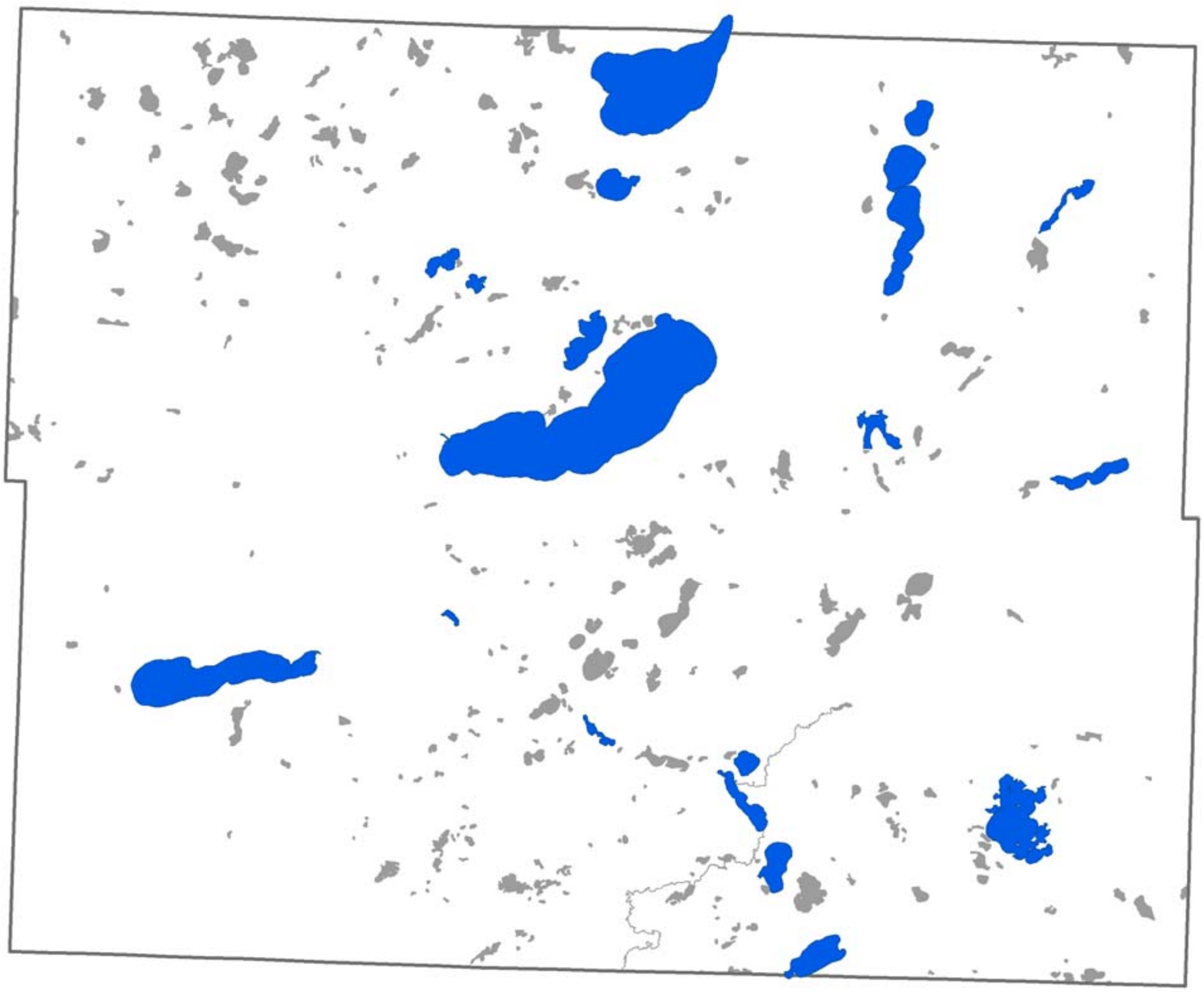
Pope County
Lake Prioritization

2016



POPE SOIL & WATER

CONSERVATION DISTRICT

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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Introduction

Pope County is located in west-central Minnesota and has 65,032 acres of wetlands and 20,593 acres of lakes, which together cover 19% of the county's area. There are three major watersheds in Pope County: Chippewa River, North Fork Crow River.

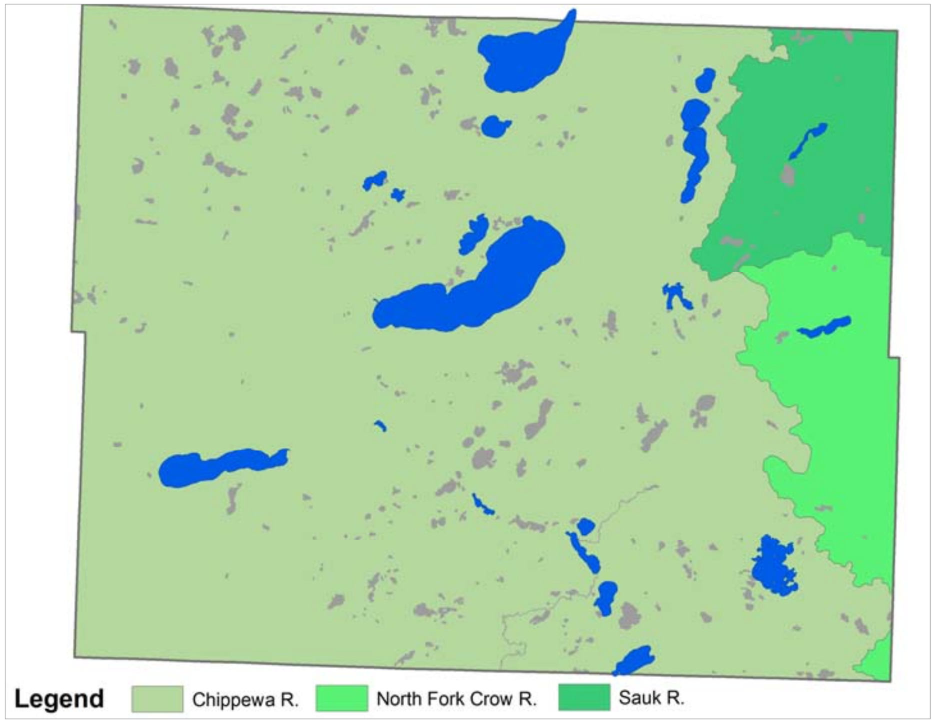


Figure 1. Lakes of Pope County. Lakes evaluated in this report are in dark blue, while each major basin is highlighted in a different color.

In 2016, for the purpose of their water plan update, the Pope Soil and Water Conservation District (SWCD) decided to evaluate the water quality of lakes that have over 10 years of water quality monitoring data in Pope County. Water quality is often related to the trophic state of a lake, where lakes fall on a continuum from clear, which is valued for swimming, fishing, and boating and turbid, which signifies high biological productivity and associated fish yields. There are a total of 20 lakes reported on in this summary (Fig. 1; Table 1).

Pope County lakes have been monitored during periods between 1970 and 2016 by Lake Associations, Minnesota Pollution Control Agency, Minnesota Department of Natural Resources, and the Pope Coalition of Lake Associations (COLA).

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

Table 1. Data availability for Pope County Lakes.

Data Availability

Transparency data		All lakes evaluated in this report had enough data to perform trend analysis except for Simon.
Chemical data (phosphorus and chlorophyll a)		All the lakes in this report had at least 2 years of phosphorus data needed for state assessment. Most of the lakes had enough data to perform trend analysis on phosphorus and chlorophyll a concentration except for Simon, Marlu, Hoff and Ann.
Inlet/Outlet data		Inlet/outlet data exist for many lakes, and could be collected on lakes with declining transparency trends to investigate the cause in water quality decline.

Table 2. Lakes assessed in the 2016 lakes assessment.

	Lake Name	Lake ID	Lake Size (acres)
1	Amelia	61-0064-00-205	938.4
2	Ann	61-0122-00-201	369.8
3	Emily	61-0180-00-201	2,311.1
4	Gilchrist	61-0072-00-201	336.0
5	Grove	61-0023-00-204	344.6
6	Hoff	61-0092-00-201	101.1
7	Johanna	61-0006-00-203	1,399.3
8	Leven	61-0066-00-203	282.0
9	Linka	61-0037-00-202	174.9
10	Malmedahl	61-0162-00-201	198.6
11	Marlu	61-0060-00-202	281.1
12	Minnewaska	61-0130-00-201	8,050.3
13	Pelican	61-0111-00-204	520.7
14	Reno	61-0078-00-201	3,793.7
15	Scandinavian	61-0041-00-203	415.8
16	Signalness	61-0149-00-201	41.1
17	Simon	61-0034-00-201	549.1
18	Strandness	61-0128-00-202	92.1
19	Villard	61-0067-00-204	544.4
20	Westport	61-0029-00-202	203.1

Trophic State Index (TSI)

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

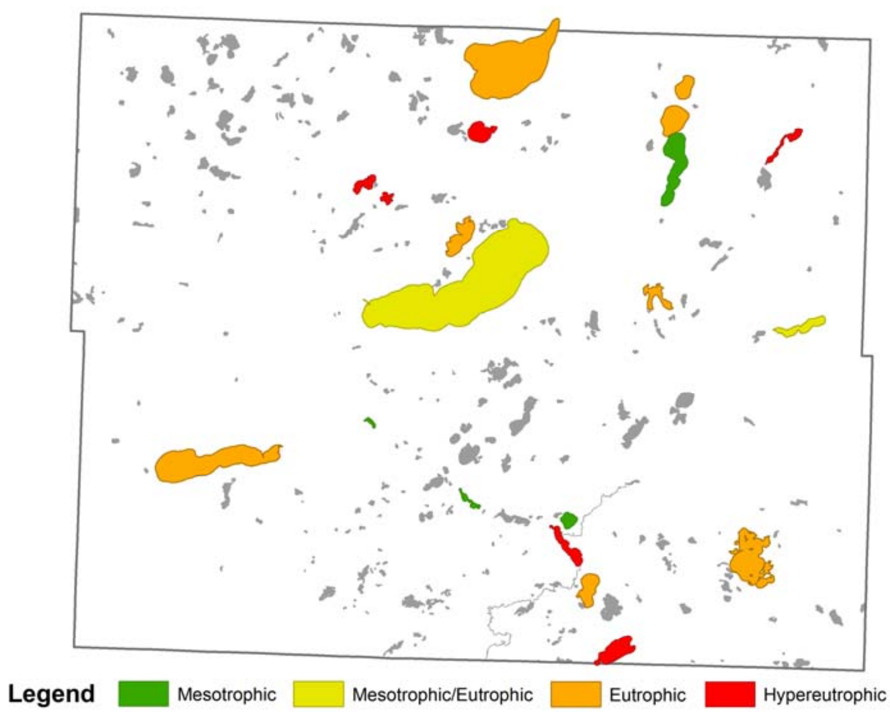


Figure 1. Trophic state of Pope County lakes.

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.

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. Algae, like plants, use carbon dioxide coupled with phosphorus to grow. 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 Secchi depth of approximately 3 inches. For every increase of 10 units in the TSI, the Secchi depth halves and the phosphorus doubles.

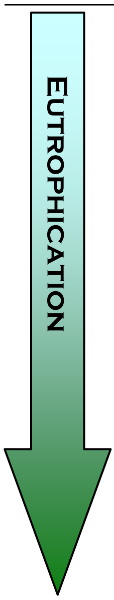
Most of the large Pope County lakes fall into the eutrophic category (Table 3, Figure 2).

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

Lake	**Mean TSI**	**Trophic State**	**Mean TSI Secchi**	**Mean TSI Phosphorus**	**Mean TSI Chlorophyll *a***
Linka	46	Mesotrophic	40	51	46
Hoff	45	Mesotrophic	44	49	47
Signalness	46	Mesotrophic	44	49	46
Amelia	46	Mesotrophic	42	47	50
Scandinavian	49	Mesotrophic	46	51	49
Minnewaska	50	Eutrophic	45	53	52
Reno	54	Eutrophic	47	59	56
Grove	53	Eutrophic	49	55	55
Villard	56	Eutrophic	50	58	58
Marlu	58	Eutrophic	52	59	61
Leven	59	Eutrophic	53	62	61
Pelican	59	Eutrophic	54	61	61
Johanna	60	Eutrophic	52	65	64
Gilchrist	60	Eutrophic	54	64	66

Lake	Mean TSI	Trophic State	Mean TSI Secchi	Mean TSI Phosphorus	Mean TSI Chlorophyll *a*
Westport	64	Eutrophic	59	67	65
Strandness	66	Eutrophic	62	72	65
Emily	68	Eutrophic	70	70	60
Ann	70	Hypereutrophic	53	85	70
Malmedahl	72	Hypereutrophic	70	75	68
Simon	75	Hypereutrophic	77	74	72

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.

There were enough historical data to perform trend analysis for total phosphorus and chlorophyll *a* for all the lakes except for 4 (Table 5). All of the lakes evaluated had sufficient transparency data to perform a statistical trend analysis except Simon (Table 5). It should be a priority for these lakes to monitor transparency in the next few years to enable a trend analysis. The data were analyzed using the Mann Kendall Trend Analysis (Tables 6-8).

Table 5. Pope County Lakes with insufficient data for trend analysis (TP=Total phosphorus, CHLA= Chlorophyll a).

Lake	Parameter	Date Range	Trend
Ann	TP & CHLA	2007, 2010-2011, 2013-2016	Insufficient Data
Hoff	TP & CHLA	2009-2010	Insufficient Data
Marlu	TP & CHLA	2009-2010	Insufficient Data
Simon	TP, CHLA, Secchi	2008-2012	Insufficient Data

Table 6. Pope County Lakes with improving water quality trends (TP=Total phosphorus, CHLA= Chlorophyll a).

Lake	Parameter	Date Range	Trend	Probability
Johanna	Transparency	2007-2016	Improving	95%
Johanna	TP & CHLA	2007-2016	No Trend	-
Leven	TP	1994-2016	Improving	95%
Leven	Transparency & CHLA	1992-2016	No Trend	-
Malmedahl	Transparency	1994-2016	Improving	99.9%
Malmedahl	CHLA	1996-2002, 2004-2011, 2013-2016	Improving	95%
Malmedahl	TP	1996-2016	No Trend	-
Reno	TP	1996-2016	Improving	95%
Reno	Transparency, CHLA	1996-2016	No Trend	-
Strandness	Transparency	1995-2016	Improving	90%
Strandness	TP, CHLA	1997-2016	No Trend	-
Westport	Transparency	2007-2016	Improving	95%
Westport	TP & CHLA	2007-2016	No Trend	-

Table 7. Pope County Lakes with declining water quality trends. For transparency, a declining trend means that the clarity is decreasing (TP=Total phosphorus, CHLA= Chlorophyll a).

Lake	Parameter	Date Range	Trend	Probability
Ann	Transparency	1992-2016	Declining	90%
Hoff	Transparency	2000-2007, 2009-2011, 2013	Declining	99%
Villard	Transparency	1993-2016	Declining	99.9%
Villard	CHLA	1996-2002, 2004-2011, 2013-2016	Declining	95%
Villard	TP	1994-2016	No Trend	-

Table 8. Pope County Lakes with no evidence of water quality trends (TP=Total phosphorus, CHLA= Chlorophyll a).

Lake	Parameter	Date Range	Trend
Amelia	Transparency, TP, CHLA	1996-2016	No Trend
Emily	Transparency, TP, CHLA	1996-2016	No Trend
Gilchrist	Transparency, TP, CHLA	1996-2016	No Trend
Grove	Transparency, TP, CHLA	1994-2016	No Trend
Linka	Transparency, TP, CHLA	1994-2016	No Trend
Marlu	Transparency	1992-2015	No Trend
Minnewaska*	Transparency	1996-2016	No Trend
Pelican	Transparency, TP, CHLA	1994-2016	No Trend
Scandinavian	Transparency, TP, CHLA	1996-2016	No Trend
Signalness	Transparency, TP, CHLA	2000-2016	No Trend

**Lake Minnewaska is unclear in its trends and has changed in the past couple years. See page 14 for more explanation.*

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.

Most of Pope County, and all of its large lakes, is in the Central Hardwood Forest (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.

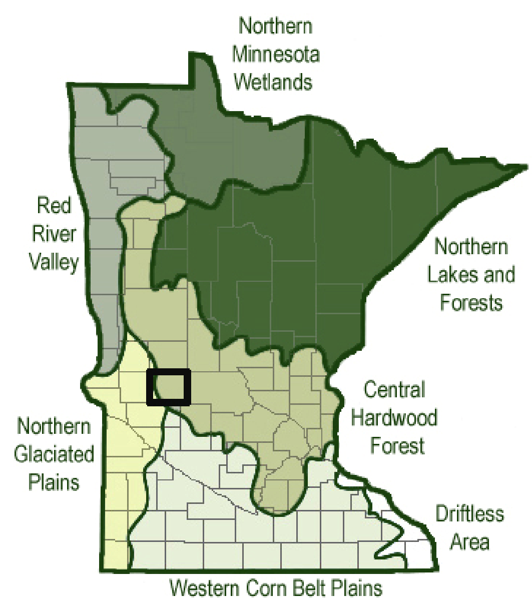


Figure 3. Minnesota Ecoregions. Pope County is indicated in black.

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. Amelia, Hoff and Linka are better than the expected ecoregion ranges. Ann, Gilchrist, Malmedahl, Simon, Strandness and Westport lakes are poorer than the ecoregion range. Most of these lakes are shallow, which means they don't compare to the ecoregion ranges as well.

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 8 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.

T he 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. The Pope County COLA has been implementing a condition monitoring program with volunteer monitors for the past 20 years (1996-2016). This data has enabled lake assessments in the county and implementation projects to improve water quality.

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.

Many of the Pope 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.
% 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 lakes in Table 9 are currently listed as impaired for eutrophication as of the 2016 Draft Impaired Waters List (Figure 4). Total Maximum Daily Load (TMDL) Studies are currently being completed for many of these lakes.

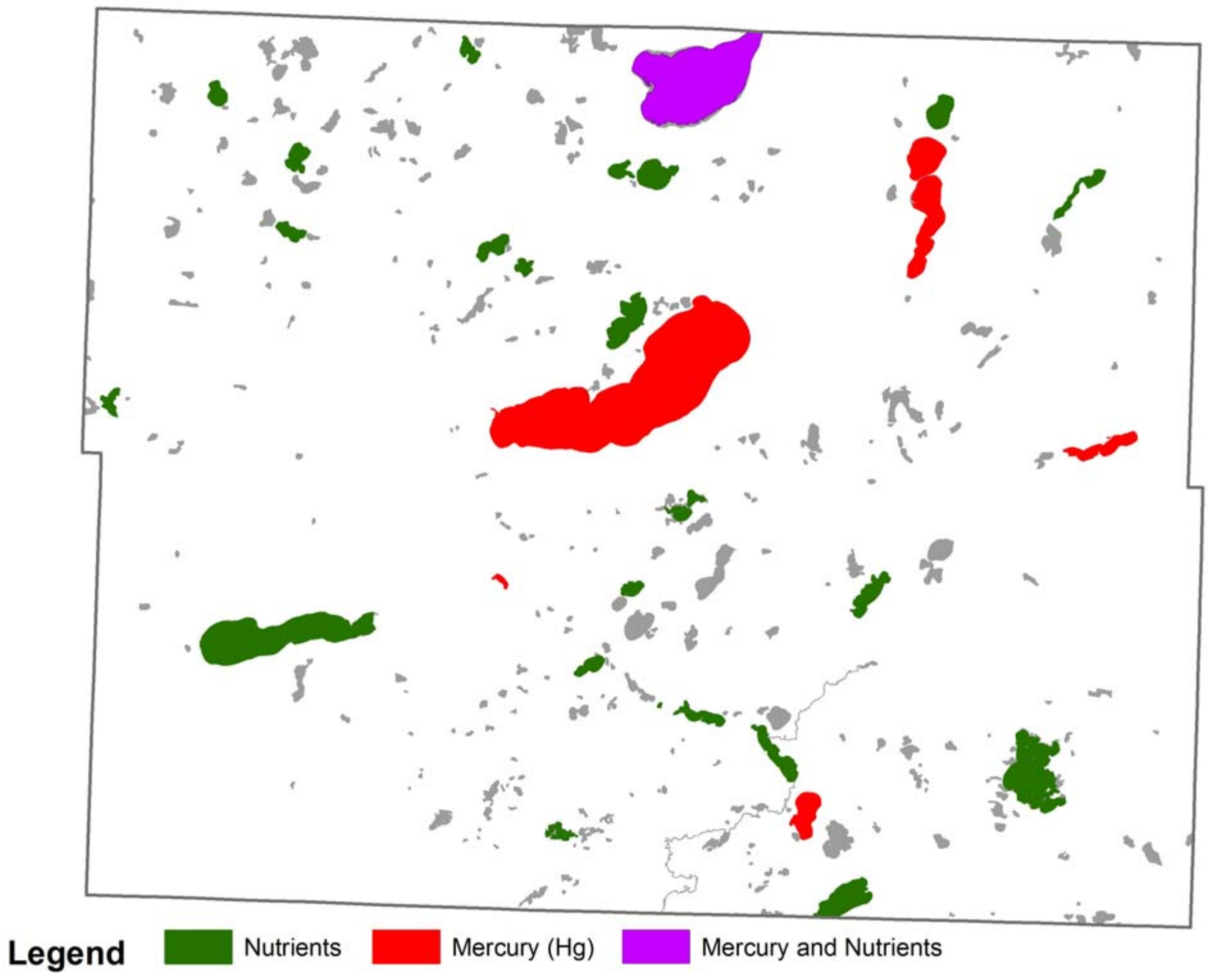


Figure 2. Pope County lakes illustrating impaired waters status.

Table 9. Lakes in Pope County that are impaired for excess nutrients and eutrophication, 2016 MPCA Draft Impaired Waters List.

DOW	Lake	Year added to List	TMDL Target start	TMDL Target completion
61-0122-00	Ann	2006	2008	2016
61-0194-00	Danielson Slough	2012	2009	2016
61-0106-00	Edwards	2012	2009	2016
61-0180-00	Emily	2002	2008	2016
61-0072-00	Gilchrist	2002	2008	2016
61-0080-00	Hanson	2012	2009	2016
61-0211-00	Irgens	2012	2009	2016
61-0006-00	Johanna	2010	2009	2016
61-0123-00	John	2012	2009	2016
61-0164-00	Jorgenson	2012	2009	2016
61-0066-00	Leven	2002	2008	2016
61-0162-00	Malmedal	2002	2008	2016
61-0099-00	Mary	2012	2009	2016

Table continued to next page

Table 9 continued. Lakes in Pope County that are impaired for excess nutrients and eutrophication, 2016 MPCA Draft Impaired Waters List.

DOW	Lake	Year added to List	TMDL Target start	TMDL Target completion
61-0199-00	McIver	2012	2009	2016
61-0111-00	Pelican	2002	2008	2016
61-0086-00	Rasmuson	2012	2009	2016
61-0078-00	Reno	2002	2008	2016
61-0034-00	Simon	2012	2009	2016
61-0095-00	Steenerson	2012	2019	2024
61-0128-00	Strandness	2006	2008	2016
61-0051-00	Swenoda	2012	2009	2016
61-0204-00	Wicklund	2012	2009	2016
61-0029-00	Westport	2010	2013	2018

The following reports show the draft results from the TMDL studies conducted on these lakes.

Chippewa River WRAPS page:
https://www.pca.state.mn.us/water/watersheds/chippewa-river

Pope County 8 Lakes TMDL page:
https://www.pca.state.mn.us/water/tmdl/pope-county-8-lakes-excess-nutrients-total-phosphorus-tmdl-project

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 2016, Pope County has numerous infestations (Figure 6, Table 10). The most difficult infestation to deal with is zebra mussels, since there is currently no method of controlling them.

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 Pope 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.

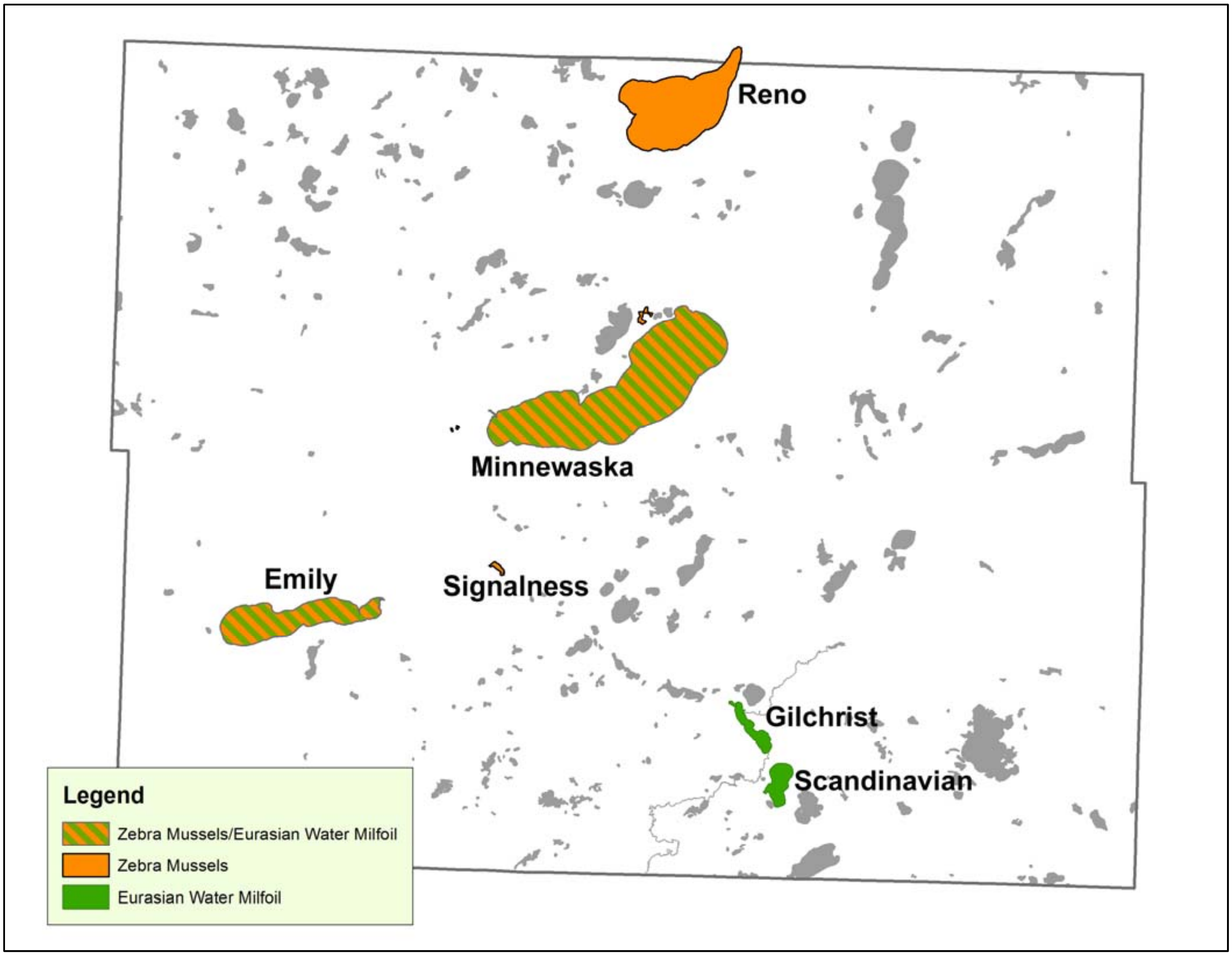


Figure 6. Pope County lakes with invasive species.

Table 10. Lakes infested with aquatic invasive species in Pope County (MN DNR, 11-10-2016).

Water body name	DOW number	Aquatic invasive species	Year listed as infested
Emily	61-0180	Eurasian watermilfoil	2014
Gilchrist	61-0072	Eurasian watermilfoil	1997
Minnewaska	61-0130	Eurasian watermilfoil	1998
Scandinavian	61-0041	Eurasian watermilfoil	2014
Emily	61-0180	zebra mussel	2012
Minnewaska	61-0130	zebra mussel	2012
Reno	61-0078	zebra mussel	2014
Shallow Pond	61-0112	zebra mussel	2012
Signalness	61-0149	zebra mussel	2016

Lake Prioritization

Prioritization Methods
The lakes were first considered in one large matrix. Trend information, phosphorus sensitivity and phosphorus targets were included in the matrix (2015 Radomski). Then the lakes were sorted by trend. Three categories were formed by comparing water quality trends with the phosphorus concentrations and targets. The categories include: 1) first priority lakes to watch, 2) second priority lakes to watch, and 3) Impaired Waters. For details see Tables 11-13.

First Priority Lakes to Watch
This category is defined as lakes with declining water quality trends and/or lakes with phosphorus concentrations higher than the target TP. Hoff and Villard Lakes were ranked in the “Highest” category for phosphorus sensitivity in Minnesota Lakes (Radomski 2015). This sensitivity means that additional phosphorus to the lakes would likely result in declines in water transparency.

Hoff Lake is showing evidence of a declining trend in transparency from 2000-2007, 2009-2011, 2013. Phosphorus and chlorophyll a were only monitored in 2009-2010 in this lake, so trend analysis was not possible for those two parameters. It should be a priority to monitor phosphorus and chlorophyll a on Hoff Lake in the next few years to get a better understanding of the lake’s water quality. Villard Lake is showing evidence of a declining trend in transparency and chlorophyll a. This means the algae concentration is increasing in the lake. The phosphorus concentration in the lake is over the target TP as well.

Lake Minnewaska is one of the most important lakes, economically, in Pope County. It is heavily developed and has three towns on its shoreline. Data are showing some changes in the lake’s condition. There is evidence of a declining transparency trend from 1996-2013, but no trend from 1996-2016 (Figure 11). Zebra mussels were discovered in Lake Minnewaska in 2012. Usually they take about two years to start impacting water clarity, so it could be that the zebra mussels have improved water transparency in Lake Minnewaska in 2015-2016. The chlorophylla has also decreased (improved) in 2015-2016, which could be due to zebra mussels. It will be more difficult in the future to separate phosphorus loading effects with zebra mussel effects on transparency and chlorophyll a concentrations, as the chlorophyll a and transparency may not follow phosphorus concentrations closely. Monitoring should continue so that these trends can be tracked in future years.

Table 11. First priority lakes to watch in Pope County.

Lake	ID	Trend	Mean TSI	TP Sensitivity	Target TP	Historical TP	2016 TP	Prioritization Comments
Hoff	61-0092-00	Declining – Secchi	45 - Mesotrophic	Highest	21.9	22.7	NA	Declining Trend, but not impaired
Villard	61-0067-00	Declining – Secchi & CHLA	56 - Eutrophic	Highest	35.6	43.2	39.6	Declining Trend, but not impaired
Minnewaska	61-0130-00	Unclear	50 - Eutrophic	Highest	24.3	28.8	19.4	Watch - zebra mussels

Table 11 Definitions
TP Sensitivity: 2015 Paul Radomski modeling of phosphorus sensitivity significance in Minnesota Lakes. Lakes in the "Highest" category ranked in the top 200 priority lakes in the state for phosphorus sensitivity.
Target TP: Target phosphorus concentration for the lake as set by the 2015 Paul Radomski modeling of phosphorus sensitivity significance in Minnesota Lakes.
Historical TP = Historical mean phosphorus from 1996-2016 through the Pope COLA monitoring program.
2016 TP = 2016 mean phosphorus through the Pope COLA monitoring program.

Second Priority Lakes to Watch

The lakes in Table 12 are listed as lower concern because they are stable or improving and are near their phosphorus target concentration. Amelia, Linka, Scandinavian, Signalness and Grove Lakes have no trend in transparency, phosphorus or chlorophyll a and are near their phosphorus target concentration (Table 12). Marlu Lake has no transparency trend, but only has phosphorus and chlorophyll a data from 2009-2010. Marlu Lake was not included in the 2015 Radomski study, so there is no target phosphorus included in Table 12.

Signalness Lake is showing no evidence of trends in transparency, phosphorus or chlorophyll a, but the phosphorus is variable year to year, and over the target TP. Signalness is a very small, shallow lake, which could contribute to its variable phosphorus concentrations. This lake should be watched and potential phosphorus sources to the lake reduced.

Table 12. Lakes listed as lower concern in Pope County due to no trends and phosphorus concentrations near their target.

Lake	ID	Trend	Mean TSI	TP Sensitivity	Target TP	Historical TP	2016 TP
Amelia	61-0064-00	No Trend	46 - Mesotrophic	Highest	17.6	20.0	16.8
Linka	61-0037-00	No Trend	46 - Mesotrophic	Highest	23.0	26.0	21.8
Signalness	61-0149-00	No Trend	46 - Mesotrophic	Higher	18.5	22.5	31.8
Scandinavian	61-0041-00	No Trend	49 - Mesotrophic	Highest	20.6	25.1	21.6
Grove	61-0023-00	No Trend	53 - Eutrophic	Highest	29.5	34.8	30.4
Marlu	61-0060-00	No Trend	58 - Eutrophic	NA	NA	45.2	NA

Table 12 Definitions
TP Sensitivity: 2015 Paul Radomski modeling of phosphorus sensitivity significance in Minnesota Lakes. Lakes in the "Highest" category ranked in the top 200 priority lakes in the state for phosphorus sensitivity.
Target TP: Target phosphorus concentration for the lake as set by the 2015 Paul Radomski modeling of phosphorus sensitivity significance in Minnesota Lakes.
Historical TP = Historical mean phosphorus from 1996-2016 through the Pope COLA monitoring program.
2016 TP = 2016 mean phosphorus through the Pope COLA monitoring program.

Impairments

The Lakes in Table 13 are listed as impaired for excess nutrients on the 2016 Draft MPCA Impaired Waters List. Total Maximum Daily Load (TMDL) studies have been carried out in the past couple years for many of these lakes, and are currently in draft form (see links below). The TMDL sets a goal for reduction in phosphorus needed for the lake to meet the state standard (Target TP).

Reno and Levin have a strong indication of an improving trend in total phosphorus, which indicates progress towards their phosphorus reduction target. Mahlmedahl Lake is showing strong indication in improvement in transparency and chlorophyll a, and weak indication of an improvement in phosphorus, which is also indicating progress toward its reduction target. Johanna, Westport, and Strandness lakes are showing an improving trend in transparency (Secchi), but no trend in phosphorus concentration. Pelican, Gilchrist and Emily lakes are showing no trends in transparency, phosphorus or chlorophyll a.

Ann Lake is showing a declining trend in transparency, and it requires a 90% reduction in phosphorus to achieve the state standard (target phosphorus concentration). Simon Lake does not have enough data to evaluate trends.

Table 13. Lakes with impairments in Pope County.

Lake	ID	Trend	Mean TSI	Trophic State	Target TP	Historical TP	2016 TP	% Target Reduction
Malmedahl	61-0162-00	Improving - all 3	72	Hypereutrophic	60.0	146.7	88.1	72%
Reno	61-0078-00	Improving - TP	54	Eutrophic	40.0	44.4	33.6	36%
Leven	61-0066-00	Improving - TP	59	Eutrophic	40.0	53.7	42.8	35%
Johanna	61-0006-00	Improving - Secchi	60	Eutrophic	60.0	69.0	78.5	NA
Westport	61-0029-00	Improving - Secchi	64	Eutrophic	60.0	78.0	82.4	NA
Strandness	61-0128-00	Improving - Secchi	66	Eutrophic	60.0	107.0	53.0	54%
Pelican	61-0111-00	No Trends	59	Eutrophic	40.0	53.3	43.4	35%
Gilchrist	61-0072-00	No Trends	60	Eutrophic	40.0	62.9	59.6	48%
Emily	61-0180-00	No Trends	68	Eutrophic	90.0	102.2	91.0*	35%
Ann	61-0122-00	Declining - Secchi	70	Hypereutrophic	60.0	274.6	429.0	90%
Simon	61-0034-00	Insufficient Data	75	Hypereutrophic	60.0	125.0	NA	NA

*2015 mean. There were only two data points collected in 2016.

Table 13 Definitions

Target TP = State standard for phosphorus that applies to that lake (https://www.pca.state.mn.us/water/water-quality-standards#resources-7ee2a711)
Historical TP = Historical mean phosphorus from 1996-2016 through the Pope COLA monitoring program
2016 TP = 2016 mean phosphorus
% Target Reduction = the percent phosphorus reduction needed to meet the state standard, which was calculated in the TMDL (see report links below).

Chippewa River WRAPS: https://www.pca.state.mn.us/water/watersheds/chippewa-river
Pope County 8 Lakes TMDL: https://www.pca.state.mn.us/water/tmdl/pope-county-8-lakes-excess-nutrients-total-phosphorus-tmdl-project

Summary and Recommendations

Overall Conclusions

The large Pope County lakes have been monitored by Pope County Coalition of Lake Association (COLA) volunteers for 20 years (1996-2016). The dedication to data collection by this program is so valuable, as it has provided the data necessary for statewide assessments, TMDLs, and trend analysis. The volunteers should be commended for the quality of data available for this report.

All of the lakes evaluated had enough transparency data to perform a trend analysis, except for Simon (Table 5). In addition, most of the lakes had enough data to perform trend analysis on phosphorus and chlorophyll a concentration except for Simon, Marlu, Hoff and Ann. Overall, six lakes had improving water quality trends, three lakes had declining trends, and nine lakes had no detectable trends (Tables 6-8).

Twenty-three lakes in Pope County are currently listed as impaired for eutrophication as of the 2016 Draft Impaired Waters List (Table 10). A Total Maximum Daily Load (TMDL) study is being conducted on these lakes to determine how to reduce phosphorus levels. The TMDL schedule can be found in Table 10. Draft TMDL reports for some of the lakes can be found at the MPCA's website:
Chippewa River WRAPS: https://www.pca.state.mn.us/water/watersheds/chippewa-river
Pope County 8 Lakes TMDL: https://www.pca.state.mn.us/water/tmdl/pope-county-8-lakes-excess-nutrients-total-phosphorus-tmdl-project.

Sources of phosphorus to Pope County lakes include point sources such as feedlots and wastewater treatment facilities, stormwater runoff, loading from upstream waters, subsurface sewage treatment systems (SSTS), internal loading and in-stream erosion. Point sources such as permitted feedlots and wastewater treatment plants can be reduced through the permitting process. Non-point sources can be reduced through reducing stormwater runoff from the land. Project ideas include shoreline restoration, rain gardens, septic system maintenance, wetland restoration, holding ponds, and enforcing county shoreline ordinances.

Specific Conclusions

The goal of this report was to create a prioritization list of lakes so that the county water plan can address which lakes are highest priority for implementation projects. The details of this prioritization are in Tables 11-13.

Lakes considered first priority watch lakes include Hoff, Villard, and Minnewaska (Table 11). Hoff and Villard Lakes are showing declining trends in water quality.

Lake Minnewaska is one of the most important lakes, economically, in Pope County. It is heavily developed and has three towns on its shoreline. Data are showing some changes in the lake's condition. There is evidence of a declining transparency trend from 1996-2013, but no trend from 1996-2016 (Figure 11). Zebra mussels were discovered in Lake Minnewaska in 2012. Usually they take about two years to start impacting water clarity, so it could be that the zebra mussels have improved water transparency in Lake Minnewaska in 2015-2016. The chlorophylla has also decreased (improved) in 2015-2016, which could be due to zebra mussels (Figure 12). It will be more difficult in the future to separate phosphorus loading effects with zebra mussel effects on transparency and chlorophyll a concentrations, as the chlorophyll a and transparency may not follow phosphorus concentrations closely. Monitoring should continue so that these trends can be tracked in future years.

Lakes considered second priority watch lakes are Amelia, Linka, Scandinavian, Signalness, Grove, and Marlu. These lakes have no detectable trends and are close to their target phosphorus concentration as determined in the 2015 Radomski study of phosphorus sensitivity in lakes (Table

12). Signalness lake has variable phosphorus year-to-year, which makes it difficult to determine the historical mean phosphorus levels. It is a very small shallow lake, which is likely why the phosphorus levels are so variable.

Impaired lakes include Malmedahl, Reno, Levin, Johanna, Westport, Strandness, Pelican, Gilchrist, Emily, Ann and Simon (Table 13). These lakes are being addressed in TMDL studies. Of these impaired lakes, Malmedahl, Reno, Leven, Johanna, Westport and Strandness are showing improving trends, which show they are making progress toward their phosphorus target. Pelican, Gilchrist and Emily have no detectable trends. Ann Lake has a declining trend in transparency and the TMDL shows a 90% phosphorus reduction is necessary to meet the phosphorus standard.

Monitoring Recommendations

Lake monitoring is most effective when done at one primary site in the lake over many consecutive years. The Pope COLA monitoring program was set up by Pope COLA and RMB Environmental Laboratories and has collected data now for 20 years. This program should continue as it provides data for tracking future water quality trends.

Hoff and Villard Lakes are showing a declining trend in transparency and were classified in the “highest” category for phosphorus sensitivity (Table 11). Phosphorus data only exists for Hoff Lake from 2009-2010. Hoff Lake should be monitored for phosphorus again and Villard should continue monitoring to help determine the cause of the declining transparency trends.

Lakes that have declining trends and nuisance algae blooms should be monitored for internal loading and inlet loading. To confirm if internal loading is occurring, hypolimnion water samples (water samples taken 1 foot above the lake’s bottom) and corresponding dissolved oxygen profiles could be monitored for a summer or two. 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 loading are identified in Tables 11-13.

Signalness Lake’s phosphorus concentrations are variable year-to-year; monitoring should continue to track any future trends in the lake.

Lake Minnewaska has unclear trends, which could be affected by zebra mussels. Monitoring should continue so that these trends can be tracked in future years.

Shallow Lakes

Around half of the lakes evaluated in this report are considered 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 include Emily, Strandness, Johanna, Malmedahl, Westport, Signalness, Ann, Villard,and Reno.

Stormwater Management.
Stormwater management is an issue anywhere there is concentrated development, such as Lake Minnewaska. 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 Minnewaska, 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.

Project Implementation
The best management practices above can be implemented by a variety of entities. Some possibilities are listed below.

Individual property owners
- Shoreline restoration
- Rain gardens
- Aquatic plant bed protection (only remove a small area for swimming)
- Forest Stewardship Planning
- Conservation Easements

Lake Associations
- Lake condition monitoring
- Ground truthing – visual inspection upstream on stream inlets
- Shoreline inventory study by a consultant
- Forest Stewardship Planning
- Conservation Easements

Soil and Water Conservation District (SWCD) and Natural Resources Conservation Service (NRCS)
- Shoreline restoration
- Stream buffers
- Forest Stewardship Planning
- Conservation Easements

Grant 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

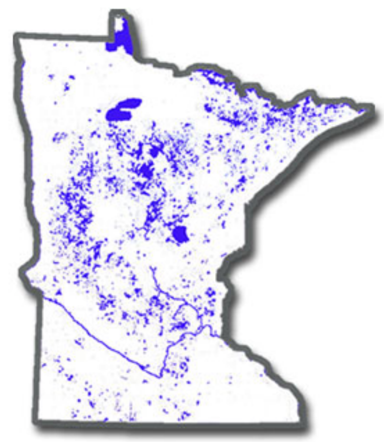
DNR Shoreline Habitat Restoration Grants: Shoreland and Aquatic Habitat Block Grants are designed to provide cost share funding to counties, cities, watershed districts, other local units of government, conservation groups, and lake associations. It allows participants to conduct shoreline and watershed 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

References

Radomski, Paul. 2015. Lakes of Phosphorus Sensitivity Significance. Department of Natural Resources.

Appendix I: Limnology Educational Summary

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.

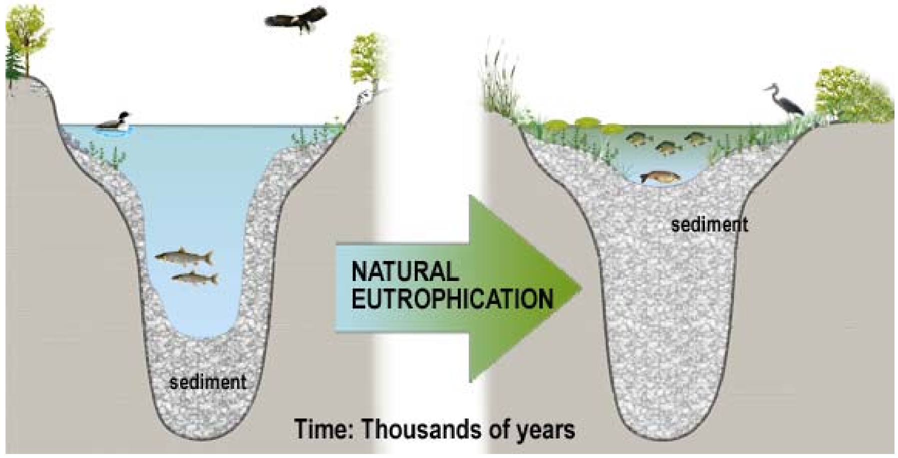
Shallow lakes are lakes where the sunlight can reach the entire bottom. Generally, this corresponds to about 15 feet deep or less. Since the sunlight can reach the bottom, aquatic plants are able to grow there. In deep lakes, the bottom does not receive sunlight, so no plants grow there and it stays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

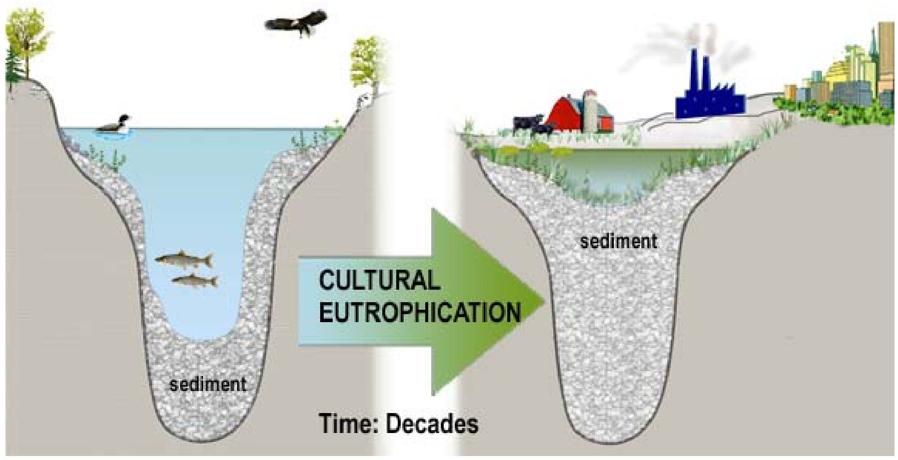
If a lake has a very small watershed or is at the top of a watershed (in topography terms), the lake usually has better water clarity than a lake at the bottom of a large watershed. As water flows downhill through a watershed it picks up sediment from erosion and nutrients from runoff. This sediment 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.

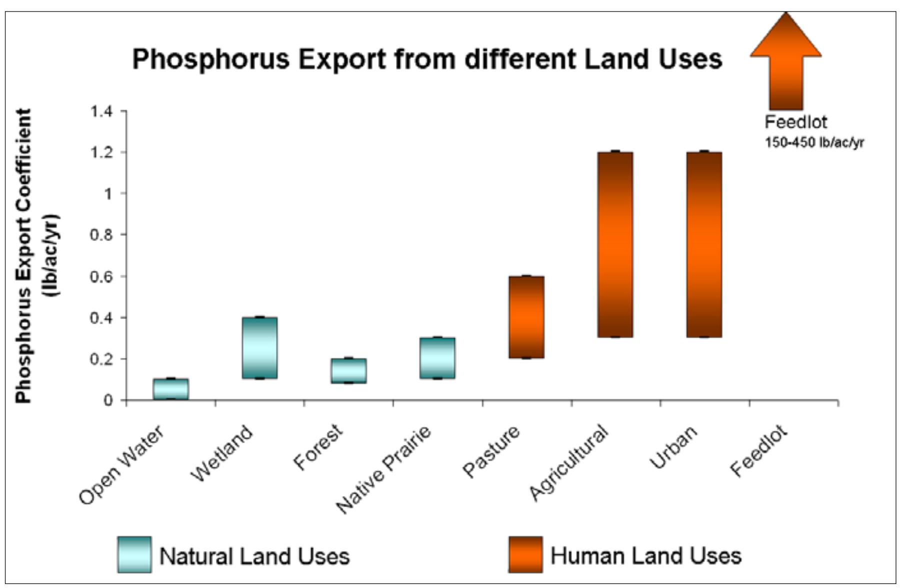
Humans can speed up the process of eutrophication by adding excess nutrients and sediment quickly, where the lake will change trophic states in a matter of decades instead of centuries. This type of eutrophication is called cultural eutrophication because humans cause it. We have changed the landscape 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.

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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.

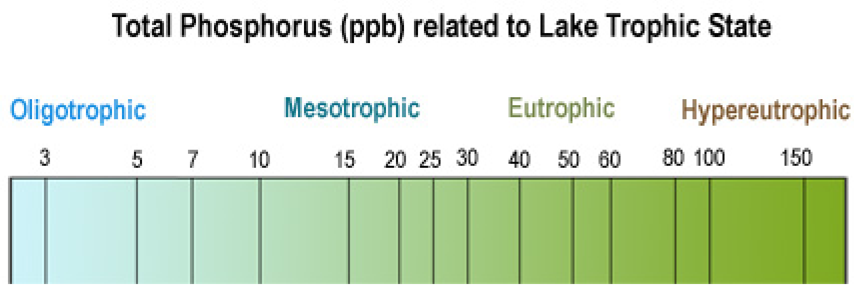


Figure 1. Phosphorus concentration (ppb) related to lake trophic state.

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.

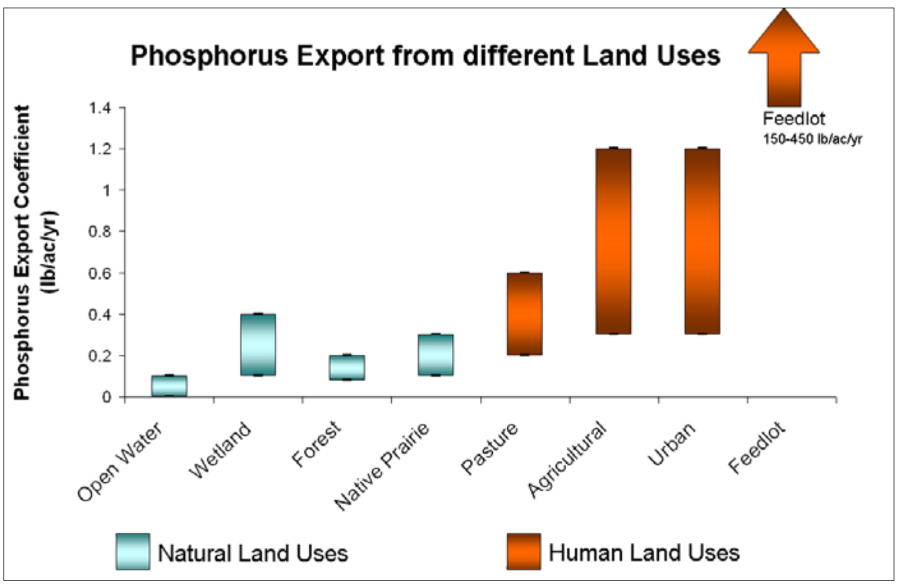


Figure 2. Phosphorus export coefficient for natural vs human land uses.

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).

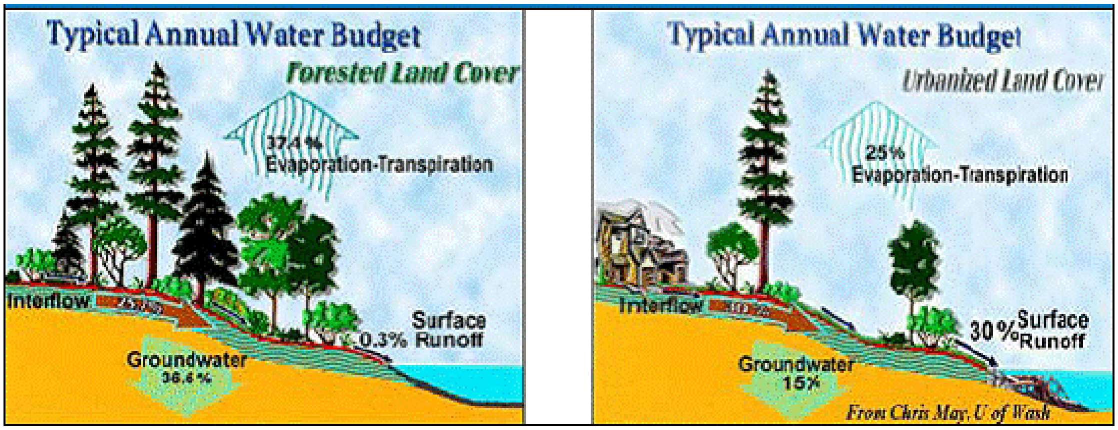
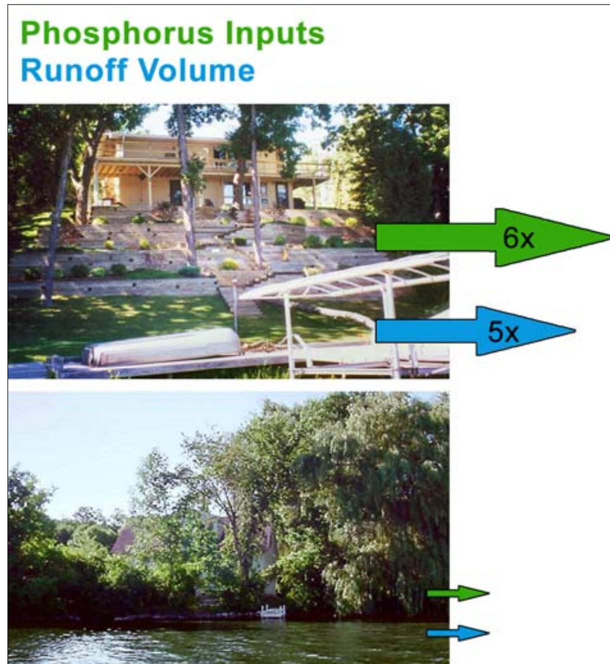


Figure 3. Differences in annual water budget from natural land cover to urbanized land cover (Source: May, University of Washington).

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 3: 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.