Big Swan Lake 77-0023-00 TODD COUNTY

Lake Water Quality

Summary

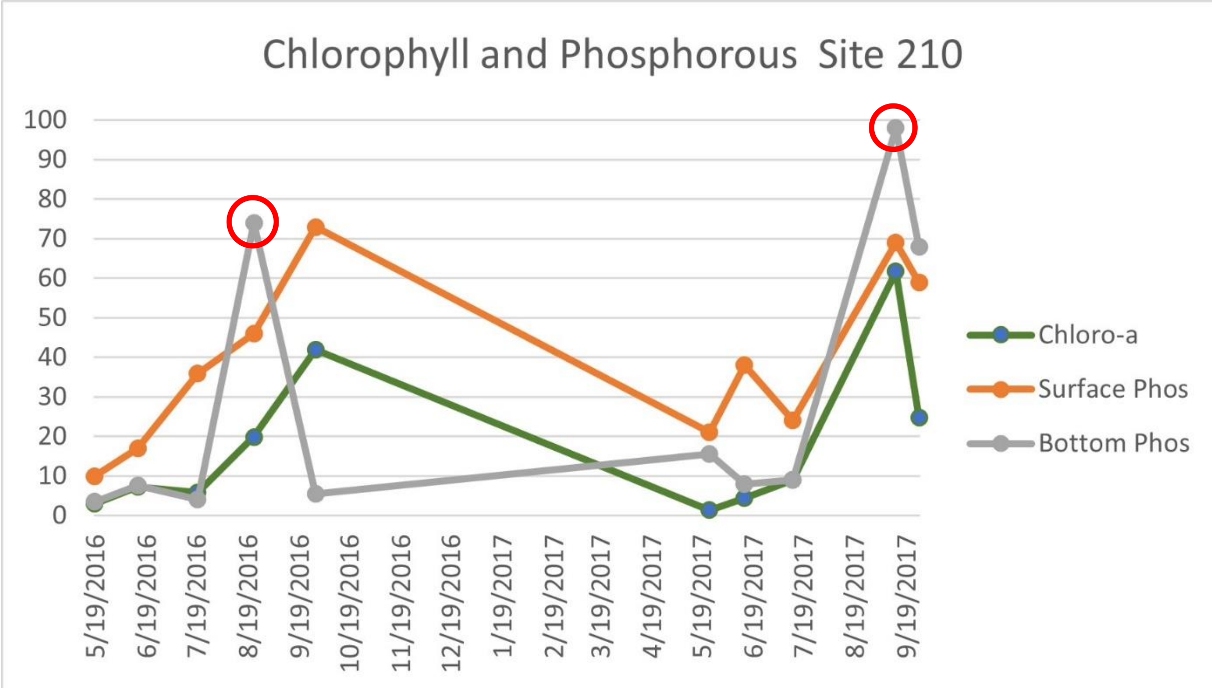
Big Swan Lake is located 9 miles southeast of Long Prairie, MN in Todd County. It is a long lake covering 887 acres (Table 1).

Big Swan Lake has four inlets and one outlet, which classify it as a drainage lake. It is the headwaters of the Swan River. Water enters Big Swan Lake from Long Lake to the East, Lady Lake to the south, and from origin streams to the west. The Swan River exits Big Swan Lake to the north and joins up with the Mississippi River to the east, just south of Little Falls.

Water quality data have been collected on Big Swan Lake since 1980 (Tables 2 & 3). These data show that the lake is eutrophic (TSI = 56) with moderate levels of algae at all times and occasional nuisance algae blooms. Eutrophic lakes have bountiful plant growth and Big Swan Lake is representative of this characteristic. In May and June algae and nutrient levels are low in the lake and water quality is good. From early July to mid September algae levels are high and sometimes levels get very high, impacting recreation and aesthetic enjoyment. This boost in mid-late summer algae is caused by an excess of plant available nutrients in the lake. Big Swan Lake has been listed as Impaired by the State of Minnesota and a clean up plan called a Total Maximum Daily Load (TMDL) has been developed that outlines steps that could lead to improvements in lake water quality.

Priority Impact to Big Swan Lake

The priority impact to Big Swan Lake appears to be Internal Loading. Spikes in algae production are generally preceded by or concurrent with high levels of nutrients release from the lake bottom. Nutrients are released from the lake bottom when excess plant and algae production in the lake depletes the oxygen content of the water allowing normal nutrient storage processes to reverse. This internal load is released in a plant available form and immediately affects the observed levels of plant and algae growth. Sampling of the deep lake water, surface lake water, and algae levels in 2017 and 2018 showed a pattern where high nutrient levels in the deep waters preceded or coincided with high algae and nutrient levels in the surface waters. When internal nutrient release is low the observed clarity is good and algal production is low.



Spikes in Plant Available Nutrients, Surface Phosphorous is partially plant available.

Historical phosphorus loading from intensive land uses has contributed to the buildup of legacy nutrients in the soils, wetlands, and lake bottom sediments. This phosphorus is still affecting the lake's water quality. Internal loading can be a hard problem to fix. The first thing to do is to reduce current phosphorus inputs, which the Big Swan Lake Improvement District has likely started doing due to their many improvement projects around the lake in the past few years. A treatment that can be looked into for internal loading is Alum treatment. This treatment only works in specific conditions and is more of a middle-term treatment than a long-term treatment. To read more about Alum treatment, visit: http://dnr.wi.gov/lakes/publications/documents/alum_brochure.pdf.

Nutrient Sources to Big Swan Lake

Stream and runoff monitoring around the lake indicates nutrient loading to the lake is occurring. This runoff occurs primarily during spring snow melt and summer storm events. This nutrient loading is **not** sufficient to be responsible for the observed water quality conditions. Much of the nutrient loading observed in samples taken around the lake is not in a plant available form and does not immediately effect observed water quality conditions but rather builds up over time and gradually changes observed conditions. It is possible that additional nutrient sources occur between the Schwanke Creek sampling point and the lake. The most likely source would be nutrients released from a wetland saturated with legacy pollution. Historical data and local input strongly suggest that the primary source of loading is from agricultural and feedlot practices due to the high E.coli levels (Figure 16). A 2014 county study shows that septic systems do not seem to be a major phosphorus source to the lake (page 22).

The State of Minnesota TMDL plan projects that the balance on nutrient sources to the lake is:

Nutrient Source Area	Annual Nutrient Load Pounds	State Plan Reductions	RMB Proposed Reductions
From Trace Lake	128	55%	5%
From Long Lake	1868	52%	5%
From Direct Runoff, Schwanke, and Van Heel Creeks	4083	45%	5%
Recycling of nutrients from the lake bottom	3886	8%	75%
Septic Systems	24	100%	100%

The proposed nutrient reductions in the State TMDL Plan are: 3214 lbs
To achieve this goal the State proposes over one hundred private land conservation projects totaling around $5,000,000 in project costs.

The proposed nutrient reductions in the RMB Restoration Plan are: 3242 lbs
To achieve this goal RMB proposes several dozen private land conservation projects and one In-Lake Treatment totaling around $2,000,000 in project costs.

Comparison of Proposed Actions

Plan	State of Minnesota Plan TMDL	Big Swan LID & RMB Plan
Action	Eliminate 50% of nutrient loading from the watershed.	Eliminate 75% of the internal loading. Eliminate 5% of watershed runoff.
Scale	One hundred private land projects or more.	One In Lake project and several dozen private land projects.
Cost	Around $5,000,000	Around $2,000,000
Funding Source	Multiple Clean Water Legacy Grants, USDA, Landowners, other programs	Two Clean Water Legacy Grants
Pollution Reduction	3,214 pounds	3,242 pounds

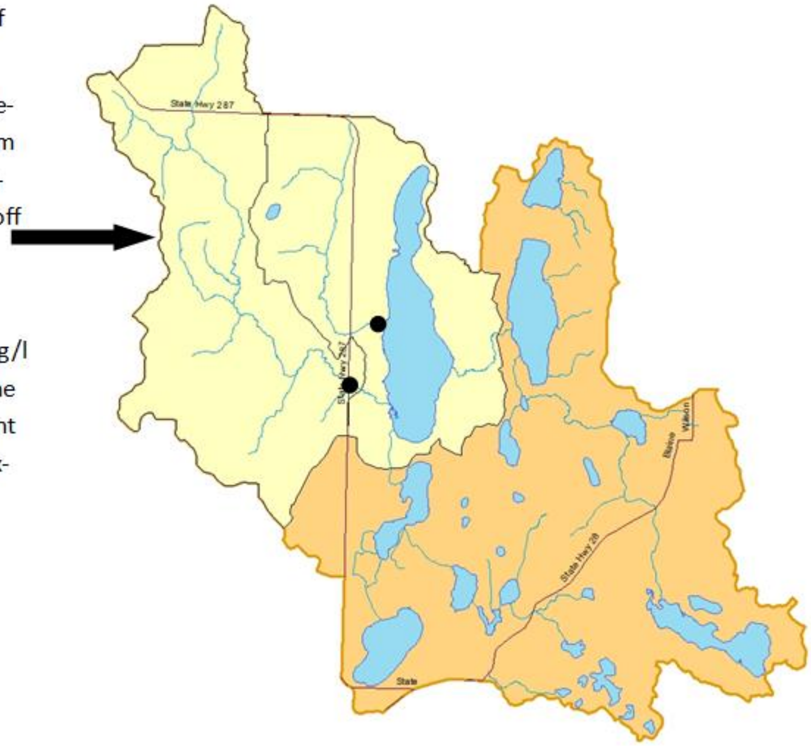
Sub-Watershed Nutrient Source Maps

Big Swan Direct Drainage

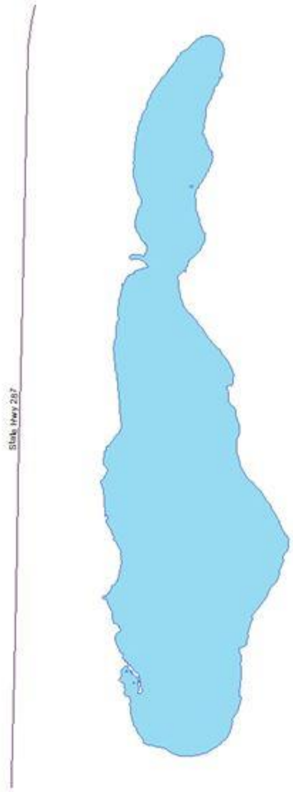
10154 Acres

MPCA estimates this area is the source of 4038 lbs of nutrient loading annually.

The Big Swan Lake TMDL calls for a 52% reduction in runoff and nutrient loading from this area. This would primarily be accomplished through cropland and pasture runoff reductions.



Stream Inlet Average Phosphorous is 102 ug/l and 151 ug/l. These observations are in the medium to medium-high range for nutrient levels and are not outside the range of expected levels for this area.

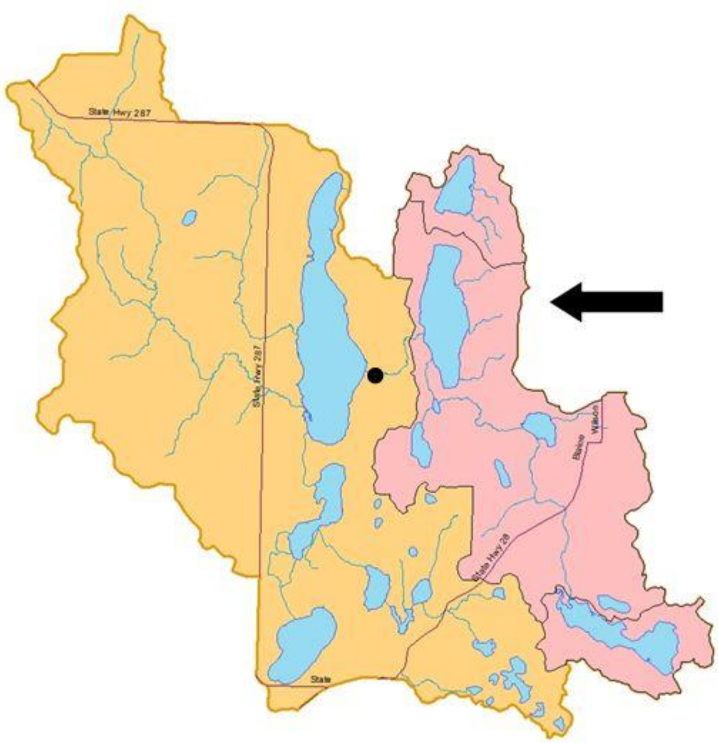


Internal Loading is a significant source of nutrients to Big Swan Lake. When oxygen levels are low near the lake bottom previously stored phosphorous can be released back into the water column. Nutrients released through internal loading are in a plant available form and contribute directly to observed nuisance plant and algae growth. Most nutrients delivered by stream flow and other sources is sediment or organic matter bound and is not plant available.

MPCA estimates, by the size of the gap in their model, that internal loading is the second biggest source of nutrients to Big Swan Lake. The estimated annual load is **3886 lbs** of phosphorous. This estimate is well reflected in the lake water samples taken near the lake bottom where phosphorous concentration regularly exceed the maximum observed surface level of 100 ug/l and occasionally approach 1000 ug/l.

The Big Swan TMDL calls for an 8% internal loading reduction which is an interesting reduction falling between do nothing (0% reduction) and an Alum treatment which would likely result in a greater than 50% reduction.

An alum treatment to reduce internal loading by around 50% would achieve 2/3rds of MPCA's entire TMDL planned nutrient reductions for Big Swan Lake. By targeting internal loading the phosphorous eliminated is in the plant available form and algae growth would be directly impacted.



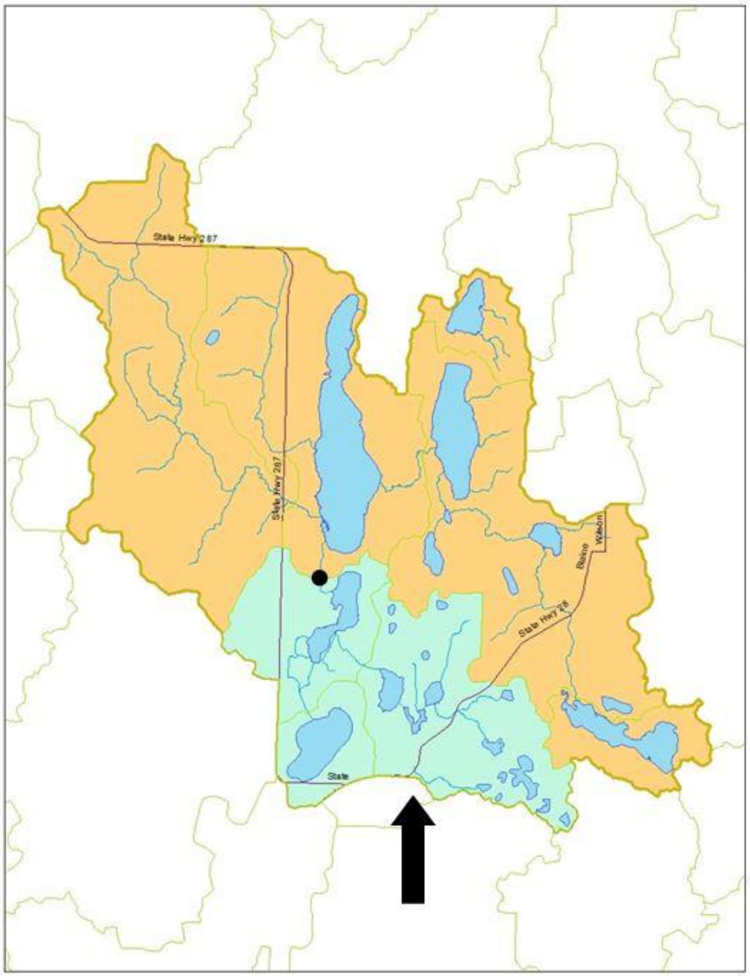
Long Lake Area

6839 acres

MPCA estimates loading from this area is 1868 lbs of nutrient annually.

The Big Swan TMDL calls for a 52% reduction in nutrients and runoff from this area. With the significant filtration already provided by Long Lake this level of nutrient reduction will be difficult to achieve.

The Stream Phosphorous Average is 65 ug/l which is fairly low and indicates currently there is a low level of nutrient loading from the Long Lake Area.



Trace & Lady Lake Watershed

5265 acres

MPCA estimates 128 lbs of nutrient loading annually.

The Big Swan TMDL calls for a 55% reduction in nutrient export from this watershed. To achieve this Trace Lake would be restored through a combination of reducing runoff by 50% (41% of overall reduction), improvements at the Grey Eagle Wastewater Plant reducing the output by 50% (39% of overall reduction), and an internal load reduction of 40% (20% of overall reduction).

Stream Phosphorous Average at sampling point shown below Lady Lake is 62 ug/l

Priority Management Actions

The management focus for Big Swan Lake should be to restore the lake's water quality by eliminating the majority of the internal loading and improving conditions within the lakeshed (direct drainage area). Improving conditions in the lakeshed can be done by partnering with farmers in the lakeshed to implement conservation farming practices, increase shoreline buffers, stream buffers, grassed waterways, retention ponds, restore wetlands, or place priority parcels into land retirement programs to decrease the impacts of agriculture.

Reducing nutrient loading sufficient to restore the water quality of Big Swan Lake would require a 50% reduction in runoff and pollutants from the watershed which is mainly agricultural land. This would require well over one hundred individual conservation practices and several million dollars expended on runoff reduction. Alternatively, the lake association could pursue a grant fund Alum treatment of the lake. This should result in a nutrient reduction equivalent to the proposed agricultural land practices but shifts the plan from over one hundred projects on private land to one project in a public water.

In addition, efforts should be focused on managing and/or decreasing the impact caused by additional development, including second tier development, and impervious surface area. Project ideas include enforcing county shoreline ordinances, smart development, shoreline restoration, rain gardens, and septic system maintenance.

Big Swan Lake has an organized association and Lake Improvement District that is involved in activities such as water quality monitoring, lake protection and education.

Lake Location and Characteristics

Table 1. Big Swan Lake location and key physical characteristics.

Location Data		Physical Characteristics	
MN Lake ID:	77-0023-00	Surface area (acres):	887
County:	Todd	Littoral area (acres):	383
Ecoregion:	Central Hardwood Forest	% Littoral area:	43%
Major Drainage Basin:	Upper Mississippi	Max depth (ft), (m):	45
Latitude/Longitude:	45.879, -94.749	Inlets:	4
Invasive Species:	Curly-leaf pondweed	Outlets:	1
		Public Accesses:	1

Table 2. Availability of primary data types for Big Swan Lake.

Data Availability	
Transparency data	1992-1993, 1995, 1997-2005, 2007-2021
Chemical data	1980, 1995, 2006-2009, 2015, 2017-2018
Inlet/Outlet data	2008-2009
Recommendations	**For recommendations refer to page 23.**

Lake Map

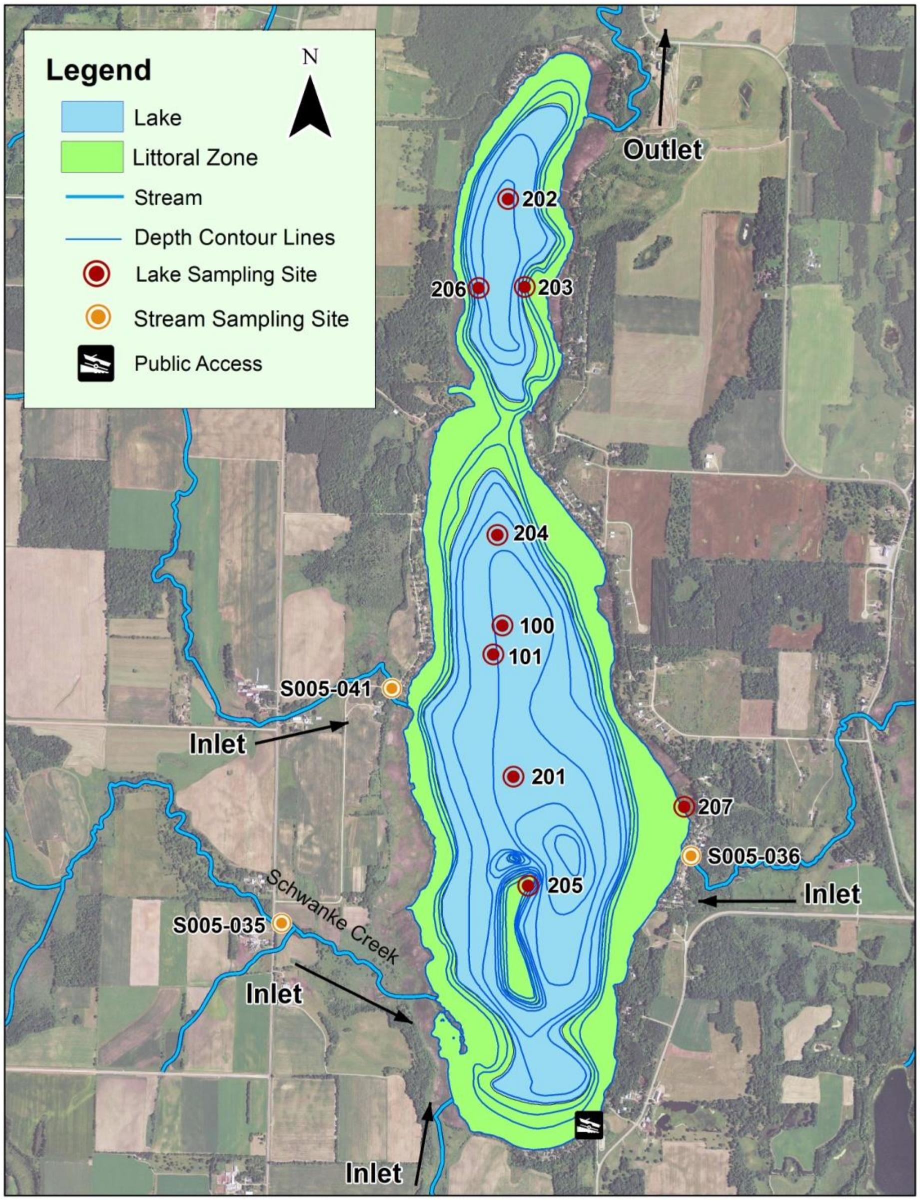


Figure 1. Map of Big Swan Lake with 2010 aerial imagery and illustrations of lake depth contour lines, sample site locations, inlets and outlets, and public access points. The light green areas in the lake illustrate the littoral zone, where the sunlight can usually reach the lake bottom, allowing aquatic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

Table 3. Monitoring programs and associated monitoring sites. Monitoring programs include the Citizen Lake Monitoring Program (CLMP), Minnesota Pollution Control Agency (MPCA), Swan River Headwaters Lakes Monitoring (SRHLM), Clean Water Condition Monitoring (CWCM – MPCA), and RMB Environmental Laboratories Lakes Program (RMBEL).

Lake Site	Depth (ft)	Monitoring Programs
100/101	30	MPCA: 1980, 1995
201*primary	30	CLMP: 1992-1993, 1995, 1997-2005, 2007-2021; RMBEL: 2007, 2015; SRHLM: 2008
202	25	CLMP: 1992, 2007-2008, 2010-2021; SRHLM: 2008
203	20	CLMP: 2001-2008
204	30	CLMP: 2004-2007; RMBEL: 2006-2007
205	30	CLMP: 2009-2010, 2012-2013
206	20	CLMP: 2009

210	20	CWCM: 2017-2018

Average Water Quality Statistics

The information below describes available chemical data for Big Swan Lake through 2015 (Table 4). Data for total phosphorus, chlorophyll *a*, and Secchi depth are from the primary site 201.

Minnesota is divided into 7 ecoregions based on land use, vegetation, precipitation and geology. The MPCA has developed a way to determine the "average range" of water quality expected for lakes in each ecoregion. For more information on ecoregions and expected water quality ranges, see page 11. Big Swan Lake is in the Central Hardwood Forest 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)	43	23 – 50	> 40	Some results are within the expected range for the Central Hardwood Forest Ecoregion. The algae levels are above the normal range. Big Swan Lake is over the impaired waters standard for algae and nutrients.
[3]Chlorophyll *a* (ug/L)	23	5 – 22	> 14	
Chlorophyll *a* max (ug/L)	64	7 – 37		
Secchi depth (ft)	7.5	4.9 - 10.5	< 7	
Dissolved oxygen	*See page 8*			Dissolved oxygen depth profiles show that the lake mixes periodically in summer.
Total Kjeldahl Nitrogen (mg/L)	0.99	< 0.60 - 1.2		Indicates insufficient nitrogen to support summer nitrogen-induced algae blooms.
Alkalinity (mg/L)	166	75 - 150		Indicates a low sensitivity to acid rain and a good buffering capacity.
Color (Pt-Co Units)	13.75	10 - 20		Indicates clear water with little to no tannins (brown stain).
pH	8.4	8.6 - 8.8		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)	10	4 - 10		At the upper limit for the ecoregion, which may be set too low. Similar to other lakes in the area
Total Suspended Solids (mg/L)	5	2 - 6		Near the upper range for the ecoregion. Indicates suspended solids, likely dead organic matter, is common.
Specific Conductance (umhos/cm)	345	300 - 400		Within the expected range for the ecoregion.
TN:TP Ratio	23:1	25:1 - 35:1		Below the expected range for the ecoregion, and shows the

	lake has higher than expected levels of phosphorous relative to nitrogen. This indicates an excess of phosphorous accumulating in the lake.

[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	Site 202	Site 204	Site 210
Total Phosphorus Mean (ug/L):	**42.7**	**35.5**	**58.5**	**37.8**
Total Phosphorus Min:	17	16	24	10
Total Phosphorus Max:	110	91	105	73
Number of Observations:	22	10	11	11
Chlorophyll *a* Mean (ug/L):	**22.6**	**13.9**	**33.8**	**17.7**
Chlorophyll-a Min:	1	4	4	3
Chlorophyll-a Max:	64	55	85	62
Number of Observations:	22	10	11	11
Secchi Depth Mean (ft):	**7.5**	**8.2**	**7.7**	**8.5**
Secchi Depth Min:	2.0	3.0	1.5	2.9
Secchi Depth Max:	24.0	24.0	18	21.4
Number of Observations:	260	102	39	10

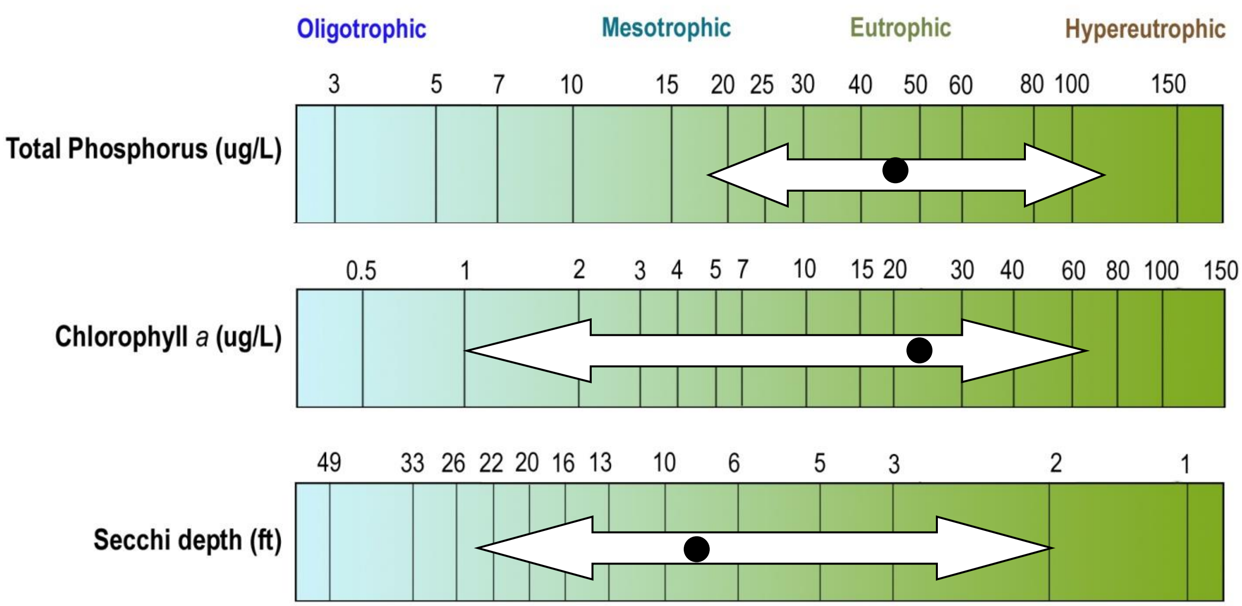


Figure 2. Big Swan Lake total phosphorus, chlorophyll a and transparency historical ranges. The arrow represents the range and the black dot represents the historical mean (Primary Site 201). Figure adapted after Moore and Thornton, [Ed.]. 1988. Lake and Reservoir Restoration Guidance Manual. (Doc. No.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

Transparency (Secchi Depth)

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

The annual mean transparency in Big Swan Lake ranges from 5 to 1o feet (Figure 3). For trend analysis, see page 10. Transparency monitoring should be continued monthly or biweekly at site 201 every year in order to track water quality changes.

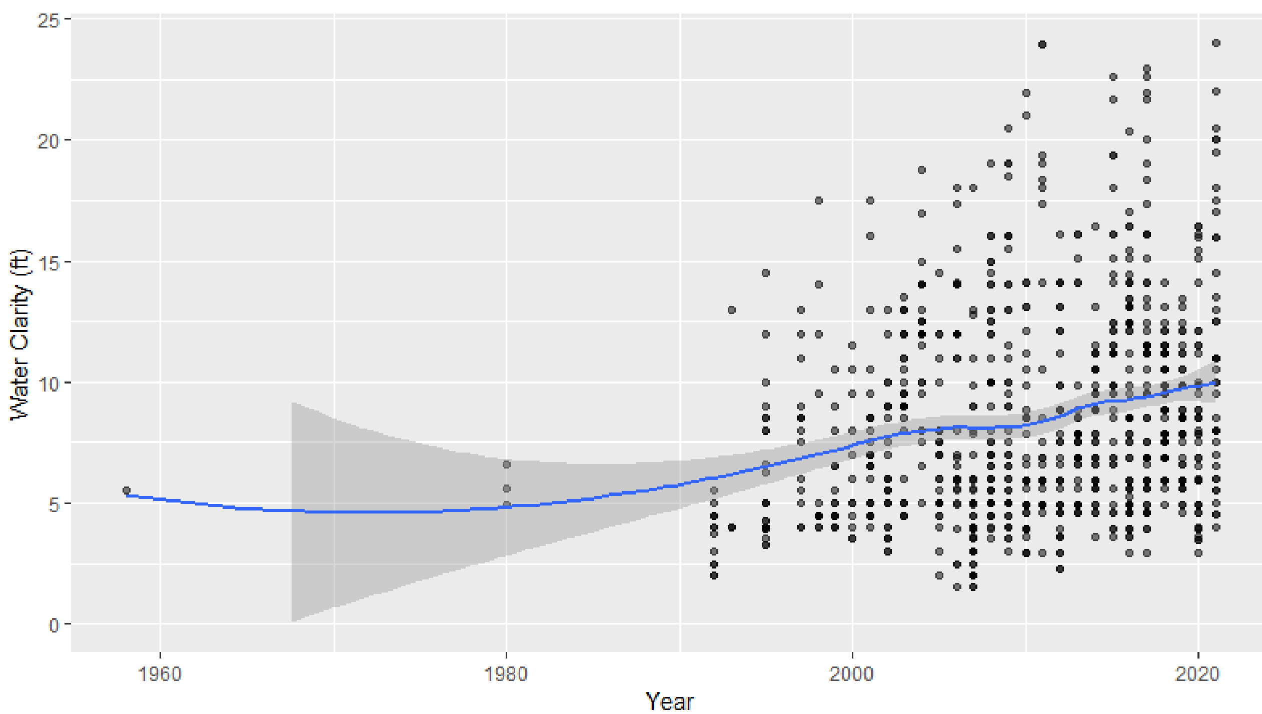


Figure 3. Annual mean transparency compared to long-term mean transparency at the primary site 201.

Big Swan Lake transparency ranges from 2 to 24 feet at the primary site (201). Figure 4 shows the seasonal transparency dynamics. The maximum Secchi reading is usually obtained in early summer. Big Swan Lake transparency is high in May and June, and then declines through August. The transparency then rebounds in October after fall turnover. 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.

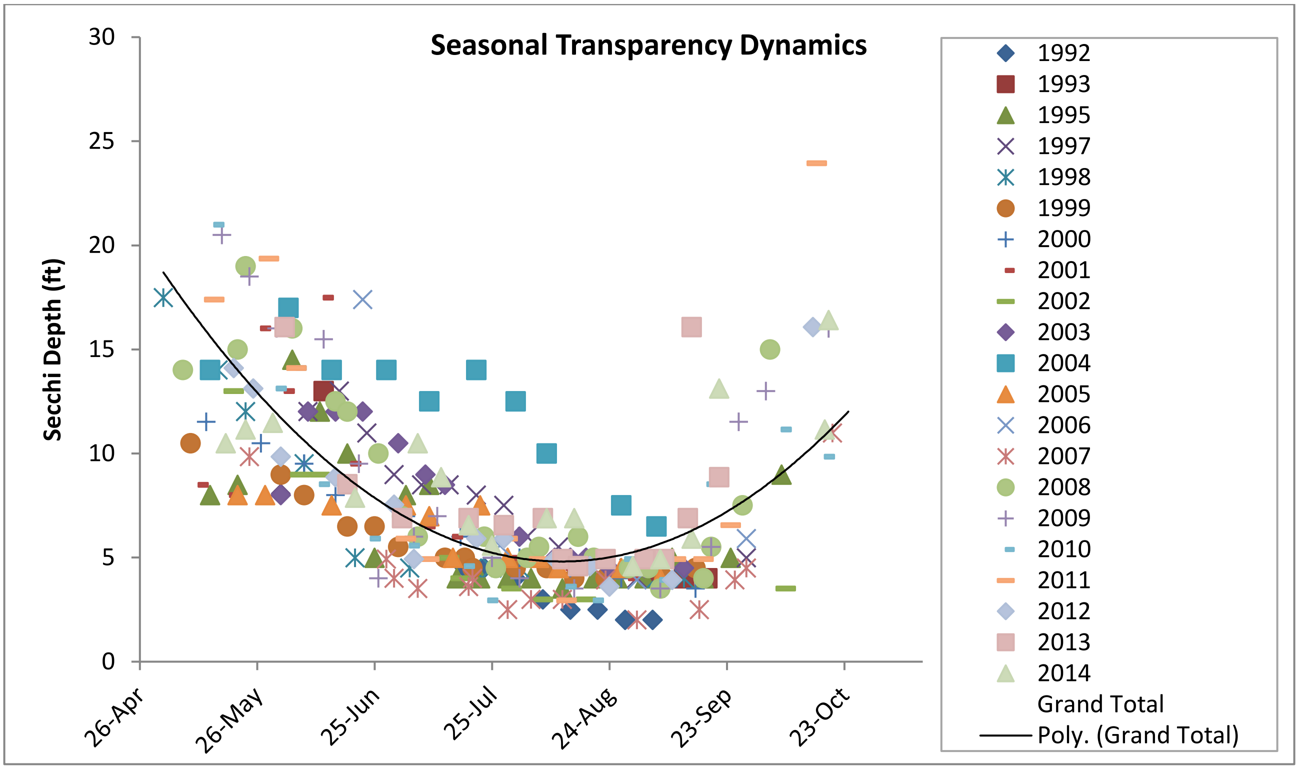


Figure 4. Seasonal transparency dynamics and year to year comparison (Primary Site 201). The black line represents the pattern in the data.

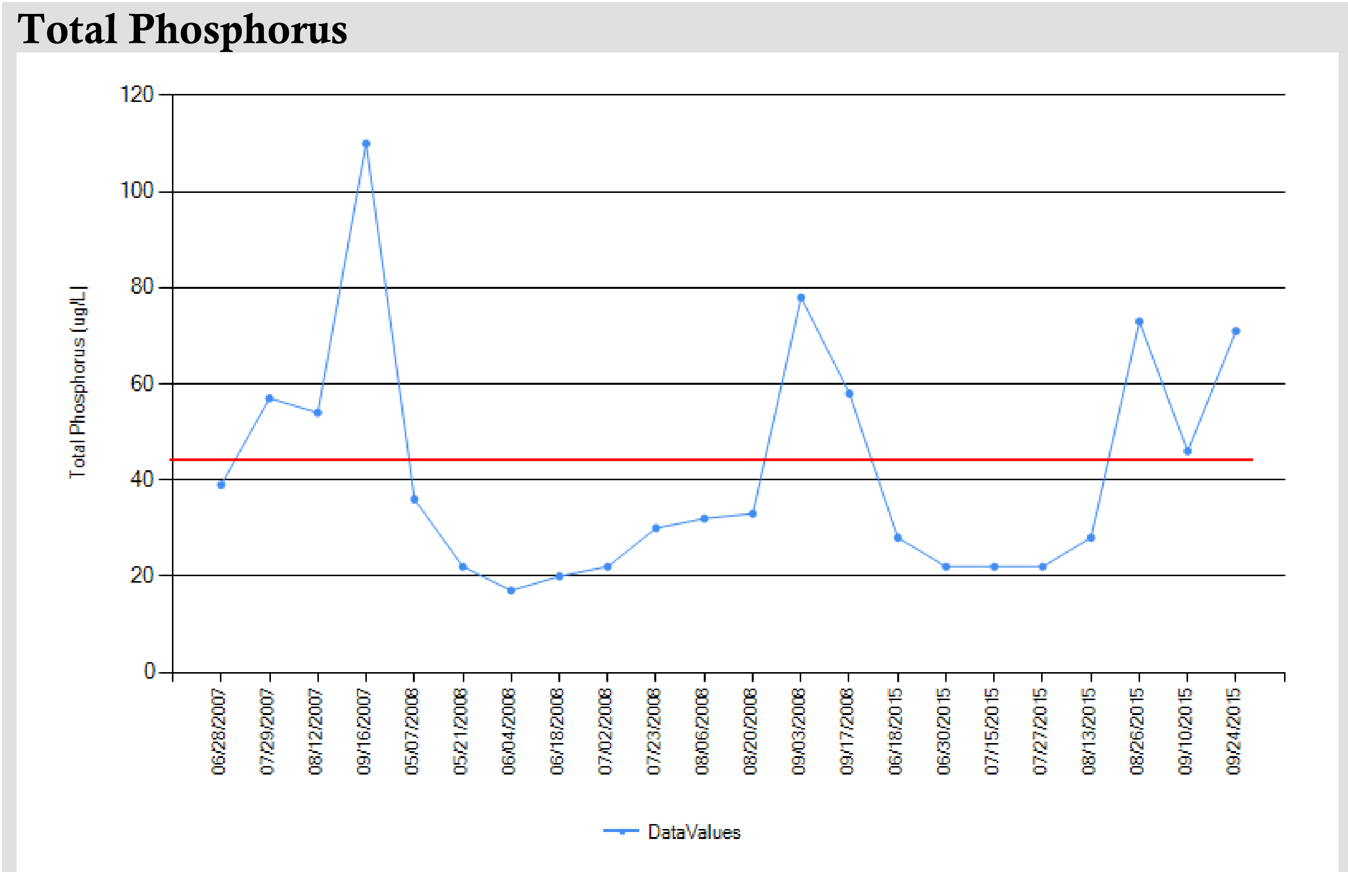
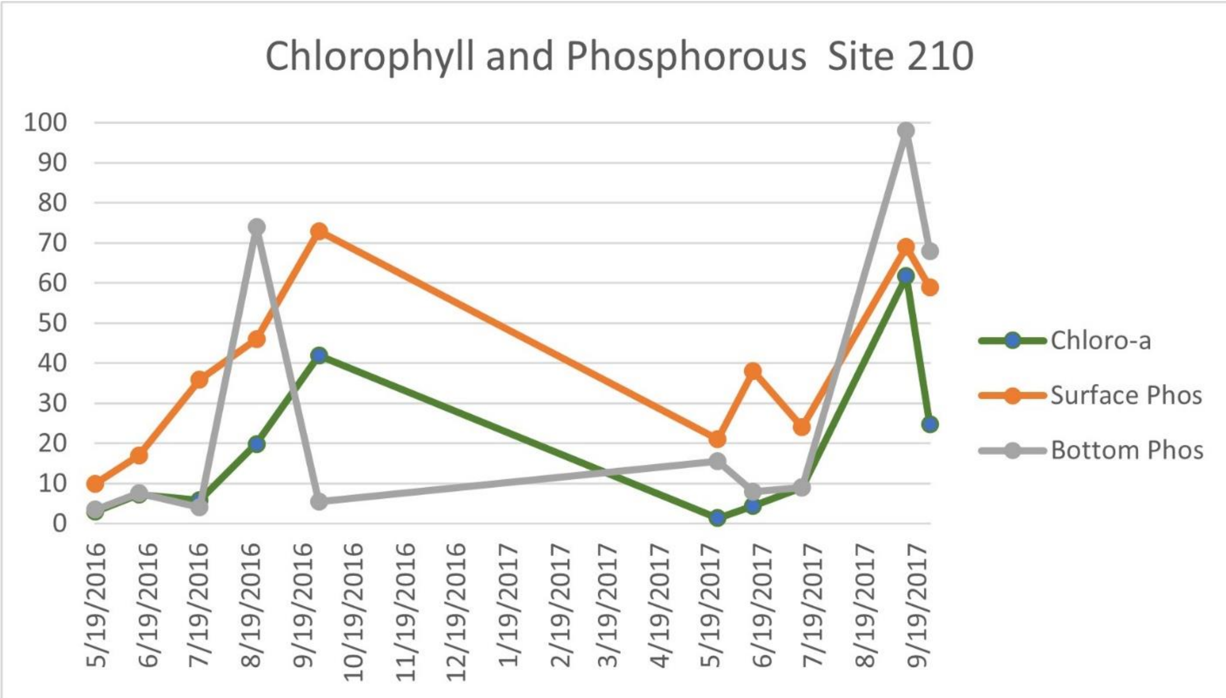


Figure 5. Historical total phosphorus concentrations (ug/L) for Big Swan Lake.

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

Total phosphorus was evaluated in Big Swan Lake in 1980, 1995, 2006-2015. The data show a strong pattern of relatively low phosphorus in June and high phosphorus in September. This pattern could be due to internal loading. Internal loading occurs in mid to late summer when the bottom of the lake doesn't have any oxygen present and a chemical reaction occurs that releases phosphorus out of the sediments and back into the water.

Hypolimnion (deep water) phosphorus samples from Big Swan Lake indicate high phosphorus levels (158-221 ug/L) at depths of 26-30 feet. These high nutrient levels in the deep waters are normally observed either preceding or coincident with high levels of algae. The graph below outlines the observations from 2017 and 2018 when intensive sampling was done to provide the information necessary to develop the Big Swan TMDL plan.



The majority of the data points for Big Swan Lake fall into the eutrophic range (Figure 7). Phosphorus should continue to be monitored at the primary site in the lake to track any future changes in water quality.

Chlorophyll *a*

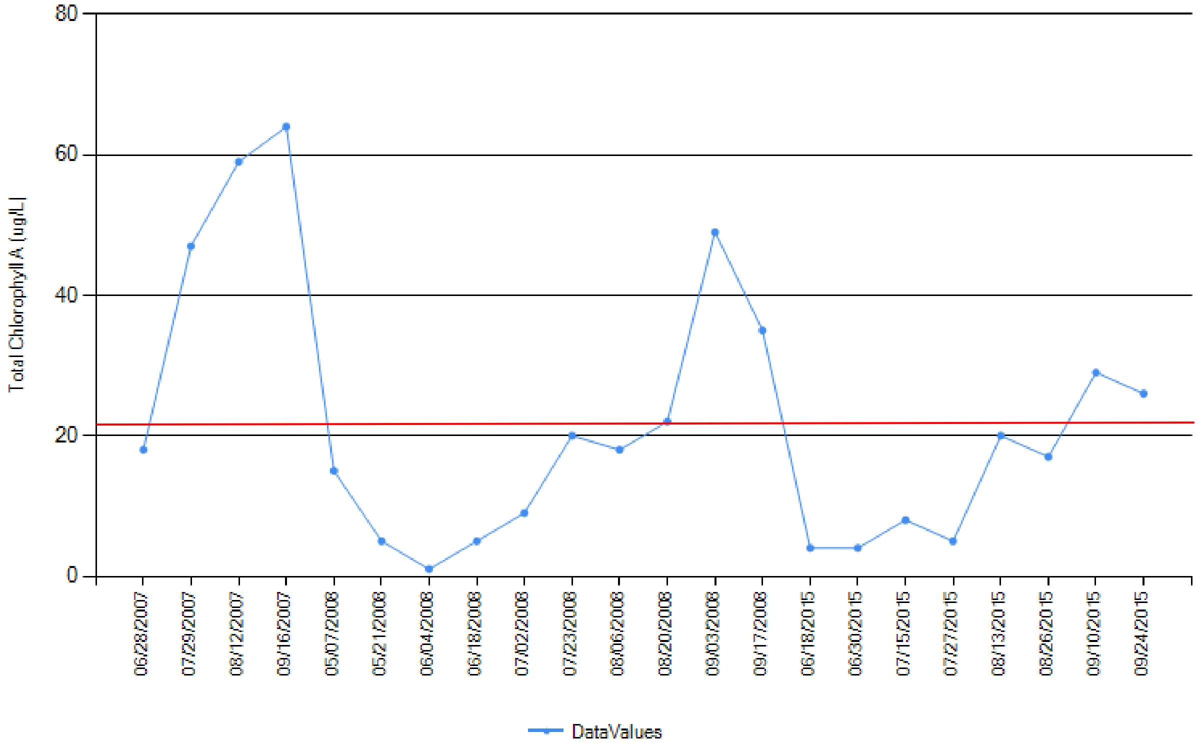


Figure 6. Chlorophyll *a* concentrations (ug/L) for Big Swan Lake.

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.

Chlorophyll *a* was evaluated in Big Swan Lake in 1980, 1995, 2006-2015 (Figure 8). Chlorophyll *a* concentrations went above the 20 ug/L nuisance level in all years monitored, indicating major algae blooms. This means that the high phosphorus is feeding the algae and causing algae blooms.

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. When the lake water near the lake bottom has low oxygen levels nutrients stored in the lake bottom are released in a plant available form. These nutrients can be mixed into the upper lake water causing significant algae and plant growth.

Big Swan Lake is a moderately shallow lake, with a maximum depth of approximately 45 feet. Dissolved oxygen profiles from data collected in 2006 and 2007 at site 201 and 202 show periodic stratification developing mid-summer (Figure 9). In a shallow lake, the water column never completely stratifies. Any windy day can mix up the water column causing phosphorus from the anoxic lake bottom to re-suspend into the water. This phenomenon is known as internal loading.

The dissolved oxygen levels in Big Swan Lake show that nutrient enriched water appears to be mixing into the entire lake by August. This will fluctuate yearly due to weather conditions and should be monitored into the future to determine if there is a nutrient loading and mixing pattern.

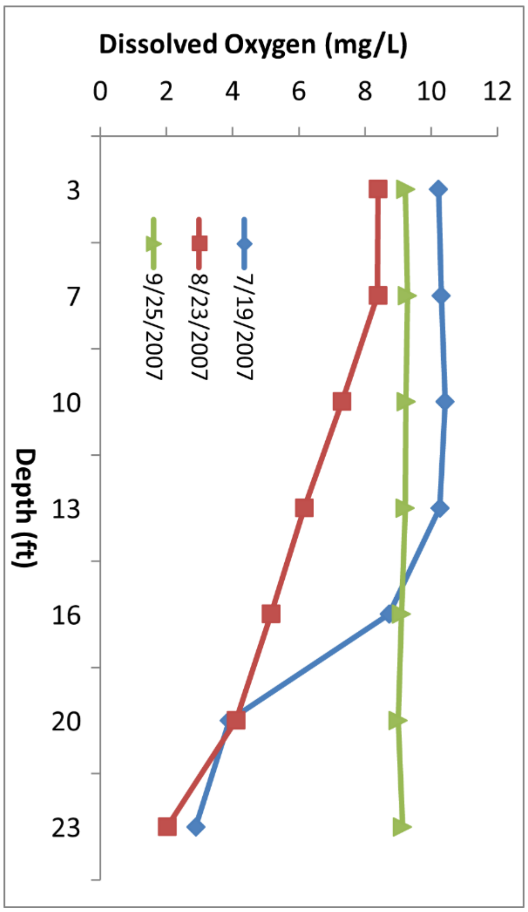


Figure 7. Dissolved oxygen profiles for Big Swan Lake.

Trophic State Index (TSI)

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

Phosphorus (nutrients), chlorophyll *a* (algae concentration) and Secchi depth (transparency) are related. As phosphorus increases, there is more food available for algae, resulting in increased algae concentrations. When algae 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 Big Swan Lake falls into the eutrophic range (Figure 10). The TSI for chlorophyll a is higher than the phosphorus and Secchi, indicating that there could be a loss of rooted vegetation and/or excess production of algae particles (Table 6).
Internal loading could also be fueling algae growth by releasing plant available nutrients into the lake water. The pattern transparency observations is indicative of internal loading with generally good observations in the spring and greatly reduced observations in mid to late summer.

Table 6. Trophic State Index for site 201.

Trophic State Index	Site 201
TSI Total Phosphorus	58
TSI Chlorophyll-a	63
TSI Secchi	48
TSI Mean	56
Trophic State:	Eutrophic

Numbers represent the mean TSI for each parameter.

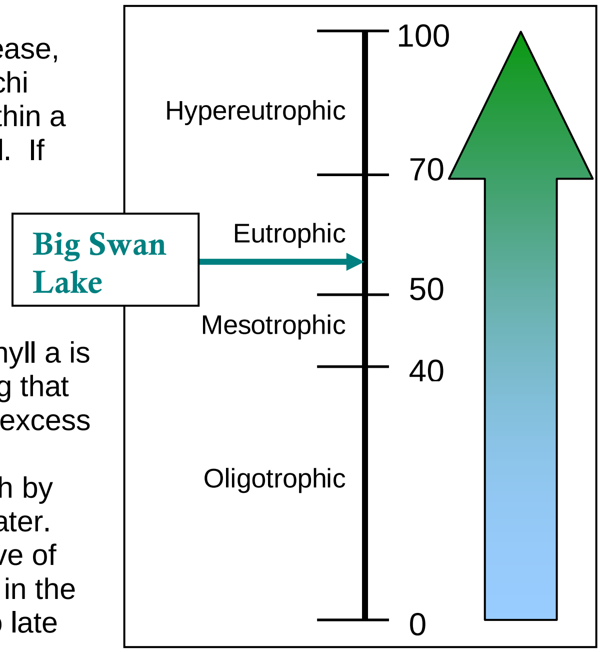


Figure 8. Trophic state index chart with corresponding trophic status.

Eutrophic lakes (TSI 50-70) are characterized by moderately clear water most of the summer. Eutrophic lakes commonly have algae and aquatic plant problems. These lakes are at risk of transitioning to warm water fisheries where bass and panfish dominate. They are aging past the period where they support good walleye populations. (Table 7).

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

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

>80	Algal scums, few aquatic plants	Rough fish (carp) dominate; summer fish kills possible

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

Trend Analysis

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

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

Table 8. Trend analysis for site 202.

Lake Site	Parameter	Date Range	Trend	Probability
201	Total Phosphorus	1980, 1995, 2006-2008, 2015	Insufficient data	-
201	Chlorophyll *a*	1980, 1995, 2006-2008, 2015	Insufficient data	-
201	Transparency	1992-1993, 1995, 1997-2005, 2007-2021	Improving	95%

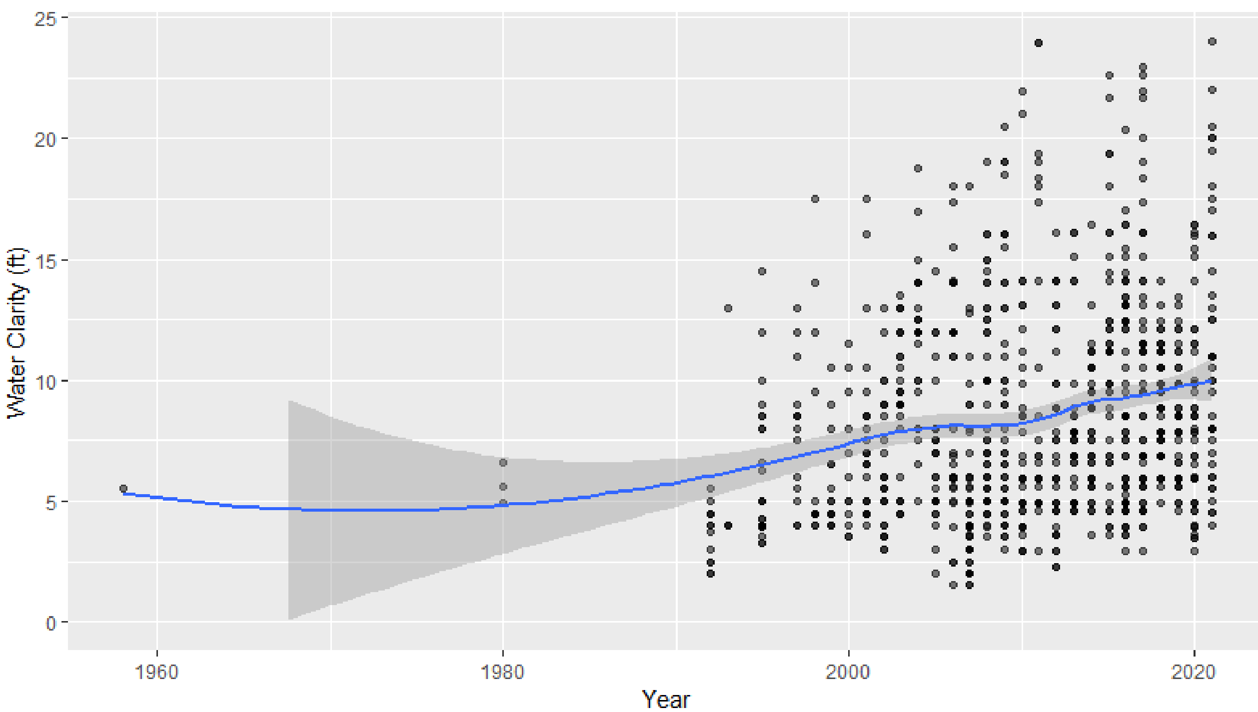


Figure 9. MPCA transparency graph with trend line.

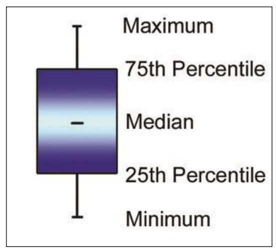
According to MPCA's analysis Big Swan Lake shows evidence of an improving transparency trend (Figure 11). According to the analysis performed by RMB there is an improving trend in mean annual transparency, maximum annual transparency, June transparency and mid-August transparency. Because all these different data types are showing the same trend, it is very robust. The annual minimum transparency has stayed steady in the 2 to 4 foot range indicating severe algae blooms in certain seasons. 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 10. Minnesota Ecoregions.

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



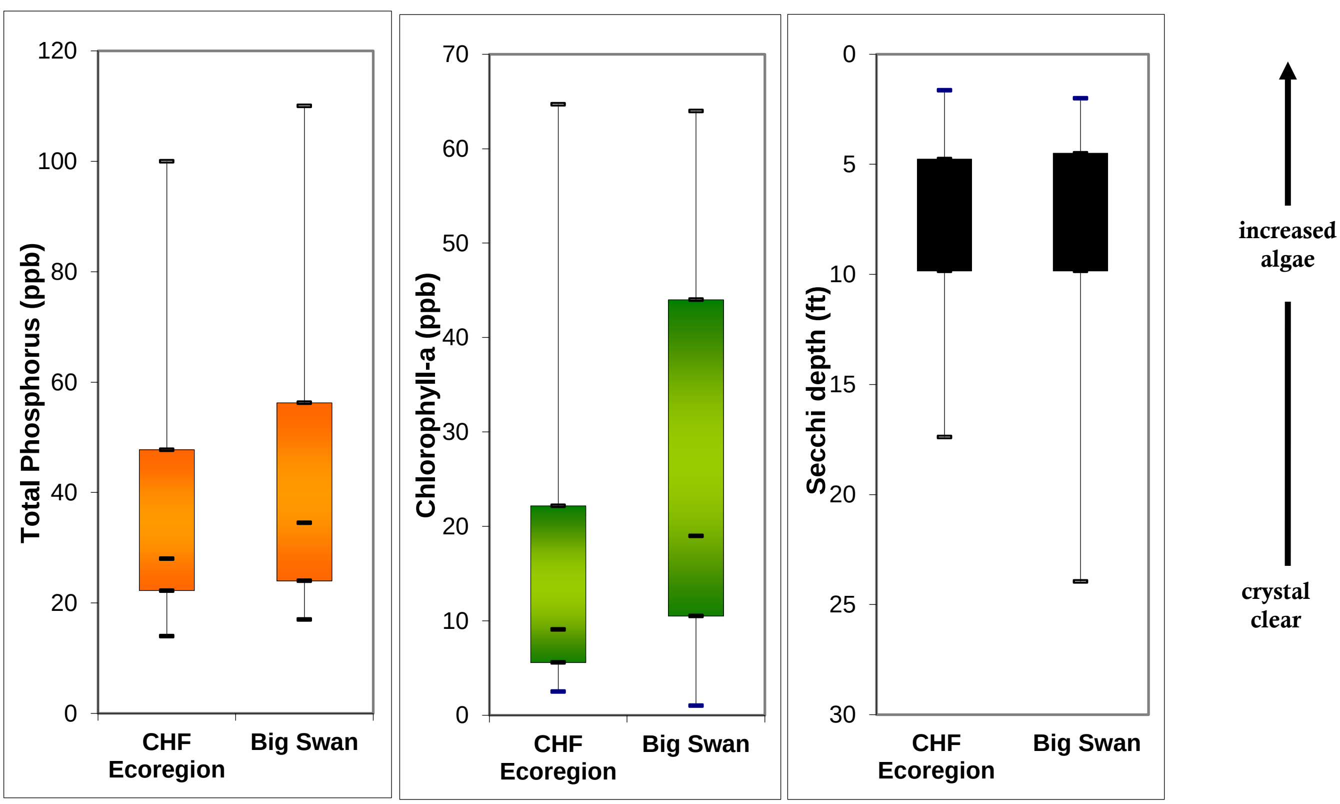


Figure 11. Big Swan Lake ranges compared to Central Hardwood Forest ranges. The Big Swan Lake total phosphorus and chlorophyll *a* ranges are from 14 data points collected in May-September of 1980, 1995, 2006-2008. The Big Swan Lake Secchi depth range is from 260 data points collected in May-September of 1992-1993, 1995, 1997-2005, 2007-2014.

Stream Monitoring

Big Swan Lake has four inlets and one outlet (Figure 14). Data was collected at these sites from 2008-2009 as a comprehensive water quality study by Todd SWCD and the Big Swan Lake Improvement District.

The total suspended solids and nitrogen levels were relatively low and not a concern. The phosphorus and *E.coli* were a concern on certain dates.

When total phosphorus is graphed with precipitation, it shows how loading occurs during large rain events, although not every rain event (Figure 15). The most loading occurred in late March of 2009 at all the inlet sites. The phosphorus could have come from the snow melt and/or exposed fields.

After March, the rest of 2009 showed very little loading, even during storm events. These sites should be monitored again in the future to see if any additional loading is occurring.

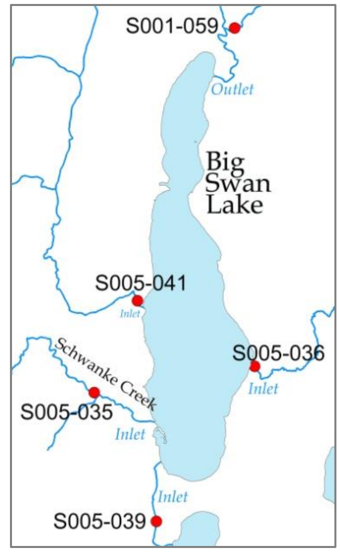


Figure 12. Map of stream monitoring sites around Big Swan Lake.

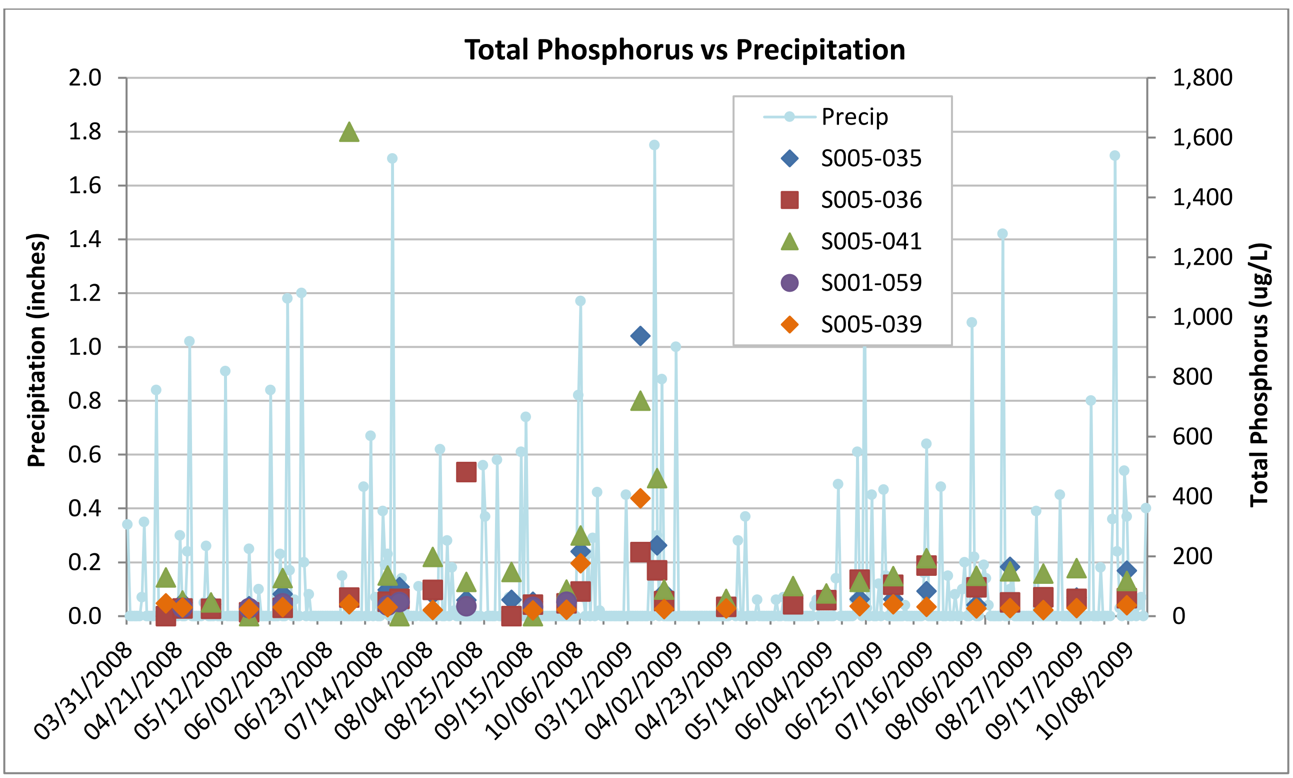


Figure 13. Total phosphorus results in Big Swan Lake streams graphed with precipitation, 2008-2009.

When *E.coli* is graphed with precipitation, it shows how loading occurs during large rain events, (Figure 16). This loading could come from exposed fields and feedlots. *E.coli* comes from warm-bodied mammals.

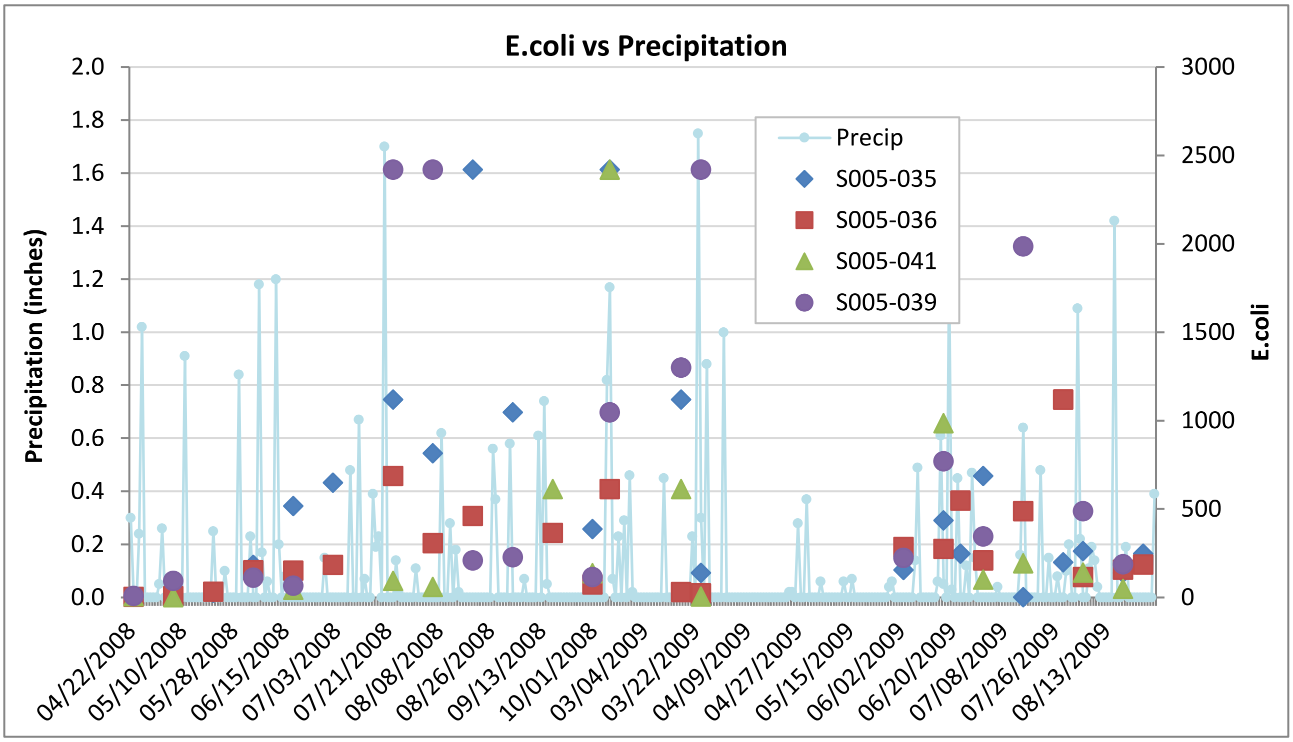


Figure 14. *E.coli* results in Big Swan Lake streams graphed with precipitation, 2008-2009.

The outlet of Big Swan Lake is listed as impaired by the MPCA for dissolved oxygen. This means that there is not enough oxygen for a healthy biological community in that area.

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 Mississippi River - Brainerd Major Watershed is one of the watersheds that make up the Upper Mississippi River Basin, which drains south to the Gulf of Mexico (Figure 17). This major watershed is made up of 128 minor watersheds. Big Swan Lake is located in minor watershed 10133 (Figure 18).

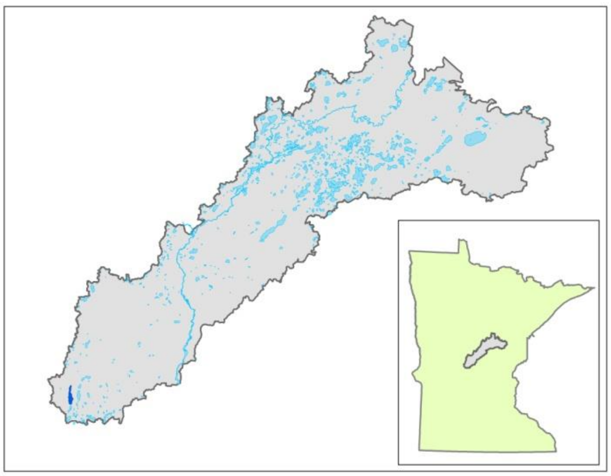


Figure 15. Mississippi – Brainerd Major Watershed.

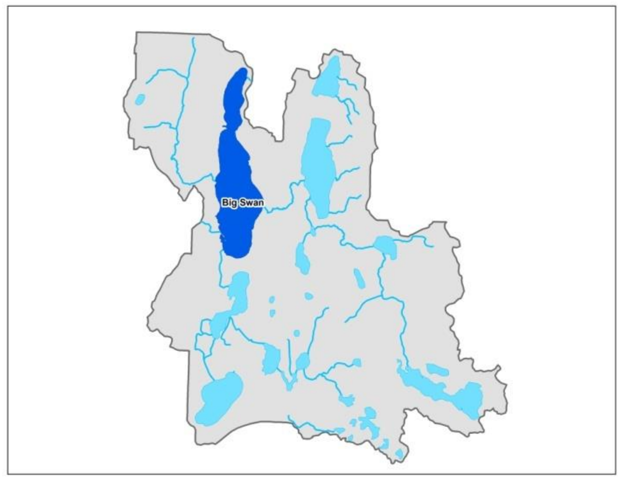


Figure 16. Big Swan Lake's minor watershed.

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. Big Swan Lake falls within lakeshed 1013300 (Figure 19). 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 Big Swan Lake 's watershed, containing all the lakesheds upstream of the Big Swan Lake

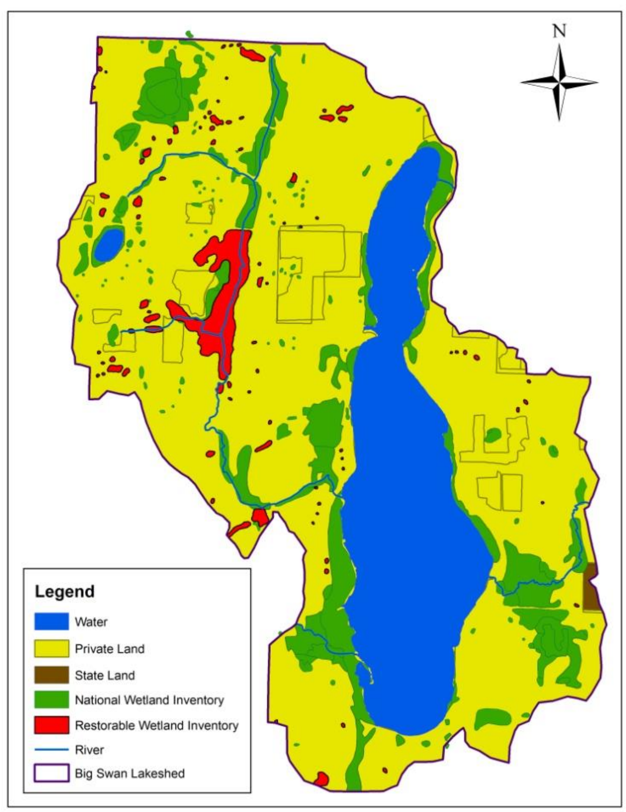


Figure 17. Big Swan Lake lakeshed (1013300) with land ownership, lakes, wetlands, and rivers illustrated.

lakeshed, see page 20. The data interpretation of the Big Swan Lake lakeshed includes only the immediate lakeshed as this area is the land surface that flows directly into Big Swan Lake.

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

KEY

- (dark oval) Possibly detrimental to the lake
- (medium oval) Warrants attention
- (light oval) Beneficial to the lake

Table 9. Big Swan Lake lakeshed vitals table.

Lakeshed Vitals		**Rating**
Lake Area (acres)	887	descriptive
Littoral Zone Area (acres)	383	descriptive
Lake Max Depth (feet)	45	descriptive
Lake Mean Depth (feet)	16.4	descriptive
Water Residence Time	NA	NA
Miles of Stream	10.1	descriptive
Inlets	4	(Warrants attention)
Outlets	1	(Warrants attention)
Major Watershed	10 - Mississippi River - Brainerd	descriptive
Minor Watershed	10133 - Big Swan Lake	descriptive
Lakeshed	1013300	descriptive
Ecoregion	Central Hardwood Forest	descriptive
Total Lakeshed to Lake Area Ratio (total lakeshed includes lake area)	4:1	(Beneficial to the lake)
Standard Watershed to Lake Basin Ratio (standard watershed includes lake areas)	21:1	(Beneficial to the lake)
Wetland Coverage (NWI)	13.84%	(Beneficial to the lake)
Aquatic Invasive Species	Curly-leaf Pondweed	(Possibly detrimental to the lake)
Public Drainage Ditches	0	(Beneficial to the lake)
Public Lake Accesses	1	(Warrants attention)
Miles of Shoreline	8.1	descriptive
Shoreline Development Index	1.9	(Possibly detrimental to the lake)
Public Land to Private Land Ratio	1:3	(Warrants attention)
Development Classification	Recreational Development	(Warrants attention)
Miles of Road	11.8	descriptive
Municipalities in lakeshed	0	(Beneficial to the lake)
Forestry Practices	None	(Beneficial to the lake)
Feedlots	6	(Possibly detrimental to the lake)
Sewage Management	Individual Waste Treatment Systems	(Warrants attention)
Lake Management Plan	Healthy Lakes and Rivers 2003	(Beneficial to the lake)
Lake Vegetation Survey/Plan	07/13/2004	(Beneficial to the lake)

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.

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 allowing nutrients and sediment to move towards the lowest point, typically the lake. 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 20). Even though the entire lakeshed has the potential to drain towards the lake, the land use occurring directly around the lakeshore will most likely have the greatest impact to the lake.

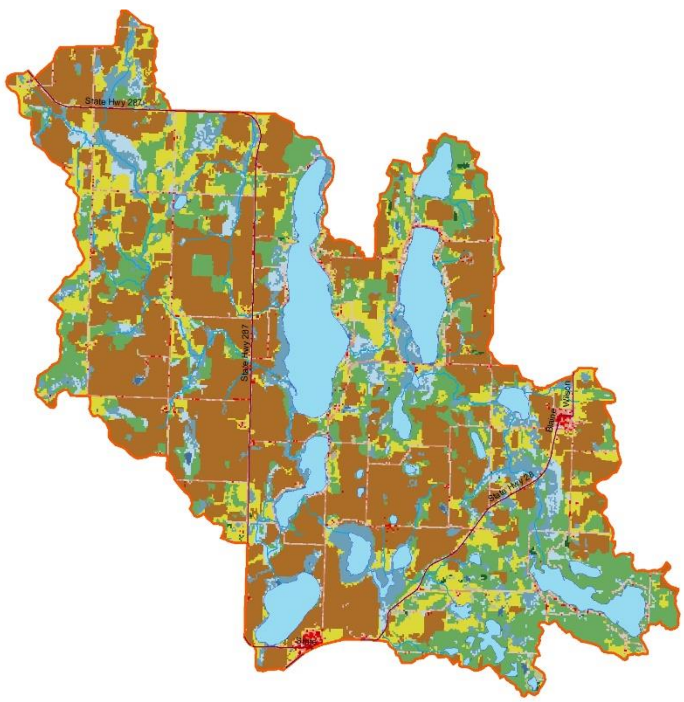


Figure 18. Big Swan lakeshed (1013300) 2019 land cover (NLCD 2019).

Developed land cover 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. Big Swan Lake has 5% 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 six registered animal feedlots in the Big Swan Lake lakeshed (Table 9). The second highest agricultural runoff generally comes from row crops. There are some row crops all around Big Swan Lake, although it looks like there is some forested buffer and wetlands between the row crops and the lake (Figure 20). This buffer is important for filtering the runoff and helping it infiltrate into the ground. 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, 42.7% of the Big Swan Lake lakeshed is classified in low nutrient runoff land uses.

Table 10. Land cover in the Big Swan lakeshed.

Runoff Potential	Category	Specific Landcover	Acres	Percent
High	Agriculture	**Row Crop**	995.02	21.42%
High	Urban	**Developed**	239.67	5.16%
High	Agriculture	**Close Seeded**	726.62	15.64%
High	Agriculture	**Small Grain**	18.34	0.39%
High	Agriculture	**Fallow**	3.77	0.08%
Low	Forest	**Forest**	761.89	16.40%
Low	Water	**Water**	934.59	20.12%
Low	Agriculture	**Pasture/Grassland**	488.40	10.52%
Low	Wetlands	**Wetlands**	474.98	10.23%
Low	Agriculture	**Meadow**	0.00	0.00%
Low	Grass/Shrub	**Brush**	1.48	0.04%
Total area with low runoff potential			2,661.34	42.7%
Total area with high runoff potential			1,983.42	57.3%
Total			4,644.76	100.00%

The University of Minnesota has online records of land cover statistics from years 1990 and 2000 (http://land.umn.edu). Although this data is quite old, it is the only data set that is comparable over that decade's time. In addition, a lot of lake development occurred from 1990 to 2000 when the US economy was booming. Table 11 describes Big Swan Lake'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. Big Swan Lake development area and % change from 1990-2000 (Data Source: UMN Landsat).

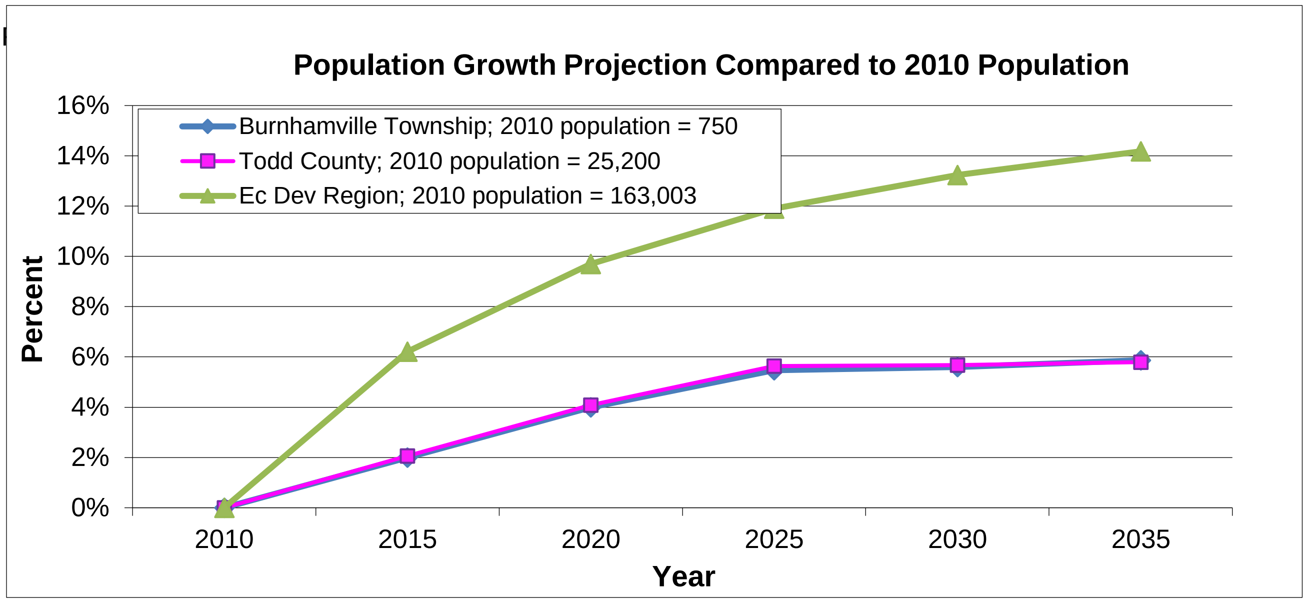
Category	1990 Acres	Percent	2000 Acres	Percent	Change 1990 to 2000
Total Impervious Area	26	0.69	56	1.47	Increase of 30 acres
Urban Acreage	136	2.93	288	6.2	Increase of 152 acres

Demographics

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

The Minnesota Department of Administration Geographic and Demographic Analysis Division extrapolated future population in 5-year increments out to 2035. Compared to Todd County as a whole, Burnhamville Township has a similar growth projection (Figure 22).
(source: http://www.demography.state.mn.us)

Figure 19. Big Swan Lake is located in Burnhamville Township.



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 Big Swan Lake's lakeshed is classified as agriculture (Table 12). This land can be the focus of 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 (76.81%)					22.94%	Public (0.25%)		
	Developed	Agriculture	Forested Uplands	Other	Wetlands	Open Water	County	State	Federal
Land Use (%)	5.2	63.2	8.5	0.9	2.9	19.3	0	100	0
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	10.9 – 363.2	762.8 – 2,640.4	35.5		12.0		0	1.03	0
Description	1st and 2nd Tier Development	Cropland Pasture CRP	Forest, Timber, Undeveloped	Open, pasture, grassland, shrubland	Protected				
Ideas for protection and restoration	Shoreline restoration Rain Gardens Conservation Easements	Restore wetlands; CRP Stream buffers Grassed waterways	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.

Big Swan Lake's lakeshed is classified with having 28% of the watershed protected and 68% of the watershed disturbed (Figure 23). Therefore, this lakeshed should have a partial restoration focus. Goals for the lake should be to limit any increase in disturbed land use. (Figure 24).

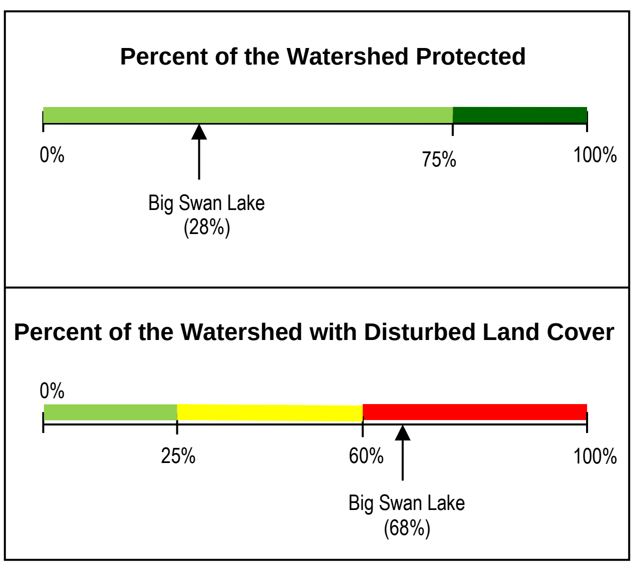


Figure 23. Big Swan Lake's lakeshed percentage of watershed protected and disturbed.

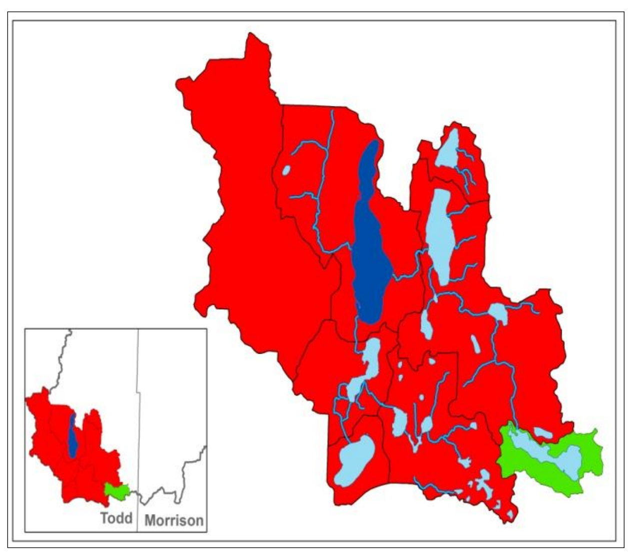


Figure 24. Lakesheds that contribute water to the Big Swan Lake lakeshed. Color-coded based on management focus (Table 13).

Drainage Map

Figure 25. The highlighted area drains to Big Swan Lake. The pour point of the highlighted area is the Swan River Outlet of Big Swan Lake.

Status of the Fishery (DNR, as of 07/30/2012)

Status of the Fishery

A survey using 12 gill nets was completed on Big Swan Lake from July 20-24, 2020. Fish species targeted in the survey were Walleye, Northern Pike and Yellow Perch.

Big Swan Lake is primarily managed for Walleye and Northern Pike. Walleye abundance has remained stable for the past 20 years. Each survey, conducted every four years, we find similar numbers of Walleyes in the gill nets, about 5 fish per gill net on average which is what we'd expect to see in lakes similar to Big Swan. The 2020 catch of 6.3/lift was the highest recorded since 1996. It appears that Walleyes were a bit larger back in the early 2000s compared to now but not by a large margin. The survey in 2016 saw a "bump" in large Walleyes for that year. The highest numbers of Walleye captured in this most recent survey measured 11-15 inches. These fish should recruit well to larger size classes and fishing should be good in 2021-2022. While not as abundant as 11-15 inch fish, Walleyes 16-22 inches were found in good numbers as well. These fish likely range in age from 4-8 years old. There is a long history of Walleye fry and fingerling stocking, dating back to 1946. Currently, Walleye fry are stocked in odd numbered years and fingerlings on even. Gill netting surveys indicate that fingerlings have provided a better return to the fishery than fry, but at a higher price tag. Due to mild winters, fingerling production in area ponds has become more difficult, therefore, while fingerling stocking will become the focus for Big Swan, fry will continue to be stocked as well to see if quality fishing opportunities can be maintained for a cost that's much less expensive.

A special Northern Pike harvest regulation was launched in 1997 to improve the average size of pike. The current regulation consists of a 24-36 inch protected slot limit and a 6 fish bag limit, only one pike may exceed 36 inches. Today, the results appear to be mixed. Comparative spring ice-out trap netting before the regulation and after the regulation show that the average sample percentages of pike larger than 24, 30 and 36 inches improved greatly by the mid-2000s. Pike size structure has declined since that peak but remains better than pre-regulation conditions. Continued monitoring is warranted in order to ascertain the long-term effectiveness of this regulation. At this time the overall abundance of pike is less than it was ten years ago, but still higher than we'd like to see. Research has shown that low-density pike populations comprised of larger-sized individual fish can be more desirable from an angling perspective and be beneficial to the entire fish community.

Yellow Perch, a preferred prey fish for pike and Walleye, have declined in abundance over the years. At this time, average size is less than six inches. It will be important going forward that Yellow Perch are able to sustain adequate abundance and size structure as they are directly connected to the overall health of the Walleye population and to a lesser extent, Northern Pike. No Cisco (Tullibee) were caught in the 2020 nets and they have not been observed since 2000.

For More Information

Little Falls Area Fisheries Supervisor
16543 Haven Rd
Little Falls, MN
Phone: 320-232-1060
Email: LittleFalls.Fisheries@state.mn.us
https://www.dnr.state.mn.us/areas/fisheries/littlefalls/index.html

Individual Waste Treatment Systems Status

In 2014, Todd County completed a comprehensive individual waste treatment system inspection of shoreline properties on Big Swan Lake. The inventory consisted of 226 properties within 1,000 feet of the lake. Of these properties, 129 required inspection of the drainfield and/or septic tanks. The current septic system status of the 129 properties within 1,000 feet of Big Swan Lake are as follows:

- 109 properties found fully compliant (84.5%)
- 11 properties that still must complete a tank inspection (8.5%)
- 1 property could not be completed (unable to auger due to rocks) (0.8%)
- 8 properties found to have failed systems (6.2%)*

**A failed system is defined as a drainfield not meeting soil separation requirements or a septic tank that is leaking at or below its normal operating level.*

The majority of these compliant systems are less than 15 years old, and were constructed under Todd County's current ordinance language. All systems that were found to be failing were installed prior to 1996 when the MPCA modified the methods for determining the restrictive soils. Property owners with failed septic systems received a formal letter from the county requiring the updating or repair of the existing failed system.

Aquatic Plant Community

In 2004, the DNR conducted a plant survey of the littoral area of Big Swan Lake. This was mainly the areas that are less than 20 feet deep.

Big Swan Lake has extensive areas of emergent plants, such as cattails and bulrush, around the lake's edge. They are especially thick along the northeast and southwest shores. Emergent plants are important as they help minimize shoreline erosion by stabilizing soils and dissipating wave action.

Curly-leaf pondweed, an aquatic invasive species, was found in 2004, but was likely present in the lake for several years. Curly-leaf pondweed was found to be the most common aquatic plant in Big Swan Lake. In fact, it was found in 64% of the sample points in the littoral zone.

Overall, the lake supports a relatively high number of native species, but they are present in low abundance compared to the non-native curly-leaf pondweed. Curly-leaf pondweed can do well in lakes with lower clarity because it grows up before the clarity begins to decline in mid-summer.

The Curly-leaf pondweed has been treated in the lake since 2006, and it does not form large mats anymore, but is still present in the lake.

Key Findings / Recommendations

Monitoring Recommendations

In-Lake

Total Phosphorus, chlorophyll *a* (algae concentration), and transparency monitoring should continue monthly (May-September) every year at site 201, to track trends in water quality. Because the transparency is improving, it would be nice to have phosphorus and chlorophyll a data to see if they are improving as well.

Lake bottom Phosphorous samples taken in July and August would allow for the calculation of annual internal loading.

Depth profiles of temperature and dissolved oxygen taken monthly while lake monitoring would allow for an estimation of how often internally sourced nutrients are mixing into the upper water column.

Inlets

The inlets should be tested regularly, at least once each in spring, summer, and fall each year. Ideally one sample will represent a 'post 1 inch rainfall' sample.

Overall Summary

Big Swan Lake is a eutrophic lake (TSI = 56) with evidence of an improving trend in water transparency (Secchi depth). The total phosphorus, chlorophyll *a* and transparency ranges are within the ecoregion ranges.

Big Swan Lake was listed on the MPCA Impaired Waters List in 2010. The TMDL Study is currently scheduled for 2016. This study will go into more depth on what specific phosphorus sources are contributing to the lake and set goals on how to reduce them.

Fifty-seven percent (57%) of the Big Swan Lake lakeshed is disturbed by development and agriculture (High Runoff Potential Land Uses, Table 10). The threshold of disturbance where water quality tends to decline is 25%. Big Swan Lake is over this threshold, which could be why it experiences major algae blooms in late summer.

Big Swan Lake is a dynamic lake, and the transparency, chlorophyll-a and phosphorus follow the same pattern, showing they are closely related. In the spring, the transparency (clarity) is high, and typically in August, the phosphorus is high, the transparency is low and there are major algae blooms (Figures 7-8). The historical transparency data do show that it is improving, however conditions are still below the expected range(Table 8). The spring maximum clarity is especially higher since 2007.

The data indicate that the highest phosphorus and algae levels occur in late summer, which means that internal loading could be occurring in the lake (Figures 7-8). Historical phosphorus loading from the watershed (from agriculture and possibly the City of Grey Eagle) has accumulated in the sediments of Big Swan Lake. Because of the intermediate depth of Big Swan Lake (25-35 feet), it likely stratifies releasing nutrients from the lake bottom. This nutrient enriched lower water can mix up in the water column after a couple days of high winds. When mixing occurs during the summer, the phosphorus from the bottom of the lake can be re-suspended to the surface, fueling algae blooms. Hypolimnion phosphorus samples from Big Swan Lake indicate high phosphorus levels (158-221 ug/L) at depths of 26-30 feet during midsummer and preceding observed nuisance algae blooms indicating these plant available nutrients are likely responsible for the worst of the algae blooms observed in the lake.

The Big Swan Lake Association and Improvement District have accomplished many projects over the past decade that could be contributing to improving water quality and limiting additional phosphorus runoff into the lake, including a septic system study, working with area farmers on four major agricultural runoff improvement projects on the west-side inlets, promoting Best Management Practices in the watershed, 9 years of treatment on Curly-leaf pondweed, and various shoreline improvement projects. Continuing these projects to reduce phosphorus runoff into the lake would go a long way towards protecting the current water quality and preventing future declines.

Priority Impacts to the Lake

The priority impact to Big Swan Lake appears to be Internal Loading. Spikes in algae production are generally preceded by or concurrent with high levels of nutrient release from the lake bottom. When internal nutrient release is low the observed clarity is good and algal production is low.

Historical phosphorus loading has contributed to phosphorus building up in the soils, wetlands, and lake bottom sediments. This phosphorus is still affecting the lake's water quality. Internal loading can be a hard problem to fix. The first thing to do is to reduce current phosphorus inputs, which the Big Swan Lake Improvement District has likely started doing due to their many improvement projects around the lake in the past few years. A treatment that can be looked into for internal loading is Alum treatment. This treatment only works in specific conditions and is more of a middle-term treatment than a long-term treatment. To read more about Alum treatment, visit: http://dnr.wi.gov/lakes/publications/documents/alum_brochure.pdf.

Inlet monitoring data indicate nutrient loading to the lake is occurring. This runoff occurs primarily during spring snow melt and summer storm events. This nutrient loading is not sufficient to be responsible for the observed water quality conditions. It is possible that additional nutrient sources occur between the Schwanke Creek sampling point and the lake. The most likely source would be nutrients released from a wetland saturated with legacy pollution. Historical data and local input strongly suggest that the primary source of loading is from agricultural and feedlot practices due to the high E.coli levels (Figure 16).

A 2014 county study shows that septic systems do not seem to be a major phosphorus source to the lake (page 22).

Best Management Practices Recommendations

The management focus for Big Swan Lake should be to restore the lake's water quality and improve conditions within the lakeshed. Improving conditions in the lakeshed can be done by partnering with farmers in the lakeshed to implement conservation farming practices, increase shoreline buffers, stream buffers, grassed waterways, retention ponds, restore wetlands, or place priority parcels into land retirement programs to decrease the impacts of agriculture.

Reducing nutrient loading sufficient to restore the water quality of Big Swan Lake would require a 50% reduction in runoff and pollutants from the watershed which is mainly agricultural land. This would require well over one hundred individual conservation practices and several million dollars expended on runoff reduction. Alternatively, the lake association could pursue a grant fund Alum treatment of the lake. This should result in a nutrient reduction equivalent to the proposed agricultural land practices but shifts the plan from over one hundred projects on private land to one project in a public water.

In addition, efforts should be focused on managing and/or decreasing the impact caused by additional development, including second tier development, and impervious surface area. Project ideas include enforcing county shoreline ordinances, smart development, shoreline restoration, rain gardens, and septic system maintenance.

Improving water clarity will help the native vegetation grow up and replace the curly-leaf pondweed after it's treated. 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. Lake residents should be educated to protect the submergent and emergent vegetation.

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
- Conservation easements

Lake Associations

- Affect local watershed and lake plans to prioritize lake restoration projects including the types that could be most effective for Big Swan Lake such as internal load management.
- Lake sediment sampling to determine internal loading
- Ground truthing – visual inspection to determine priority nutrient and sediment sources to the lake and streams.
- Pursue Clean Water Legacy funding for in lake treatments, runoff reduction projects, and conservation easements

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

- Shoreline restoration
- Stream buffers and stream corridor grazing management
- Retention ponds
- Wetland restoration
- Work with farmers to
    - Restore wetlands
    - Implement conservation farming practices
    - Land retirement programs such as Conservation Reserve Program

Organizational contacts and reference sites

Big Swan Lake Improvement District	http://bigswanlake.com/lid.html bigswanlake@hotmail.com.
Todd Soil and Water Conservation District	215 1st Avenue South, Suite 104 Long Prairie, MN 56347 (320) 732-2644 http://www.co.todd.mn.us/departments/soil_water/soil_water_frontpage_panel
DNR Fisheries Office	16543 Haven Rd, Little Falls, MN (320) 616-2450 http://www.dnr.state.mn.us/areas/fisheries/littlefalls/index.html
Regional Minnesota Pollution Control Agency Office	7678 College Road, Suite 105 Baxter, MN 56425 218-828-2492, 1-800-657-3864 http://www.pca.state.mn.us/index.php/about-mpca/mpca-overview/agency-structure/mpca-offices/brainerd-office.html