Lake Emily 61-0180-00 POPE COUNTY

Lake Water Quality

Summary

Lake Emily is located 6 miles east of Hancock, MN in Pope County. It is an oval lake covering 2,311 acres (Table 1).

Lake Emily has eight inlets and two outlets, which classify it as a drainage lake. Water enters Lake Emily from Outlet Creek on the east end of the lake. Lake Emily Outlet Creek exits the lake on the west side of Lake Emily and carries water westward to the Chippewa River. In the early 1900s, County Ditch #2 was created and connected the Little Chippewa River with Outlet Creek. This increased the size of Lake Emily Watershed from approximately 150 square miles to over 200 square miles (DNR Waters 2008). Lake Emily Watershed can be divided into three parts: the watershed of Lake Minnewaska via Outlet Creek (approximately 49,838 acres), the watershed of the Little Chippewa River via County Ditch #2 (approximately 46,660 acres), and Lake Emily's direct drainage area (approximately 36,328 acres) (Lake Emily TMDL, 2016).

Water quality data have been collected on Lake Emily from 1993-2015 (Tables 2 & 3). These data show that the lake is eutrophic (TSI = 68) with algae blooms and turbid water.

The Lake Emily Improvement Association that is involved in activities such as water quality monitoring and education.

Table 1. Lake Emily location and key physical characteristics.

Location Data		Physical Characteristics	
MN Lake ID:	61-0180-00	Surface area (acres):	2,311.05
County:	Pope	Littoral area (acres):	2,311.05
Ecoregion:	Northern Glaciated Plains	% Littoral area:	100%
Major Watershed:	Chippewa River	Max depth (ft):	6
Latitude/Longitude:	47.426579/ -93.631843	Inlets:	8
Invasive Species:	Eurasian Milfoil, Zebra Mussels	Outlets:	2
		Public Accesses:	1

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

Data Availability		
Transparency data		Citizen Lake Monitoring Program, 1993-2016.
Chemical data		RMB Lab Lakes Monitoring Program, 1994-2016.
Inlet/Outlet data		Chippewa River Watershed Project, 2007-2016.
Recommendations		**For recommendations refer to page 19.**

Lake Map

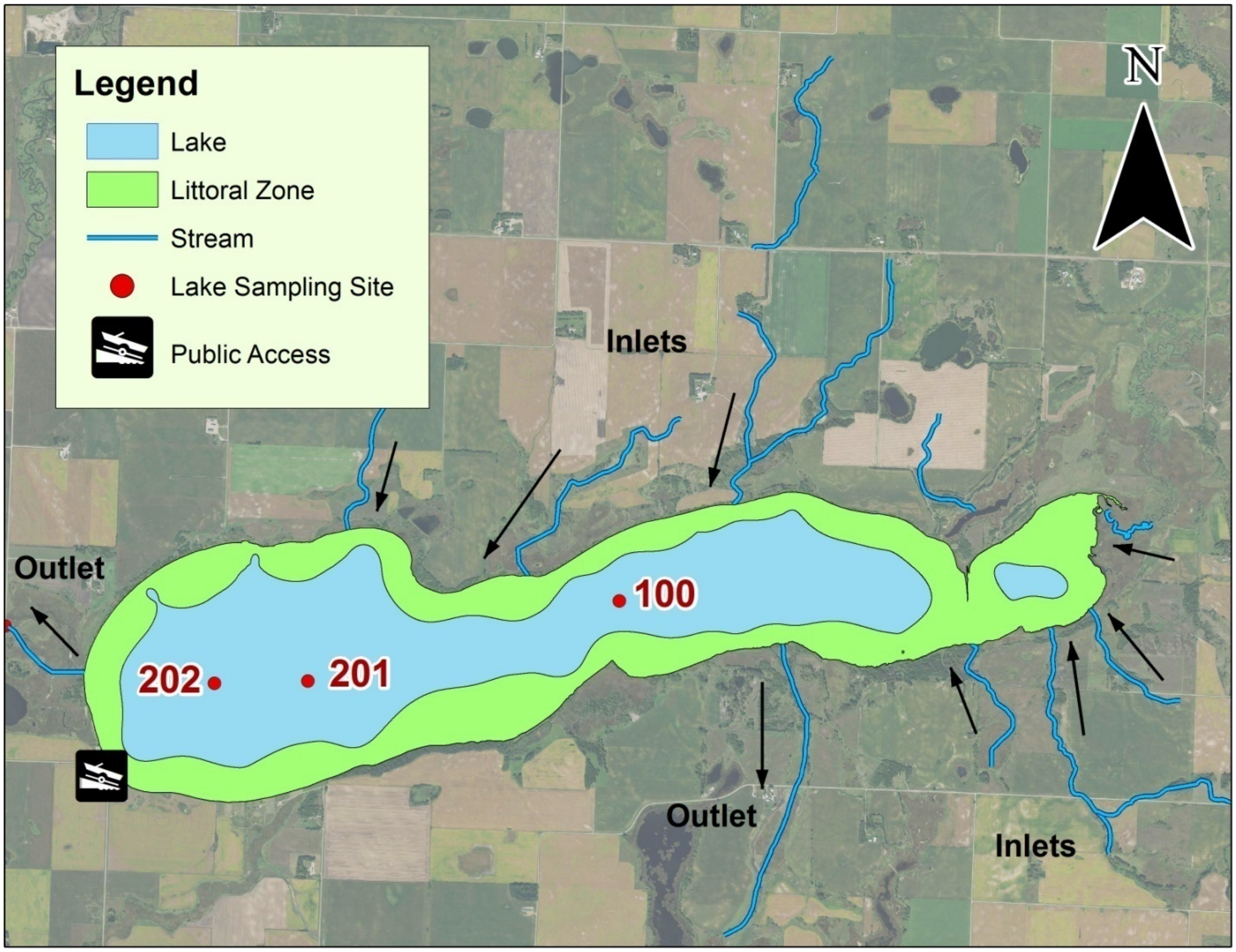


Figure 1. Map of Lake Emily with 2010 aerial imagery and illustrations of lake depth contour lines, sample site locations, inlets and outlets, and public access points. The light green areas in the lake illustrate the littoral zone, where the sunlight can usually reach the lake bottom, allowing aquatic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

Table 3. Monitoring programs and associated monitoring sites. Monitoring programs include the Citizen Lake Monitoring Program (CLMP), MPCA Lake Monitoring Program Project (LMPP), Pope Coalition of Lake Association Monitoring (COLA), RMB Environmental Laboratory Monitoring Program (RMBEL).

Lake Site	Depth (ft)	Monitoring Programs
100	4	LMPP: 1995
201	6	CLMP: 1993-1994, COLA: 1994-1995, RMBEL: 1996-2016
202	6	CLMP: 2007-2008

Average Water Quality Statistics

The information below describes available chemical data for Lake Emily through 2016 (Table 4). Data for Secchi depth, chlorophyll-a, and phosphorous are from the primary site 201. All other parameters are from site 100.

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. Lake Emily is in the Northern Glaciated Plains 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)	106.2	122 – 160	> 90	Results are within the ecoregion range, but over the impaired waters standard. Lake Emily is on the MPCA Impaired Waters list.
[3]Chlorophyll *a* (ug/L)	39.4	36 – 61	> 30	
Chlorophyll *a* max (ug/L)	174.0	66 – 88		
Secchi depth (ft)	1.76	1.3 – 2.6	< 2.3	
Dissolved oxygen	*See page 8*			Dissolved oxygen depth profiles show that the lake is polymictic.
Total Kjeldahl Nitrogen (mg/L)	1.67	1.8 – 2.3		Within the ecoregion range. Indicates insufficient nitrogen to support summer nitrogen-induced algae blooms.
Alkalinity (mg/L)	240	160 – 260		Within the ecoregion range. Indicates a low sensitivity to acid rain and a good buffering capacity.
Color (Pt-Co Units)	22.5	20 – 30		Within the ecoregion range. Indicates somewhat turbid water due to algae and/or sediment.
pH	8.6	8.3 – 8.6		Indicates a hardwater lake. 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)	17.5	11 – 18		Within the expected range for the ecoregion.
Total Suspended Solids (mg/L)	38.6	10 – 30		Indicates turbid water due to algae and/or sediment.
Specific Conductance (umhos/cm)	550	640 – 900		Within the expected range for the ecoregion.
TN:TP Ratio	15.7	7:1 - 18:1		Within the expected range for the ecoregion. 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 201
Total Phosphorus Mean (ug/L):	**102.2**
Total Phosphorus Min:	36.0
Total Phosphorus Max:	221
Number of Observations:	103
Chlorophyll *a* Mean (ug/L):	**38.8**
Chlorophyll-a Min:	1
Chlorophyll-a Max:	174
Number of Observations:	91
Secchi Depth Mean (ft):	**1.9**
Secchi Depth Min:	0
Secchi Depth Max:	6.5
Number of Observations:	102

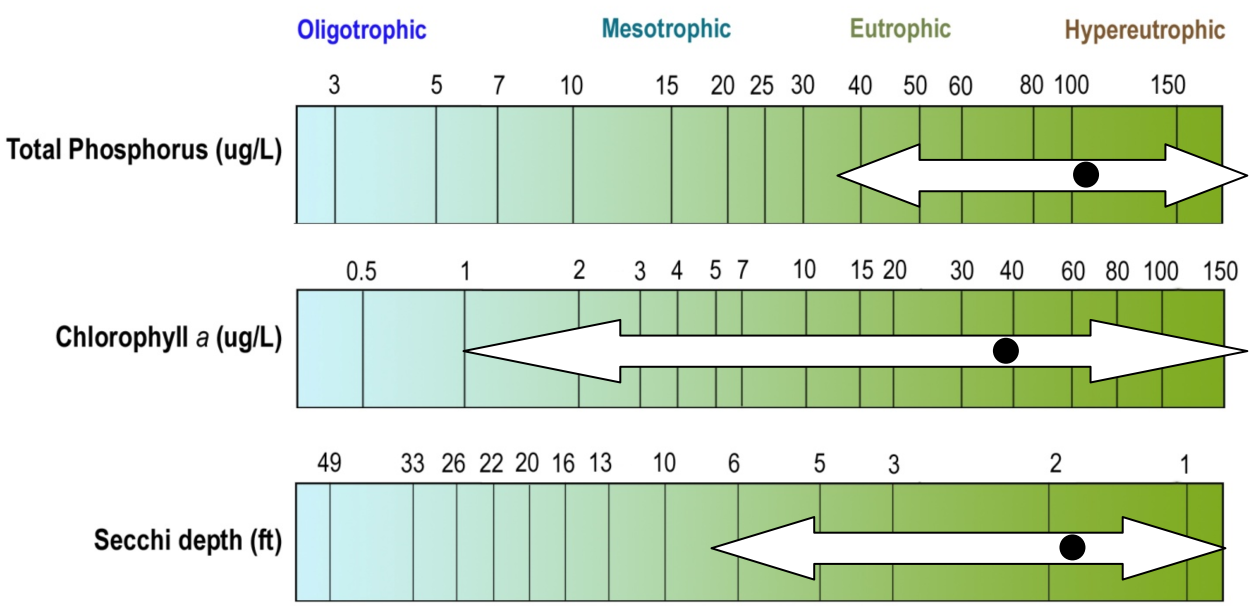


Figure 2. Lake Emily total phosphorus, chlorophyll a and transparency historical ranges. The arrow represents the range and the black dot represents the historical mean (Primary Site 201). Figure adapted after Moore and Thornton, [Ed.]. 1988. Lake and Reservoir Restoration Guidance Manual. (Doc. No. 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 Lake Emily ranges from 0.8 to 4.3 feet (Figure 3). The annual mean has been increasing steadily since 2009, which indicates an increase in water quality. In 2016 the mean transparency was lower, but there were only two data points collected that year. For trend analysis, see page 10. Transparency monitoring should be continued annually in order to track water quality changes.

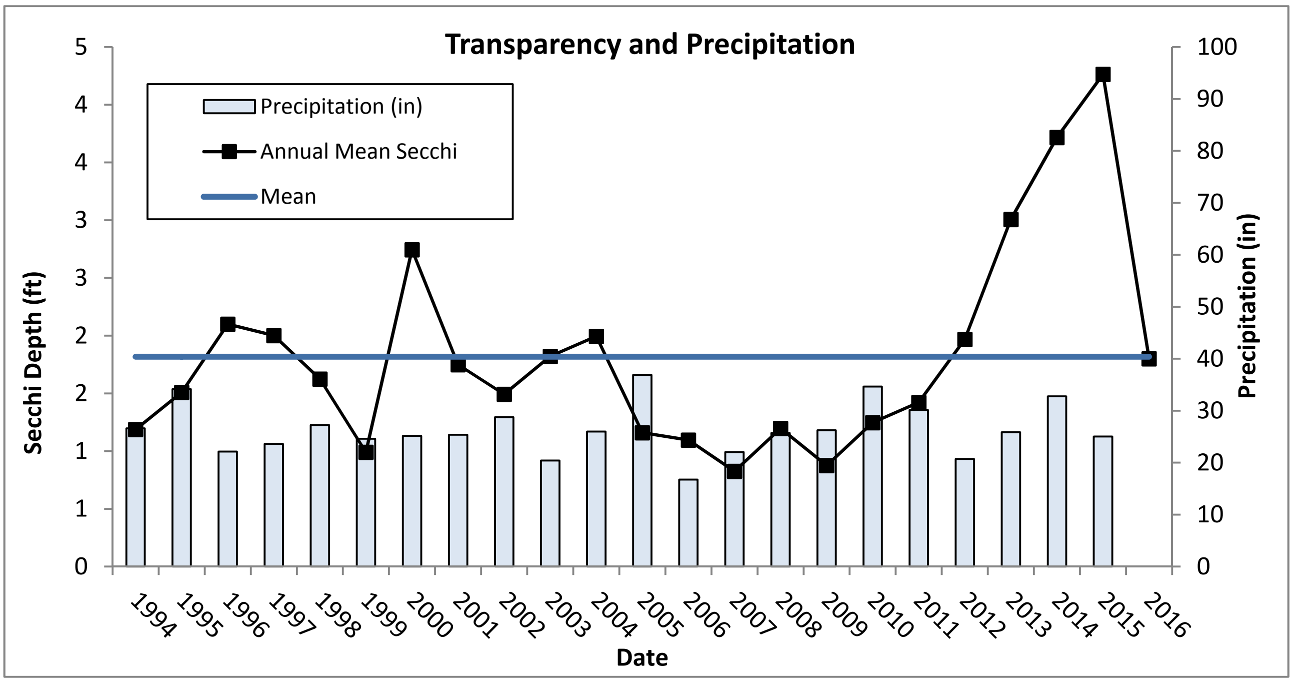


Figure 3. Annual mean transparency compared to long-term mean transparency.

Lake Emily transparency ranges from 0.7 to 6.6 ft at the primary site (201). Figure 4 shows the seasonal transparency dynamics. The maximum Secchi reading is usually obtained in early summer. Lake Emily transparency is highest in May and June, and then declines through August. 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.

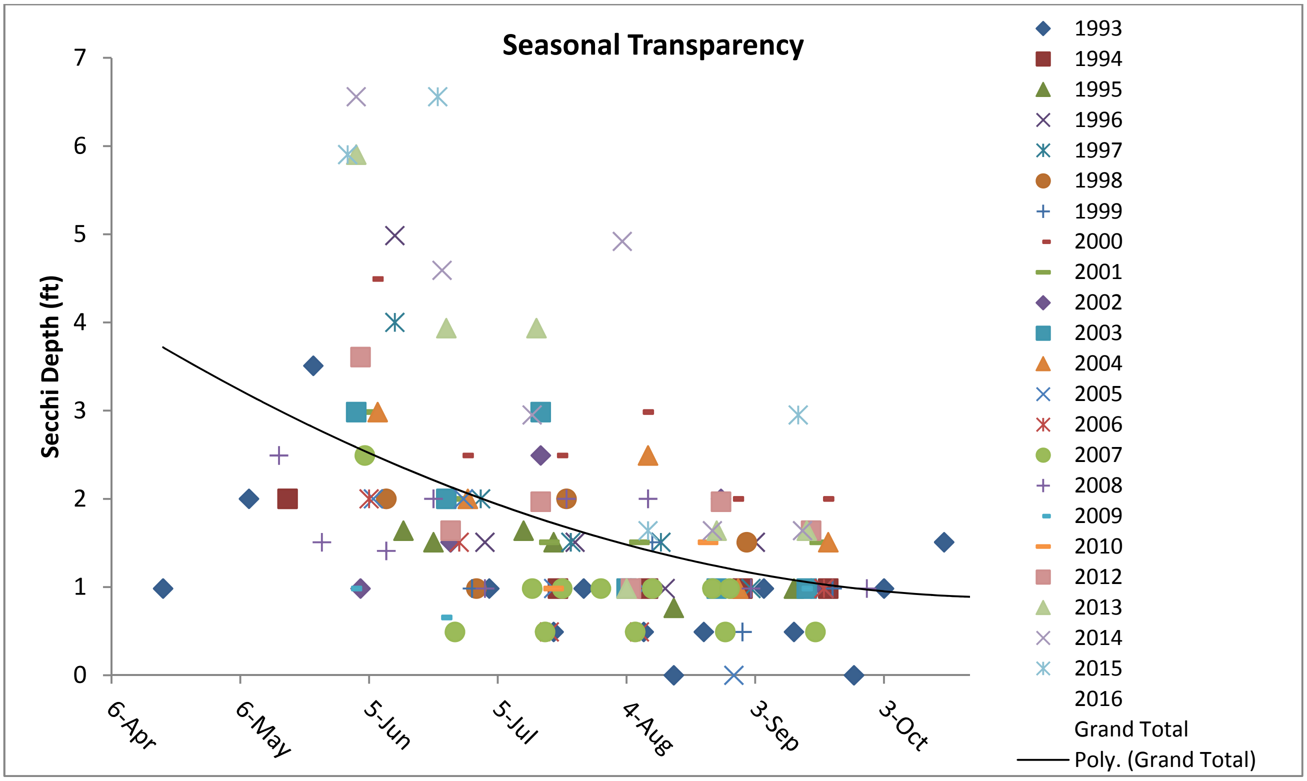


Figure 4. Seasonal transparency dynamics and year to year comparison (Primary Site 201). The black line represents the pattern in the data.

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. Lake Emily was rated as being "not quite crystal clear" 23% of the time by samplers at site 201 between 2007 and 2016 (Figure 5).

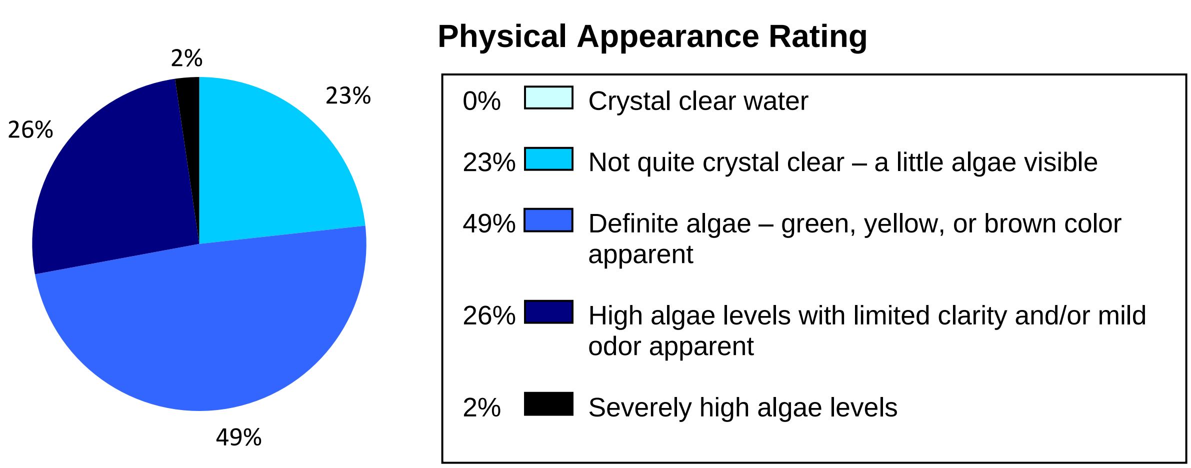


Figure 5. Lake Emily physical appearance ratings by samplers.

As the Secchi depth decreases, the perception of recreational suitability of the lake decreases. Lake Emily was rated as being "slightly impaired for swimming" 42% of the time from 2007 to 2016 (Figure 6).

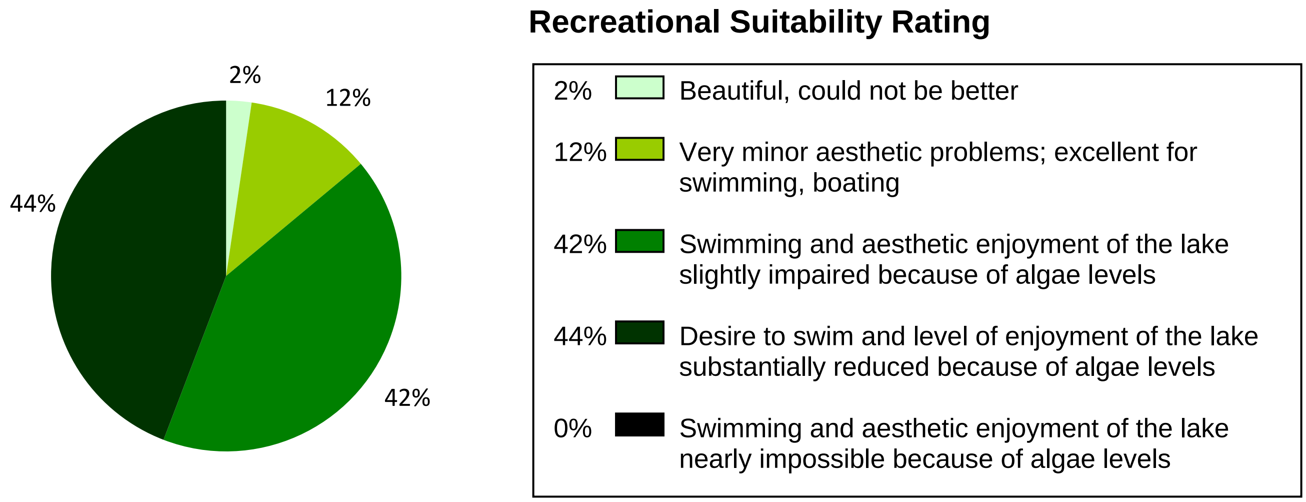


Figure 6. Recreational suitability rating, as rated by the volunteer monitor.

Total Phosphorus

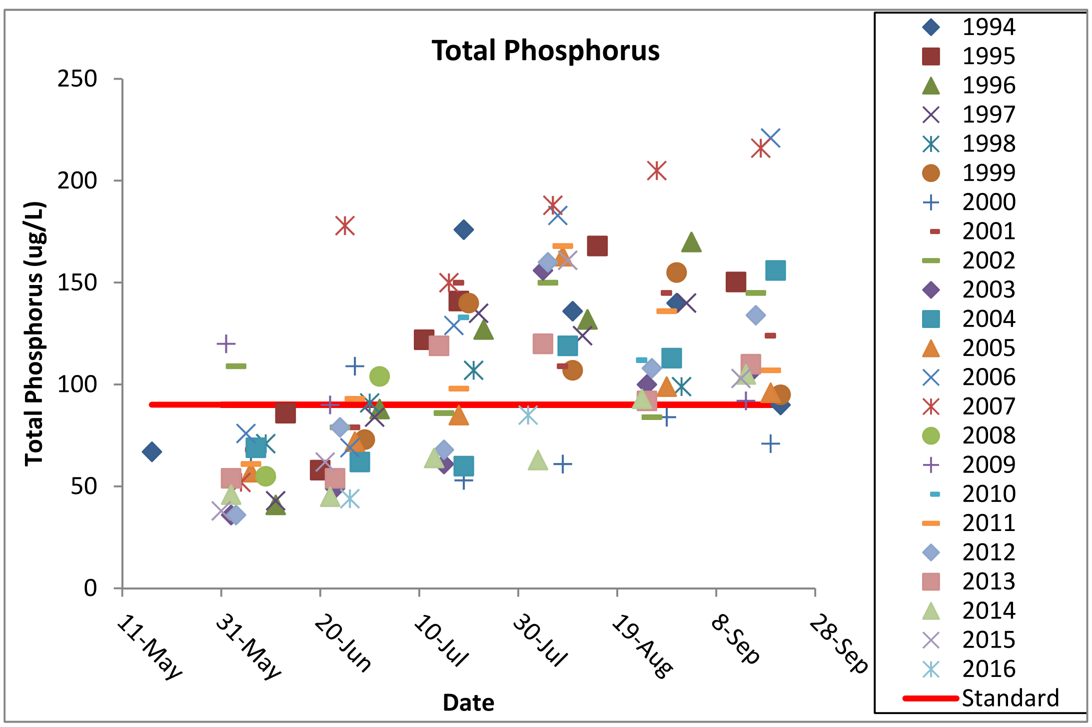


Figure 7. Historical total phosphorus concentrations (ug/L) for Lake Emily site 201.

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

Total phosphorus was monitored in Lake Emily from 1994-2016. The state phosphorus standard for Impaired Waters in the Northern Glaciated Plains Ecoregion is shown in red (Figure 7). Over half of the data points are exceeding the standard, and Lake Emily is on the Minnesota Impaired Waters List. A Total Maximum Daily Load (TMDL) study is in draft form and will inform how to make reductions to phosphorus levels in the lake.

Phosphorus should continue to be monitored to track future changes in water quality due to improvement projects.

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 20 ug/L are perceived as a nuisance algae bloom. The state chlorophyll a standard for Impaired Waters in the Northern Glaciated Plains Ecoregion is shown in red (30 ug/L) (Figure 8). Chlorophyll *a* was evaluated in Lake Emily at site 201 from 1995-2016 (Figure 8). Chlorophyll *a* concentrations went well above 20 ug/L in all years, indicating major algae blooms.

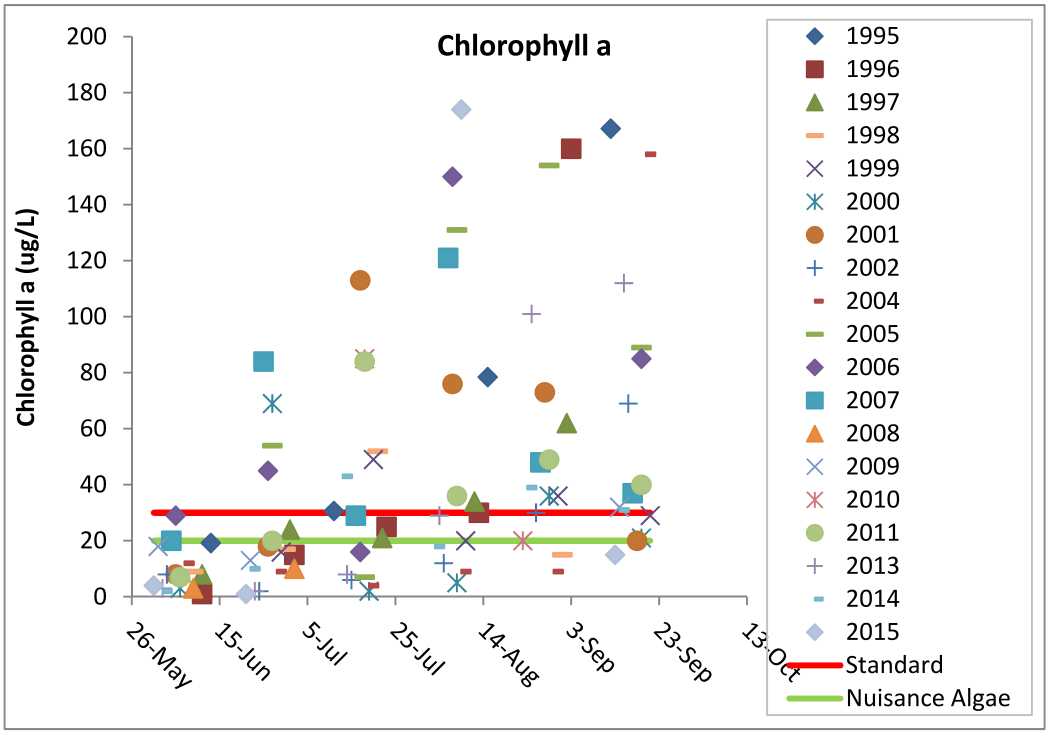


Figure 8. Chlorophyll *a* concentrations (ug/L) for Lake Emily at site 201.

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.

Lake Emily is a shallow lake, with a maximum depth of 6 feet. Dissolved oxygen profiles from data collected in 1995 at site 100 show that the lake mixes all summer.

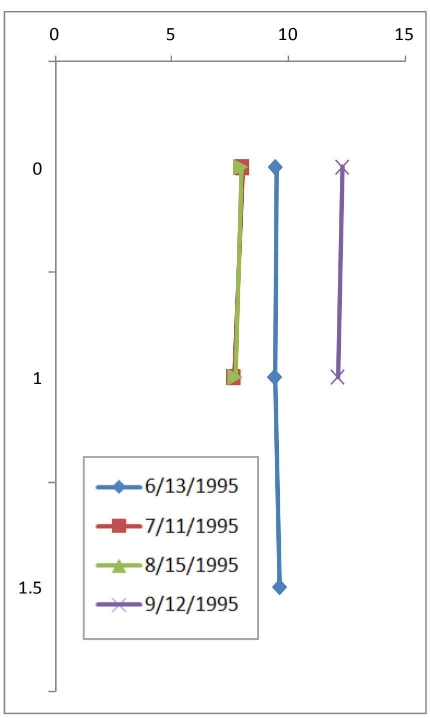


Figure 9. Dissolved oxygen profile for Lake Emily.

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 Lake Emily falls into the eutrophic range (Figure 10). There is good agreement between the TSI for chlorophyll *a* and transparency, indicating that these variables are strongly related (Table 6). The TSI for phosphorus is higher, indicating that phosphorus loading is likely at high levels.

Eutrophic lakes (TSI 50-70) are characteristic of "green" water most of the summer. "Eu" means true and the root "trophy" means nutrients therefore, eutrophic literally means true nutrients or truly nutrient rich (phosphorus). Eutrophic lakes are usually shallow, and are found where the soils are fertile. Eutrophic lakes usually have abundant aquatic plants and algae.

Table 6. Trophic State Index for Lake Emily.

Trophic State Index	Primary Site 202
TSI Total Phosphorus	71
TSI Chlorophyll-a	66
TSI Secchi	67
TSI Mean	68
Trophic State:	Eutrophic

Numbers represent the mean TSI for each parameter.

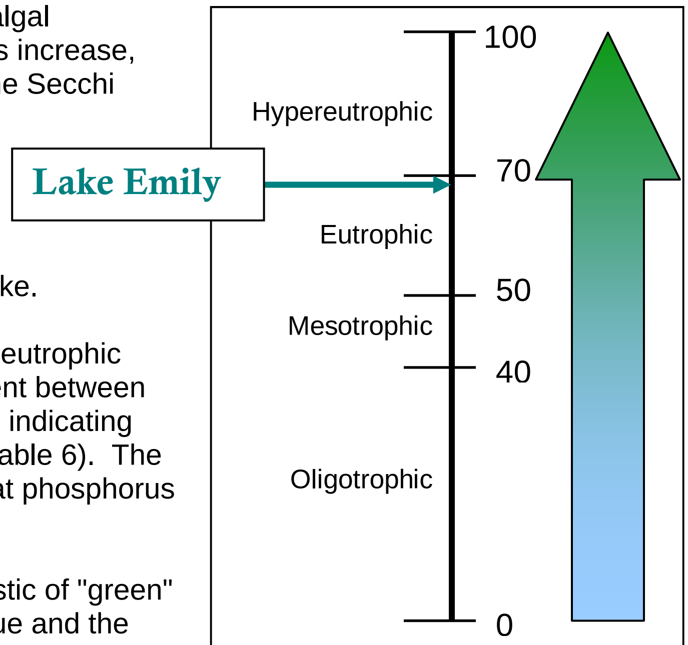


Figure 10. Trophic state index chart with corresponding trophic status.

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

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, and etc., that affect the water quality naturally.

Lake Emily 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 Lake Emily.

Lake Site	Parameter	Date Range	Trend
201	Total Phosphorus	1996-2016	No trend
201	Chlorophyll *a*	1996-2016	No trend
201	Transparency	1996-2016	No trend

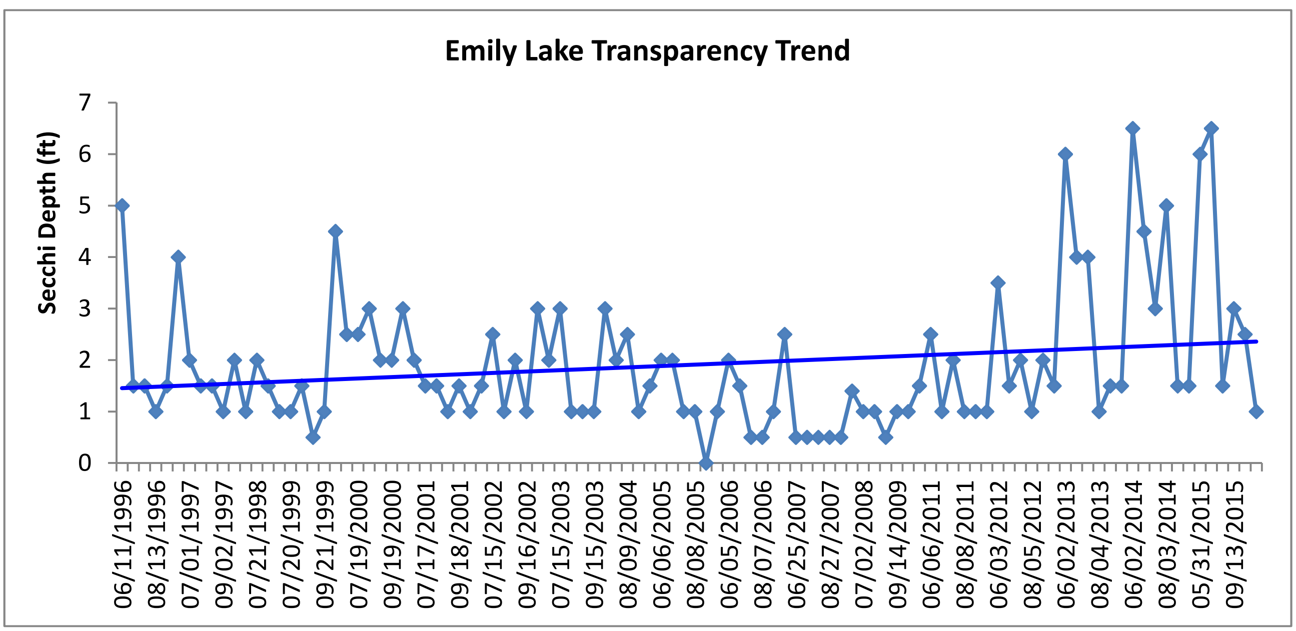


Figure 11. Transparency (feet) trend for site 201 from 1993-2016.

Emily Lake shows no evidence of water quality trends for any of the parameters monitored over the past 20 years. Overall, these trend results show that the water quality in Emily Lake is stable, with no indication of decline. 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.

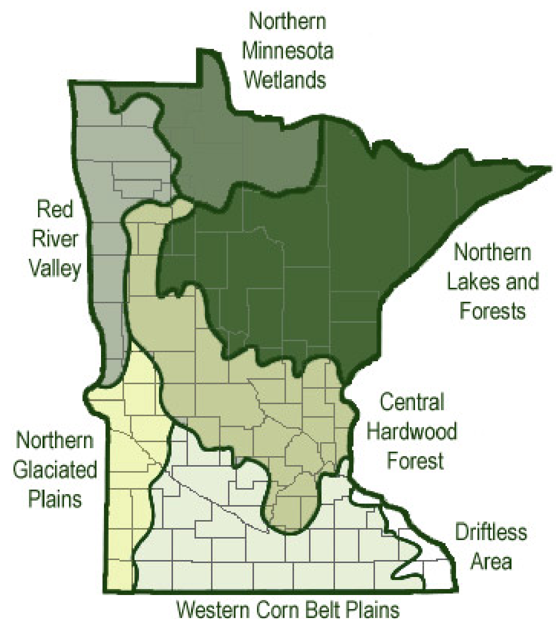
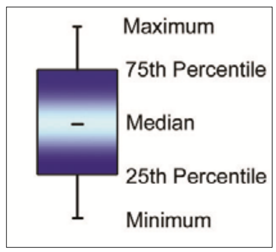


Figure 12. Minnesota Ecoregions.

Lake Emily is in the Northern Glaciated Plains Ecoregion. The mean total phosphorus and chlorophyll *a* for Lake Emily are within the ecoregion ranges (Figure 13). The Secchi is poorer than the ecoregion range.



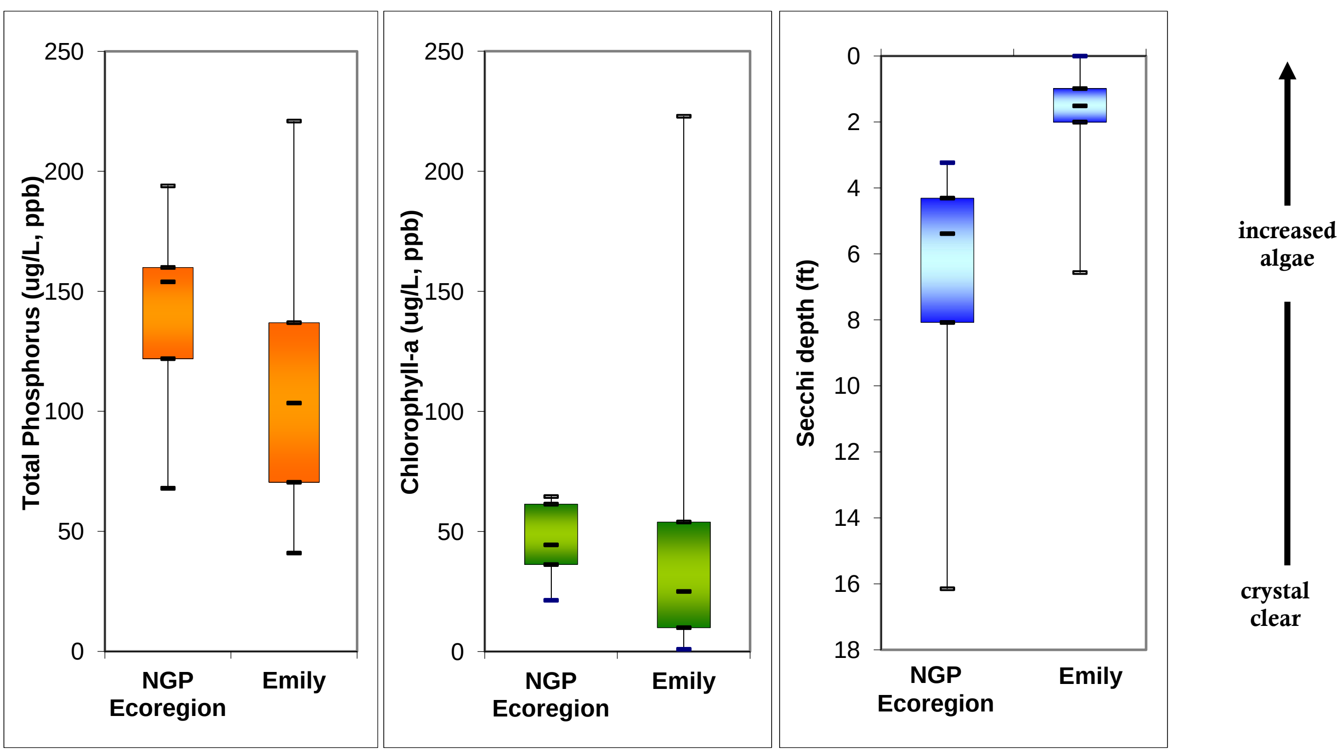


Figure 13. Lake Emily ranges compared to Northern Lakes and Forest Ecoregion ranges. The Lake Emily total phosphorus and chlorophyll *a* ranges are from 120 data points collected in June-September of 1994-2016. The Lake Emily Secchi depth range is from 244 data points collected in 150 data points collected in April-September of 1994-2016.

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 Chippewa River Major Watershed is one of the watersheds that make up the Minnesota River Basin, which drains south to the Mississippi River and eventually the Gulf of Mexico (Figure 14). Lake Emily is located in minor watershed 26011 (Figure 15).

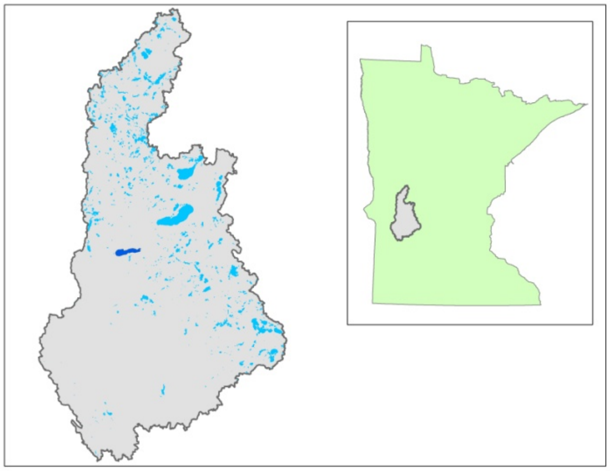


Figure 14. Major Watershed.

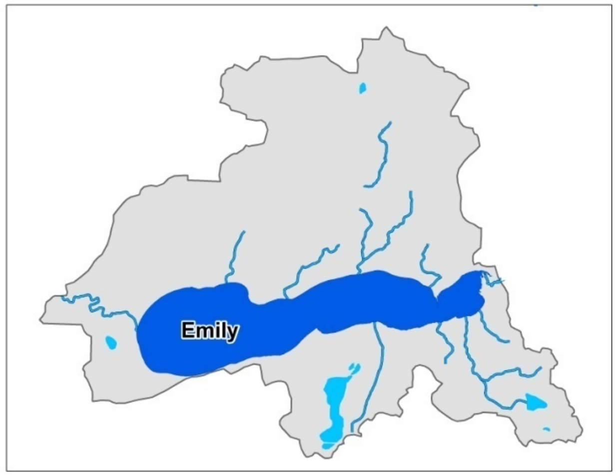


Figure 15. Minor Watershed.

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. Lake Emily falls within lakeshed 2601101 (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 may be connected to a large number of lakesheds, reflecting a larger drainage area via stream or river networks. For further discussion of Lake Emily 's watershed, containing all the lakesheds upstream of the Lake Emily lakeshed, see page 17. The data interpretation of the Lake Emily lakeshed includes only the immediate lakeshed as this area is the land surface that flows directly into Lake Emily.

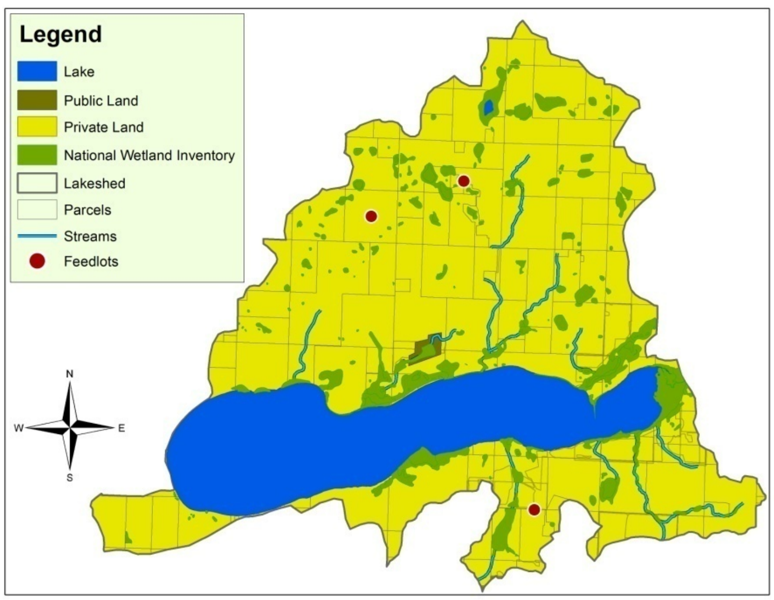


Figure 16. Lake Emily lakeshed (2601101) with land ownership, lakes, wetlands, and rivers illustrated.

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. Lake Emily lakeshed vitals table.

Lakeshed Vitals		**Rating**
Lake Area (acres)	2,311	descriptive
Littoral Zone Area (acres)	2,311	descriptive
Lake Max Depth (feet)	6.0	descriptive
Lake Mean Depth (feet)	2.0	
Water Residence Time	NA	NA
Miles of Stream	11.8	descriptive
Inlets	8	
Outlets	2	
Major Watershed	26 Chippewa River	descriptive
Minor Watershed	26011	descriptive
Lakeshed	2601101	descriptive
Ecoregion	Northern Glaciated Plains	descriptive
Total Lakeshed to Lake Area Ratio (total lakeshed includes lake area)	4:1	
Standard Watershed to Lake Basin Ratio (standard watershed includes lake areas)	62:1	
Wetland Coverage (NWI) (acres)	828.4	
Aquatic Invasive Species	Eurasian Water Milfoil, Zebra Mussels	
Public Drainage Ditches	0	
Public Lake Accesses	1	
Miles of Shoreline	12.7	descriptive
Shoreline Development Index	1.9	
Public Land to Private Land Ratio	1 : 231.7	
Development Classification	Natural Environment	
Miles of Road	21.9	descriptive
Municipalities in lakeshed	0	
Forestry Practices	None	
Feedlots	3	
Sewage Management	Individual Waste Treatment Systems (septic systems and holding tanks)	
Lake Management Plan	None	
Lake Vegetation Survey/Plan	DNR, 2000	

Land Cover / Land Use

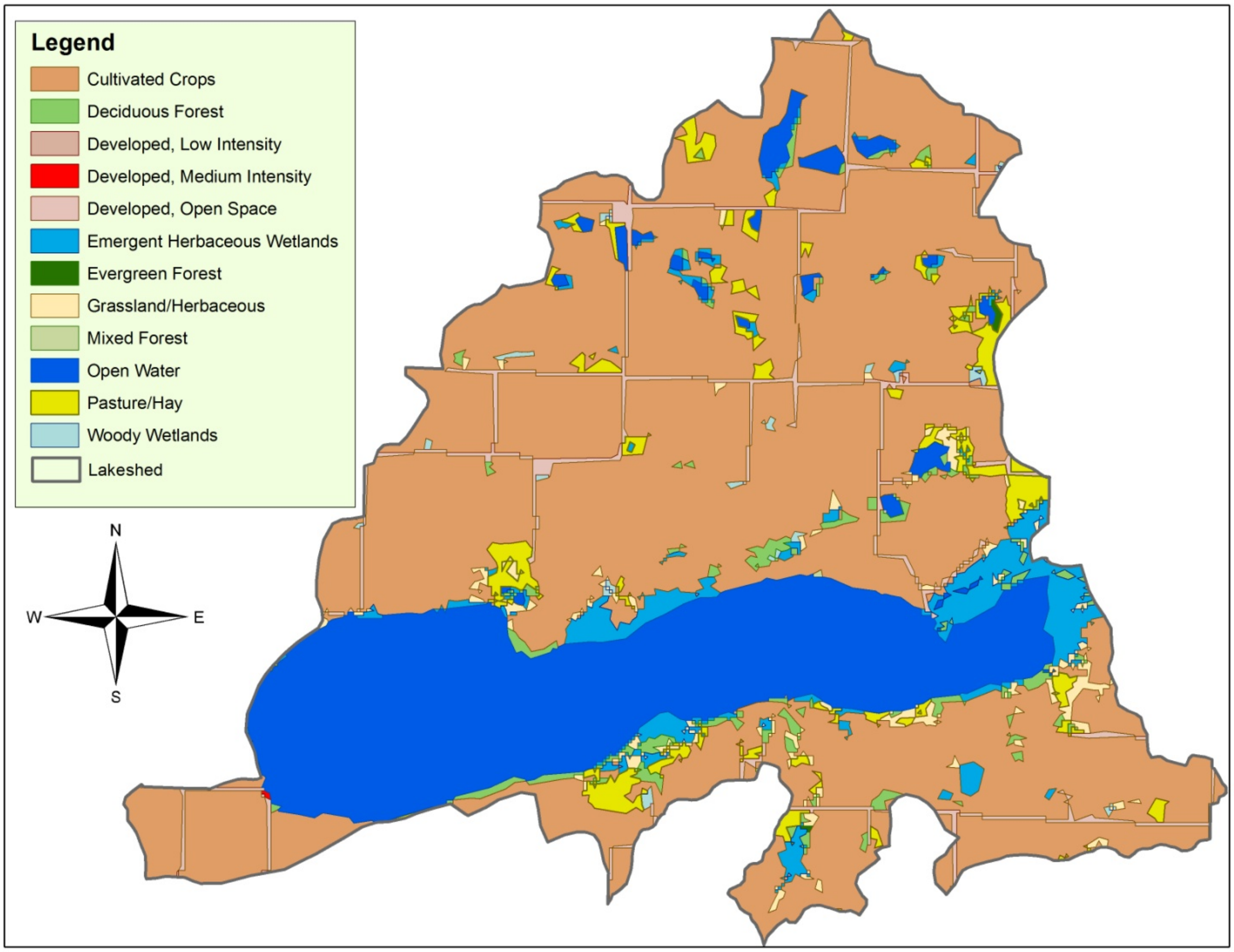


Figure 17. Lake Emily lakeshed (2601101) land cover (NLCD 2011).

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.

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 Lake Emily's lakeshed.

Table 10. Land cover in the Lake Emilyshed.

Runoff Potential	Category	Specific Landcover	Acres	Percent
High	Agriculture	**Cultivated Crop**	7,017.1	63.8%
High	Urban	**Developed, Low**	1.1	0.01%
High	Urban	**Developed, Medium**	1.0	0.01%
High	Urban	**Developed, Open**	316.2	2.9%
Low	Forest	**Deciduous Forest**	203.8	1.9%
Low	Wetlands	**Herbaceous Wetlands**	435.8	4.0%
Low	Agriculture	**Grassland/Herbaceous**	154.5	1.4%
Low	Forest	**Evergreen Forest**	5.1	0.05%
Low	Forest	**Mixed Forest**	1.0	0.01%
Low	Water	**Open Water**	2,464.5	22.4%
Low	Agriculture	**Pasture/Hay**	369.5	3.4%
Low	Wetlands	**Woody Wetlands**	33.6	0.31%
Total area with low runoff potential			3,667.8	33.3%
Total area with high runoff potential			7,335.4	66.7%
Total			11,003.2	100.0%

Developed land cover (Table 10) mostly describes impervious surface. In impervious areas, such as roads and houses, the land is unable to absorb water and it runs off the landscape carrying with it any nutrients or sediment in its path. The higher the impervious intensity the more area that water cannot penetrate in to the soils. Impervious areas can contribute 0.45 – 1.5 pounds of phosphorus per year in runoff. Lake Emily has 2.9% of its lakeshed classified as developed (Table 10). This doesn't sound like much area, but if it is mainly concentrated on the lakeshore, the runoff from impervious areas can run directly into the lake.

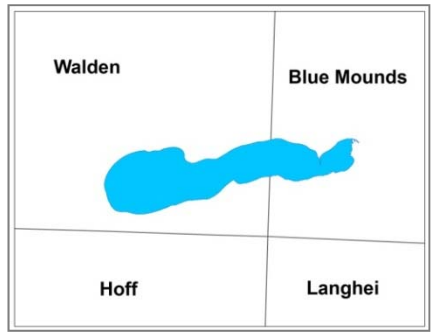
Agricultural land use has the potential to contribute nutrients to a lake through runoff, but the amount of phosphorus runoff depends on the type of agricultural land use. Generally, the highest concentration of agricultural nutrient runoff comes from animal feedlots. There are three animal feedlots in the Lake Emily lakeshed (Table 9). The second highest agricultural runoff generally comes from row crops. In the Lake Emily lakeshed, 64% of the land is row crops (Figure 17). . Pasture land has less nutrient runoff, and most likely doesn't impact the lake as much as other agricultural uses. Therefore, the statistics in Table 10 are valuable for evaluating runoff in the lakeshed. Overall, 67% of the Lake Emily lakeshed is classified in high nutrient runoff land uses (Table 10).

The University of Minnesota has online records of land cover statistics from years 1990 and 2000 (http://land.umn.edu). Although this data is 16 years old, it is the only data set that is comparable over a decade's time. In addition, a lot of lake development occurred from 1990 to 2000 when the US economy was booming. Table 11 describes Emily's lakeshed land cover statistics related to development and percent change from 1990 to 2000. Due to the many factors that influence demographics, one cannot determine with certainty the projected statistics over the next 10, 20, 30+ years, but one can see the impervious area has increased, which has implications for storm water runoff into the lake. The increase in impervious area is consistent with the increase in urban acreage.

Table 11. Lake Emily 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	67	0.64	76	0.73	+9 acres
Urban Acreage	325	2.53	428	3.33	+103 acres

Demographics



Lake Emily is classified as a Natural Environment lake. Natural Environment lakes usually have less than 150 total acres, less than 60 acres per mile of shoreline, and less than three dwellings per mile of shoreline. They may have some winter kill of fish; may have shallow, swampy shoreline; and are less 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 Pope County as a whole, Walden Township has a higher growth projection (Figure 18). (source: http://www.demography.state.mn.us)

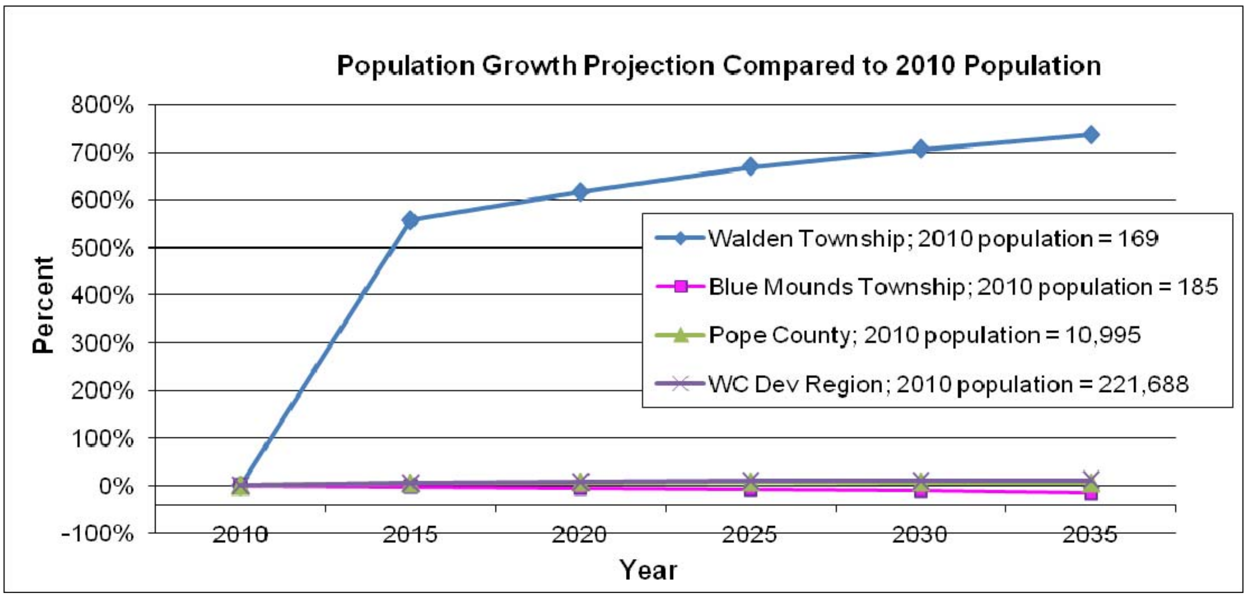


Figure 18. Population growth projection for adjacent townships and Pope County.

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 Lake Emily's lakeshed is privately owned cultivated row crops (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 (78.77)						Public (0.34)		
	Developed	**Agriculture**	**Forested Uplands**	**Other**	**Wetlands**	**Open Water**	**County**	**State**	**Federal**
Land Use (%)	2.87	63.74	1.85	4.69	5.62	20.89	0	0.33	0.02
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	143-477	1,838-6,364	18.5		56.0		0	3.27	0.16
Description	Focused on Shoreland	Cropland	Focus of develop-ment and protection efforts	Open, pasture, grass-land, shrub-land	Protected				
Protection and Restoration Ideas	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.

Lake Emily's lakeshed is classified with having 30% of the watershed protected and 70% of the watershed disturbed (Figure 19). Therefore, this lakeshed should have a partial restoration focus. Goals for the lake should be to decrease the disturbed land use. Numerous other lakesheds flow into Lake Emily.

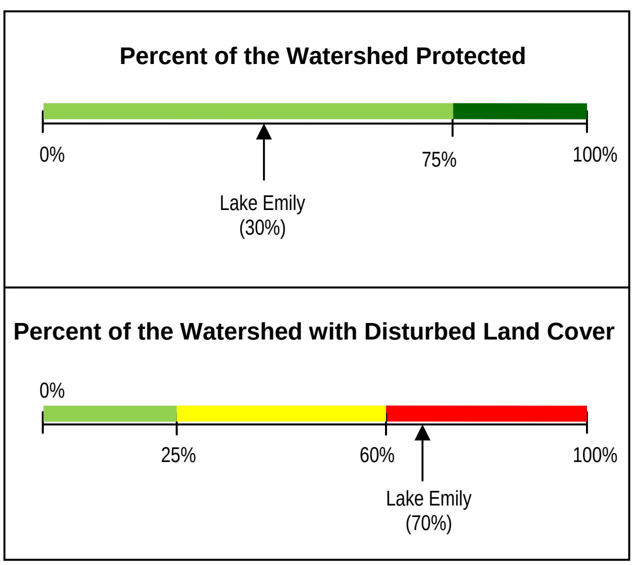


Figure 19. Lake Emily's lakeshed percentage of watershed protected and disturbed.

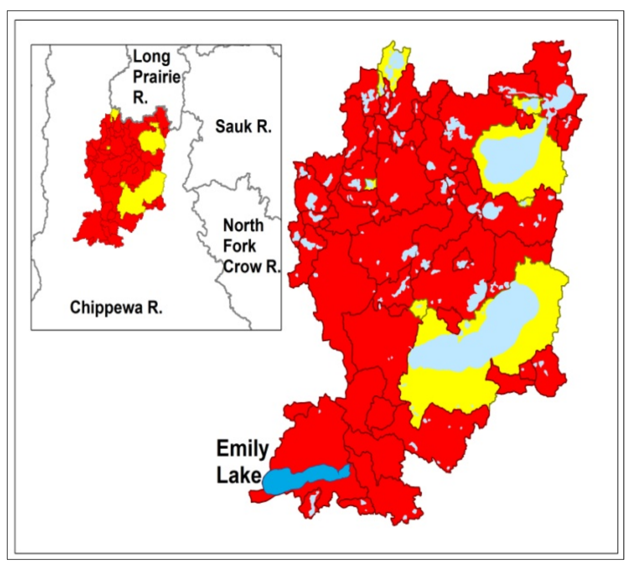


Figure 20. Lakesheds that contribute water to the Lake Emily lakeshed. Color-coded based on management focus (Table 13).

Status of the Fishery (DNR, as of 06/07/2010)

Lake Emily is a large (2,377 acres), shallow lake located in southwestern Pope County. Maximum depth is approximately six feet. Despite shallowness of the lake, winterkill has been limited to infrequent partial fish losses. Groundwater exchange, springs, and flowage from the Little Chippewa River and Lake Minnewaska are likely very important in maintaining sufficient dissolved oxygen levels to support the fish community. At present, summer water quality and clarity is poor due to wave-induced suspension of sediment and algal blooms. In addition, a significant nutrient load is delivered to the lake from the Little Chippewa River.

Walleye net catches averaged 31.0 fish per gillnet lift, which greatly exceeds the average catch rate from lakes with similar physical and chemical characteristics. Two-year-olds accounted for 73% of the walleye population sample. These juvenile walleye averaged 11.8 inches at age 2. Numerous consecutive age classes are represented in assessment gear which indicates some natural reproduction occurs.

Northern pike catches averaged 3.7 fish/gillnet. Lengths ranged from 13 inches to 33 inches. Mean weight of northern pike captured was 2.4 lbs. Black crappie net catches averaged 5.3 fish per gillnet. Average size of black crappie was small since most captures were young fish (ages 1 and 2). Black crappie grow rapidly in Lake Emily and they should recruit to a harvestable size in 2011.

Lake Emily is unique within the Glenwood management area as it is the only lake that currently supports a channel catfish fishery. Netted channel catfish lengths ranged from 15 to 24 inches with a mean weight of 3.5 lbs. White bass are a recent addition to the fish community. The species has moved upstream from the Minnesota River. A single specimen was netted during the current survey. Angling reports indicate they have been present for several years.

Bluegill and largemouth bass are present in Lake Emily. Abundance is limited due to their dependence on rooted vegetation. A species tolerant of poor water quality, white crappie, are abundant with a catch of 7.6 fish per trap net. Mean size is small, although a few captures exceeded 12 inches in length. Other species captured in the fish community assessment include, bigmouth buffalo, black bullhead, brown bullhead, common carp, freshwater drum (sheepshead), shorthead redhorse, white sucker and yellow perch.

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=61018000

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.

In the Lake Emily TMDL, 50% of the phosphorus loading to the lake was attributed to the Little Chippewa River. Monitoring this inlet will help determine the effectiveness of phosphorus reduction projects as part of the TMDL recommendations.

Overall Summary
Lake Emily is a eutrophic lake (TSI = 68) with no evidence of a long-term trend in water clarity. Seventy percent (70%) of Lake Emily lakeshed is disturbed by development and agriculture (Figure

19). The threshold of disturbance where water quality tends to decline is 25%. Lake Emily is over this threshold. The total phosphorus, chlorophyll *a* and transparency ranges are within the ecoregion ranges, but over the impaired waters standards for shallow lakes in the Northern Glaciated Plains ecoregion Table 4).

Priority Impacts to the Lake

Because Lake Emily is over the impaired waters standards, a Total Maximum Daily Load (TMDL) study was conducted in 2016 to quantify phosphorus sources to the lake and determine where and how they can be improved. Half of the phosphorus loading to Lake Emily was determined to be from the Little Chippewa River. A third of the loading is from direct drainage from stormwater runoff (Figure 19). The Lake Emily TMDL recommends a 35% reduction in phosphorus loading in order to meet water quality standards.

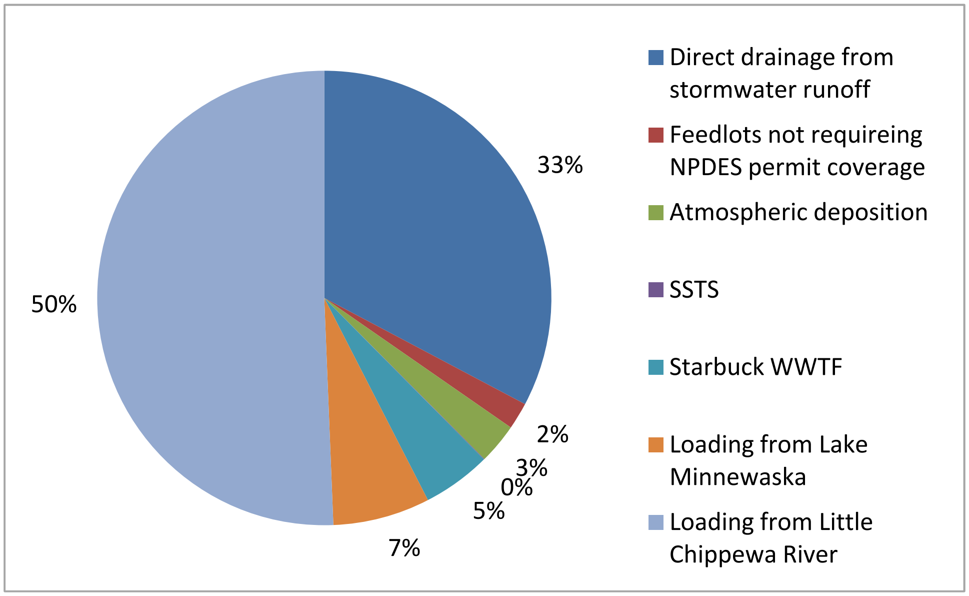


Figure 19. Lake Emily Phosphorus Inventory, from Lake Emily TMDL, 2016.

The Lake Emily TMDL report can be found here: https://www.pca.state.mn.us/water/tmdl/pope-county-8-lakes-excess-nutrients-total-phosphorus-tmdl-project

Best Management Practices Recommendations

Point source phosphorus reductions, mainly the Starbuck Waste Water Treatment Facility, are addressed in the Lake Emily TMDL. Contribution of phosphorus from sub-surface waste treatment systems (SSTS, Figure 19) was negligible since there are only 6 shoreline property owners around the lake.

For non-point source watershed loading, which is a large part of Lake Emily's phosphorus sources, a variety of projects can be implemented. These projects take time and buy-in from local landowners, but as more and more people implement them they have an additive effect in reducing phosphorus runoff. Filter strips, grassed waterways, holding ponds, native vegetative buffers, and restored wetlands could be installed to decrease or slow the runoff reaching the lake.

The lakeshed still has large undeveloped shoreline parcels (Figure 16). 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.

Internal phosphorus loading can be addressed by the removal of carp, establishment of macrophytes and possible alum treatment. Native aquatic plants stabilize the lake's sediments and tie up phosphorus in their tissues. When aquatic plants are uprooted from a shallow lake, the lake bottom is disturbed, and the phosphorus in the water column gets used by algae instead of plants. This contributes to “greener” water and more algae blooms. Protecting native aquatic plant beds will ensure a healthy lake and healthy fishery.

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
- Conservation easements

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

Organizational contacts and reference sites

Lake Emily Improvement Association	No contact information
Pope County Environmental Services Department	130 East Minnesota Avenue, Glenwood, MN 56334 (320) 634-7791 https://www.co.pope.mn.us
Pope Soil and Water Conservation District	1680 Franklin Street North, Glenwood, MN 56334 (320) 634-5327 http://popeswcd.org
DNR Fisheries Office	10 First Ave SW Glenwood, MN 56334 (320) 634-7322 http://www.dnr.state.mn.us/areas/fisheries/glenwood/index.html
Regional Minnesota Pollution Control Agency Office	714 Lake Ave., Suite 220, Detroit Lakes, MN 56501 (218) 847-1519 http://www.pca.state.mn.us
Regional Board of Soil and Water Resources Office	520 Lafayette Road North, St Paul, MN 55155 (651) 297-2906 http://www.bwsr.state.mn.us