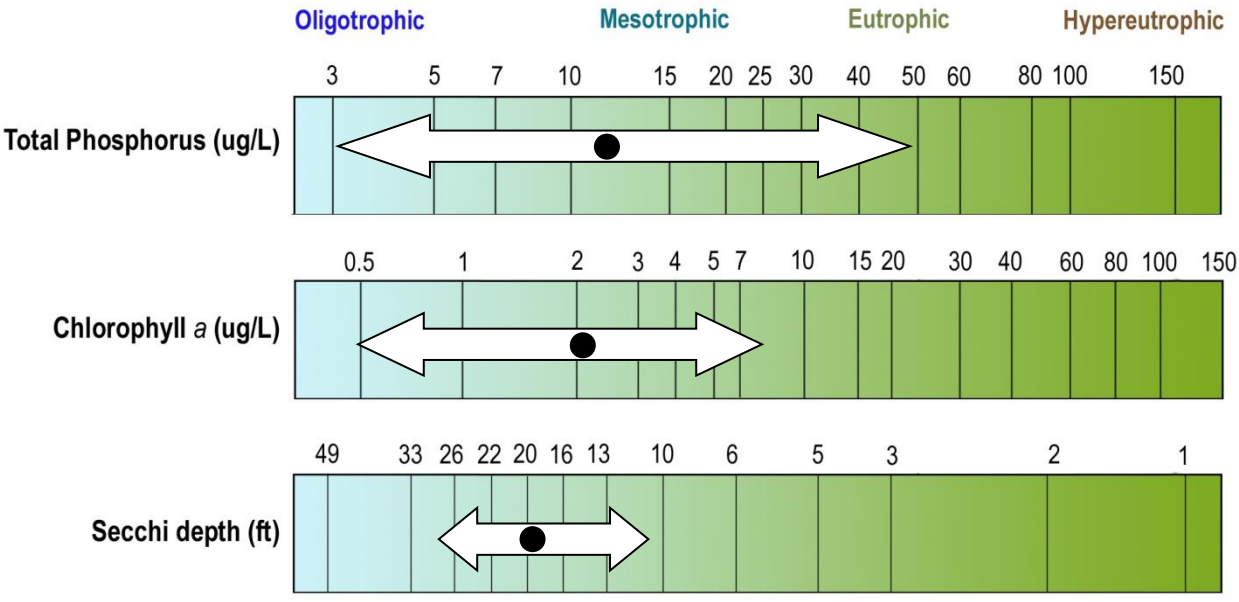


Figure 2. Ten Mile Lake total phosphorus, chlorophyll a and transparency historical ranges. The arrow represents the range and the black dot represents the historical mean (Primary Site 202). Figure adapted after Moore and Thornton, [Ed.]. 1988. Lake and Reservoir Restoration Guidance Manual. (Doc. No. 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 Ten Mile Lake at the main bay ranges from 15 to 23 feet (Figure 3). Of all the sites, the main bay has the best transparency (Figure 4). This could be expected because it is the deepest site and in the middle of the main lake. For trend analysis, see page 18. Transparency monitoring should be continued annually at site 202 in order to track water quality changes.

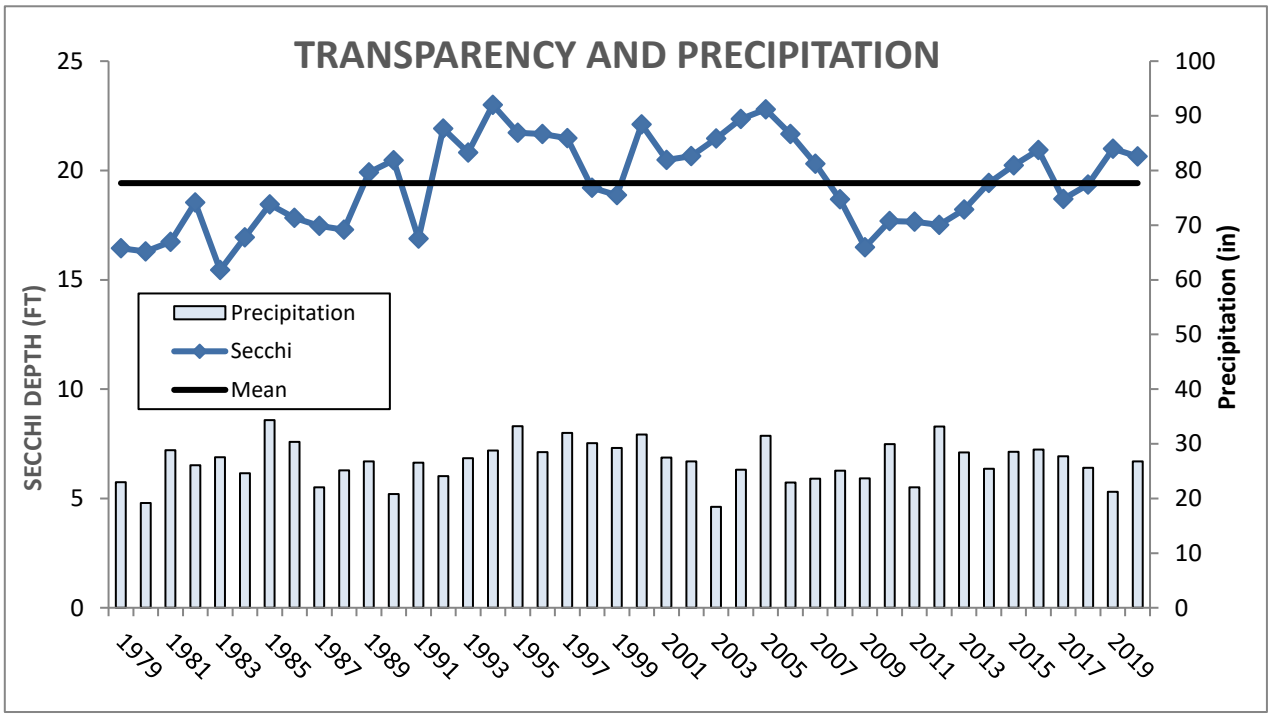


Figure 3. Annual mean transparency compared to long-term mean transparency at the Main Bay site 202

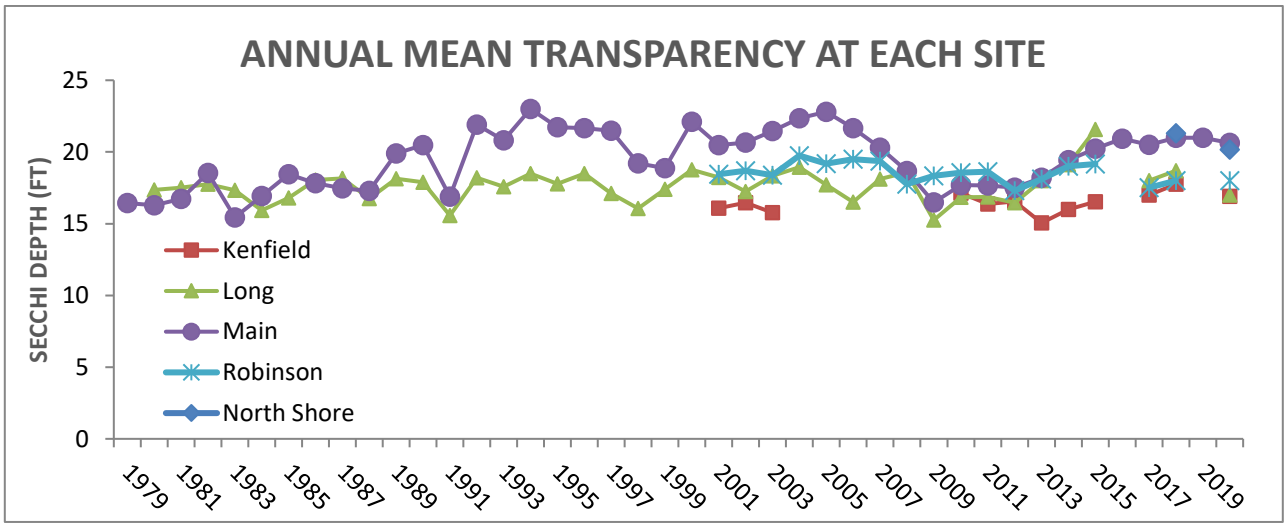


Figure 4. Annual mean transparency comparison between sites

Ten Mile Lake transparency ranges from 10.5 to 27.0 feet at the primary site (202). Figure 5 shows the seasonal transparency dynamics. The maximum Secchi reading is usually obtained in early summer. Ten Mile Lake transparency is high in May and June, and then declines slightly through August, but still is relatively high. This transparency dynamic is typical of an oligotrophic Minnesota lake. There are not enough nutrients to fuel late summer algae blooms, which cause the Secchi to decline. The dynamics have to do with algae and zooplankton population interaction 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.

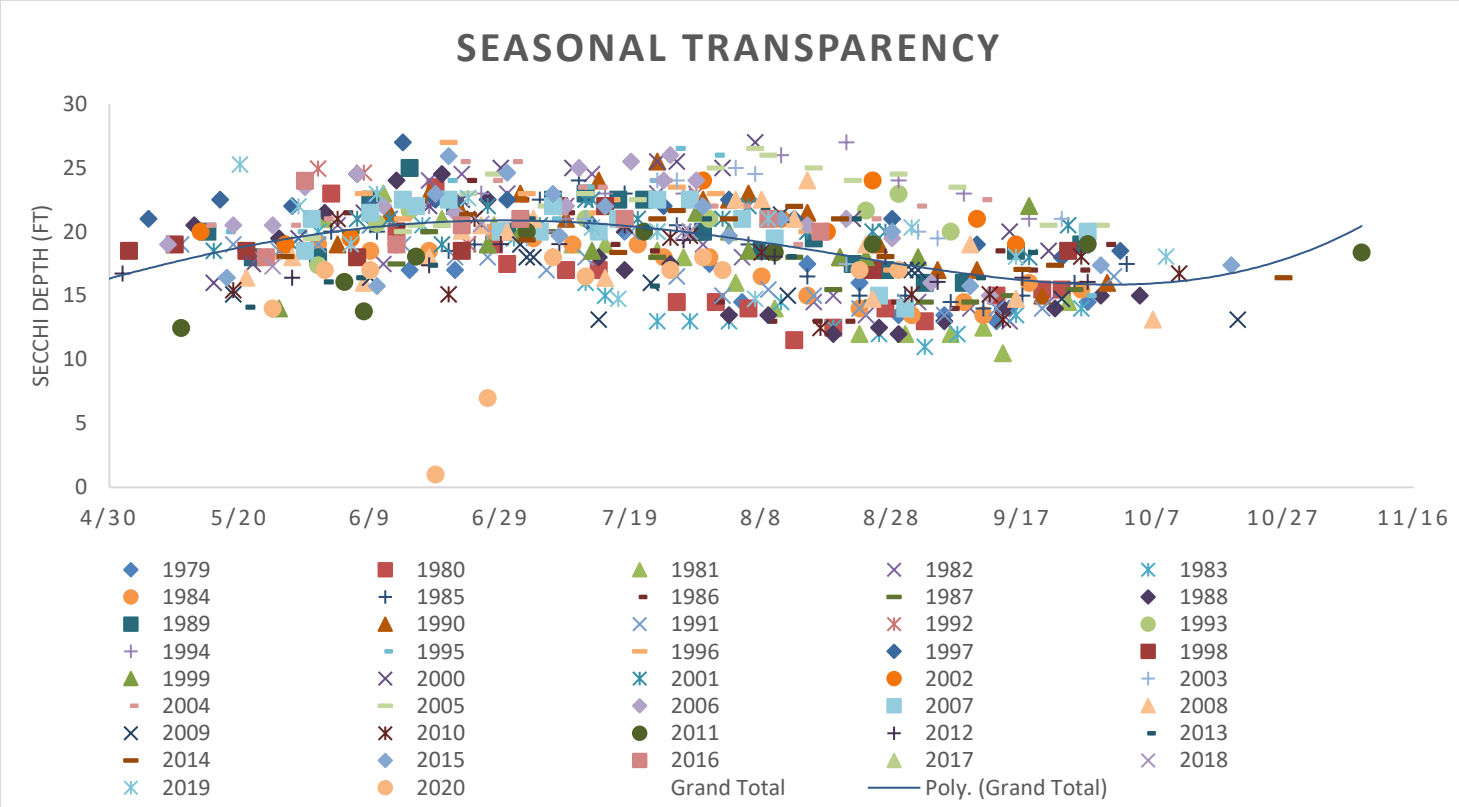


Figure 5. Seasonal transparency dynamics and year to year comparison (Primary Site 202). The black line represents the pattern in the data.

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. Ten Mile Lake was rated as being "crystal clear" 71% of the time by samplers at site 202 between 1987 and 2020 (Figure 6).

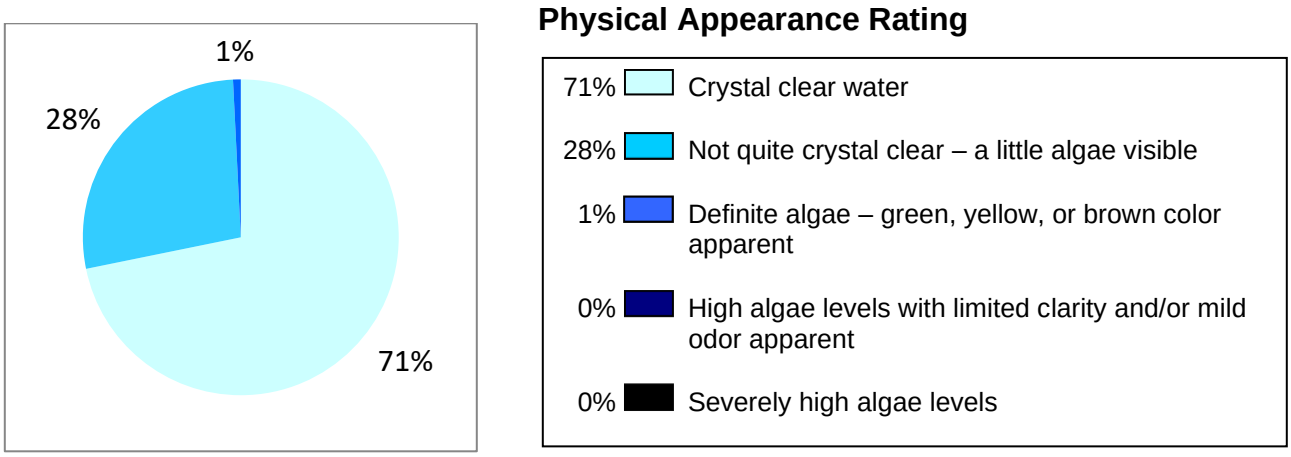


Figure 6. Ten Mile Lake physical appearance ratings by samplers

As the Secchi depth decreases, the perception of recreational suitability of the lake decreases. Ten Mile Lake was rated as being "beautiful" 81% of the time from 1987 to 2020 (Figure 7).

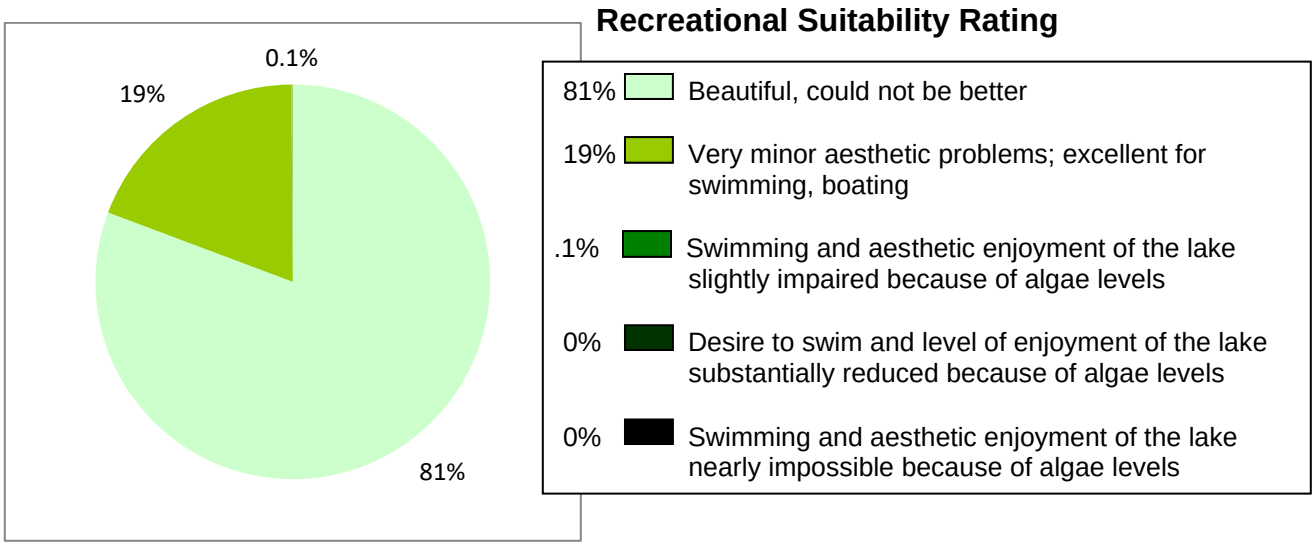


Figure 7. Recreational suitability rating, as rated by the volunteer monitor

Total Phosphorus

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

Total phosphorus was evaluated in Ten Mile Lake in the Main Bay in 1974-2020. The majority of the data points fall into the mesotrophic and oligotrophic ranges (Figure 8). From 1974-1996 the phosphorus maximums were higher than after 1996. This could be due to improvements in septic systems around the lake or lab method accuracy in the 1970s – 1980s.

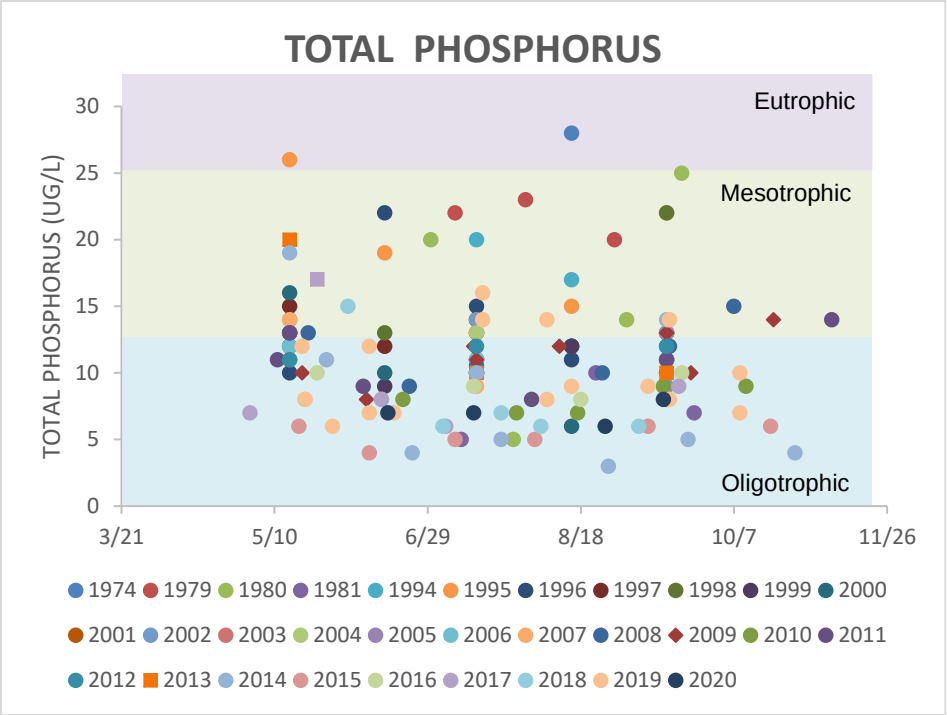


Figure 8. Historical total phosphorus concentrations (ug/L) for Ten Mile Lake site 202

In looking at all the monitored sites in Ten Mile Lake, the Main Bay consistently has the lowest phosphorus concentrations (Figure 9). This can be expected because the site is 200 feet deep and in the middle of the lake. Phosphorus concentrations are higher in the shallower bays, but not much higher. The shallower bays still are in the mesotrophic range rather than the eutrophic range. Phosphorus should continue to be monitored to track any future changes in water quality.

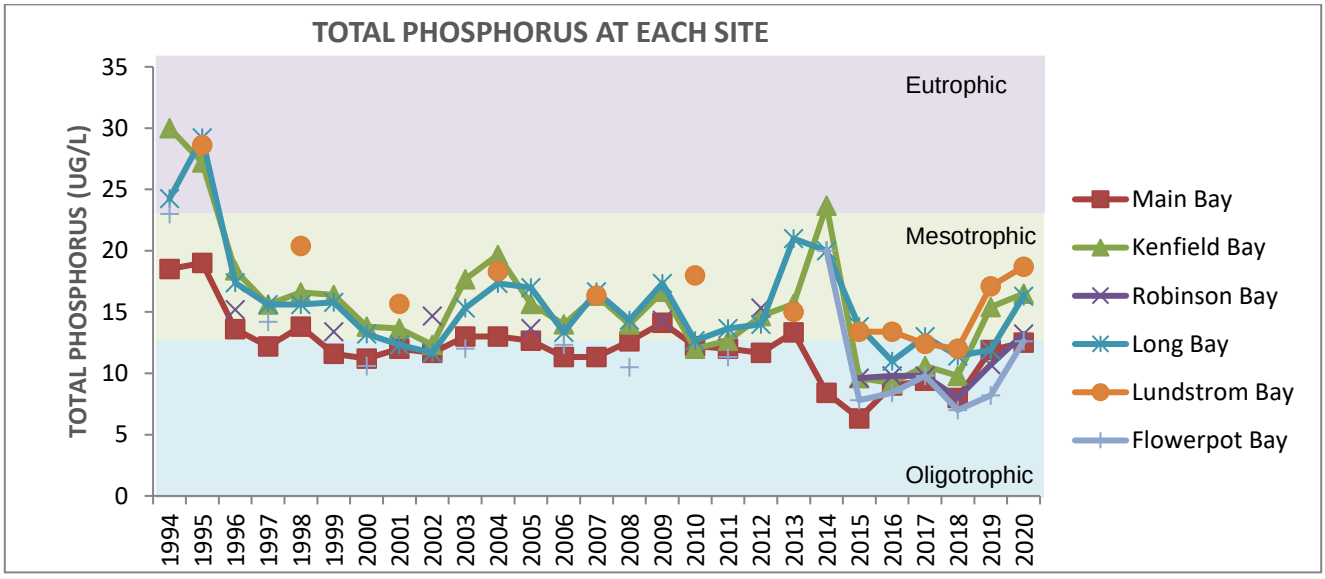


Figure 9. Historical annual mean total phosphorus concentrations (ug/L) for Ten Mile Lake comparing sites

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.

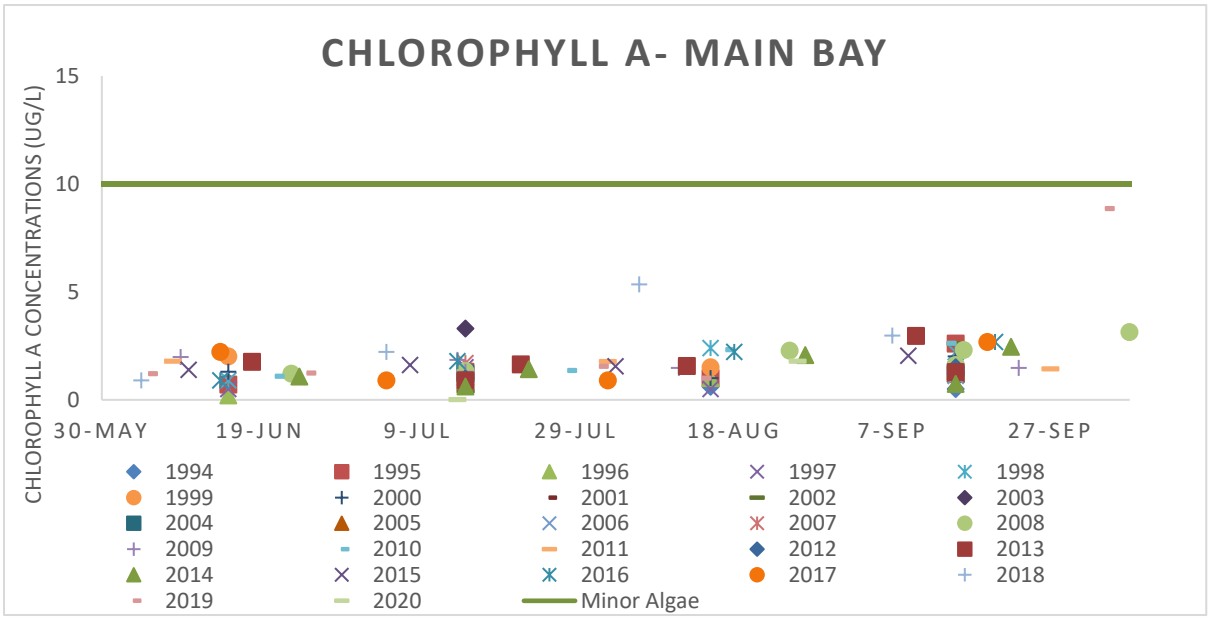


Figure 10. Chlorophyll *a* concentrations (ug/L) for Ten Mile Lake at site 202

Chlorophyll *a* was evaluated in Ten Mile Lake in the main bay from 1994-2020 (Figure 10). Chlorophyll *a* concentrations never went above 8.86 ug/L in all years, indicating very clear water.

In comparing the different bays, all of them have very low chlorophyll a concentrations and none ever reached even the minor algae bloom threshold of 10 ug/L (Figure 11).

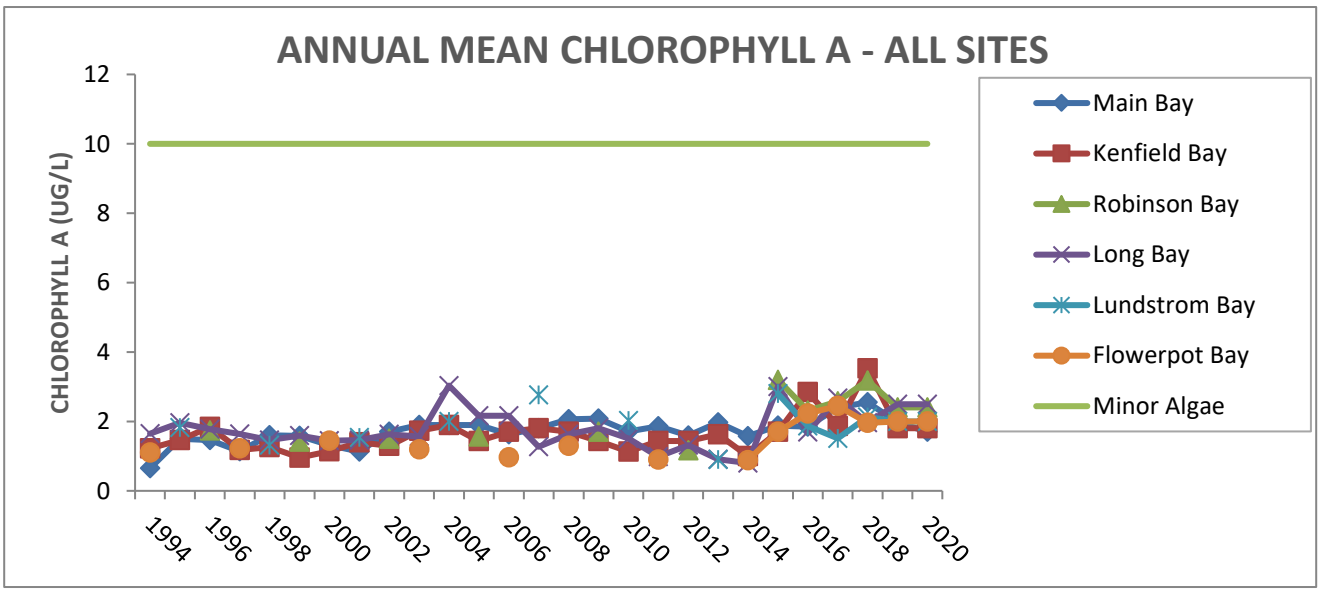


Figure 11. Historical annual mean chlorophyll a concentration (ug/L) for Ten Mile Lake comparing sites

Nitrogen

The expected threshold for Total Nitrogen in the Northern Lakes and Forests Ecoregion of Minnesota is 0.75 mg/L. The Total Nitrogen concentration in Ten Mile Lake has historically remained well below this threshold. This means there are no nitrogen-driven algae blooms.

Because the nitrogen levels are so low in Ten Mile Lake, this parameter would not need to be monitored into the future. It could just be checked every few years.

Nutrient concentrations in Ten Mile Lake were a bit higher in 2013 (Figures 9, 12), but 2012 was a historically wet year (Figure 3). Overland runoff potentially caused the higher nutrient levels in 2013. In 2014-2016 nitrogen levels were lower again.

There was one outlier in Flowerpot Bay in 2008. This could have been the result of a loading event, or contamination during the field sampling process.

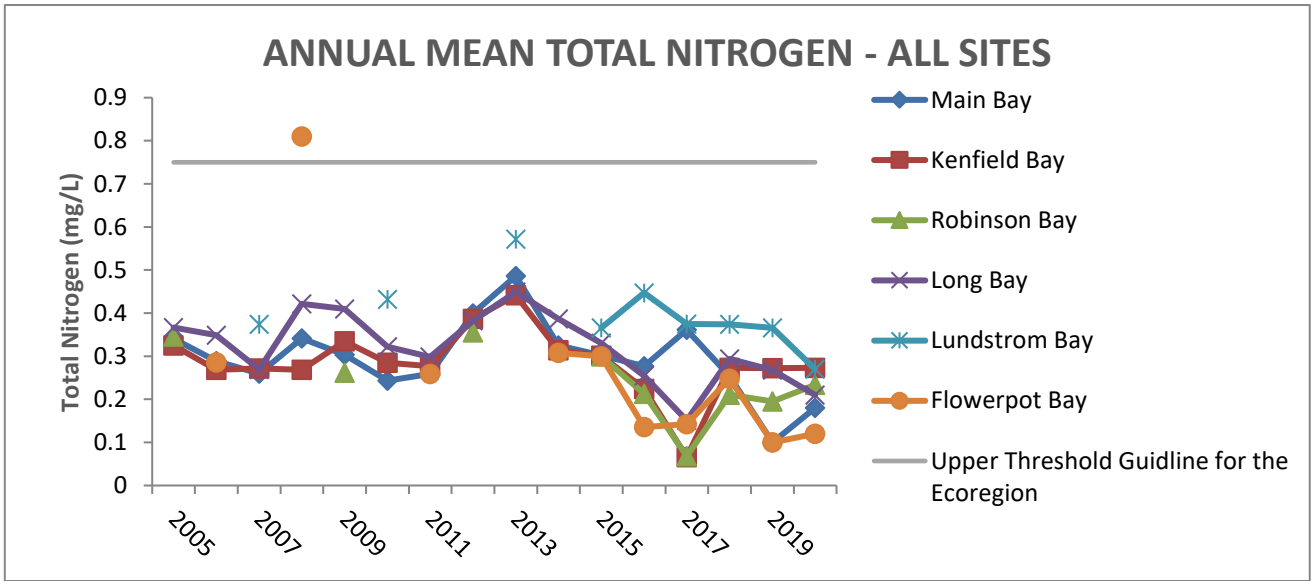
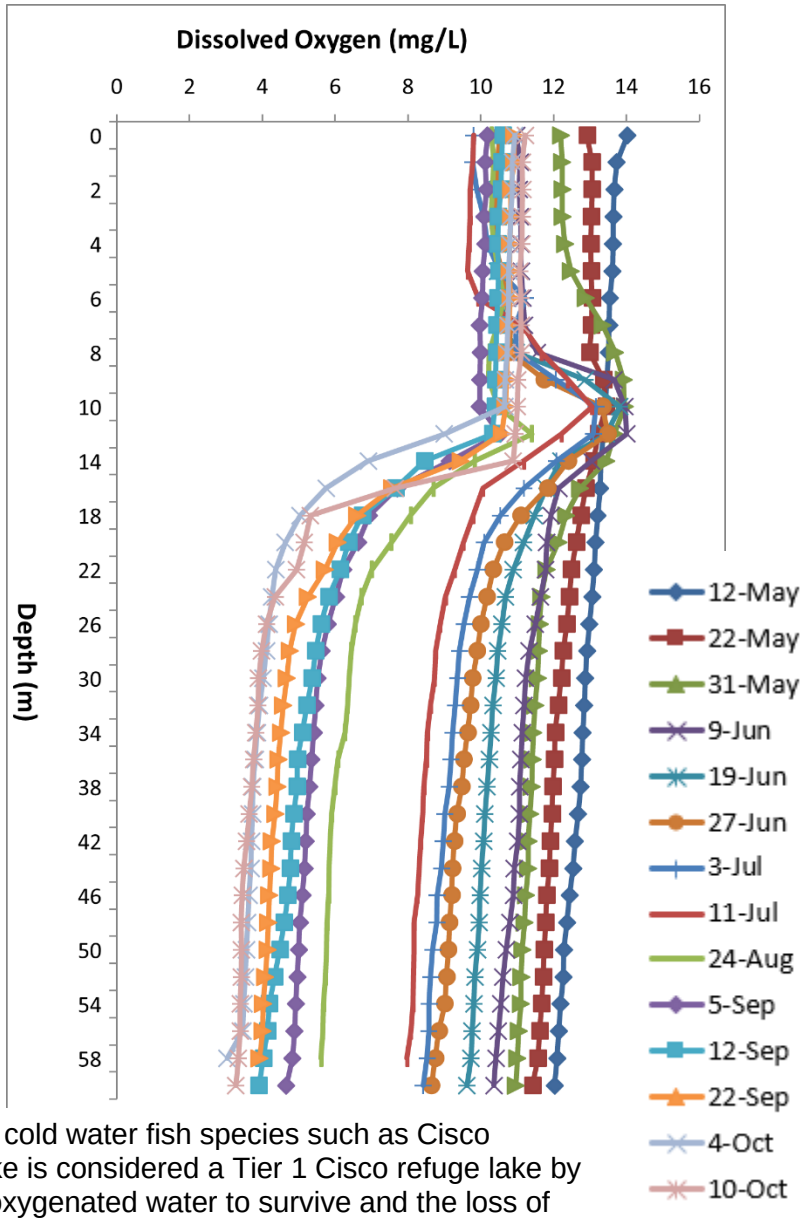


Figure 12. Historical annual mean total nitrogen concentrations (ug/L) for Ten Mile Lake comparing sites.

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.

Ten Mile Lake is a deep lake, with a maximum depth of 200 feet (60 meters). Dissolved oxygen profiles from data collected in 2020 at site 202 show stratification developing in June (Figure 13). However, oxygen levels in the hypolimnion stay high until late-August, when they drop below 5 mg/L. Based on 2020 data, the lake is still stratified into October.



The oxygen shows an interesting pattern in that it is highest from 8-12.5 meters (26 - 41 feet). This pattern is called a Metalimnetic Oxygen Maxima. It is caused by algae producing oxygen in that area of 26-46 feet deep. This pattern is usually only observed in lakes with good transparency and a very strongly stratified deep basin, which applies to site 202 in Ten Mile Lake (Figure 1).

Because oxygen levels remain over 5 mg/L in the hypolimnion for most of the summer, Ten Mile Lake is good habitat for cold water fish species such as Cisco (Tullibee) (Figure 15). In fact, Ten Mile Lake is considered a Tier 1 Cisco refuge lake by the Minnesota DNR. Ciscos require cold, oxygenated water to survive and the loss of Ciscos can indicate eutrophication in lakes. Ten Mile Lake also supports a lake whitefish population, which also requires cold, well-oxygenated water (Figure 14).

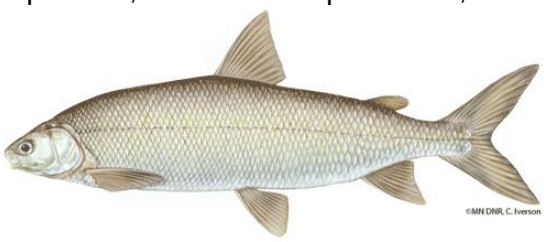


Figure 14. Lake Whitefish (MNDNR).

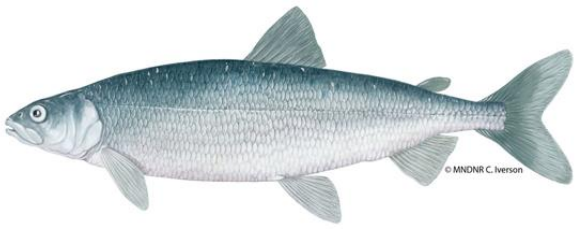


Figure 15. Cisco (MNDNR)

Trophic State Index (TSI)

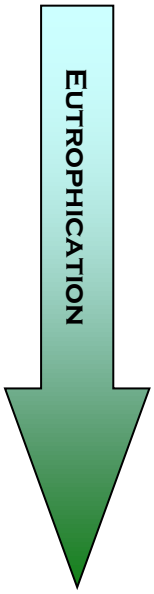
TSI is a standard measure or means for calculating the trophic status or productivity of a lake. More specifically, it is the total weight of living algae (algae biomass) in a waterbody at a specific location and time. Three variables, chlorophyll a, Secchi depth, and total phosphorus, independently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

It is important to understand that Trophic States are defined divisions of a continuum in phosphorus and algal concentration. The TSI ranges from 0-100. 0-30 is Oligotrophic, where water is very clear, phosphorus is low, and algae is sparse. 30-50 is an in-between stage where the number of aquatic plants algae increase due to more available phosphorus (Table 6).

Trophic State Index is not necessarily interchangeable with water quality. Water quality is subjective and depends on how you intend to use the water body. A lake that is good for duck hunting is not necessarily good for water skiing. In turn, a lake that is great for swimming may not be great for bass fishing.

Table 6. Trophic states and corresponding lake and fisheries conditions



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, Tullibee 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.

The mean TSI for Ten Mile Lake falls into the oligo-mesotrophic range of 36-41 (Figure 16). There is good agreement between the TSI for chlorophyll *a* and transparency, indicating that these variables are strongly related (Table 7).

The TSI for phosphorus is slightly higher than for chlorophyll a and transparency. There could be various reasons for this:

1. Zooplankton grazing is contributing to the low algae concentrations.
2. Phosphorus was monitored in May, July and September. Phosphorus concentrations tend to be higher in May and September during lake turnover.
3. Many laboratories have a 10 ug/L reporting limit for phosphorus and Ten Mile Lake has such low phosphorus levels that it can actually be often less than 10 ug/L. This is especially true for the older data.

The best indicator of lake trophic state is not the average TSI, but the TSI for chlorophyll a (Carlson 1983). This value shows how much production the nutrients are fueling. The chlorophyll a TSI is in the mid-30s, which shows oligo-mesotrophic conditions.

Table 7. Trophic State Index for Ten Mile Lake

Trophic State Index	Main Bay	Kenfield	Robinson	Long Bay	Lundstrom	Flowerpot
TSI Total Phosphorus	41	45	41	44	46	41
TSI Chlorophyll-a	36	36	39	40	37	37
TSI Secchi	35	37	35	36	NA	NA
TSI Mean	37	39	39	40	42	39
Trophic State:	Oligotrophic	Oligotrophic	Oligotrophic	Mesotrophic	Mesotrophic	Oligotrophic

Numbers represent the mean TSI for each parameter.

Oligo-mesotrophic lakes (TSI 30-40) are characteristic of extremely clear water throughout the summer and sandy or rocky shores. They are excellent for recreation. Some very deep oligotrophic lakes are able to support a trout fishery. Ten Mile Lake supports healthy Cisco (Tullibee) and White Fish populations due to the deep, cold nature of the lake.

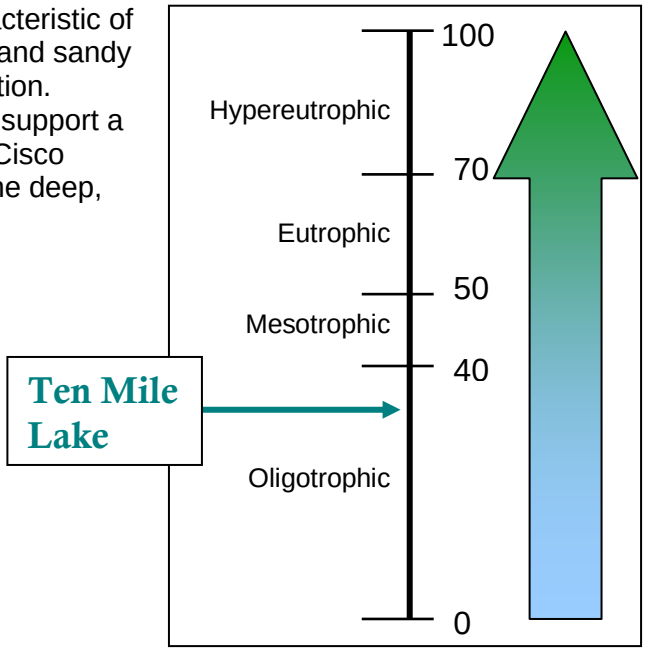


Figure 16. Trophic state index chart with corresponding trophic status

Trend Analysis

In assessing water quality, agencies and other lake data users want to know if the amount of algae has been changing over time. Scientists test hypotheses using statistics, and the hypothesis used in a trend analysis is that no trend exists. In other words, we begin with the assumption that there is no trend. We collect data and use statistics to determine the probability of collecting our data if this hypothesis of no trend is indeed true. The output from a statistical test is called the probability value (or p-value for short) of collecting data given the hypothesis of no trend is true. The smaller this probability value, the more likely the null hypothesis of no trend can be rejected. The MPCA has set the acceptable p-value to be less than 10%. In other words, if $p < 0.10$ we reject the hypothesis of no trend and accept that a trend likely exists. Another way to think of this is to say that there is in reality an existing trend, there is a 90% chance we would have collected the data we collected and that a 10% chance that the trend is a random result of the data. For detecting trends, a minimum of 8-10 years of data with four or more readings per season are recommended by the MPCA. Where data does not cover at least eight years or where there are only few samples within a year, trends can be misidentified because there can be different wet years and dry years, water levels, weather, etc., that affect the water quality naturally.

Ten Mile Lake had enough data to perform a trend analysis on phosphorus, chlorophyll a and transparency (Table 8). The data was analyzed using the Mann-Kendall Trend Analysis.

Table 8. Trend analysis for Primary site 202

Lake Site	Parameter	Date Range	Water Quality Trend	Probability
202	Total Phosphorus	1994-2020	Improving	99.9%
202	Chlorophyll *a*	1994-2020	Declining	99.9%
202	Transparency (long-term)	1979-2020	Improving	90%
202	Transparency (short-term)	2006-2020	No trend	--

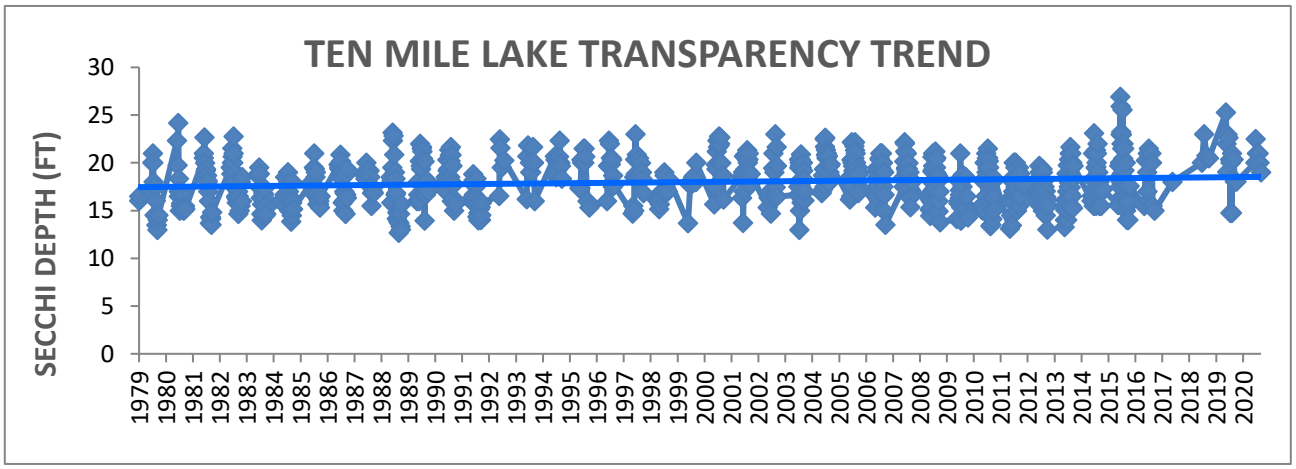


Figure 17. Transparency (feet) trend for site 202 from 1979-2020

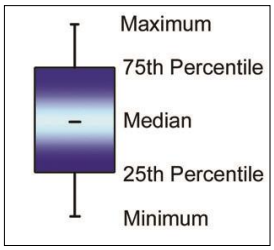
Ten Mile Lake shows evidence of an improving transparency trend from 1979-2020, and a stable trend from 2006-2020 (Figure 17). Figure 17 shows the transparency was lower in 2009-2012, but higher again from 2014-2016. There is strong evidence of an improving total phosphorus trend indicating that the concentration of total phosphorus is decreasing. There is also a statistically significant declining trend for Chlorophyll a, indicating that Chlorophyll a concentrations are increasing.

Ecoregion Comparisons

Minnesota is divided into 7 ecoregions based on land use, vegetation, precipitation and geology (Figure 18). 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 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 18. Minnesota Ecoregions

Ten Mile Lake is in the Northern Lakes and Forest Ecoregion. The mean total phosphorus, chlorophyll *a* and transparency (Secchi depth) for Ten Mile Lake are better than the ecoregion ranges (Figure 19).



Legend for Figure 19 below.

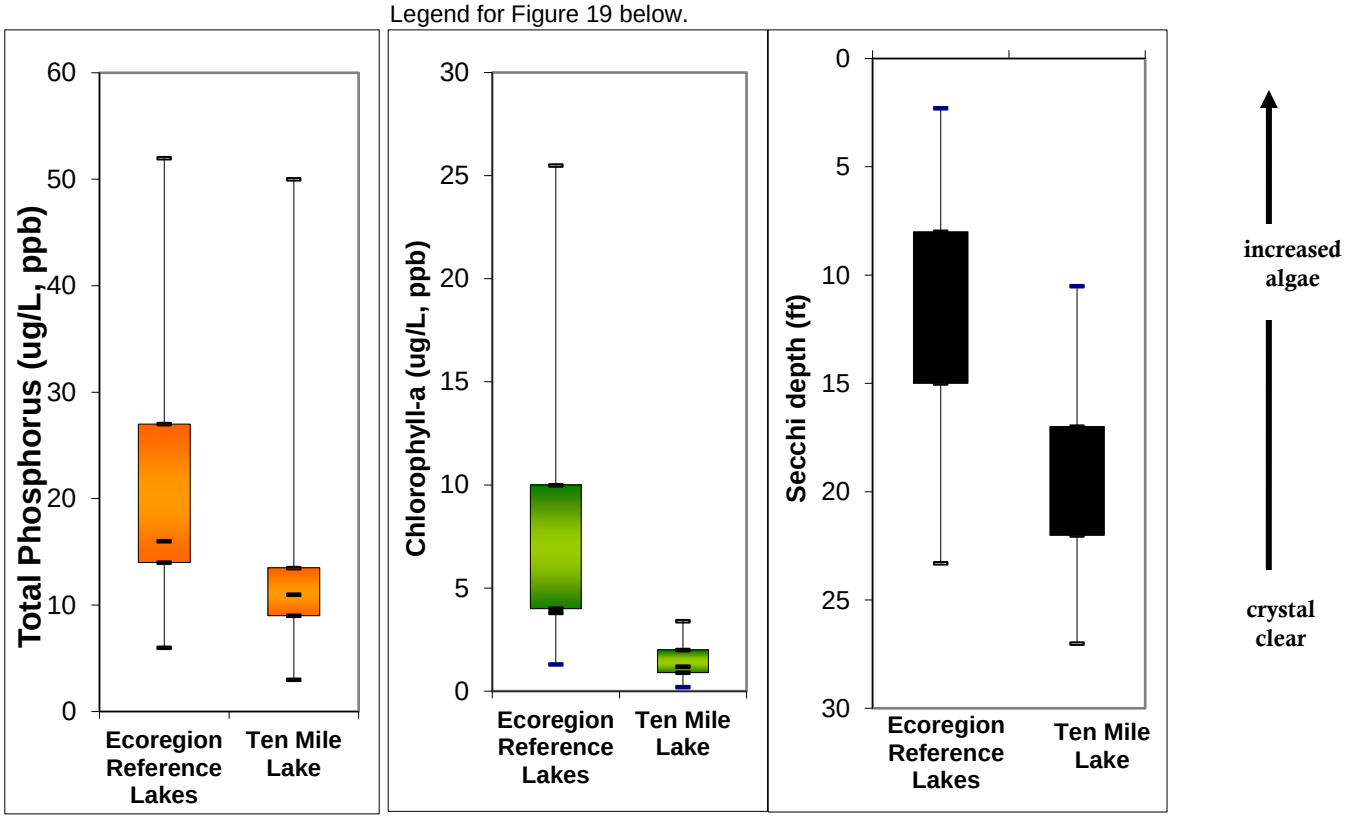


Figure 19. Ten Mile Lake (Main Basin, site 202) ranges compared to Northern Lakes and Forest Ecoregion ranges. The colored boxes represent the 25th to 75th percentile of the data for each the ecoregion reference lakes and Ten Mile Lake. The bars represent the maximum and the minimum. The Ten Mile Lake total phosphorus and chlorophyll *a* ranges are from 380 data points collected in May-September of 1994-2020. The Ten Mile Lake Secchi depth range is from 638 data points collected in May-September from 1979-2020.

Lakeshed Vitals

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. Ten Mile Lake lakeshed vitals table

Lakeshed Vitals		**Rating**
Lake Area (acres)	5,047	descriptive
Littoral Zone Area (acres)	1,316	descriptive
Lake Max Depth (feet)	208 ft. (63.4 m)	
Lake Mean Depth (feet)	53 ft. (16.2 m)	
Water Residence Time	13.2 years	
Miles of Stream	0.43	descriptive
Inlets	0	
Outlets	1 – Boy River	
Major Watershed	Leech Lake River	descriptive
Minor Watershed	8019	descriptive
Lakeshed	Ten Mile Lake (801900)	descriptive
Ecoregion	Northern Lakes and Forests	descriptive
Total Lakeshed to Lake Area Ratio (total lakeshed includes lake area)	3.5:1	
Standard Watershed to Lake Basin Ratio (standard watershed includes lake areas)	5:1	
Wetland Coverage (NWI)	9.5%	
Aquatic Invasive Species	Chinese Mystery Snail, Banded Mystery Snail, Purple Loosestrife, Zebra Mussel	
Public Drainage Ditches	None	
Public Lake Accesses	1	
Miles of Shoreline	25.06	descriptive
Shoreline Development Index	2.5	
Public Land to Private Land Ratio	1.7:1	
Shoreland Conservation Potential (% shoreland identified for conservation)	33%	
Development Classification	General Development	
Miles of Road	34.4	descriptive
Municipalities in lakeshed	None	
Forestry Practices	None within 200 feet from shore	
Feedlots	None	
Sewage Management	Individual waste treatment systems (septic systems and holding tanks – Inspections ongoing every 3 years)	
Lake Management Plan	Current: 2013-2016, http://www.tenmilelake.org	
Lake Vegetation Survey/Plan	Survey Completed June 2006	

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.

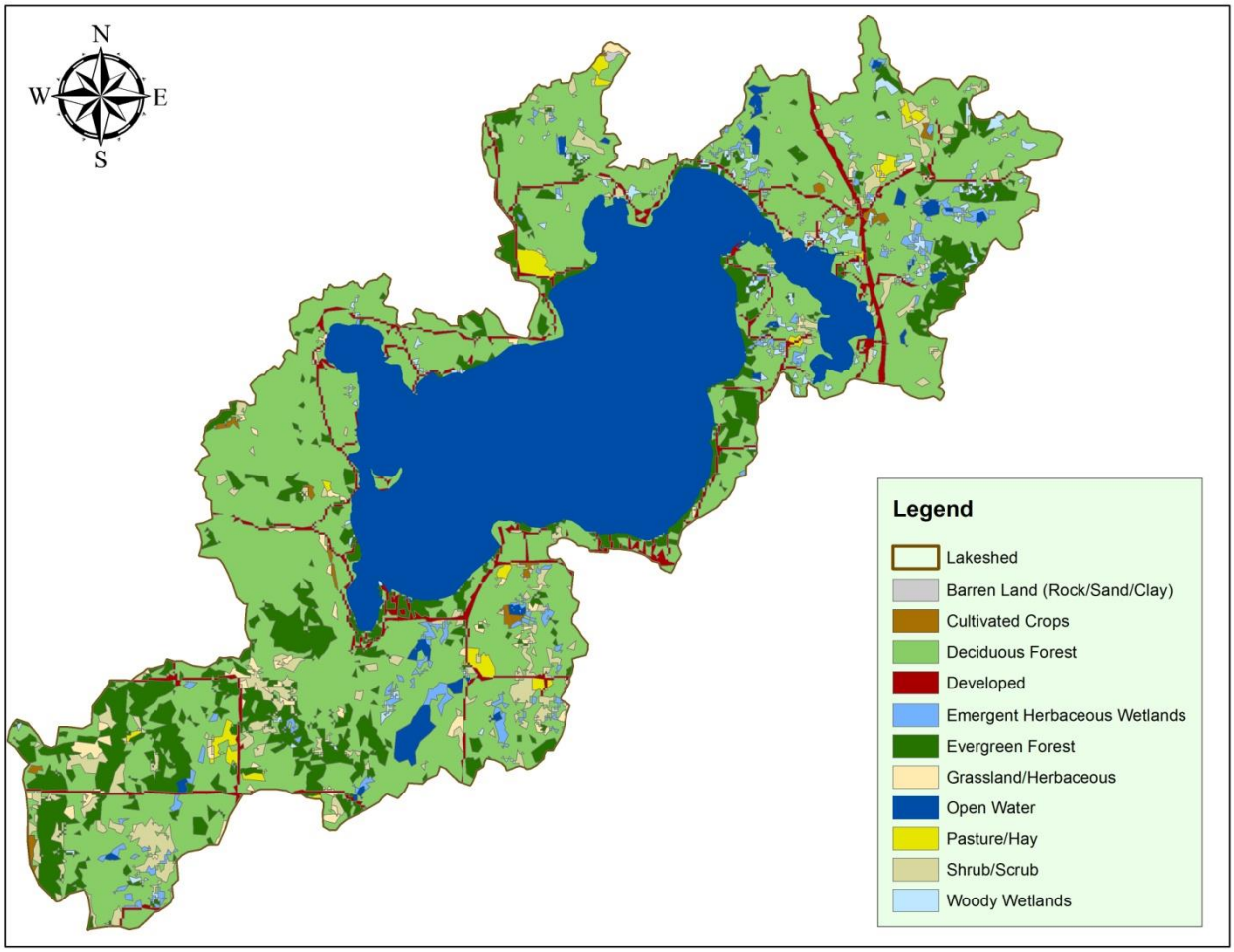


Figure 20. Land use in the Ten Mile Lake lakeshed (801900). Data source: 2011 National Land Cover Data Set

Table 10. Land Use in the Ten Mile Lake lakeshed

	Acres	Percentage
Cultivated Crops	68.8	0.4%
Deciduous Forest	8,471.7	48.0%
Emergent Herbaceous Wetlands	251.6	1.4%
Evergreen Forest	1,896.5	10.7%
Grassland/Herbaceous	174.9	1.0%
Open Water	5,199.7	29.5%
Pasture/Hay	167.1	0.9%
Shrub/Scrub	622.4	3.5%
Woody Wetlands	221.4	1.3%
Developed	574.9	3.3%
Total	17,649.0	100.0

The majority of the Ten Mile Lake Lakeshed is covered by forests (58%, Table 10). This is the best land use for protecting water quality.

Only a very small percentage of land use includes developed and cultivated crops, which have the highest phosphorus export of the land use categories (Tables 10 - 11).

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 privately-owned land within Ten Mile Lake's lakeshed is forested (Table 11). This land can be the focus of development and protection efforts in the lakeshed.

Table 11. 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 (42.3%)					**34.6%**	**Public (23.1%)**		
	Developed	**Agriculture**	**Forested Uplands**	**Other**	**Wetlands**	**Open Water**	**County**	**State**	**Federal**
Land Use (%)	1.9%	0.2%	35.1%	3.5%	1.6%	34.6%	0%	14.3%	8.8%
Phosphorus Export Coefficient Lbs. of phosphorus/acre/ year	0.45 - 1.5	0.26 - 0.9	0.09		0.09		0.09	0.09	0.09
Description	Focused on Shoreland	Cropland	Focus of develop-ment and protection efforts	Open, pasture, grass-land, shrub-land	Protected				
Ideas for Protection and Restoration	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 12). Watershed disturbance was defined as having urban, agricultural and mining land uses. Watershed protection is defined as publicly owned land or conservation easement.

Table 12. 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.

Ten Mile Lake's lakeshed is classified with having 73% of the watershed protected and 3.7% of the watershed disturbed (Figure 21). The lake is just below the 75% protected threshold, so this lakeshed should have a vigilance/protection focus. Goals for the lake should be to limit any increase in disturbed land use. Ten Mile Lake has three other lakesheds flowing into it, but they are well protected (Figure 22).

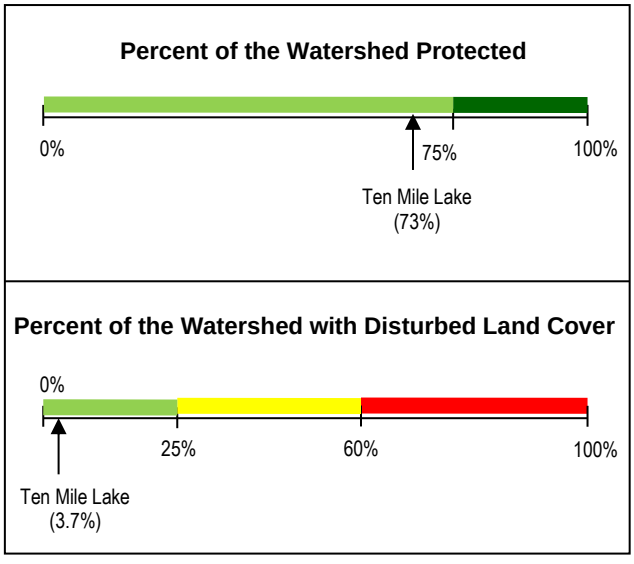


Figure 21. Ten Mile Lake lakeshed percentage of watershed protected and disturbed

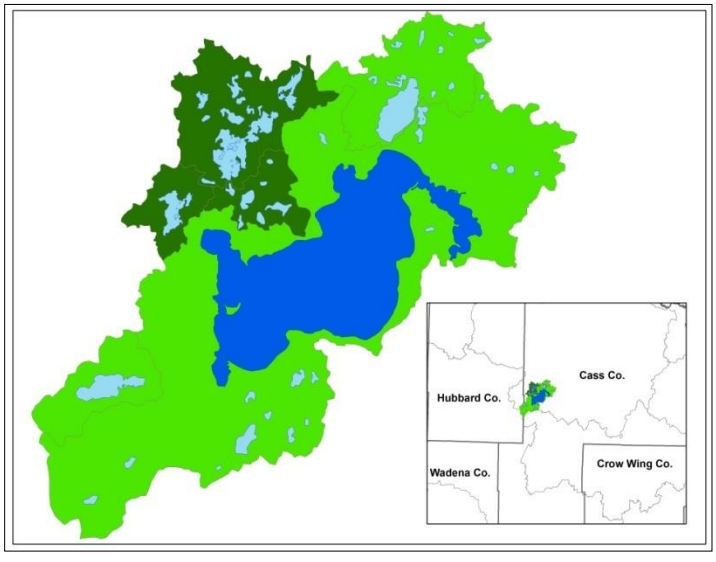
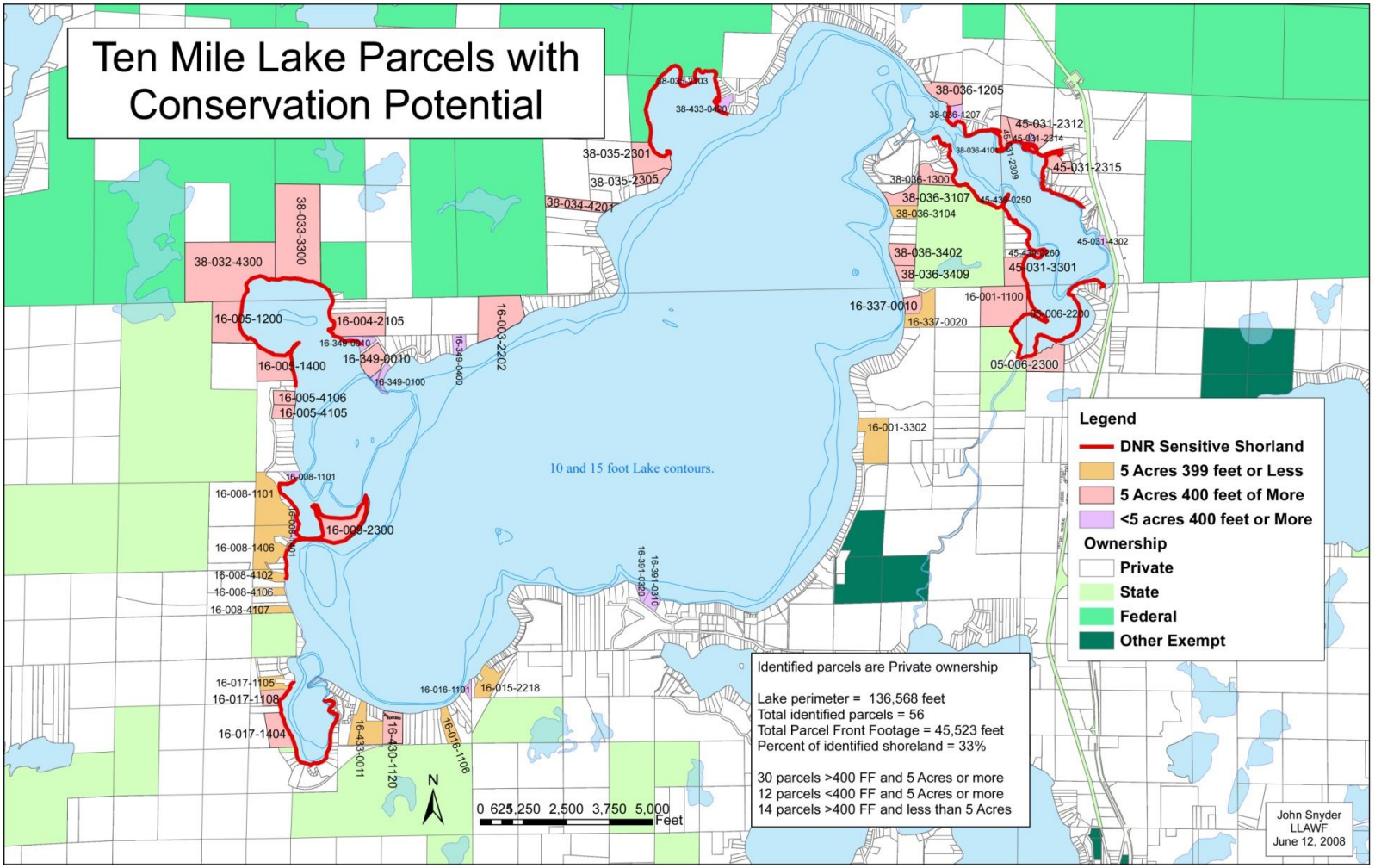


Figure 22. Lakesheds that contribute water to the Ten Mile Lake lakeshed, color-coded based on management focus (Table 12)

Conservation Easement Potential

In an ever-growing society, today's landscapes are being urbanized more and more to sustain the ever-growing population and behavior of recreational usage. In Minnesota, the land of ten thousand lakes, it is only natural to develop properties within the boundaries and beauty of our lakes and streams. Conservation efforts to limit or slow down the development process can only assist in the preservation of the lakeshed and inevitably the water quality of water bodies found within. Figure 23 identifies parcels within the lakeshed that are large enough to warrant the investigation of parcel conservation practices and purchase. This map was created in 2008, so some of these parcels may have already been enrolled into conservation easements, such as the ones on Lundstrom's Bay.

Figure 23. Lake parcels with conservation potential (developed by John Snyder, LLAWF, 2008)



Status of the Fishery (DNR, as of 08/20/2018)

Ten Mile Lake is a 5080-acre lake located near Hackensack, MN that has 24.8 miles of shoreline and a maximum depth of 208 feet. There is a Minnesota Department of Natural Resources (DNR) public access on the southwest shore off of County Road 6. The DNR has classified Minnesota's lakes into 43 different classes based on physical, chemical and other characteristics. Ten Mile Lake is in Lake Class 22; lakes in this class are large, deep, clear, and irregularly shaped. Other lake class 22 lakes in the Walker Area include Steamboat, Woman, Little Boy, and Wabedo lakes. There is a lot mid-lake structure with steep drop offs in the lake. The purpose of this survey was to assess game fish populations and provide additional fish information to the MNDNR Long Term Monitoring Program.

Northern Pike in the 2018 sample averaged 20 inches long with fish up to 31 inches sampled. Currently there is 24 to 36 inch protected slot limit which has been in effect since 2008. Walleye are abundant in Ten Mile Lake compared to other Lake Class 22 waters. Large year classes from 2015 and 2013 should provide immediate and future fishing opportunities. Nearly half the walleyes sampled in 2018 were between 15 and 20 inches long with fish up to 27 inches long present. On the main part of the lake, Walleyes will often suspend over deep water while feeding on the abundant small Tullibee (Cisco) which only reach a maximum length of around 6 inches. Largemouth and Smallmouth bass also provide additional quality fishing opportunities to anglers. Fish approaching 19 inches long for both species have been sampled. Yellow Perch populations are low and the fish are small. Lake Whitefish are present with an average length of 18 inches, but they can be difficult to locate. Winter fishing can be difficult due to limited public access and highly variable ice conditions. Even during the coldest winters the ice can be inconsistent from area to area, with several ice ridges forming on the lake adding to the hazards of on ice travel and creating potentially dangerous conditions. Other fish species that anglers can expect to encounter include Black Crappie, Bluegill, Bowfin (dogfish), Brown Bullhead, Pumpkinseed Sunfish, Rock Bass, White Sucker, and Yellow Bullhead.

People can have significant impacts on lakes and the fish populations they support. Harvest, lakeshore development, removal of shoreline vegetation, and introductions of invasive species can all adversely affect fish populations. Currently the aquatic invasive species (AIS) that have been identified in Ten Mile Lake are the Chinese Mystery Snail and Purple Loosestrife. AIS are moved from infested to non-infested waters by anglers, boaters, and lake shore owners and can adversely impact lakes and fish populations. To avoid spreading AIS, lake users are required to remove all aquatic plants or animals from their watercraft and drain all water from their boat before leaving the access. If you suspect an infestation of an invasive species in this lake, save a specimen and report it to a local natural resource office. Additional information on all of these topics can be found on the DNR website (www.dnr.state.mn.us) or by contacting the Walker Area Fisheries office.

See the link below for specific information on gillnet surveys, stocking information, and fish consumption guidelines. https://www.dnr.state.mn.us/lakefind/showreport.html?downum=11041300

Water Levels

Ten Mile Lake is groundwater fed, therefore its water levels can be tied to groundwater levels and precipitation. Historical data show that 2012 was a very wet year, 2014 a dryer year (Figure 3). Lake water level data show that the lake was above the ordinary high water mark (red line, Figure 24) in 2013-2014. In 2015-2016, water levels were back under the ordinary high water mark (Figure 25).

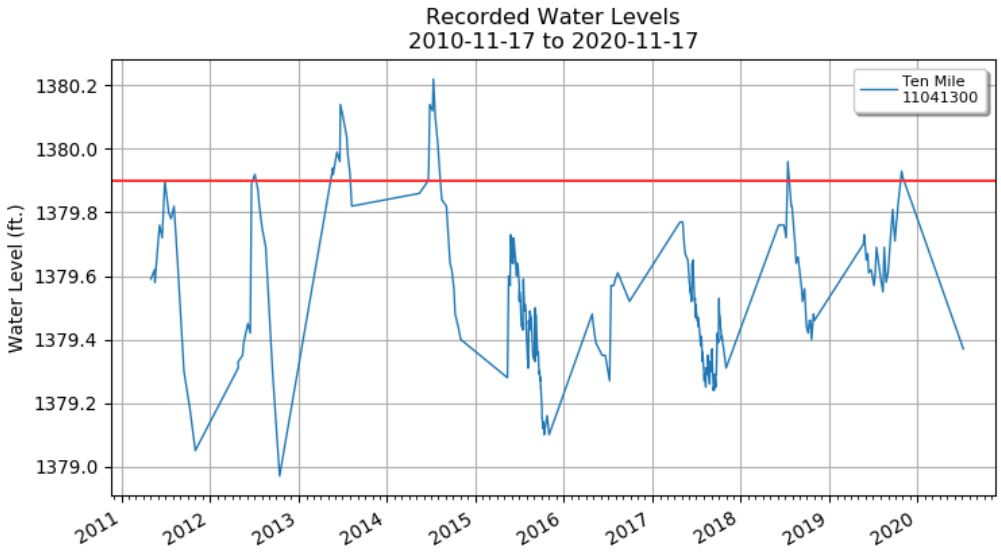


Figure 24. Ten Mile Lake water levels from 2010-2020, MN DNR.

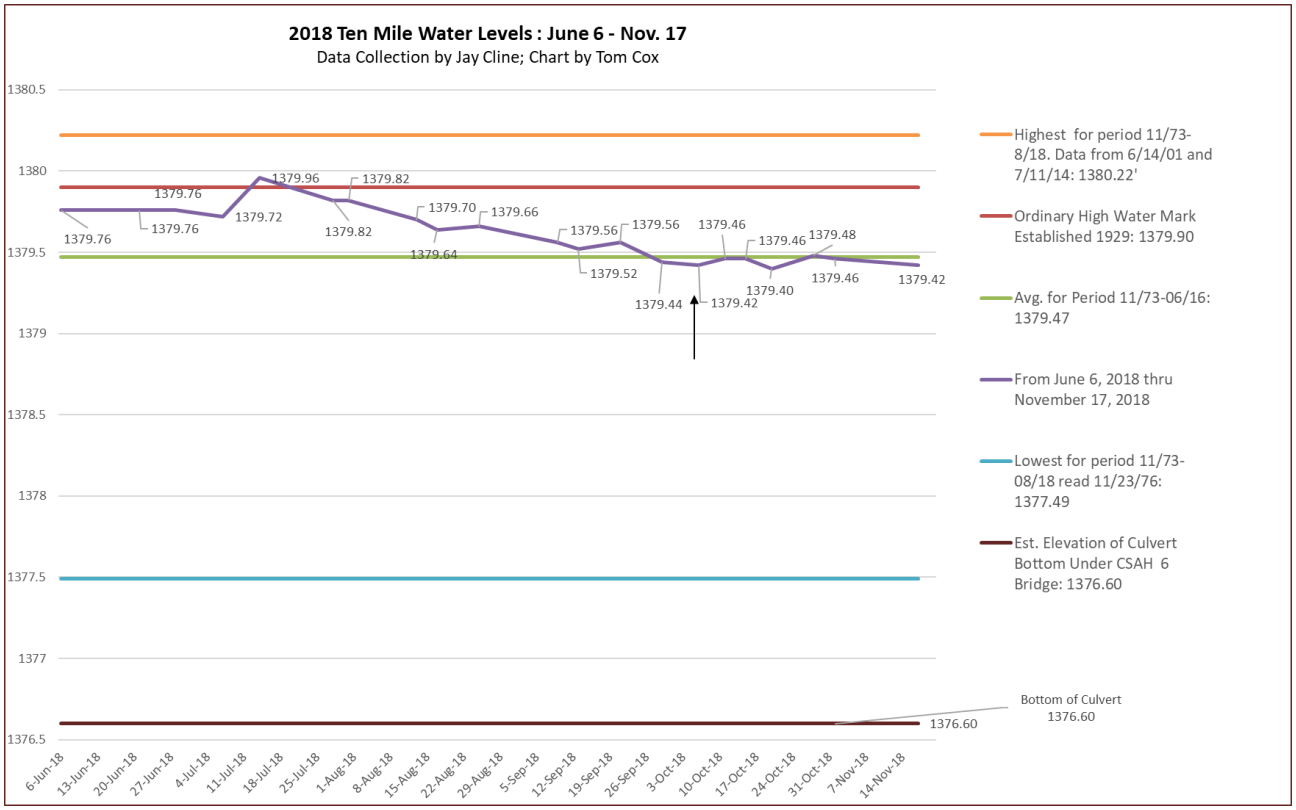


Figure 25. Ten Mile Lake water levels, 2017, Ten Mile Lake Association.

Ground water/Drinking water

Ten Mile Lake Association has completed four drinking water studies with RMB Environmental Laboratories. On July 18, 2015, 60 wells were tested, on July 15, 2017, 64 wells were tested, and on July 5, 2018 RMB staff collected samples from 5 wells and samples were tested. On August 12 2019, 78 wells were tested. Samples in 2015, 2017, and 2019 were collected by individual property owners. All of these samples were received on the same day they were collected, so they all met the necessary holding time for laboratory analysis. Individual result reports were sent to each property owner. Below is a summary of the project results in total.

Nitrates

The EPA's allowable safe limit is 10 mg/L. All the Ten Mile Lake property owner samples were well below the EPA's allowable safe limit for nitrates both in 2015, 2017, 2018, and 2019. In fact, all the results were under 1 mg/L except for two properties, which were 2 mg/L.

Bacteria

The Total Coliform Bacteria test is a presence/absence test. Of the 78 tests in 2019, 7 tested positive for Coliform Bacteria. These 7 samples were then tested for *E.coli* bacteria, and those results were negative.

Key Findings and Recommendations

Monitoring Recommendations

Transparency, total phosphorus, and chlorophyll *a* monitoring at site 202 should be continued annually to track trends in water quality. Total nitrogen levels are very low in all bays, and wouldn't need to be monitored every year (Figure 12).

The other surrounding small bays can be monitored periodically to track and detect any water quality changes. In the past few years, they haven't shown any issues.

Since the lake is at least 50% groundwater fed, ground water monitoring should continue to be implemented. In the past, ground water was monitored from designated well locations around the lake. Additional drinking water monitoring for arsenic levels should also continue to be implemented. This area is known to have arsenic in drinking water and no level is safe to drink.

Overall Summary

Ten Mile Lake is an oligo-mesotrophic lake (TSI = 37 at site 202) with evidence of a long-term improving trend in water clarity. The total phosphorus, chlorophyll *a* and transparency ranges are better than the ecoregion ranges. Ten Mile Lake is an exceptional water resource in Minnesota that has some of the best water quality and is one of the deepest lakes in the state. Even the surrounding shallow bays around the main lake have TSIs in the high 30s - low 40s, which indicate excellent water quality.

Only three percent (3.7%) of the Ten Mile Lake lakeshed is disturbed by development and agriculture (Figure 20). The threshold of disturbance where water quality tends to decline is 25%. Ten Mile Lake is well under this threshold. A third (37%) of the lakeshed is publicly owned, which protects that land from development (Table 11). Nearly three quarters (73%) of the lakeshed is protected, which is good for water quality.

Ten Mile Lake has the advantage of a very small watershed (5:1 watershed to lake area ratio). The lake does not have any major inlets or rivers flowing into it, which means that it is generally or substantially groundwater fed. The MPCA reported (1991 Hydraulic Assessment) that Ten Mile

Lake receives approximately 50% of its water from groundwater. The fact that it has a natural outlet, the Boy River, helps alleviate any high water level issues that could cause erosion and home damage.

Because of the small watershed and lack of major inlets, the main potential impacts and nutrient sources to Ten Mile Lake are the land practices around the shoreline. Impervious surface and turfgrass lawns export nutrients during rain events directly into the lake.

The Ten Mile Lake Association does a great job with lake stewardship and water quality protection. They are involved in promoting conservation easements for land protection and septic system checks for residents. These practices go a long way towards protecting the lake's excellent water quality into the future. Sensitive shoreline areas shown in Figure 23 should be first priority for protection.

Priority Impacts to the Lake

The priority impact to Ten Mile Lake would be the expansion of residential housing development in the lakeshed and second tier development along the lakeshore. The conversion of small lake cabins to year-round family homes increases the impervious surface and runoff from the lake lots. Much of the private land around the lake has been developed in the first tier (Figure 23). Most of the second tier remains in large parcels and has not been subdivided for development (Figure 23).

Best Management Practices Recommendations

The management focus for Ten Mile Lake should be to protect the current water quality and lakeshed. Efforts should be focused on managing and/or decreasing the impact caused by additional development and impervious surface area on existing lots (conversion of seasonal cabins to year-round homes).

The current lakeshore homeowners can lessen their negative impact on water quality by installing or maintaining the existing trees on their properties. Forested uplands contribute significantly less phosphorus (lbs/acre/year) than developed land cover (Table 12). In addition, filter strips or native vegetative buffers could be installed to decrease or slow the runoff reaching the water's edge. Septic systems should be pumped and inspected regularly.

The lakeshed still has large undeveloped shoreline parcels (Figure 23). Because a lot of undeveloped private land still exists, there is a great potential for protecting this land with conservation easements and aquatic management areas (AMAs). Conservation easements can be set up easily and with little cost with help from organizations such as the Board of Soil and Water Resources and the Minnesota Land Trust. AMAs can be set up through the local DNR fisheries office.

Property owners who own large forested tracts of land can work with the Soil and Water Conservation District or The Minnesota Forest Resources Council to set up forest stewardship plans. These plans help ensure the long-term health of the forest.

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
- Forest Stewardship Planning

Lake Association

- Lake condition monitoring
- Watershed runoff mapping by a consultant
- Shoreline inventory study by a consultant
- Conservation easements
- Forest Stewardship Planning

Soil and Water Conservation District (SWCD) and Natural Resources Conservation Service (NRCS)

- Shoreline restoration
- Stream buffers
- Wetland restoration
- Forest Stewardship Planning
- Work with farmers to
    - Restore wetlands
    - Implement conservation farming practices
    - Land retirement programs such as Conservation Reserve Program

Organizational contacts

Ten Mile Lake Association	P.O. Box 412, Hackensack, MN 56452 http://www.tenmilelake.org/
Cass County Environmental Services Department	303 Minnesota Avenue W, P.O. Box 3000, Walker, MN 56484-3000 (218) 547-7241 http://www.co.cass.mn.us/government/county_directory/environmental_services/index.php
Cass County Soil and Water Conservation District	303 Minnesota Avenue W, P.O. Box 3000, Walker, MN 56484-3000 (218) 547-7241 http://www.co.cass.mn.us/government/county_directory/soil_and_water_conservation_district/home.php
DNR Fisheries Office	7316 State Hwy 371 NW, Walker, MN 56484 (218) 547-1683 http://www.dnr.state.mn.us/lakefind/index.html
Regional Minnesota Pollution Control Agency Office	7678 College Road, Suite 105, Baxter, MN 56425 (218) 828-2492 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