Big McDonald Lake 56-0386-01 OTTER TAIL COUNTY

Lake Water Quality

Summary

Big McDonald Lake is located 6 miles northwest of Dent, MN in Otter Tail County. It is a long and narrow lake covering 992 acres (Table 1).

Big McDonald Lake has no major inlets or outlets, which characterizes it as a groundwater seepage lake. It has a connection with McDonald Lake to the east and West McDonald Lake to the west. It also flows south into Archie Lake, but that lake is not connected to any other water bodies.

Water quality data have been collected on Big McDonald Lake in 1990-1991 and 1996-2012 (Tables 2 & 3). These data show that the lake is mesotrophic (TSI = 41) with clear water conditions most of the summer and excellent recreational opportunities.

The Big McDonald Lake Association is involved in many activities including water quality monitoring, education, and is a member of the Otter Tail County Lakes Association (DCLA). Big McDonald Lake is also in the process of forming a Lake Improvement District, which has taxing authority on lakeshore owners.

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

Location Data	
MN Lake ID:	56-0386-01
County:	Otter Tail
Ecoregion:	North Central Hardwood Forests
Major Drainage Basin:	Red River Basin
Latitude/Longitude:	46.579, -95.767
Invasive Species:	None as of 2013

Physical Characteristics	
Surface area (acres):	992
Littoral area (acres):	368
% Littoral area:	37
Max depth (ft), (m):	46, 14
Inlets:	2
Outlets:	1
Public Accesses:	1

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

Data Availability		
Transparency data		Excellent data source from 1990-1991 and 1996-2012
Chemical data		Excellent data source from 1996-2012
Inlet/Outlet data	--	Not necessary due to no major inlets or outlets.

Recommendations **For recommendations refer to page 19.**

Lake Map

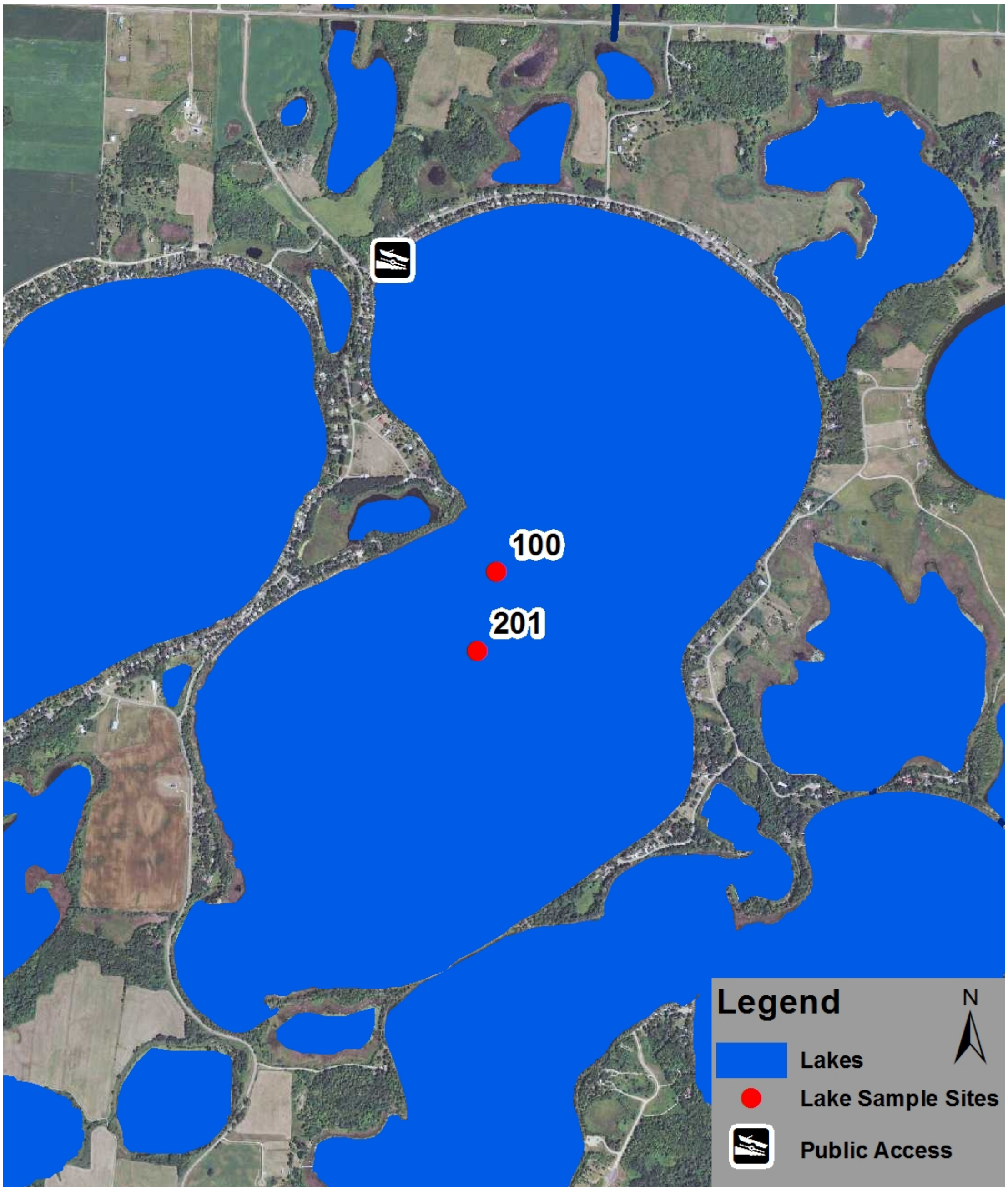


Figure 1. Map of Big McDonald Lake with 2010 aerial imagery, sample site locations, inlets and outlets, and public access points. There is no bathymetry data available electronically for this lake.

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

Lake Site	Depth (ft)	Monitoring Programs
201* Primary site	25	CLMP: 1991, 2002-2006, 2008-2012; RMBEL: 1996-2012
100	NA	MPCA: 1990

Water Quality Characteristics - Historical Means and Ranges

Table 4. Water quality means and ranges for primary sites.

Parameters	Primary Site 201
Total Phosphorus Mean (ug/L):	**14.6**
Total Phosphorus Min:	5.0
Total Phosphorus Max:	37.0
Number of Observations:	121
Chlorophyll *a* Mean (ug/L):	**4**
Chlorophyll-a Min:	1
Chlorophyll-a Max:	11
Number of Observations:	122
Secchi Depth Mean (ft):	**16.4**
Secchi Depth Min:	9.0
Secchi Depth Max:	38.0
Number of Observations:	116

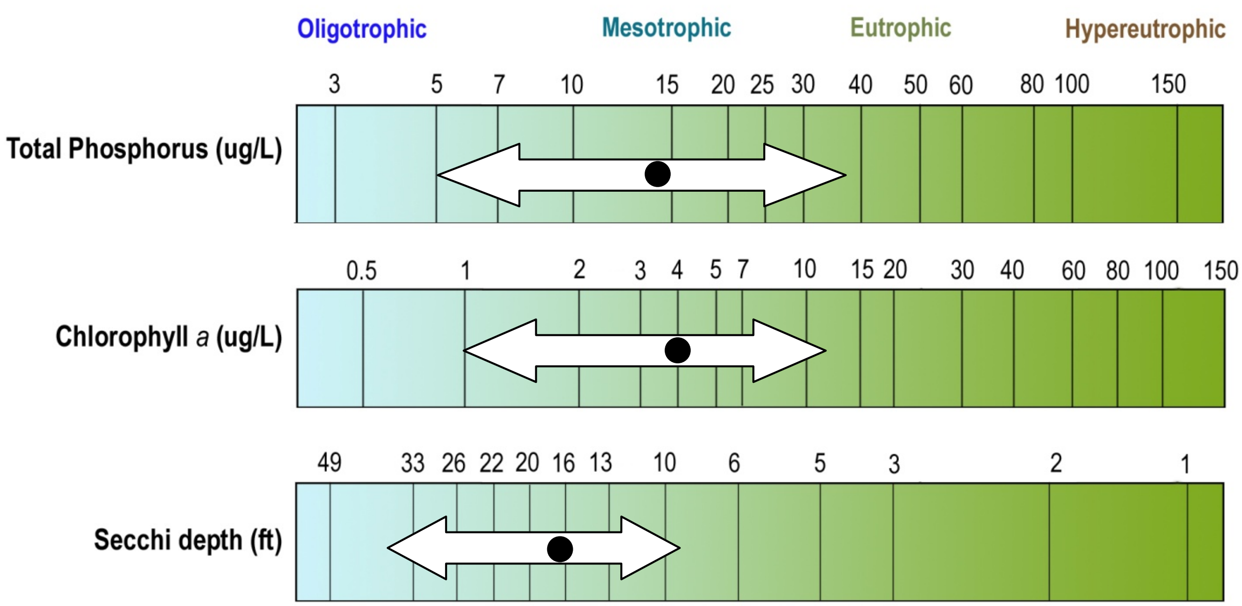


Figure 2. Big McDonald Lake total phosphorus, chlorophyll a and transparency historical ranges. The arrow represents the range and the black dot represents the historical mean (Primary Site 201). Figure adapted after Moore and Thornton, [Ed.]. 1988. Lake and Reservoir Restoration Guidance Manual. (Doc. 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 McDonald Lake ranges from 13.2 to 20.4 feet (Figure 3). The transparency at site 201 appears to be relatively consistent with an average Secchi reading of 16.4 feet between 1991 and 1996- 2012. Transparency monitoring should be continued every year at site 201 in order to track future changes in water quality.

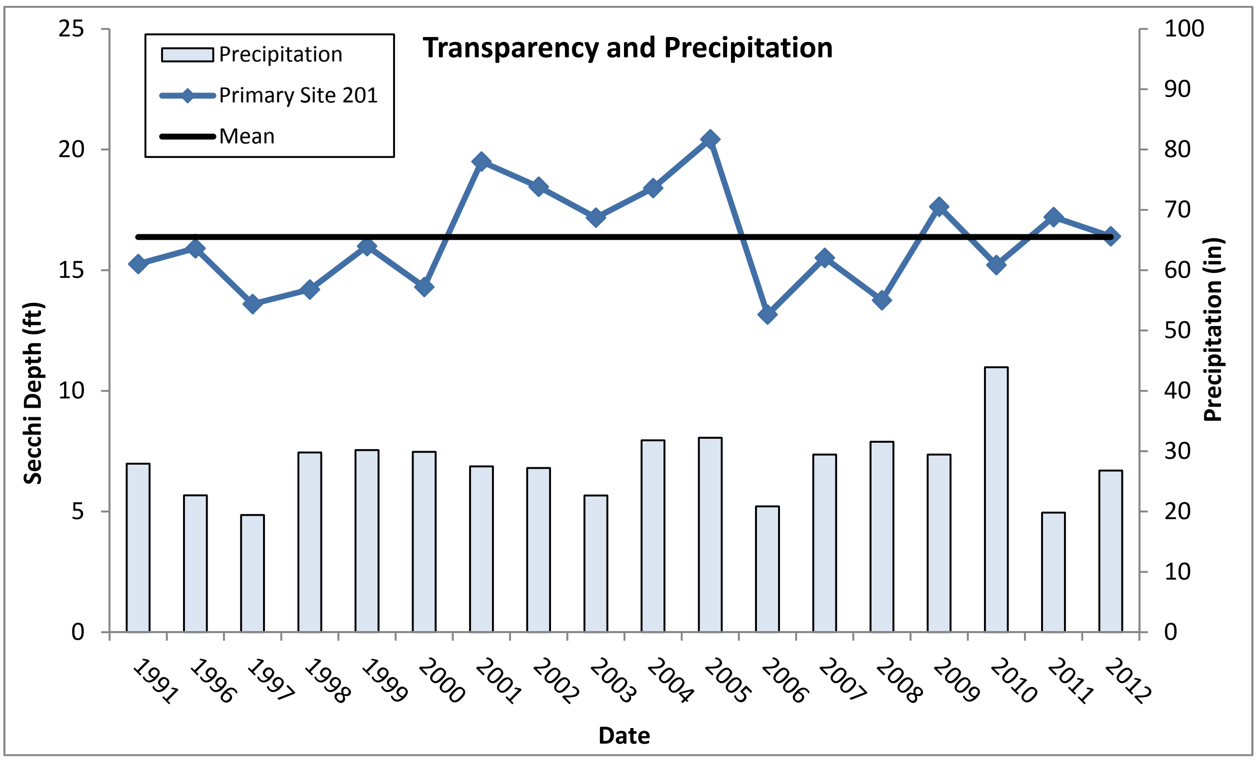


Figure 3. Annual mean transparency compared to long-term mean transparency.

Big McDonald Lake transparency ranges from 9.0 to 38 ft at the primary site (Table 4). Figure 4 shows the seasonal transparency dynamics. The maximum Secchi reading is usually obtained in early summer. Big McDonald Lake transparency is high in May and June, and then declines through August. The transparency then rebounds in late September 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.

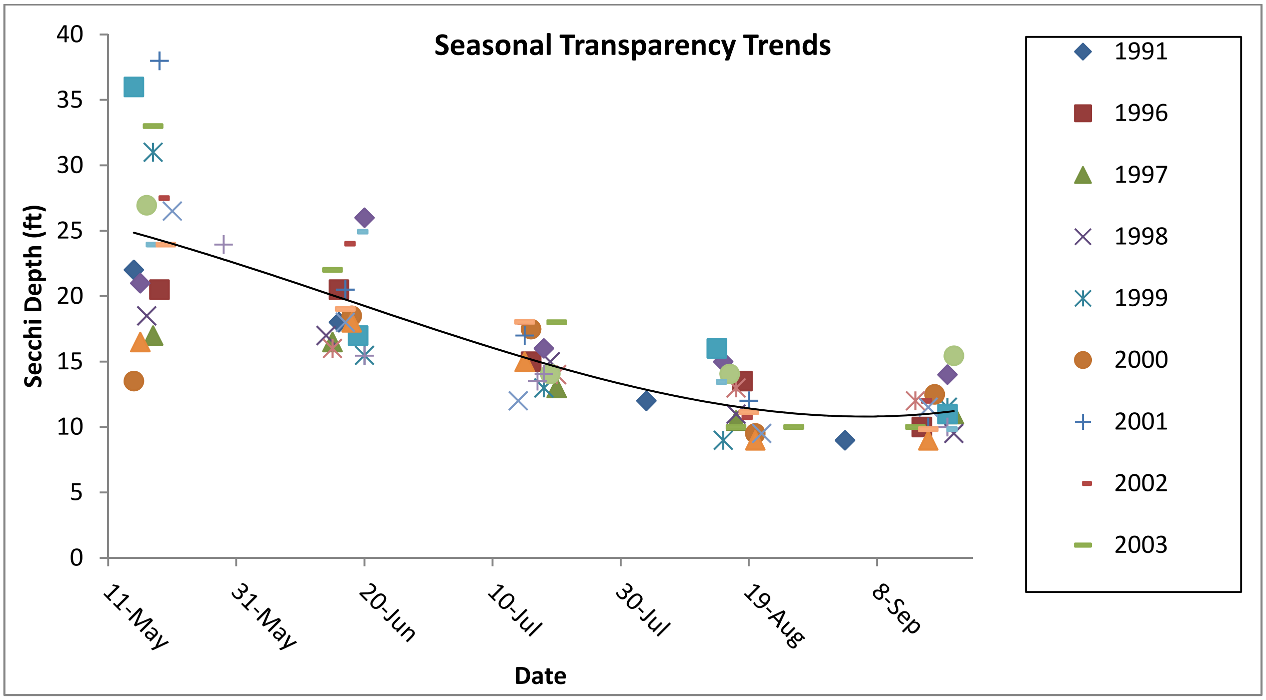


Figure 4. Seasonal transparency dynamics and year to year comparison (Primary Site 201). The black line represents the pattern in the data.

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 McDonald Lake was rated as being "crystal clear" 60% of the time by samplers at site 201 between 2002-2006 and 2008-2012 (Figure 5).

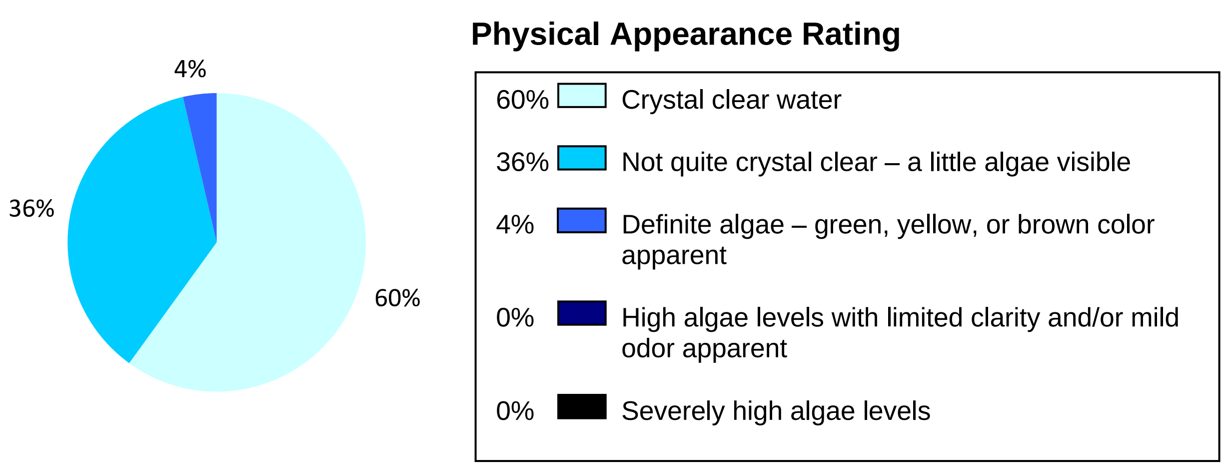
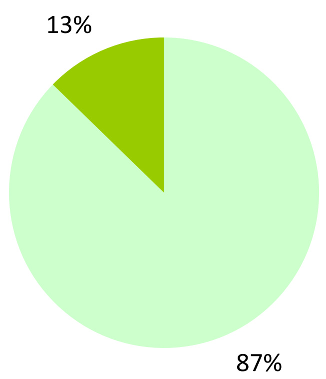


Figure 5. Big McDonald Lake physical appearance ratings by samplers.

As the Secchi depth decreases, the perception of recreational suitability of the lake decreases. Big McDonald Lake was rated as being "beautiful" 87% of the time from 2002-2006 and 2008-2012 (Figure 6).



Recreational Suitability Rating

87% Beautiful, could not be better

13% Very minor aesthetic problems; excellent for swimming, boating

0% Swimming and aesthetic enjoyment of the lake slightly impaired because of algae levels

0% Desire to swim and level of enjoyment of the lake substantially reduced because of algae levels

0% Swimming and aesthetic enjoyment of the lake nearly impossible because of algae levels

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

Total Phosphorus

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

Total phosphorus was evaluated in Big McDonald Lake in 1996-2012. The data show that phosphorus increases slightly as the beginning to the end of summer. The majority of the data points fall between the oligotrophic and mesotrophic range (Figure 7).

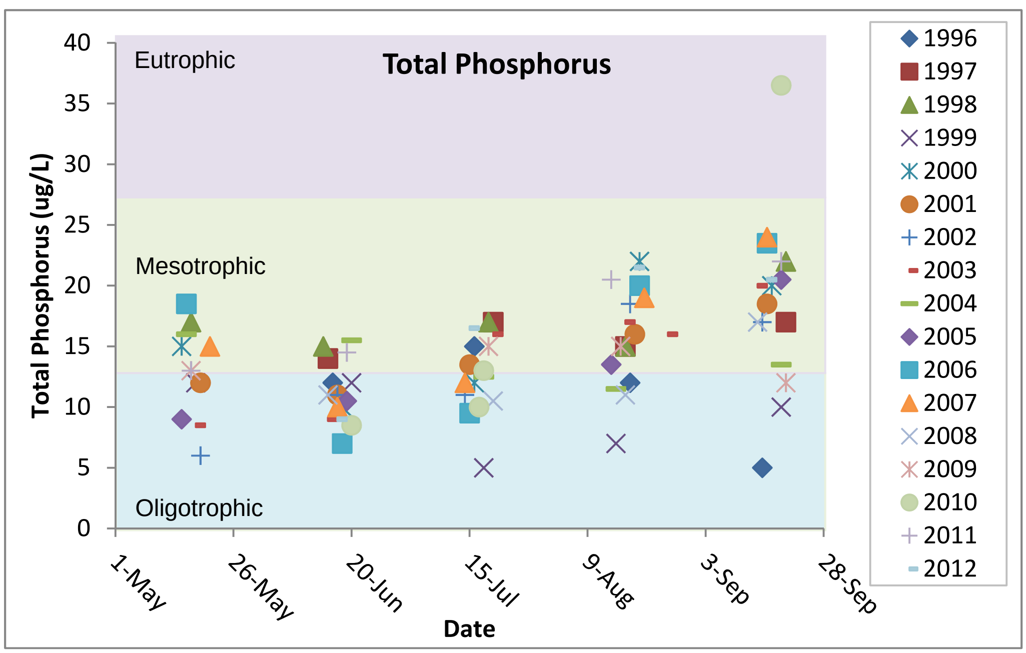


Figure 7. Historical total phosphorus concentrations (ug/L) for Big McDonald Lake site 201.

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

Chlorophyll *a*

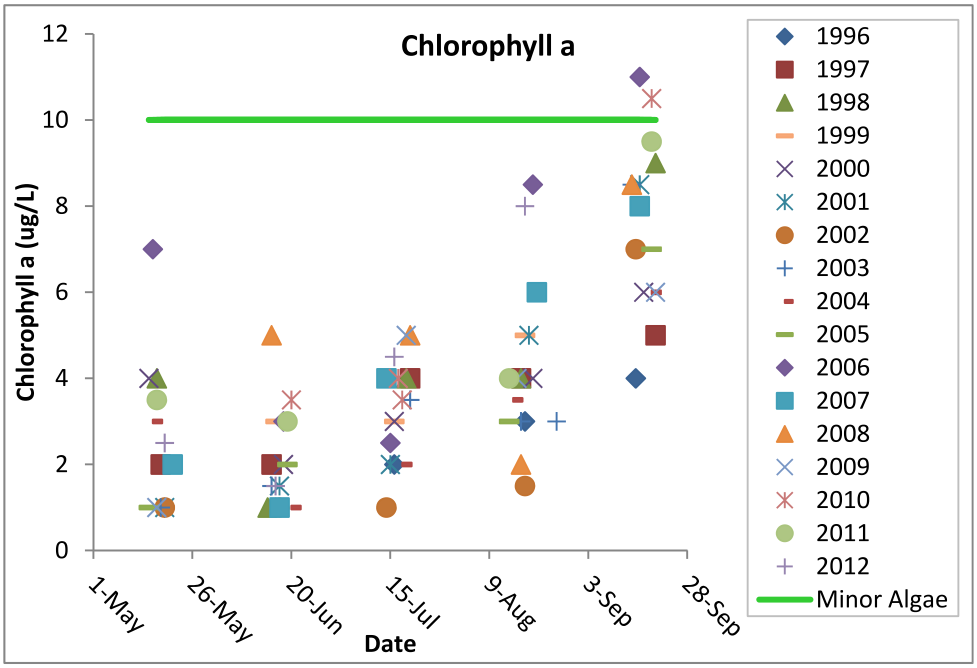


Figure 8. Chlorophyll *a* concentrations (ug/L) for Big McDonald Lake at site 201.

Chlorophyll *a* is the pigment that makes plants and algae green. Chlorophyll *a* is tested in lakes to deter mine the algae concentration or how "green" the water is. Chlorophyll *a* concentrations greater than 10 ug/L are perceived as a mild algae bloom, while concentrations greater than 20 ug/L are perceived as a nuisance.

Chlorophyll *a* was evaluated in Big McDonald Lake at site 201 from 1996-2012 (Figure 8). Chlorophyll *a* concentrations remained below 10 ug/L on all sample dates except for two, indicating clear water most of the summer. Throughout the years of sampling, chlorophyll a increases every year in late summer and early fall. This is consistent with the total phosphorus pattern (Figure 7).

Dissolved Oxygen

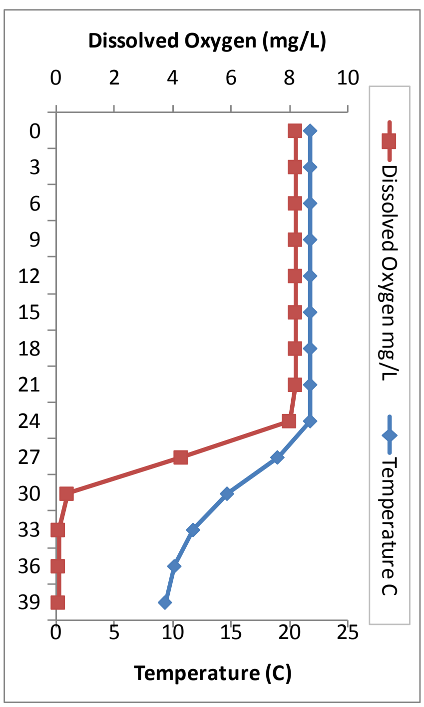


Figure 9. Dissolved oxygen profile of a lake.

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 McDonald Lake is a relatively deep lake, with a maximum depth of 46 ft. Dissolved oxygen profiles from a DNR Fisheries survey in 2013 show stratification developing in the summer. The thermocline is located at approximately 25 feet, which means that gamefish likely won't be present below this depth.

Trophic State Index (TSI)

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

Phosphorus (nutrients), chlorophyll *a* (algae concentration) and Secchi depth (transparency) are related. As phosphorus increases, there is more food available for algae, resulting in increased algal concentrations. When algal concentrations increase, the water becomes less transparent and the Secchi depth decreases. If all three TSI numbers are within a few points of each other, they are strongly related. If they are different, there are other dynamics influencing the lake's productivity, and TSI mean should not be reported for the lake.

Table 5. Trophic State Index for site 201.

Trophic State Index	Site 201
TSI Total Phosphorus	43
TSI Chlorophyll-a	44
TSI Secchi	37
TSI Mean	41
Trophic State:	Mesotrophic

Numbers represent the mean TSI for each parameter.

The mean TSI for Big McDonald Lake falls into the mesotrophic range (Figure 10). There is good agreement between the TSI for phosphorus and chlorophyll *a*, indicating that these variables are strongly related (Table 5). The transparency TSI is lower, which could be due to zooplankton selectively grazing the smaller algal cells or large algal cells dominating the algae community.

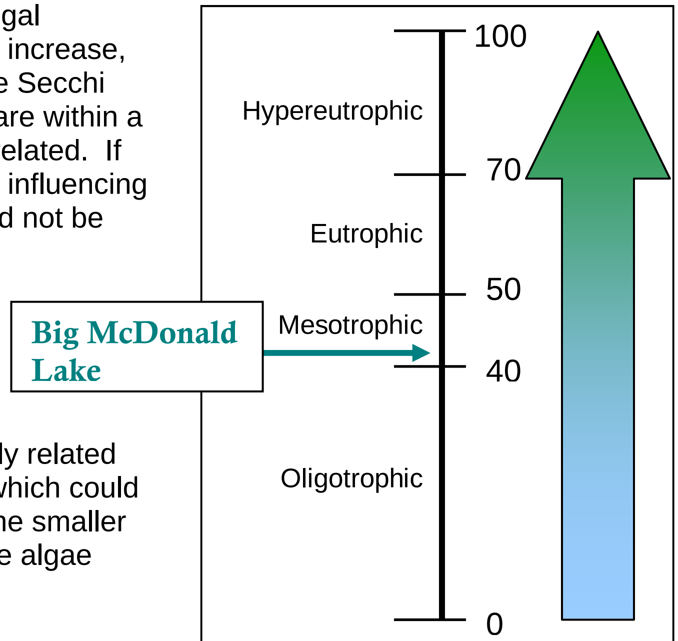


Figure 10. Trophic state index chart with corresponding trophic status.

Mesotrophic lakes (TSI 40-50) are characterized by moderately clear water most of the summer. "Meso" means middle; therefore, mesotrophic means a medium amount of productivity. Mesotrophic lakes are found in central Minnesota and have clear water with algal blooms in late summer (Table 6).

Table 6. 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 McDonald Lake had enough data to perform a trend analysis on all three parameters (Table 7). The data was analyzed using the Mann Kendall Trend Analysis.

Table 7. Trend analysis for Big McDonald Lake.

Lake Site	Parameter	Date Range	Trend
201	Total Phosphorus	1996-2012	No trend
201	Chlorophyll *a*	1996-2012	No trend
201	Transparency	1996-2012	No trend

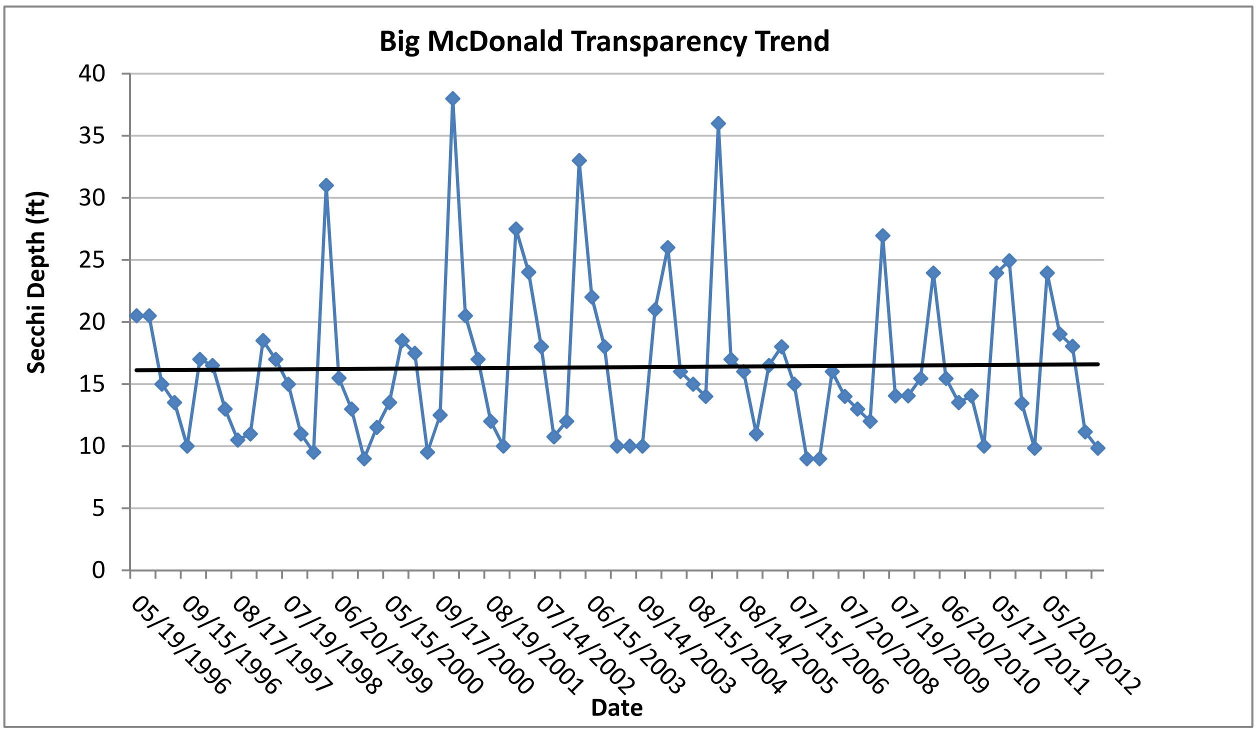


Figure 11. Transparency (feet) trend for site 201 from 1996-2006 and 2008-2012.

Big McDonald Lake shows no evidence of water quality trends (Figure 11). That means that the water quality is stable. Transparency monitoring should continue so that this trend can be tracked in future years.

Ecoregion Comparisons

Minnesota is divided into 7 ecoregions based on land use, vegetation, precipitation and geology (Figure 12). The MPCA has developed a way to determine the "average range" of water quality expected for lakes in each ecoregion. From 1985-1988, the MPCA evaluated the lake water quality for reference lakes. These reference lakes are not considered pristine, but are considered to have little human impact and therefore are representative of the typical lakes within the ecoregion. The "average range" refers to the 25th - 75th percentile range for data within each ecoregion. For the purpose of this graphical representation, the means of the reference lake data sets were used.

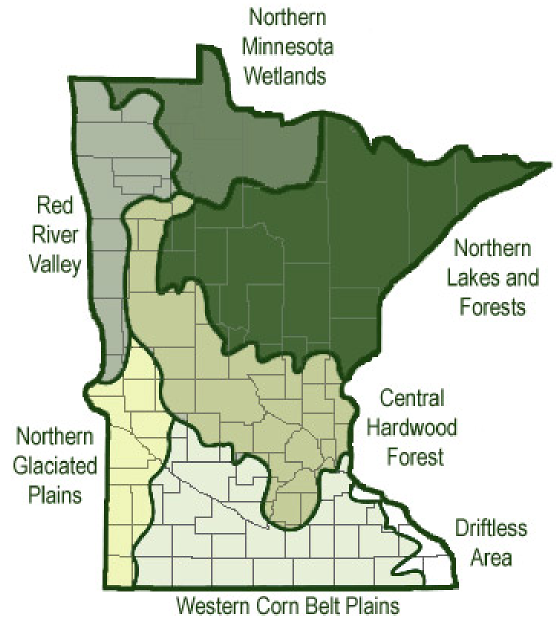
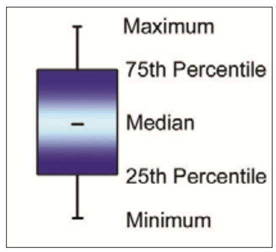


Figure 12. Minnesota Ecoregions.

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



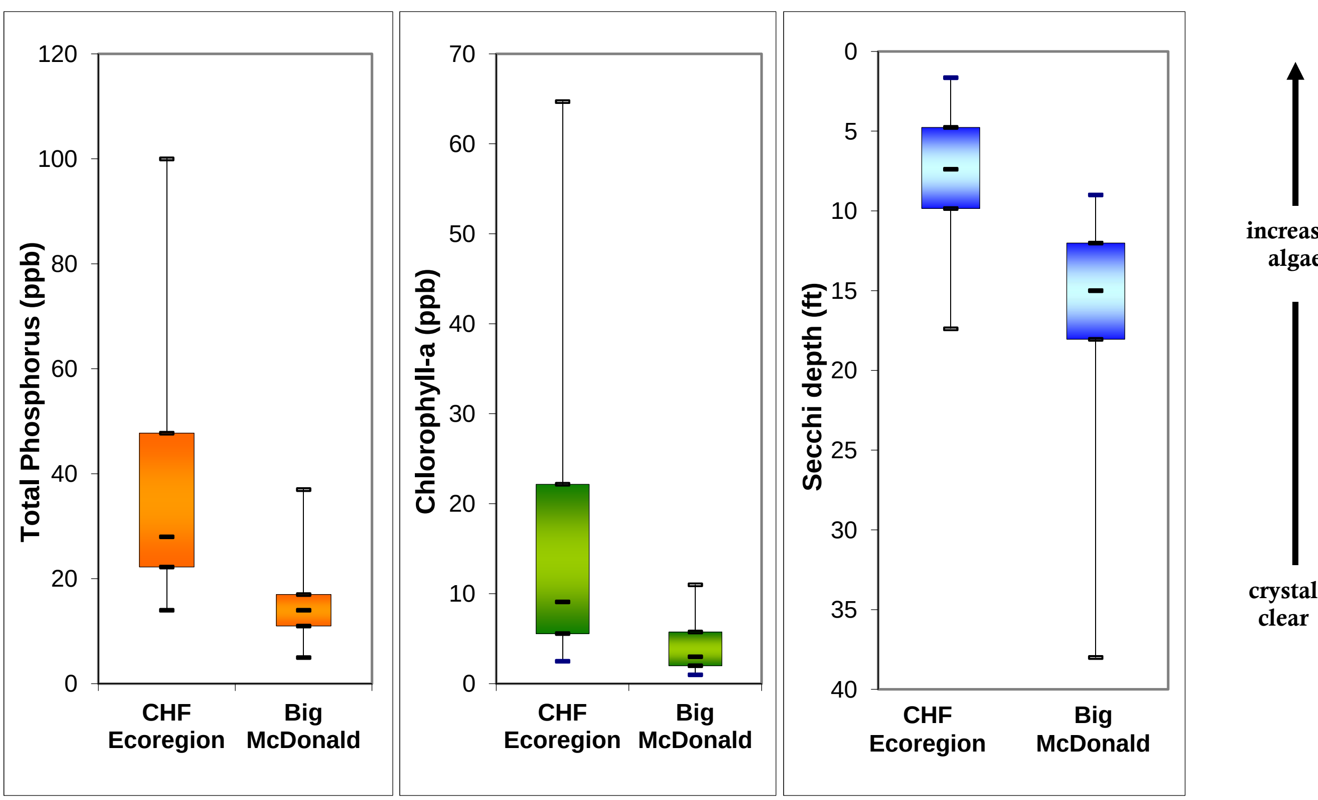


Figure 13. Big McDonald Lake ranges compared to Central Hardwood Forest Ecoregion ranges. The Big McDonald Lake total phosphorus and chlorophyll *a* ranges are from 122 data points collected in May-September of 1996-2012. The Big McDonald Lake Secchi depth range is from 117 data points collected in May-September of 1990-1991, 1996-2012.

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 Ottertail River Major Watershed is one of the watersheds that make up the Red River Basin, which drains north to Lake Winnipeg (Figure 14). This major watershed is made up of 106 minor watersheds. Big McDonald Lake is located in minor watershed 56021 (Figure 15).

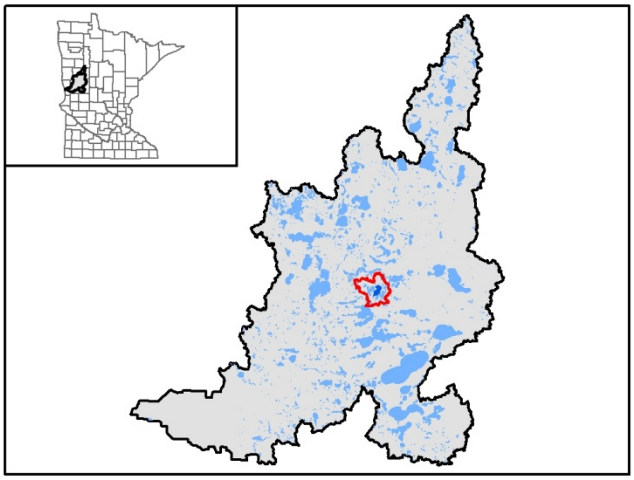


Figure 14. Otter Tail River Watershed.

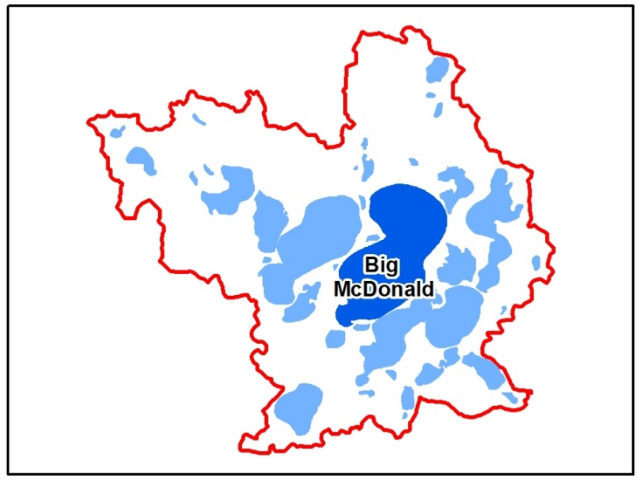


Figure 15. Minor Watershed 56021.

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 McDonald Lake falls within lakeshed 5602101 (Figure 16). Though very useful for displaying the land and water that contribute directly to a lake, lakesheds are not always true watersheds because they may not show the water flowing into a lake from upstream streams or rivers. While some lakes may have only one or two upstream lakesheds draining into them, others may be connected to a large number of lakesheds, reflecting a larger drainage area via stream or river networks. For further discussion of Big McDonald Lake's watershed, containing all the lakesheds upstream of the Big McDonald Lake lakeshed, see page 17.

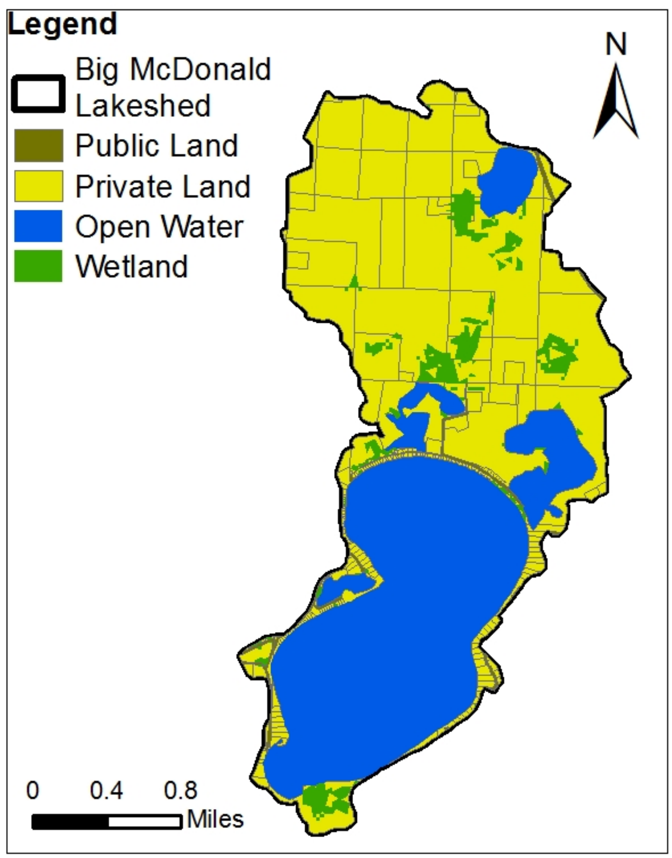


Figure 16. Big McDonald Lake lakeshed (5602101) with land ownership, lakes, wetlands, and rivers illustrated.

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

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

Lakeshed Vitals		**Rating**
Lake Area (acres)	992	descriptive
Littoral Zone Area (acres)	368	descriptive
Lake Max Depth (feet)	46	descriptive
Lake Mean Depth (feet)	NA	NA
Water Residence Time	NA, but probably high due to no major inlets or outlets	NA
Miles of Stream	0	descriptive
Inlets	0	Beneficial
Outlets	0	Warrants attention
Major Watershed	56 – Otter Tail River	descriptive
Minor Watershed	56021	descriptive
Lakeshed	5602102	descriptive
Ecoregion	North Central Hardwood Forests	descriptive
Total Lakeshed to Lake Area Ratio (total lakeshed includes lake area)	3:1	Warrants attention
Standard Watershed to Lake Basin Ratio (standard watershed includes lake areas)	6:1	Beneficial
Wetland Coverage (NWI)	9.9%	Beneficial
Aquatic Invasive Species	None as of 2013	Beneficial
Public Drainage Ditches	1	Warrants attention
Public Lake Accesses	1	Warrants attention
Miles of Shoreline	5.8	descriptive
Shoreline Development Index	1.3	Beneficial
Public Land to Private Land Ratio	0.02:1	Warrants attention
Development Classification	Recreational Development	Warrants attention
Miles of Road	8.19	descriptive
Municipalities in lakeshed	0	Beneficial
Forestry Practices	None	Beneficial
Feedlots	1	Possibly detrimental
Sewage Management	Individual Subsurface Sewage Treatment Systems (20 year rechecks completed in 2010)	Beneficial
Lake Management Plan	None	Warrants attention
Lake Vegetation Survey/Plan	None	Warrants attention

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 17). 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.

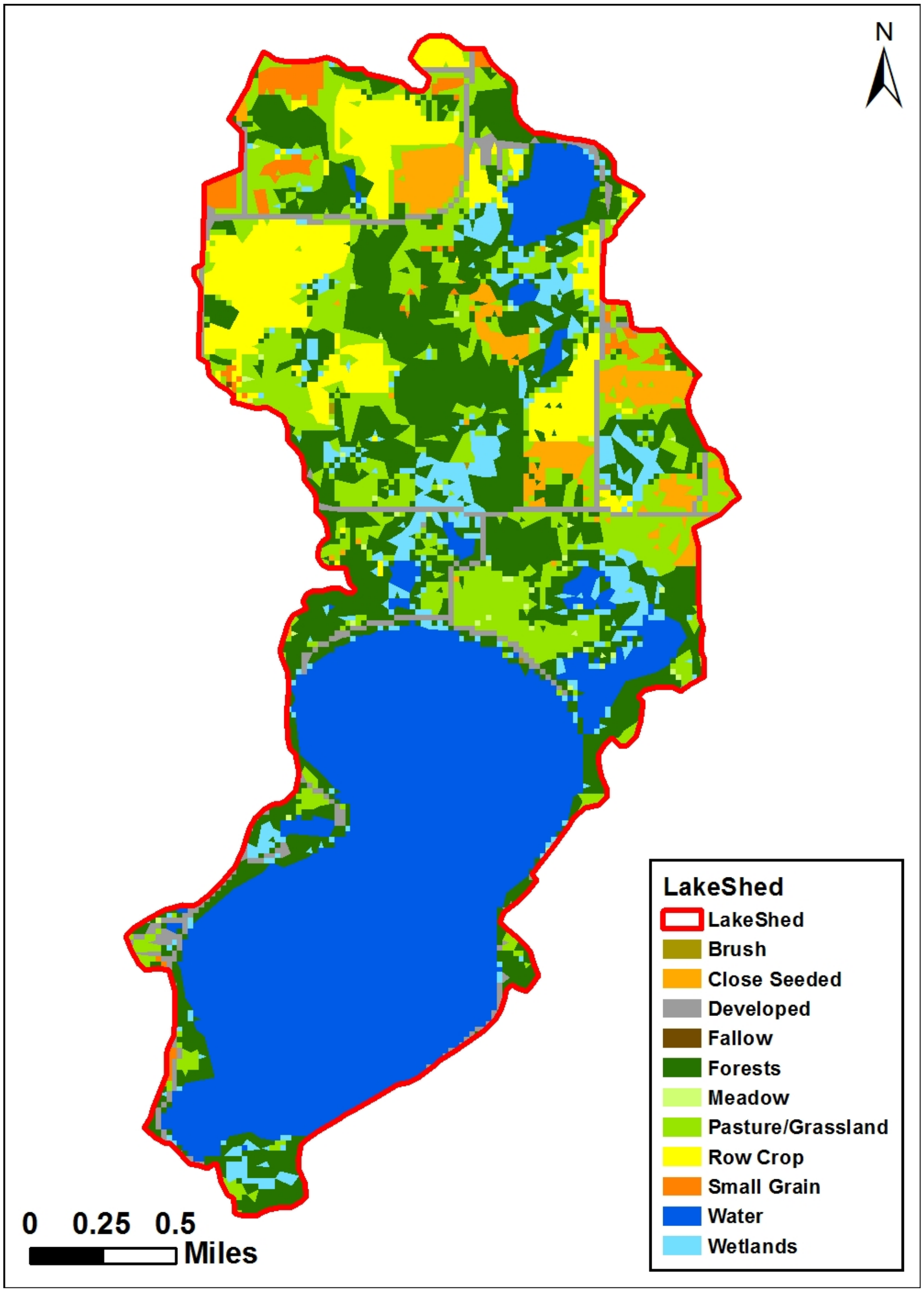


Figure 17. Big McDonald lakeshed (5603104) land cover (NASS, 2012).

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 McDonald Lake has 4% of its lakeshed classified as developed (Table 9). 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.

Table 9. Land cover in the Big McDonald lakeshed.

Runoff Potential	Category	Specific Landcover	Acres	Percent
High	Agriculture	**Row Crop**	248.1	8.3%
High	Urban	**Developed**	119.2	4.0%
High	Agriculture	**Close Seeded**	103.4	3.5%
High	Agriculture	**Small Grain**	49.4	1.6%
High	Agriculture	**Fallow**	0.5	0.0%
Low	Forest	**Woods**	749.3	25.0%
Low	Water	**Water**	1098.9	36.7%
Low	Agriculture	**Pasture/Grassland**	454.2	15.2%
Low	Wetlands	**Wetlands**	161.0	5.4%
Low	Agriculture	**Meadow**	11.7	0.4%
Low	Grass/Shrub	**Brush**	0.8	0.0%
Total area with low runoff potential			2475.9	82.6%
Total area with high runoff potential			520.7	17.4%
Total			2996.6	100.0%

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 is one animal feedlot in the Big McDonald Lake lakeshed (Table 8). The second highest agricultural runoff generally comes from row crops. There are some row crops within the northern portion of the lakeshed but some of the nutrients may be buffered out before reaching the lake (Figure 17). Buffer areas composed of wetlands or forest are 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 9 are valuable for evaluating runoff in the lakeshed. Overall, 83% of the Big McDonald Lake lakeshed is classified as having low nutrient runoff land uses (Table 9).

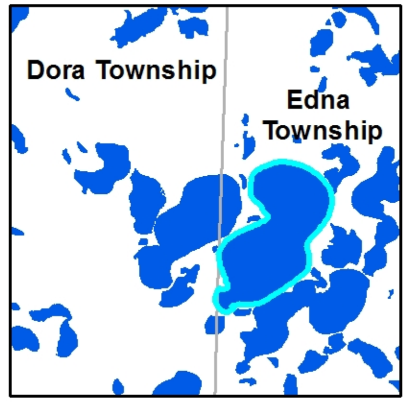
The University of Minnesota has online records of land cover statistics from years 1990 and 2000 (http://land.umn.edu). Although this data is 12 years old, it is the only data set that is comparable over a decade's time. In addition, a lot of lake development occurred from 1990 to 2000 when the US economy was booming. Table 10 describes Big McDonald'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 10. Big McDonald Lake's lakeshed land cover statistics and % change from 1990 to 2000 (http://land.umn.edu).

Land Cover	1990 Acres	Percent	2000 Acres	Percent	Comments
Urban	101	3.4 %	139	4.6 %	Increase of 38 acres
Total Impervious Area*	19 acres	1.0 %	39 acres	2.1 %	Increase of 20 acres

*Percent Impervious Area Excludes Water Area

Demographics



Big McDonald 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 Otter Tail County as a whole, Edna and Dora Township have a higher extrapolated growth projection (Figure 18).
(source:http://www.demography.state.mn.us/resource.html?Id=19332)

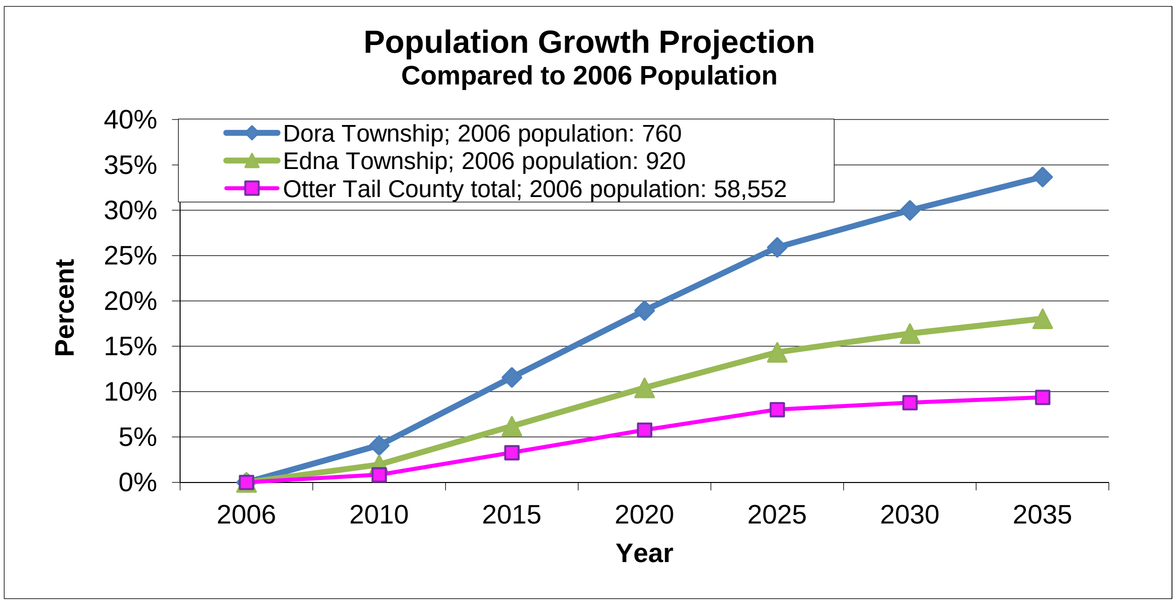


Figure 18. Population growth projection for Edna and Dora Township and Otter Tail County.

Lakeshed Water Quality Protection Strategy

Each lakeshed has a different makeup of public and private lands. Looking in more detail at the makeup of these lands can give insight on where to focus protection efforts. The protected lands (easements, wetlands, public land) are the future water quality infrastructure for the lake. Developed land and agriculture have the highest phosphorus runoff coefficients, so this land should be minimized for water quality protection.

The majority of the land within Big McDonald Lake's lakeshed is privately owned and used for agricultural production (Table 11). This land can be the focus of development and protection efforts in the lakeshed.

Table 11. Land ownership, land use/land cover, estimated phosphorus loading, and ideas for protection and restoration in the lakeshed (Sources: Otter Tail County parcel data and the 2006 National Land Cover Dataset).

	Private (58%)					41%	Public (1%)		
	Developed	**Agriculture**	**Forested Uplands**	**Other**	**Wetlands**	**Open Water**	**County**	**State**	**Federal**
Land Use (%)	3.5	27.8	18.8	3.5	4.4	41	0.9	0.1	0
Runoff Coefficient Lbs of phosphorus/acre/year	0.45 – 1.5	0.26 – 0.9	0.09		0.09		0.09	0.09	0.09
Estimated Phosphorus Loading Acreage x runoff coefficient	47–155	217–750	51		12		3	<1	0
Description	Focused on Shoreland	Cropland	Focus of develop-ment and protection efforts	Open, pasture, grass-land, shrub-land	Protected				
Potential Phase 3 Discussion Items	Shoreline restoration	Restore wetlands; CRP	Forest stewardship planning, 3rd party certification, SFIA, local woodland cooperatives		Protected by Wetland Conservation Act		County Tax Forfeit Lands	State Forest	National Forest

DNR Fisheries approach for lake protection and restoration

Credit: Peter Jacobson and Michael Duval, Minnesota DNR Fisheries

In an effort to prioritize protection and restoration efforts of fishery lakes, the MN DNR has developed a ranking system by separating lakes into two categories, those needing protection and those needing restoration. Modeling by the DNR Fisheries Research Unit suggests that total phosphorus concentrations increase significantly over natural concentrations in lakes that have watershed with disturbance greater than 25%. Therefore, lakes with watersheds that have less than 25% disturbance need protection and lakes with more than 25% disturbance need restoration (Table 12). Watershed disturbance was defined as having urban, agricultural and mining land uses. Watershed protection is defined as publicly owned land or conservation easement.

Table 12. Suggested approaches for watershed protection and restoration of DNR-managed fish lakes in Minnesota.

Watershed Disturbance (%)	Watershed Protected (%)	Management Type	Comments
< 25%	> 75%	Vigilance	Sufficiently protected -- Water quality supports healthy and diverse native fish communities. Keep public lands protected.
	< 75%	Protection	Excellent candidates for protection -- Water quality can be maintained in a range that supports healthy and diverse native fish communities. Disturbed lands should be limited to less than 25%.
25-60%	n/a	Full Restoration	Realistic chance for full restoration of water quality and improve quality of fish communities. Disturbed land percentage should be reduced and BMPs implemented.
> 60%	n/a	Partial Restoration	Restoration will be very expensive and probably will not achieve water quality conditions necessary to sustain healthy fish communities. Restoration opportunities must be critically evaluated to assure feasible positive outcomes.

The next step was to prioritize lakes within each of these management categories. DNR Fisheries identified high value fishery lakes, such as cisco refuge lakes. Ciscos (*Coregonus artedi)* can be an early indicator of eutrophication in a lake because they require cold hypolimnetic temperatures and high dissolved oxygen levels. These watersheds with low disturbance and high value fishery lakes are excellent candidates for priority protection measures, especially those that are related to forestry and minimizing the effects of landscape disturbance. Forest stewardship planning, harvest coordination to reduce hydrology impacts and forest conservation easements are some potential tools that can protect these high value resources for the long term.

Big McDonald Lake's lakeshed is classified with having 41.3% of the watershed protected and 32.4% of the watershed disturbed (Figure 19). Therefore, this lakeshed should have a full restoration focus. This lake is just over the 25% disturbed threshold. Goals for the lake should be to limit any increase in disturbed land use. Figure 20 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 McDonald Lake, whether through direct overland flow or through a creek or river. There are three lakesheds upstream of the Big McDonald Lake lakeshed.

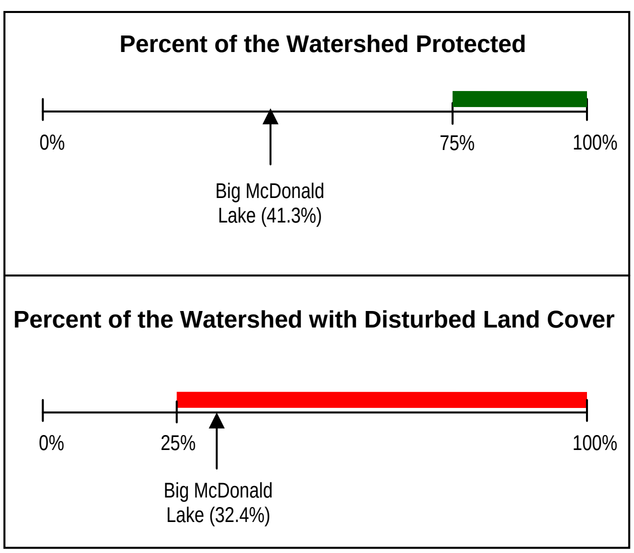


Figure 19. Big McDonald Lake's lakeshed percentage of watershed protected and disturbed.

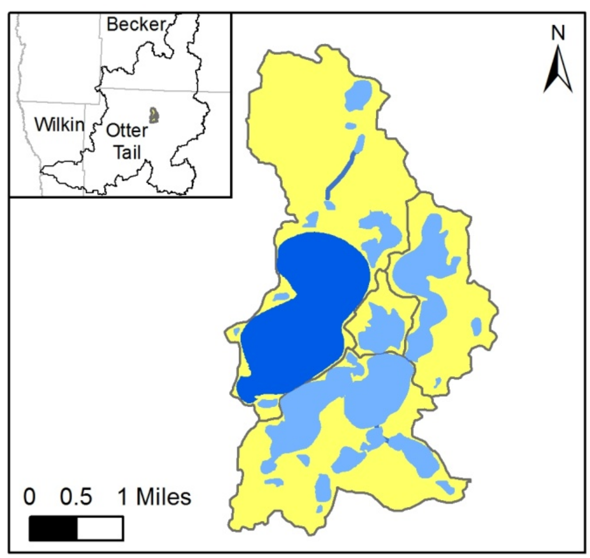


Figure 20. Upstream lakesheds that contribute water to the Big McDonald Lake lakeshed. Color-coded based on management focus (Table 12).

Surface Runoff Analysis (East Otter Tail SWCD)

The map below (Figures 21) shows the different catchments that drain into Lake Lida. These catchments are delineated by land elevation, as everything drains downhill. Each catchment was evaluated for potential surface erosion. Catchments that are colored red have a relatively high potential for surface erosion and soil loss and catchments that are colored dark green have a relatively low potential for soil loss. Shoreline in red areas would be good candidates for shoreline restoration, rain gardens, grassed waterways, filter strips and other best management practices addressing overland flow and erosion. Contact the Otter Tail SWCD for help with these areas.

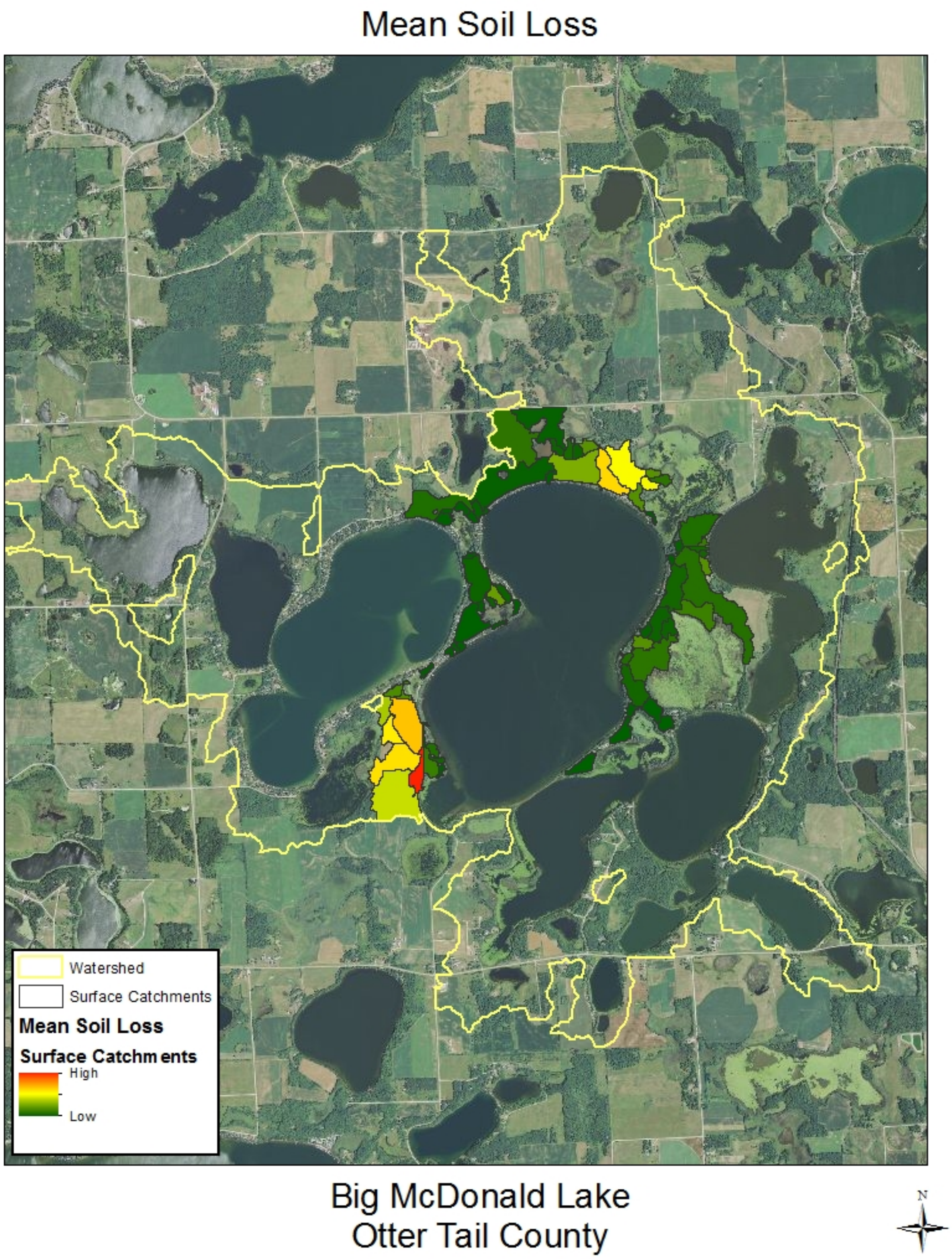


Figure 21. Potential for erosion in the surface catchments for Big McDonald Lake.

Status of the Fishery (DNR, as of 08/11/2008)

Big McDonald Lake is a 935-acre mesotrophic (moderately fertile) lake located in north-central Otter Tail County approximately nine miles west of Perham, MN. Big McDonald Lake is located within the Otter Tail River Watershed. The immediate watershed is composed primarily of agricultural land interspersed with hardwood woodlots. Big McDonald Lake is connected to Schwartz Lake during high water years by a channel located along the southeast shoreline. An unnavigable outlet is located along the south shoreline of the lake and connects Big McDonald Lake Lake with Round Lake. The maximum depth of Big McDonald Lake is 46 feet; however, 39 percent of the lake is less than 15 feet in depth. The secchi disk reading during the 2008 lake survey was 11.6 feet, which indicates good water clarity. Previous secchi disk readings have ranged from 9.0 to 13.9 feet.

The north and west shorelines of Big McDonald Lake have been extensively developed. Homes, cottages and resorts compose the majority of the development. A DNR owned concrete public water access is located off of County Road 35 along the northwest shoreline of the lake. The shoal water substrates consist primarily of sand and gravel. Large stands of hardstem bulrush are located along the west, south, and east shorelines. Areas of common cattail and wild rice are also scattered along the southwest shoreline. Emergent aquatic plants such as bulrush, cattail, and wild rice provide valuable fish and wildlife habitat, and are critical for maintaining good water quality. Emergent plants provide spawning areas for fish such as northern pike, largemouth bass, and panfish. They also serve as important nursery areas for all species of fish. Because of their ecological value, emergent plants may not be removed without a DNR permit. To maintain the excellent water quality and angling that this lake has to offer, it is imperative to preserve the quality of the aquatic habitat.

Big McDonald Lake can be ecologically classified as a bass-panfish-walleye type of lake and this is reflected in the assemblage of the fish community. Walleye, northern pike, largemouth bass, black crappie, and bluegill are the dominant game fish species present. Walleye is a primary management specie in this lake. The test-net catch rate of walleye was within the normal range for this class of lake. Walleye ranged in length from 9.7 to 24.4 inches with an average length and weight of 17.3 inches and 1.9 pounds. Walleye exhibit excellent growth rates with an average length of 15.6 inches at four years of age.

Northern pike population characteristics have remained stable over the recent series of lake surveys. Northern pike abundance has remained at a moderate density since the 1986 survey and age data indicate that natural reproduction has continued to be consistently good. Northern pike ranged in length from 13.6 to 33.2 inches with an average length and weight of 17.5 inches and 1.1 pounds. Pike growth is slow with an average length of 16.9 inches at four years of age. The slow growth rates for pike may be attributed to the low abundance of yellow perch, a preferred forage fish.

The bluegill test-net catch rate was within the normal range for this class of lake. Blulegill test-net catch rates have historically fluctuated. The bluegill population retained a good size distribution. Sixty percent of the bluegill sample was at least 7.0 inches in length. Bluegill attain an average length of 7.0 inches at seven years of age. Data from a spring electrofishing assessment indicate that a high-density largemouth bass population exists. Age data indicate that bass reproduction is consistently good.

Although bass are abundant the average size is small and growth is slow. Bass ranged in length from 5.9 to 18.3 inches with an average length and weight of 10.1 inches and 0.6 pounds. Bass attain an average length of 12.5 inches at five years of age.

Data from a spring trapnetting assessment indicated that black crappies are also abundant. Size structure is also good with 58 percent of the crappies measuring 10.0 inches or greater in length. The 2005 year class is strong and should provide consistently good crappie angling for several years. Crappies attain an average length of 9.1 inches at four years of age. Anglers can maintain the quality of fishing by practicing selective harvest.

Selective harvest encourages the release of medium to large-size fish while allowing the harvest of the more abundant smaller fish for table fare. Releasing the medium to large fish will ensure that the lake will have enough spawning age fish on an annual basis and will provide anglers with more opportunities to catch large fish in the future.

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=56038601

Key Findings / Recommendations

Monitoring Recommendations
Transparency monitoring at site 201 should be continued annually. It is important to continue transparency monitoring weekly or at least bimonthly every year to enable year-to-year comparisons and trend analyses. Total Phosphorus and chlorophyll *a* monitoring should continue at site 201, as the budget allows, to track trends in water quality.

Overall Summary
Big McDonald Lake is a mesotrophic lake (TSI = 41) with no evidence of a trend in water quality. The total phosphorus, chlorophyll *a* and transparency ranges are better than the ecoregion ranges.

Thirty-two percent (32%) of the lakeshed is disturbed by development and agriculture (Figure 19). The threshold of disturbance where water quality tends to decline is 25%. Big McDonald Lake is over this threshold; however, most of the agricultural land is in pasture, which has much less runoff potential than row crops. A more accurate estimate of disturbed land is 17% (Table 9), which is below the 25% threshold.

Big McDonald Lake has the advantage of a very small watershed. The lake does not have any major inlets or outlets, which means that it probably has a high residence time. Therefore nutrients in the lake tend to stay there instead of getting flushed out. The oldest septic systems around the lake were re-checked by the county in 2010, so the septic systems around the lake should be in good working order. The land practices around the lake and the runoff from them are the main impacts to the lake.

A map showing the surface runoff potential from the different catchments around the lake show that there is a potential area for soil erosion on the southwest corner of the lake (Figure 21). This area needs to be visually inspected for high elevation and potential runoff. If this type of scenario is occurring there, shoreline restoration, rain gardens, grassed waterways, filter strips and other best management practices could be applied to address overland flow and erosion.

Priority Impacts to the Lake
The priority impact to Big McDonald Lake is expansion of residential housing development in the lakeshed and second tier development along the lakeshore. The runoff from this development (impervious surface) delivers nutrients to the lake. The majority of first tier shoreline parcels have been developed. From 1990-2000, the urban area around the lake increased by 38 acres (Table 10). In addition, the conversion of seasonal cottages to year-round homes increases the impervious area of the home.

The reason the lakeshed is rated as "full restoration (Figure 20)" is surrounding agriculture (Figure 17). Agriculture is the dominant land use type on private lands (27.8%) within the lakeshed, but most of it is located north of the lake instead of around the lakeshore. Surface runoff mapping shows that this farmland north of the lake is likely not running off into the lake (Figure 21).

Best Management Practices Recommendations

The management focus for Big McDonald Lake should be to protect the current water quality and restore the lakeshed. This can be done by focusing on managing and/or decreasing the impact caused by additional development, including second tier development, and impervious surface area. Project ideas include protecting land with conservation easements, enforcing county shoreline ordinances, smart development, shoreline restoration, rain gardens, and septic system maintenance.

Partnering with farmers in the lakeshed to implement conservation farming practices, increase shoreline buffers, restore wetlands, or place priority parcels into land retirement programs will help decrease the impacts of agriculture in the lakeshed.

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) and Natural Resources Conservation Service (NRCS)

- Shoreline restoration
- Stream buffers
- 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 McDonald Lake Association	No contact information.
Big McDonald Lake Improvement District	No contact information.
DNR Fisheries Office	1509 1st Avenue North, Fergus Falls, MN 56537 218-739-7576 fergusfalls.fisheries@state.mn.us http://www.dnr.state.mn.us/areas/fisheries/fergusfalls/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
East Otter Tail Soil and Water Conservation District	801 Jenny Ave SW Suite 2, Perham, MN 56573 218-346-4260 ext.3 http://www.eotswcd.org/