Long Lost 15-0068-00 CLEARWATER COUNTY

Lake Water Quality

Summary

Long Lost Lake is located 23 miles northwest of Park Rapids, MN. It has a unique shape and is approximately 501 acres in size (Table 1). The exact acreage of this lake fluctuates, based on lake level. According to the MN DNR Fisheries report, since the early 1990s the lake has risen twelve feet which increased its size by approximately 100 acres.

Long Lost Lake has no inlets or outlets, which classifies it as a groundwater seepage lake. It is common to see large fluctuations in lake levels in groundwater seepage lakes. The recent increase in lake levels flooded out numerous cabins and created large amounts of standing dead timber, submerged in water.

Water quality data have been collected on Long Lost Lake since 1986. These data show that the lake is oligotrophic (TSI=38), which is characteristic of clear water throughout the summer and sustainable trout fisheries in deeper lakes (page 9).

The Long Lost Lake Area Association first organized in 1980 to afford members the maximum enjoyment and benefits of the lake, to provide and improve facilities for recreation, and to help preserve the lake for the enjoyment of their children and future generations.

Table 1. Long Lost Lake location and key physical characteristics. (Source data for area and depth: MN DNR GIS Lake Basin Morphology Layer)

Location Data		Physical Characteristics	
MN Lake ID:	15-0068-00	Surface area (acres):	501
County:	Clearwater	Littoral area (acres):	383
Ecoregion:	Northern Lakes and Forests	% Littoral area:	76%
Major Drainage Basin:	Upper Mississippi River	Max depth (ft), (m):	53
Latitude/Longitude:	47.19105737/-95.413494092	Inlets:	0
Invasive Species:	None as of 2012	Outlets:	0
		Public Accesses:	1

Table 2. Availability of primary data types for Long Lost Lake.

Data Availability

Transparency data		Excellent data source from 1986-2011.
Chemical data		Good data set, but not enough to run trend analysis.
Inlet/Outlet data	—	Not applicable.

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

Lake Map

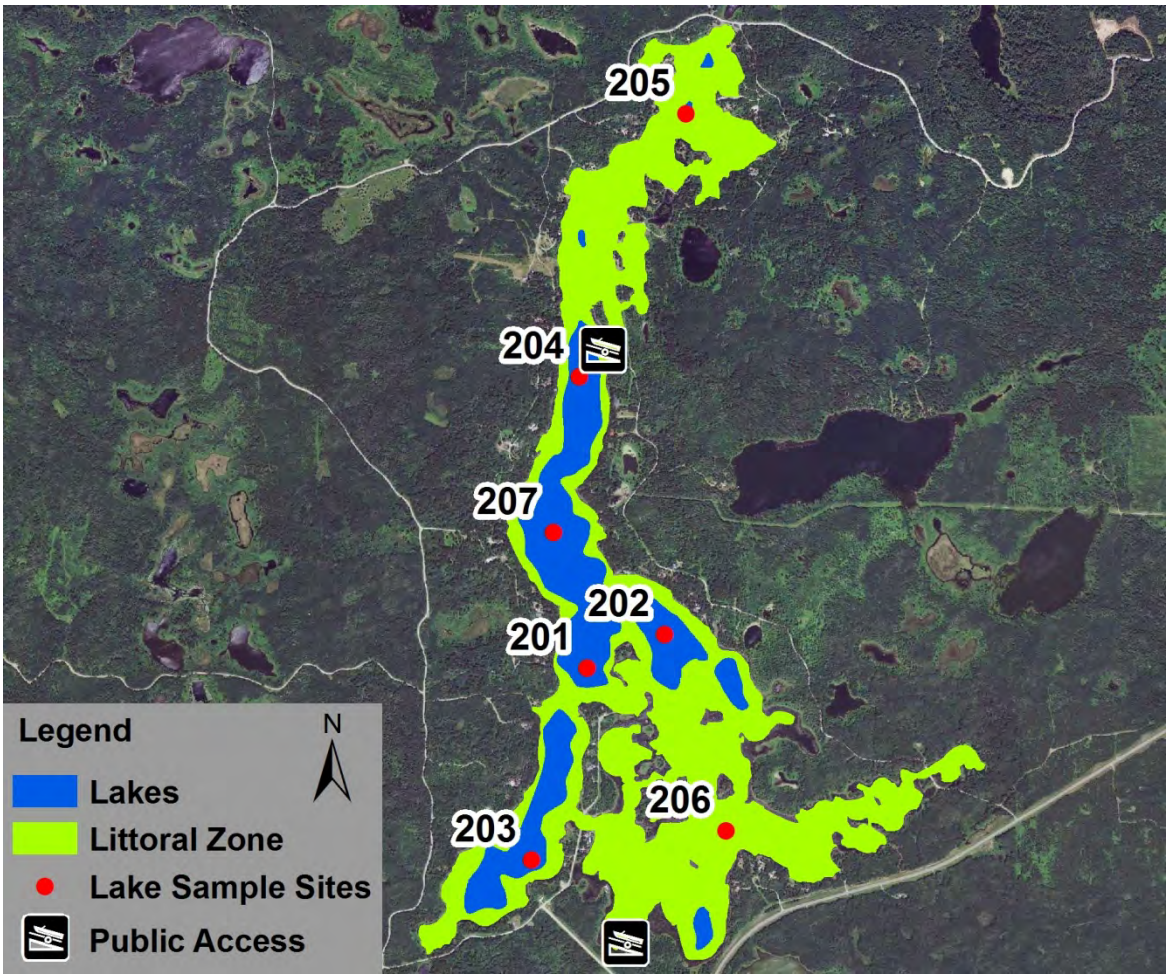


Figure 1. Map of Long Lost lake with 2010 aerial imagery and illustrations of lake sample site locations and public access points. The light green areas in the lake illustrate the littoral zone, where the sunlight can usually reach the lake bottom allowing aquatic plants to grow.

Table 3. Monitoring programs and associated monitoring sites. Monitoring programs include the MPCA Lake Monitoring Program Project (MPCA), Citizen Lake Monitoring Program (CLMP), Clearwater County 2011 Lake Monitoring Program (CCLMP), and RMB Environmental Laboratories Lakes Program (RMBEL).

Lake Site	Depth (ft)	Monitoring Programs
100	7	MPCA: 1993
201	30	CLMP: 1986-2011
202	33	CLMP: 1993, 1995-2011; MPCA: 1993
203	37	CLMP: 1993; MPCA: 1993
204	46	CLMP: 1993, 1995
205	16	CLMP: 1993
206	11	CLMP: 1993
207*Primary Site	53	CLMP: 1993, 1995, 1997-2006, 2008-2011; CCLMP: 2008, 2009; MPCA: 1993; RMBEL: 2002-2004, 2011

Average Water Quality Statistics

The information below describes available data for Long Lost Lake through 2011 (Table 4). Data means are calculated from site 207. Chlorophyll *a* and total phosphorus data were collected in 1993, 2002-2004, 2009, 2009, and 2011. Secchi depth readings were measured in 1993, 1995, 1997-2006, and 2008-2011. All other parameter means are calculated from data collected in 1993.

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	Mean	Ecoregion Range[1]	Impaired Waters Standard[2]	Interpretation
Total phosphorus (ug/L)	11	14 - 27	> 30	Results are better than the expected ecoregion regions. Chlorophyll *a* was only recorded above 7 ug/L two times (11 and 16 ug/L).
[3]Chlorophyll *a* (ug/L)	3.2	4 - 10	> 9	
Chlorophyll *a* max (ug/L)	16	<15		
Secchi depth (ft)	20.2	7.5 - 15	< 6.5	
Dissolved oxygen	*Dimictic* See page 8			Dissolved oxygen depth profiles show that the lake stratifies in the summer.
Total Kjeldahl Nitrogen (mg/L)	0.56	0.4 - 0.75		Indicates insufficient nitrogen to support summer nitrogen-induced algae blooms.
Alkalinity (mg/L)	138	40 - 140		Indicates a low sensitivity to acid rain and a good buffering capacity.
Color (Pt-Co Units)	9	10 - 35		Indicates clear water with little to no tannins (brown stain).
pH	8.3	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)	0.6	0.6 - 1.2		Within the expected range for the ecoregion.
Total Suspended Solids (mg/L)	1.2	<1 - 2		Within the expected range for the ecoregion.
Specific Conductance (umhos/cm)	208	50 - 250		Within the expected range for the ecoregion.
Total Nitrogen :Total Phosphorus	47:1	25:1 – 35:1		Indicates 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 and Ranges

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

Parameters	Site 201	Site 202	Site 207
Total Phosphorus Mean (ug/L):		**12.2**	**11.3**
Total Phosphorus Min:		9	7
Total Phosphorus Max:		15	22
Number of Observations:		5	34
Chlorophyll *a* Mean (ug/L):		**3.7**	**3.2**
Chlorophyll-a Min:		2.9	< 1
Chlorophyll-a Max:		4.8	16
Number of Observations:		3	34
Secchi Depth Mean (ft):	**21.4**	**18.8**	**20.2**
Secchi Depth Min:	12.0	8.0	7.5
Secchi Depth Max:	33.1	36.1	35.4
Number of Observations:	287	197	186

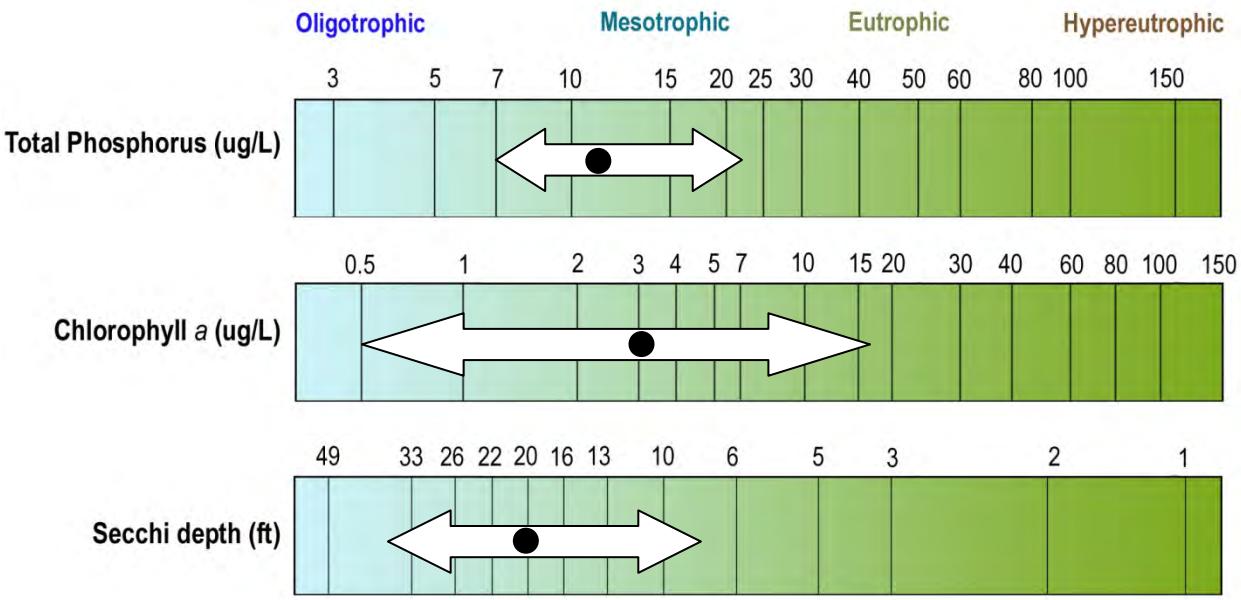


Figure 2. Long Lost Lake total phosphorus, chlorophyll *a* and transparency historical ranges. The arrow represents the range and the black dot represents the historical mean (Primary Site 207). Figure adapted after Moore and Thornton, [Ed.]. 1988. Lake and Reservoir Restoration Guidance Manual. (Doc. 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 mean transparency in Long Lost Lake ranges from 15.6 to 26.2 feet (Table 5). Based on Figure 3, it appears that transparency has been improving since the mid-1980s. The increase in water levels could play a role in this improvement. Site 201 consistently has better transparency readings than sites 202 and 207. All other variables equal, the deeper sites usually have better transparency readings, which would be site 207 (53 ft). It does appear that the last several years the annual means were closer across sites.

These 3 sites are all relatively close to each other. Site 201 has 25 years of historical data and site 207 is the deepest site on the lake. Most of the chemical data has been collected at site 207. Transparency monitoring should be continued annually at sites 201 and 207 in order to track water quality changes. Site 202 has been monitored since 1995. This site could continue to be monitored, but it does appear to track very similarly to site 207. The spike in 2007 at site 202 is probably because transparency was only collected twice that year, both in the spring.

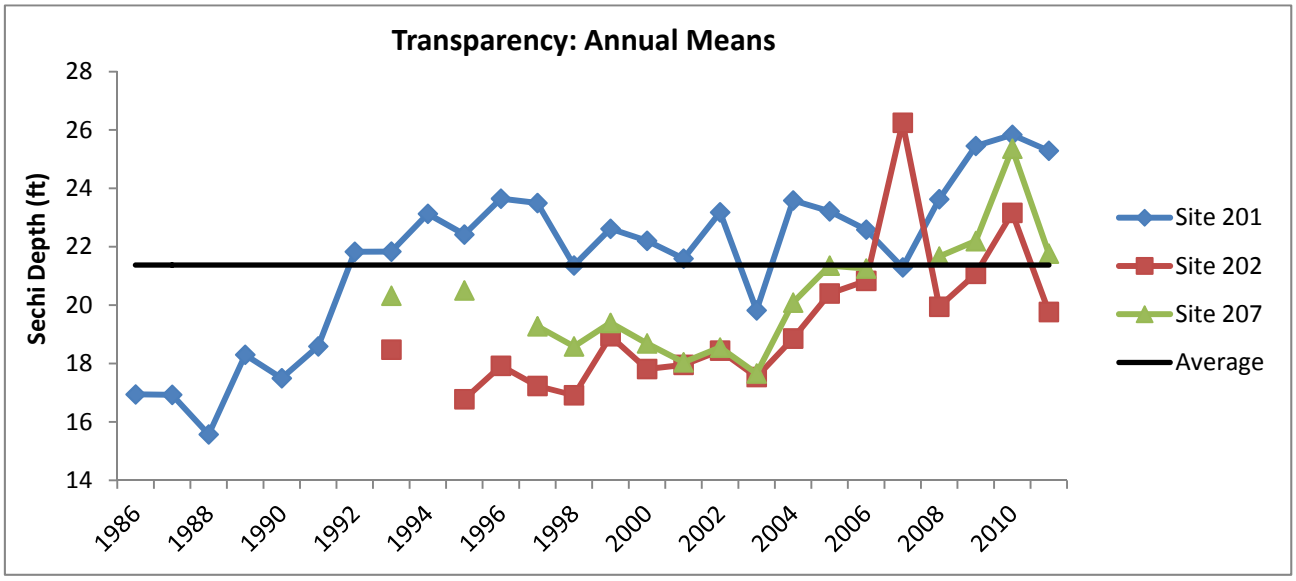


Figure 3. Annual mean transparency compared to long-term mean transparency, sites 201, 202, and 207.

Long Lost Lake transparency ranges from 12.0 to 33.1 ft at site 201. Figure 4 shows the seasonal transparency dynamics. The maximum Secchi reading is usually obtained in early summer. Long Lost Lake transparency is high in May and June, and then declines through August. The transparency would likely rebound in October if readings were collected 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.

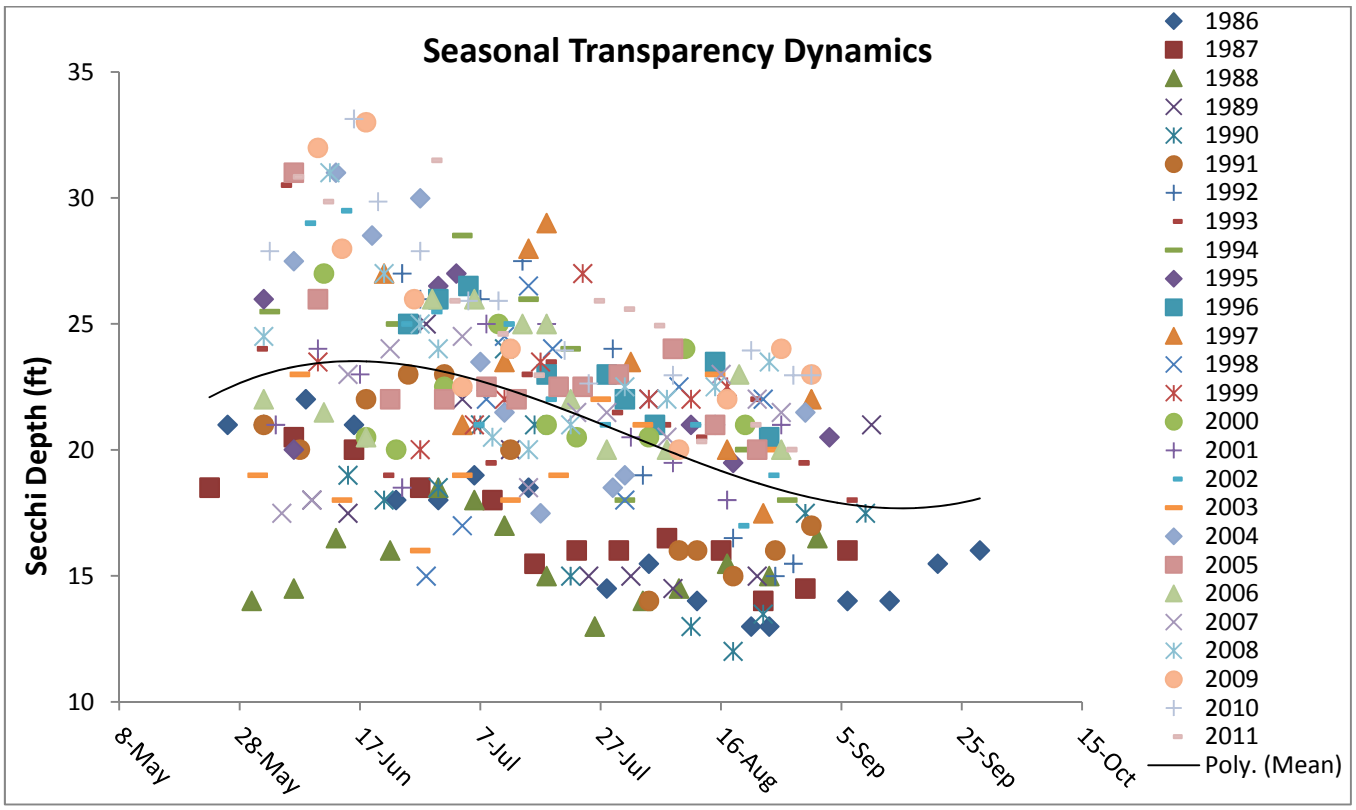


Figure 4. Seasonal transparency dynamics and year to year comparison (Site 201). The black line represents the pattern in the data.

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. Long Lost Lake was rated as being "crystal clear" 97% of the time by samplers at site 201 during the years 1989-2011 (Figure 5).

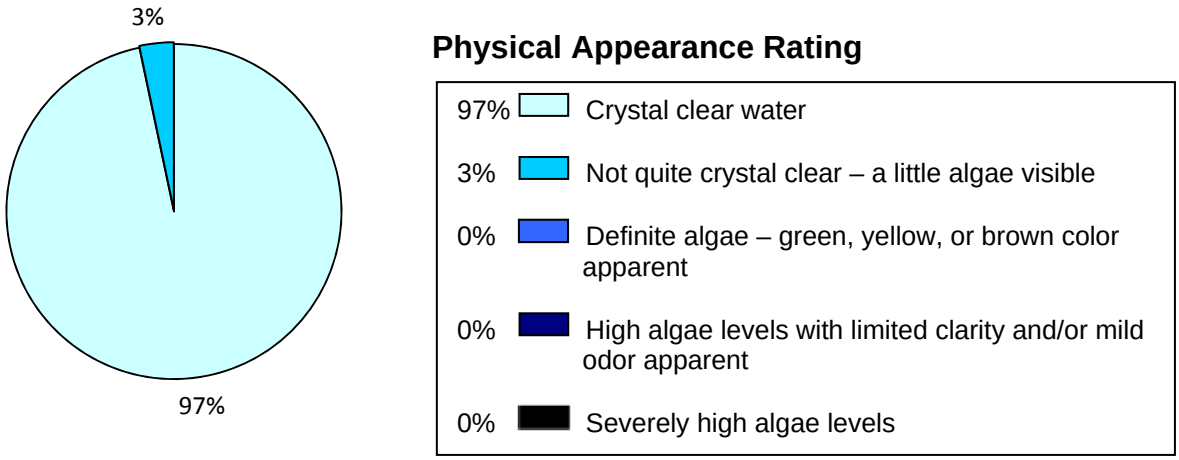


Figure 5. Long Lost lake physical appearance ratings by samplers at site 201.

As the secchi depth decreases, the perception of recreational suitability of the lake decreases. Long Lost Lake was rated as being "beautiful" 99% of the time during the years 1989-2011 at site 201 (Figure 6).

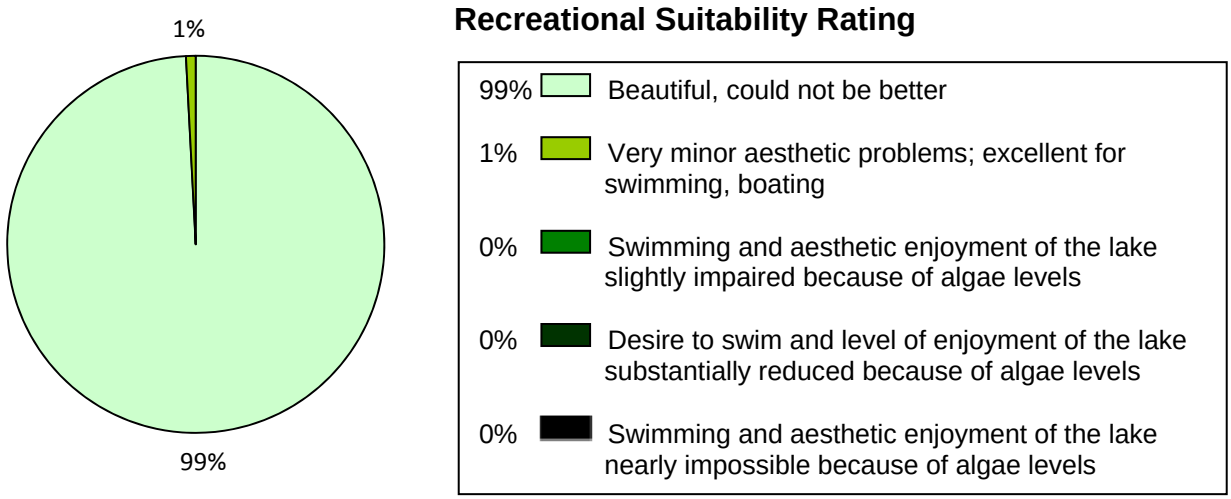


Figure 6. Recreational suitability rating, as rated by the volunteer monitor at site 201.

Total Phosphorus

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

Total phosphorus was evaluated in Long Lost Lake in 2002-2004, 2008, 2009, and 2011. The data do not indicate much seasonal variability. The majority of the data points fall into the oligotrophic range (Figure 7).

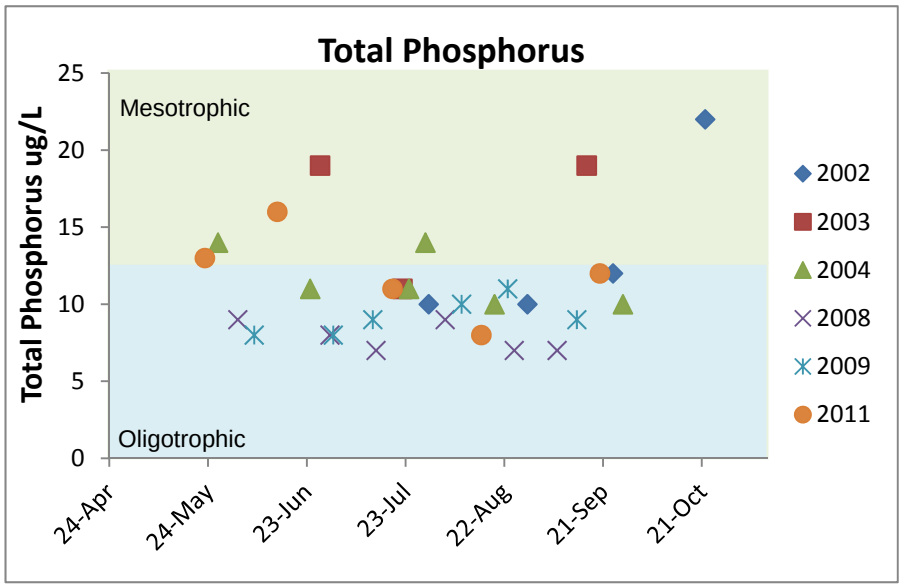


Figure 7. Historical total phosphorus concentrations (ug/L) for Long Lost Lake site 207.

Near bottom water samples were collected on Long Lost Lake in 1993 to evaluate the level of total phosphorus. The levels in 1993 were quite low (22-45 ug/L).

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 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.

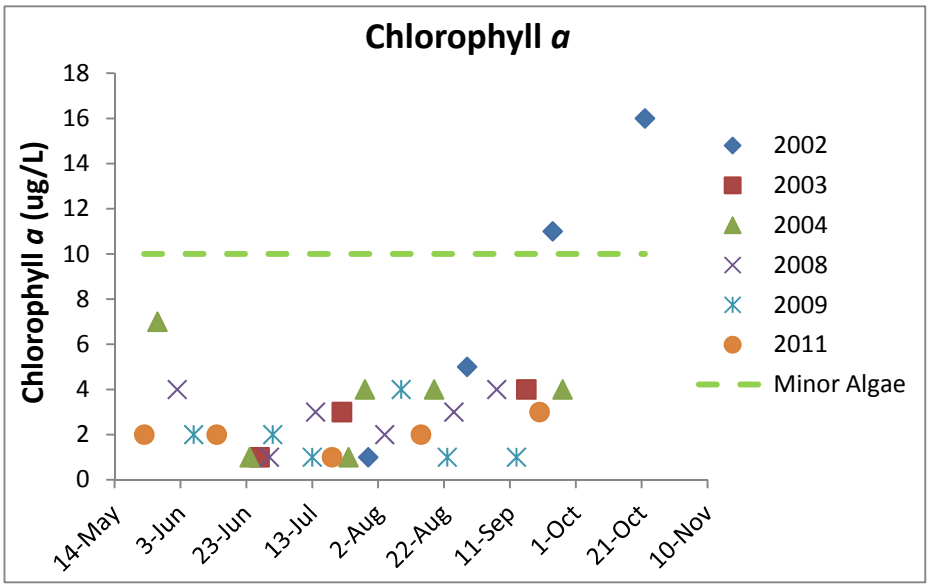
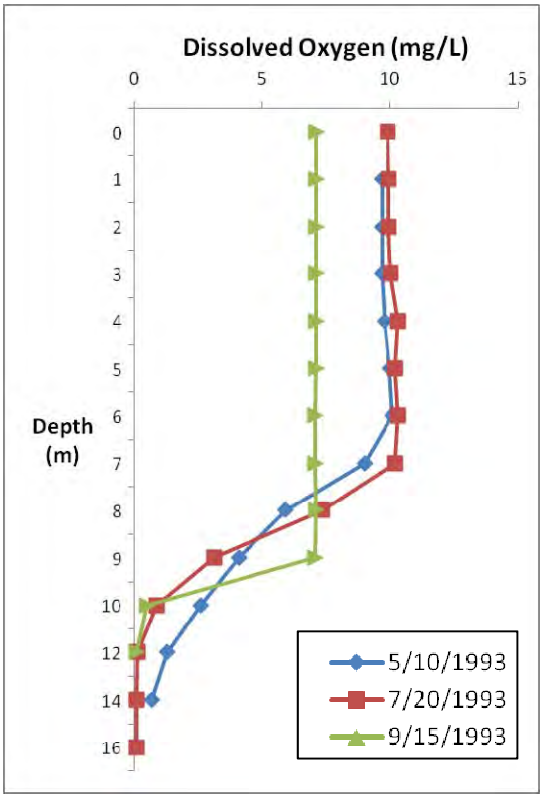


Figure 8. Chlorophyll *a* concentrations (ug/L) for Long Lost lake at site 207.

Chlorophyll *a* was evaluated in Long Lost Lake at site 207 from 2002-2004, 2008, 2009, and 2011 (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



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.

Long Lost Lake is a relatively shallow lake, with a maximum depth of 53 ft. Dissolved oxygen profiles from data collected in 1993 at site 207 show stratification developing mid-summer. The thermocline occurs at approximately 9.5 meters (31 feet), which means that gamefish will be scarce below this depth. Figure 9 is a representative DO profile for Long Lost Lake and it illustrates stratification in the summer of 1993 at site 207.

Figure 9. Dissolved oxygen profile for Long Lost lake in 1993 at site 207.

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 Long Lost Lake falls into the oligotrophic range (Figure 10). There is good agreement between the TSI for chlorophyll *a* and transparency (Table 6). The total phosphorus TSI is somewhat lower than the other two measures, which could be due to a loss of rooted vegetation.

Oligotrophic lakes (TSI 0-39) are characteristic of extremely clear water throughout the summer and sandy or rocky shores. They are excellent for recreation. Some very deep oligotrophic lakes are able to support a trout fishery.

Table 6. Trophic State Index for site 207.

Trophic State Index	Site 207
TSI Total Phosphorus	34
TSI Chlorophyll-a	42
TSI Secchi	39
TSI Mean	38
Trophic State:	Oligotrophic

Numbers represent the mean TSI for each parameter.

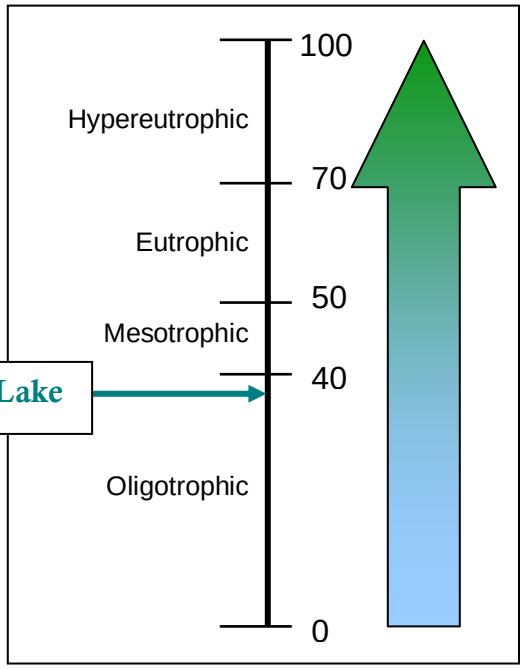


Figure 10. Trophic state index chart with corresponding trophic status.

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

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

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

Trend Analysis

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

Long Lost Lake had enough data to perform a trend analysis on transparency at sites 201 and 207 (Table 8). The data was analyzed using the Mann Kendall Trend Analysis. Two more years of data are needed to run the trend analysis on total phosphorus and chlorophyll *a*.

Table 8. Trend analysis for sites 201 and 207.

Lake Site	Parameter	Date Range	Trend	Probability
201	Transparency	1986-2011	Improving	95%
207	Total Phosphorus	1993, 2002-2004, 2008, 2009, 2011	Insufficient Data	--
207	Chlorophyll a	1993, 2002-2004, 2008, 2009, 2011	Insufficient Data	--
207	Transparency	1993, 1995, 1997-2006, 2008-2011	No Trend	--

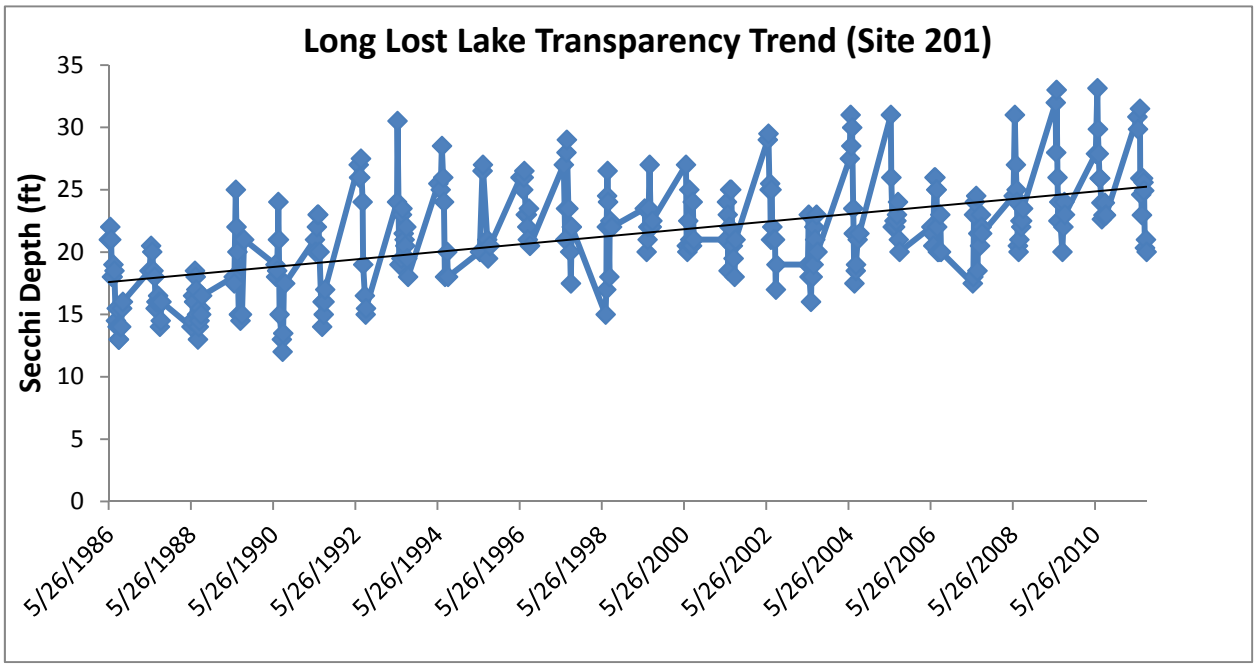


Figure 11. Transparency (ft) trend for site 201 from 1986-2011.

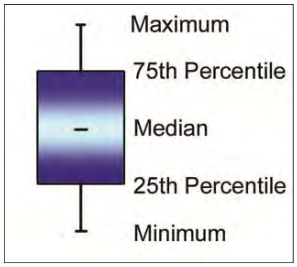
Long Lost Lake shows an improving trend in transparency at site 201 using all of the data from 1986-2011 (Figure 11). When a trend analysis was run on the last decade of data (2001-2011) the transparency was more stable and no trend existed. Though no trend was detected at site 207 using all the available data, an improving trend resulted from analyzing just the spring data (May and June, across all years). Transparency monitoring should continue so that these trends and potential trends can be tracked in future years.

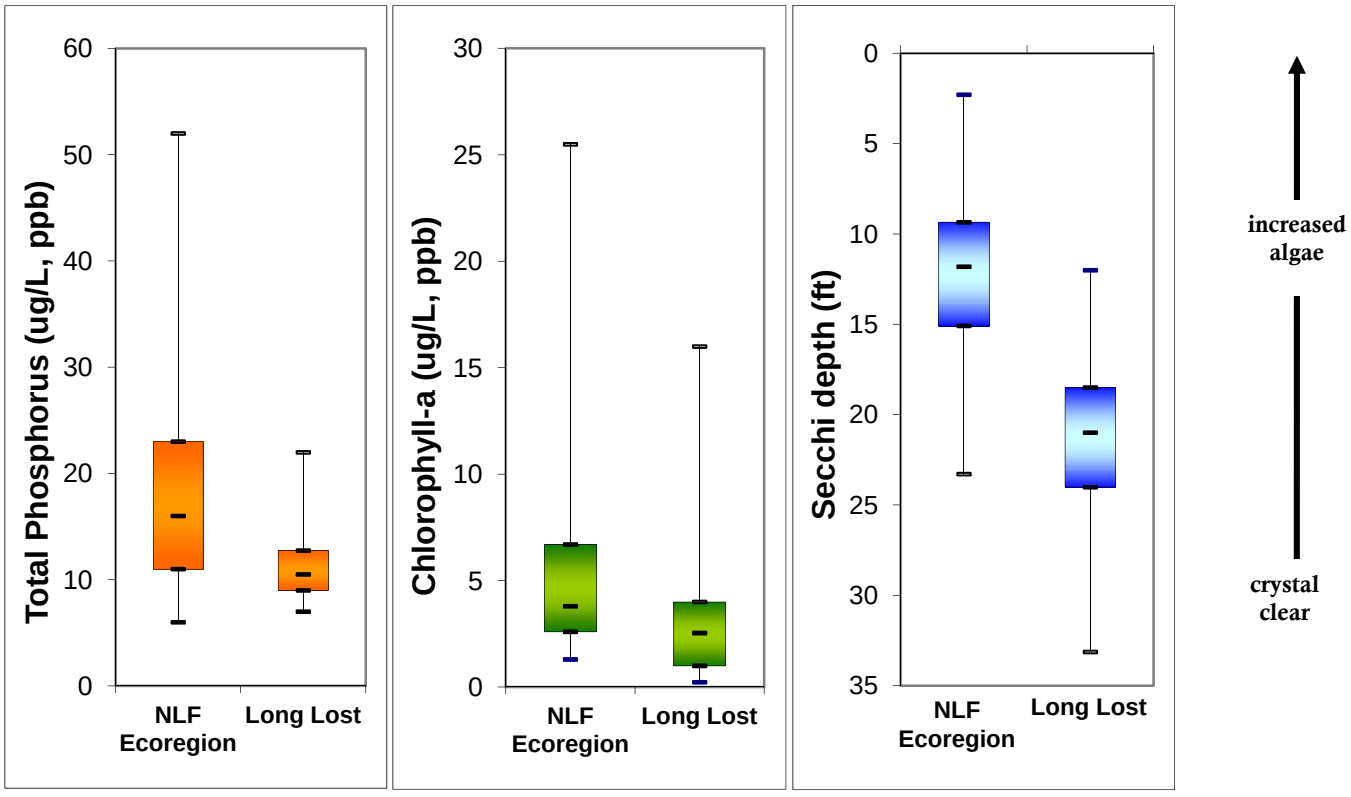
Ecoregion Comparisons

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. 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.

Long Lost Lake is in the Northern Lakes and Forests Ecoregion (Figure 12). The mean total phosphorus, chlorophyll *a*, and transparency (secchi depth) for Long Lost are slightly better than the ecoregion ranges (Figure 13).





Figures 13a-c. Long Lost Lake ranges compared to Northern Lakes and Forest Ecoregion ranges. The Long Lost Lake total phosphorus and chlorophyll *a* ranges are from 34 data points collected in May-September in 1993, 2002-2004, 2008, 2009, and 2011. The Long Lost Lake secchi depth range is from 287 data points collected in May-September from 1986-2011.

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 14). This major watershed is made up of 136 minor watersheds. Long Lost Lake is located in **minor watershed** 12141 (Figure 15).

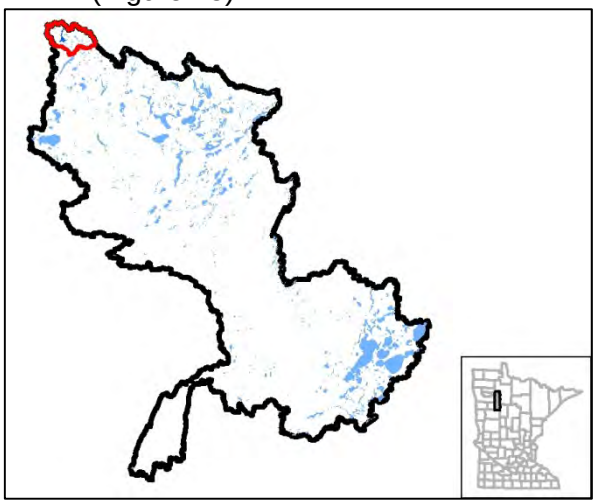


Figure 14. Crow Wing River Major Watershed.

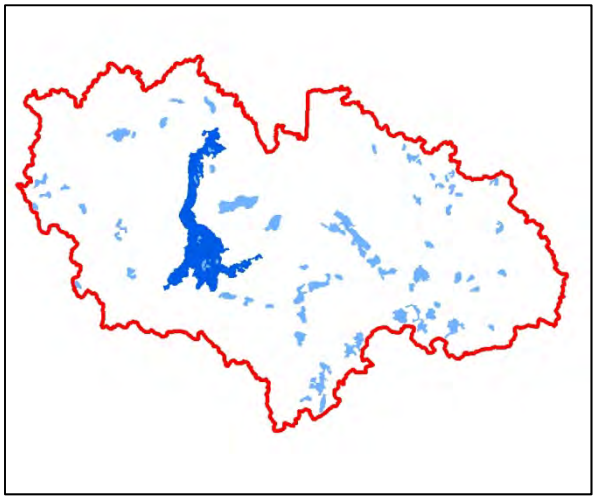


Figure 15. Minor Watershed 12141

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. Long Lost Lake falls within **lakeshed 1214100** (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. However, Long Lost Lake's lakeshed is a

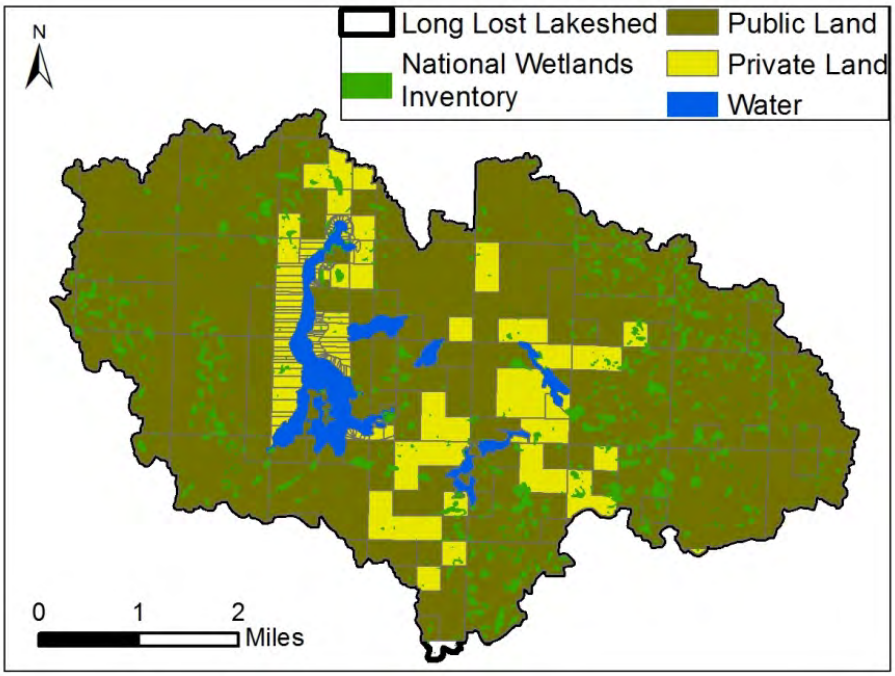


Figure 16. Long Lost Lake lakeshed (1214100) with land ownership, lakes, wetlands, and rivers illustrated.

headwaters catchment, which means the area displayed in Figure 16 is the only lakeshed that contributes water to the Lake.

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

KEY
Possibly detrimental to the lake
Warrants attention
Beneficial to the lake

Table 9. Long Lost lakeshed vitals table.

Lakeshed Vitals		Rating
Lake Area	501 acres	descriptive
Littoral Zone Area	383 acres	descriptive
Lake Max Depth	53 ft.	descriptive
Lake Mean Depth	9.5 ft.	
Water Residence Time	NA	NA
Miles of Stream	0	descriptive
Inlets	0	
Outlets	0	
Major Watershed	12 – Crow Wing River	descriptive
Minor Watershed	12141	descriptive
Lakeshed	1214100	descriptive
Ecoregion	Northern Lakes and Forests	descriptive
Total Lakeshed to Lake Area Ratio (total lakeshed includes lake area)	40:1	
Standard Watershed to Lake Basin Ratio (standard watershed includes lake areas)	40:1	
Wetland Coverage	7.7%	
Aquatic Invasive Species	None as of 2012	
Public Drainage Ditches	None	
Public Lake Accesses	2	
Miles of Shoreline	15.46	descriptive
Shoreline Development Index	4.1:1	
Public Land to Private Land Ratio	5.5:1	
Development Classification	Recreational Development	
Miles of Road	32.3	descriptive
Municipalities in lakeshed	None	
Forestry Practices	Yes, managed by the Clearwater County Resource Management Plan	
Feedlots	None	
Sewage Management	Individual waste treatment systems	
Lake Management Plan	None	
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.

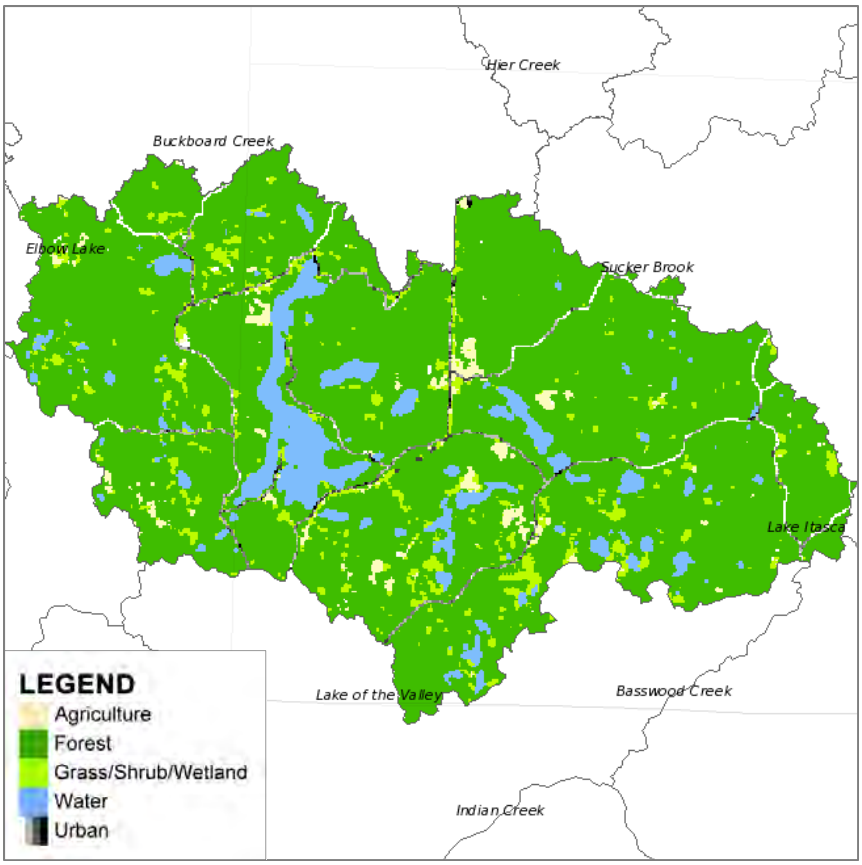


Figure 17. Long Lost Lake lakeshed (1214100) land cover (http://land.umn.edu).

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. Figure 17 depicts the land cover in Long Lost Lake's lakeshed.

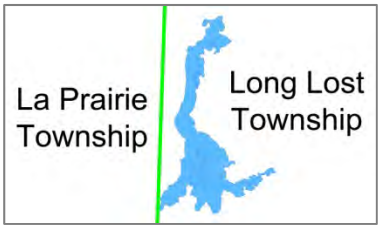
The University of Minnesota has online records of land cover statistics from years 1990 and 2000 (http://land.umn.edu). Although this data is 12 years old, it is the only data set that is comparable over a decade's time. Table 10 describes Long Lost Lake's lakeshed land cover statistics and percent change 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 transition within the lakeshed from agriculture, grass/shrub/wetland, and water acreages to forest and urban acreages. The largest change was a 49.1% decrease in grassland/wetland land use. Agriculture land use also decreased (44.6%). The biggest increase was in the forest land use category (9% or 1,091 acres). Urban acreage increased by 9 acres.

Table 10. Long Lost Lake's lakeshed land cover statistics and % change from 1990 to 2000 (http://land.umn.edu).

	1990		2000		% Change
Land Cover	**Acres**	**Percent**	**Acres**	**Percent**	**1990 to 2000**
Agriculture	504	3.2	279	1.77	44.6% Decrease
Forest	12122	76.97	13213	83.9	9.0% Increase
Grass/Shrub/Wetland	1484	9.42	756	4.8	49.1% Decrease
Water	1320	8.38	1174	7.45	11.1% Decrease
Urban	443	2.81	452	2.87	2.0% Increase
Impervious Intensity %					
0	15587	98.98	15417	97.9	1.1% Decrease
1-10	75	0.48	139	0.88	85.3% Increase
11-25	52	0.33	117	0.74	125% Increase
26-40	17	0.11	38	0.24	123.5% Increase
41-60	11	0.07	23	0.15	109.1% Increase
61-80	4	0.03	12	0.08	200% Increase
81-100	1	0.01	1	0.01	No Change
Total Area	15749		15749		
Total Impervious Area (Percent Impervious Area Excludes Water Area)	26	0.18	59	0.4	126.9% Increase

Demographics

Long Lost Lake is classified as a recreational development lake. Recreational development lakes usually have less than 150 total acres, less than 60 acres per mile of shoreline, and less than 3 dwellings per mile of shoreline. They may have some winter kill of fish; may have shallow, swampy shoreline; and are less 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 Clearwater County as a whole, La Prairie Township has a similar extrapolated growth projection and Long Lost Township has a higher extrapolated growth projection (Figure 18). (source:http://www.demography.state.mn.us/resource.html?Id=19332)

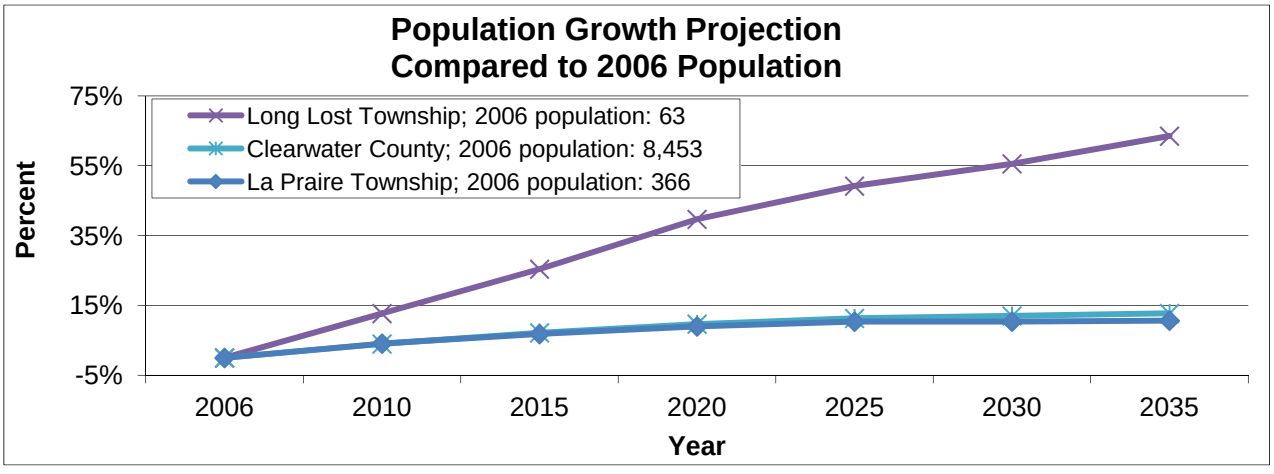


Figure 18. Population growth projection for Long Lost and La Prairie Townships and Clearwater County, MN.

Long Lost 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 Long Lost Lake's lakeshed is publicly owned county land (65.3%, Table 11). The majority of the privately owned land is currently categorized as forested uplands.

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

	Private (15%)					4%	Public (81%)		
	Developed	**Agriculture**	**Forested Uplands**	**Other**	**Wetlands**	**Open Water**	**County**	**State**	**Federal**
Land Use (%)	0.3	0.1	11.5	2.3	0.8	4	65.3	10.6	5.1
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	20 – 66	5 – 18	165		11		933	151	72
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.

Long Lost Lake's lakeshed is classified with having 83.6% of the watershed protected and 1.7% of the watershed disturbed (Figure 19). Therefore, this lakeshed should have a vigilance focus. Goals for the lake should be to limit any increase in disturbed land use. Figure 20 displays all the land area that contributes water to Long Lost Lake, whether through direct overland flow or through a creek or river. This particular lakeshed is a headwaters catchment, which means no additional lakesheds upstream contribute water to this area.

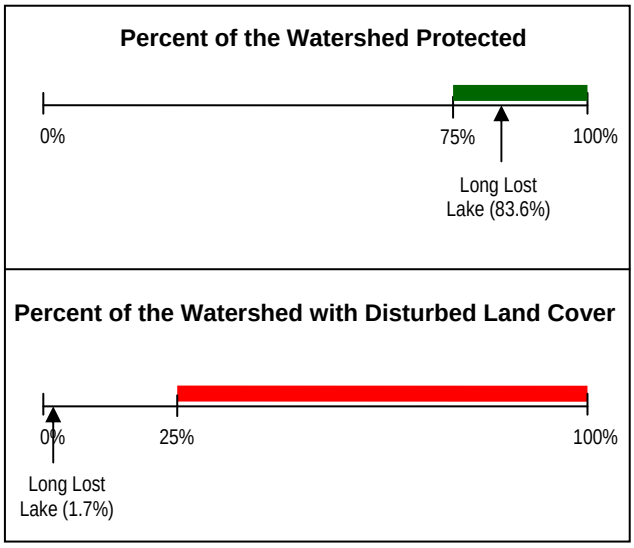


Figure 19. Long Lost Lake's lakeshed percentage of watershed protected and disturbed.

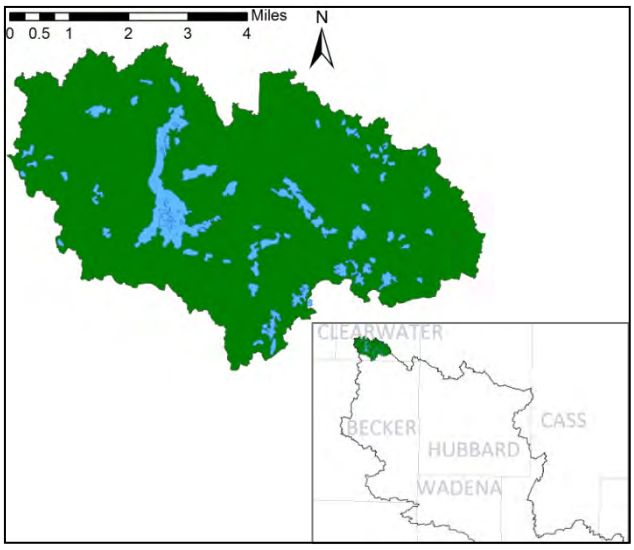


Figure 20. Upstream lakesheds that contribute water to the Long Lost Lake's lakeshed. Color-coded based on management focus (table 12).

Status of the Fishery (DNR, as of 08/02/2010)

Long Lost Lake is a scenic 493-acre lake located about ten miles west of Itasca State Park in southern Clearwater County. Long Lost Lake has clear water; the Secchi depth was 16.8 feet in August 2010. Bluegill, largemouth bass, and black crappie are the primary management species, with walleye, smallmouth bass, and northern pike managed as secondary species. Long Lost Lake has an interesting history. Since the early 1990's, the level of the lake has risen twelve feet, and recently has receded by two feet. This has increased the surface area of the lake by approximately 100 acres, flooding lake cabins (some of which are still standing), and creating large amounts of standing timber in deep water. This type of aquatic habitat is unique to natural lakes in northern Minnesota, and is more typical of a flood control reservoir.

Another recent change has been the unauthorized introduction of smallmouth bass. These fish were first documented in 1993, and are now well established in Long Lost Lake, making it one of the only lakes in the Bemidji area with a fishable smallmouth bass population. The bluegill catch rate from the 2010 population assessment (38.5/TN) was nearly twice the median catch rate for class 25 lakes. The population is currently dominated by smaller fish, with no bluegill greater than 7.5 inches in length captured in the assessment. The average size was 0.11 pounds (5.3 inches in length). Growth rates for bluegill in Long Lost Lake are slow. There are good numbers of bluegill from 6.0 to 7.5 inches in length present, and some of these fish will grow to a size preferred by anglers in the near future. The black crappie catch rate of 0.8/TN was below the median for this lake class (1.5/TN) and similar to the previous assessment in 2005. The largest black crappie captured was 12.2 inches in length. Four age classes of crappie were identified in the catch. Black crappie reproduction can be inconsistent in northern Minnesota Lakes. Habitat for black crappie in Long Lost Lake is abundant, and potential fishing spots are numerous. Fishing with a bobber around the flooded timber can be productive but be prepared to deal with numerous snags. Largemouth bass and smallmouth bass (LMB and SMB) electrofishing catch rates in the 2010 assessment were good, and substantially higher than historic catch rates from the 1990's. LMB outnumbered SMB in the sample by 4 to 1. LMB up to 16.7 inches and SMB up to 14.8 inches in length were captured. Larger fish were observed but not captured. Given the extensive flooded timber-deep water habitat, it may not be possible to get a truly representative sample of the bass population. Interestingly, bass catch rates in the gill net portion of the 2010 assessment were high, which is not typical for this gear type, and suggests that bass (particularly SMB) in Long Lost Lake are utilizing deep water habitat as some of the gill nets are set in 45 feet of water. Bass anglers should enjoy the scenery and diversity of habitat on Long Lost Lake and have an opportunity for some quality fishing. Walleye have been sampled in low numbers in the past few assessments. Average size of the walleye catch in 2010 was impressive, with fish up to 29.7 inches in length captured, and a wide range of age classes present in the catch. Walleye utilize deep water habitat in Long Lost Lake.

The lake stratifies deeply, with good oxygen levels down to 40+ feet in August of 2010. Catch rates for walleye in Long Lost Lake may not be comparable to the more popular walleye lakes in the area, but the opportunity to catch a truly large walleye exists.

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=15006800

Key Findings / Recommendations

Monitoring Recommendations
Transparency monitoring should be continued annually at sites 201 and 207 in order to track water quality changes. 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, as the budget allows, to track trends in water quality.

Overall Summary
Long Lost Lake is a high quality water resource with excellent water quality (TSI=38). A long-term trend analysis showed transparency readings improving since 1986, but stabilizing in recent years (2001-2011). Long Lost Lake was rated as "beautiful, could not be better" 99% of the time during 242 sampler observations from 1989 to 2011 (Figure 6).

The surrounding watershed area is also in excellent condition for water quality. Eighty-one percent (81%) of the land is in public ownership and not developed (Table 11). According to the MN DNR analysis, 83.6% of the lakeshed is protected and should have a vigilance management focus for water quality (Figure 19). Most of the public land is a part of the Clearwater County's Memorial Forest. In addition, the surrounding lakeshed is a headwaters catchment, which means no additional water flows in from other upstream lakesheds.

The lakeshed is dominantly forested uplands, which has a very low estimated phosphorus loading (0.09 lbs of phosphorus/acre/year) and 7.7% is categorized as wetlands. The little development that is present in the lakeshed is near the lake itself. There is some forestry occurring in the lakeshed, that is managed by the Clearwater County Resource Management Plan.

It is often difficult to determine why a lake has an improving trend in transparency. Usually improving transparency corresponds with declining clarity due to increased shoreline erosion. In the case of Long Lost Lake, the improving clarity could just be due to the fact that the water is deeper due to increased water levels. The lakeshed is well forested, so it could be that the increased water levels did not cause significant shoreline erosion.

Priority Impacts to the lake
The priority impact to Long Lost Lake's water quality is probably lakeshore development. The lake has a high shoreline development index (Table 9), which means it has an irregular shoreline, allowing from more development compared to a perfectly round lake. Fortunately, the development that has occurred along the shoreline consists of larger size properties (200-300 ft. frontage).

Numerous concerns arise as lakeshore develops, related to water quality, including increased impervious surfaces, increased inputs to maintain traditional turf lawns, removal of near shore, native plant beds, and proper maintenance of septic systems. Long Lost Lake has the added concern that increased lake levels could submerge developed lots. A setback ordinance on new development would help alleviate concerns will near-shore contamination.

Though Long Lost Lake has a maximum depth of approximately 53 feet, the mean lake depth is about 9.5 feet (Table 9). Most of the outer bays are considered littoral zone (less than 15 feet, Figure1). The shallow mean depth of Long Lost Lake could also impact water quality.

Protecting native aquatic plant beds is extremely important for shallow lakes. The higher chlorophyll *a* TSI and lower total phosphorus TSI could reflect a loss of rooted vegetation (Table 6). Plant beds function is several ways to protect water quality including, holding bottom sediment in place, utilizing available nutrients, and providing fish habitat. One of the most common variables found in shallow lakes with exceptional water clarity is healthy, submerged aquatic vegetation.

Best Management Practices Recommendations
The management focus for Long Lost Lake should be to protect the current water quality and the level of undisturbed land use in the lakeshed. Efforts should be focused on managing and/or decreasing the impact caused by additional 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.

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.

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

Organizational contacts and reference sites

Lake Association	http://www.longlostlake.com/ http://www.minnesotawaters.org/group/long-lost-lake-association/welcome
DNR Fisheries Office	2114 Bemidji Avenue, Bemidji, MN 56601 218-308-2339 bemidji.fisheries@state.mn.us http://www.dnr.state.mn.us/areas/fisheries/bemidji/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
Clearwater Soil and Water Conservation District	312 Main Avenue North, Suite 3, Bagley, Minnesota 56621 218.694.6845 http://www.clearwaterswcd.org/