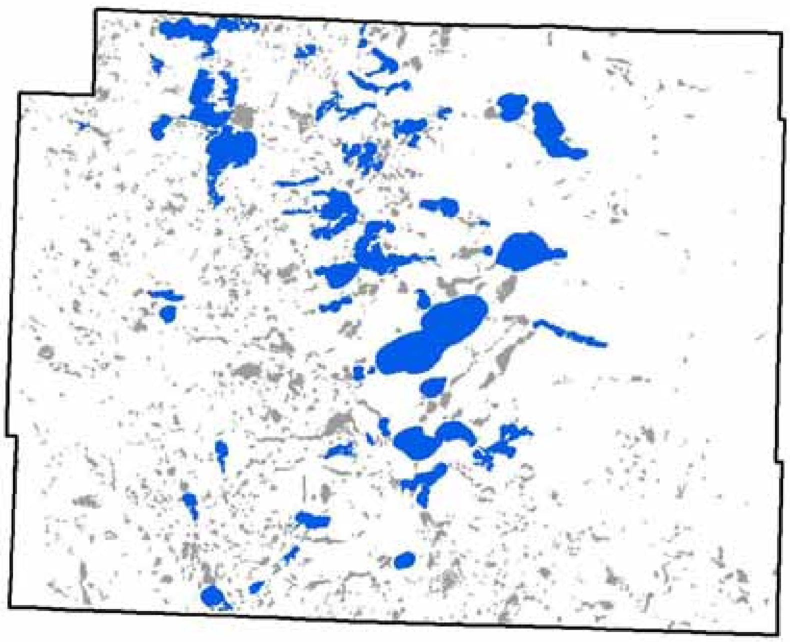
Otter Tail County
Lakes Assessment



2013

Otter Tail County Soil and Water Conservation District
Minnesota Board of Soil and Water Resources

List of Abbreviations

BWSR: Board of Soil and Water Resources

CHLA: Chlorophyll *a*

CLMP: Citizens Lake Monitoring Program – transparency data collection

CLMP+: Citizens Lake Monitoring Program – transparency and chemical data collection

CSMP: Citizens Stream Monitoring Program

DNR: Minnesota Department of Natural Resources

LAP: Lake Assessment Program

MPCA: Minnesota Pollution Control Agency

SWCD: Soil and Water Conservation District

TMDL: Total Maximum Daily Load

TP: Total phosphorus

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Lake Associations

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Otter Tail County Coalition of Lake Associations
Lake Associations

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Introduction

Otter Tail County is located in the lakes country of northwest Minnesota. The county is home to 1,048 lakes and many rivers and streams. These resources are valued for their excellent recreation opportunities and water quality.

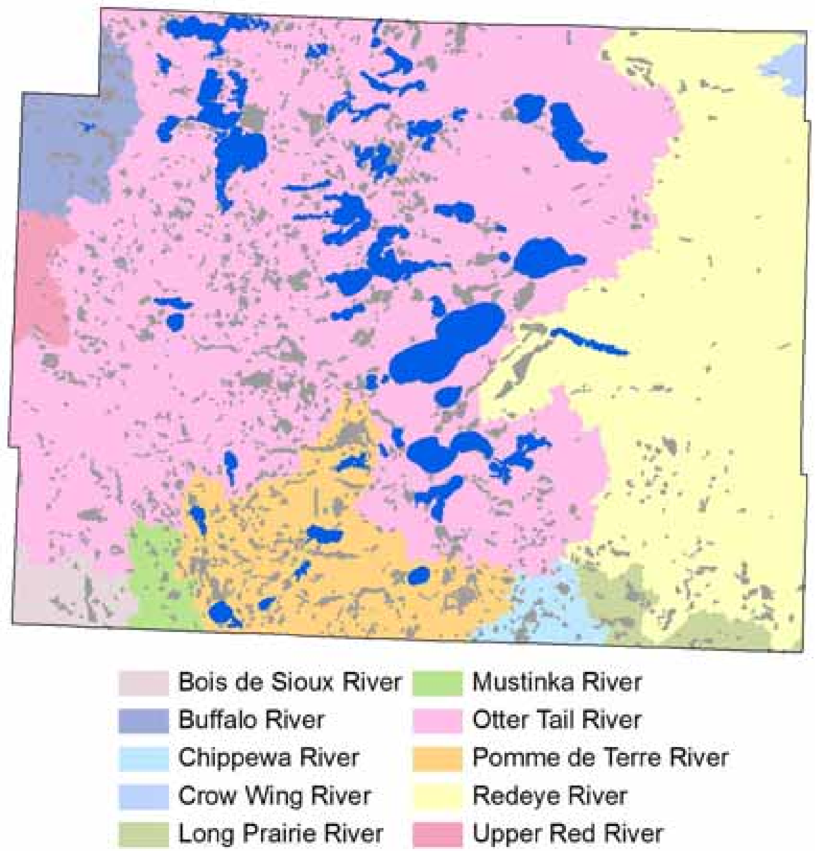


Figure 1. Major watersheds in Otter Tail County. The lakes featured in this report are highlighted in blue.

The Otter Tail County Coalition of Lake Associations (COLA) has a very large volunteer monitoring program, and over 50 lakes have been monitored annually for the past 10-15 years. Due to this successful monitoring program, there is a wealth of water quality data on the large Otter Tail County Lakes (Table 1).

For the purpose of future water planning, the East Otter Tail Soil and Water Conservation District (SWCD) wanted an evaluation of current lake water quality. They chose 63 lakes/bays to be evaluated in this report (Figure 1,Table 2). These are the lakes that have sufficient data for assessment and in most cases enough data for trend analysis.

The purpose of this report was to compile all available data for these lakes from all the different sources, evaluate the data quality, identify data gaps, assess the data, and look for water quality trends. This report contains a summary of the current state of large Otter Tail County lakes and recommendations for future monitoring.

Table 1. Data availability for Otter Tail County Lakes.

Data Availability		
Transparency data		Secchi disk data have been collected extensively and should continue yearly since it is relatively easy and inexpensive.
Chemical data		Most Otter Tail County COLA lakes have at least 10 years of phosphorus and chlorophyll *a* data, which enables trend analysis.
Inlet/Outlet data		Inlet/outlet data are sparse, and could be collected on lakes with declining transparency trends to investigate the cause in water quality decline.

Table 2. Lakes assessed in the 2012-2013 lakes assessments.

	Lake Name	Lake ID	Lake Size (acres)
1	Big McDonald Lake	56-0386-01	992
2	Big Pine Lake	56-0130-00	4,725
3	Blanche Lake	56-0240-00	1,314
4	Boedigheimer Lake	56-0212-00	169
5	Clear Lake	56-0559-00	399
6	Clitherall Lake	56-0238-00	2,539
7	Dead Lake	56-0383-00	7,535
8	Deer Lake	56-0298-00	445
9	Devils Lake	56-0245-00	355
10	Eagle Lake	56-0253-00	907
11	East Battle Lake	56-0138-00	1,985
12	East Leaf Lake	56-0116-02	423
13	East Loon Lake	56-0523-00	1,044
14	East Silent Lake	56-0517-00	310
15	Elbow Lake	56-0306-00	188
16	First Silver Lake	56-0302-01	528
17	Fish Lake	56-0768-00	277
18	Franklin Lake	56-0759-00	1,088
19	Hoffman Lake	56-1627-00	157
20	Jewett Lake	56-0877-00	730
21	Johnson Lake	56-0393-00	419
22	Kerbs Lake	56-1636-00	101
23	Lake Seven	56-0358-00	254
24	Lake Six	56-0369-00	193
25	Leek Lake	56-0532-02	346
26	Little McDonald Lake	56-0328-00	1,312
27	Little Pelican Lake	56-0761-00	345
28	Little Pine Lake	56-0142-00	2,080
29	Lizzie Lake (north portion)	56-0760-01	1,902
30	Long Lake [by Vergas]	56-0388-02	1,273
31	Long Lake [by Elizabeth]	56-0784-00	758
32	Marion Lake	56-0243-00	1,624
33	McDonald Lake	56-0386-03	561
34	Middle Leaf Lake	56-0116-01	404
35	North Lida Lake	56-0747-01	5,513

Table 2. continued…

	Lake Name	Lake ID	Lake Size (acres)
36	Otter Tail Lake	56-0242-00	14,074
37	Paul Lake	56-0335-00	346
38	Pelican Lake	56-0786-00	3,963
39	Pickerel Lake	56-0475-00	838
40	Prairie Lake	56-0915-00	1,004
41	Rose Lake	56-0360-00	1,200
42	Round Lake [by Rush Lake]	56-0214-00	273
43	Round Lake [by Deer Lake]	56-0297-00	155
44	Rush Lake	56-0141-00	5,234
45	Rush-Lizzie Lake (south portion)	56-0760-02	1,832
46	South Lida Lake	56-0747-02	775
47	South Turtle Lake	56-0377-00	837
48	Stalker Lake	56-0437-00	1,357
49	Star Lake	56-0385-00	4,454
50	Stuart Lake (Main Basin)	56-0191-01	681
51	Stuart Lake (Little West Bay)	56-0191-02	48
52	Swan Lake	56-0781-00	738
53	Sybil Lake	56-0387-00	671
54	Tamarac Lake	56-0931-00	445
55	Ten Mile Lake	56-0613-00	1,428
56	Trowbridge Lake	56-0532-01	288
57	Walker Lake	56-0310-00	578
58	Wall Lake	56-0658-00	728
59	West Battle Lake	56-0239-00	5,565
60	West Leaf Lake	56-0114-00	684
61	West McDonald Lake	56-0386-02	597
62	West Olaf Lake	56-0950-01	209
63	West Silent Lake	56-0519-00	347

Trophic State Index (TSI)

Trophic State Index (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 biological material (*biomass*) in a waterbody at a specific location and time.

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.

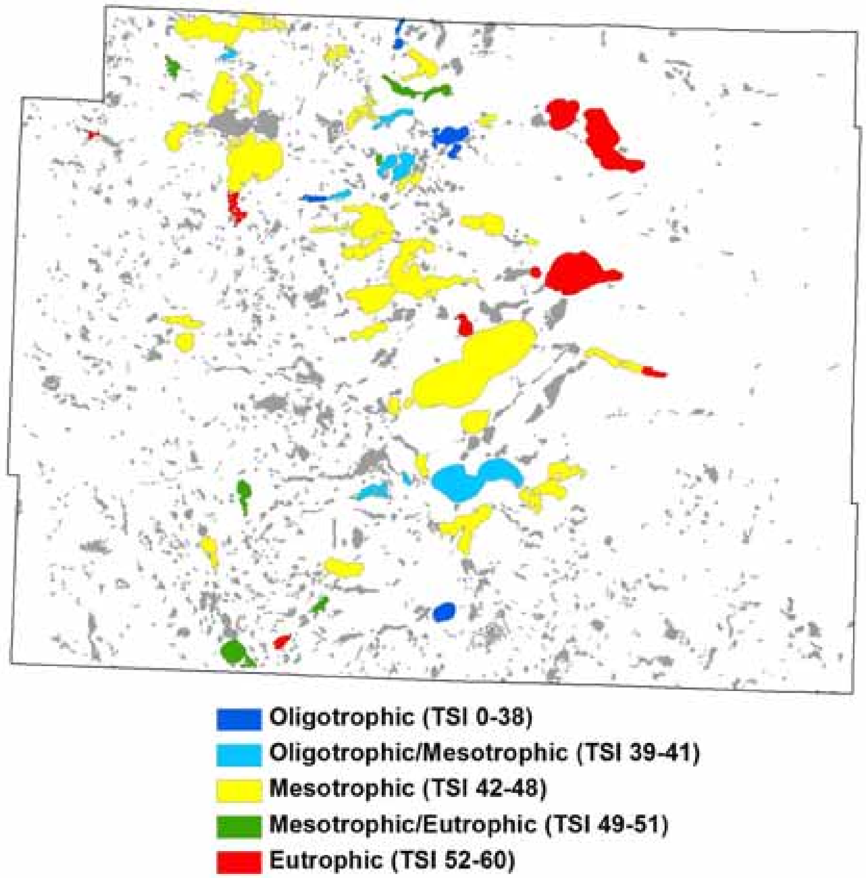


Figure 2. Otter Tail County lakes illustrating trophic states.

Trophic states are defined divisions of a continuum in water quality. The continuum is total phosphorus concentration, chlorophyll a concentration and Secchi depth. Scientists define certain ranges in the above lake measures as different trophic states so they can be easily referred to.

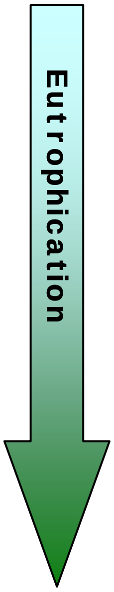
Most of the large Otter Tail County lakes fall into the mesotrophic category (Table 3-4, Figure 2).

Table 3. Trophic state and trophic state index for large lakes in Otter Tail County.

Lake	Mean TSI	Trophic State	Mean TSI Secchi	Mean TSI Phosphorus	Mean TSI Chlorophyll - *a*
Little McDonald	36	Oligotrophic	34	37	37
Kerbs	36	Oligotrophic	35	37	37
Paul	36	Oligotrophic	32	39	37
Eagle	38	Oligotrophic	35	40	40
Seven	38	Oligotrophic	34	40	40
Six	38	Oligotrophic	35	39	39
West Silent	38	Oligotrophic	35	39	39
East Silent	39	Oligotrophic/Mesotrophic	34	39	44
Fish	40	Oligotrophic/Mesotrophic	40	39	42
Elbow	40	Oligotrophic/Mesotrophic	35	40	41
Sybil	40	Oligotrophic/Mesotrophic	37	40	42
West McDonald	40	Oligotrophic/Mesotrophic	37	39	42
West Battle	41	Oligotrophic/Mesotrophic	41	41	41
Big McDonald	41	Oligotrophic/Mesotrophic	37	43	44

Lake	Mean TSI	Trophic State	Mean TSI Secchi	Mean TSI Phosphorus	Mean TSI Chlorophyll - *a*
South Turtle	41	Oligotrophic/Mesotrophic	35	46	41
Clitherall	42	Mesotrophic	40	41	44
Pelican	42	Mesotrophic	40	42	44
East Loon	42	Mesotrophic	41	42	44
McDonald	42	Mesotrophic	40	42	44
Pickerel	42	Mesotrophic	40	42	46
Blanche	43	Mesotrophic	40	43	46
Devils	43	Mesotrophic	40	44	44
East Battle	43	Mesotrophic	40	44	46
Lizzie	44	Mesotrophic	41	44	47
Rose	44	Mesotrophic	42	43	46
Stuart	44	Mesotrophic	42	43	46
Deer	45	Mesotrophic	42	46	47
Leek Trowbridge	45	Mesotrophic	40	46	47
Marion	45	Mesotrophic	42	46	48
Star	45	Mesotrophic	40	46	48
Jewett	46	Mesotrophic	43	49	46
Long [Elizabeth]	46	Mesotrophic	43	48	48
North Lida	46	Mesotrophic	41	47	48
Otter Tail	46	Mesotrophic	43	46	48
Silver	46	Mesotrophic	43	48	48
West Leaf	47	Mesotrophic	44	47	51
Stalker	47	Mesotrophic	42	48	50
Round [by Deer]	47	Mesotrophic	44	50	46
Boedigheimer	47	Mesotrophic	43	49	50
Prairie	47	Mesotrophic	45	47	48
Middle Leaf	48	Mesotrophic	44	47	51
Swan	48	Mesotrophic	42	51	50
Little Pelican	48	Mesotrophic	46	49	49
Dead	48	Mesotrophic	43	50	51
Franklin	48	Mesotrophic	44	49	51
Long [Vergas]	49	Mesotrophic/Eutrophic	45	51	51
Ten Mile	49	Mesotrophic/Eutrophic	48	51	50
Wall	50	Mesotrophic/Eutrophic	45	53	52
Hoffman	50	Mesotrophic/Eutrophic	45	52	52
Johnson	50	Mesotrophic/Eutrophic	42	53	53
Tamarac	50	Mesotrophic/Eutrophic	49	50	48
Rush	52	Eutrophic	50	52	55
South Lida	52	Eutrophic	44	54	56
West Olaf	52	Eutrophic	47	54	55
Little Pine	53	Eutrophic	48	54	57
Clear	53	Eutrophic	47	56	56
Round [by Rush]	53	Eutrophic	52	54	54
Walker	54	Eutrophic	50	55	58
East Leaf	55	Eutrophic	49	56	60
Big Pine	55	Eutrophic	49	55	60

Table 4. Trophic states and corresponding lake and fisheries conditions.



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

Water Quality Trends

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.

Most of the lakes evaluated in this report had enough transparency data to perform a trend analysis (Tables 5-7). The only lakes that didn't were Rose, Johnson, Kerbs, and West Olaf. Because of participation in the Otter Tail COLA monitoring program, most of the lakes also had enough phosphorus and chlorophyll *a* data to perform trends. The lakes that didn't have enough data for phosphorus and chlorophyll a trends were First Silver, Six, Clear, Rose, Johnson, Kerbs, Wall, and West Olaf. Overall, 17 lakes had improving water quality trends (Table 5), four lakes had a declining trend (Table 7), and 35 lakes had no significant trends (Table 6). The data were analyzed using the Mann Kendall Trend Analysis.

Table 5. Otter Tail County lakes with improving water quality trends.

Lake	Parameter	Date Range	Trend	Probability
Big Pine	Transparency	1997-2011	Improving	95%
	Total Phosphorus	1997-2011	No trend	--
	Chlorophyll *a*	1997-2011	No trend	--
Blanche	Transparency	1996-2003, 2004-2012	Improving	95%
	Chlorophyll *a*	1996-2003, 2004-2012	No trend	--
	Total Phosphorus	1996-2012	No trend	--
Clitherall	Total Phosphorus	1996-2011	Improving	95%
	Transparency	1996-2011	No trend	-
	Chlorophyll *a*	1996-2011	No trend	-

Table 5. Continued…

Lake	Parameter	Date Range	Trend	Probability
Dead	Transparency	1992-2011	Improving	95%
	Total Phosphorus	1996-2011	No trend	--
	Chlorophyll *a*	1996-2011	No trend	--
Eagle	Transparency	1995-2011	Improving	95%
	Phosphorus	1996-2011	Improving	99%
	Chlorophyll *a*	1996-2011	No trend	--
East Loon	Transparency	1999-2012	Improving	90%
	Chlorophyll *a*	2005-2012	No Trend	--
	Total Phosphorus	2005-2012	No Trend	--
First Silver	Transparency	1996-1998, 2008-2012	Insufficient data	--
	Chlorophyll *a*	1996-1998, 2008-2012	Insufficient data	--
	Total Phosphorus	1995-2003, 2008-2012	Improving	95%
Fish	Total Phosphorus	2003-2011	Improving	99.90%
	Transparency	2003-2011	No trend	-
	Chlorophyll *a*	2003-2011	No trend	-
Little McDonald	Transparency	2002-2011	Improving	99%
	Total Phosphorus	2004-2011	Improving	90%
	Chlorophyll *a*	2004-2011	No Trend	--
Lizzie	Transparency	2002-2012	Improving	95%
	Chlorophyll *a*	2002-2012	No Trend	--
	Total Phosphorus	2002-2012	Improving	80%
Pelican	Transparency	1996-2011	Improving	99%
	Total Phosphorus	1996-2011	No trend	-
	Chlorophyll *a*	1996-2011	No trend	-
Seven	Transparency	1992-2011	Improving	99%
	Chlorophyll *a*	2002-2011	No Trend	--
	Total Phosphorus	2002-2011	No Trend	--
Six	Transparency	1996-2007, 2009-2012	Improving	90%
	Chlorophyll *a*	1996, 1998, 2002, 2004, 2007, 2010-2012	Insufficient data- too many gaps	--
	Total Phosphorus	1996, 1998, 2002, 2004, 2007, 2010-2012	Insufficient data- too many gaps	--
Star	Transparency	1996-1998, 2001-2012	Improving	90%
	Chlorophyll *a*	1996-1998, 2002-2012	No trend	--
	Total Phosphorus	1996-1998, 2002-2012	No trend	--
Stuart	Transparency	1992-2012	Improving	99%
	Chlorophyll *a*	1996-1998, 2001-2012	No trend	--
	Total Phosphorus	1996-1998, 2001-2012	No trend	--
Tamarac	Transparency	1992-1996, 1998-2012	Improving	99%
	Chlorophyll *a*	2002-2012	No trend	--
	Total Phosphorus	2002-2012	No trend	--
West McDonald	Transparency	1996-2012	Improving	95%
	Chlorophyll *a*	1996-2012	No trend	--
	Total Phosphorus	1996-2012	No trend	--

Table 6. Otter Tail County Lakes with no significant evidence of water quality trends (TP=Total Phosphorus, CHLA=Chlorophyll *a*).

Lake	Parameter	Date Range	Trend
Big McDonald	Transparency	1996-2012	No Trends
	TP & CHLA	1996-2012	No Trends
Boedigheimer	Transparency	2002-2012	No Trends
	TP & CHLA	2002-2012	No Trends
Deer	Transparency	1996-2012	No Trends
	TP & CHLA	1996-2012	No Trends
Devils	Transparency	2002-2013	No Trends
	TP & CHLA	2002-2013	No Trends
East Battle	Transparency	1996-2012	No Trends
	TP & CHLA	1996-2012	No Trends
East Leaf	Transparency	1996-1998, 2000-2011	No Trends
	TP & CHLA	1996-1998, 2000-2011	No Trends
East Silent	Transparency	1996-2011	No Trends
	TP & CHLA	1996-2011	No Trends
Elbow	Transparency	1998-2012	No Trends
	TP & CHLA	1998-2012	No Trends
Franklin	Transparency	1998-2011	No Trends
	TP & CHLA	1998-2011	No Trends
Hoffman	Transparency	2002-2012	No Trends
	TP & CHLA	2002-2012	No Trends
Leek & Trowbridge	Transparency	1996-2012	No Trends
	TP & CHLA	1996-2012	No Trends
Little Pelican	Transparency	2003-2011	No Trends
	TP & CHLA	2003-2011	No Trends
Little Pine	Transparency	1995-2011	No Trends
	TP & CHLA	1996-1998, 2001-2011	No Trends
Long (56-0388)	Transparency	1996-2011	No Trends
[by Vergas]	TP & CHLA	1996-1999, 2001-2004, 2006, 2006, 2009-2011	No Trends
Long (56-0784)	Transparency	2001-2002, 2005-2012	No Trends
[by Elizabeth]	TP & CHLA	2001-2002, 2005-2012	No Trends
Marion	Transparency	1998-2012	No Trends
	TP & CHLA	1998-2012	No Trends
McDonald	Transparency	1998-2012	No Trends
	TP & CHLA	1998-2012	No Trends
Middle Leaf	Transparency	1995-2011	No Trends
	TP & CHLA	2001-2011	No Trends
North Lida	Transparency	1998-2012	No Trends
	TP & CHLA	1998-2012	No Trends
Otter Tail	Transparency	1997-2012	No Trends
	TP & CHLA	1997-2012	No Trends
Paul	Transparency	2001-2012	No Trends
	TP & CHLA	2001-2012	No Trends
Pickerel	Transparency	1996-2011	No Trends
	TP & CHLA	1996-2011	No Trends

Table 6. Continued… (TP=Total Phosphorus, CHLA=Chlorophyll *a*).

Lake	Parameter	Date Range	Trend
Prairie	Transparency	2003, 2005-2012-2011	No Trends
	TP & CHLA	2003, 2005-2012-2011	No Trends
Round 56-0214	Transparency	2004-2012	No Trends
[by Rush Lake]	TP & CHLA	2004-2012	No Trends
Rush	Transparency	1996-2011	No Trends
	TP & CHLA	1996-2011	No Trends
South Lida	Transparency	1998-2012	No Trends
	TP & CHLA	1998-2012	No Trends
South Turtle	Transparency	2002-2012	No Trends
	TP & CHLA	2002-2012	No Trends
Stalker	Transparency	1998-2011	No Trends
	TP & CHLA	1998-2011	No Trends
Swan	Transparency	1987-2011	No Trends
	TP & CHLA	2002, 2005-2011	No Trends
Ten Mile	Transparency	1998-2011	No Trends
	TP & CHLA	1998-2011	No Trends
Walker	Transparency	1996-2011	No Trends
	TP & CHLA	2000-2011	No Trends
Wall	Transparency	1995-2011	No Trends
	TP & CHLA	1996-2000, 2005-2011	Insufficient data
West Battle	Transparency	1997-2011	No Trends
	TP & CHLA	1998-2011	No Trends
West Leaf	Transparency	1996-2011	No Trends
	TP & CHLA	1996-2011	No Trends
West Silent	Transparency	1996-2012	No Trends
	TP & CHLA	1996-2012	No Trends

Table 7. Otter Tail County Lakes with declining water quality trends. For chlorophyll a and phosphorus parameters, a declining trend means that their concentrations are increasing. For transparency, a declining trend means that the clarity is decreasing.

Lake	Parameter	Date Range	Trend	Probability
Clear	Transparency	1999-2012	Declining	90%
	Total Phosphorus	2008-2009	Insufficient data	--
	Chlorophyll *a*	2008-2009	Insufficient data	--
Jewett	Transparency	1996-2012	No trend	--
	Total Phosphorus	1996-2012	No trend	--
	Chlorophyll *a*	1996-2012	Declining	95%
Round 56-0297	Transparency	1996-2010	No trend	--
[by Deer Lake]	Total Phosphorus	1996-2010	Declining	95%
	Chlorophyll *a*	1996-2010	No trend	--
Sybil	Transparency	2002-2012	Declining	95%
	Total Phosphorus	1996-2012	No trend	--
	Chlorophyll *a*	1996-2012	Declining	99%

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. 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.

Figure 3. Minnesota Ecoregions. Otter Tail County is indicated in black.

All of Otter Tail County is in the Central Hardwood Forests (CHF) Ecoregion (Figure 3). This ecoregion is an area of transition between the forested areas to the north and east and the agricultural areas to the south and west. The terrain varies from rolling hills to smaller plains. Upland areas are forested by hardwoods and conifers. Plains include livestock pastures, hay fields, and row crops such as potatoes, beans, peas, and corn.

The ecoregion contains many lakes, and water clarity and nutrient levels are moderate. Land surrounding many of these lakes has been developed for housing and recreation, and the densely populated metropolitan area dominates the eastern portion of this region. Water quality problems that face many of the water bodies in this area are associated with contaminated runoff from paved surfaces and lawns.

Most of the lakes evaluated in this report fall within the expected ecoregion ranges, while some lakes are even better than the expected ecoregion ranges (Table 8). None of the lakes evaluated in this report were poorer than the ecoregion ranges.

Table 8. Central Hardwood Forest Ecoregion Ranges (MPCA).

	Total Phosphorus (ug/L)	Chlorophyll a (ug/L)	Transparency (ft)
Central Hardwood Forest Ecoregion Ranges	23-50	5-22	5-10.5

Statewide Assessments

Lake monitoring should be designed and accomplished for achieving specific goals. There are two main purposes for lake monitoring in Minnesota. The first is the MPCA statewide 303(d) and 305(b) assessments that occur every two years. Statewide MPCA Assessments are performed with a minimum data set of 10 data points each of total phosphorus, chlorophyll *a*, and Secchi depth over a two-year period in the past 10 years. This assessment can be considered the first step to understanding a lake.

The second purpose for lake monitoring is ongoing education, awareness, and lake condition. After the lake's current condition is determined, associations can monitor water quality each year to learn about seasonal variability, year-to-year variability, and if the water quality is improving, declining or staying the same (trend analysis). Condition monitoring involves collecting at least 5 samples during the growing season (the typical program involves monitoring once a month May-September) each year.

Impaired Waters Assessment 303(d) List

There are two main types of Impaired Waters Assessment for lakes: eutrophication (phosphorus) for aquatic recreation and mercury in fish tissue for aquatic consumption.

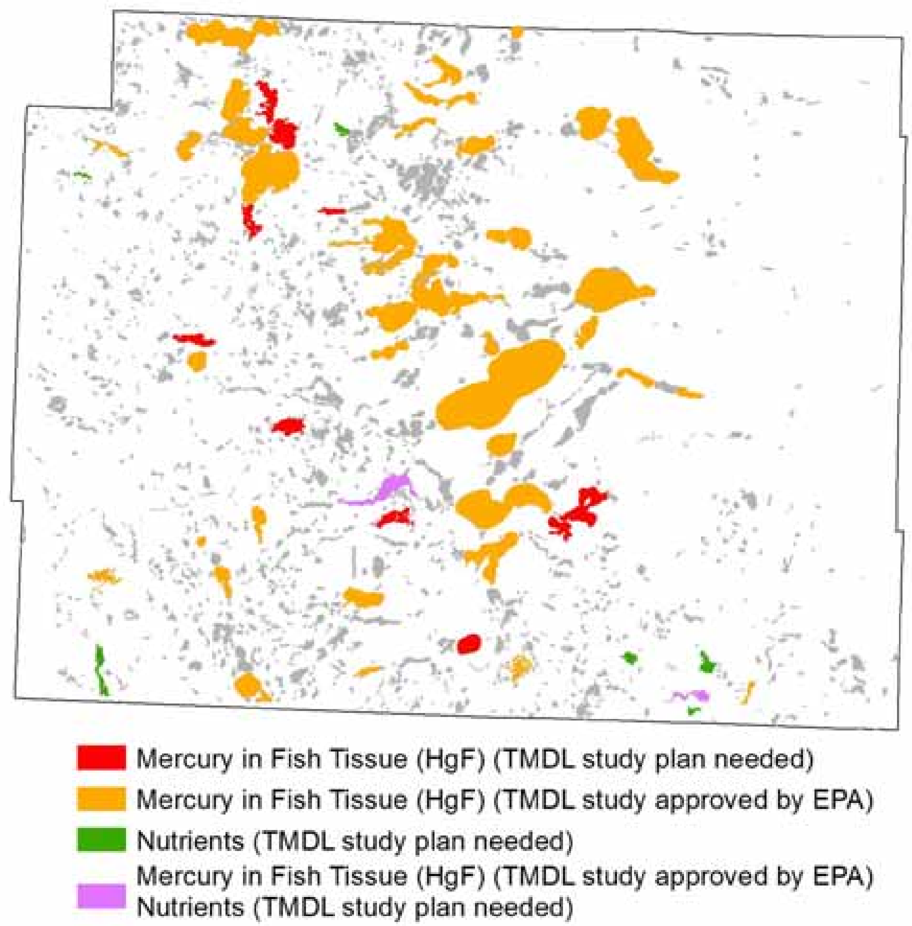


Figure 4. Otter Tail County lakes illustrating impaired waters status.

Many of the Otter Tail County lakes are listed as impaired for mercury; however, they are part of the statewide mercury TMDL (Figure 4). The remaining lakes in the county most likely are not listed due to lack of fish tissue data. There are statewide fish consumption guidelines available from the Minnesota Department of Health: http://www.health.state.mn.us/divs/eh/fish/index.html.

Most mercury comes from the air. Mercury gets into the air through emissions from coal-burning plants and taconite processing and moves long distances in the wind currents. From there, it settles into our lakes and streams and bacteria convert it to a toxic form, methylmercury. The problem is that 90% of the mercury in our waters comes from other states and countries, which is why it is so hard to regulate. In turn, 90% of the mercury emitted in Minnesota goes to other states and countries.

The mercury that settles into our lakes and streams gets filtered by zooplankton, the tiny animals that get eaten by small fish. The larger the small fish gets, the more mercury builds up in its tissue from all the zooplankton eaten. Mercury bioaccumulates, which means that at each step in the food chain the mercury builds to higher levels, especially in large predatory fish such as walleye, northern pike, and muskies.

Currently, eight lakes in Otter Tail County are listed as impaired for eutrophication as of the Draft 2014 Impaired Waters List (February, 2014): Block, North Turtle, Jacobs, Upper Lightning, West Spirit, Fish (56-0066), Nelson, and Twin (Figure 4). A Total Maximum Daily Load (TMDL) study will be conducted on these lakes to determine how to reduce phosphorus levels.

All the lakes in this report, including all the other Otter Tail COLA lakes have sufficient data to be assessed by the MPCA. In addition, the Otter Tail COLA finished a two-year Surface Water Assessment Grant in 2012 that collected data an additional 80 lakes. These lakes were assessed in the 2014 Impaired Waters Assessment.

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 9). Watershed disturbance was defined as having urban, agricultural, and mining land uses. Watershed protection is defined as publicly owned land or conservation easement.

Table 9. 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.

Most of the lakes evaluated in this report have a full restoration focus (yellow, Figure 5, Table 9). The lakesheds around Clear, Hoffman, Paul, Swan, Tamarac and Wall Lakes are listed in the partial restoration (red, Figure 5, Table 10), which means they are more than 60% disturbed. The disturbance on these lakes includes development and agriculture.

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. There are ten Otter Tail County lakes that are listed as Cisco refuge lakes (Table 11).

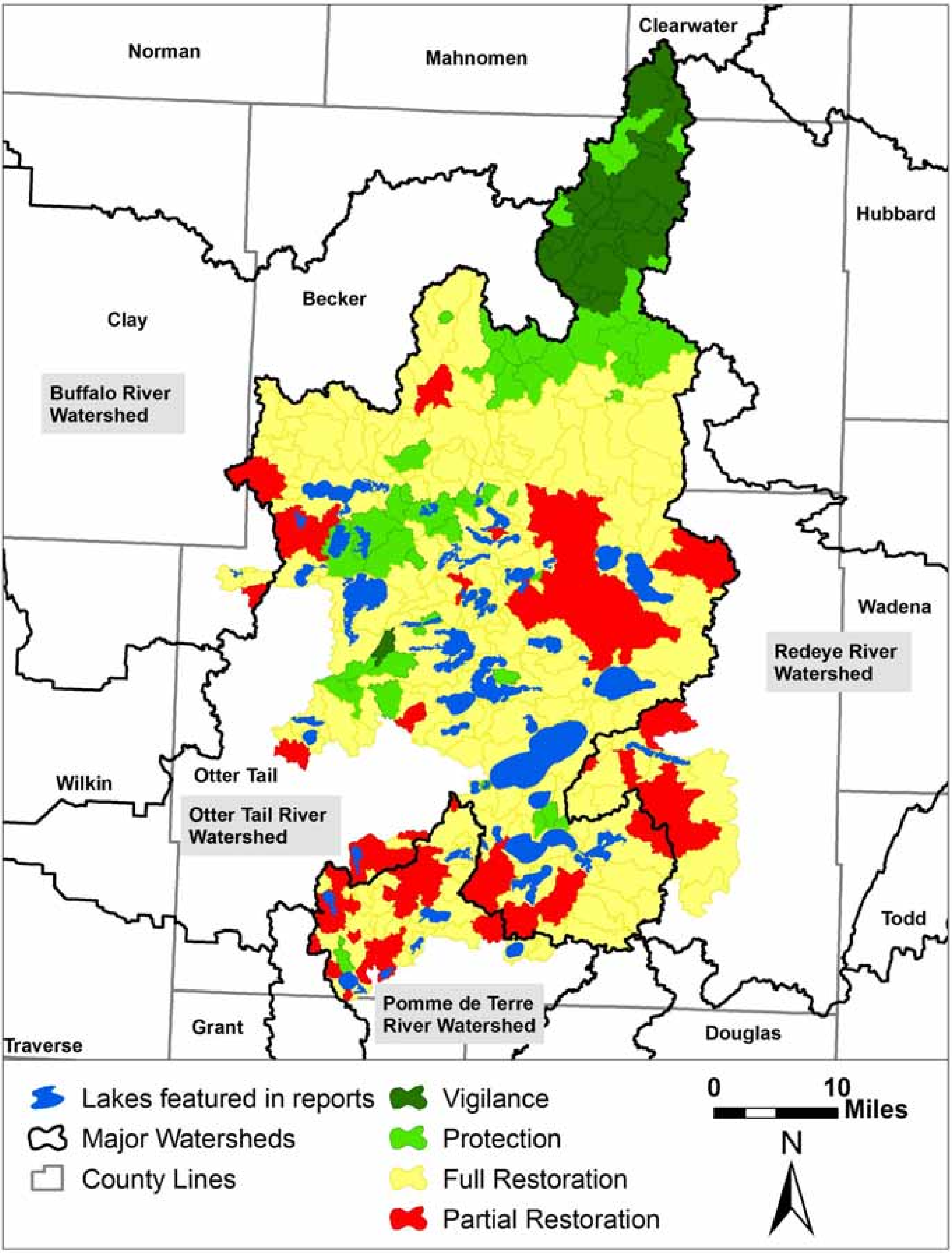


Figure 5. Map of lakesheds color-coded with management focus (Table 9).

Table 10. Otter Tail County lakes evaluation of watershed protection and disturbance. See Table 9 for color codes.

Lake Name	Management Focus
East Silent	Protection
Franklin	Protection
Seven	Protection
Leek & Trowbridge	Protection
Lizzie	Protection
Round [by Deer Lake]	Protection
Big McDonald	Full Restoration
Big Pine	Full Restoration
Blanche	Full Restoration
Boedigheimer	Full Restoration
Clitherall	Full Restoration
Dead	Full Restoration
Deer	Full Restoration
Devils	Full Restoration
Eagle	Full Restoration
East & Middle Leaf	Full Restoration
East Battle	Full Restoration
East Loon	Full Restoration
Elbow	Full Restoration
First Silver	Full Restoration
Jewett	Full Restoration
Johnson	Full Restoration
Kerbs	Full Restoration
Lida	Full Restoration
Little McDonald	Full Restoration
Little Pine	Full Restoration
Long [Elizabeth]	Full Restoration
Long [Vergas]	Full Restoration
Marion	Full Restoration
McDonald	Full Restoration
Otter Tail	Full Restoration
Pickerel	Full Restoration
Prairie	Full Restoration
Rose	Full Restoration
Round [by Rush Lake]	Full Restoration
Rush	Full Restoration
Six	Full Restoration
South Turtle	Full Restoration
Stalker	Full Restoration
Star	Full Restoration
Stuart	Full Restoration
Sybil	Full Restoration
Ten Mile	Full Restoration
Walker	Full Restoration

Table 10. Continued…

Lake Name	Management Focus
West Battle	Full Restoration
West Leaf	Full Restoration
West McDonald	Full Restoration
West Olaf	Full Restoration
West Silent	Full Restoration
Clear	Partial Restoration
Hoffman	Partial Restoration
Paul	Partial Restoration
Swan	Partial Restoration
Tamarac	Partial Restoration
Wall	Partial Restoration

Table 11. DNR designated Cisco refuge lakes.

Lake Name	Lake ID
East Loon	56-0523-00
Fish	56-0768-00
Jewett	56-0877-00
Little McDonald	56-0328-00
Long	56-0388-02
Pickerel	56-0475-00
Rose	56-0360-00
Scalp	56-0358-00
Six	56-0369-00
Sybil	56-0387-00

Aquatic Invasive Species

Invasive species are a large threat to Minnesota's lakes. Invasive species can get out of control because there is nothing in the ecosystem naturally to keep the population in check. They can also replace native beneficial species and change the lake's ecosystem.

As of 2013, Otter Tail County has numerous infestations (Figure 6). The most difficult infestation to deal with is zebra mussels, since there is currently no method for controlling them.

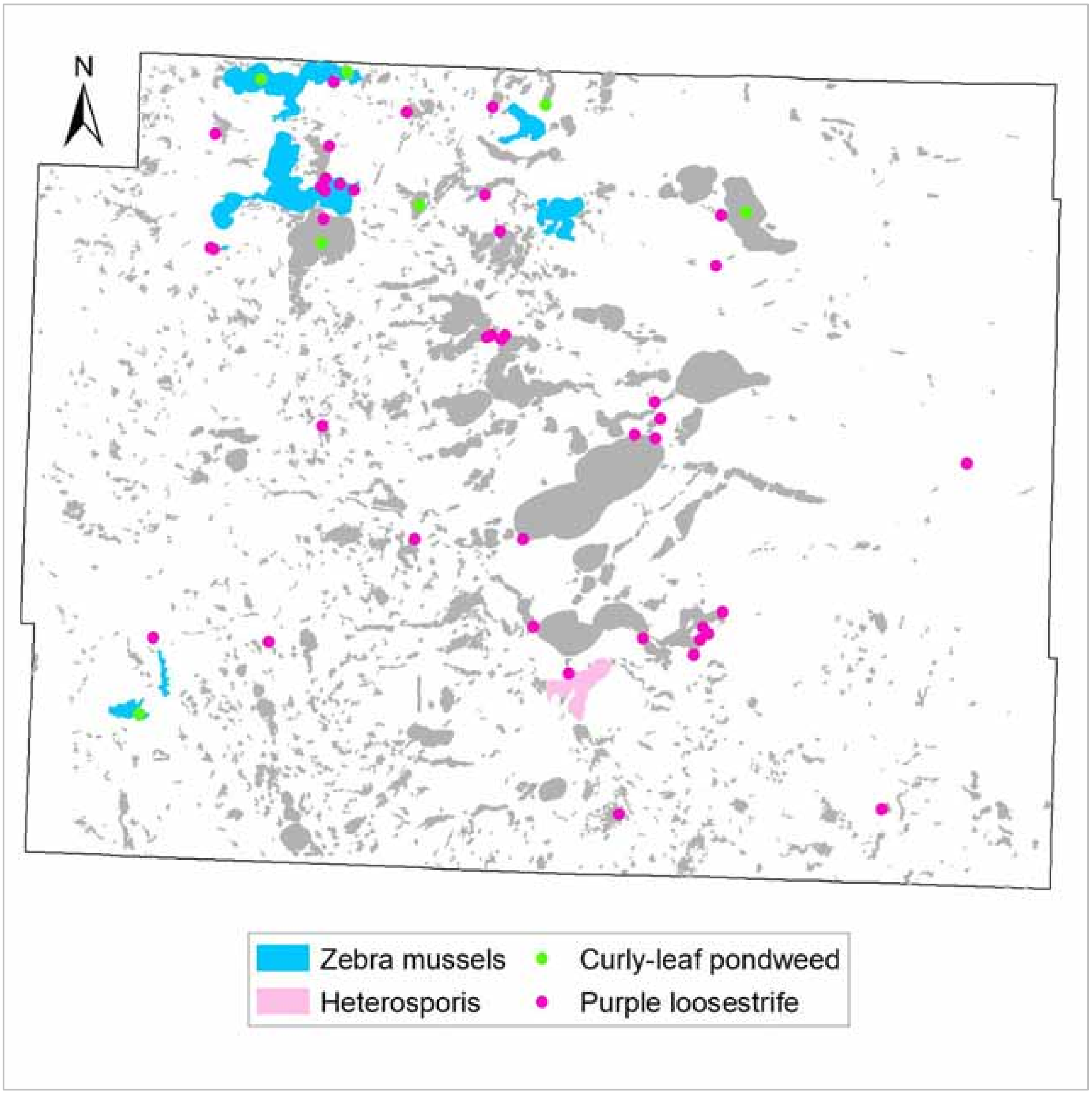


Figure 6. Otter Tail County lakes with aquatic invasive species and fish pathogens.

At boat landings, there are usually DNR signs stating which invasive species are present in the waterbody and how to prevent their spread. Boaters should be educated about how to check for invasive species before moving from lake to lake. Care should be taken to protect Otter Tail County's water resources from future aquatic invasive species infestations.

For a current list of the infested waters in Minnesota, visit the DNR's website: http://www.dnr.state.mn.us/invasives/index_aquatic.html.

Matrix of Lake Impacts

Table 11. Definitions of lake impacts from Table 11. For more explanation and recommendations, see pages 14-16.

Lake Impact	Definition
Agriculture	Agriculture is present near the lakeshore and there may not be sufficient buffers to protect the lake from runoff.
Development	Development has occurred around the lakeshore (impervious surface, septic systems), and additional development is possible.
Shallow	The majority of the lake is 25 feet deep or less. Aquatic plants and sediments must be protected to prevent a switch to the turbid state.
Internal Loading	Internal loading could be occurring due to lake depth and frequent mixing in the summer. The internal loading shows as increasing phosphorus toward the end of the summer and nuisance algae blooms.
Inlet Loading	Phosphorus could be impacting the lake through inlet loading.
Large Watershed	The large watershed of the lake contributes nutrients cumulatively to the lake.

Table 12. Matrix showing which impacts apply to the assessed lakes in Otter Tail County.

Lake	ID	Agriculture	Development	Shallow	Internal Loading, Algae Blooms	Inlet loading	Large Watershed
Big McDonald	56-0386-01		x				
Big Pine	56-0130-00	x	x		x	x	x
Blanche	56-0240-00		x		x	x	x
Boedigheimer	56-0212-00	x	x			x	
Clear	56-0559-00	x					
Clitherall	56-0238-00	x	x				
Dead Lake	56-0383-00	x	x	x		x	
Deer	56-0298-00	x	x	x		x	x
Devils	56-0245-00	x	x				
Eagle Lake	56-0253-00	x	x				
East & Middle Leaf	56-0116-02	x	x				
East Battle	56-0138-00	x	x			x	
East Loon	56-0523-00		x				
East Silent	56-0517-00		x				
Elbow	56-0306-00		x				
First Silver	56-0302-01	x	x				
Fish Lake	56-0768-00	x	x				
Franklin	56-0759-00		x				

Table 12. Continued…

Lake	ID	Agriculture	Development	Shallow	Internal Loading, Algae Blooms	Inlet loading	Large Watershed
Hoffman	56-1627-00	x	x	x	x		
Jewett	56-0877-00	x	x				
Johnson	56-0393-00	x			x		
Kerbs	56-1636-00		x				
Leek & Trowbridge	56-0532-00		x				
Little McDonald	56-0328-00	x	x				
Little Pelican	56-0761-00	x	x	x		x	
Little Pine	56-0142-00	x	x			x	x
Lizzie	56-0760-00		x			x	x
Long [Elizabeth]	56-0784-00		x			x	
Long [Vergas]	56-0388-02	x	x				
Marion	56-0243-00		x				
McDonald	56-0386-03		x				
North Lida	56-0747-01		x			x	
Otter Tail	56-0242-00		x			x	x
Paul	56-0335-00	x	x				
Pelican	56-0786-00	x	x			x	
Pickerel	56-0475-00	x	x				
Prairie	56-0915-00	x	x	x	x	x	x
Rose	56-0360-00		x				
Round [by Rush]	56-0214-00		x				
Round [by Deer]	56-0297-00		x	x			
Rush	56-0141-00	x	x	x	x	x	x
Seven	56-0358-00		x				
Six	56-0369-00		x				
South Lida	56-0747-02		x		x	x	
South Turtle	56-0377-00	x	x				
Stalker	56-0437-00	x	x			x	
Star	56-0385-00		x				x
Stuart	56-0191-01		x			x	

Table 12. Continued…

Lake	ID	Agriculture	Development	Shallow	Internal Loading, Algae Blooms	Inlet loading	Large Watershed
Swan	56-0781-00	x	x				
Sybil	56-0387-00	x	x				
Tamarac	56-0931-00	x	x	x	x		
Ten Mile	56-0613-00					x	x
Walker	56-0310-00	x	x	x	x	x	
Wall	56-0658-00	x	x	x	x		
West Battle	56-0239-00	x	x			x	
West Leaf	56-0114-00	x	x				
West McDonald	56-0386-02		x				
West Olaf	56-0950-01	x	x				
West Silent	56-0519-00		x				

Individual Waste Treatment System Status

Otter Tail County's Land and Resource Department does periodic checks on Individual Waste Treatment Systems (septic systems and holding tanks) around lakes. They choose a few lakes a year to evaluate (Table 13). Systems that do not meet inspection guidelines are abated. It usually takes a couple years after the county's inspection process to get all the systems into compliance. Therefore, any possible improvement in water quality can be delayed a few years from the original inspection year.

Lakes that don't have any major inlets or outlets have a high residence time, which means that the lake does not get flushed out periodically and nutrients just sit in the lake. Failing septic systems are more detrimental to these lakes than lakes that continually get flushed out by inlets and outlets such as Little Pine Lake. Lakes without major inlets or outlets that haven't been checked in the last 15 years should be prioritized for septic system checks in the future. These high priority lakes are indicated in Table 13 below: Devils, Eagle, Elbow, Little McDonald, Marion, Pickerel, and First Silver. This table spans two pages.

Table 13. Dates of last county inspection of individual waste treatment systems.

Lake	DNR ID	Date of last county septic inspection	No major inlets/outlets	Re-checks high priority
Big McDonald	56-0386-01	2010 (20 Yr. Re-Checks)	x	
Big Pine	56-0130-00	2009		
Blanche	56-0240-00	2010		
Boedigheimer	56-0212-00	2006		
Clear	56-0559-00	2002	x	
Clitherall	56-0238-00	1991		
Dead	56-0383-00	1997		
Deer	56-0298-00	OTWMD		
Devils	56-0245-00	1995	x	x
Eagle	56-0253-00	1984	x	x
East & Middle Leaf	56-0116-02	1998		
East Battle	56-0138-00	1988		
East Loon	56-0523-00	2006	x	
East Silent	56-0517-00	2002	x	
Elbow	56-0306-00	Proposed in 2015	x	x
First Silver	56-0302-04	1994	x	x
Fish	56-0768-00	2009		
Franklin	56-0759-00	2004	x	
Hoffman	56-1627-00	2006	x	
Jewett	56-0877-00	2001	x	
Johnson	56-0393-00	2013	x	
Kerbs	56-1636-00	2012	x	
Seven	56-0358-00	1999		
Leek Trowbridge	56-0532-01	2001	x	
Little McDonald	56-0328-00	1991	x	x
Little Pelican	56-0761-00	2009		
Little Pine	56-0142-00	2008		

Table 13. Continued…

Lake	DNR ID	Date of last county septic inspection	No major inlets/outlets	Re-checks high priority
Lizzie	56-0760-01	1994		
Long [Elizabeth]	56-0784-00	1988		
Long [Vergas]	56-0388-02	2004		
Marion	56-0243-00	1993	x	x
McDonald	56-0386-03	2010 (20 Yr. Re-Checks)		
Otter Tail	56-0242-00	OTWMD		
Paul	56-0335-00	2006	x	
Pelican	56-0786-00	2009		
Pickerel	56-0475-00	1989	x	x
Prairie	56-0915-00	2007		
Rose	56-0360-00	2004		
Round [by Rush Lake]	56-0214-00	2006	x	
Round [by Deer Lake]	56-0297-00	OTWMD*****	x	
Rush	56-0141-00	1994		
Six	56-0369-00	1999	x	
South Turtle	56-0377-00	1997	x	
Stalker	56-0437-00	2000		
Star	56-0385-00	2000		
Stuart	56-0191-01	1986		
Swan	56-0781-00	2010	x	
Sybil	56-0387-00	2006	x	
Tamarac	56-0931-00	2005		
Ten Mile	56-0613-00	2002		
Walker	56-0310-00	OTWMD*****		
Wall	56-0658-00	2009		
West Battle	56-0239-00	2000		
West Leaf	56-0114-00	1998		
West McDonald	56-0386-02	2010 (20 Yr. Re-Checks)	x	
West Olaf	56-0950-01	2009	x	
West Silent	56-0519-00	2002	x	

*Otter Tail Water Management District

Recommendations

Monitoring Recommendations

Monitor transparency weekly or bi-monthly through the MPCA Citizen Lakes Monitoring Program (CLMP) every year on every lake in the county. Continual annual transparency data is a great way to monitor lake water quality and track trends. Avoid missing years of monitoring, which leads to gaps in data. For example, if a lake is showing a significant decline in water quality but there are gaps in their data, it is hard to determine when the impact occurred and whether it was acute or chronic.

Monitor phosphorus and chlorophyll *a* concentrations. If annual monitoring is not feasible, consider monitoring on a 3 year rotation. This would involve collecting 5 samples per year in one out of three years. Collecting less than 4 samples in one year are not enough data to get a good seasonal average, and therefore not a good use of funding.

In some of the lakes that have major inlet loading, monitoring the inlets to the lake will help determine where potential water quality impacts are (Big Pine, Dead, Little Pelican, Little Pine, Pelican, Rush, Stalker, Walker, West Battle, Blanche, Boedigheimer, Deer, East Battle, Lizzie, Long, North Lida, South Lida, Otter Tail, Prairie, Stuart and Ten Mile).

Overall Conclusions

The lakes in Otter Tail County have a wide variety of conditions due to ten different major watersheds. Many of the lakes evaluated in this report had similar conditions: mesotrophic lakes between 40-70 feet deep at the maximum. This seems to be the natural state of these lakes after the glaciers receded.

Most of the lakes evaluated in this report had enough transparency data to perform a trend analysis (Tables 5-7). The only lakes that didn't were Rose, Johnson, Kerbs, and West Olaf. Most of the lakes also had enough phosphorus and chlorophyll *a* data to perform trends because of participation in the Otter Tail COLA monitoring program. The lakes that didn't have enough data for phosphorus and chlorophyll a trends were First Silver, Six, Clear, Rose, Johnson, Kerbs, Wall, and West Olaf. Overall, 17 lakes had improving water quality trends (Table 5), four lakes had a declining trend (Table 7), and 35 lakes had no significant trends. The data were analyzed using the Mann Kendall Trend Analysis.

Currently, eight lakes in Otter Tail County are listed as impaired for eutrophication as of the Draft 2014 Impaired Waters List (February, 2014): Block, North Turtle, Jacobs, Upper Lightning, West Spirit, Fish (56-0066), Nelson, and Twin (Figure 4). A Total Maximum Daily Load (TMDL) study will be conducted on these lakes by the MPCA in the future to determine how to reduce phosphorus levels.

Ten of the lakes in Otter Tail County are designated as Cisco refuge lakes by the DNR: East Loon, Fish, Jewett, Little McDonald, Long, Pickerel, Rose, Seven, Six, and Sybil (Table 11). Ciscos (*Coregonus artedi)* can be an early indicator of eutrophication in a lake because they require cold hypolimnetic temperatures and high dissolved oxygen levels. Cisco refuge lakes are usually deep and have good oxygen levels. Protecting the water quality and lakesheds of these lakes will help ensure the Cisco's survival. Dissolved oxygen profile data show that Six, Sybil, East Loon and Jewett Lakes had anoxic hypolimnia mid-summer, which is not ideal Cisco habitat. The DNR Fisheries office has been made aware of this finding.

Increased first and second tier development and agriculture (row crops and animal feedlots) seem to be the largest overall risks to the lakes in Otter Tail County. Once the second tier is developed, the drainage in the lakeshed significantly changes and more runoff reaches the lake from impervious surface and lawns. Project ideas include protecting land with conservation easements, enforcing county shoreline ordinances, smart development without developing substandard lots or allowing variances, shoreline restoration, rain gardens, and septic system maintenance. Proper vegetative buffers, wetland restoration, and conservation farming practices would decrease the impact by agriculture.

Lakes of least concern

Many lakes evaluated in this report are exceptional water resources, including Big McDonald, Clitherall, Eagle, East Loon, East Silent, Elbow, Fish, Kerbs, Little McDonald, McDonald, Pelican, Seven, Six, South Turtle, West Battle, West McDonald, and West Silent Lakes. Many of these lakes have improving water quality trends (Clitherall, Eagle, East Loon, Fish, Little McDonald, Pelican Seven, Six, and West McDonald, Table 5). East Silent, Six, and Seven Lakes have well protected lakesheds, while the other lakes have a fair amount of development and agriculture. It's imperative to maintain the current water quality in these lakes. Care should be taken to protect these lakes from any new disturbance. New development should follow county ordinances without variances, include proper shoreline buffers and minimize impervious surface.

Sybil and Paul Lakes have excellent water quality, but are not considered lakes of least concern. They are addressed in the next section below.

Lakes of greatest concern

The lakes that are the greatest cause for concern are those that have a high level of disturbance in the watershed, possible internal loading, nuisance algae blooms in August – September, and/or declining water quality trends. Lakes with possible internal loading and nuisance algae blooms include Big and Little Pine, Walker, and Wall. The lakes that have declining trends include Round (56-0297 by Deer Lake), Clear, Jewett and Sybil. Paul Lake has excellent water quality, but a very high level of disturbance in the lakeshed.

Big and Little Pine Lakes have the Otter Tail River flowing through them, a high degree of agriculture in their lakesheds, and the City of Perham nearby. These items all pose challenges to water quality. Installing proper vegetative buffers around the lake and upstream in the Otter Tail River Watershed could help protect the lake from agricultural runoff. Rain gardens around the lakes and in Perham can capture stormwater runoff from Perham and the developed areas around the lake. In addition, wetland restoration and conservation farming practices upstream in the Otter Tail River Watershed would decrease the impact by agriculture.

Wall Lake is a moderately sized (728 acres), somewhat shallow lake (34 foot maximum depth) and is heavily developed in the first and second tiers due to its proximity to Fergus Falls. It has a very dynamic seasonal transparency pattern. It averages a high of 15 feet in May and a low of 6 feet in August. In August through September, the lake experiences algae blooms that could reach nuisance levels. Since 2008, the May readings haven't been higher than 10 feet, which could indicate the start of a declining trend. The lake does not have a large volume of water to dilute the runoff flowing into it. The phosphorus from the runoff has most likely settled to the bottom of the lake and is causing internal loading and major algae blooms. A lake-wide septic system check of the oldest systems was completed by Otter Tail County in 2009. Therefore, the septic systems around the lake should be up to date and working properly. To confirm internal loading, the lake's hypolimnion could be monitored for phosphorus and oxygen next year. If internal loading is occurring, an alum treatment could be applied to keep the phosphorus bound in the sediments. Wall Lake could also benefit from a lake-wide push for shoreline restorations and rain gardens.

Walker Lake is right next to Otter Tail Lake, and has a very large watershed (136:1 watershed area to lake area ratio). The Dead River enters Walker Lake on the north side. Walker Lake experiences increasing phosphorus and nuisance algae blooms in August – September, which may indicate internal loading. Since Walker Lake is part of the Otter Tail Water Management District, septic systems are not an impact, so the main sources of phosphorus to the lake are shoreline runoff, internal loading and the large watershed.

Swan Lake has a high level of disturbance in the watershed, but it currently has good water clarity with no nuisance algae blooms. Because it has a relatively small watershed, no direct major inlets, and a county-wide septic upgrade in 2010, it doesn't seem to be negatively impacted by the watershed. The main impact to Swan Lake is most likely runoff from first tier development around the lake. Shoreline restoration and rain gardens should be implemented to protect this vulnerable lake from future decline.

Round Lake has a declining trend in transparency. Round Lake is right next to Deer Lake, but has its own headwaters lakeshed. This means that no other lakes flow into it and the main impact to the lake comes from the shoreline and the lake itself. Since Round Lake is part of the Otter Tail Water Management District, septic systems are not an impact. The main impacts to the lake are most likely attributed to shoreline runoff and aquatic plant removal. Shoreline restoration and rain gardens should be implemented to restore this lake from its declining trend in transparency. See the shallow lakes section below for how and why to protect native plant communities.

Sybil Lake has a declining trend in transparency and an increasing trend in chlorophyll *a*. This means the lake is getting greener over time. Because Sybil Lake doesn't have any inlets or outlets, it has a low residence time, which means the lake does not get flushed out very quickly. Therefore, all the nutrients that runoff into the lake accumulate at the lake's bottom. The nutrients could be from the surrounding row crops and impervious surface from development. The septic systems were last checked by the county in 2006, so they are most likely in good working order. See the future studies section for project ideas.

Jewett Lake has an increasing trend in chlorophyll a, which means the lake is getting greener over time. In addition, the conductivity and chloride are much higher than other lakes in the area, which could indicate problems with runoff or septic systems. Septic systems were last checked by the county in 2001, and noncompliant systems were required to come into compliance at that time. Therefore, the septic systems around the lake should be in good working order. Because the lake has no natural outlets, high water has been a problem. Shoreline erosion from high water and runoff from impervious surfaces in developed lots around the shoreline could be affecting the water quality.

Clear Lake has a declining trend in transparency over the past decade. An estimate of disturbed land in the lakeshed, which includes row crops and development, is 53%. The lakeshed (land area directly draining to the lake) is most likely affecting the water quality of Clear Lake.

Paul Lake has excellent water quality, but an estimate of disturbed land in the lakeshed, which includes row crops and development, is 44%. This disturbance has the potential to affect water quality in the future. The dominant soil type in the lakeshed is Hydrologic Soil Group B. This soil has a low runoff potential when wet and water transmission through the soil is unimpeded. The soil is 10-20% clay and 50-90% sand. Therefore, it could be that the agriculture in the lakeshed is not impacting the lake and just draining through.

Shallow Lakes

There are many shallow lakes in Otter Tail County that have good water quality. Shallow lakes usually have a maximum depth around 25 feet deep or less, and don't completely stratify all summer. A healthy shallow lake should have clear water and abundant aquatic plants. 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 fishery.

The shallow lakes in Otter Tail County include: Dead, Deer, Hoffman, Little Pelican, Prairie, Round, Rush, Tamarac, Walker, and Wall.

Future Actions/Studies
Lakes that don't have any major inlets or outlets have a high residence time, which means that the lake does not get flushed out periodically and nutrients just sit in the lake. Failing septic systems are more detrimental to these lakes than lakes that continually get flushed out by inlets and outlets such as Little Pine Lake. Lakes without major inlets or outlets that haven't been checked in the last 15 years should be prioritized for septic system checks by the county in the future. These high priority lakes are: Devils, Eagle, Elbow, Little McDonald, Marion, Pickerel, and First Silver (Table 13).

Because a significant amount of undeveloped privately-owned land still exists around some of the lakes (Blanche, Clear, Dead, Devils, East Silent, Elbow, Hoffman, Johnson, Leek Trowbridge, Lizzie's south bay, Long [by Elizabeth], Prairie, Rose, Six, South Turtle, Star, Stuart, Sybil, Walker, West Olaf, and West Silent), there is a great potential for protecting this land with conservation easements and aquatic management areas (AMAs). Conservation easements can be set up easily and with little cost with help from organizations such as the Board of Soil and Water Resources and the Minnesota Land Trust. AMAs can be set up through the local DNR fisheries office in Fergus Falls.

For lakes with heavy shoreline development, a future study that would better pinpoint the impacts on the lake should include a shoreline inventory. The shoreline inventory would consist of boating around the lake and rating each parcel determining how much of the frontage has a vegetative buffer.

For lakes that have a large watershed and major inlet, inlet and outlet monitoring should be implemented for several consecutive years to get an idea of nutrient flow.

The Otter Tail SWCD has staff and funding available for shoreline restorations and rain garden installation. Shoreline restoration projects would be very beneficial and have the potential to reverse the water quality trends in the lakes of greatest concern (Clear, Jewett, Paul, Round [by Deer], Swan, Sybil, and Wall).

Next Step: 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
- Proper setbacks on new construction
- Not developing sub-standard lots

Lake Associations
- Lake condition monitoring
- Stream inlet monitoring
- Ground truthing (visual inspection upstream on stream inlets)
- Shoreline inventory study

Soil and Water Conservation District (SWCD) and Natural Resources Conservation Service (NRCS)
- Shoreline restoration
- Stream buffers
- Work with farmers to:
    - Restore wetlands
    - Implement conservation farming practices
    - Participate in land retirement programs such as Conservation Reserve Program

Grant Possibilities

MPCA Clean Water Partnership Grants: These grants are available for nonpoint source water pollution projects such as diagnostic studies or implementation projects to protect water bodies. This grant would apply well to a large chain of lakes.
http://www.pca.state.mn.us/aj0rb37

BWSR Clean Water Grants: These grants can be used for a variety of "on-the-ground" projects, where citizens and local governments are installing conservation practices to improve the quality in lakes, rivers and wetlands.
http://www.bwsr.state.mn.us/grants/index.html

DNR Conservation Partners Legacy Grant Program: These grants can be used for projects that restore, enhance and/or protect habitats for MN's fish, game, and wildlife.
http://www.dnr.state.mn.us/grants/habitat/cpl/index.html

DNR Shoreline Habitat Restoration Grants: Shoreland and Aquatic Habitat Block Grants are designed to provide cost share funding to counties, cities, watershed districts, other local units of government, conservation groups, and lake associations. It allows participants to conduct shoreline and watershed enhancement projects with native plants, while improving aquatic habitat and water quality for fish and wildlife.
http://www.dnr.state.mn.us/grants/habitat/shoreland.html

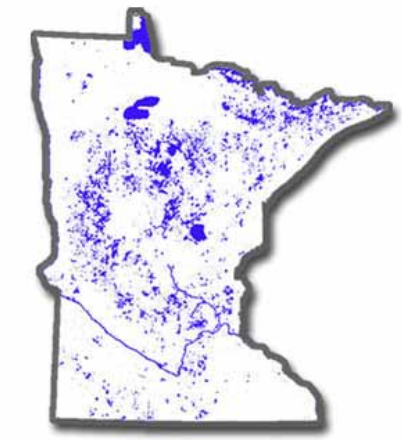
Aquatic Invasive Species

As of 2013, there are a growing number of Otter Tail County lakes infested with zebra mussels. Great care should be taken to protect Otter Tail County's excellent water resources from any future infestations. Protection projects could include lake access boat inspections and educational campaigns.

Appendix I. Limnology Education

Lake Water Quality: the natural-and-human factors

There are many facets that contribute to a lake's current condition, including natural and human factors. Once these elements are understood, a more comprehensive grasp of past, present and future lake water quality is possible.



Most of the lakes in Minnesota were formed as glaciers receded during the last ice age. Approximately 15,000 to 9,000 years ago, glaciers alternately retreated and advanced over the landscape, carving out holes and leaving behind ice chunks. As the ice melted, lakes were formed in the holes left behind. Northern Minnesota was scraped down to the bedrock, with boulders, sand and clay left behind, while southern Minnesota was left with a rich, prairie (now agricultural) soil.

To understand a lake, one must first be knowledgeable of its geological area. Northern Minnesota lakes are commonly very deep and rocky residing in forested areas. These lakes have very clear water and characteristically low phosphorus and algae concentrations due to the abundance of sandy, relatively infertile soil. The lakes in southwestern Minnesota are shallower prairie lakes surrounded by fertile soil. Lakes in this area tend to have more nutrients available for plants and algae to grow, and therefore get "greener" in the summer.

The geology and glacial formation of a lake usually determines its shape, size and depth. These factors contribute to nearly all physical, chemical and biological properties of a water body. Lake users, such as fishermen, are probably aware of these characteristics already because they determine where the fish are. A large, round lake is very different from one with many bays, points, and bottom structure. Shape is also important, a long narrow water feature is more affected by wind (which mixes the lake) than a round one. Variation in depth and volume also attribute to lake dynamics; increased volume allows for better dilution of unwanted pollutants.

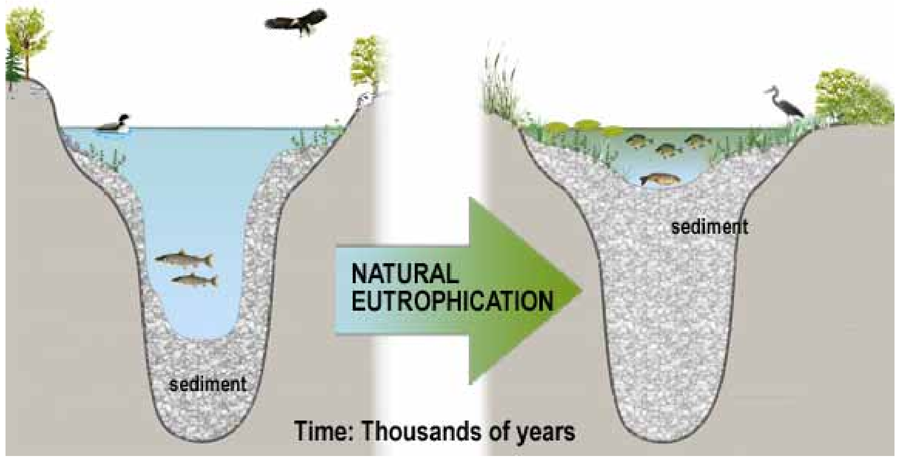
Shallow lakes are water bodies with a depth of 15 feet or less. Shallow water allows sunlight to reach the bottom, encouraging aquatic plant growth. Sunlight does not penetrate to the bottom of deeper lakes, resulting in a much darker and cooler lake-bed environment.

Lake conditions are also determined by the size of the watershed and its location within it. A watershed is an area of land where all the water drains into the same river system. These areas are defined by topography, or ridges of elevation, therefore, watersheds are mainly driven by gravity – water runs down hill.

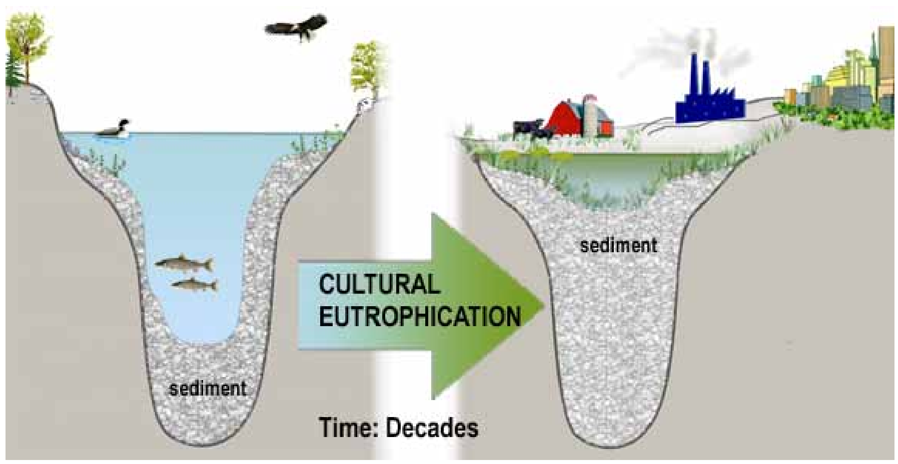
If a lake has a very small watershed or is at the top of a watershed (in topography term) it usually has better water clarity than a lake at the bottom of a large watershed. As water flows downhill through a watershed it picks up sediment from erosion and nutrients from runoff. These sediment and nutrients can feed algae and cause the lake to become "greener".

Lakes go through a natural ageing process where they gradually receive nutrients (phosphorus and nitrogen) and sediment from erosion in the surrounding watershed and become more fertile and shallow. This process is called eutrophication. Eutrophication is a natural process that a lake goes through over thousands of years.

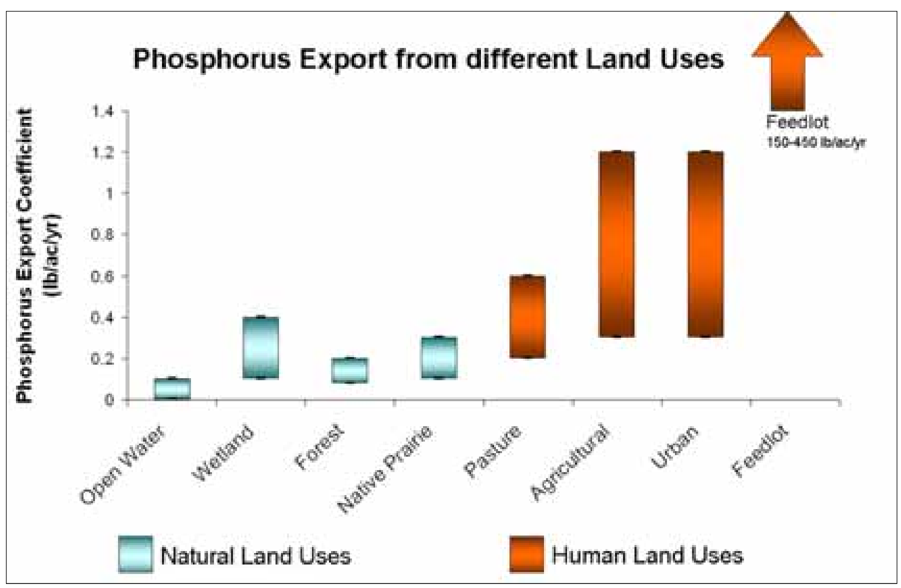
Humans can speed up the process of eutrophication by adding excess nutrients and sediment causing the lake to change trophic states in a matter of decades instead of centuries. This type of eutrophication is called cultural eutrophication because humans cause it. We have changed the landscape around lakes, which changes their water quality and speeds up eutrophication.



Around lakes, we have added many impervious surfaces to our environment. Impervious surface is any surface on land that is impenetrable to water and prevents its absorption into the ground. Examples include rooftops, sidewalks, parking lots, and roads. The more impervious surface in a concentrated area, the less surface there is for rain to be absorbed into the ground. Instead, it runs into lakes and streams, carrying nutrients and sediment from the land it flows over.



Land practices such as urban areas, factories, agriculture, animal feedlots contain very concentrated amounts of nutrients. These nutrients wash into lakes and streams during heavy rains or through storm sewers. The additional nutrients that run into lakes and streams cause algal blooms and additional plant growth.



When erosion occurs along a lakeshore or a stream bank of a lake inlet, that extra soil can wash into the lake. The extra soil particles cause cloudier water and eventually settle on the bottom of the lake making it mucky and less stable. The soil also carries with it nutrients such as phosphorus and nitrogen.

Eutrophication can be slowed if the inputs of nutrients (especially phosphorus) and sediment are slowed. Creating natural vegetation buffers along lakeshores and streams soak up nutrients and filter runoff. When planning new construction near water, make sure erosion is prevented by silt fences and minimize creating more impervious surface.

So how can one tell if the lake's water quality is declining or improving? The best way to determine long-term trends is to have 8-10 years of lake water quality data such as clarity (Secchi disk), phosphorus, and chlorophyll *a* (algae concentration). Only short-term trends can be determined with just a few years of data, because there can be different wet years, dry years, weather, water levels, etc., that affect the water quality naturally. The data needs to be analyzed with a statistical test (i.e.: Mann Kendall Trend Analysis) to be confident in a true trend.

In summary, lakes start out with a certain natural condition that depends on their location, their watershed size, area, depth, and shape. Then we add pollutants to that through land practices we implement near and upstream from the lake. Lakes in more heavily populated areas usually have had more cultural eutrophication than lakes that are in sparsely populated areas.

When it comes to protecting our lakes, stewardship is the best attitude. It is the understanding that what we do to land and water affects the lake. It is recognition that lakes are vulnerable and in order to make them thrive, citizens, both individually and collectively, must assume responsibility for their care. Once you learn more about all the factors that potentially affect your lake, you can practice preventative care of your lake, and hopefully avoid costly problems.

"In the end, we will conserve only what we love; we will love only what we understand; and we will understand only what we have been taught." - Baba Dioum, a Senegalese ecologist.

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Appendix 2. Phosphorus Export Education

Introduction

The purpose of lakeshed assessment is to develop an inventory and assess the resources within each lakeshed. The assessment can then be used as a tool to evaluate issues and create a framework of goals and strategies for citizens, as well as representatives from local units of government and resources agencies in the region. This information helps support the continued commitment to a collaborative effort to protect and improve water quality of Minnesota lakes and manage our limited resources.

Understanding a lakeshed requires the understanding of basic hydrology. A watershed is the area of land that drains into a surface water body such as a stream, river, or lake and contributes to the recharge of groundwater. There are three categories of watersheds: 1) basins, 2) major watersheds, and 3) minor watersheds.

Within this watershed hierarchy, lakesheds also exist. A lakeshed is defined simply as the land area that drains to a lake. While some lakes may have only one or two minor watersheds draining into them, others may be connected to a large number of minor watersheds, reflecting a larger drainage area via stream or river networks.

This summary includes educational information about phosphorus and nutrient transport in watersheds and lakesheds. For each individual lakeshed assessment, conclusions can be drawn as to the best way to protect and conserve land within the lakeshed. See individual lake reports for specific recommendations. Overall recommendations include:

- Continue to follow BMPs (Best Management Practices) in the lakeshed:
    - Plant natural vegetation along the shoreline
    - Protect and extend low phosphorus land covers wherever possible (forest/wetland)
    - Limit the use phosphorus fertilizer on lawns
    - Surface water onsite management (rain gardens, drainage, etc.)

- For lakes located near a town, investigate where storm water drains so that it is not impacting the lake. Rain gardens and wetlands can be good areas for storm water storage and infiltration.

Phosphorus

Phosphorus is a nutrient important for plant growth. In most lakes, phosphorus is the limiting nutrient, which means that everything that plants and algae need to grow is available in excess (sunlight, warmth, water, nitrogen, etc.), except phosphorus. This means that phosphorus has a direct effect on plant and algal growth in lakes – the more phosphorus that is available, the more plants and algae there are in the lake. Phosphorus originates from a variety of sources, many of which are related to human activities. Major sources include human and animal wastes, soil erosion, detergents, septic systems and runoff from farmland or fertilized lawns.

Phosphorus is usually measured in two ways in lakes, ortho-phosphate (soluble reactive phosphorus) and total phosphorus. Ortho-phosphate (soluble reactive phosphorus) is the chemically active, dissolved form of phosphorus that is taken up directly by plants. Ortho-phosphate levels fluctuate daily, and in lakes there usually isn't a lot of ortho-phosphate because it is incorporated into plants quickly. Total phosphorus (TP) is a better way to measure phosphorus in lakes because it includes both ortho-phosphate and the phosphorus in plant and animal fragments suspended in lake water. TP levels are more stable and an annual mean can tell you a lot about the lake's water quality and trophic state, as shown in Figure 1.

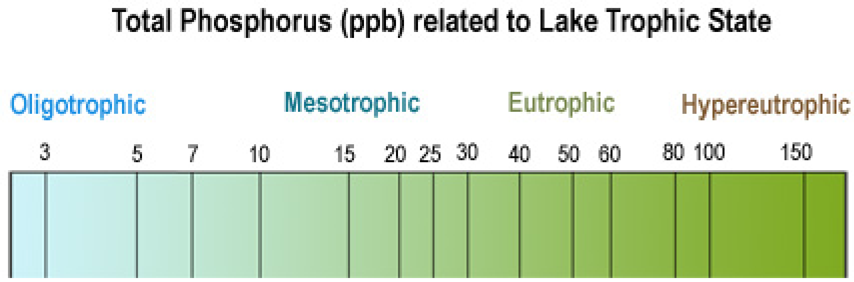

Figure 1. Phosphorus concentration (ppb) related to lake trophic state.

If phosphorus inputs are decreased or eliminated, less plants and algae are able to grow and water quality can improve.

Nutrient export to lakes

Phosphorus export, which is the main cause of lake eutrophication, depends on the type of land use occurring in the lakeshed. Phosphorus export (in lbs/acre/year) can be estimated from different land uses using the phosphorus export coefficient. Figure 2 shows the phosphorus export from the natural landscape versus human land uses. Humans alter the landscape, thereby adding more phosphorus to the lake than would occur naturally.

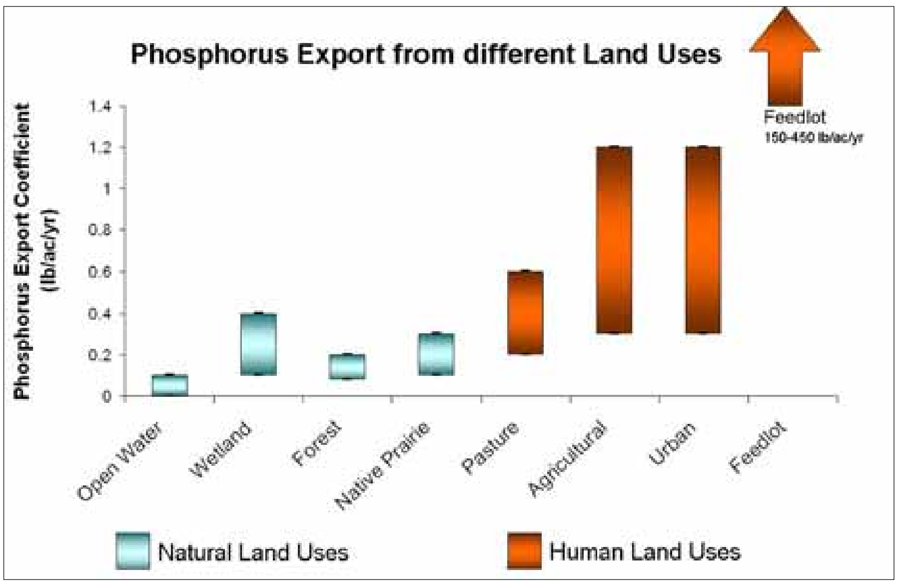

Figure 2. Phosphorus export coefficient for natural vs human land uses.

Stormwater is an all-inclusive term that refers to any of the water running off of the land’s surface after a rainfall or snowmelt event. Stormwater carries nutrients and other pollutants, the largest being phosphorus. Around lakes, urban development is one of the largest contributors of phosphorus. Prior to development, stormwater is a small component of the annual water balance. However, as development increases, the paving of pervious surfaces (that is, surfaces able to soak water into the ground) with new roads, shopping centers, driveways and rooftops all adds up to mean less water soaks into the ground and more water runs off. Figure 2 is a variation on a classic diagram that has appeared in many documents describing the effects of urbanization. This adaptation from the University of Washington shows how the relative percentages of water soaking into the ground change once development begins in a forested area. Note that the numbers assigned to the arrows depicting the movement of water will vary depending upon location within Minnesota (MPCA 2008).

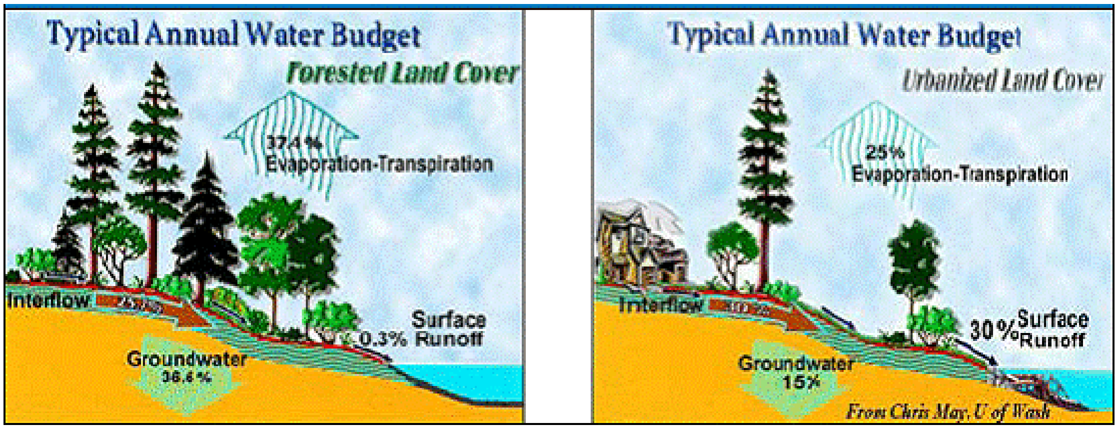

Figure 2. Differences in annual water budget from natural land cover to urbanized land cover (Source: May, University of Washington).

The changes in the landscape that occur during the transition from rural and open space to urbanized land use have a profound effect on the movement of water off of the land. The problems associated with urbanization originate in the changes in landscape, the increased volume of runoff, and the quickened manner in which it moves (Figure 3). Urban development within a watershed has a number of direct impacts on downstream waters and waterways, including changes to stream flow behavior and stream geometry, degradation of aquatic habitat, and extreme water level fluctuation. The cumulative impact of these changes should be recognized as a stormwater management approach is assembled (MPCA 2008).

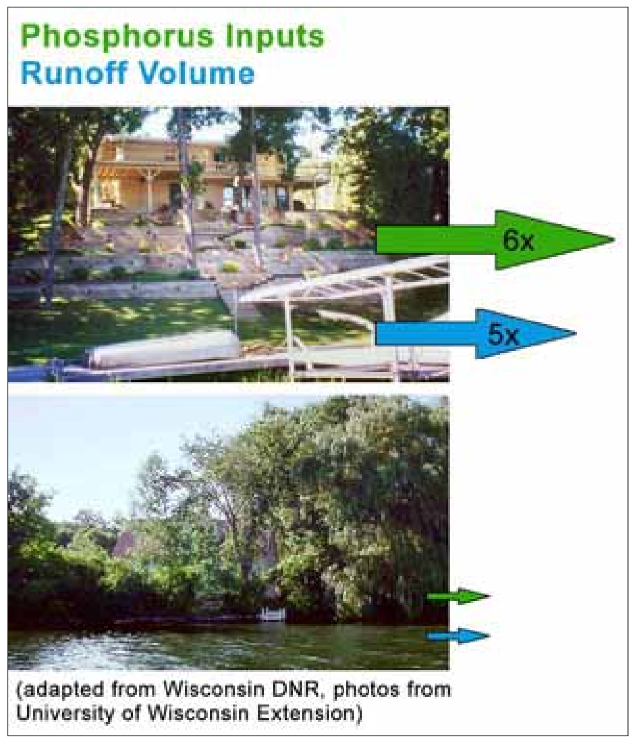

Figure 3. The effects of development on the amount of phosphorus and total runoff from a shoreland property. A large landscaped lot with a manicured lawn, a beach, and a retaining wall can increase total runoff volume by 500% and the phosphorus inputs to the lake by 600% (University of Wisconsin–Extension and Wisconsin Department of Natural Resources. 2002).

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University of Wisconsin–Extension and Wisconsin Department of Natural Resources. 2002. A guide to environmentally sound ownership. A publication of the Southeast Wisconsin Fox River Basin Partnership Team, University of Wisconsin–Extension, and Wisconsin Department of Natural Resources.

Appendix III: Glossary of terms

Glossary

Anoxic: without oxygen. Organisms cannot survive in prolonged periods of anoxia.

Chlorophyll-a: the pigment that makes plants and algae green. Chlorophyll-a is measured in lakes to determine algal concentration.

Dissolved oxygen: oxygen that is dissolved in the water column. Aquatic organisms (zooplankton, aquatic invertebrates and fish) need this oxygen to survive.

Epilimnion: The top layer of a lake where the sunlight penetrates and provides energy for plants and algae to grow.

Eutrophic: A lake that has low water clarity and high productivity (phosphorus and chlorophyll-1). Eutrophic lakes have a Trophic State Index between 50 and 70, an anoxic hypolimnion in the summer, algal and aquatic plants are prevalent, and can only support warm water fish.

Fall turnover: when the summer stratification layers of a lake mix due to the cooling epilimnion (upper layer of the lake). This mixing distributes all the nutrients evenly through the water column.

Fertility: the amount of plant and animal life that can be produced within a lake. Fertility is directly related to the amount of nutrients present in the lake to "feed" plants and animals (phosphorus, nitrogen).

Hypereutrophic: A lake that has very low water clarity and very high productivity (phosphorus and chlorophyll-a). Hypereutrophic lakes have a Trophic State Index over 70, and usually have heavy algal blooms and very dense aquatic plants.

Hypolimnion: The deep part of a lake that is cold and dark due to no sunlight penetration. This area of a lake can be anoxic in the summer due to stratification and decomposition.

Littoral area: the area around a lake that is shallow enough to support plant growth (usually less than 15 feet). This part of the lake also provides the essential spawning habitat for most warm water fishes (e.g. bass, walleye, and panfish).

Mesotrophic: A lake that has moderate water clarity and productivity (phosphorus and chlorophyll-a). Mesotrophic lakes have a Trophic State Index between 30 and 50, and the hypolimnion can become anoxic during the summer.

Nitrogen: a nutrient important for plant growth. Nitrogen can enter a lake through groundwater, surface runoff and manure.

Oligotrophic: A lake that has very clear water and very low productivity (phosphorus and chlorophyll-a). Oligotrophic lakes have a Trophic State Index under 30, the hypolimnion contains oxygen throughout the year and can support trout.

OP (Ortho Phosphate): the amount of inorganic phosphorus within a lake. Inorganic phosphorus is readily usable by algae and plants for growth.

Phosphorus: a nutrient needed for plant growth. Phosphorus can enter a lake through runoff from manure and fertilizer or through seepage from leaking septic and holding tanks.

Productivity: the amount of plant and animal life that can be produced within a lake. Productivity is directly related to the amount of nutrients present in the lake to "feed" plants and animals (phosphorus, nitrogen).

Secchi Depth: a measure of water clarity that can indicate the overall health of a lake. A black and white metal disc is lowered into the water on a rope until it can't be seen anymore and raised to the point it can be seen. The depth of the disk to the surface of the water is the Secchi Depth.

Spring turnover: when the ice melts off the lake in the spring and cold water on the top of the lake sinks. This mixing distributes all the nutrients evenly through the water column.

Stratification: The process in which most Minnesota lakes separate into three layers during the summer. The upper layer (epilimnion) becomes warm and is penetrated by sunlight, the lower layer (hypolimnion) is cold and dark and the middle area (thermocline) separates the top and bottom layers. Warm water is less dense than cold water, which is why the upper layer floats on top of the bottom layer and does not mix in the summer. Minnesota lakes mix in the spring and the fall, when the top layer of the lake cools off.

Thermocline: The area between the warm top layer of a lake and the cold bottom part of the lake. The thermocline is characterized by a sharp drop in temperature.

TP (Total Phosphorus): the total amount of organic and inorganic phosphorus within a lake. Organic phosphorus includes detritus, feces, dead leaves and other organic matter.

TMDL (Total Maximum Daily Load): the amount of a particular pollutant that a body of water can handle without violating state water quality standards.

Trend Analysis (Mann Kendall statistic): a way to test the probability of a trend being real versus just happening by chance. A trend probability of 90% (minimum probability used by MPCA) means that there is a 90% probability that the observed trend is real and a 10% probability that the observed trend is just from random chance.

Trophic State: Trophic states are defined divisions of a continuum in water quality. The continuum is Total Phosphorus concentration, Chlorophyll a concentration and Secchi depth. Scientists define certain ranges in the above lake measures as different trophic states so they can be easily referred to. See Oligotrophic, Mesotrophic, Eutrophic, Hypereutrophic.

TSI: Trophic State Index is a measurement of overall lake productivity (nutrient enrichment). The overall TSI of a lake is the average of the TSI for phosphorus, chlorophyll-a and secchi depth.

Turbidity: refers to how clear the water is. Cloudiness (turbidity) in the water can be due to suspended matter such as silt, clay, plankton and other organic matter. The more turbid the water is, the less sunlight can pass through.

Watershed: the area of land that drains into a lake directly or by way of a stream that flows into the lake. The land use practices of an entire watershed can affect the water quality of a lake.