

# 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 moderately clear water conditions.

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.

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, 2007-2014
Chemical data		1980, 1995, 2006-2008
Inlet/Outlet data		2008-2009
Recommendations		For recommendations refer to page 23.

# Lake Map

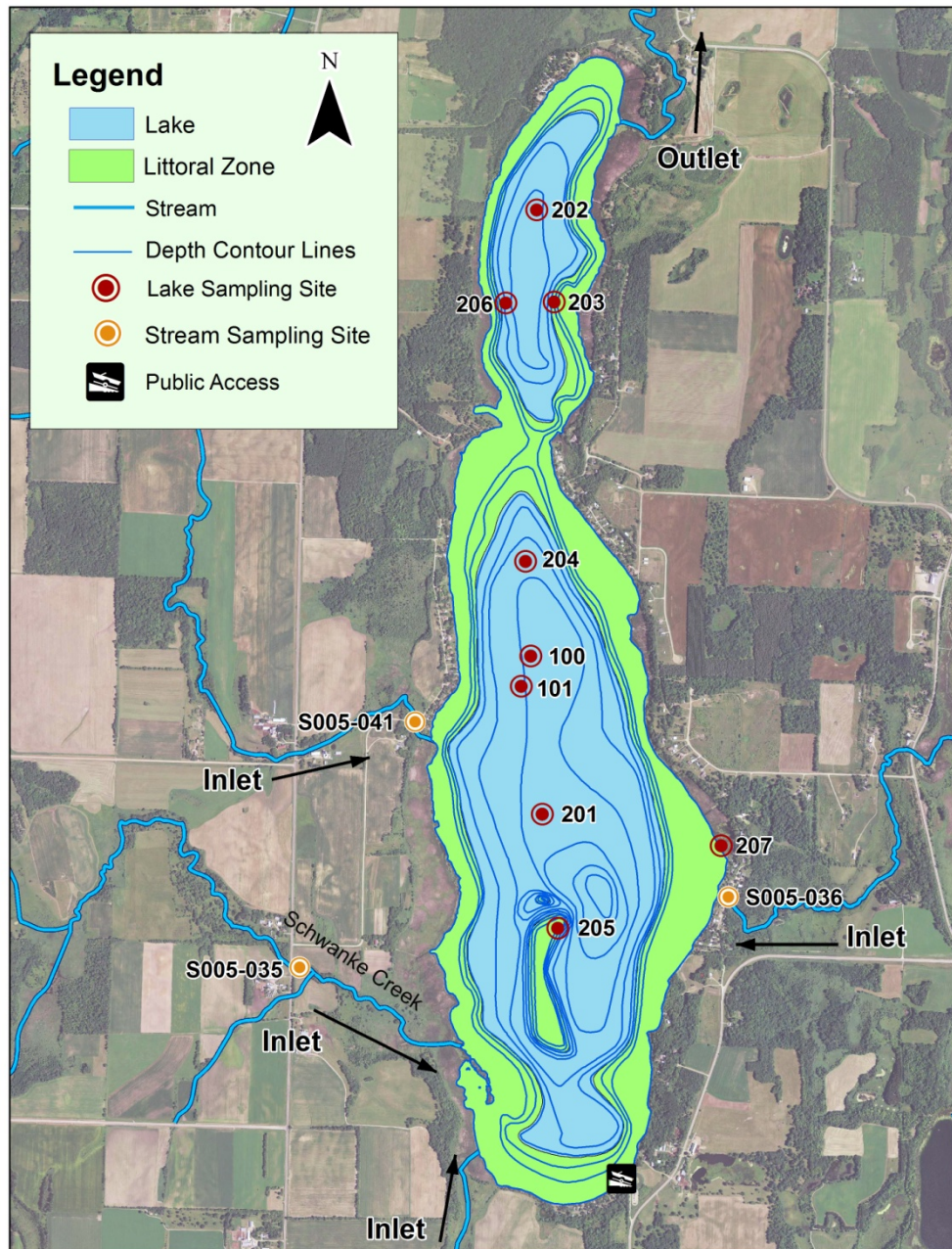


Table 3. Monitoring programs and associated monitoring sites. Monitoring programs include the Citizen Lake Monitoring Program (CLMP), Minnesota Pollution Control Agency (MPCA), Swan River Headwaters Lakes Monitoring (SRHLM), and RMB Environmental Laboratories Lakes Program (RMBEL).

Lake Site	Depth (ft)	Monitoring Programs
100/101	30	MPCA: 1980, 1995
201*primary	30	CLMP: 1992-1993, 1995, 1997-2005, 2007-2014; RMBEL: 2007; SRHLM: 2008
202	25	CLMP: 1992, 2007-2008, 2010-2014; 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

## Average Water Quality Statistics

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

Minnesota is divided into 7 ecoregions based on land use, vegetation, precipitation and geology. The MPCA has developed a way to determine the "average range" of water quality expected for lakes in each ecoregion. For more information on ecoregions and expected water quality ranges, see page 11. 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 <sup>1</sup>	Impaired Waters Standard <sup>2</sup>	Interpretation
Total phosphorus (ug/L)	43	23 – 50	> 40	Results are within the expected range for the Central Hardwood Forest Ecoregion. Big Swan Lake is over the impaired waters standard and was added to the MPCA Impaired Waters List in 2010.
<sup>3</sup> Chlorophyll <i>a</i> (ug/L)	26	5 – 22	> 14	
Chlorophyll <i>a</i> 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		Within the expected range for the ecoregion.
Total Suspended Solids (mg/L)	5	2 - 6		Within the expected range for the ecoregion. Indicates low suspended solids and clear water.
Specific Conductance (umhos/cm)	345	300 - 400		Within the expected range for the ecoregion.
TN:TP Ratio	23:1	25:1 - 35:1		Within the expected range for the ecoregion, and shows the lake is phosphorus limited.

<sup>1</sup>The ecoregion range is the 25<sup>th</sup>-75<sup>th</sup> percentile of summer means from ecoregion reference lakes

<sup>2</sup>For further information regarding the Impaired Waters Assessment program, refer to <http://www.pca.state.mn.us/water/tmdl/index.html>

<sup>3</sup>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
<b>Total Phosphorus Mean (ug/L):</b>	<b>43.4</b>	<b>35.5</b>	<b>58.5</b>
Total Phosphorus Min:	17	16	24
Total Phosphorus Max:	110	91	105
Number of Observations:	14	10	11
<b>Chlorophyll a Mean (ug/L):</b>	<b>26.2</b>	<b>13.9</b>	<b>33.8</b>
Chlorophyll-a Min:	1	4	4
Chlorophyll-a Max:	64	55	85
Number of Observations:	14	10	11
<b>Secchi Depth Mean (ft):</b>	<b>7.5</b>	<b>8.2</b>	<b>7.7</b>
Secchi Depth Min:	2.0	3.0	1.5
Secchi Depth Max:	24.0	24.0	18
Number of Observations:	260	102	39

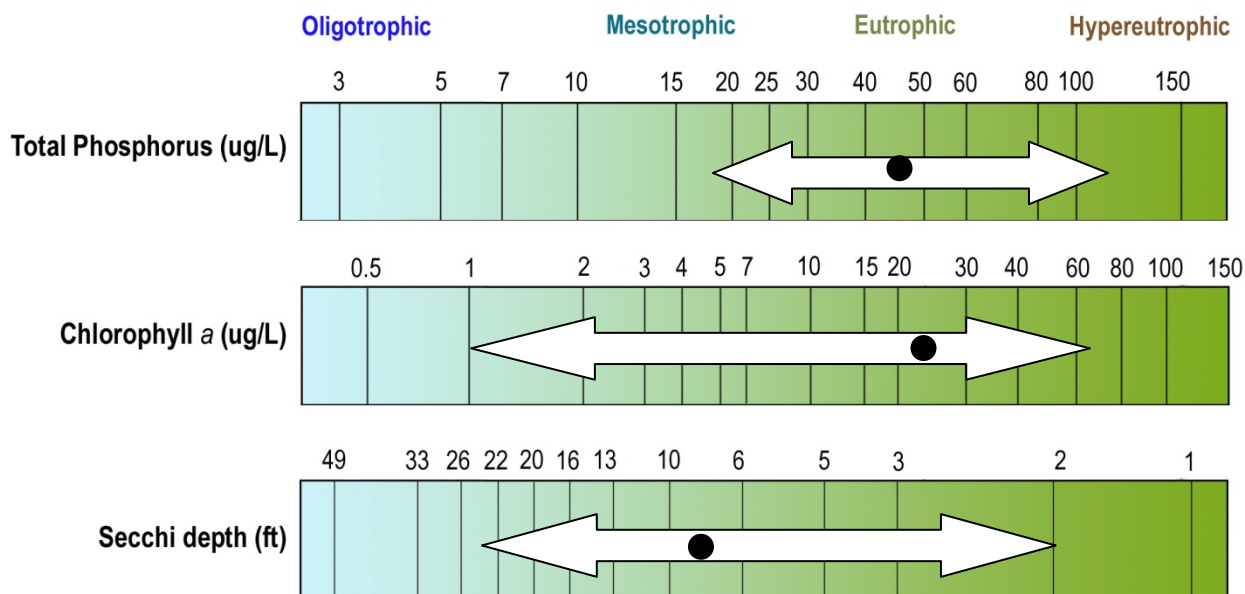


Figure 2. Big Swan Lake total phosphorus, chlorophyll a and transparency historical ranges. The arrow represents the range and the black dot represents the historical mean (Primary Site 201). Figure adapted after Moore and Thornton, [Ed.]. 1988. Lake and Reservoir Restoration Guidance Manual. (Doc. No. 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 3.1 to 12.2 feet (Figure 3). The annual means have varied quite a bit from year to year. 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.

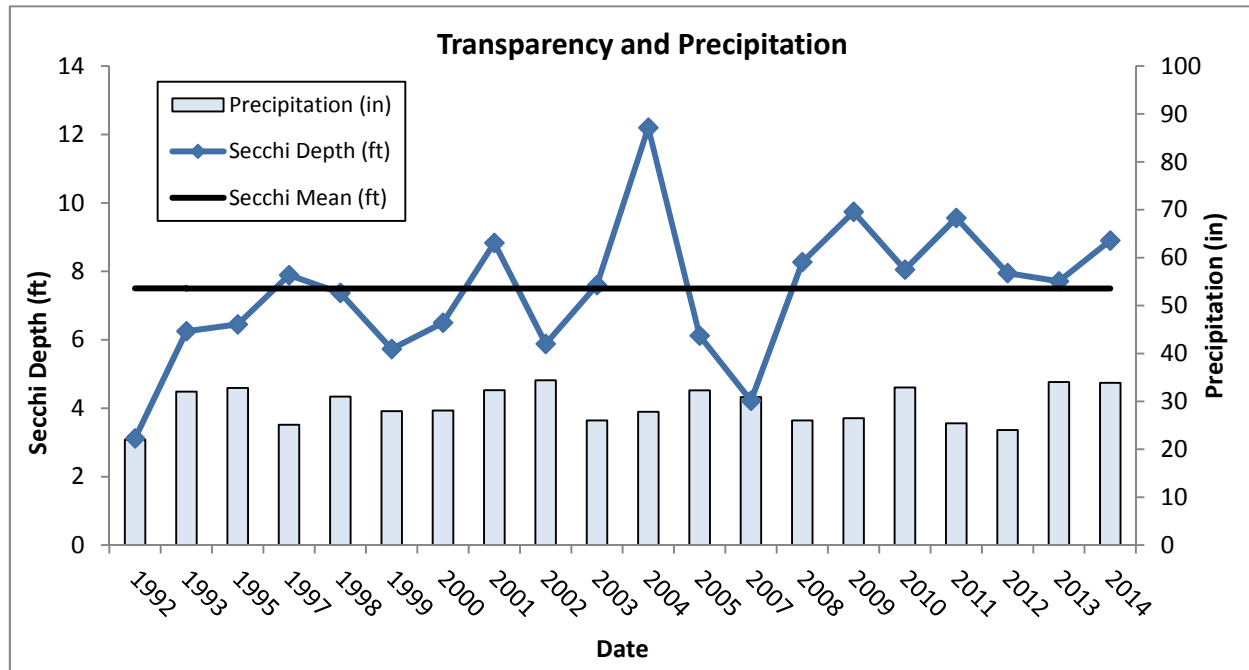


Figure 3. Annual mean transparency compared to long-term mean transparency at the primary site 201.

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. 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.

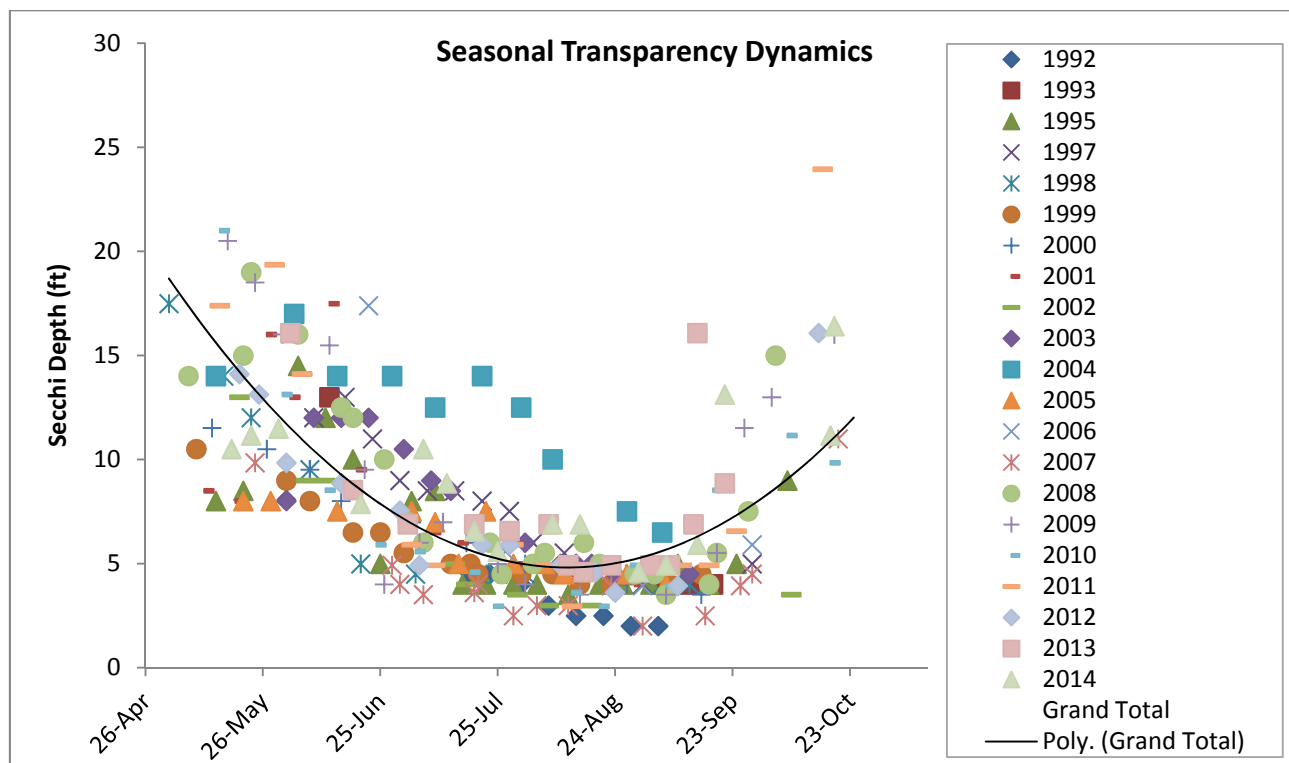


Figure 4. Seasonal transparency dynamics and year to year comparison (Primary Site 201). The black line represents the pattern in the data.

## 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. Big Swan Lake was rated as being "not quite crystal clear" 56% of the time by samplers at site 201 between 1992 and 2014 (Figure 5).

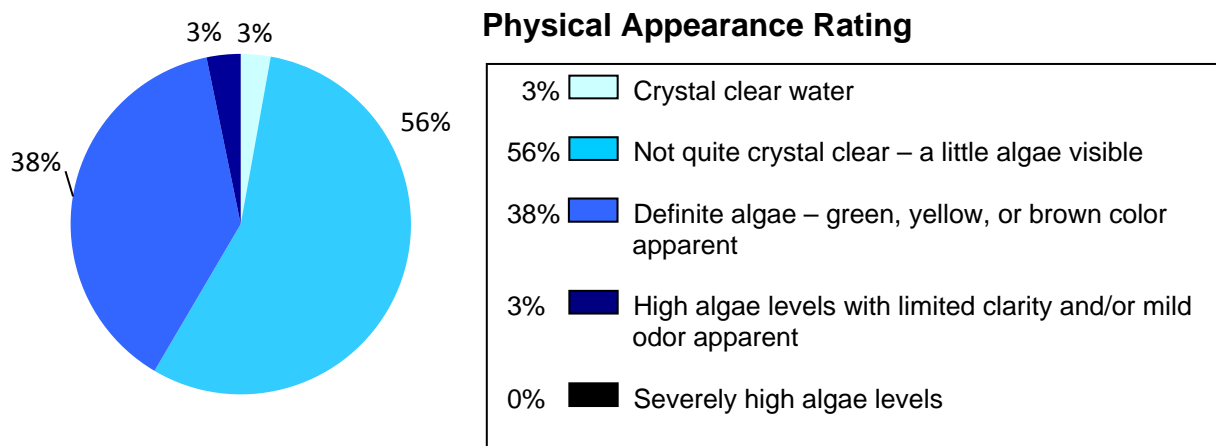


Figure 5. Big Swan Lake physical appearance ratings by samplers.

As the Secchi depth decreases, the perception of recreational suitability of the lake decreases. Big Swan Lake was rated as being "beautiful" 59% of the time from 1992 to 2014 (Figure 6).

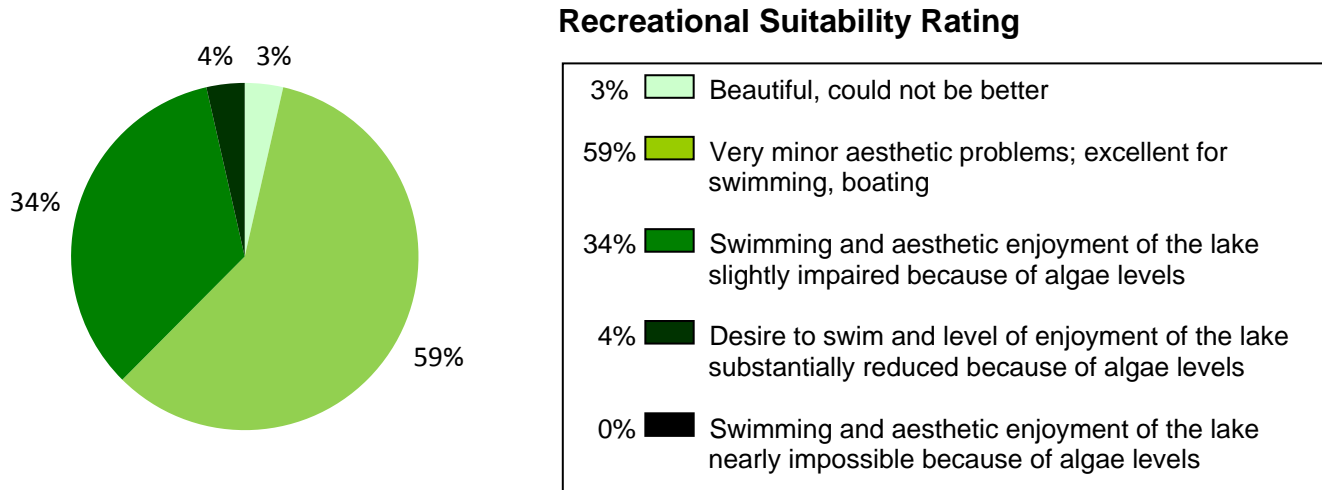


Figure 6. Recreational suitability rating, as rated by the volunteer monitor.

## Total Phosphorus

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, 2006-2008. 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 and fall turnover. 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 phosphorus samples from Big Swan Lake indicate high phosphorus levels (158-221 ug/L) at depths of 26-30 feet.

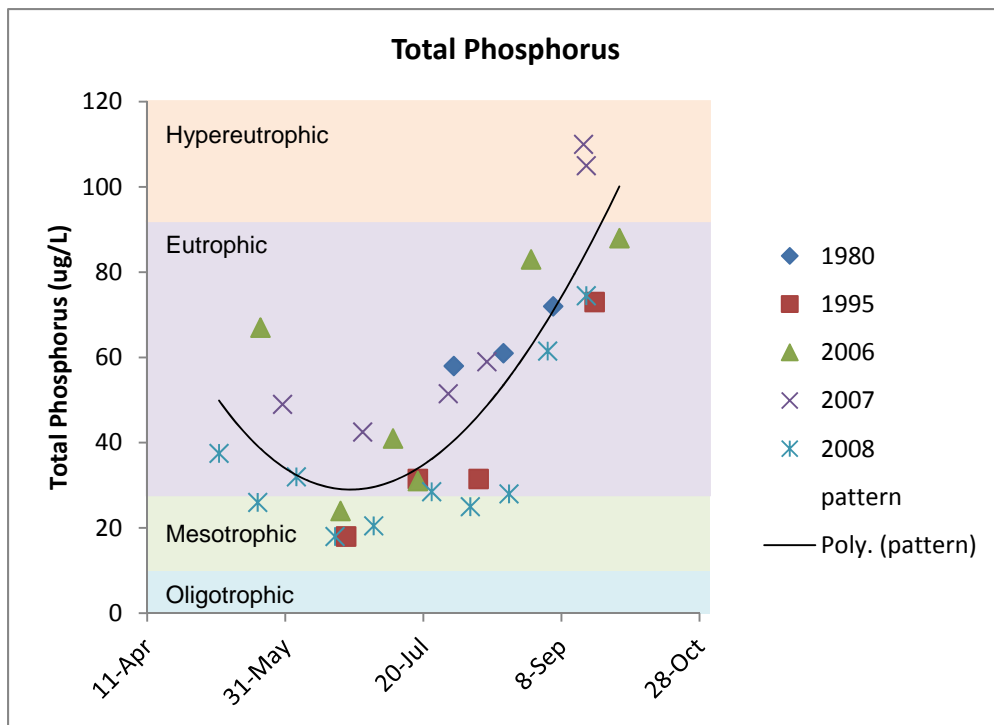


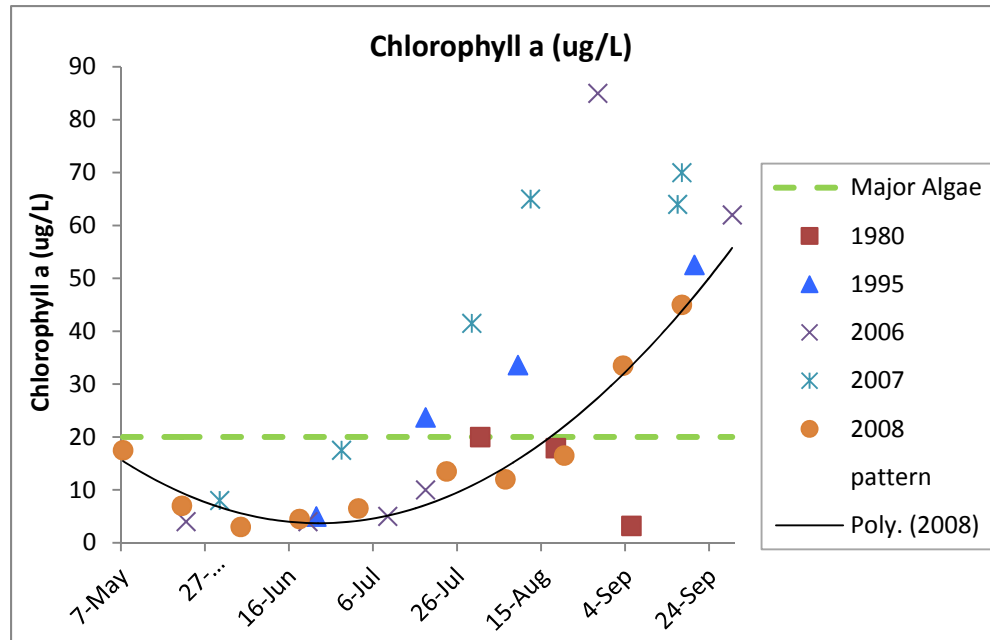
Figure 7. Historical total phosphorus concentrations (ug/L) for Big Swan Lake.

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*

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 µg/L are perceived as a mild algae bloom, while concentrations greater than 20 µg/L are perceived as a nuisance.

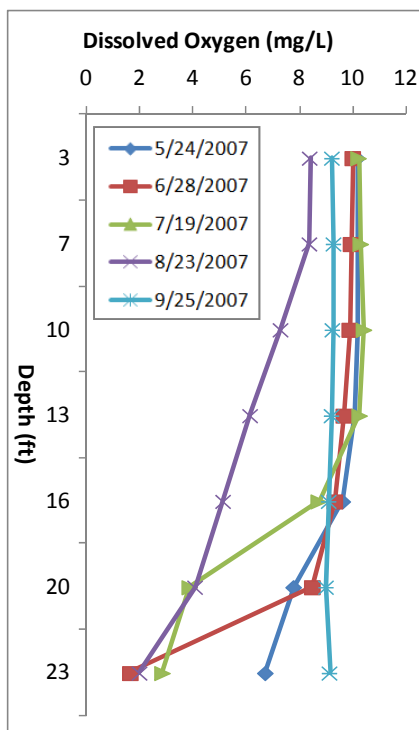


Chlorophyll *a* was evaluated in Big

Figure 8. Chlorophyll *a* concentrations (µg/L) for Big Swan Lake.

Swan Lake in 1980, 1995, 2006-2008 (Figure 8). Chlorophyll *a* concentrations went above 20 µg/L in all years monitored, indicating major algae blooms. The chlorophyll *a* follows the same pattern as phosphorous in the lake (Figure 7), with the highest levels occurring in September. 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.

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.

Figure 9. Dissolved oxygen profile 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 large algae particles dominate the algal community (Table 6). Internal loading could also be fueling algae growth.

Eutrophic lakes (TSI 50-70) are characterized by moderately clear water most of the summer. "Meso" means middle or mid; therefore, mesotrophic means a medium amount of productivity. Mesotrophic lakes are commonly found in central Minnesota and have clear water with algal blooms in late summer (Table 7). They are also good for walleye fishing.

Table 6. Trophic State Index for site 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.*

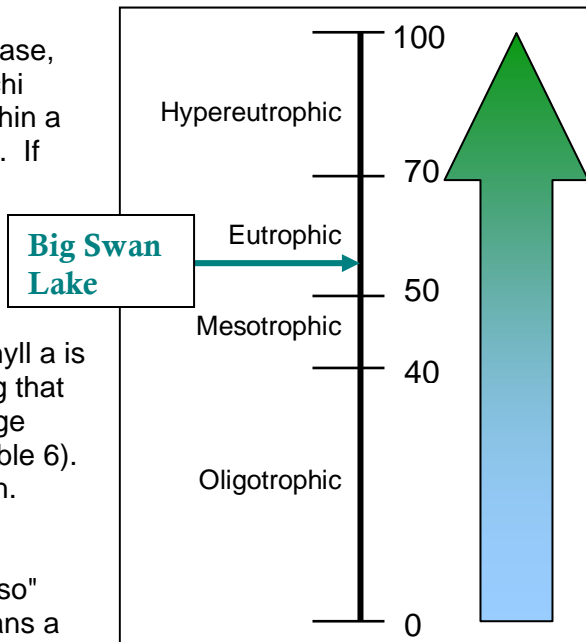


Figure 10. Trophic state index chart with corresponding trophic status.

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

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

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

## Trend Analysis

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

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	Insufficient data	-
201	Chlorophyll a	1980, 1995, 2006-2008	Insufficient data	-
201	Transparency	1992-1993, 1995, 1997-2005, 2007-2014	Improving	95%

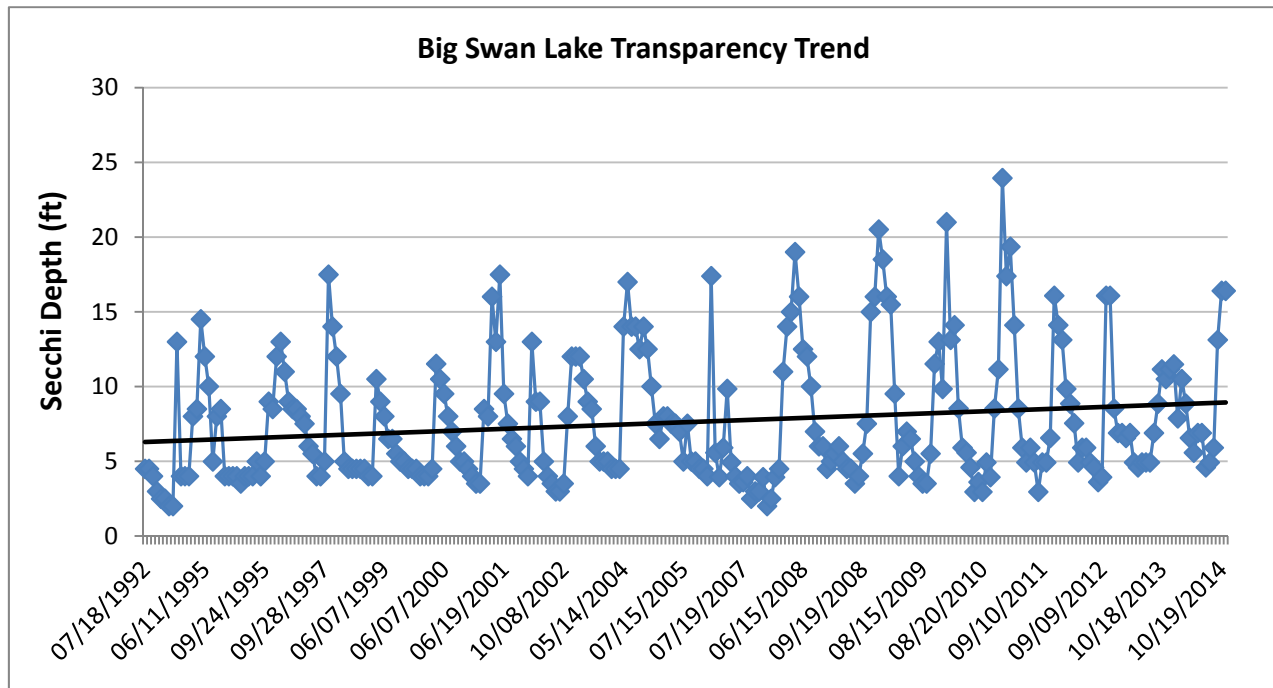


Figure 11. Transparency (feet) trend for site 201 from 1992-2014.

Big Swan Lake shows evidence of an improving transparency trend (Figure 11). 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. Figure 11 shows the annual maximum, which usually occurs in June, increasing every year starting in 2007. 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 25<sup>th</sup> - 75<sup>th</sup> percentile range for data within each ecoregion. For the purpose of this graphical representation, the means of the reference lake data sets were used.

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).

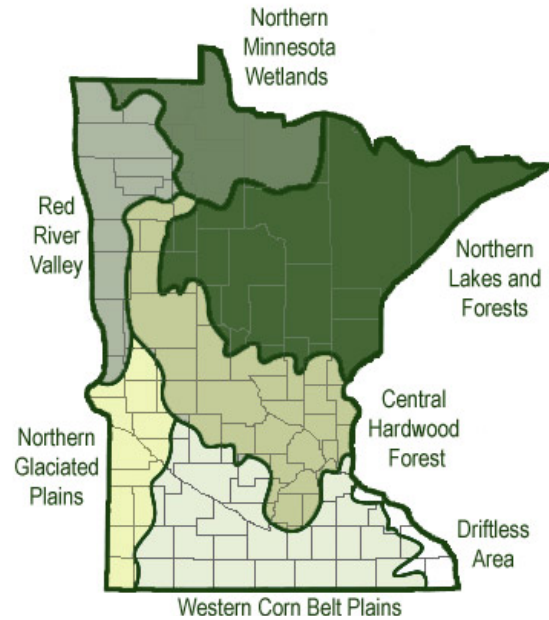
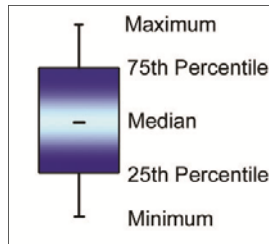


Figure 12. Minnesota Ecoregions.

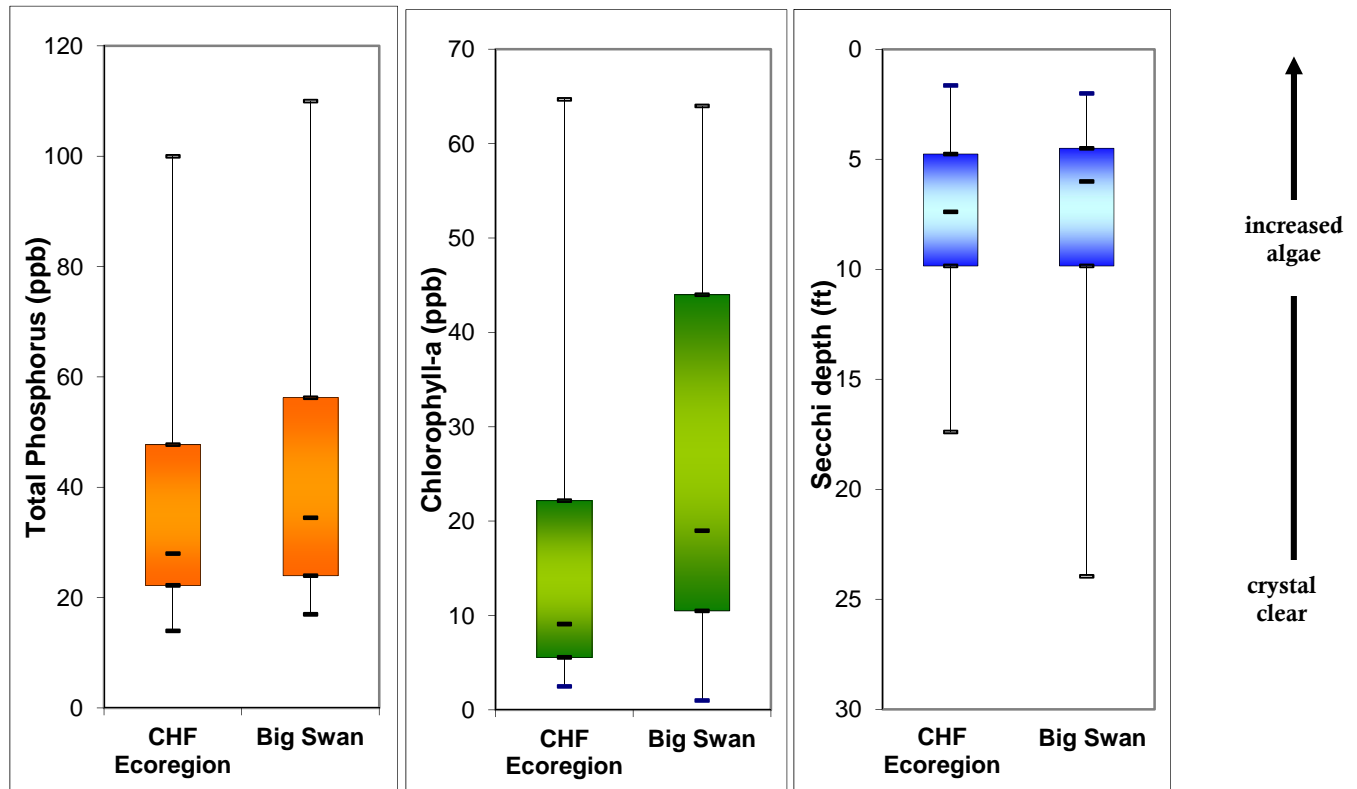


Figure 13. Big Swan Lake ranges compared to Central Hardwood Forest ranges. The Big Swan Lake total phosphorus and chlorophyll *a* ranges are from 14 data points collected in May-September of 1980, 1995, 2006-2008. The Big Swan Lake Secchi depth range is from 260 data points collected in May-September 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.

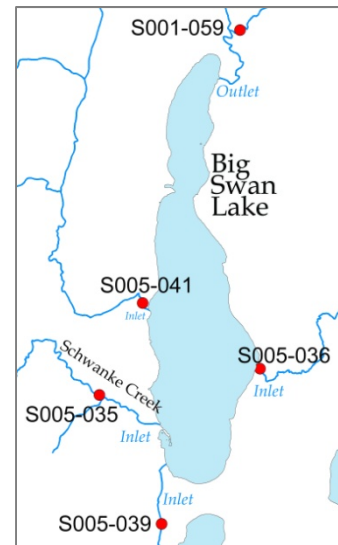


Figure 14. Map of stream monitoring sites around Big Swan Lake.

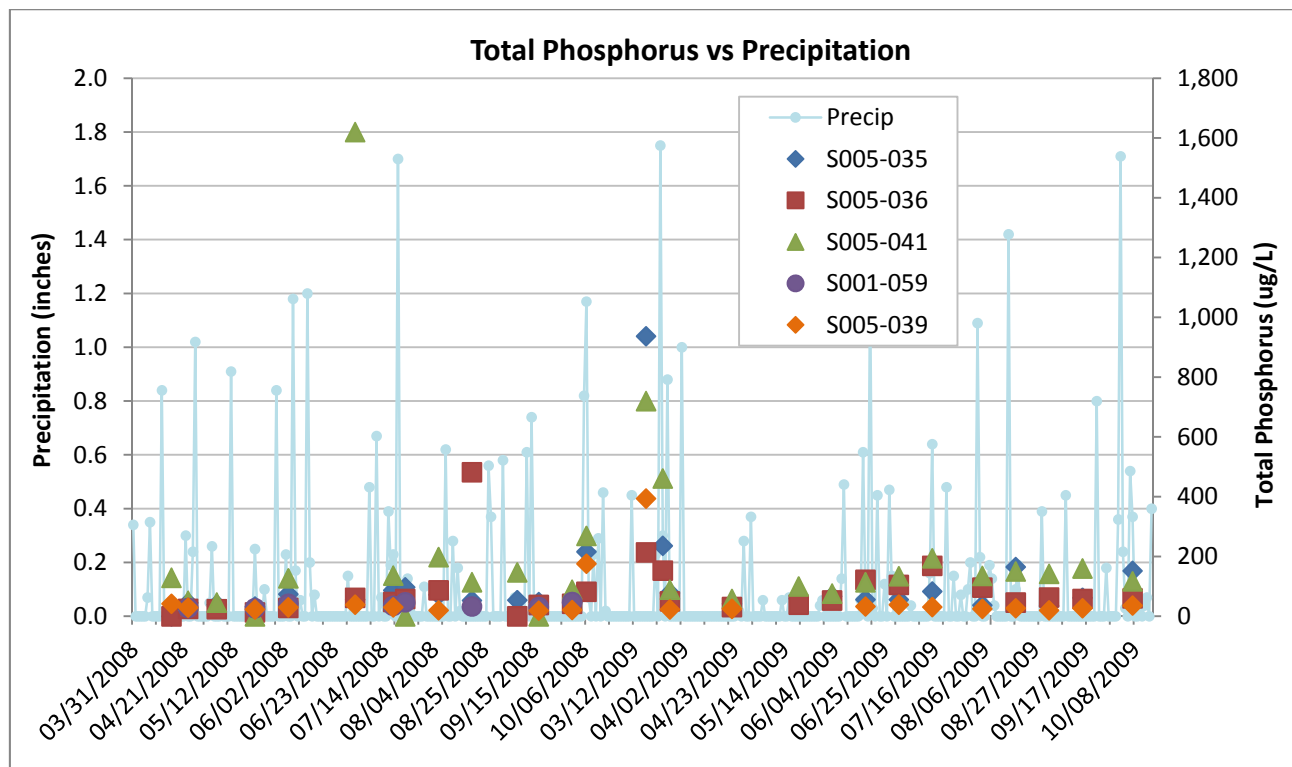


Figure 15. Total phosphorus results in Big Swan Lake streams graphed with precipitation, 2008-2009.

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.

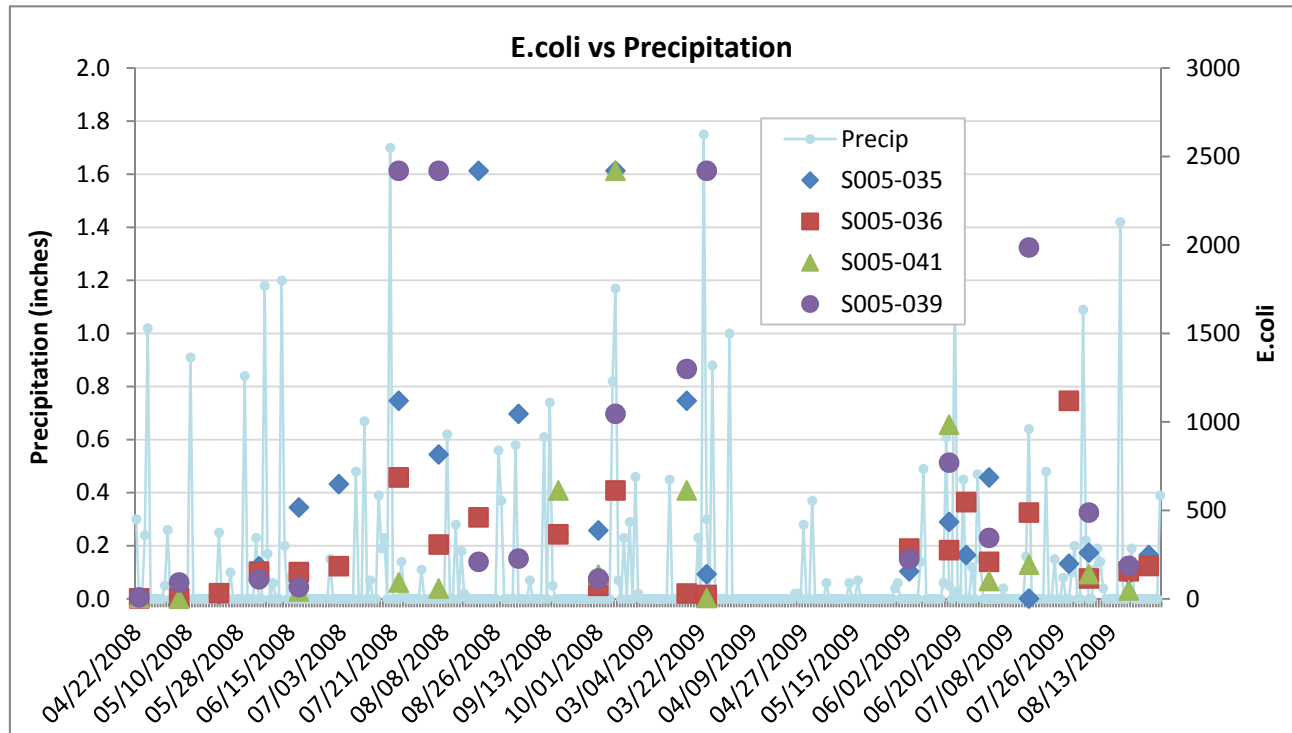


Figure 16. *E.coli* results in Big Swan Lake streams graphed with precipitation, 2008-2009.

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).

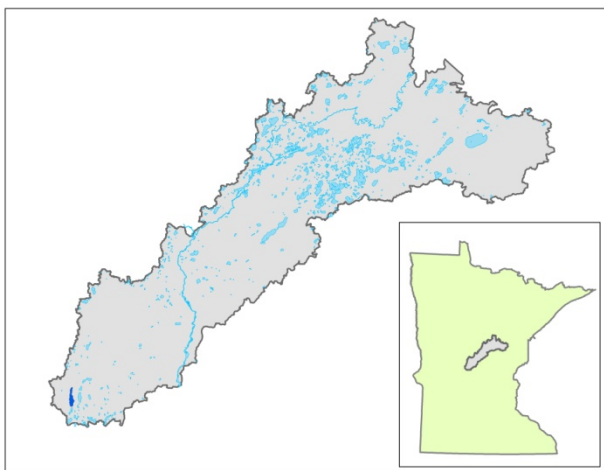


Figure 17. Mississippi – Brainerd Major Watershed.

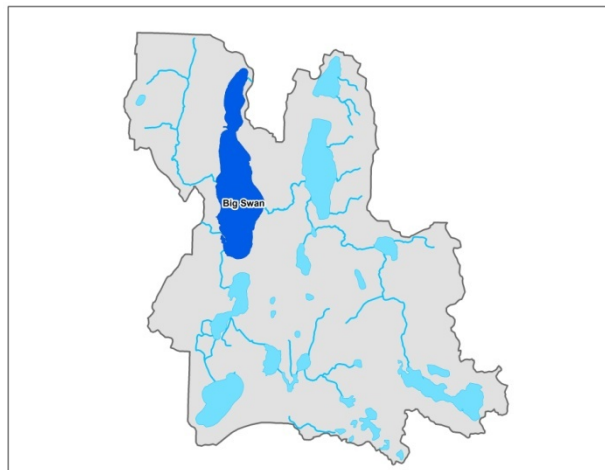
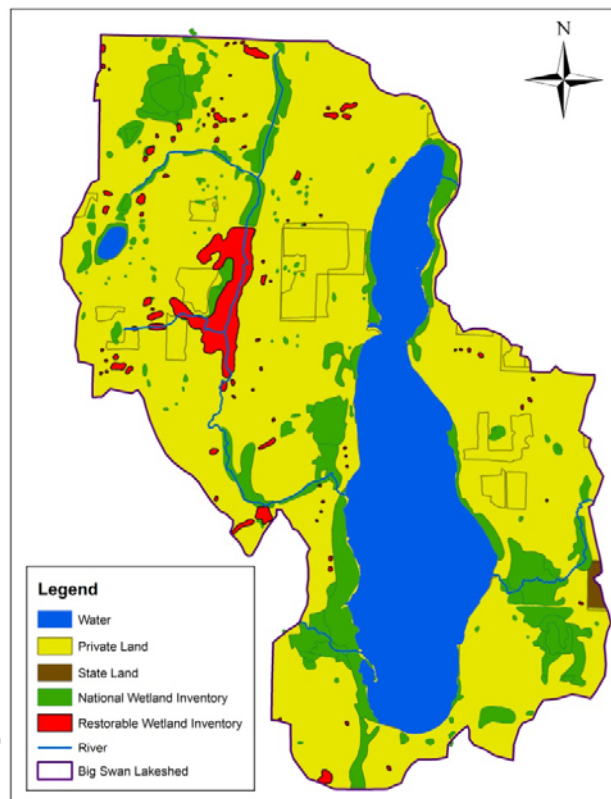


Figure 18. Big Swan Lake's minor watershed.

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 lakeshed, see page 20. The data

Figure 19. Big Swan Lake lakeshed (1013300) with land ownership, lakes, wetlands, and rivers illustrated.



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





















-  Possibly detrimental to the lake
-  Warrants attention
-  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	
Outlets	1	
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	
Standard Watershed to Lake Basin Ratio (standard watershed includes lake areas)	21:1	
Wetland Coverage (NWI)	13.84%	
Aquatic Invasive Species	Curly-leaf Pondweed	
Public Drainage Ditches	0	
Public Lake Accesses	1	
Miles of Shoreline	8.1	descriptive
Shoreline Development Index	1.9	
Public Land to Private Land Ratio	1:3	
Development Classification	Recreational Development	
Miles of Road	11.8	descriptive
Municipalities in lakeshed	0	
Forestry Practices	None	
Feedlots	6	
Sewage Management	Individual Waste Treatment Systems	
Lake Management Plan	Healthy Lakes and Rivers 2003	
Lake Vegetation Survey/Plan	07/13/2004	

## 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.

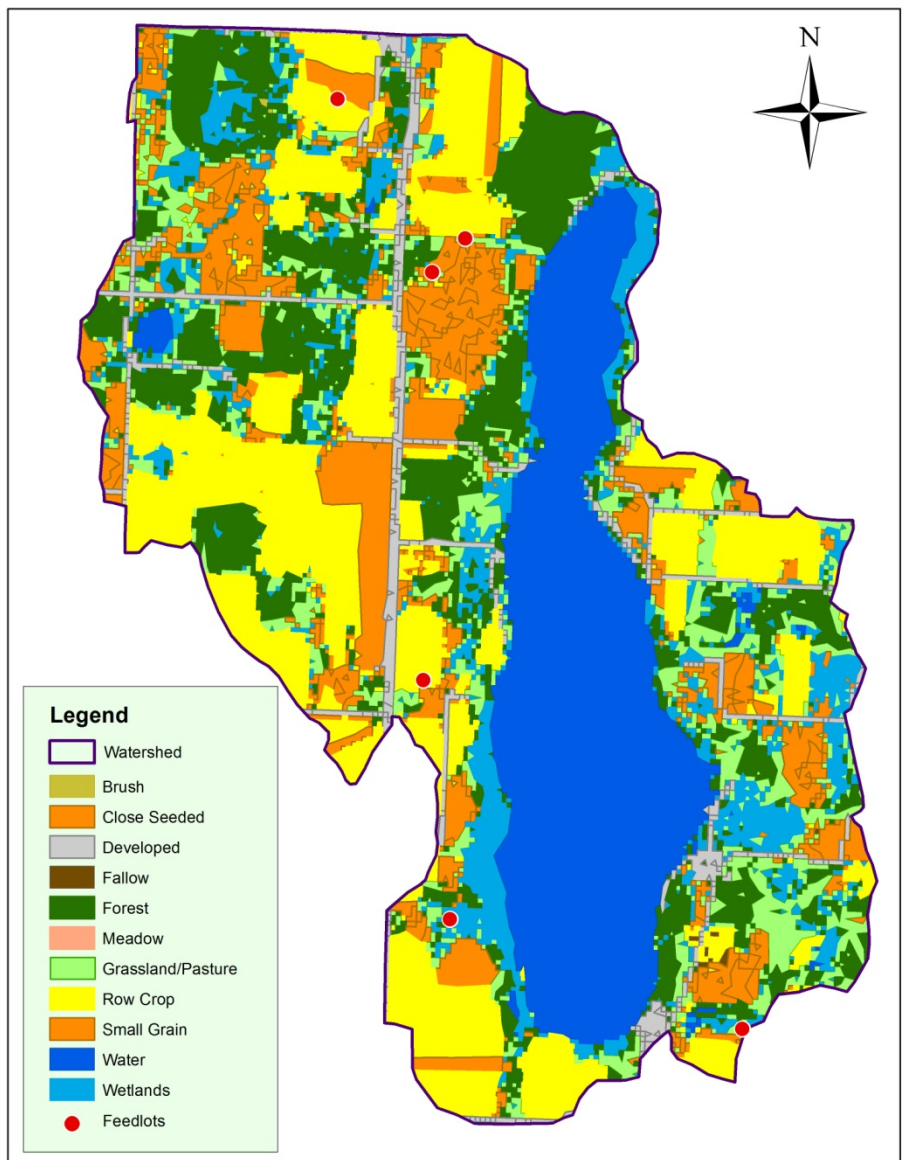


Figure 20. Big Swan lakeshed (1013300) land cover (NASS, 2013).

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.

<b>Runoff Potential</b>	<b>Category</b>	<b>Specific Landcover</b>	<b>Acres</b>	<b>Percent</b>
High	Agriculture	<b>Row Crop</b>	995.02	21.42%
High	Urban	<b>Developed</b>	239.67	5.16%
High	Agriculture	<b>Close Seeded</b>	726.62	15.64%
High	Agriculture	<b>Small Grain</b>	18.34	0.39%
High	Agriculture	<b>Fallow</b>	3.77	0.08%
Low	Forest	<b>Forest</b>	761.89	16.40%
Low	Water	<b>Water</b>	934.59	20.12%
Low	Agriculture	<b>Pasture/Grassland</b>	488.40	10.52%
Low	Wetlands	<b>Wetlands</b>	474.98	10.23%
Low	Agriculture	<b>Meadow</b>	0.00	0.00%
Low	Grass/Shrub	<b>Brush</b>	1.48	0.04%
<b>Total area with low runoff potential</b>			2,661.34	42.7%
<b>Total area with high runoff potential</b>			1,983.42	57.3%
<b>Total</b>			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 12 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 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).

<b>Category</b>	<b>1990 Acres</b>	<b>Percent</b>	<b>2000 Acres</b>	<b>Percent</b>	<b>Change 1990 to 2000</b>
<b>Total Impervious Area</b>	26	0.69	56	1.47	Increase of 30 acres
<b>Urban Acreage</b>	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>)

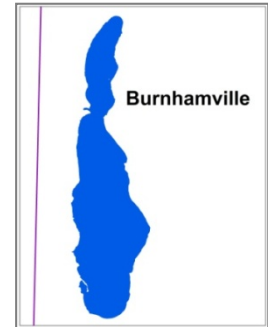


Figure 21. Big Swan Lake is located in Burnhamville Township.

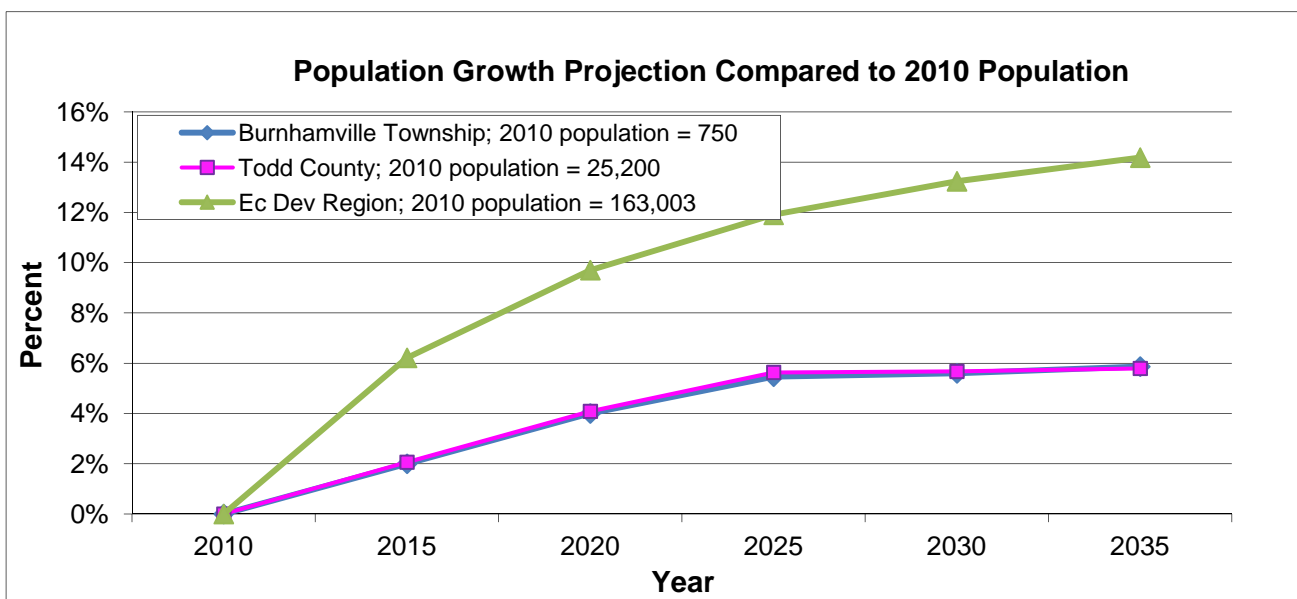


Figure 22. Population growth projection for adjacent townships.

## 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
<b>Land Use (%)</b>	5.2	63.2	8.5	0.9	2.9	19.3	0	100	0
<b>Runoff Coefficient</b> Lbs of phosphorus/acre/year	0.45 – 1.5	0.26 – 0.9	0.09		0.09		0.09	0.09	0.09
<b>Estimated Phosphorus Loading</b> Acreage x runoff coefficient	10.9 – 363.2	762.8 – 2,640.4	35.5		12.0		0	1.03	0
<b>Description</b>	1 <sup>st</sup> and 2 <sup>nd</sup> Tier Development	Cropland Pasture CRP	Forest, Timber, Undeveloped	Open, pasture, grassland, shrubland	Protected				
<b>Ideas for protection and restoration</b>	Shoreline restoration Rain Gardens Conservation Easements	Restore wetlands; CRP Stream buffers Grassed waterways	Forest stewardship planning, 3 <sup>rd</sup> 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 artedii*) 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).

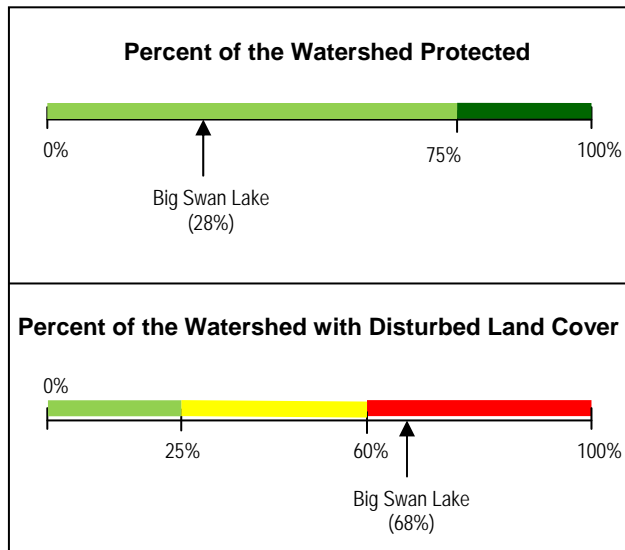


Figure 23. Big Swan Lake's lakeshed percentage of watershed protected and disturbed.

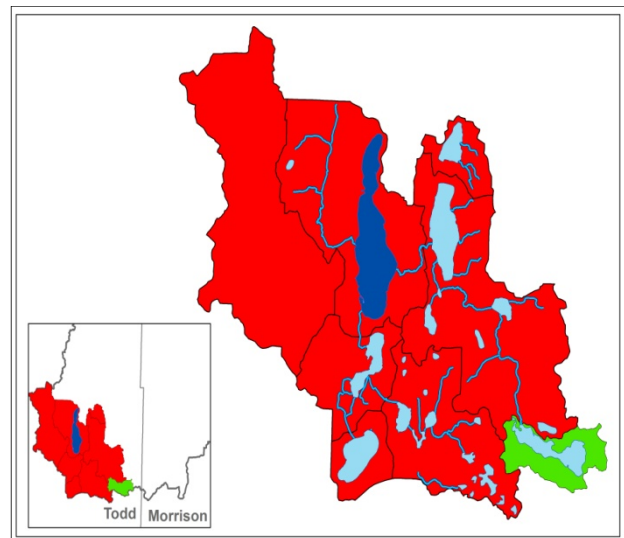


Figure 24. Lakesheds that contribute water to the Big Swan Lake lakeshed. Color-coded based on management focus (Table 13).

## Drainage Map

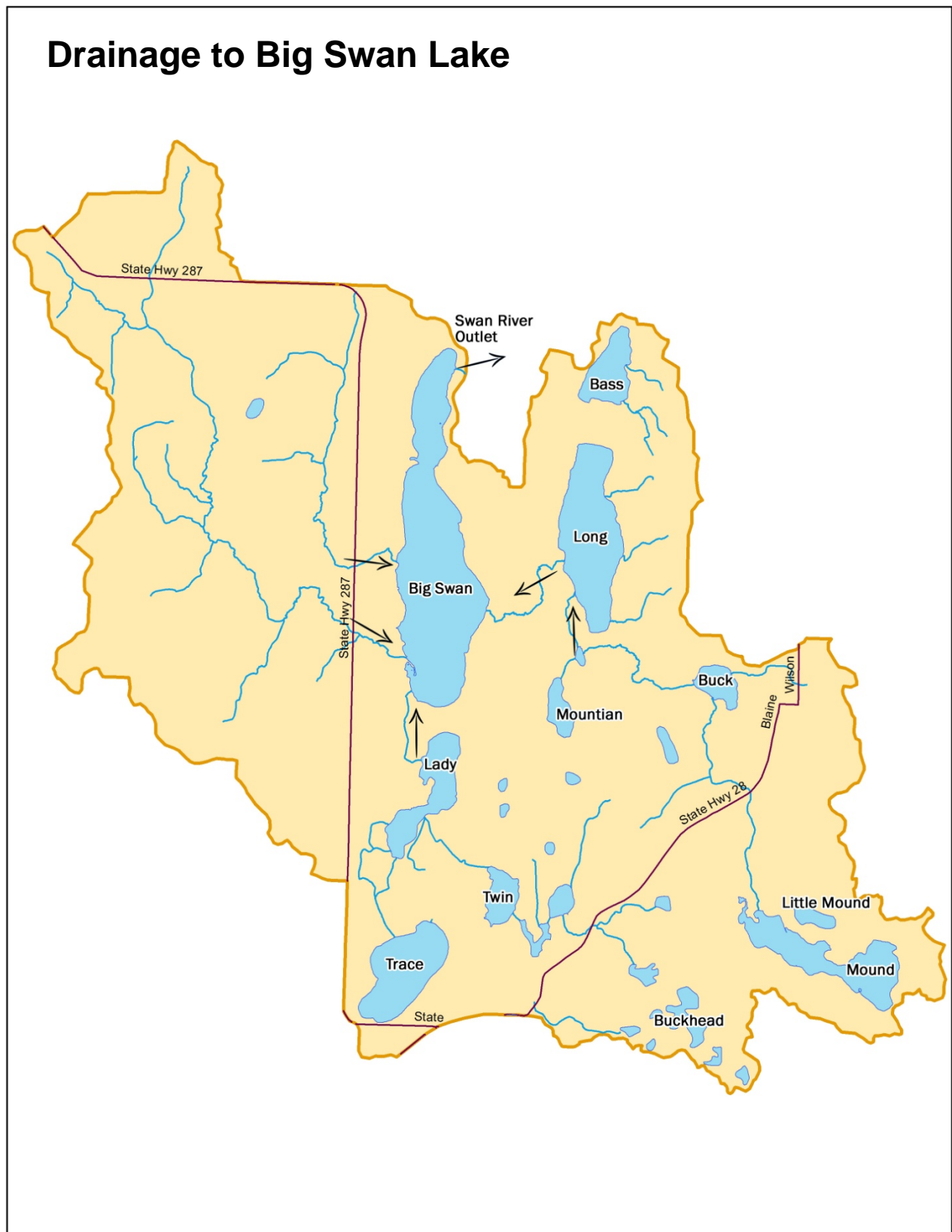


Figure 25. The highlighted area drains to Big Swan Lake. The pour point of the highlighted area is the Swan River Outlet of Big Swan Lake.

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

Big Swan Lake is a popular fishing lake west of the Town of Burtrum in Todd County. Big Swan Lake lies within an agricultural watershed, which results in reduced water clarity especially following snow melt and rain events. The lake also has curly leaf pondweed, which adds to the mid-summer nutrient loading. Algae blooms during the summer months are a common occurrence.

Fishing structure includes weedlines, sunken bars and islands, as well as extensive bulrush beds. The lake supports a diverse fish community that attracts anglers, including species such as walleye, northern pike, largemouth bass, bluegill, and black crappie. There is a regulation on the lake prohibiting the possession of northern pike between 24 and 36 inches, with one over 36 inches allowed. The regulation will change in spring of 2013 to a bag limit of six pike, but, the slot limit will be retained. The goal of the regulation is to improve the size structure of the pike population while decreasing numbers of smaller pike. Northern pike abundance, however, has shown increases the last two surveys and appears to be at a record high. Most of the pike observed in the survey were between 17 and 22 inches in length, however, fish over 30 inches were caught.

Walleye stocking appears to sustain the fishery in Big Swan Lake and a wide range of sizes look to be available to anglers. Average size in the survey was about 2 pounds but some trophy size fish have been observed. Larger largemouth bass up to 19 inches in length were observed in the spring electrofishing assessment which is the method used to evaluate bass populations. There also appears to be good numbers of bass between 15 and 17 inches. Yellow perch abundance showed a decline again since the last survey and although some anglers consider them to be pests, they can be an important food species for both northern pike and walleye. Perch can also be instrumental in helping maintain a well-balanced bluegill population with fast growing, quality size individuals. Bluegill provide a popular summer fishery in the area at times. Anglers report having good luck catching 6 to 7-inch bluegill and fish up to 9 inches have been found.

Winter seems to be the best time to find black crappies in Big Swan Lake. Recent ice fishing reports indicate the presence of a strong year class providing 8 to 10-inch crappie during the day. Spring assessments, spring electrofishing, and summer surveys have documented larger crappie over 12 inches.

Other panfish species in Big Swan Lake include pumpkinseed sunfish, rock bass, and hybrid sunfish. Big Swan Lake would also be an excellent choice for any angler seeking quality size bullhead. Two species of bullhead are present in the lake and both the brown and yellow bullhead catches had individuals over 13 inches in length.

Other fish species found in Big Swan Lake include white sucker, bowfin or dogfish, and common carp. Suckers were caught during the summer survey while bowfin were observed in both the spring panfish and spring electrofishing assessment. Carp were observed in the spring electrofishing assessment.

Along with the release of the larger northern pike, anglers are encouraged to practice catch and release with the larger individuals of other species to achieve a balanced fish community and provide opportunity for quality size fish.

Improving the water quality in Big Swan Lake should be a high priority of the lake association and landowners around the lake. Preservation of the emergent vegetation beds can help to improve water quality and protect shorelines as well as valuable fish habitat. Buffer strips along inlets and lakeshore property would also help to reduce nutrients entering the lake. Maintaining adequate septic systems, keeping grass clippings and raked leaves out of the lake, and the use of zero

phosphorus lawn fertilizer are all ways for homeowners to help reduce added nutrients from entering the lake and contributing to excess algae and weed growth.

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=77002300>

## 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

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* (algae concentration) 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.

#### Inlets

The inlets have not been tested since 2009 and could be tested again in the next couple years to see if the improvement projects near the inlets on the west side have improved the water quality. Ideally, to get the best understanding of the lake, streams would be tested every other week and at storm events all year to see if *E.coli* is still a problem.

### 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 (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, but turnover can occur after a couple days of high winds. When turnover 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.

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 and the reason the lakeshed is rated as “partial restoration (Figure 24)” is surrounding agriculture (Figure 20). Agriculture is the dominant land use type on private lands (63%) within the lakeshed (Table 12). From maps, it appears there are some buffers between farmed fields and developed lakeshore parcels (Figures 1, 20).

Inlet monitoring data indicate nutrient loading to the lake. This runoff occurs primarily during spring snow melt and summer storm events. 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).

The historical phosphorus loading have contributed to phosphorus building up in the sediments. This phosphorus could be involved in internal loading in the lake. 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 short-term treatment than a long-term treatment. To read more about Alum treatment, visit: [http://dnr.wi.gov/lakes/publications/documents/alum\\_brochure.pdf](http://dnr.wi.gov/lakes/publications/documents/alum_brochure.pdf).

A third potential impact to the lake is expansion of residential housing development in the lakeshed and second tier development along the lakeshore. The majority of first tier shoreline parcels have been developed on the eastern shoreline. A significant portion of properties on the western shore remain in large parcels and have not been subdivided for development. This area contains many wetlands, which are crucial for water storage and filtration in the lakeshed (Figure 20). If this land was converted to housing developments, it could increase the runoff around the lake. From 1990-2000, the urban area around the lake increased by 152 acres and the impervious area increased by 30 acres (Table 13).

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 protect the current water quality and restore the lakeshed. This 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 in the lakeshed.

More specifically, installing vegetative stream buffers and filter strips along the inlets to the lake would help filter and slow down the water runoff into lake.

Protecting the undeveloped parcels on the western side of the lake will help protect the lake from further decline. 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 in Little Falls.

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
- 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 mapping by a consultant
- Shoreline inventory study by a consultant
- Conservation easements

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

- Shoreline restoration
- Stream buffers
- Grassed waterways
- Filter strips
- 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](mailto:bigswanlake@hotmail.com).

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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](http://www.co.todd.mn.us/departments/soil_water/soil_water_frontpage_panel)

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DNR Fisheries Office 16543 Haven Rd, Little Falls, MN  
(320) 616-2450  
<http://www.dnr.state.mn.us/areas/fisheries/littlefalls/index.html>

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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>

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