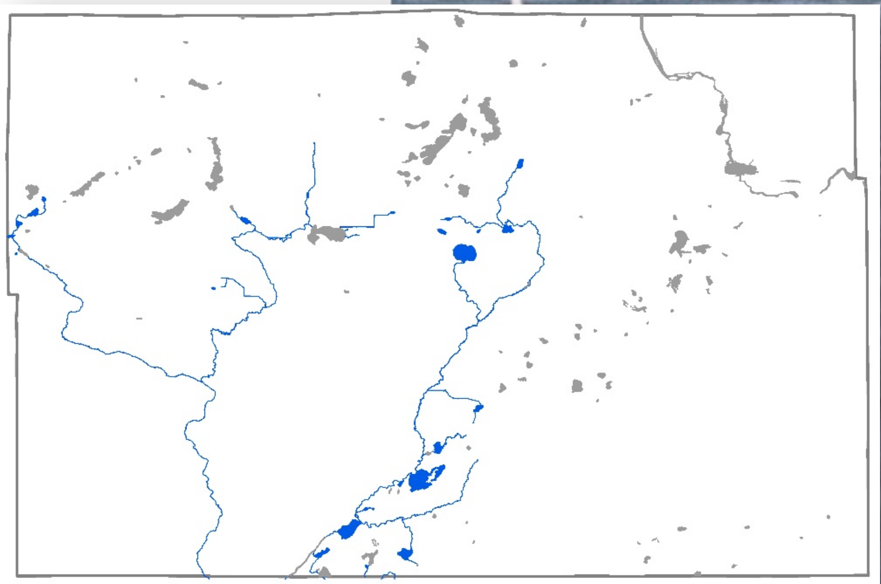
# Kettle River Watershed, Carlton County

## Lake Prioritization and Protection Planning Document

**2018**



CARLTON SWCD
SOIL & WATER CONSERVATION DISTRICT


Prepared by:
RMB Environmental Laboratories, Inc.

22796 County Highway 6
Detroit Lakes, MN 56501
(218) 846-1465
www.rmbel.info

| | |
|---|---|
| Date: | March 8, 2018 |
| To: | Carlton County Soil & Water Conservation District<br>808 3rd St<br>Carlton, MN 55718 |
| Subject: | Kettle River Watershed, Carlton County, Lake Prioritization and Planning Document |
| From: | Moriya Rufer<br>RMB Environmental Laboratories, Inc<br>22796 County Highway 6<br>Detroit Lakes, MN 56501<br>218-846-1465<br>moriyar@rmbel.info<br>www.rmbel.info |
| Authors: | Moriya Rufer, RMBEL, oversight and report<br>Emelia Hauck, RMBEL, mapping and data analysis |

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## Introduction

The Kettle River Watershed covers 672,235 acres in northeast Minnesota and lies within Northern Lakes and Forests ecoregion. Parts of Aitkin, Carlton, Kanabec, and Pine counties are in the Kettle River watershed. The headwaters for the Kettle River begin in Carlton County, and the river flows 104 miles south to its confluence with the St. Croix River south of Hinckley.

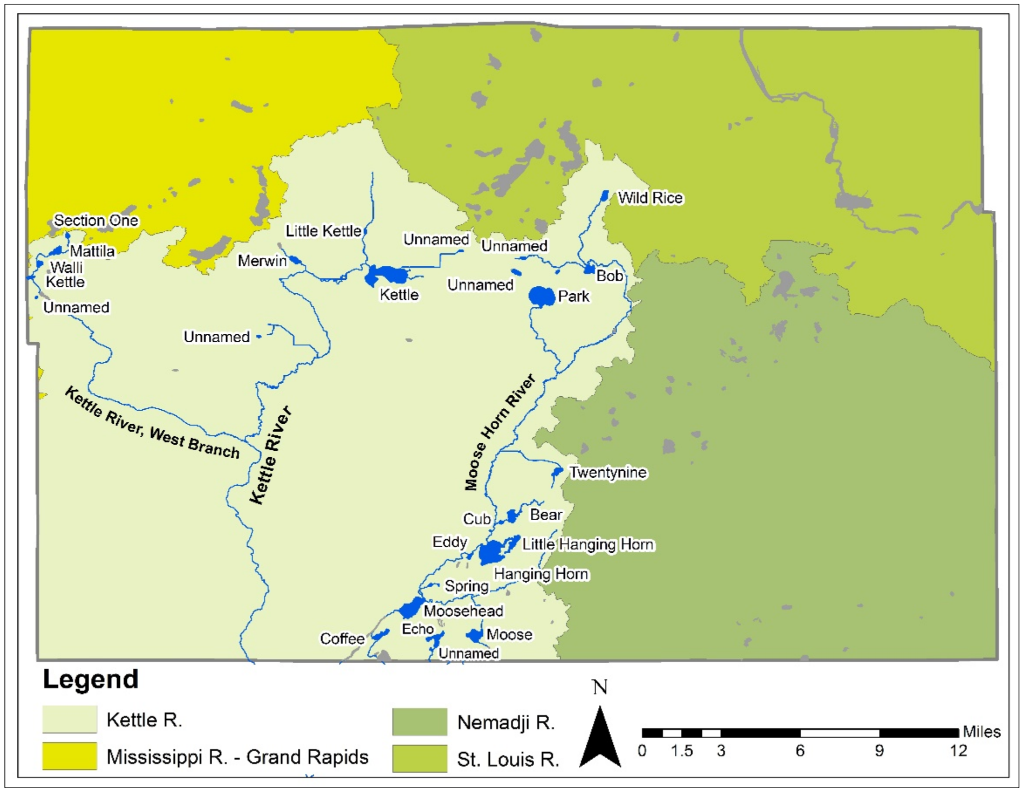


Figure 1. Lakes of Carlton County and the Kettle River Watershed. Lakes evaluated in this report are in dark blue, while each major basin is highlighted in a different color.

In 2018 the Carlton Soil and Water Conservation District (SWCD) decided to evaluate the water quality of the lakes in the Kettle River Watershed in Carlton County as civic engagement outreach. There are 29 lakes in the Kettle River Watershed and they are indicated in dark blue in Figure 1 and listed in Table 1.

Carlton County lakes have been monitored off and on between the 1970s and 2017. This monitoring has been completed by numerous organizations including Lake Associations, Minnesota Pollution Control Agency, Minnesota Department of Natural Resources, and Carlton SWCD.

The purposes of this report were 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, and prioritize lakes for management. This report contains a summary of the current state of selected Kettle River Watershed Lakes in Carlton County and recommendations for future monitoring. Individual lake reports follow with more in-depth assessments and recommendations.

Table 1. Data availability for Carlton County Lakes.

| Prioritization and Potential Lake Impacts | | |
|---|---|---|
| Transparency data |  | Secchi disk data have been collected extensively and should continue annually since it is relatively easy and inexpensive. |
| Chemical data (phosphorus) |  | Most large Carlton County lakes have at least two years of water quality data in the past 10 years. They don't have long-term data sets for trend analysis. |
| Inlet/Outlet data |  | Inlet/outlet data have been collected as part of the Kettle River Watershed Restoration and Protection Strategy. |

Table 2. Lakes assessed in the 2018 lake assessment.

| Lake Name | Lake ID | Lake Size (acres) |
|---|---|---|
| Bob | 09-0026-00 | 75.2 |
| Bear | 09-0034-00 | 90.4 |
| Coffee | 09-0045-00 | 71.1 |
| Cub | 09-0118-00 | 17 |
| Echo | 09-0044-00 | 108.3 |
| Eddy | 09-0039-00 | 23.5 |
| Hanging Horn | 09-0038-00 | 408.7 |
| Kettle | 09-0049-00 | 503.3 |
| Kettle | 09-0074-00 | 22.1 |
| Little Hanging Horn | 09-0035-00 | 114.4 |
| Little Kettle | 09-0077-00 | 14 |
| Mattila | 09-0070-00 | 65.4 |
| Merwin | 09-0058-00 | 52.6 |
| Moose | 09-0043-00 | 132.7 |
| Moosehead | 09-0041-00 | 274.8 |
| Park | 09-0029-00 | 381.3 |
| Section One | 09-0069-00 | 20.1 |
| Spring | 09-0094-00 | 18.1 |
| Twentynine | 09-0022-00 | 51.8 |
| Unnamed | 09-0027-00 | 16.9 |
| Unnamed | 09-0028-00 | 37.2 |
| Unnamed | 09-0075-00 | 6.3 |
| Unnamed | 09-0078-00 | 10.4 |
| Unnamed | 09-0092-00 | 12.4 |
| Unnamed | 09-0093-00 | 8.9 |
| Unnamed | 09-0124-00 | 12.4 |
| Unnamed | 09-0145-00 | 196.2 |
| Walli | 09-0071-00 | 32.8 |
| Wild Rice | 09-0023-00 | 55.3 |

## Trophic State Index

Trophic State Index (TSI) is a standard measure or means for estimating the amount of algae in a lake. The TSI is used to classify the "trophic state" of a lake, which broadly includes three categories: oligotrophic (little algae), mesotrophic (moderate algae), and eutrophic (high algae).

Many lakes, over long periods of time naturally "age" as runoff from adjacent lands adds nutrients into a lake. Young lakes start off oligotrophic and become eutrophic as they age, a process called "eutrophication". When human use of lakes increases the rate of nutrients into lakes, above background rates, for example through agriculture, sewage leakage, lawn fertilization, or more, lakes are said to undergo "cultural eutrophication". While preventing natural eutrophication is difficult, through modifying behavior and lake use, people can slow the rate of cultural eutrophication. Typical characteristics of these trophic states as well as some finer trophic state divisions are given in Table 4.

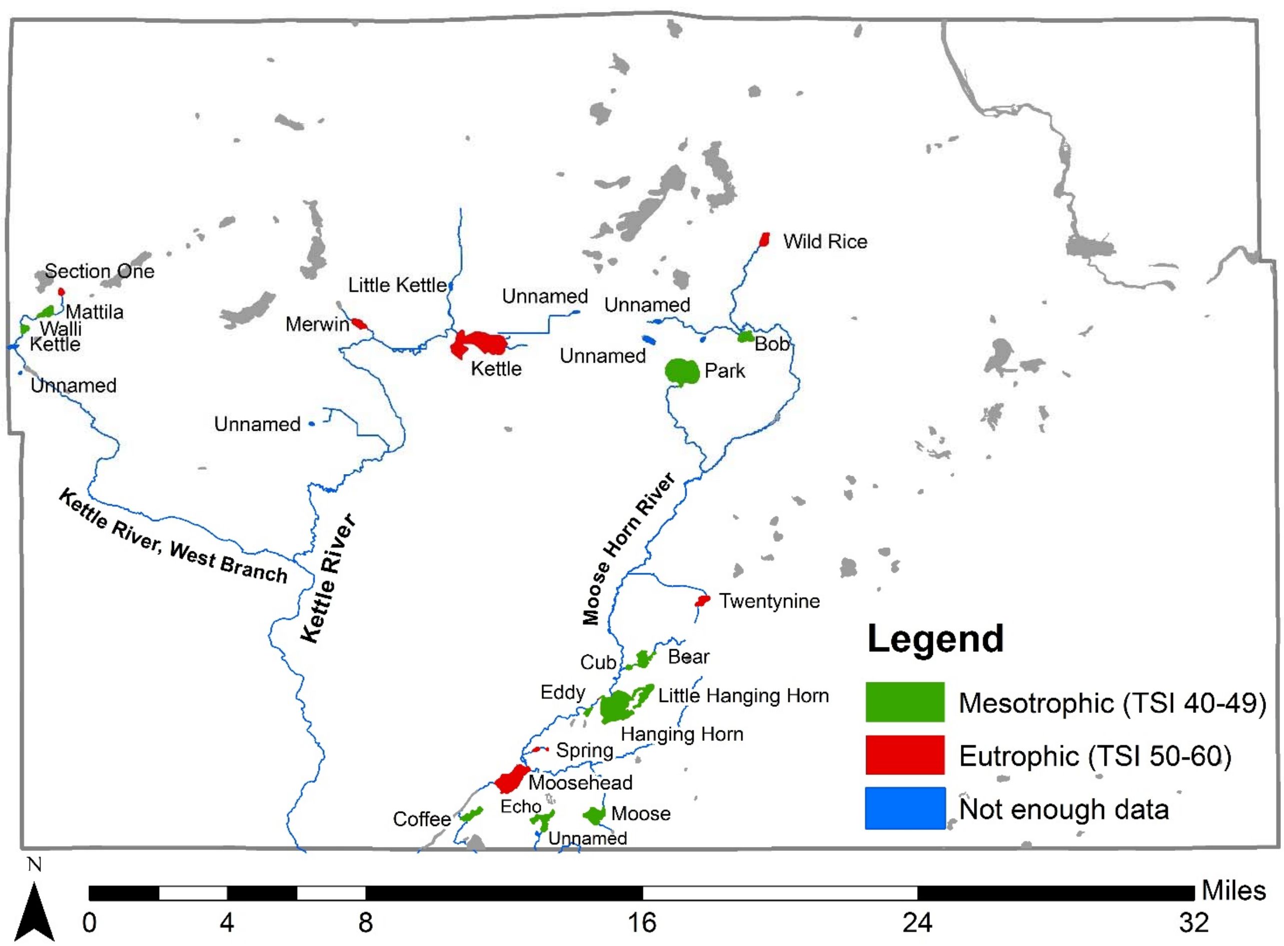



Figure 2. Trophic state index of selected lakes in the Kettle River Watershed in Carlton County

Phosphorus (a nutrient), chlorophyll *a* (an indication of algal concentration) and Secchi depth (transparency measure of water transparency/clarity) are usually related and are the primary measurements used to determine a lake's TSI. The more phosphorus that is available, the more algae that can grow. As algal concentrations increase, it causes water to become turbid or murky, which results in the water becoming less transparent and subsequently, the Secchi depth decreases.

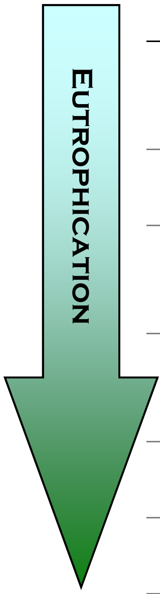
The TSI is unitless but can range from 0 (as oligotrophic as possible) to 100 (as eutrophic as possible). In real terms, a TSI of 0 would have a Secchi depth of approximately 210 feet while a TSI of 100 would have a TSI of approximately 3 inches. For every increase of 10 units in the TSI, the Secchi depth halves and the phosphorus doubles. Most of the large Carlton County lakes fall into the mesotrophic category (Table 3, Figure 2).

Table 3. Trophic state and trophic state index for Kettle River Watershed lakes in Carlton County.

| Lake | Mean TSI | Trophic State | Mean TSI Secchi | Mean TSI Phosphorus | Mean TSI Chlorophyll *a* |
|---|---|---|---|---|---|
| Echo | 41 | Mesotrophic | 32 | 45 | 47 |
| Park | 43 | Mesotrophic | 42 | 44 | 44 |
| Bob | 44 | Mesotrophic | 38 | 45 | 50 |
| Little Hanging Horn | 44 | Mesotrophic | 42 | 46 | 43 |
| Coffee | 45 | Mesotrophic | 39 | 47 | 50 |
| Moose | 46 | Mesotrophic | 36 | 50 | 53 |
| Eddy | 48 | Mesotrophic | 51 | 48 | 45 |
| Kettle (0049) | 48 | Mesotrophic | 51 | 53 | 42 |
| Bear | 49 | Mesotrophic | 45 | 51 | 50 |
| Hanging Horn | 49 | Mesotrophic | 48 | 49 | 50 |
| Mattlia* | See Secchi | Mesotrophic | 44* | | |
| Cub* | See Secchi | Mesotrophic | 46* | | |
| Walli* | See Secchi | Mesotrophic | 49* | | |
| Merwin | 51 | Eutrophic | 39 | 57 | 57 |
| Moosehead | 55 | Eutrophic | 56 | 55 | 55 |
| Twentynine | 56 | Eutrophic | 52 | 62 | 55 |
| Section One* | See Secchi | Eutrophic | 50* | | |
| Spring* | See Secchi | Eutrophic | 53* | | |
| Wild Rice* | See Secchi | Eutrophic | 55* | | |

**No water quality data exist for these lakes, but transparency TSI can be estimated from the University of Minnesota Remote Sensing Lab 2008 data. http://lakes.rs.umn.edu/*

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

In assessing water quality, agencies and other lake data users want to know if the amount of algae has been changing over time. Scientists test hypotheses using statistics, and the hypothesis used in a trend analysis is that no trend exists. In other words, we begin with the assumption that there is no trend. We collect data and use statistics to determine the probability of collecting our data if this hypothesis of no trend is indeed true. The output from a statistical test is called the probability value (or p-value for short) of collecting data given the hypothesis of no trend is true. The smaller this probability value, the more likely the null hypothesis of no trend can be rejected. The MPCA has set the acceptable p-value to be less than 10%. In other words, if $p < 0.10$ we reject the hypothesis of no trend and accept that a trend likely exists. Another way to think of this is to say that there is in reality an existing trend, there is a 90% chance we would have collected the data we collected and that a 10% chance that the trend is a random result of the data.

For detecting trends, a minimum of 8-10 years of data with four or more readings per season are recommended by the MPCA. Where data does not cover at least eight years or where there are only few samples within a year, trends can be misidentified because there can be different wet years and dry years, water levels, weather, and etc., that affect the water quality naturally.

The lakes in Table 5 had sufficient transparency data to perform a statistical trend analysis (Table 5). The data were analyzed using the Mann Kendall Trend Analysis. The lakes in Table 6 had insufficient data to perform a statistical trend analysis.

Table 5. Kettle River Carlton County lakes with enough data to determine trends in transparency.

| Lake Name | Lake ID | Years | Trend |
|---|---|---|---|
| Eddy | 09-0039-00 | 1995-2015 | Declining Trend |
| Little Hanging Horn | 09-0035-00 | 2006-2016 | Improving Trend |
| Bear | 09-0034-00 | 1996-2000, 2006-2016 | No Trend |
| Hanging Horn | 09-0038-00 | 2006-2016 | No Trend |
| Moosehead | 09-0041-00 | 2012-2017 | Improving Trend |
| Park | 09-0029-00 | 1985-2010 | No Trend |

Table 6. Kettle River Carlton County lakes with insufficient data to determine trends in transparency.

| Lake Name | Lake ID | Years | Trend |
|---|---|---|---|
| Bob | 09-0026-00 | 1982, 2016 | Insufficient Data |
| Coffee | 09-0045-00 | 2014-2016 | Insufficient Data |
| Cub | 09-0118-00 | NA | Insufficient Data |
| Echo | 09-0044-00 | 2016 | Insufficient Data |
| Kettle | 09-0049-00 | 2004, 2016-2017 | Insufficient Data |
| Kettle | 09-0074-00 | NA | Insufficient Data |
| Little Kettle | 09-0077-00 | NA | Insufficient Data |
| Mattila | 09-0070-00 | NA | Insufficient Data |
| Merwin | 09-0058-00 | 2016 | Insufficient Data |
| Moose | 09-0043-00 | 2016 | Insufficient Data |
| Section One | 09-0069-00 | NA | Insufficient Data |
| Spring | 09-0094-00 | NA | Insufficient Data |
| Twentynine | 09-0022-00 | 2016 | Insufficient Data |
| Unnamed | 09-0027-00 | NA | Insufficient Data |
| Unnamed | 09-0028-00 | NA | Insufficient Data |
| Unnamed | 09-0075-00 | NA | Insufficient Data |
| Unnamed | 09-0078-00 | NA | Insufficient Data |
| Unnamed | 09-0092-00 | NA | Insufficient Data |
| Unnamed | 09-0093-00 | NA | Insufficient Data |
| Unnamed | 09-0124-00 | NA | Insufficient Data |
| Unnamed | 09-0145-00 | NA | Insufficient Data |
| Walli | 09-0071-00 | NA | Insufficient Data |
| Wild Rice | 09-0023-00 | NA | Insufficient Data |

## 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.

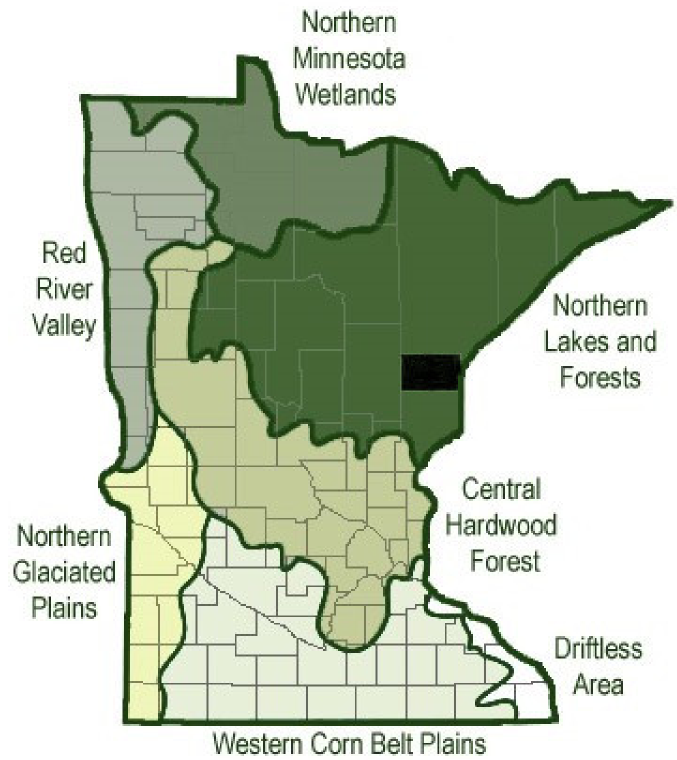



Figure 3. Minnesota Ecoregions. Carlton County is indicated in black.

All of Carlton County is in the Northern Lakes and Forests (NLF) Ecoregion (Figure 3). This heavily forested ecoregion is made up of steep, rolling hills interspersed with pockets of wetlands, bogs, lakes and ponds. Lakes are typically deep and clear, with good gamefish populations. These lakes are very sensitive to damage from atmospheric deposition of pollutants (mercury), storm water runoff from logging operations, urban and shoreland development, mining, inadequate wastewater treatment, and failing septic systems. Agriculture is somewhat limited by the hilly terrain and lack of nutrients in the soil, though there are some beef and dairy cattle farms.

Most of the lakes evaluated in this report fall within the expected ecoregion ranges for the Northern Lakes and Forests Ecoregion (Table 7). The lakes that don't fit these ranges are very small and shallow, and aren't as comparable to these ranges: Twentynine and Moosehead.

Table 7. Ecoregion ranges.

| **Ecoregion** | **Total Phosphorus (ug/L)** | **Chlorophyll *a* (ug/L)** | **Secchi Depth (ft)** |
|---|---|---|---|
| Northern Lakes and Forest (NLF) | 14 - 27 | <10 | 8 - 15 |

## DNR Fisheries Approach to 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 8). Watershed disturbance was defined as having urban, agricultural and mining land uses. Watershed protection is defined as publicly owned land or conservation easement.

Table 8. 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. |

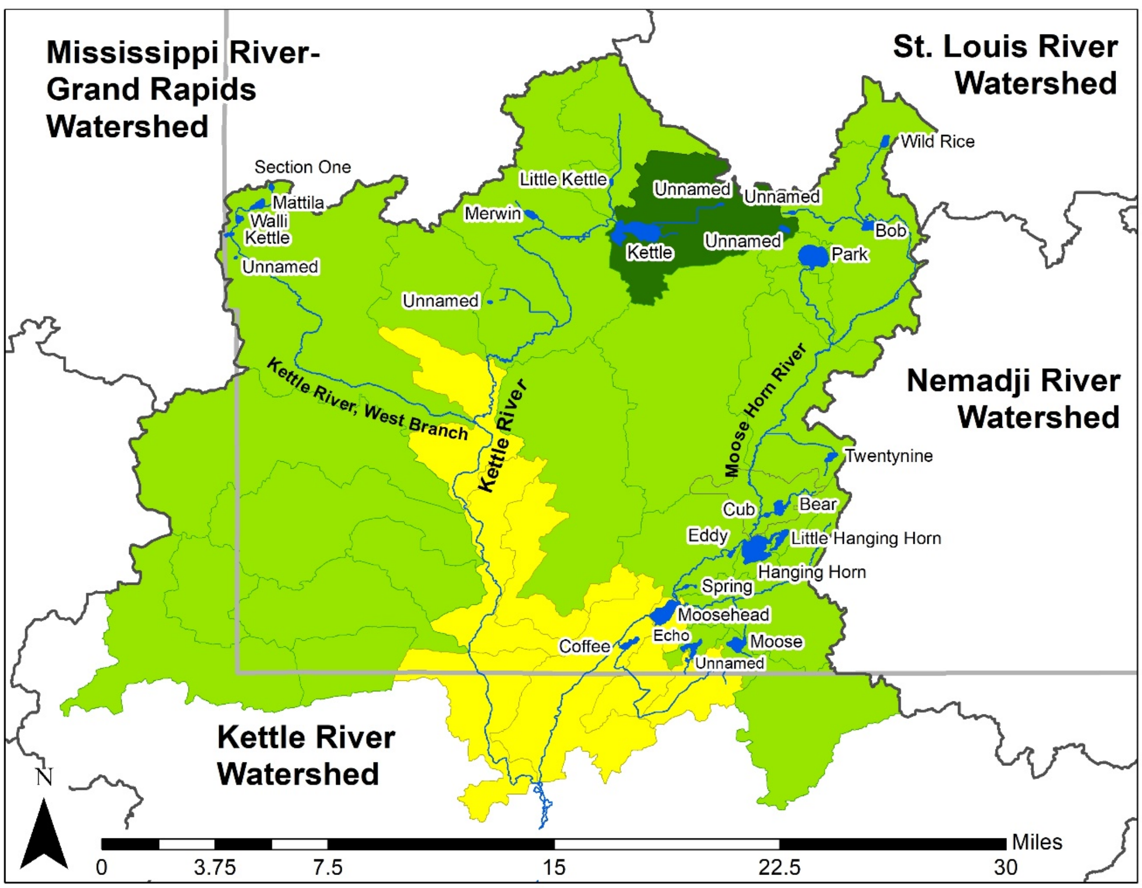



Figure 5. Map of lakesheds color-coded with management focus (Table 8).

Most of the lakes evaluated in this report have a protection management focus (light green, Figure 5, Table 8).

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 two Carlton County Lakes in the Kettle River Watershed evaluated in this report that are listed as Cisco refuge lakes: Hanging Horn and Little Hanging Horn (Table 9).

Table 9. Carlton County Lakes evaluation of watershed protection and disturbance.

| Lake Name | MN Lake ID | Management Focus | Cisco Refuge Lakes |
|---|---|---|---|
| Bob | 09-0026-00 | Protection | |
| Bear | 09-0034-00 | Full Restoration | |
| Coffee | 09-0045-00 | Full Restoration | |
| Cub | 09-0118-00 | Full Restoration | |
| Echo | 09-0044-00 | Protection | |
| Eddy | 09-0039-00 | Protection | |
| Hanging Horn | 09-0038-00 | Protection | Tier 2 |
| Kettle | 09-0049-00 | Vigilance | |
| Kettle | 09-0074-00 | Protection | |
| Little Hanging Horn | 09-0035-00 | Protection | Tier 2 |
| Little Kettle | 09-0077-00 | Protection | |
| Mattila | 09-0070-00 | Protection | |
| Merwin | 09-0058-00 | Protection | |
| Moose | 09-0043-00 | Protection | |
| Moosehead | 09-0041-00 | Full Restoration | |
| Park | 09-0029-00 | Protection | |
| Section One | 09-0069-00 | Protection | |
| Spring | 09-0094-00 | Protection | |
| Twentynine | 09-0022-00 | Protection | |
| Unnamed | 09-0027-00 | Protection | |
| Unnamed | 09-0028-00 | Vigilance | |
| Unnamed | 09-0075-00 | Protection | |
| Unnamed | 09-0078-00 | Protection | |
| Unnamed | 09-0092-00 | Protection | |
| Unnamed | 09-0093-00 | Full Restoration | |
| Unnamed | 09-0124-00 | Vigilance | |
| Walli | 09-0071-00 | Protection | |
| Wild Rice | 09-0023-00 | Protection | |

## 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 2018, Carlton County has some infestations, mostly Eurasian watermilfoil (Figure 6). There are currently no lakes infested with zebra mussels.

At boat landings, there are usually DNR signs telling 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 Carlton 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/ais/infested.html](http://www.dnr.state.mn.us/invasives/ais/infested.html)

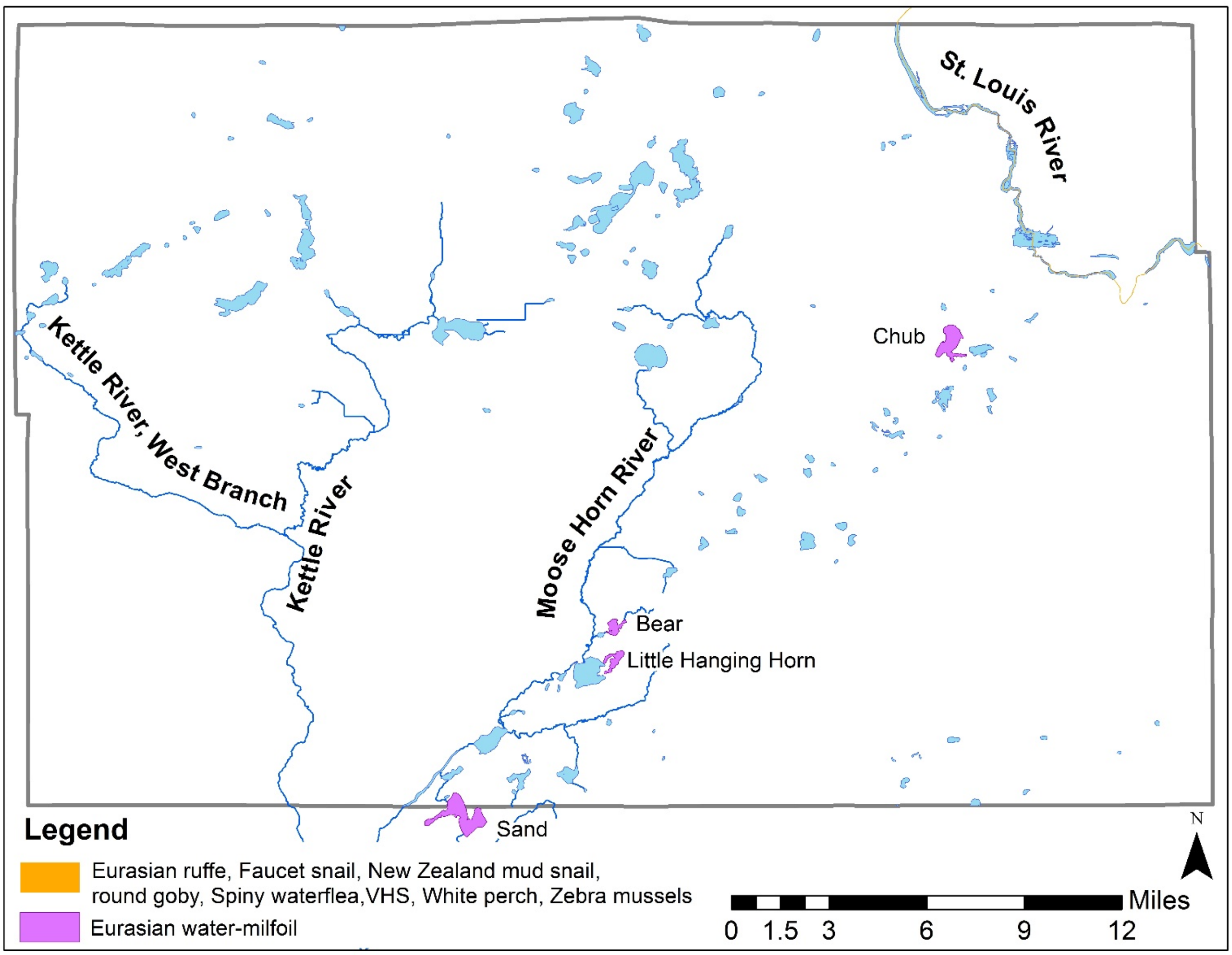



Figure 6. Carlton County lakes with invasive species as of February 2018.

# Prioritization and Potential Lake Impacts

## Prioritization

On a county-wide basis, it is helpful to prioritize lakes for projects and management. Due to their water quality and good fisheries, Hanging Horn and Little Hanging Horn lakes are highly developed and highly used for recreation and fishing. They are also classified as cisco refuge lakes by the DNR. These would likely be the top priority lakes for protection in the Kettle River Watershed in Carlton County. The other lakes that had more than a few years of water quality data and shoreline development include Bear Lake, Moosehead Lake and Park Lake. These would be the next priority. The lakes that did not have much or any water quality data or shoreline development would be the third priority.

Tier 1 Priority
- Hanging Horn Lake
- Little Hanging Horn Lake

Tier 2 Priority
- Bear Lake
- Moosehead Lake
- Park Lake

Tier 3 Priority
- All other lakes

Since not all lakes in the Kettle River Watershed in Carlton County had enough water quality data for a full analysis, a table was put together to summarize all the lakes (Table 11). Using information about the lake and its watershed, the lakes were separated into a nearshore focus or a watershed focus for best management practices.

## Nearshore Impacts Focus

Lakes with small watershed to lake area ratios (<10:1) and no inlets have a near shore focus. This means that the main impact to the lake's water quality is from land practices directly around the shoreline. Best management practices specific to nearshore impacts include:

- Evaluate the shoreline with Score Your Shore: http://www.dnr.state.mn.us/scoreyourshore/index.html
- Shoreline Restoration
- Rain Gardens
- Septic System Maintenance
- Plant Trees
- Establish Conservation Easements, Forest Stewardship Plans, and Aquatic Management Areas

## Watershed Impacts Focus

Lakes with large watersheds, inlets, and connections with upstream lakes have a watershed focus. This means that the main impact to the lake's water quality is the accumulation of nutrients from the whole watershed, and land practices upstream. Best management practices specific to watershed impacts include:

- Look at a map and identify all possible organizations in the watershed including lake associations, counties, national wildlife refuges, etc. Organize a "get to know your watershed" summit to brainstorm how to work together.
- Work with upstream partner organizations and the county as a whole to implement projects.
- Form a watershed district or lake improvement district, which provides additional funding for projects (tax funding).
- Encourage all riparian land owners to follow the best management practices in the nearshore section above.
- Enforce county shoreline and riparian ordinances to protect sensitive areas.

Table 10. Definitions of the column headings for Table 11.

| Column Heading | Definition |
|---|---|
| DOW | Lake Identification Number assigned by the DNR Division of Waters. |
| % Lakeshore Private | The percentage of the lakeshore that is in private ownership. Private land owners can implement best management practices on their own property with help from the SWCD. |
| # Inlets | The number of inlets to the lake.  Inlets can bring nutrients and invasive species into a lake. |
| # Outlets | The number of outlets to a lake.  If a lake doesn't have outlets it can experience high water levels. |
| Watershed to Lake Area Ratio | The standard watershed to lake area ratio shows how much total land area (including water features) that may drain to a lake outlet compared to the size of the lake.  Lakes with very large ratios (>50) have increased risk for nutrient loading from upstream. |
| Tribal Land | This is a yes/no on if there is Tribal Land within the lakeshed.  This could indicate shared management of the water body. |
| Notable Characteristics | These are special classifications for lakes that have specific management from the DNR or MPCA. |
| BMP Focus | This rating provides guidance as to where to focus best management practices (BMPs) for protecting the lake.  Lakes with small watershed to lake area ratios and no inlets have a near shore focus, lakes with large watersheds and inlets have a watershed focus. |

Table 11. Summary table of lake characteristics with recommendations for management focus.

| Lake Name | DOW | % Lakeshore Private | # Inlets | # Outlets | Watershed: Lake Area Ratio | Tribal Land | Notable Characteristics | Notes on possible water quality impacts | BMP Focus |
|---|---|---|---|---|---|---|---|---|---|
| Bear | 09003400 | 99.5% | 2 | 1 | 574:1 | no | Shallow Lake | City of Barnum | Nearshore & Watershed* |
| Bob | 09002600 | 100% | 1 | 1 | 195:1 | yes | Wild Rice | | Watershed |
| Coffee | 09004500 | 100% | 1 | 1 | 1,270:1 | no | | Feedlot on the SE shore | Watershed |
| Cub | 09011800 | 0% | 2 | 1 | 3,056:1 | no | | | Watershed |
| Echo | 09004400 | 29% | 0 | 1 | 9:1 | no | Shallow Lake | | Nearshore |
| Eddy | 09003900 | 100% | 2 | 1 | 2,563:1 | no | | feedlot about 750 feet upstream of lake in lakeshed | Watershed |
| Hanging Horn | 09003800 | 100% | 4 | 1 | 131:1 | no | Cisco Refuge Lake Tier 2, Lake Trout | | Watershed |
| Kettle | 09007400 | 100% | 1 | 1 | 1,135:1 | yes | Wild Rice | | Watershed |
| Kettle | 09004900 | 4% | 4 | 1 | 23:1 | no | Priority Shallow Lake, Wild Rice, WMA | | Watershed |
| Little Hanging Horn | 09003500 | 100% | 1 | 1 | 6:1 | no | Cisco Refuge Lake Tier 2 | | Nearshore |
| Little Kettle | 09007700 | 21% | 1 | 1 | 875:1 | no | | | Watershed |
| Mattlia | 09007000 | 100% | 1 | 1 | 383:1 | no | Shallow Lake | | Watershed |
| Merwin | 09005800 | 100% | 1 | 1 | 771:1 | no | | Feedlot on the NW shore | Watershed |
| Moose | 09004300 | 100% | 1 | 1 | 7:1 | no | Shallow Lake, Wild Rice | | Watershed |
| Moosehead | 09004100 | 98.8% | 3 | 1 | 260:1 | no | Wild Rice | City of Moose Lake | Nearshore & Watershed* |
| Park | 09002900 | 100% | 0 | 1 | 4:1 | no | NA | Feedlot west of the lake | Nearshore |
| Section One | 09006900 | 76% | 0 | 1 | 1,247:1 | no | | | Nearshore** |
| Spring | 09009400 | NA | 1 | 1 | 3,328:1 | no | Priority shallow Lake | | Watershed |
| Twentynine | 09002200 | 29% | 1 | 1 | 566:1 | no | | | Watershed |
| Walli | 09007100 | 100% | 1 | 1 | 764:1 | no | | | Watershed |
| Wild Rice | 09002300 | 86% | 0 | 1 | 47:1 | yes | Priority Shallow Lake, Wild Rice | | Nearshore** |

*Table continued on next page…*

*Bear and Moosehead Lakes have a BMP focus of nearshore and watershed because they have cities adjacent to the lake.

**These lakes have large watersheds, but no inlets so their BMP focus is nearshore.

Table 11 continued. Summary table of lake characteristics with recommendations for management focus.

| Lake Name | DOW | % Lakeshore Private | # Inlets | # Outlets | Watershed: Lake Area Ratio | Tribal Land | Notable Characteristics | Notes on possible water quality impacts | BMP Focus |
|---|---|---|---|---|---|---|---|---|---|
| Unnamed | 09002800 | 100 | 0 | 0 | 314 | yes | | | Nearshore** |
| Unnamed | 09012400 | 0 | 0 | 1 | 942 | yes | | | Nearshore** |
| Unnamed | 09009200 | 86 | 0 | 1 | 1184 | yes | | | Nearshore** |
| Unnamed | 09007800 | 23 | 0 | 0 | 3902 | no | | | Nearshore** |
| Unnamed | 09007500 | 50 | 0 | 1 | 3981 | no | | | Nearshore** |
| Unnamed | 09009300 | 100 | 1 | 1 | 450 | no | | | Watershed |
| Unnamed | 09002700 | 79 | 1 | 1 | 714 | yes | | | Watershed |
| Unnamed | 09014500 | 58 | 2 | 1 | 74 | no | Wild Rice | | Watershed |

**These lakes have large watersheds, but no inlets so their BMP focus is nearshore.

Table 12 outlines best management practices for different land use types around the lakes, along with who can do the project and who can help with expertise and funding.

Table 12. Best Management Practices for different land use types.

| Category | Land use type | Conservation project ideas | Results | Who | Contact for help |
|---|---|---|---|---|---|
| Conservation Potential Land | private forests | Forest stewardship planning, 3rd party certification, SFIA, local woodland cooperatives | Conserve and protect current forest cover | • Individual Property Owners | Carlton SWCD<br>(218) 384-3891<br>https://carltonswcd.org/ |
| | pasture/hay | Conservation Reserve Program (CRP), maintain vegetative cover, plant trees, conservation easements, grassed waterways, ditch buffers, maintain/restore wetlands. | Reduce water runoff and soil erosion, better water storage | • Individual Property Owners | Natural Resources Conservation Service<br>218-720-5209 |
| Disturbed Land | developed, low intensity | Shoreline buffers, rain gardens | Reduce water runoff and shoreline erosion. | • Individual Property Owners | Carlton SWCD<br>(218) 384-3891<br>https://carltonswcd.org/ |
| | developed, high intensity | Sediment basins, rain gardens, shoreline buffers, stormwater retention. | Reduce water runoff into streams and lakes. | • Individual Property Owners<br>• Cities<br>• Lake Associations | Carlton SWCD<br>(218) 384-3891<br>https://carltonswcd.org/ |
| | cultivated crops | Restore wetlands; Conservation Reserve Program (CRP), Cover Crops. | Reduce water runoff and soil erosion, better water storage. | • Individual Property Owners | Natural Resources Conservation Service<br>218-720-5209 |

## Summary and Recommendations

### Overall Conclusions

Overall, the lakes in Carlton County that were evaluated in this report have good water quality and are in good condition.

Six of the lakes evaluated had enough transparency data to perform a trend analysis. Overall, 2 lakes had improving water quality trends, one lake had a declining trend, and the rest had no trends (Tables 5-6).

Two of the lakes evaluated in this report are designated as Cisco refuge lakes by the DNR: Hanging Horn and Little Hanging Horn 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. 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.

Shoreline development and land disturbance seems to be the largest overall human-caused impact and risk to the lakes in Carlton County. From looking at GIS mapping layers over time, it appears that development on lakes in Carlton County has increased significantly since 1980. Once the second tier around the lake is developed, the drainage in the lakeshed changes and more runoff reaches the lake from impervious surface and lawns. See project ideas for nearshore best management practices on page 14.

Another potential lake impact is the size of the watershed. Lakes with large watersheds receive nutrients cumulatively from the entire upstream area. See project ideas for watershed best management practices on page 14.

### Monitoring Recommendations

At a minimum, every lake of significance to the county should have one primary site (recommended in each individual report) that should be monitored for transparency with a Secchi disk weekly or bimonthly every summer. This monitoring is free and is tracked through the Minnesota Pollution Control Agency's Citizen Lake Monitoring Program (CLMP, https://www.pca.state.mn.us/water/resources-volunteers). After 8-10 years of consecutive data, a trend analysis can be completed for each lake.

Large lakes with significance to the county and shoreline development should be monitored for phosphorus and chlorophyll a at least 2 years in every decade. This allows for MPCA Assessment.

To determine the phosphorus loading from the watershed, the inlets could be monitored during baseline and peak flow events (spring thaw and heavy rains). Lakes with possible inlet and watershed loading are identified in Table 11.

### Shallow Lakes

Shallow lakes usually have a maximum depth around 20 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 healthy fishery.

Studies have shown that large boat motors can re-suspend the phosphorus from the lake's sediment and cause algae blooms. Boaters should be encouraged to drive slowly through areas shallower than 10 feet.

The shallow lakes evaluated in this report are listed in Table 11.

## Stormwater Management

Stormwater management is an issue anywhere there is concentrated development. Any impervious surface, including driveways, roads, roofs and patios cause the rain to run off of them instead of soaking into the ground. Turf grass does not sufficiently infiltrate rainwater either. Rain gardens and wetlands can be good areas for storm water storage and infiltration. For lakes located adjacent to a town, such as Bear and Moosehead, investigate specifically where storm water drains so that it is not impacting the lake. Towns have a high density of impervious surface. It is not possible to remove this impervious surface, but it is possible to install stormwater management practices to prevent the stormwater from running into the lakes.

## Future Studies

Future studies that would better pinpoint the impacts on the lake include a shoreline inventory, monitoring stream inlets, monitoring for internal loading, and a watershed flow analysis. The shoreline inventory would consist of driving around the lake and rating each parcel as to how much of the frontage has a vegetative buffer.

To determine the phosphorus loading from the watershed, the inlets could be monitored during baseline and peak flow events (spring thaw and heavy rains). The inlets could also be ground-truthed, which entails walking them to look for erosion and insufficient vegetative buffers.

Monitoring for internal loading involves collecting hypolimnion water samples (water samples taken 1 foot above the lake's bottom) and corresponding dissolved oxygen profiles.

A watershed flow analysis would be done using GIS software to see the areas of heaviest runoff into the lake. This analysis would also help where stormwater mitigation, rain gardens and shoreline restoration would have the most positive impact on the lake.

## Grant and Cost Share Possibilities

*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

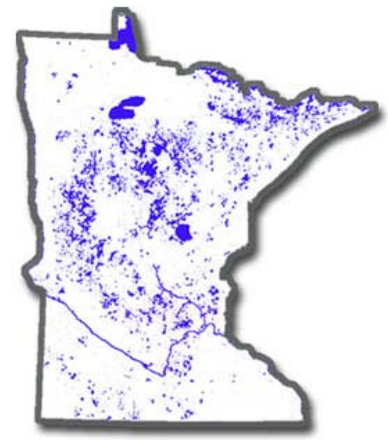
*DNR Conservation Partners Legacy Grant Program:* These grants can be used for projects that restore, enhance and/or protect habitats for MN's fish, game, and wildlife.
http://www.dnr.state.mn.us/grants/habitat/cpl/index.html

*DNR Forest Stewardship Program:* This program has a cost share for landowners to protect and manage forests on private lands.
http://www.dnr.state.mn.us/woodlands/cost-share.html

*Minnesota Land Trust Conservation Easements*: This program is for landowners to donate land into conservation easements, which protects them perpetually.
http://www.mnland.org/conservation-options

## Appendix I: Lake Education

### Lake Water Quality: the natural factors and the human factors



There are many factors that contribute to a lake's current condition, including natural factors and human factors. Once these factors are understood, a better understanding 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 years ago to about 9,000 years ago, glaciers alternately retreated and advanced over the landscape, carving out holes and leaving behind ice chunks. As these ice chunks melted in the holes left behind, lakes were formed. Northern Minnesota was scraped fairly clean down to the bedrock, with boulders, sand and clay left behind, while southern Minnesota was left with a rich, fine prairie (now agricultural) soil.

The first thing that goes into understanding a lake is what sort of geological area it is in. Northern Minnesota lakes are commonly very deep, rocky lakes 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 lake. Lake users such as fishermen are probably aware of these characteristics already because they also determine where the fish are. A lake that is one large round hole is different than a lake that has a lot of bays, points and bottom structure. A long narrow lake is more affected by wind (which mixes the lake) than a round lake. Deep lakes have different dynamics than shallow lakes, and most of all, deep lakes have more water. The more water a lake has (volume), the better it is able to dilute what runs into it.

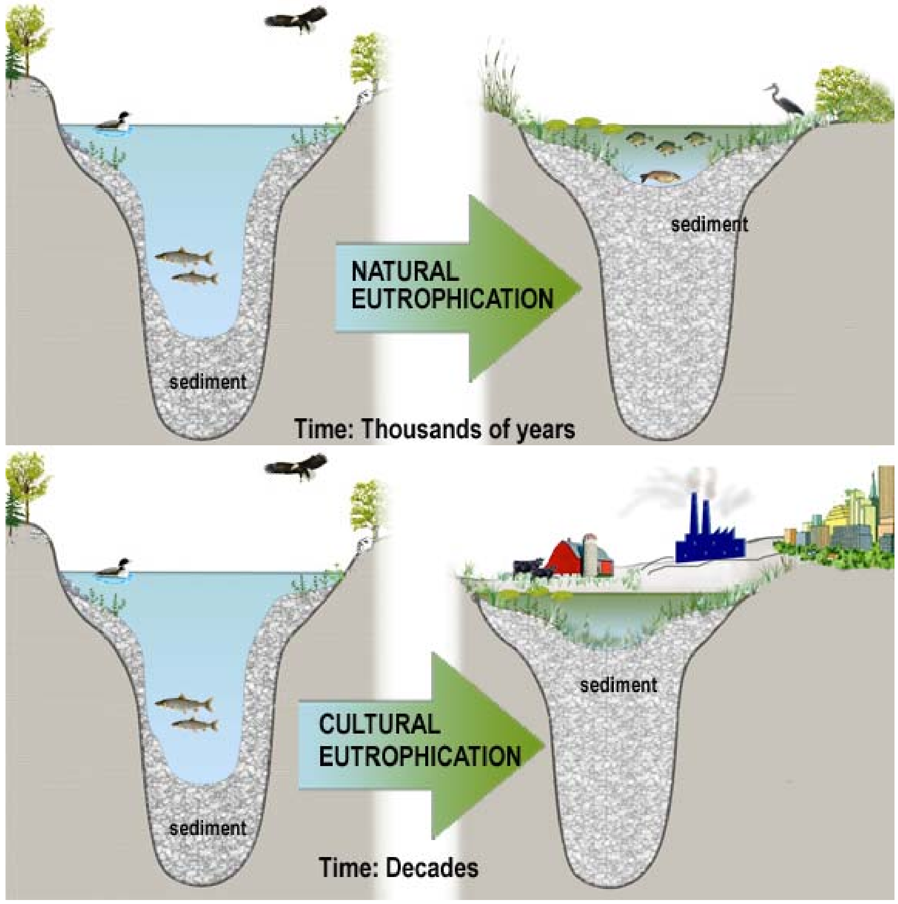
Shallow lakes are lakes where the sunlight can reach the entire bottom. Generally, this corresponds to about 15 feet deep or less. Since the sunlight can reach the bottom, aquatic plants are able to grow there. In deep lakes, the bottom does not receive sunlight, so no plants grow there and it stays dark and cold.

Another major factor affecting lake condition is the size of its watershed and where the lake sits within the watershed. A watershed is an area of land where all the water drains into the same river system. These watershed areas are defined by topography, or ridges of elevation. Therefore, watersheds are mainly driven by gravity – water runs down hill.

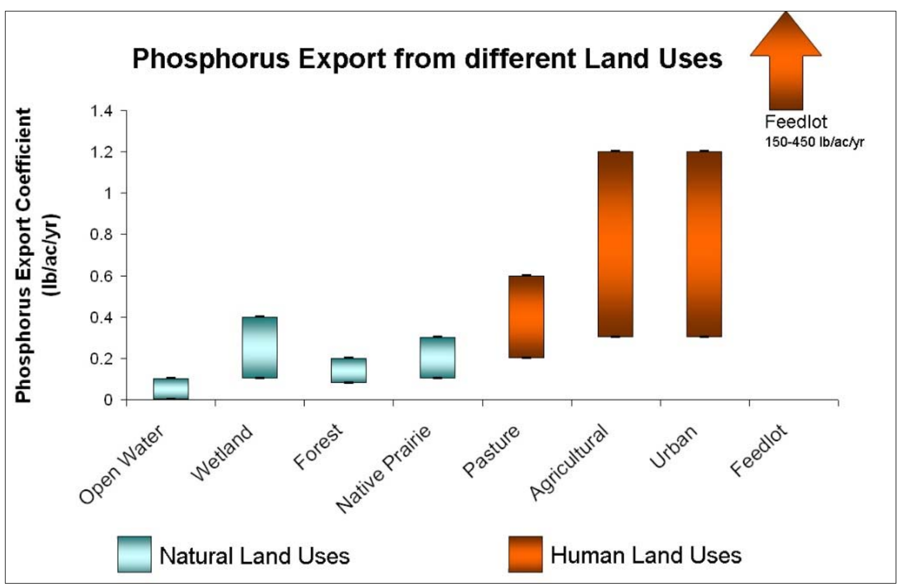
If a lake has a very small watershed or is at the top of a watershed (in topography terms), the lake usually has better water clarity than a lake at the bottom of a large watershed. As water flows downhill through a watershed it picks up sediment from erosion and nutrients from runoff. This sediment 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 quickly, where the lake will 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 a lot of impervious surface. 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 ends up running into lakes and streams and 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 get washed 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, and their area, depth and shape. Then we humans add to that by what type of land practices we implement near the lake and upstream from the lake. Lakes that are 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 an attitude. It is the understanding that what we do on land and in the water affects the lake. It is recognition that lakes are vulnerable and that 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.

*Written by Moriya Rufer, RMB Environmental Laboratories, Inc, 218-846-1465, lakes@rmbel.info*

# Appendix II: Phosphorus Export Educational Summary

## 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)
  - 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.

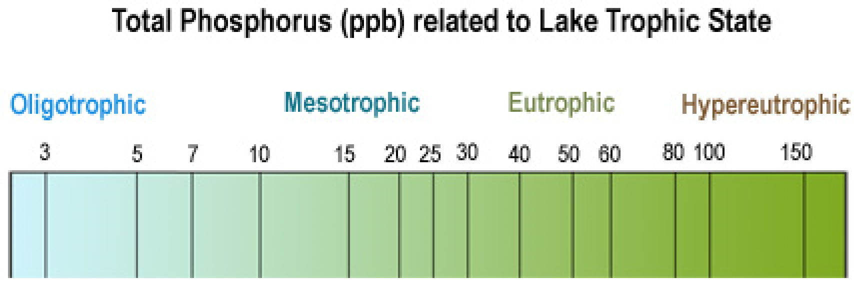



Figure 1. Phosphorus concentration (ppb) related to lake trophic state.

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.

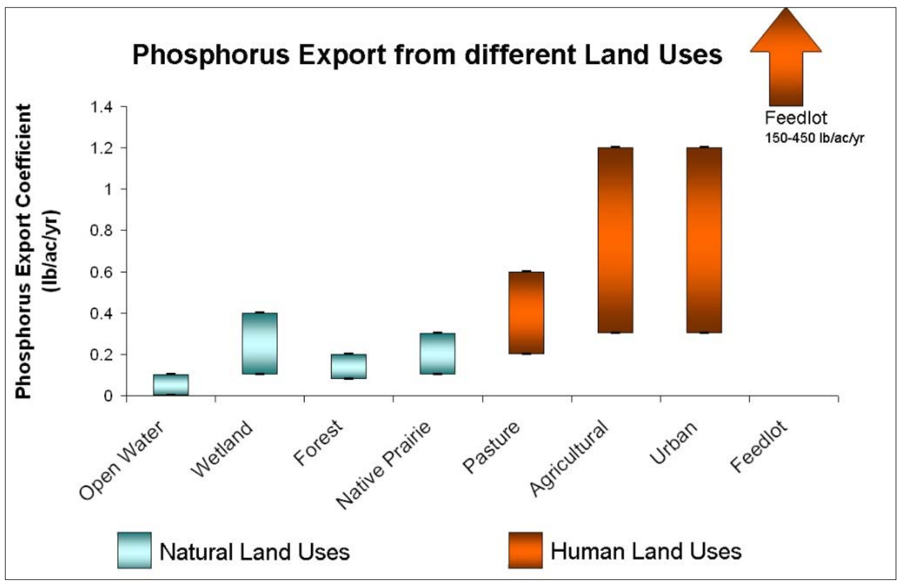



Figure 2. Phosphorus export coefficient for natural vs human land uses.

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).

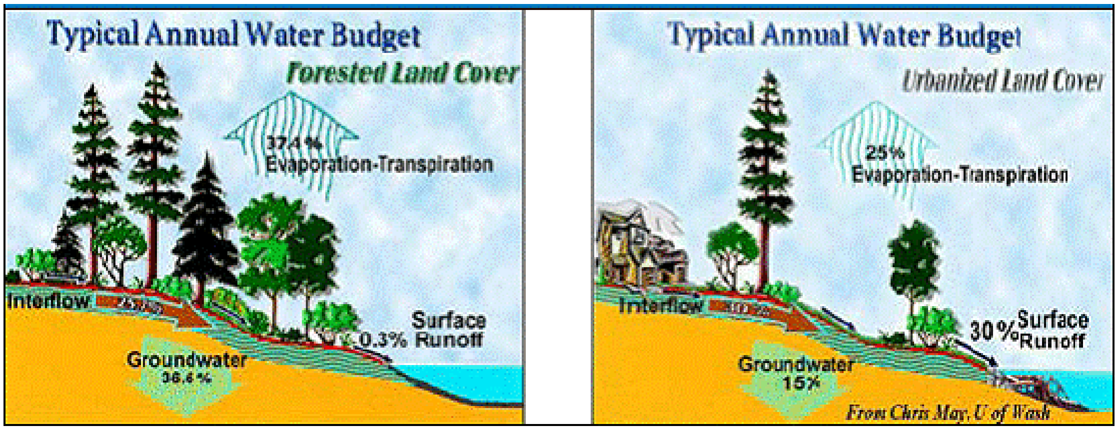
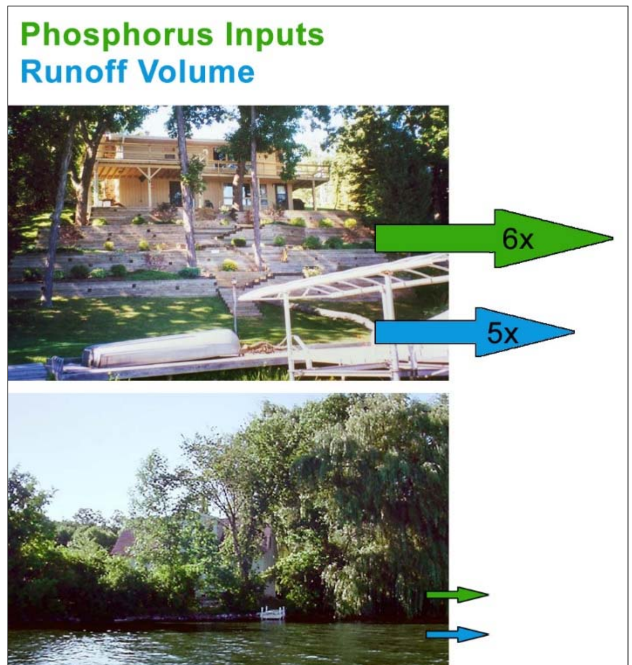



Figure 3. Differences in annual water budget from natural land cover to urbanized land cover (Source: May, University of Washington).

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).




(adapted from Wisconsin DNR, photos from University of Wisconsin Extension)

Figure 4. 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).

## References

Minnesota Pollution Control Agency (MPCA). 2008. Minnesota Stormwater Manual Version 2. January 2008. Minnesota Pollution Control Agency, St. Paul, MN 55155-4194

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

**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.