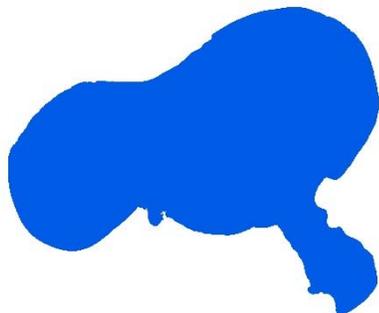


Big Sand Lake 29-0185-00 HUBBARD COUNTY

Lake Water Quality

Summary



Big Sand Lake is located eight miles northeast of Park Rapids, Minnesota. It covers 1,659 acres and has a mostly round shape.

Big Sand Lake has two inlets and one outlet, which classifies it as a drainage lake. The inlets enter from Emma Lake and a wetland area. The outlet is located at the south end of the lake, and flows through Ida Lake into Little Sand Lake. From Little Sand Lake, the water flows through many other lakes, and ends up draining into the Crow Wing River.

Water quality data have been collected on Big Sand Lake since 1975 (Table 3). These data show that the lake is at the oligotrophic, which is characterized by clear water throughout the summer and excellent recreational opportunities.

The Big Sand Lake Association was formed during the summer of 1988 and is “dedicated to the betterment and preservation of Big Sand Lake”. They are active in many projects, including water quality monitoring, safety buoys, a newsletter, a resident directory and social activities. They are also a member of the Hubbard County Coalition of Lake Associations (COLA).

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

Location Data		Physical Characteristics	
MN Lake ID:	29-0185-00	Surface area (acres):	1,659
County:	Hubbard	Littoral area (acres):	465
Ecoregion:	Northern Lakes and Forests	% Littoral area:	28%
Major Drainage Basin:	Upper Mississippi River	Max depth (ft), (m):	135, 41.1
Latitude/Longitude:	47.00111111 / -94.96750000	Inlets:	2
Invasive Species:	None as of 2017	Outlets:	1
		Public Accesses:	1

Table 2: Availability of data and an observation of the quantity of sample points.

Data Availability

Transparency data



Excellent data set through the Citizens Lake Monitoring Program.

Chemical data



Excellent data set through the RMB Lab Lakes Program.

Inlet/Outlet data



No inlet or outlet data exist for this lake.

Recommendations

For recommendations refer to page 22.

Lake Map

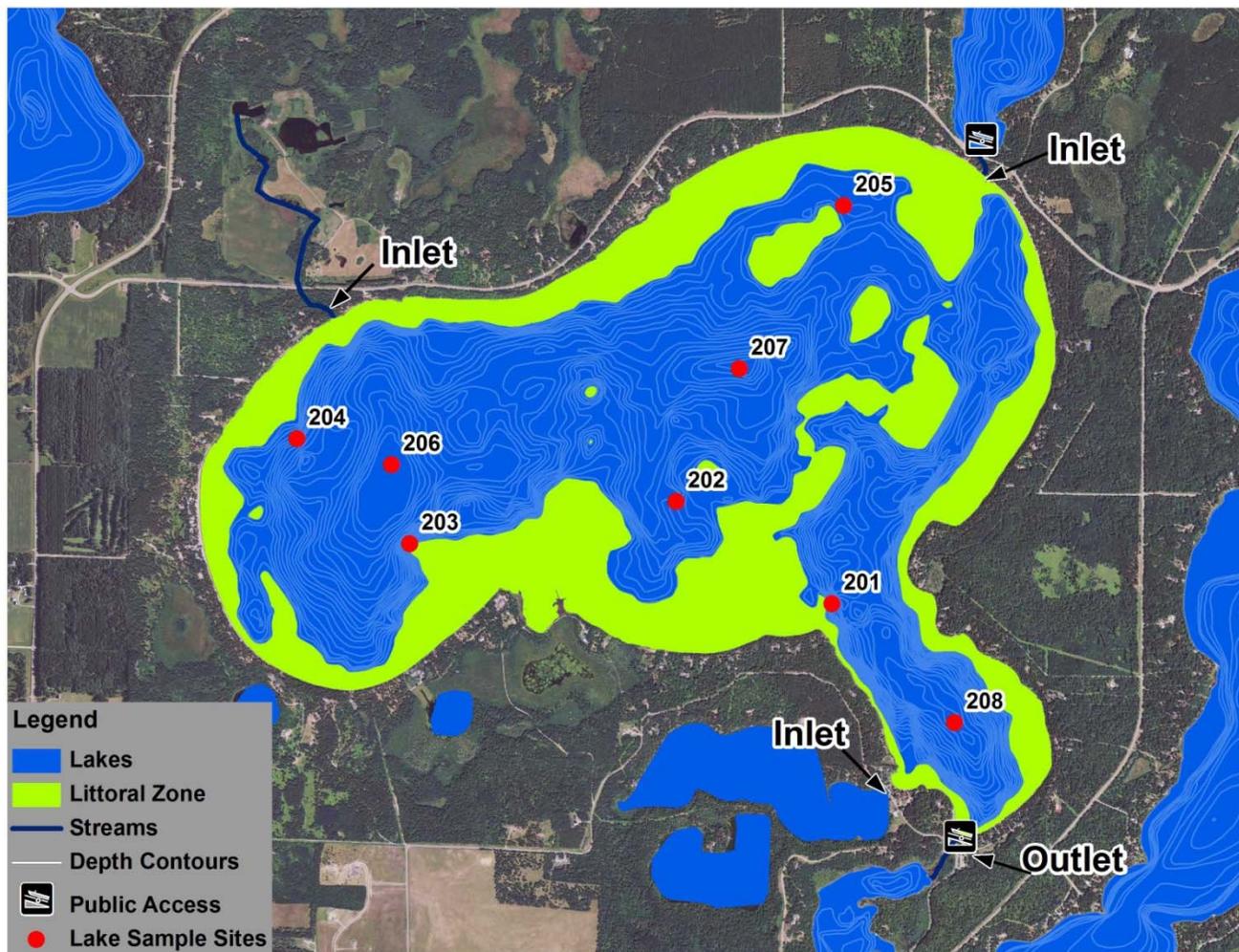


Figure 1. Map of Big Sand Lake with 2010 aerial imagery and illustrations of sample site locations, inlets and outlets, and public access points. The green areas in the lake illustrate the littoral zone, where the sunlight can usually reach the lake bottom allowing aquatic plants to grow.

Table 3. Monitoring programs and associated monitoring sites. Monitoring programs include the Citizens Lake Monitoring Program (CLMP) and RMB Environmental Laboratories Lakes Program (RMBEL).

Lake Site	Depth (ft)	Monitoring Programs
201	45	CLMP: 1975
202	40	CLMP: 1987-1994, 2003
203	35	CLMP: 1987-2003, 2008-2010
204	65	CLMP: 1989-2008
205	35	CLMP: 1990-2002
206	130	CLMP: 1994-2010
207* Primary site	110	CLMP: 1994-2011; RMBEL: 1998-2016
208	110	CLMP: 1994-2010

Water Quality Characteristics - Historical Means and Ranges

Table 4. Water quality means and ranges for primary sites, 1997-2011.

Parameters	Primary		
	Site 207	Site 206	Site 208
Total Phosphorus Mean (ug/L):	8.7		
Total Phosphorus Min:	<5		
Total Phosphorus Max:	22.0		
Number of Observations:	95		
Chlorophyll a Mean (ug/L):	2.3		
Chlorophyll-a Min:	<1		
Chlorophyll-a Max:	9.0		
Number of Observations:	94		
Secchi Depth Mean (ft):	22.3	20.8	21.6
Secchi Depth Min:	8.0	8.0	9.0
Secchi Depth Max:	45.5	44.9	44.0
Number of Observations:	92	222	176

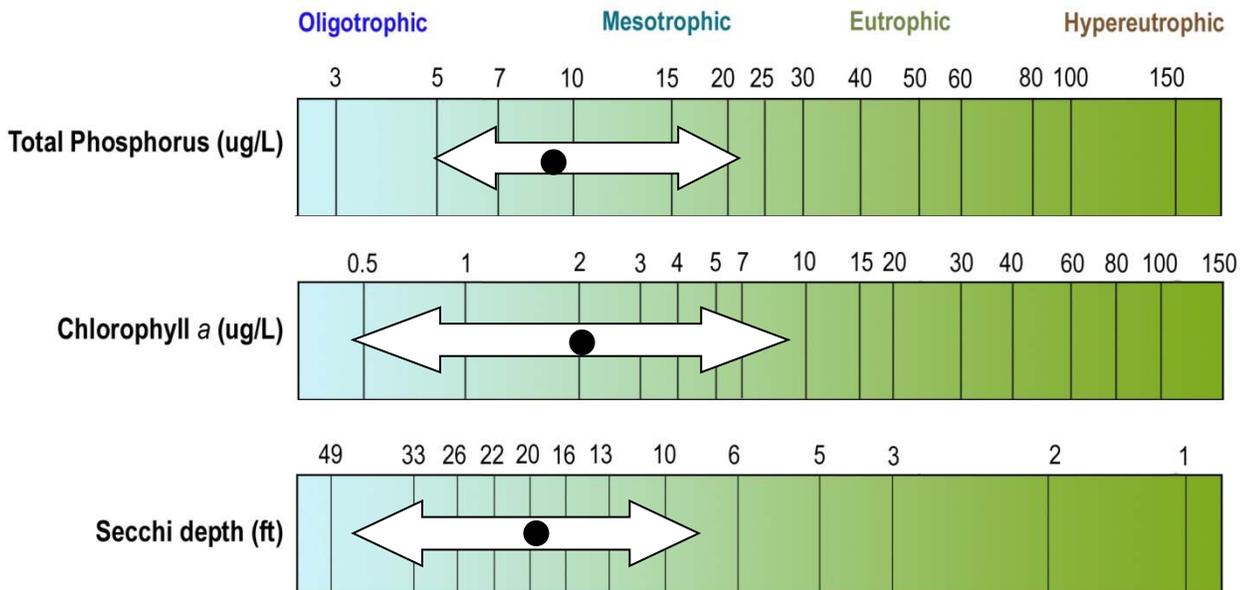


Figure 2. Big Sand Lake total phosphorus, chlorophyll a and transparency historical ranges. The arrow represents the range and the black dot represents the historical mean (Primary Site 207). Figure adapted after Moore and Thornton, [Ed.]. 1988. Lake and Reservoir Restoration Guidance Manual. (Doc. No. 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 means for Big Sand Lake range from 10.8 - 29.8 ft (Figure 3). The transparency pattern is very interesting in Big Sand Lake, as the annual mean transparencies are low in the 1990s and very high in the 2000s. See the recommendations (page 18) for more explanation on trends. Transparency monitoring should be continued at all three sites to track water quality in Big Sand Lake.

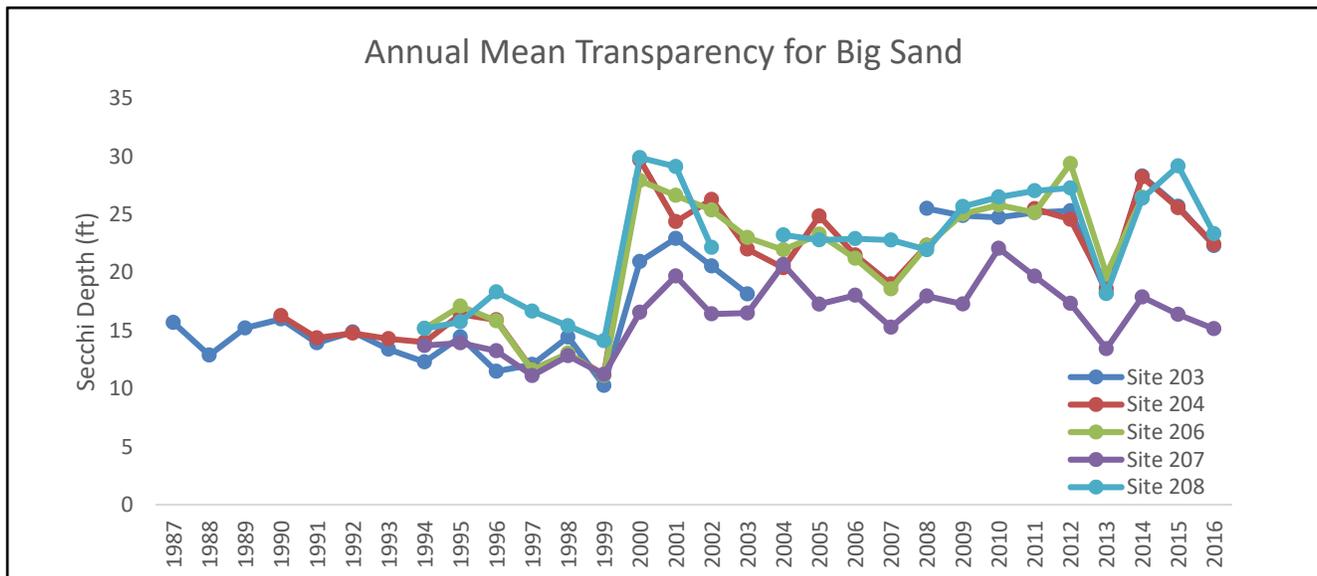


Figure 3. Annual mean transparency for sites 203, 204, 206, 207 and 208.

Big Sand Lake transparency ranges from 8 to 45 feet throughout the summer. Figure 4 shows the seasonal transparency dynamics. The maximum Secchi reading is usually obtained in early summer. Big Sand Lake transparency is high in May and June and depending on the year, may decline slightly through August. When transparency was measured in late September and October the transparency rebounded. 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 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

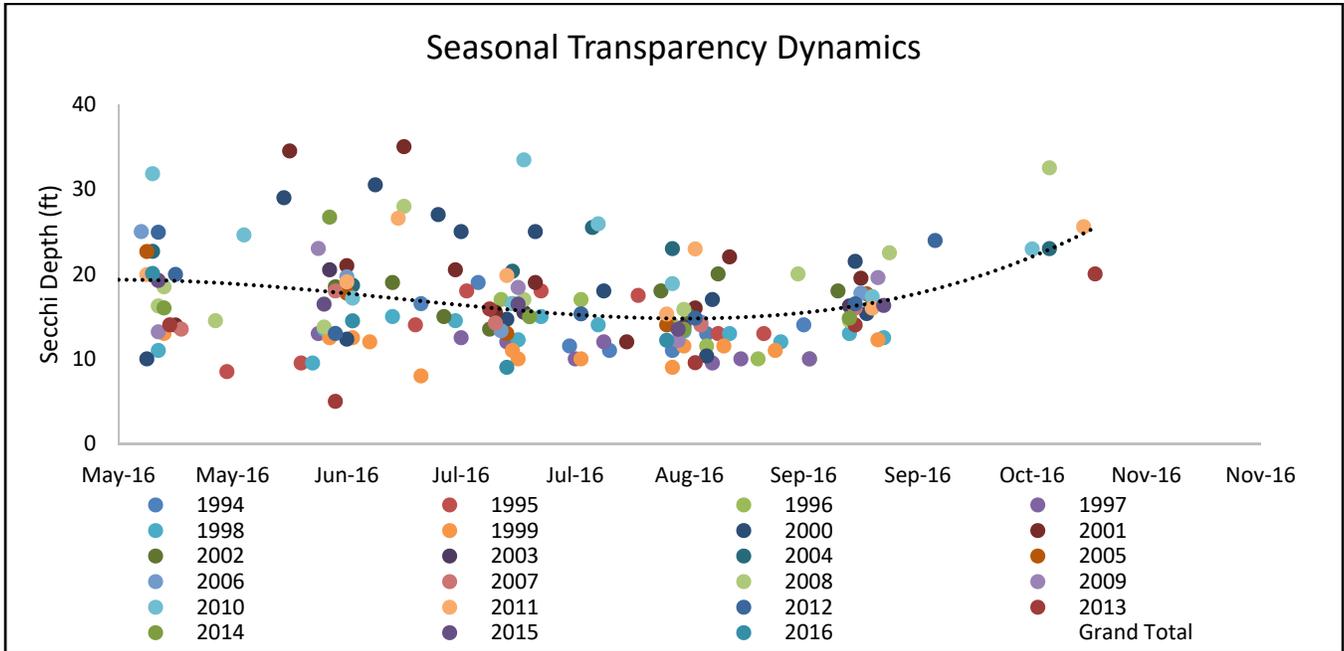


Figure 4. Seasonal transparency dynamics and year-to-year comparison, 1994-2016 (site 207). The black line represents the pattern in the data.

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 Sand Lake was rated as being "crystal clear" 41% of the time between 1994-2016 (Figure 5).

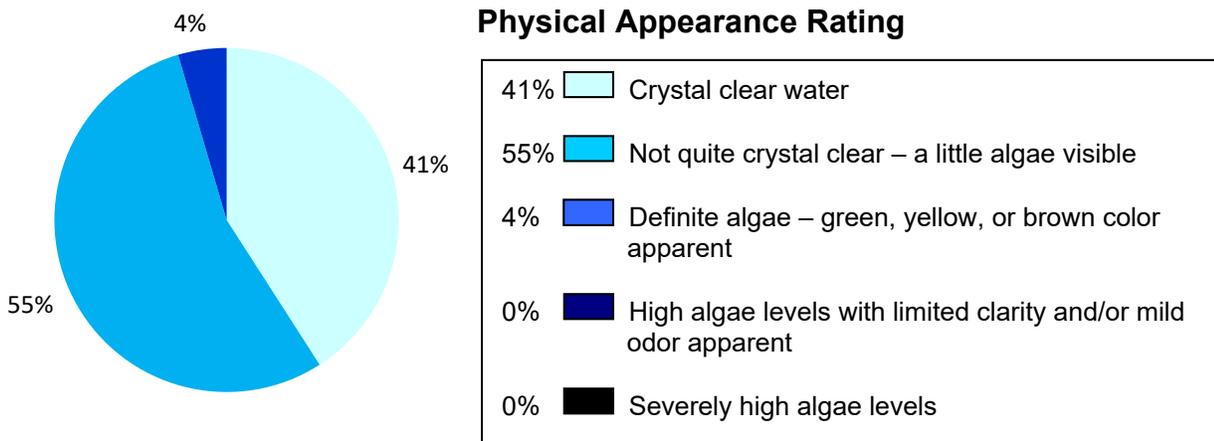


Figure 5. Physical appearance rating, as rated by the volunteer monitor.

As the secchi depth decreases, the perception of recreational suitability of the lake decreases. Big Sand Lake was rated as being "beautiful" 69% of the time from 1994-2016.

Recreational Suitability Rating

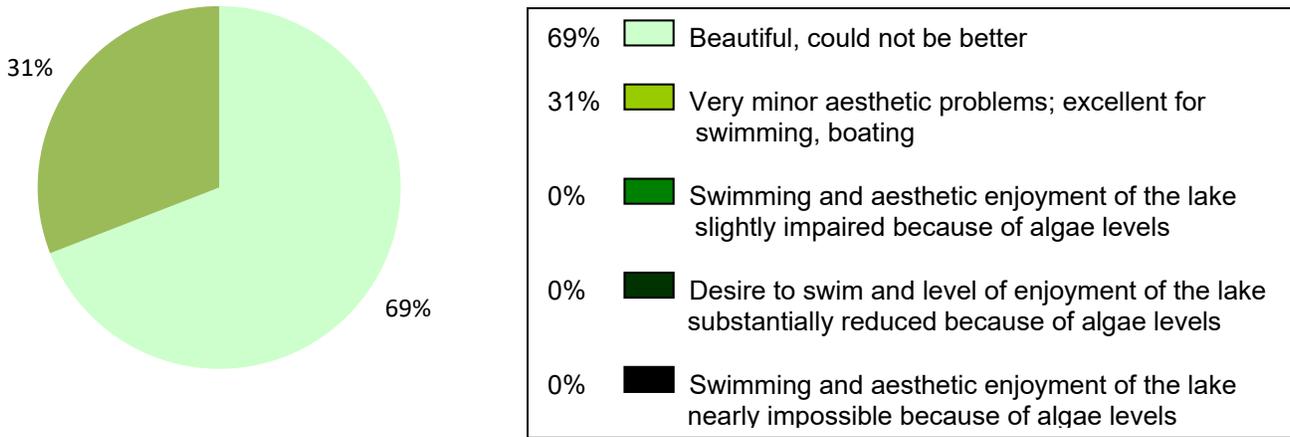


Figure 6. Recreational suitability rating, as rated by the volunteer monitor.

Total Phosphorus

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

Total phosphorus was evaluated in Big Sand Lake in 1998-2016. Most of the data points fall into the oligotrophic range (Figure 7). There is not much seasonal variation in phosphorus concentration for Big Sand Lake.

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

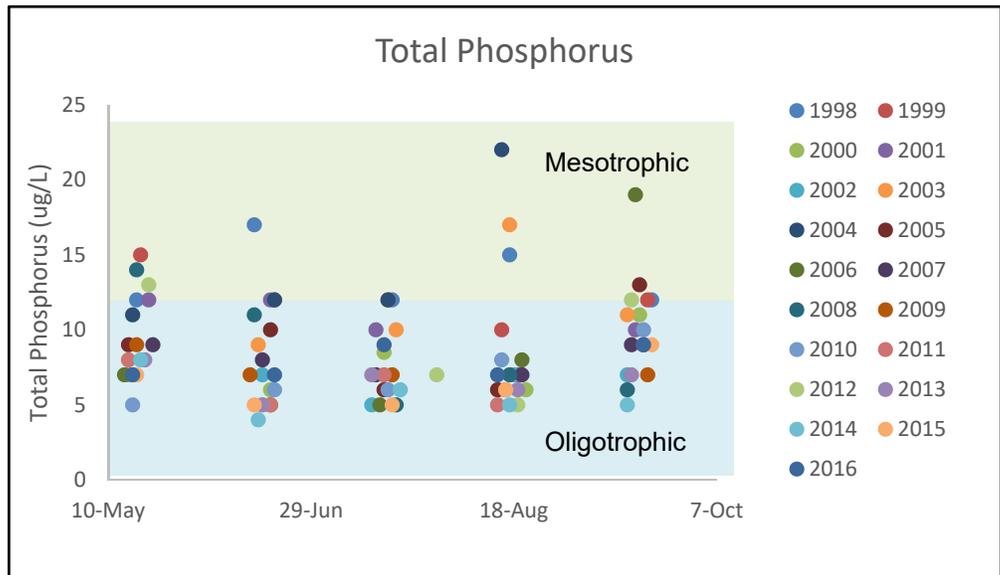


Figure 7. Historical total phosphorus concentrations (ug/L) from 1998-2016 at site 207 for Big Sand Lake.

Chlorophyll *a*

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

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

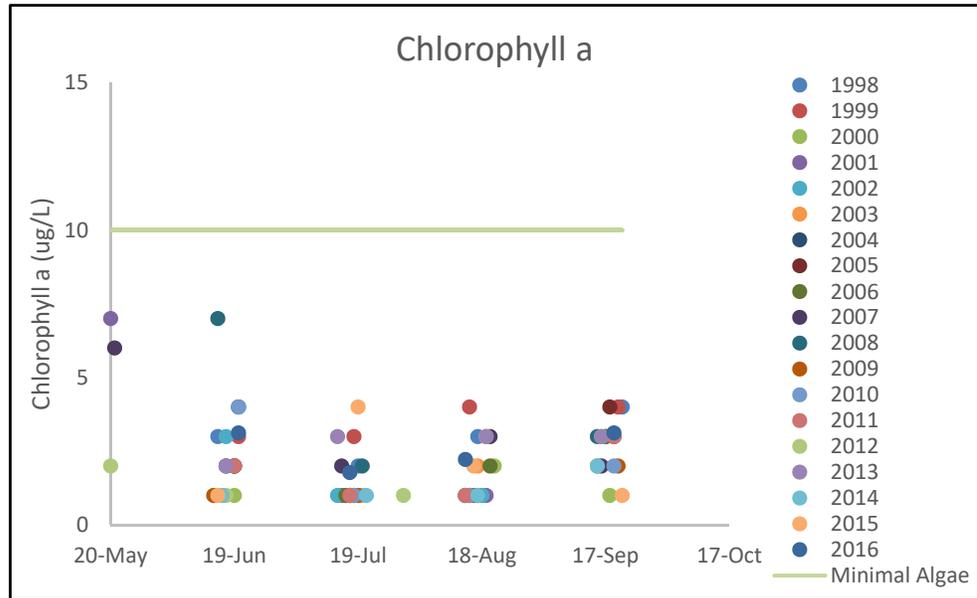
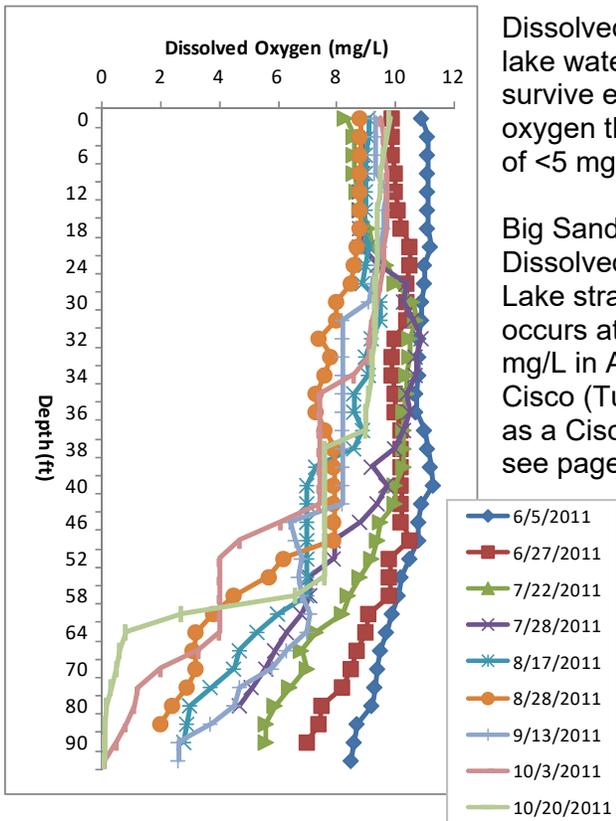


Figure 8. Chlorophyll *a* concentrations (ug/L) for Big Sand Lake, 1998-2016, site 207.

Chlorophyll *a* was evaluated in Big Sand Lake in 1998-2011 (Figure 8). Chlorophyll *a* concentrations remained well below 10 ug/L, indicating clear water all summer and no nuisance 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 Sand Lake is a deep lake, with a maximum depth of 135 ft. Dissolved oxygen profiles from 2011 indicate that Big Sand Lake stratifies in the summer (Figure 9). The thermocline occurs at 46-58 feet, although the oxygen only drops below 5 mg/L in August and September. This is excellent habitat for Cisco (Tullibee) fish. Big Sand Lake is designated by the DNR as a Cisco refuge lake. To read more about this designation, see page 16.

Figure 9. Dissolved oxygen profiles for Big Sand Lake in 2011, DNR.

11 Years of Dissolved Oxygen (DO) / Temperature Monitoring at Big Sand Lake

The attached chart shows the results of dissolved oxygen (DO) and temperature sampling from 2007 through 2017. The black shaded areas show the bottom layer of water with DO levels less than 3 ppm. The dark gray shaded areas show the upper layer of water with temperature exceeding 68° F. The light gray shaded areas show the middle layer of water with conditions suitable for Cisco because temperatures were lower than 68° and DO was higher than 3 ppm.

When sampling starts in May or June, the lake is still somewhat mixed from the spring “turnover”, so temperatures are low and fairly uniform from top to bottom. As surface water warms during the summer, the layer of water exceeding 68° F gets deeper. 2012 and 2016 were warmer summers, when the layer exceeding 68° went down to 35 feet or deeper in late August or early September. 2008, 2013, 2014 and 2017 were cooler summers. Surface water exceeded 68° for a shorter period or only down to 30 feet or less.

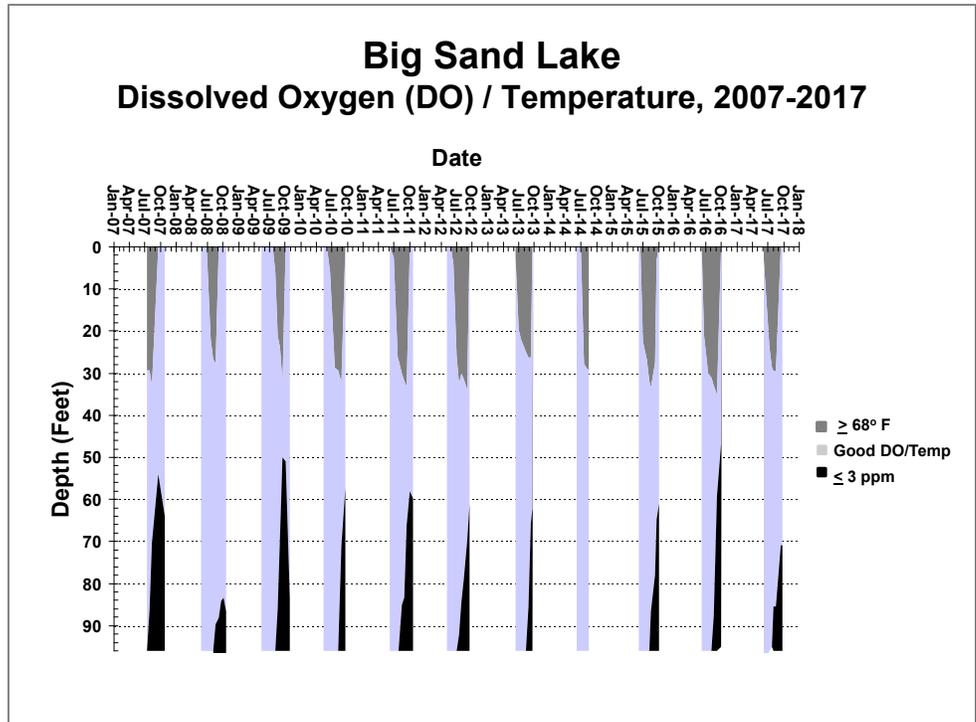


Figure 10. Big Sand Lake dissolved oxygen monitoring, 2007-2017, MN DNR.

Similarly, when sampling starts in May or early June, DO levels are high and fairly uniform from top to bottom. As the summer progresses, oxygen is consumed by organic matter decomposing on the lake bottom. As more oxygen is consumed, the bottom layer of water with DO levels less than 3 ppm increases and water with DO greater than 3 ppm gets shallower. 2008 was the worst year for low DO, when only the upper 43 feet of water had DO greater than 3 ppm in late September. 2014 might have been one of the best years, when water had DO greater than 3 ppm all the way to the bottom every time it was sampled. Later in the season, as water temperature cools and the water column mixes, DO is distributed throughout the water column and DO levels increase again in the lower layer of water.

As the two layers of unsuitable habitat for Cisco increase in mid to late summer, the middle layer of suitable Cisco habitat, where temperatures are less than 68° F and DO is greater than 3 ppm, gets narrower. If the layers of unsuitable Cisco habitat get too large and reach each other or overlap, and the layer of suitable habitat is depleted, a fish kill of Cisco will likely occur. So far, we haven't seen that type of situation in Big Sand during the years that have been monitored.

It will be good to continue monitoring DO and temperature in Big Sand Lake to look for even more extreme situations or long-term trends. Increasing oxygen consumption resulting from unregulated development or other poor land use practices, or increasing temperatures as a result of climate change, could lead to less habitat for Cisco and increased potential for fish kills. Monitoring will help look for those types of long term trends.

If there are questions about this information, you can contact:

Doug Kingsley, MN DNR Area Fisheries, 218-732-4153, doug.kingsley@state.mn.us

Trophic State Index

Phosphorus (nutrients), chlorophyll *a* (algae concentration) and Secchi depth (transparency) are related. As phosphorus increases, there is more food available for algae, resulting in increased algal concentrations. When algal concentrations increase, the water becomes less transparent and the Secchi depth decreases.

The results from these three measurements cover different units and ranges and thus cannot be directly compared to each other or averaged. In order to standardize these three measurements to make them directly comparable, we convert them to a trophic state index (TSI).

The mean TSI for Big Sand Lake falls into the oligotrophic range (Figure 11). There is good agreement between the TSI for phosphorus, chlorophyll *a* and transparency, indicating that these variables are strongly related (Table 5).

Oligotrophic lakes are characteristic of clear water throughout the summer and are excellent for recreation (Table 6). They have very low nutrient levels and sandy/rocky shores. If there is enough hypolimnetic oxygen, trout can survive.

Table 5. Trophic State Index.

Trophic State Index	Site 204
TSI Total Phosphorus	36
TSI Chlorophyll-a	35
TSI Secchi	36
TSI Mean	36
Trophic State:	Oligotrophic

Numbers represent the mean TSI for each parameter.

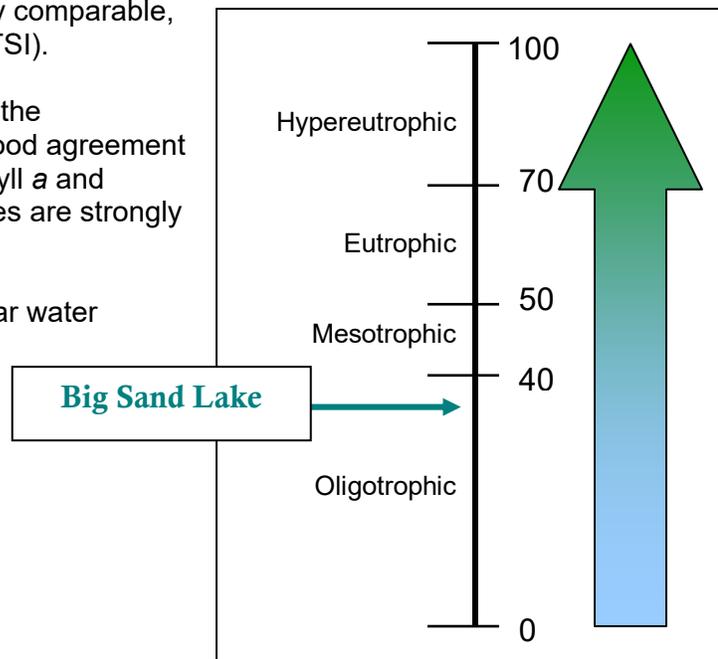


Figure 11. Trophic state index chart with corresponding trophic status.

Table 6. Trophic states and corresponding lake and fishery conditions.

TSI	Attributes	Fisheries & Recreation
<30	Oligotrophy: Clear water, oxygen throughout the year at the bottom of the lake, very deep cold water.	Trout fisheries dominate
30-40	Bottom of shallower lakes may become anoxic (no oxygen).	Trout fisheries in deep lakes only. Walleye, 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.

There is enough historical data to perform trend analysis for total phosphorus, chlorophyll *a*, and transparency on Big Sand Lake (Table 7). The data was analyzed using the Mann Kendall Trend Analysis.

Table 7. Trend analysis for Big Sand Lake.

Lake Site	Parameter	Date Range	Trend	Probability
207	Transparency	1994-2016	Improving	99%
207	Total Phosphorus	1998-2016	Improving	95%
207	Chlorophyll <i>a</i>	1998-2016	No trend	-

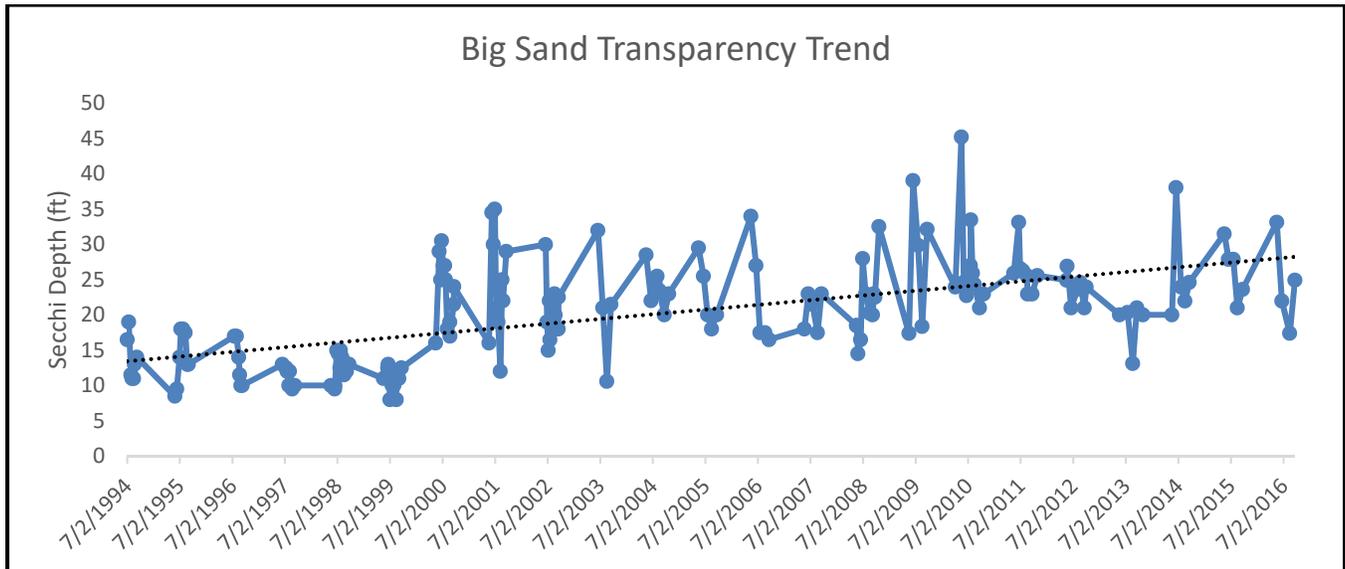


Figure 12. Long-term and short-term transparency trends for site 207 in Big Sand Lake, 1994-2016.

Site 207 shows a statistically significant improving trend in transparency from 1994-2016 (Figure 12). There is also an improving trend in phosphorus, which means that phosphorus concentrations are getting lower. Monitoring should continue at site 207 so that this trend can be tracked in future years. See the recommendations (page 18) for a discussion as to possible causes of the improving trends.

Ecoregion Comparisons

Minnesota is divided into 7 ecoregions based on land use, vegetation, precipitation and geology (Figure 13). 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.

Big Sand Lake is in the Northern Lakes and Forests Ecoregion. The means for phosphorus, chlorophyll a and transparency are better than the ecoregion ranges (Fig 14).

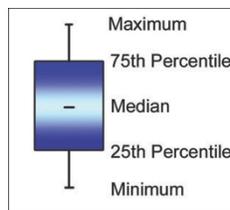
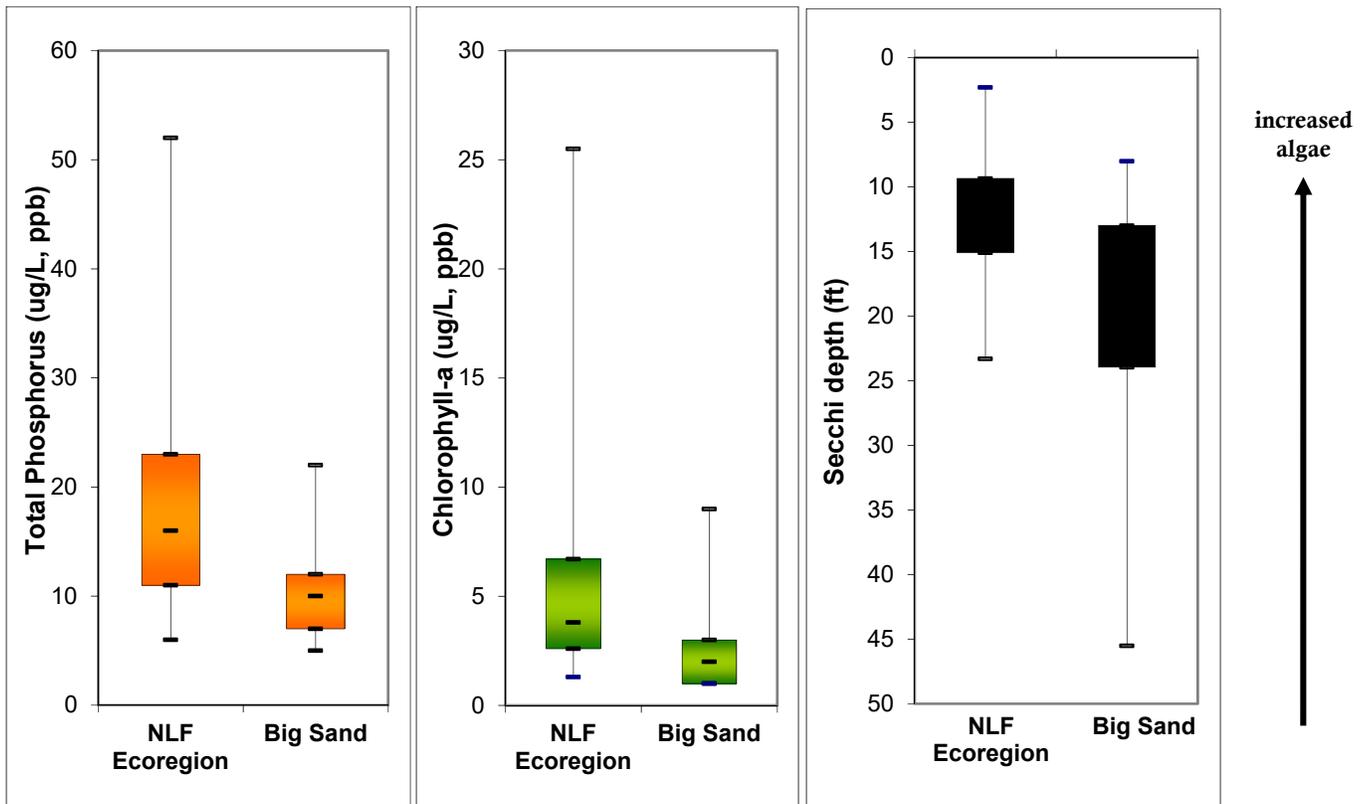


Figure 13. Map of Minnesota with the seven ecoregions.



Figures 14a-c. Big Sand Lake ranges compared to Northern Lakes and Forest Ecoregion ranges. The Big Sand Lake total phosphorus and chlorophyll a ranges are from 73 data points collected in May-September of 1998-2011. The Big Sand Lake Secchi depth range is from 171 data points collected in May-September from 1994-2011.

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 **Crow Wing River Major Watershed** is one of the watersheds that make up the Upper Mississippi River Basin, which drains south to the Gulf of Mexico (Figure 15). This major watershed is made up of 136 minor watersheds. Big Sand Lake is located in **minor watershed 12015** (Figure 16).

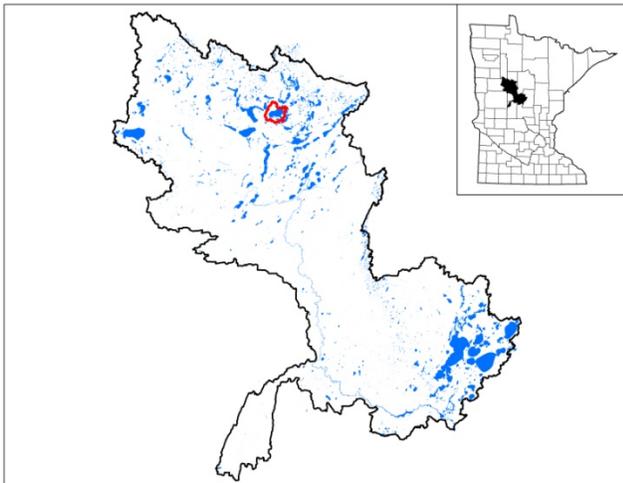


Figure 15. Crow Wing River Watershed

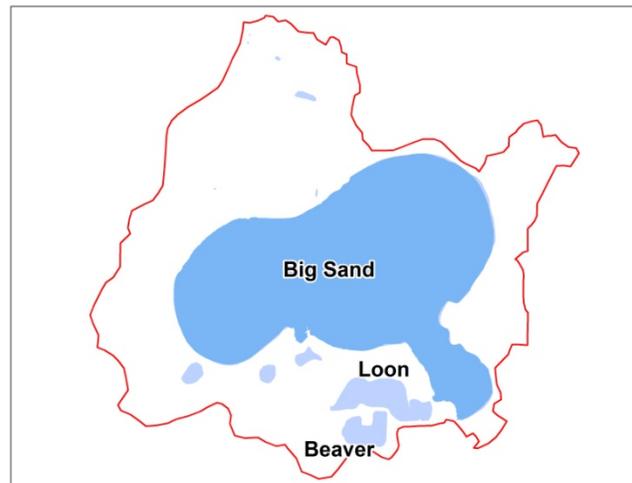


Figure 16. Minor watershed 12015.

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 Sand Lake falls within the **Big Sand (1201500) lakeshed** (Figure 17). 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 Sand Lake’s full watershed, containing all the lakesheds upstream of Big Sand Lake, see page 16.

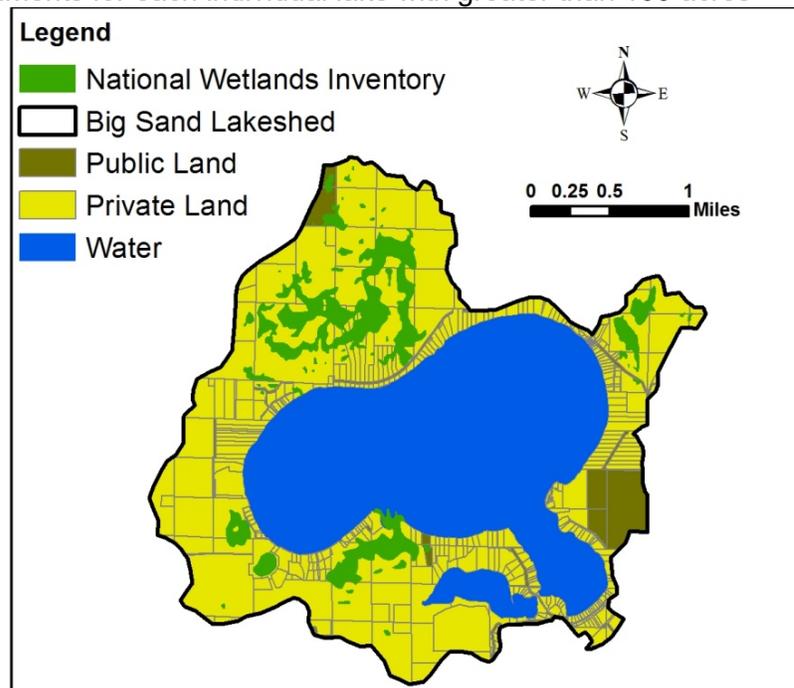


Figure 17. The Big Sand 1201500 Lakeshed with land ownership, lakes, wetlands, and rivers illustrated.

The data interpretation of the Big Sand Lake lakeshed includes only the immediate lakeshed, as that is the land surface that flows directly into Big Sand Lake.

The lakeshed vitals table (Table 8) identifies where to focus organizational and management efforts for each lake. 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 8. Lakeshed vitals for Big Sand Lake.

Lakeshed Vitals		Rating
Lake Area	1636 acres	descriptive
Littoral Zone Area	465 acres	descriptive
Lake Max Depth	135 ft.	descriptive
Lake Mean Depth	43.8 ft.	
Water Residence Time	NA	NA
Miles of Stream	0.9	descriptive
Inlets	2	
Outlets	1	
Major Watershed	12 - Crow Wing River	descriptive
Minor Watershed	12015	descriptive
Lakeshed	1201500	descriptive
Ecoregion	Northern Lakes and Forest	descriptive
Total Lakeshed to Lake Area Ratio (total lakeshed includes lake area)	3:1	
Standard Watershed to Lake Basin Ratio (standard watershed includes lake areas)	22:1	
Wetland Coverage	8%	
Aquatic Invasive Species	None	
Public Drainage Ditches	None	
Public Lake Accesses	1	
Miles of Shoreline	8.3	descriptive
Shoreline Development Index	1.5	
Public Land : Private Land (excludes water)	0.07:1	
Development Classification	Recreational Development	
Miles of Road	17.5	descriptive
Municipalities in lakeshed	None	
Forestry Practices	2002 Hubbard County Forest Resources Management Plan	
Feedlots	None	
Sewage Management	Individual waste treatment systems (last lake-wide county inspection - 1992)	
Lake Management Plan	Healthy Lakes & Rivers Partnership program, 2003	
Lake Vegetation Survey/Plan	None	

Land Cover / Land Use

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

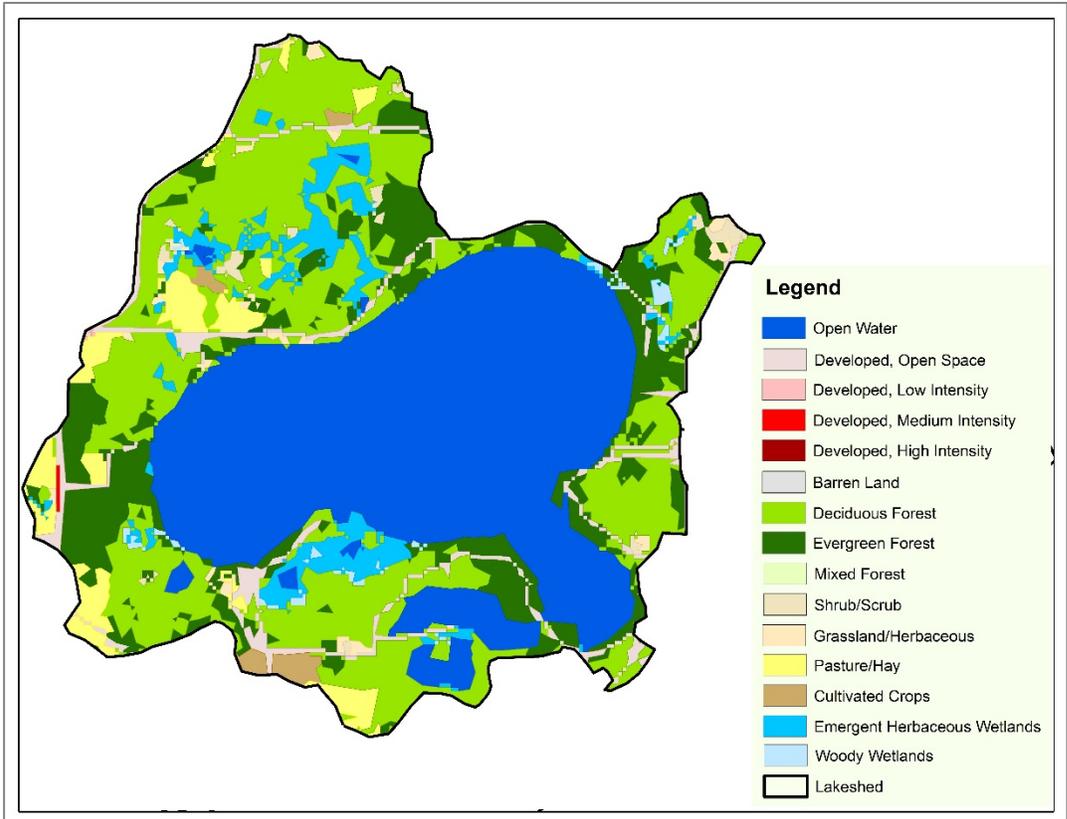


Figure 18. Big Sand lakeshed land use/land cover (www.land.umn.edu).

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

Phosphorus export, which is the main cause of lake eutrophication, depends on the type of land cover occurring in the lakeshed (Figures 18, 19).

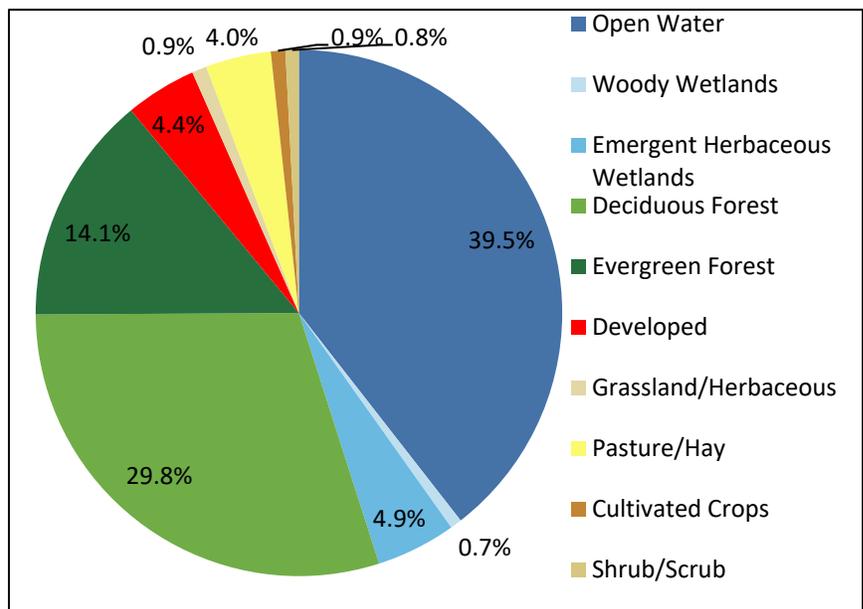


Figure 19. Percent cover of each land use in the Big Sand Lake lakeshed.

Demographics

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

The Minnesota Department of Administration Geographic and Demographic Analysis Division extrapolated future population in 5-year increments out to 2035. Compared to Hubbard County as a whole, Lake Emma Township has a higher extrapolated growth projection (Figure 20).

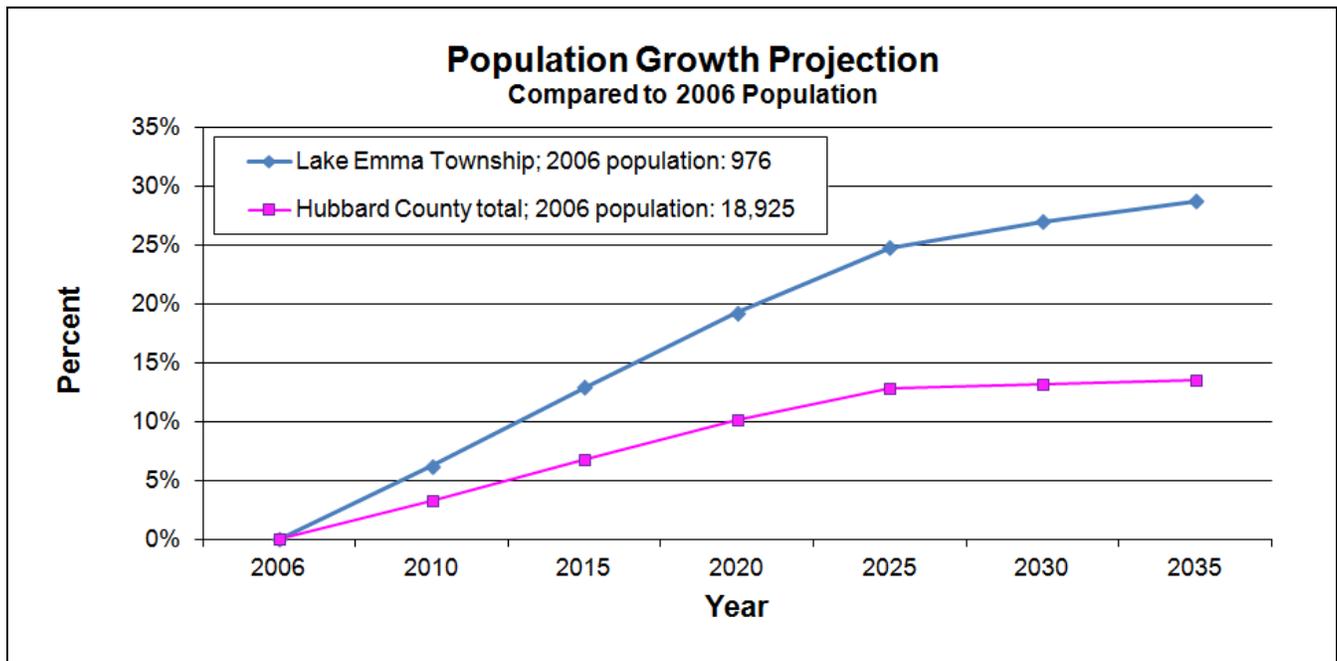
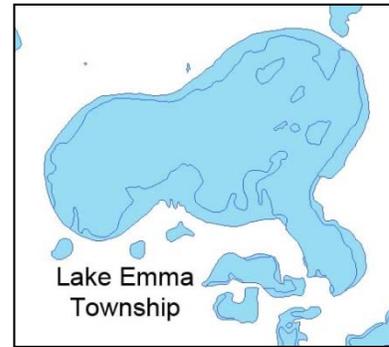


Figure 20. Population growth projection for Lake Emma Township and Hubbard County. (source: <http://www.demography.state.mn.us/resource.html?id=19332>)

Big Sand Lake 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 Sand Lake's lakeshed is made up of private forested uplands (Table 10). This land can be the focus of development and protection efforts in the lakeshed.

Table 10. Percent land use in private versus publicly owned land with corresponding phosphorus loading and protection/restoration ideas (Sources: 2011 National Land Cover Dataset and county parcel information).

	Private (57.6%)					39.2%	Public (3.2%)		
	Developed	Agriculture	Forested Uplands	Other	Wetlands	Open Water	County	State	Federal
Land Use (%)	3.8%	4.7%	42.6%	1.3%	5.1%	39.2%	2.3%	0.9%	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 * runoff coefficient	77 – 192	54 – 192	172		21		9.3	3.6	
Description	Focused on Shoreland	Cropland	Focus of development and protection efforts	Open, pasture, grassland, shrubland	Protected				
Potential Phase 3 Discussion Items	Shoreline restoration	Restore wetlands; CRP	Forest stewardship planning, 3 rd 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 11). Watershed disturbance was defined as having urban, agricultural and mining land uses. Watershed protection is defined as publicly owned land or conservation easement.

Table 11. 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.

Big Sand Lake was classified with having 42.5% of the watershed protected and 7.8% of the watershed disturbed (Figure 21). Therefore, Big Sand Lake should have a protection focus. Goals for the lake should be to limit any increase in disturbed land use. In addition, Big Sand Lake was designated by DNR Fisheries as a high valued fishery lake because of its cisco population.

Figure 22 displays the upstream lakesheds that contribute water to the lakeshed of interest. All of the land and water area in this figure has the potential to contribute water to Big Sand Lake, whether through direct overland flow or through a creek or river. All of the upstream lakesheds have a protection focus as well. Goals for this watershed should be to limit any increase in disturbed land use and implement Best Management Practices.

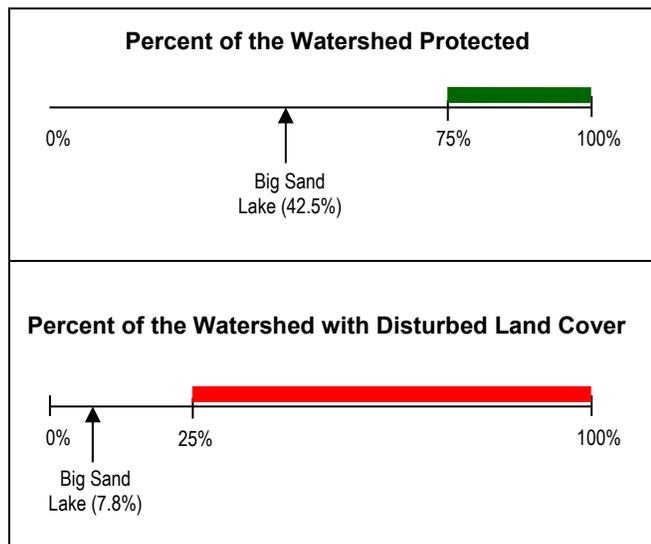


Figure 21. Big Sand Lake lakeshed's percentage of watershed protected and disturbed.

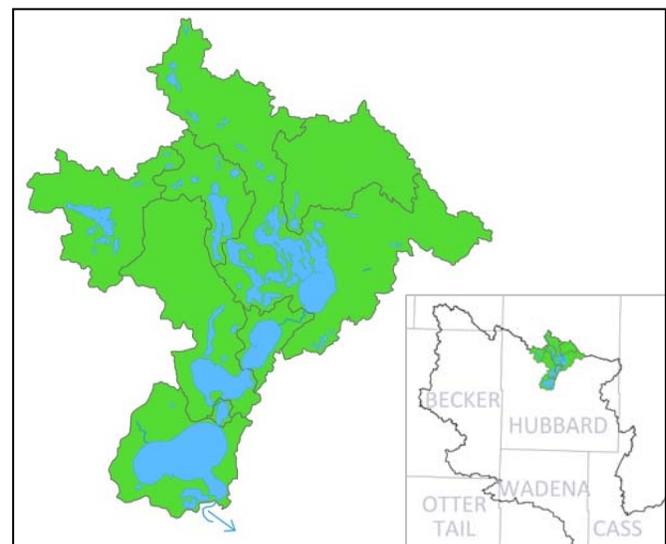


Figure 22. Upstream lakesheds that contribute water to the Big Sand lakeshed. Color-coded based on management focus (Table 3).

Big Sand, Status of the Fishery (as of 07/25/2011)

Big Sand is located 2.5 miles north of Dorset in Hubbard County. Big Sand has a surface area of 1,635 acres and a maximum depth of 135 feet. A public access is located on the southeast shore of the lake at the outlet. Access with small boats is also available from the inlet connecting to Lake Emma and from the outlet connecting to Lake Ida. Big Sand is noted for its outstanding walleye fishery. Big Sand has exceptional water clarity and lots of structure to challenge the angler. Big Sand has a protected slot length limit on walleye that requires the release of all walleye between 20 to 28 inches, with only one fish over 28 inches allowed in possession. An angler creel survey was conducted during the summer of 2011.

The Minnesota Department of Natural Resources (DNR) has classified Minnesota's lakes into 43 different types based on physical, chemical, and other characteristics. Big Sand is in lake class 22. Other area lakes in this same classification include: Lower Bottle, Kabekona, Long, and Potato.

Walleye abundance (9.2 walleye/gillnet) was above the current management goal, and similar to past surveys. Sampled walleye had an average length and weight of 13.7 inches and 1.0 pounds, with fish measured up to 24.8 inches. Multiple year classes and sizes of walleye were sampled, however, the 2007 and 2008 year classes were the strongest. Fall electrofishing surveys the past several years have shown excellent natural reproduction of walleye. Big Sand has several rock and rubble shoal areas that provide excellent walleye spawning habitat. In past years Big Sand was receiving light walleye fingerling stockings to supplement natural reproduction. Walleye stocking was discontinued after 2004, when evaluations indicated natural reproduction could sustain the population.

Yellow perch and tullibee (cisco) provide an important forage base for walleye in Big Sand. Yellow perch were sampled in low numbers, with the gillnet catch rate of 4.1 perch/gillnet below the range "typical" for this lake class. Yellow perch abundance in past surveys has generally fluctuated within this "typical" range. Tullibee (cisco) were not sampled in 2011. Summer gillnet sampling of tullibee (cisco) can be quite variable and gillnet catch rates in past surveys have fluctuated widely from low to high abundance. Some local anglers have expressed concern about low numbers of tullibee in Big Sand the past decade. Anglers are not observing schools of tullibee on their graphs or seeing them surface in the evenings as had been common in the 1970's and 1980's. Anglers have also commented about the absence of larger walleye (> 25 inches). It is unknown whether low abundance of yellow perch and tullibee and changes in walleye growth, condition and size structure are a trend or normal fluctuations of those populations, and whether the changes were caused by the walleye regulation (slot length limit) or other environmental factors.

Big Sand has a low northern pike population, however, it is known for producing some large-sized pike. Northern pike abundance was below the range "typical" for this lake class, but similar to past surveys. Northern pike up to 36.2 inches were sampled. Tullibee (cisco) and white sucker provide an excellent forage base for growing large pike. Both smallmouth bass and largemouth bass are present in Big Sand, with smallmouth bass the more abundant of the two species. Big Sand has excellent smallmouth bass habitat of rock, rubble, and sand bottom areas. Good numbers and sizes of these "brown bass" are present in Big Sand. Largemouth bass are present in low to moderate numbers and are concentrated in areas of preferred largemouth bass habitat.

Panfish abundance was up from past surveys. Bluegill were sampled at their highest abundance (33.2 bluegill/trapnet) for all surveys on Big Sand. Bluegill abundance in surveys prior to 2000 was low, generally below the range "typical" for this lake class. Anglers will find bluegill in the 6-7 inch size range. Black crappie abundance was up slightly from past surveys, but still low compared to other area lakes. Black crappie have been sampled in very low numbers in past surveys. Rock bass were abundant, with catch rates well above the range "typical" for this lake class. Angler comments from the

2011 summer creel expressed concern about an overly-abundant and possibly increasing rock bass population. Rock bass trapnet catch rates have been high for all surveys, however, gillnet catch rates have been very high since 2001.

Other species sampled include moderate numbers of yellow bullhead and white sucker, and low numbers of pumpkinseed.

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=29018500>.

Lake Water Levels

Lake water levels have been monitored from 1960-2017. The graph below shows the past 10 years of water level data (Figure 23).

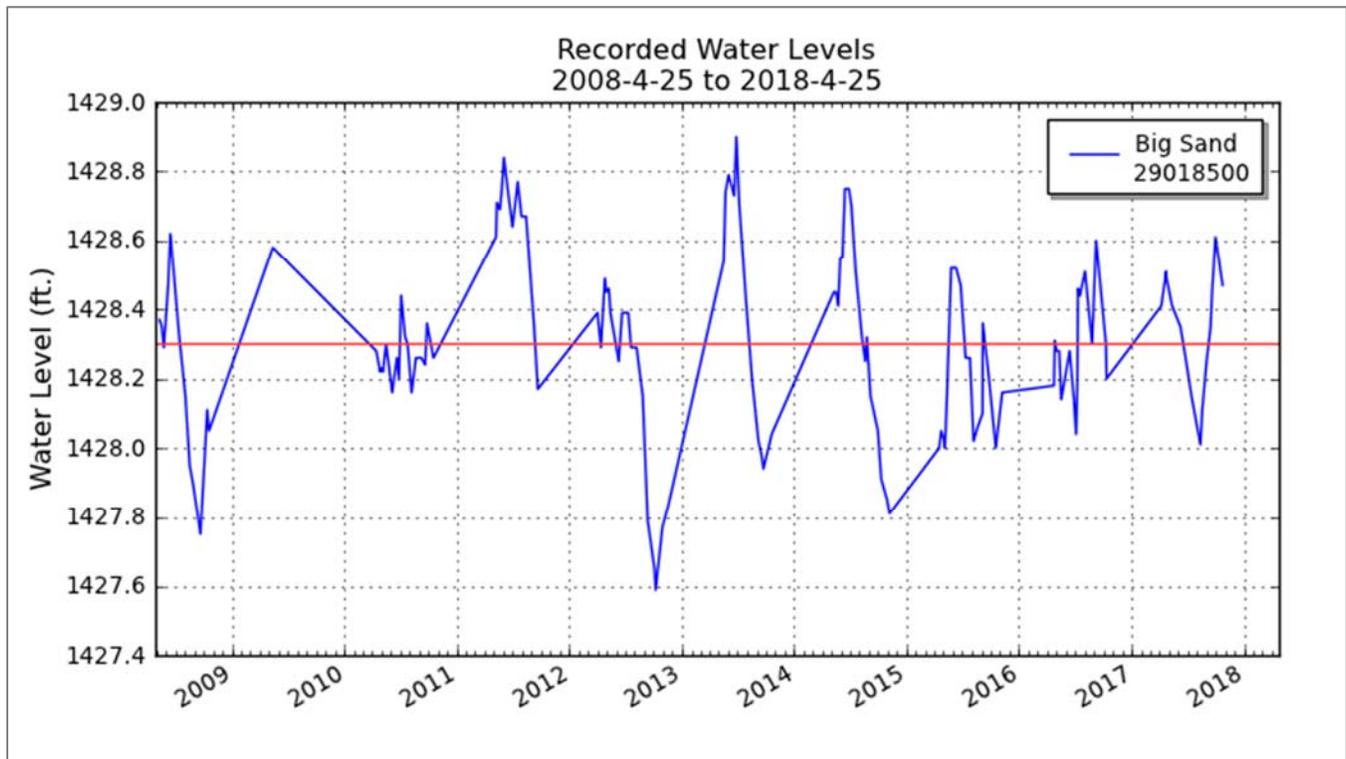


Figure 23. Big Sand Lake water levels, MN DNR.

Big Sand Submergent Vegetation Summary, 2009

Surveyors: Don and Ivy Douglas

Date: July 8 thru July 31, 2009 - 37 hours

Methods and Material

Northwood 19 foot pontoon, Garmin GPS Map 76, rake and rope collection, point-intercept grid.

Field Observations

Additional survey samples were obtained in situations where grid point intersection was devoid of vegetation. Rich vegetation beds within 20 yards were sampled and included in a separate vegetation sheet.

There were 995 points mapped for sampling, but only locations 37 feet deep or less had vegetation. Points deeper than 37 feet were not included in the summary below. The five most common plants were: muskgrass (at 51% of sites), largeleaf pondweed (4% of sites), Illinois pondweed (4% of sites), bulrush (3% of sites), and narrowleaf pondweed (3% of sites). Fifty-two percent of the sites sampled at 37 feet or less had vegetation present.

Submerged aquatic plants noted that were not on the grid intercept points:

- Canadian waterweed
- Water stargrass,
- Submersed brown-fruited rush
- Northern watermilfoil
- Leafy pondweed
- Fries' pondweed
- White water-crowfoot
- Common sago pondweed



Vegetation species or type:	Number of locations found	Percent of all locations sampled (777 sites)	Percent of locations with vegetation (404 sites)
Chara, muskgrass	397	51.1	98.3
Largeleaf pondweed	30	3.9	7.4
Illinois Pondweed	27	3.5	6.7
Bulrush	22	2.8	5.4
Narrowleaf Pondweed	21	2.7	5.2
Coontail	13	1.7	3.2
Whitestem Pondweed	9	1.2	2.2
White water buttercup	9	1.2	2.2
northern water milfoil	5	0.6	1.2
Bushy pondweed	4	0.5	1.0
Can.waterweed, Elodea	3	0.4	0.7
Wild Celery	3	0.4	0.7
Leafy Pondweed	2	0.3	0.5
Bladderwort	1	0.1	0.2
Flatstem Pondweed	1	0.1	0.2
Sheathed Pondweed	1	0.1	0.2

SUMMARY:	Number of locations present	Percent of all locations sampled (777 sites)	Percent of locations with vegetation (404 sites)
Number of sites with emergent vegetation	22	2.8	5.4
Number of sites with floating leaf vegetation	0	0.0	0.0
Number of sites with submerged vegetation	403	51.9	99.8
Total number of locations with vegetation	404	52.0	100.0
Number of locations that did NOT have any vegetation	373	48.0	92.3
Number of locations sampled*	777	100.0	192.3
*All sites 37 feet deep or less. No vegetation was found at locations deeper than 37 ft.			

NOTE: Total number of locations sampled (includes locations deeper than 37 ft).	995
---	-----

For the full report with species maps, please visit the Big Sand Lake website at <http://www.bigsandlake.org>.

Key Findings / Recommendations

Monitoring Recommendations

Transparency monitoring at site 207 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. Phosphorus and chlorophyll a monitoring should continue, as the budget allows, to track future water quality trends.

Although zebra mussels have not been discovered in Big Sand Lake to date, lake residents should be vigilant to make sure that their boats, docks, and hoists are zebra mussel-free prior to entering the lake. Zebra mussels, and other aquatic invasive species, can dramatically change the lake ecosystem if they establish populations in Big Sand Lake. Water quality (e.g. Secchi depth, chlorophyll a, and total phosphorus) can change significantly when zebra mussels become established in a lake, altering the fisheries and creating problems near shore (e.g. sharp shells can hurt when stepped on).

Overall Conclusions

Big Sand Lake is an outstanding water resource. It is an oligotrophic lake (TSI=36) with an improving water quality trend in both transparency and phosphorus. The DNR has designated Big Sand Lake as a Cisco refuge lake, which requires cold deep water with high dissolved oxygen levels. Nearly half (42%) of the watershed is protected, while only 7.8% of the watershed is disturbed (Figure 20). Another 42% of the land is private forested uplands, which is good for water quality (Table 10).

The improving water quality trend in Big Sand Lake is very significant since the year 2000 (Figure 11). From 1994-1999, the transparency averaged 12.5 feet, while from 2000-2016, the transparency has averaged 23.5 feet. The dramatic improvement that occurred in 2000 has been maintained since then. It is difficult to pinpoint exactly what caused this improvement; however, there are some potential options. In 1992, the county did a lakewide septic system upgrade program. It usually takes a few years for these upgrades to be completed and implemented, which could explain the delayed water quality improvement.

Priority Impacts to the Lake

Overall, the lake's water quality has been maintained and improving. However, this does not mean the lake is resistant to future changes in water quality. Because Big Sand Lake is such an outstanding water resource and fishery, there is a high degree of development pressure. From 1990-2000, the impervious surface area increased by 104% (25 acres). Development in the lakeshed has occurred primarily along the shoreline. The population in Lake Emma Township is projected to grow another 25% in the next 10 years (Figure 19).

In addition, the DNR fisheries report indicates a possible concern with the Cisco fishery (page 17). A decline in ciscos could indicate eutrophication in a lake. So far, Big Sand Lake is not showing signs of eutrophication.

Best Management Practices Recommendations

The management focus for Big Sand Lake should be to protect the current water quality. Protection 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.

Almost half of the lakeshed is privately owned forested uplands (Table 10). Forested uplands can be managed with Forest Stewardship Planning, 3rd party certification, SFIA, and local woodland cooperatives. Contact the Soil and Watershed Conservation District for options for managing private forests.

The lakeshed still has some of the shoreline in large undeveloped parcels (Figure 24). 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.

Project Implementation

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

Individual property owners

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

Lake Associations

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

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

- Shoreline restoration
- Stream buffers
- Wetland restoration
- Forest stewardship planning

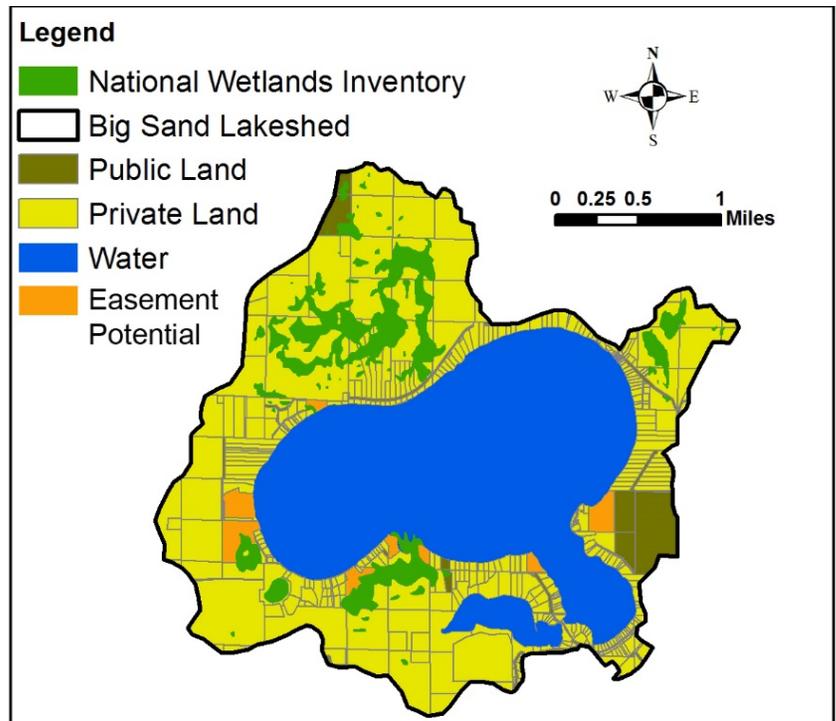


Figure 24. Big Sand Lake Lakeshed with Conservation Easement locations highlighted in orange.

Organizational contacts and reference sites

Big Sand Lake Association	P.O. Box 181 Park Rapids, MN 56470 info@bigsandlake.org http://www.bigsandlake.org
DNR Fisheries Office	301 South Grove Avenue, Park Rapids, MN 56470 218-732-4153 parkrapids.fisheries@state.mn.us http://www.dnr.state.mn.us/areas/fisheries/parkrapids/index.html
Regional Minnesota Pollution Control Agency Office	714 Lake Ave., Suite 220, Detroit Lakes, MN 56501 218-847-1519, 1-800-657-3864 http://www.pca.state.mn.us/yhiz3e0
Hubbard County Soil and Water Conservation District	212 1/2 2nd St W, Park Rapids MN 56470 218-732-0121 http://www.hubbardswcd.org/