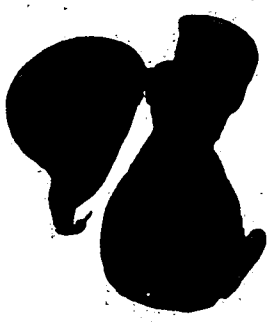
Horseshoe 18-0251-00 CROW WING COUNTY

Lake Water Quality

Summary



Horseshoe is located 8 miles south of Cross Lake MN Crow wing County. Horseshoe Lake is composed of two main basins and covers an area of 922 acres (Table 1).

Horseshoe doesn't have any inlets or outlets, which classify it as a groundwater seepage lake. Because it is groundwater fed, Horseshoe is affected by varying water levels from year to year.

Water quality data have been collected on Horseshoe in 1973-1976, 1984, and 1986-2012 (Tables 2 & 3). These data show that the lake is mesotrophic (TSI = 44) with moderately clear water conditions most of the summer and excellent recreational opportunities.

The Horseshoe Lake Association is involved in water quality monitoring.

Table 1. Horseshoe location and key physical characteristics.

Location Data		Physical Characteristics	
MN Lake ID:	18-0251-00	Surface area (acres):	922
County:	Crow Wing	Littoral area (acres):	800
Ecoregion:	Northern Lakes and Forests	% Littoral area:	87%
		Max depth (ft), (m):	55, 16.8
Major Drainage Basin:	Upper Mississippi River	Inlets:	0
Latitude/Longitude:	46.5823/-94.1141	Outlets:	0
Invasive Species:	None	Public Accesses:	1

Table 2. Availability of primary data types for Horseshoe.

Data Availability		
Transparency data		Excellent data source from 1973-1976, 1984, 1986-2016.
Chemical data		Excellent data source from 1974-1976, 1984, 1989, 1992, 1996, 2001-2016.
Inlet/Outlet data	--	Not necessary.

Recommendations **For recommendations refer to page 18.**

Lake Map

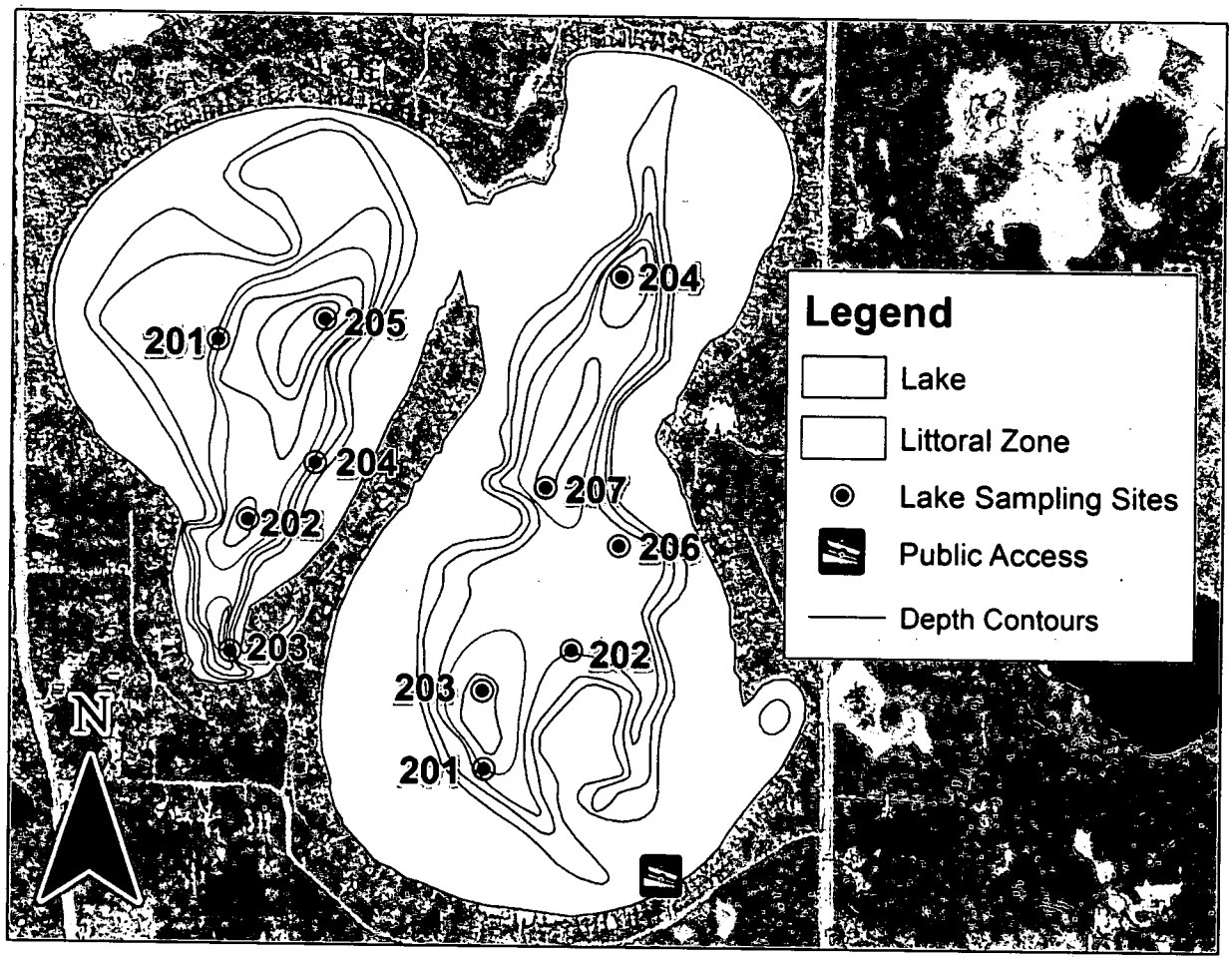


Figure 1. Map of Horseshoe with 2010 aerial imagery and illustrations of lake depth contour lines, sample site locations, inlets and outlets, and public access points. The light green areas in the lake illustrate the littoral zone, where the sunlight can usually reach the lake bottom, allowing aquatic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

Table 3. Monitoring programs and associated monitoring sites. Monitoring programs include Citizen Lake Monitoring Program (CLMP), Outdoor Corp. Lake Monitoring (OCLM), RMB Environmental Laboratories Lakes Program (RMBEL), and Thirty Lakes Watershed District (TLWD).

Basin	Lake Site	Depth (ft)	Monitoring Programs
East	201	40	No data
	202	40	CLMP: 1975, 1986-1996
	203	40	CLMP: 1991-1992; TLWD: 2009
	204	35	CLMP: 1991; TLWD: 1974-1976, 1984, 1989, 1992
	206	20	CLMP 1997-2002, 2005-2006, 2008-2010
	207*Primary site	30	CLMP: 2011; OCLM: 2003; RMBEL: 2004-2016
West	201	20	CLMP: 1973-1974; OCLM: 203
	202	35	CLMP:1986-1989, 1991
	203	30	CLMP: 1988
	204	20	CLMP: 1990-1991; OCLM: 2001
	205*Primary site	50	CLMP: 1991-2012, RMBEL: 2004-2016; TLWD: 1974-1976, 1984-1989, 1991-1992, 1996, 2002

Average Water Quality Statistics

The information below describes available chemical data for Horseshoe through 2016 (Table 4). All data is the mean data from the primary site 205 (west) from 1974-1976, 1991-2016.

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.

Table 4. Water quality means compared to ecoregion ranges and impaired waters standard.

Parameter	East Bay Mean	West Bay Mean	Ecoregion Range[1]	Impaired Waters Standard[2]	Interpretation
Total phosphorus (ug/L)	14.8	14.6	14 – 27	> 30	Results are within the expected range for the ecoregion.
[3]Chlorophyll *a* (ug/L)	5.7	5.1	4 – 10	> 9	
Chlorophyll *a* max (ug/L)	18	13	< 15		
Secchi depth (ft)	15.0	15.2	8 – 15	< 6.5	
Dissolved oxygen	Dimictic *see page 8*	Dimictic *see page 8*			Dissolved oxygen depth profiles show that the deep areas of the lake are anoxic in late summer.
Total Kjeldahl Nitrogen (mg/L)	0.68	0.64	<0.4 – 0.75		Indicates insufficient nitrogen to support summer nitrogen-induced algae blooms.
Alkalinity (mg/L)	86.7	86.7	40 – 140		Indicates a low sensitivity to acid rain and a good buffering capacity.
Color (Pt-Co Units)	NA	5.0	10 – 35		Indicates clear water with little to no tannins (brown stain).
pH	7.8	7.7	7.2 – 8.3		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)	1.0	1.0	0.6 – 1.2		Within the ecoregion range.
Total Suspended Solids (mg/L)	NA	NA	<1 – 2		No data available
Conductivity (umhos/cm)	NA	NA	50 – 250		No data available
Total Nitrogen : Total Phosphorus	45.9:1	43.8:1	25:1 – 35:1		The lake is phosphorus limited, which means that algae growth is limited by the amount of phosphorus in the lake.

[1]The ecoregion range is the 25th-75th percentile of summer means from ecoregion reference lakes
[2]For further information regarding the Impaired Waters Assessment program, refer to http://www.pca.state.mn.us/water/tmdl/index.html
[3]Chlorophyll *a* measurements have been corrected for pheophytin
Units: 1 mg/L (ppm) = 1,000 ug/L (ppb)

Water Quality Characteristics - Historical Means

Table 5. Water quality means and ranges for primary sites.

Parameters	Primary Site East 207	East 202	East 206	Primary Site West 205	West 202
Phosphorus Mean:	**14.8**			**14.6**	
Total Phosphorus Min:	5			5	
Total Phosphorus Max:	26			40	
Number of Observations:	65			65	
Chlorophyll *a* Mean:	**5.7**			**5.1**	
Chlorophyll-a Min:	1			<1	
Chlorophyll-a Max:	18			13	
Number of Observations:	70			90	
Secchi Depth Mean:	**15.0**	**15.4**	**15.7**	**15.2**	**14.8**
Secchi Depth Min:	9.5	9.0	11.0	8.5	8.5
Secchi Depth Max:	21.0	22.0	20.0	31.0	21.5
Number of Observations:	113	166	142	441	78

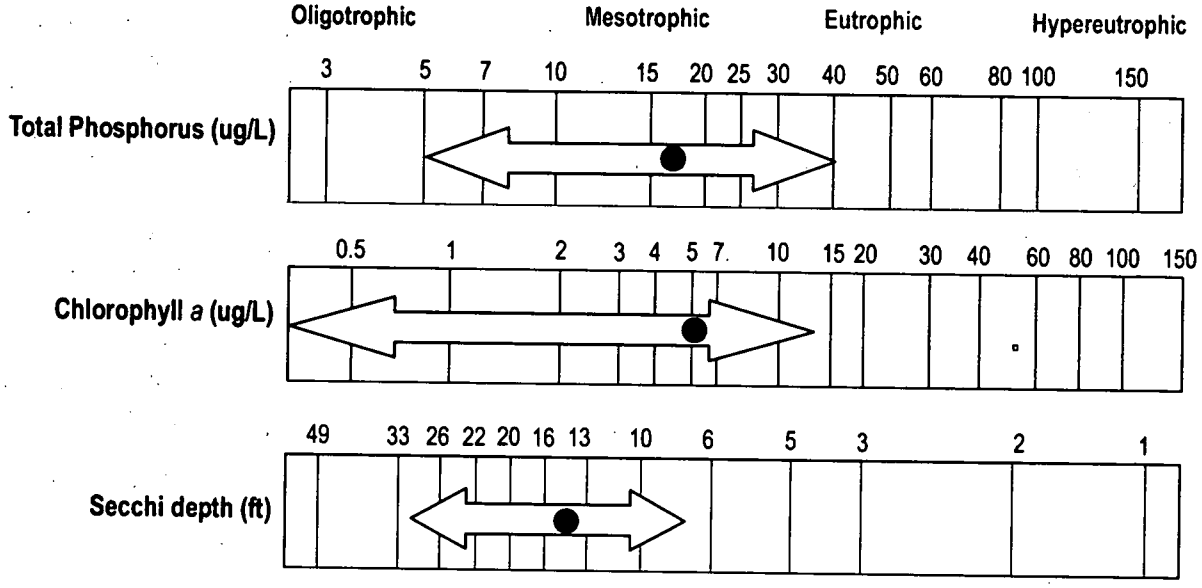


Figure 2. Horseshoe total phosphorus, chlorophyll a and transparency historical ranges. The arrow represents the range and the black dot represents the historical mean (Primary Site 205 west). Figure adapted after Moore and Thornton, [Ed.]. 1988. Lake and Reservoir Restoration Guidance Manual. (Doc. 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 Horseshoe Lake ranges from 8 to 18 feet (Figure 3). The transparency throughout the lake appears to be relatively uniform. Each site follows the same ups and downs which illustrates year-to-year variability. The primary sites in each basin (205 west, 207 east) should continue to be monitored each year to track trends.

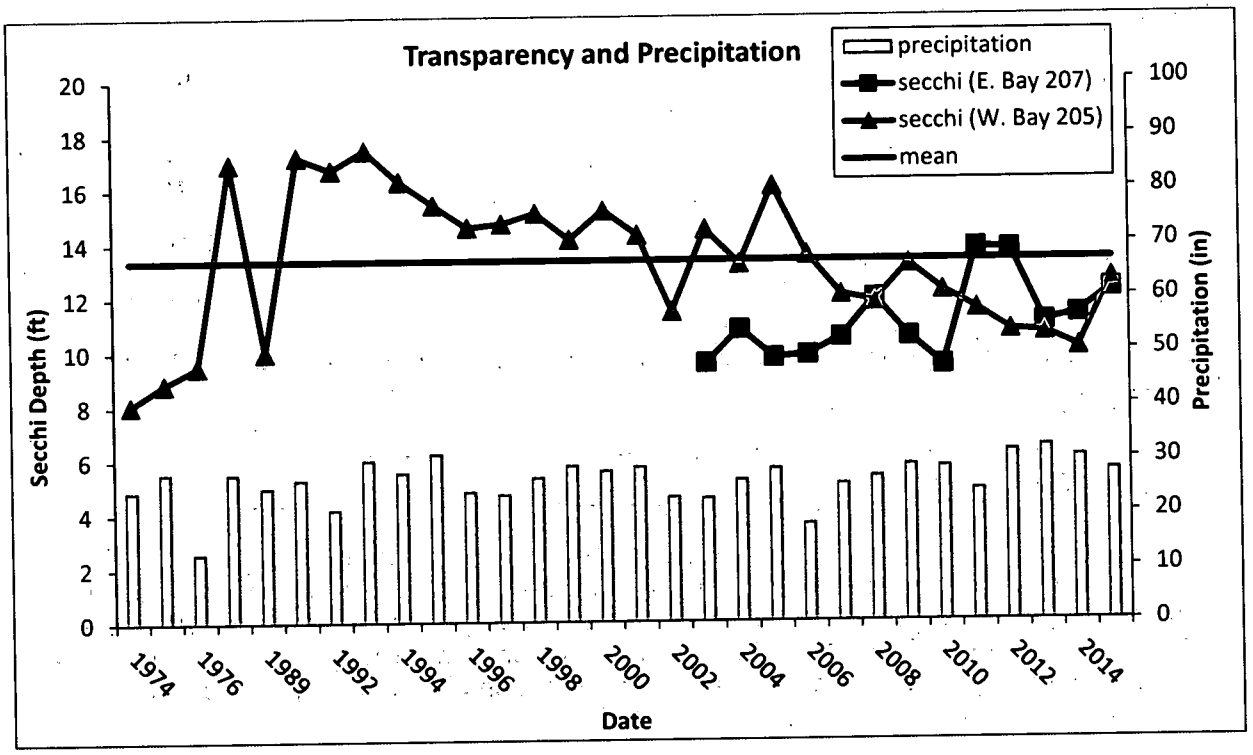


Figure 3. Annual mean transparency compared to long-term mean transparency.

Horseshoe transparency ranges from 9.5 to 21 feet at the primary site (205). Figure 4 shows the seasonal transparency dynamics. The maximum Secchi reading is usually obtained in early summer. Horseshoe transparency is high in May and June, and then declines through August. If transparency were monitored in October, it would likely rebound 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.

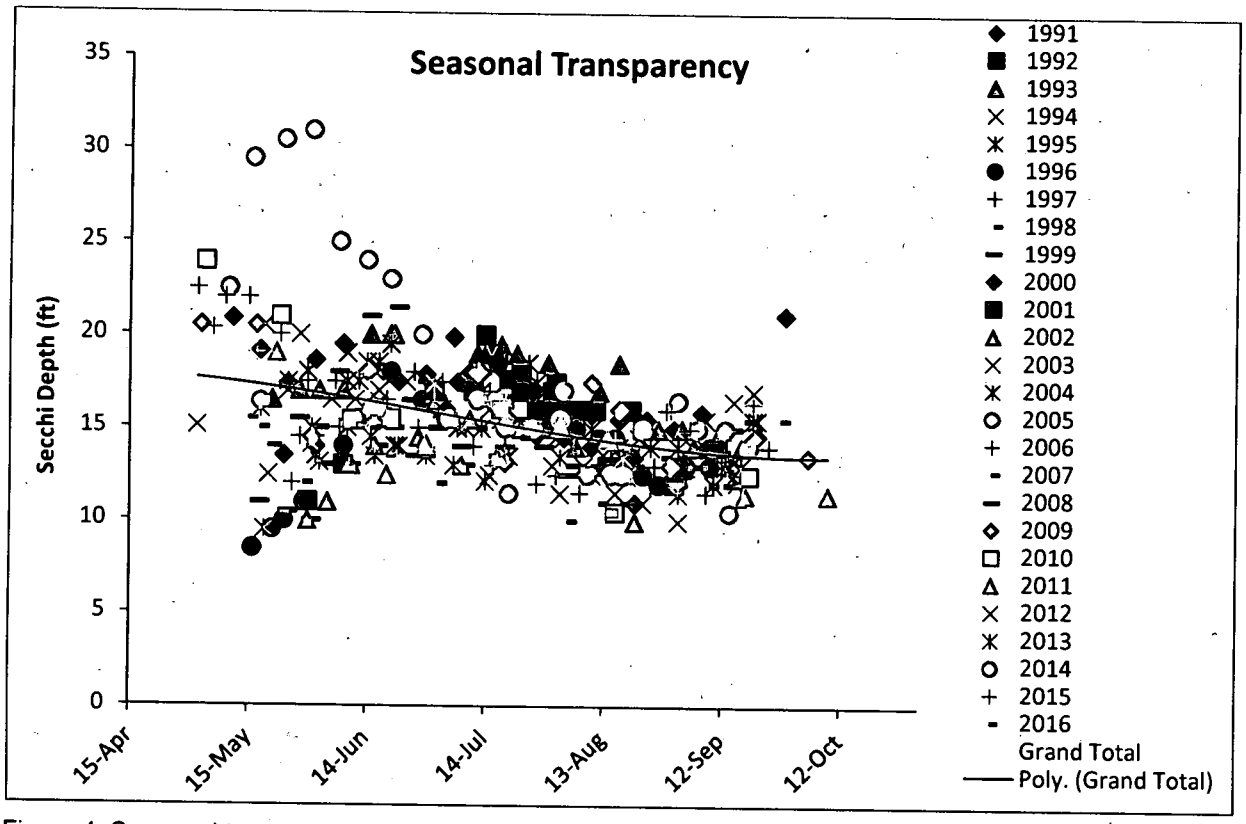


Figure 4. Seasonal transparency dynamics and year to year comparison (Primary Site 205). The black line represents the pattern in the data.

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. Horseshoe was rated as being "not quite crystal clear" 78% of the time by samplers at site 205 between 1991-2016 (Figure 5).

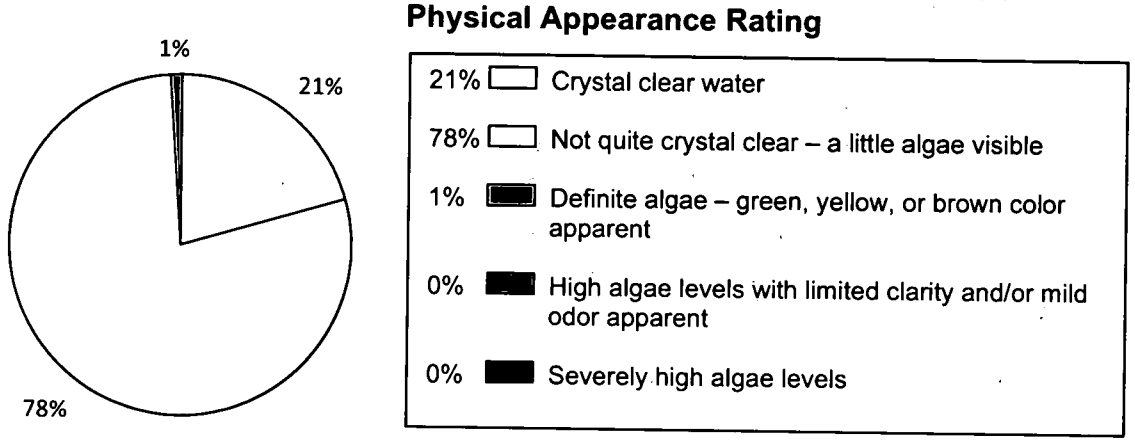


Figure 5. Horseshoe physical appearance ratings by samplers.

As the Secchi depth decreases, the perception of recreational suitability of the lake decreases. Horseshoe was rated as having "minor aesthetic problems" 59% of the time by samplers at site 205 between 1991-2016 (Figure 6).

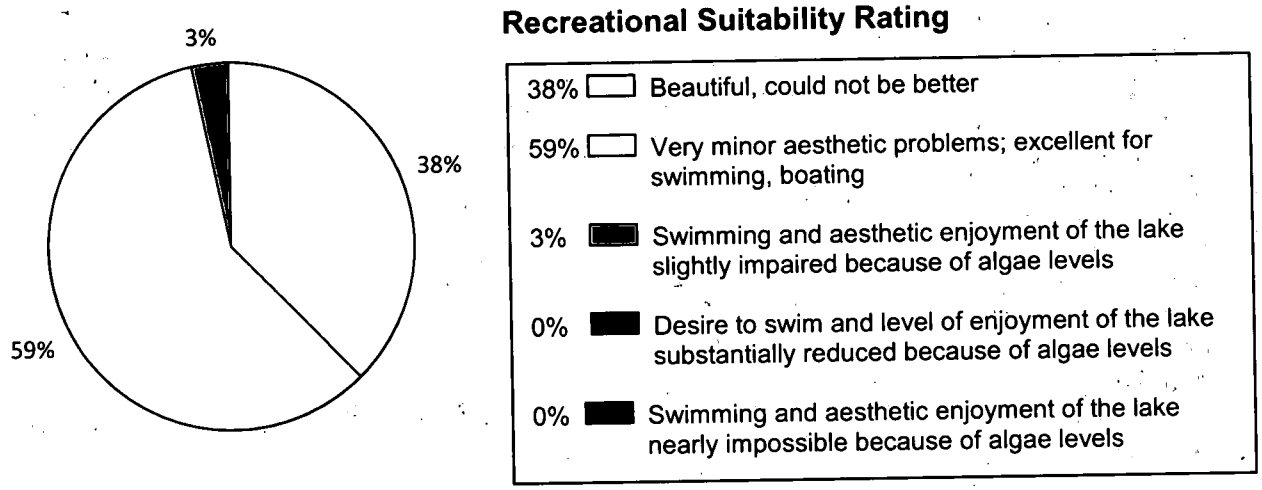


Figure 6. Recreational suitability rating, as rated by the volunteer monitor.

Total Phosphorus

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

Total phosphorus was evaluated in Horseshoe in 2002 and 2004-2016. The data do not indicate much seasonal variability. About half of the data points fall into the mesotrophic range and half into the oligotrophic range (Figure 7).

Only the west basin is shown in Figure 7 because the east basin has very similar results.

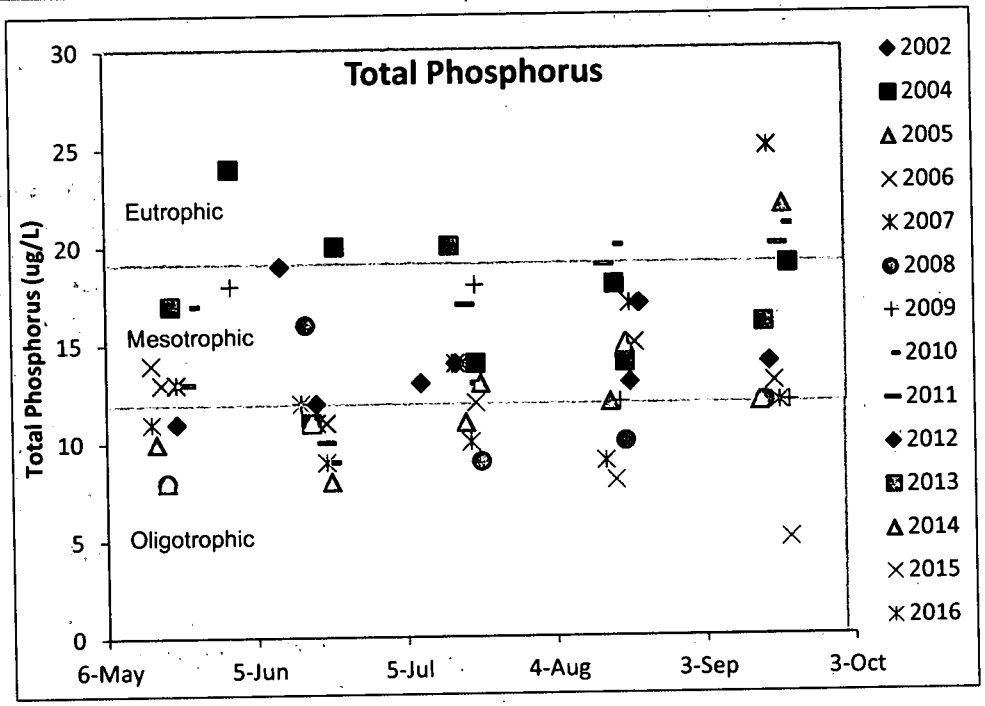


Figure 7. Historical total phosphorus concentrations (ug/L) for Horseshoe site 205 west.

Phosphorus should continue to be monitored 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 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.

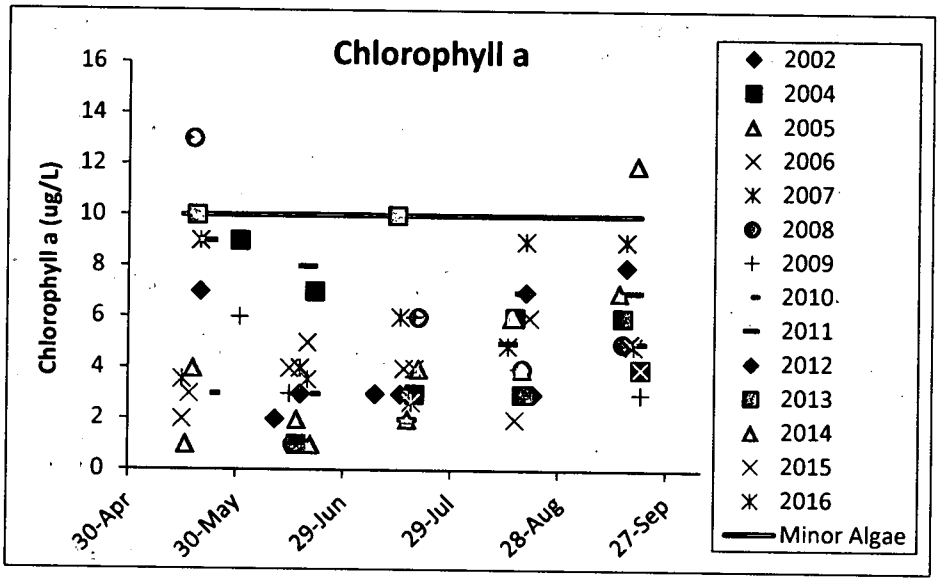


Figure 8. Chlorophyll *a* concentrations (ug/L) for Horseshoe at site 205 west.

Chlorophyll *a* was evaluated in Horseshoe at site 205 west from 2002-2016 (Figure 8). Chlorophyll *a* concentrations remained below 10 ug/L on all sample dates except for two, indicating clear water most of the summer. There was not much variation over the years monitored and chlorophyll *a* concentrations remained relatively steady over the summer.

Dissolved Oxygen

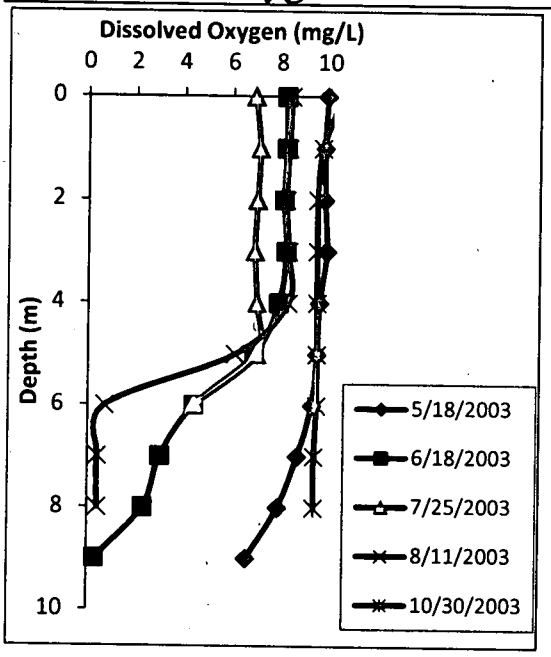


Figure 9. Dissolved oxygen profile for Horseshoe.

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.

Horseshoe is a relatively deep lake, with a maximum depth of 55 ft. Dissolved oxygen profiles from data collected in 2003 at site 207 show stratification developing mid-summer. The thermocline occurs at approximately 5 meters (16.4 feet), which means that gamefish will be scarce below this depth. Figure 9 is a representative DO profile for Horseshoe and it illustrates stratification in the summer of 2003 at site 207.

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.

Table 6. Trophic State Index for site 205.

Trophic State Index	Site 205
TSI Total Phosphorus	44
TSI Chlorophyll-a	47
TSI Secchi	38
TSI Mean	43
Trophic State:	Mesotrophic

Numbers represent the mean TSI for each parameter.

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.

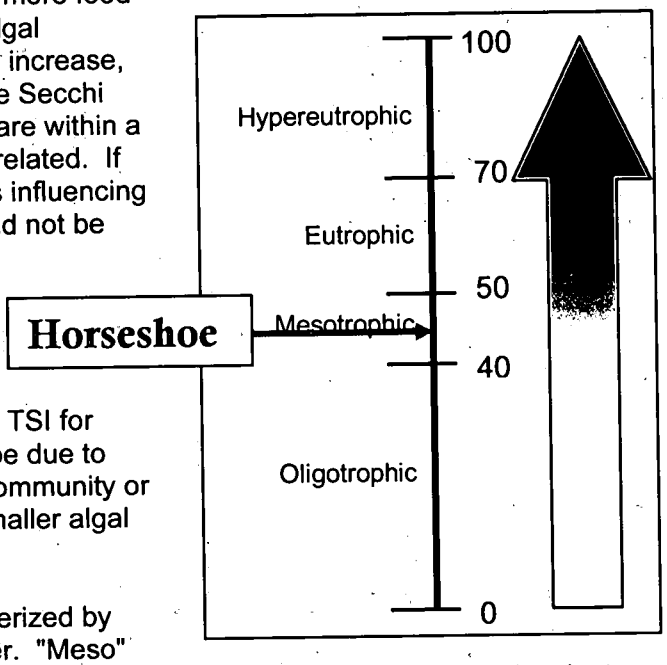


Figure 10. Trophic state index chart with corresponding trophic status.

The mean TSI for Horseshoe falls into the mesotrophic range (Figure 10). There is good agreement between the TSI for phosphorus and chlorophyll *a*. The TSI for transparency is slightly lower. This could be due to large algal particles dominating the algal community or selective grazing by zooplankton on the smaller algal cells.

Mesotrophic lakes (TSI 40-50) 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 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.

Horseshoe had enough data to perform a trend analysis on all three parameters (Table 8). The data was analyzed using the Mann Kendall Trend Analysis.

Table 8. Trend analysis for site 205.

Lake Site	Parameter	Date Range	Trend
205 (west)	Total Phosphorus	2003-2012	Improving (95%)
207 (east)	Total Phosphorus	2004-2016	Improving (99.9%)
205 (west)	Chlorophyll *a*	2003-2012	No trend
207 (east)	Chlorophyll a	2004-2016	Improving (99.9%)
205 (west)	Transparency	1991-2012	No trend
207 (east)	Transparency	2004-2016	No trend

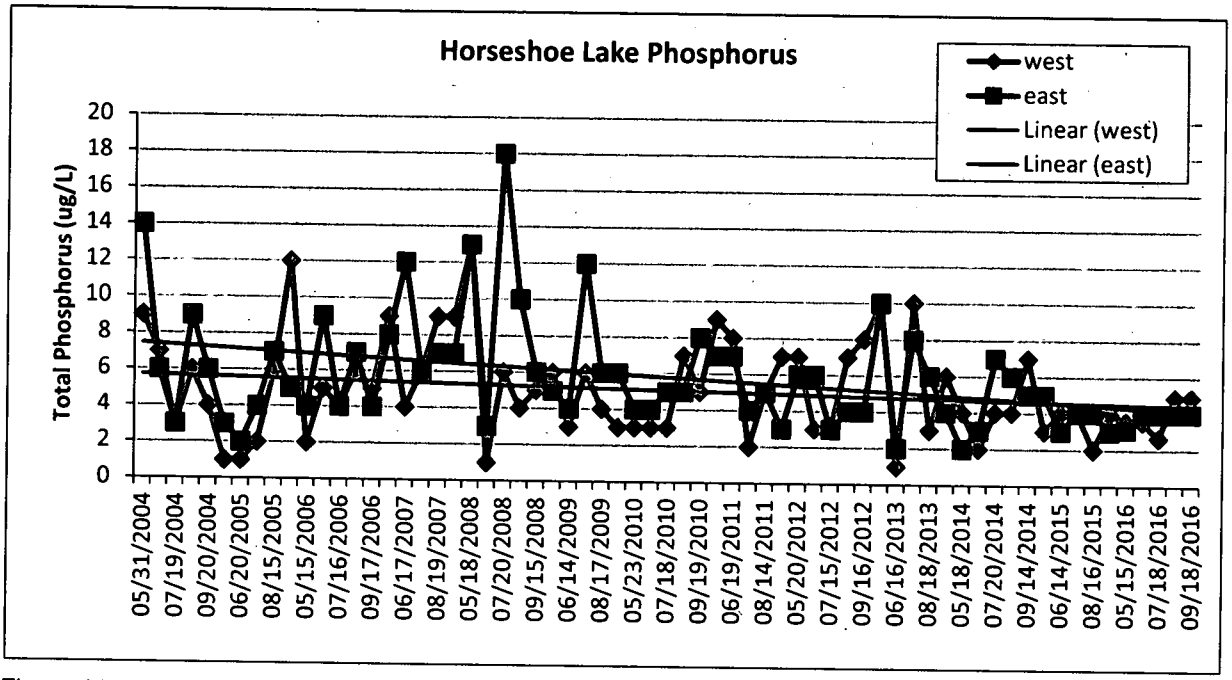


Figure 11. Total phosphorus trend for from 2004-2016.

Horseshoe Lake shows evidence of improving water quality trends (Figure 11). The phosphorus concentration is decreasing in both bays, and the chlorophyll a (algae) is decreasing in the east bay. Monitoring should continue so that these trends 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.

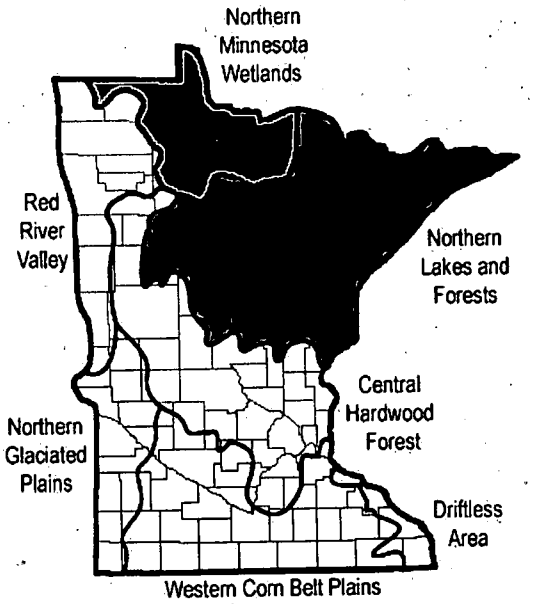
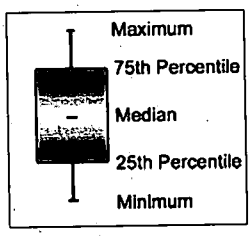


Figure 12. Minnesota Ecoregions.

Horseshoe is in the Northern Lakes and Forest Ecoregion. The mean total phosphorus, chlorophyll *a* and transparency (Secchi depth) for Horseshoe are slightly better than the ecoregion ranges (Figure 13).



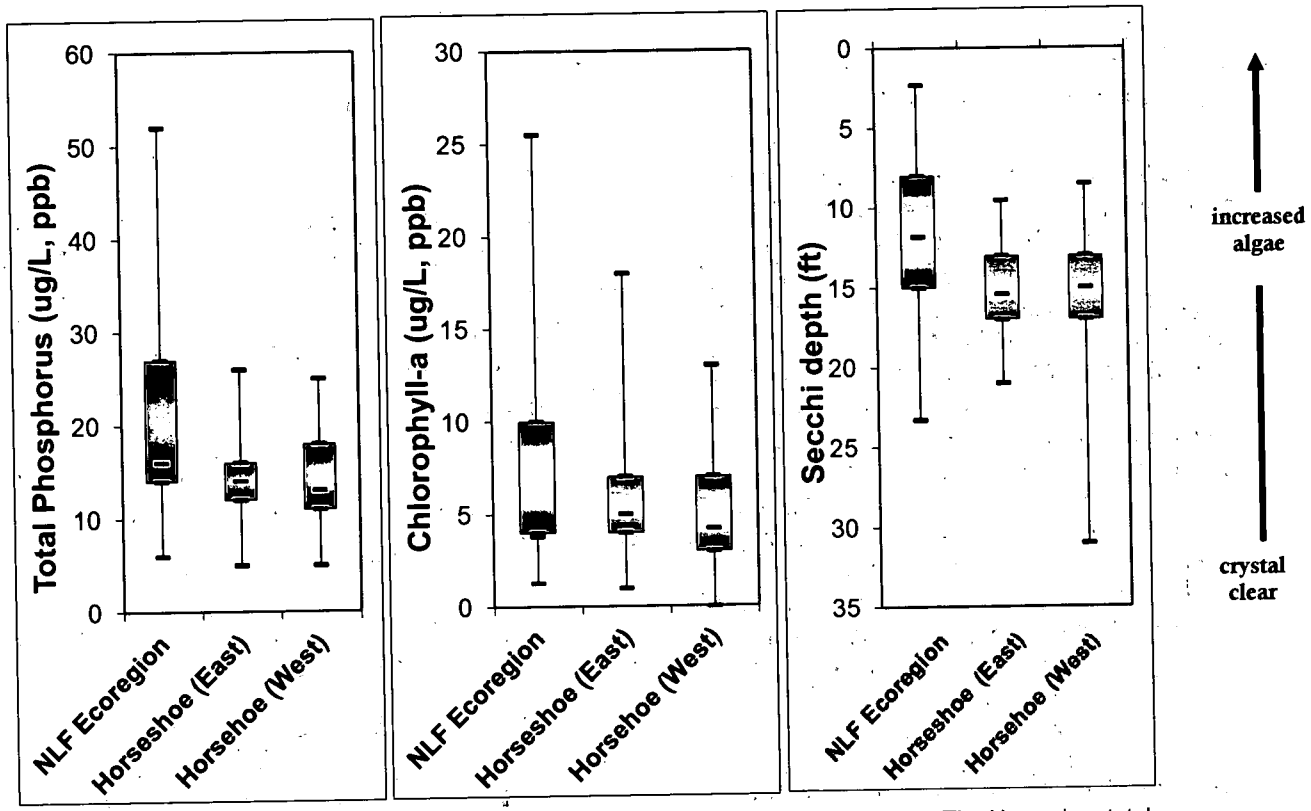


Figure 13. Horseshoe ranges compared to Northern Lakes and Forest Ecoregion ranges. The Horseshoe total phosphorus and chlorophyll *a* ranges for the east bay (site 207) are from 71 data points collected in May-September of 2003-2016. The Horseshoe Secchi depth range for the east bay (site 207) is from 114 data points collected in May-September of 2003-2016. The Horseshoe total phosphorus and chlorophyll *a* ranges for the west bay (site 205) are from 82 data points collected in 2004-2016. The Horseshoe Secchi depth range for the west bay (site 205) is from 442 data points collected in May-September of 1974-1976 and 1991-2016.

Lakeshed Data and Interpretations

Lakeshed

Understanding a lakeshed requires an understanding of basic hydrology. A watershed is defined as all land and water surface area that contribute excess water to a defined point. The MN DNR has delineated three basic scales of watersheds (from large to small): 1) basins, 2) major watersheds, and 3) minor watersheds.

The Pine 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 14). This major watershed is made up of 69 minor watersheds. Horseshoe is located in minor watershed 11062 (Figure 15).

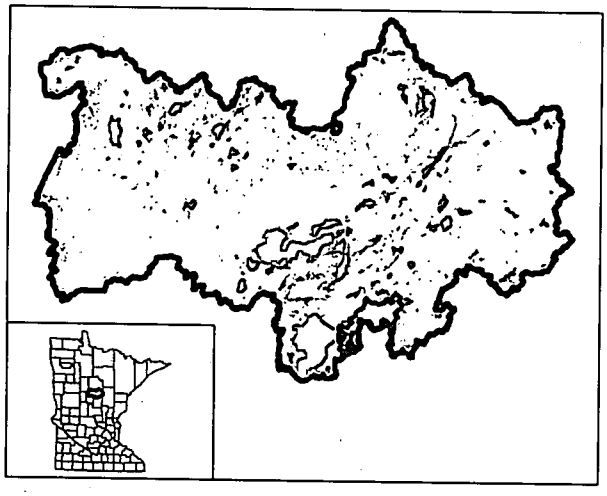


Figure 14. Pine River Watershed.

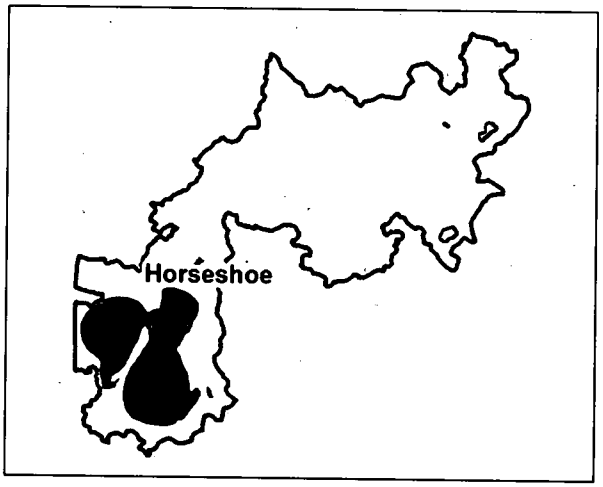


Figure 15. Minor Watershed 11062.

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. Horseshoe falls within lakeshed 1106214 (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 Horseshoe's watershed, containing all the lakesheds upstream of the Horseshoe lakeshed, see page 17. The data interpretation of the

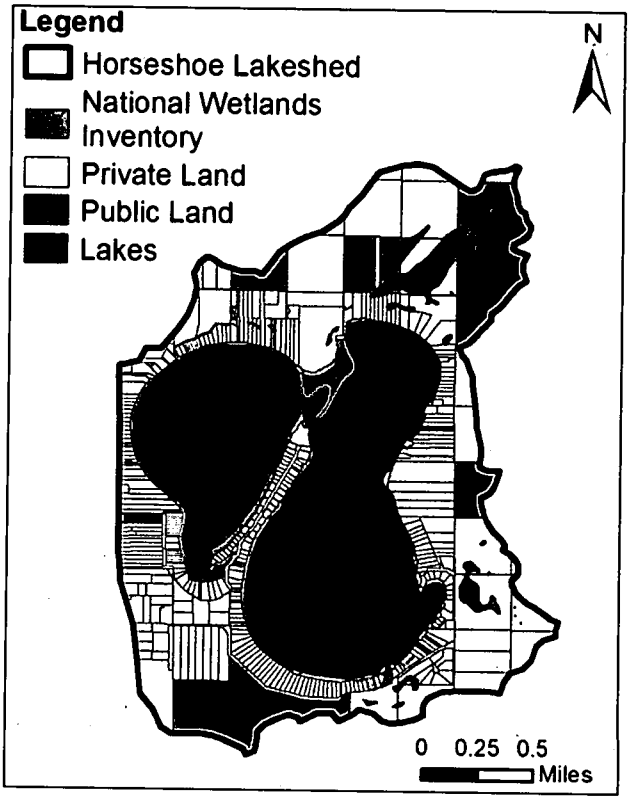


Figure 16. Horseshoe lakeshed (1106214) with land ownership, lakes, wetlands, and rivers illustrated.

Horseshoe lakeshed includes only the immediate lakeshed as this area is the land surface that flows directly into Horseshoe.

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. Horseshoe lakeshed vitals table.

Lakeshed Vitals		**Rating**
Lake Area	922 acres	descriptive
Littoral Zone Area	800 acres	descriptive
Lake Max Depth	55 feet	descriptive
Lake Mean Depth	12.1 feet	●
Water Residence Time	NA	NA
Miles of Stream	0	descriptive
Inlets	0	◉
Outlets	0	◉
Major Watershed	11 – Pine River	descriptive
Minor Watershed	11062	descriptive
Lakeshed	1106214	descriptive
Ecoregion	Northern Lakes and Forests	descriptive
Total Lakeshed to Lake Area Ratio (total lakeshed includes lake area)	2:1	○
Standard Watershed to Lake Basin Ratio (standard watershed includes lake areas)	2:1	○
Wetland Coverage (NWI)	4.6%	○
Aquatic Invasive Species	None as of 2016	○
Public Drainage Ditches	None	○
Public Lake Accesses	1	◉
Miles of Shoreline	7.6	descriptive
Shoreline Development Index	1.8	○
Public Land to Private Land Ratio	0.3:1	●
Development Classification	Recreational Development	◉
Miles of Road	8.6	descriptive
Municipalities in lakeshed	None	○
Forestry Practices	None	○
Feedlots	None	○
Sewage Management	Individual Subsurface Sewage Treatment Systems (Inspection and assessment required for all permits and property transfers within the Shoreland Protection Zone)	◉
Lake Management Plan	Healthy Lakes and Rivers Program, 2004	○
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.

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

Phosphorus export, which is the main cause of lake eutrophication, depends on the type of land cover occurring in the lakeshed. Figure 17 depicts the land cover in Horseshoe's lakeshed.

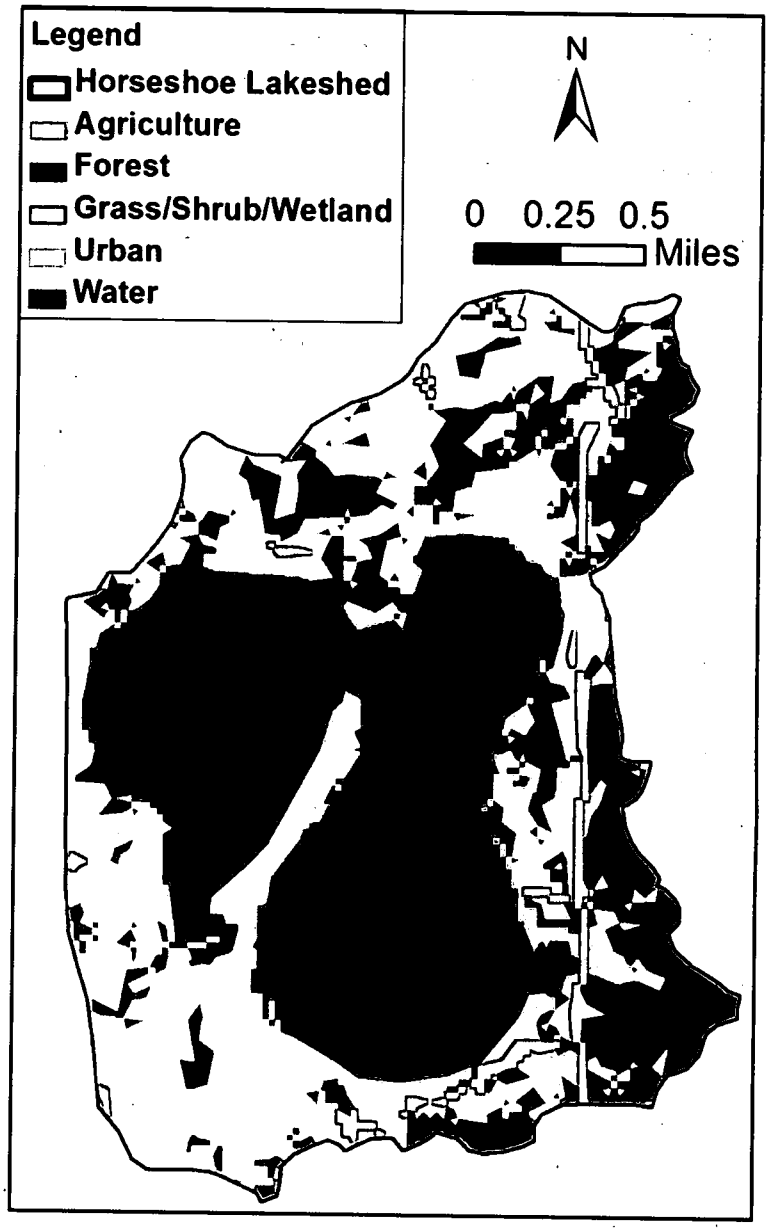


Figure 17. Horseshoe lakeshed (1106214) land cover (http://mrlc.gov)

The National Land Cover Dataset has online records of land cover statistics from years 2001 and 2006. Although some of this data is 12 years old, it is the most recent data set that is comparable. Table 10 describes Horseshoe Lake's lakeshed land cover statistics and percent change from 2001 to 2006. 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 transitions occurring within the last 12 years within the lakeshed.

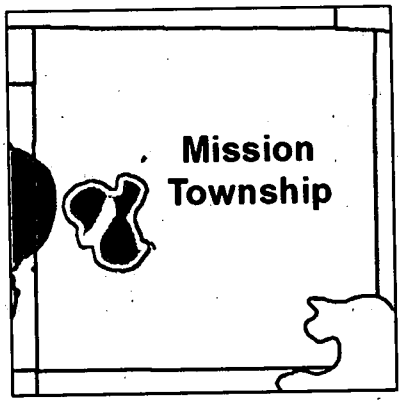
Table 10. Horseshoe's lakeshed land cover statistics and % change from 2001 to 2006 (http://mrlc.gov)

Land Cover	2001 Acres	Percent	2006 Acres	Percent	% Change 2001 to 2006
Agriculture	7	0.30	7	0.32	No Change
Forest	520	22.15	519	22.10	0.2% Decrease
Grass/Shrub/Wetland	844	35.92	863	36.74	2.3% Increase
Water	933	39.69	913	38.87	2.1% Decrease
Urban	47	2.00	46	1.98	1.3% Decrease
Impervious Intensity %					
0-19	36	1.55	36	1.52	No Change
20-49	11	0.45	11	0.45	No Change
50-79	0	0	0	0	No Change
80-100	0	0	0	0	No Change
Total Area	2350		2350		
Total Impervious Area (Percent Impervious Area Excludes Water Area)	47	2.00	47	2.00	No Change

Demographics

Horseshoe 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 Crow Wing County as a whole, Mission Township has a higher extrapolated growth projection (Figure 18).
(source:http://www.demography.state.mn.us/resource.html?Id=19332)



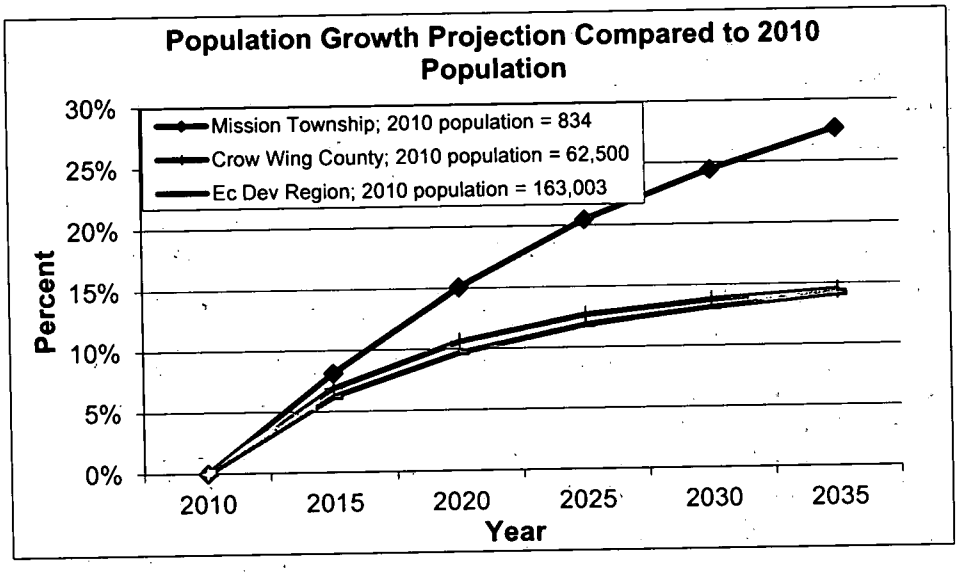


Figure 18. Population growth projection for Mission Township, and Crow Wing County.

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 Horseshoe's lakeshed is privately owned and composed of forested uplands (Table 11). In addition, a large portion of land found within the "other" category was verified as being forested. 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: Crow Wing County parcel data, National Wetlands Inventory, and the 2006 National Land Cover Dataset).

	Private (46%)					41%	Public (13%)		
	Developed	**Agriculture**	**Forested Uplands**	**Other**	**Wetlands**	**Open Water**	**County**	**State**	**Federal**
Land Use (%)	1.4	0.3	15.1	26.5	2.7	41	8.0	5.0	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	15 – 48	2 – 7	32		6		17	10.5	0
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, 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.

Horseshoe's lakeshed is classified with having 49.5% of the watershed protected and 2.6% of the watershed disturbed (Figure 19). Therefore, this lakeshed should have a protection focus. 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 Horseshoe, whether through direct overland flow or through a creek or river. Horseshoe Lake is a headwaters catchment, which means no other lakesheds flow into it.

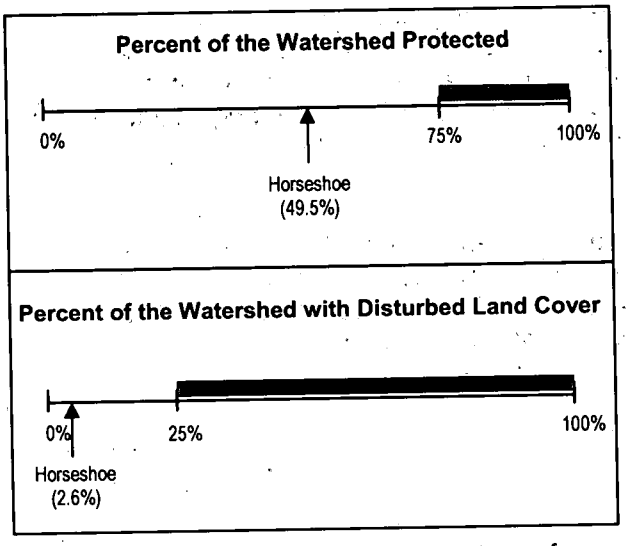


Figure 19. Horseshoe's lakeshed percentage of watershed protected and disturbed.

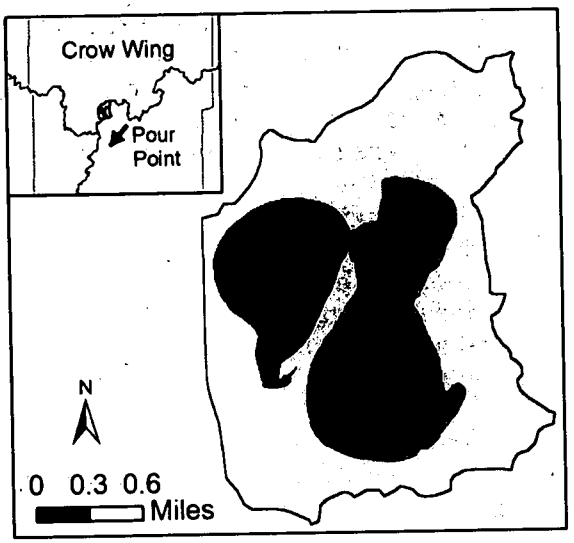


Figure 20. Upstream lakesheds that contribute water to the Horseshoe lakeshed. Color-coded based on management focus (Table 12).

Status of the Fishery (DNR, as of 08/09/2010)

Horseshoe (Sandbar) Lake is an 888 acre lake located in Crow Wing County 7 miles south of Crosslake. A public access is located on the south side of the east basin. The lake supports a minimum of 32 species of aquatic plants. Protection of aquatic vegetation, especially emergent vegetation, is important for maintaining good water quality. Also vegetation is critical for fish spawning areas as well as providing cover for fish.

Walleye catch rates are low at 0.6/gill net, although the average size was large at 22.7 inches and 4.1 lbs. Walleye stocking was discontinued in 1999 due to poor survival. Of the seven walleyes caught six were over 11 years old. Northern pike numbers at 10/gill net were the highest observed since sampling began in 1968. Northern pike over 24" made up 23% of the catch, with the largest at 32 inches.

Bluegill numbers are down from past surveys with 21.3/ trap net. However the average size increased from past surveys to 6.2 inches, with 27% over 7 inches. Growth was slower compared to other area lakes. Largemouth bass were captured by spring electrofishing at a rate of 41.7/hr. Largemouth averaged 12.6" in length, and the largest caught was 20.3".

Yellow perch are an important prey species for walleyes and northern pike. Yellow perch abundance has been extremely low the last few surveys and only two were caught in this survey. Yellow bullheads made up the bulk of gill net biomass, with 65% of the total weight. Other fish sampled include black crappie, pumpkinseed, hybrid sunfish, brown bullhead, and smallmouth bass.

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=18025100

Key Findings / Recommendations

Monitoring Recommendations
Site 207 in the east bay and site 205 in the west bay both have excellent datasets. Transparency monitoring at both of these sites 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 both of these sites, as the budget allows, to track trends in water quality.

Overall Summary
Overall, Horseshoe Lake has good water quality and the lakeshed is well protected. It is a mesotrophic lake (TSI = 43) with improving trends in water quality. Thirteen percent (13%) of the lakeshed is in public ownership, and 49.5% of the lakeshed is protected, while only 2.6% of the watershed is disturbed (Figure 19). The threshold for disturbance where water quality tends to decline is 25%, and Horseshoe Lake is well under this number.

Horseshoe Lake is at an advantage in that it is a headwaters catchment, which means that no other lakesheds flow into it. This means the land practices around the lake are the main impact to the lake's water quality.

Priority Impacts to the Lake

While Horseshoe Lake is already heavily developed, additional development within the lakeshed will have the greatest impact. Development within the first and second tiers of the lake will be of most concern because it adds impervious surface and septic systems and usually removes trees. The conversion of small lake cabins to year-round family homes increases the impervious surface and runoff from the lake lots. Most of the private land around the lake has been developed in the first tier except for the north middle shore (Figure 16). Population projection data show there is a projected increase for the township in the next 20 years (Figure 18).

Best Management Practices Recommendations

The management focus for Horseshoe Lake should be to protect the current water quality and lakeshed. Efforts should be focused on managing and/or decreasing the impact caused by additional development, and impervious surface area on existing lots (conversion of seasonal cabins to year-round homes).

The current lakeshore homeowners can lessen their negative impact on water quality by installing or maintaining the existing trees on their properties. Forested uplands contribute significantly less phosphorus (lbs/acre/year) than developed land cover (Table 11). Forested uplands can be managed with Forest Stewardship Planning.

Maintaining forested and vegetated land cover along the lake is important for protecting the current water quality. When surface runoff flows through native vegetation, which has a much more robust root system than turf grass, and infiltrates into the soil it acts as a filter, slowing down and removing potential containments in the water.

The lakeshed still has some large undeveloped shoreline parcels on the north shore (Figure 16). 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.

Native aquatic plants stabilize the lake's sediments and tie up phosphorus in their tissues. When aquatic plants are uprooted from a shallow lake, the lake bottom is disturbed, and the phosphorus in the water column gets used by algae instead of plants. This contributes to "greener" water and more algae blooms. Protecting native aquatic plant beds will ensure a healthy lake and healthy fishery. If a swimming area is necessary in front of people's docks, clear only a small area of plants. Clearing a whole 100 foot frontage is not necessary and can contribute to additional algae blooms.

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)

Lake Associations

- Lake condition monitoring
- Ground truthing – visual inspection upstream on stream inlets
- Shoreline inventory study by a consultant

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

- Shoreline restoration
- Stream buffers
- Wetlands restoration

Organizational contacts and reference sites

Horseshoe Lake Association	http://www.horseshoelakemn.com/
Crow Wing County Land Services Department	322 Laurel Street, Suite 15, Brainerd, Minnesota 56401 (218) 824-1010 http://crowwing.us/90/Land-Services
Crow Wing Soil and Water Conservation District	322 Laurel Street, Suite 22, Brainerd, Minnesota 56401 (218) 828-6197 http://www.crowwingswcd.org
DNR Fisheries Office	1601 Minnesota Drive, Brainerd, MN 56401 (218) 828-2550 http://www.dnr.state.mn.us/lakefind/index.html
Regional Minnesota Pollution Control Agency Office	7678 College Road, Suite 105, Baxter, MN 56425 (218) 828-2492 http://www.pca.state.mn.us
Regional Board of Soil and Water Resources Office	1601 Minnesota Drive, Brainerd, MN 56401 (218) 828-2383 http://www.bwsr.state.mn.us