The overall flow-weighted mean stream TP concentration is 63 ug/L. This concentration is only slightly higher than the interquartile range (20-50 ug/L) for minimally-impacted streams in the Northern Lakes and Forests Ecoregion. Those subwatersheds with high percentages of forest, wetlands, and lakes (e.g., Garrison Creek, Seguchie Creek, and Whitefish Creek) exhibit low concentrations (20-30 ug/L). In contrast, those subwatersheds with higher percentages of cultivated or urban land uses or feedlots (e.g. Marmon Creek, Seventeen Creek, and Groundhouse River) exhibit higher concentrations (100-300 ug/L).

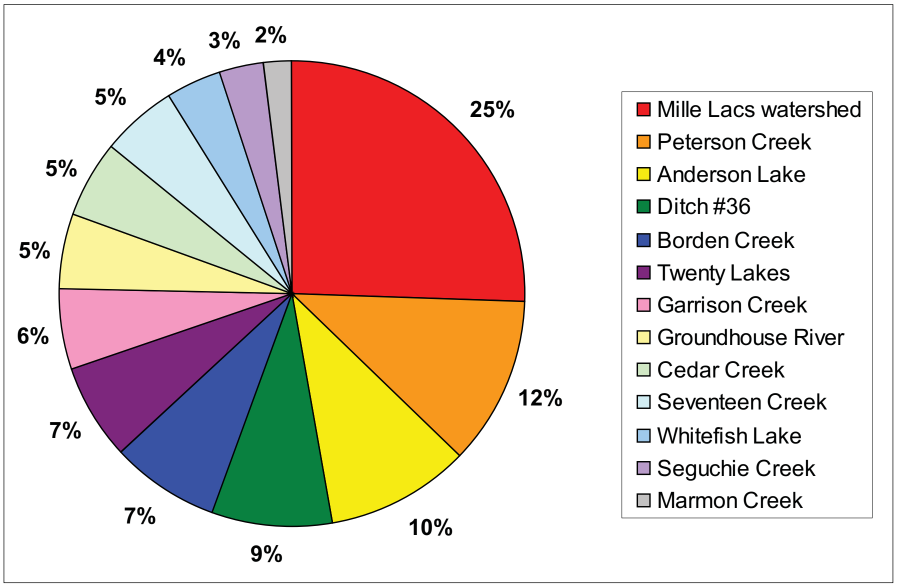


Figure 16. Mille Lacs Lake Watershed phosphorus loading.
Source: Lake Mille Lacs 1992 Clean Lakes Study (314a) Water Quality Report, MPCA.

Phosphorus loading from the subwatershed is a function of not only TP concentration but also discharge. The estimated P loading rate from the watershed is approximately 4,880 kg P/year. The Mille Lacs shoreline contributes about 25% of that loading. Other significant contributors are Peterson Creek (11%), Anderson Lake (10%), and Ditch 36 (9%). The other 9 subwatersheds contribute 45% of the P loading (Figure 16).

2007-2008 Clean Water Legacy Study

In 2007, the Mille Lacs Lake Watershed Management Group was awarded a Clean Water Legacy – Surface Water Assessment Grant from the Minnesota Pollution Control Agency. This grant covered monitoring the water quality of Lake Mille Lacs and its tributaries, during the summer of 2007 and 2008. Data was collected with the purpose to clear up conflicting information collected in the past – and to see if the quality of Mille Lacs Lake is improving, declining, or remaining the same.

Twelve tributaries around Mille Lacs Lake and the Rum River outlet were selected for monitoring. Tributaries monitored include: Peterson, Seventeen, Ditch 36, Borden, Cedar, Thaines, Seastade, Marmon (Reddie), Garrison, and Seguchie Creeks. Chemical samples were collected by the Aitkin County SWCD and analyzed for *E. coli*, total phosphorus, total suspended solids, total nitrogen, and chloride. These data are in the process of being analyzed by an outside contractor. The final report is expected to be completed in April, 2009. The report will be available through the Aitkin SWCD office.

In addition, this 2007-2008 data set will be used in the 2010 - 303 (d) State Assessment rotation.

Assessment/Findings Recommendations

Transparency

Transparency data is extremely sparse and disjointed for Lake Mille Lacs. Monitoring at sites 205, 206, 209, 211, 213 and 220 should be continued each year. It is important to continue transparency monitoring weekly or at least bimonthly every year to enable year to year comparisons and trend analyses.

Since Lake Mille Lacs is so large, it is not feasible for one person to do all the transparency monitoring. A water quality task force could be formed, where each site has their own volunteer assigned to do weekly or bimonthly secchi disk readings. That way, at the end of each year all the data would go to the MPCA and comparisons can be made between sites and years of collection.

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. Lake Mille Lacs was listed as impaired for aquatic consumption on the 2006 Impaired Waters List; however it is part of the statewide mercury TMDL and therefore was not on the 2008 Impaired Waters List.

As of 2008, the Lake Mille Lacs data set is insufficient for Impaired Waters Assessment for eutrophication. A data set of 10 data points each of total phosphorus, chlorophyll *a*, and secchi depth over a two-year period in the past 10 years is required for eutrophication assessment. Scheduling two years of chemical data collection would complete this assessment data set (see standards on page 3).

In addition, there are currently no impaired streams inletting to Lake Mille Lacs; however, most of the stream inlets have not been assessed for impaired conditions. For further information regarding the Impaired Waters Assessment program, refer to http://www.pca.state.mn.us/water/tmdl/index.html

Aquatic Recreational Use Assessment 305(b)

In the 2008 MPCA Aquatic Use Assessment (305(b)), Lake Mille Lacs did not have enough data to be included this assessment.

Inlet/Outlet Assessment

Inlet/outlet monitoring was completed in 1992. This monitoring was then updated in 2007-2008. Since tributaries contributions to the lake can change throughout the years, it is important to periodically re-check these sites to determine if any changes in loading have occurred.

Organizational contacts and reference sites

Lake Mille Lacs Watershed Group	http://www.millelacswatershed.org
Aitkin Soil and Water Conservation District	130 Southgate Drive, Aitkin, MN 56431 (218) 927-6565, http://www.aitkincountyswcd.org/
DNR Fisheries Office	1200 Minnesota Avenue South, Aitkin, MN 56431 (218) 927-3751, http://www.dnr.state.mn.us/lakefind/index.html
Regional Minnesota Pollution Control Agency Office	7678 College Road, Suite 105, Baxter, MN 56425 (218) 828-2492, http://www.pca.state.mn.us
Regional Board of Soil and Water Resources Office	1601 Minnesota Drive, Brainerd, MN 56401 (218) 828-2383, http://www.bwsr.state.mn.us

Mille Lacs Lake Lakeshed Assessment

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

Lakeshed Vitals		Rating
Major Basin	Upper Mississippi River	descriptive
Major Watershed	Rum River	descriptive
Minor Watershed	21002	descriptive
Lakeshed	Mille Lacs Lake (2100200)	descriptive
Ecoregion	Northern Lakes and Forests	descriptive
Lake Area	128,223 acres	descriptive
Miles of Shoreline	92.04	descriptive
Miles of Stream	32.48	descriptive
Miles of Road	189.8	descriptive
Lake Max Depth	42 ft (12.8 m)	descriptive
Lake Mean Depth	21 ft (6.4 m)	+
Water Residence Time	NA	NA
Municipalities	Nichols, Wealthwood, and Malmo (Aitkin county only)	-
Sewage Management	Individual waste treatment systems (septic systems and holding tanks – inspections only for new permit requests) and city sewer	x
Public Drainage Ditches	CD-36; Open ditch-county	x
Lake Management Plan	None	x
Lake Vegetation Survey/Plan	None	x
Forestry Practices	None	+
Development Classification	General Development	-

Lakeshed Vitals		Rating
Shoreline Development Index	1.8	+
Total Lakeshed to Lake Area Ratio (total lakeshed includes lake area)	1.3:1	+
Public Lake Accesses	12	x
Inlets	14 perennial inlets	x
Outlets	1 – Rum River	x
Feedlots	3	-
Agriculture Zoning	2,555 acres > 200 ft. from lake	x
Public Land : Private Land	0.23:1	-
Wetland Coverage	8%	+
Lake Transparency Trend	Declining trend (90% probability)	-
Exotic Species	Zebra mussels and Eurasian watermilfoil	-

Rating Key:
\+ *beneficial to the lake*
\- *possibly detrimental to the lake*
x *warrants attention*

Lakeshed

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.

Mille Lacs Lake is found within the **Upper Mississippi River Basin**, which includes the **Rum River Major Watershed** as one of its sixteen major watersheds (Figure 1). The basin covers 20,000 square miles, while the Rum River covers 1,557 square miles (approximately 996,699 acres). Mille Lacs Lake falls within **minor watershed 21002**, one of the 100 minor watersheds that comprise the Rum River Major Watershed (Figure 2).

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. Mille Lacs Lake falls within the **Mille Lacs Lake (2100200) lakeshed**, covering 164,552 acres (includes lake area) (Figure 3). Even though, in addition to minor watershed 21002, Mille Lacs Lake receives water from minor watersheds 21007, 21009, 21008, 21006, 21010, 21005, 21003, 21017, 21011, 21059, 21058, for the purpose of this assessment it is decided that only the immediate lakeshed be inventoried and assessed.

Mille Lacs Lake Lakeshed Water Quality Protection Strategy

Each lakeshed has a different makeup of public and private lands. Looking in more detail at the makeup of these lands can give insight on where to focus protection efforts. The protected lands (easements, wetlands, public land) are the future water quality infrastructure for the lake. Developed land and agriculture have the highest phosphorus runoff coefficients, so this land should be minimized for water quality protection.

Although the majority of Mille Lacs Lake's lakeshed is open water, private forested uplands can be the focus of development and protection efforts in the lakeshed.

	Private (18%)					**78%**	**Public (4%)**		
	Developed	**Agriculture**	**Forested Uplands**	**Other**	**Wetlands**	**Open Water**	**County**	**State**	**Federal**
Land Use (%)	2%	3%	5%	1%	7%	78%	0.05%	3.1%	0.85%
Runoff Coefficient Lbs of phosphorus/acre/ year	0.45 - 1.5	0.26 - 0.9	0.09		0.09		0.09	0.09	0.09
Description	Focused on Shoreland	Cropland	Focus of develop-ment and protection efforts	Open, pasture, grass-land, shrub-land	Protected				
Potential Phase 3 Discussion Items	Shoreline restoration	Restore wetlands; CRP	Forest stewardship planning, 3rd party certification, SFIA, local woodland cooperatives		Protected by Wetland Conservation Act		County Tax Forfeit Lands	State Forest	National Forest

Figure 1. Upper Mississippi Basin and the Rum River Watershed.

Figure 2. Minor Watersheds 21002, 21007, 21009, 21008, 21006, 21010, 21005, 21003, 21017, 21011, 21059, 21058, and 21001 contribute water to Mille Lacs Lake.

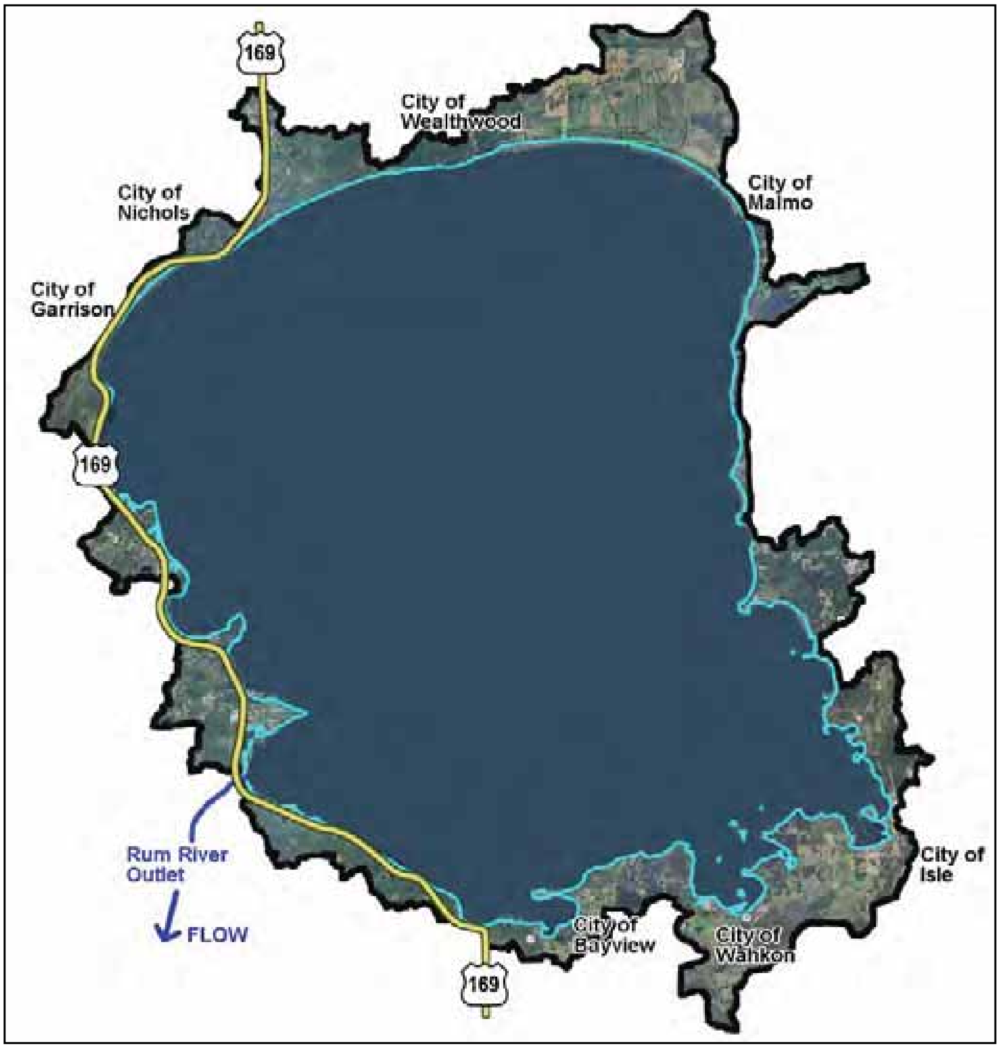


Figure 3. The Mille Lacs Lake (2100200) Lakeshed (Aerial Imagery 2008 1M).

Land Cover / Land Use

The activities that occur on the land within the lakeshed can greatly impact a lake. Land use planning helps ensure the use of land resources in an organized fashion so that the needs of the present and future generations can be best addressed. The basic purpose of land use planning is to ensure that each area of land will be used in a manner that provides maximum social benefits without degradation of the land resource.

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

Figure 5. The Mille Lacs Lake (2100200) lakeshed land cover (http://land.umn.edu).

Phosphorus export, which is the main cause of lake eutrophication, depends on the type of land cover occurring in the lakeshed. Figure 5 depicts Mille Lacs Lake's lakeshed land cover.

The University of Minnesota has online records of land cover statistics from years 1990 and 2000 (http://land.umn.edu). Table 1 describes Mille Lacs Lake's lakeshed land cover statistics and percent change from 1990 to 2000. Due to the many factors that influence demographics, one cannot determine with certainty the projected statistics over the next 10, 20, 30+ years, but one can see the transition within the lakeshed from agriculture, grass/shrub/wetland, and water acreages to forest and urban acreages. The largest change in percentage is the decrease in agriculture (23.9%); however, in acreage, forest cover has increased the most (2,850 acres). In addition, the impervious intensity has increased, which has implications for storm water runoff into the lake. The increase in impervious intensity is consistent with the increase in urban acreage.

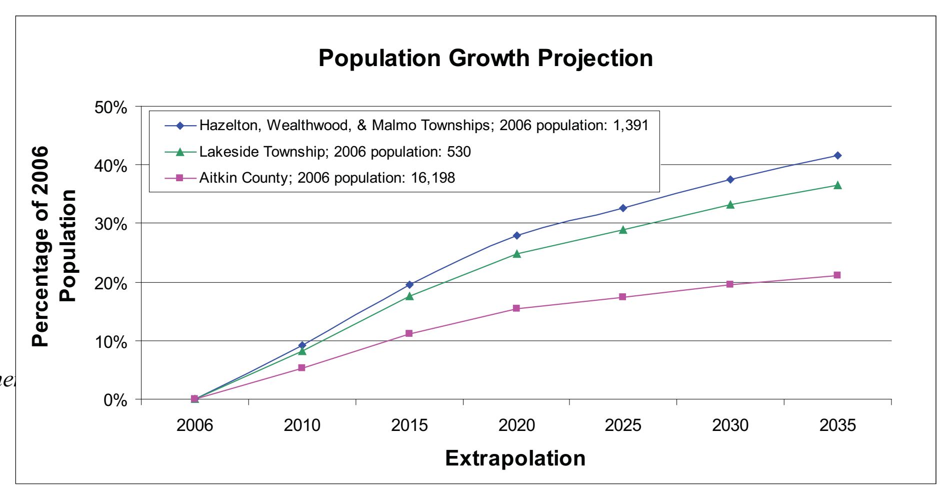
Table 1. Mille Lacs Lake's lakeshed land cover statistics and % change from 1990 to 2000 (http://land.umn.edu).

	1990		2000		% Change
Land Cover	**Acres**	**Percent**	**Acres**	**Percent**	**1990 to 2000**
Agriculture	7,369	4.48	5,605	3.41	23.9 % Decrease
Forest	15,954	9.7	18,804	11.43	17.9 % Increase
Grass/Shrub/Wetland	9,851	5.99	8,752	5.32	11.2 % Decrease
Water	128,506	78.09	127,855	77.7	0.5 % Decrease
Urban	2,865	1.74	3,528	2.14	23.1 % Increase
Impervious Intensity %					
0	162,316	98.65	161,498	98.15	0.5 % Decrease
1-10	545	0.33	672	0.41	23.3 % Increase
11-25	722	0.44	915	0.56	26.7 % Increase
26-40	415	0.25	716	0.44	72.5 % Increase
41-60	252	0.15	387	0.24	53.6 % Increase
61-80	145	0.09	185	0.11	27.6 % Increase
81-100	149	0.09	171	0.1	14.8 % Increase
Total Area	164,552		164,552		
Total Impervious Area (Percent Impervious Area Excludes Water Area)	654	1.81	901	2.46	37.8 % Increase

Demographics

Mille Lacs Lake is classified as a general development lake. General development lakes usually have more than 225 acres of water per mile of shoreline and 25 dwellings per mile of shoreline, and are more than 15 feet deep.

Aitkin County records indicate that the population in Hazelton, Wealthwood, and Malmo Townships increased 50-100% from 1990-2000, while the population of Lakeside Township increased 0-50% from 1990-2000. The Minnesota Department of Administration Geographic and



Demographic Analysis Division extrapolated future population in 5-year increments out to 2035. These projections are shown in Figure 6 below. Compared to Aitkin County as a whole, all of the townships surrounding Mille Lacs Lake have higher extrapolated growth projections over the next 30 years.

Figure 6. Population growth projection for the townships (Aitkin County only) around Mille Lacs Lake and Aitkin County (source: http://www.demography.state.mn.us/resource.html?Id=19332)

Status of the Fishery (DNR, as of 09/04/2007)

The walleye population appeared below average in the 2007 sampling. The inshore gill net catch rate, at half the long-term average, was the lowest observed. Below average catches were spread across most sizes of walleye, especially when compared to 2006. However, there was no good explanation as to why numbers decreased by so much. Furthermore, the walleye numbers were only seriously affected on the north shore. Trawling catches were average for fish older than age 1, which contradicted the abnormally low gill net catches on the north side. Ther are also conflicts between gears concerning the abundance of the 2006 year class. Nevertheless, the total weight per net in the inshore gill nets was the lowest observed since 1983, and pushed the fishery into "condition 3" according to the State harvest overage plan. This restricts State anglers to remaining within their allocation in 2008. A mark-recapture population estimate is planned for spring of 2008 to obtain a better estimate of walleye abundance.

The abundance of older yellow perch has declined as the 1996 year class has grown old and died off. The next strong year class was 2002, which contributed most of the large perch in 2007. An abundance of young-of-year yellow perch in 2007 will provide abundant forage in 2008, and is expected to moderate catch rates of walleye.

Recent warm summers may be affecting the abundance of temperature sensitive species. Obvious declines in abundance have been observed for burbot and tullibee, while more subtle declines may be occurring for white sucker. On the other hand, species like smallmouth bass, are showing a gradual increase in abundance as warmer temperatures lead to more favorable environments for warmwater species. Increases in the abundance of largemouth bass and other centrarchids are expected, but most of these species are not sampled well. Tullibee numbers fell to the lowest observed in both inshore and offshore gill nets for the second consecutive year. If the tullibee population is suffering a permanent decline, many impacts may be felt by other species in the lake. First, lack of a medium to large forage species may be increasing predation pressures on young walleye, and may be contributing to the declining year class strengths. Second, lack of tullibee may also increase energy required to feed, and decrease the quality of the food, which may in turn reduce growth rates and maximum size of walleye. Similar concerns can be applied to northern pike and muskellunge as well, and could even be exacerbated by the reduction in white sucker as well. Many muskellunge anglers are fishing Mille Lacs Lake because of the potential for very large fish, possibly even a state record. This dynamic would certainly change if maximum sizes decrease in the future. Furthermore, future muskellunge stocking rates need to consider changes in forage abundance and quality.

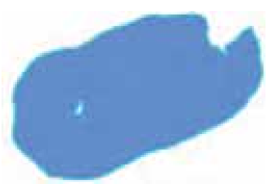
The muskellunge genetics study has confirmed that natural reproduction contributes significantly to the muskellunge population. Natural recruits contribute at least 25% and perhaps 50% of the adults. Many of the naturally reproduced muskellunge are hybrids between different stocked strains. As hybridization between the strains continues, it is likely that the Mille Lacs muskellunge population will carry genes from both of the Wisconsin strains for many generations. The continued presence of shoepack genes in some of the hybrid muskellunge was also a surprise, and demonstrates that that strain has persisted on natural reproduction alone for almost 30 years. In the spring of 2008, muskellunge will be sampled during spawning. Naturally reproduced fish from the four year stocking gap from 2000-2003 will be between 5 and 8 years old, which is a good compromise between being fully recruited to the spawning stock and being young enough for decent age assignment.

The discovery of zebra mussels in Mille Lacs Lake in 2005 represents a serious threat to Mille Lacs Lake and many others lakes to which zebra mussels from Mille Lacs Lake could be transported. Future effects to native invertebrates, walleye spawning areas, swimming beaches, the bait industry, and the local economy are unknown. In 2007, several new developments were observed. First, most of the zebra mussels found were small (less than 20 mm). Second, this was the first year that zebra mussels were collected in close enough proximity to confirm the ability to reproduce naturally. Third, zebra mussels were confirmed in the south end of the lake at three different sites. Fourth, veligers were collected in plankton tows. And finally, zebra mussels collected off a cinder block used to hold a data logger represented the first report of confirmed colonization of a temporary object. All of these developments support the classification of Mille Lacs Lake as "infested", and are evidence for significant natural reproduction.

See the link below for specific information on gillnet surveys, stocking information, and fish consumption guidelines. http://www.dnr.state.mn.us/lakefind/showreport.html?downum=48000200

Rice Lake 01-0067-00 AITKIN COUNTY

Summary



Rice Lake is located in Aitkin County near McGregor, MN. With a surface area of 3,698 acres, it is in the upper 2% of lakes in Minnesota in terms of its size.

Rice Lake has several small seepage creeks contributing water and one former logging ditch as an outlet. The outlet drains into the Rice River, which eventually drains into the Mississippi River.

Rice Lake is located in the Rice Lake National Wildlife Refuge (Refuge) and is designated as a wildlife lake. The Rice Lake National Wildlife Refuge manages Rice Lake for wild rice production and wildlife habitat. Rice Lake is closed to fishing. The shallow nature of the lake would suggest that it does not behave like a typical lake of its size in northern Minnesota. It is better described as a marsh. The entire lake can be considered littoral (shallow enough for sunlight to reach the bottom and plants to grow), and DNR plant surveys indicate a dense and diverse aquatic plant community. Approximately 80% of the lake area is covered by standing emergent vegetation. Wild Rice and pickerelweed dominate the plant community.

Records show that Rice Lake has not been a part of a regular monitoring program. The only water quality data that exist for Rice Lake include DNR Fisheries surveys in 1941, 1968 and 1993, and data from the Refuge. Data is limited for Rice Lake; however, due to the wetland complex it is a part of and the lack of development around the lake due to it's location in a National Wildlife Refuge, it is not considered high priority for a monitoring program.

Vitals	
MN Lake ID:	01-0067-00
County:	Aitkin
Ecoregion:	Northern Lakes and Forest
Major Drainage Basin:	Upper Mississippi River
Latitude/Longitude:	46.50926257154213/

Physical Characteristics	
Surface area (acres):	3,698
Littoral area (acres):	3,698
% Littoral area:	100%
Max depth (ft):	4.5 – 8 feet depending on water levels
Mean depth (ft):	2.5
Watershed size (acres):	19,200

	-93.37760925292969	Watershed:lake area ratio	5:1
Water Body Type:	P	Inlets	small seepage creeks
Monitored Sites (Primary):	None	Outlets	A former logging ditch to Rice River
Monitored Sites (Secondary):	None	Accesses	none
Invasive species present:	none recorded		

Data Availability	
Transparency data	Some transparency data exists from 1941 and 1968 DNR Fisheries surveys, and 2005 Refuge surveys.
Chemical data	Three phosphorus data points exist from 2005 Refuge monitoring.
Inlet/Outlet data	Flow data exist from a 1968 DNR Fisheries survey, but no nutrient concentration data exist. The Refuge manages the lake levels and river gauges.
Recommendations	See page 6

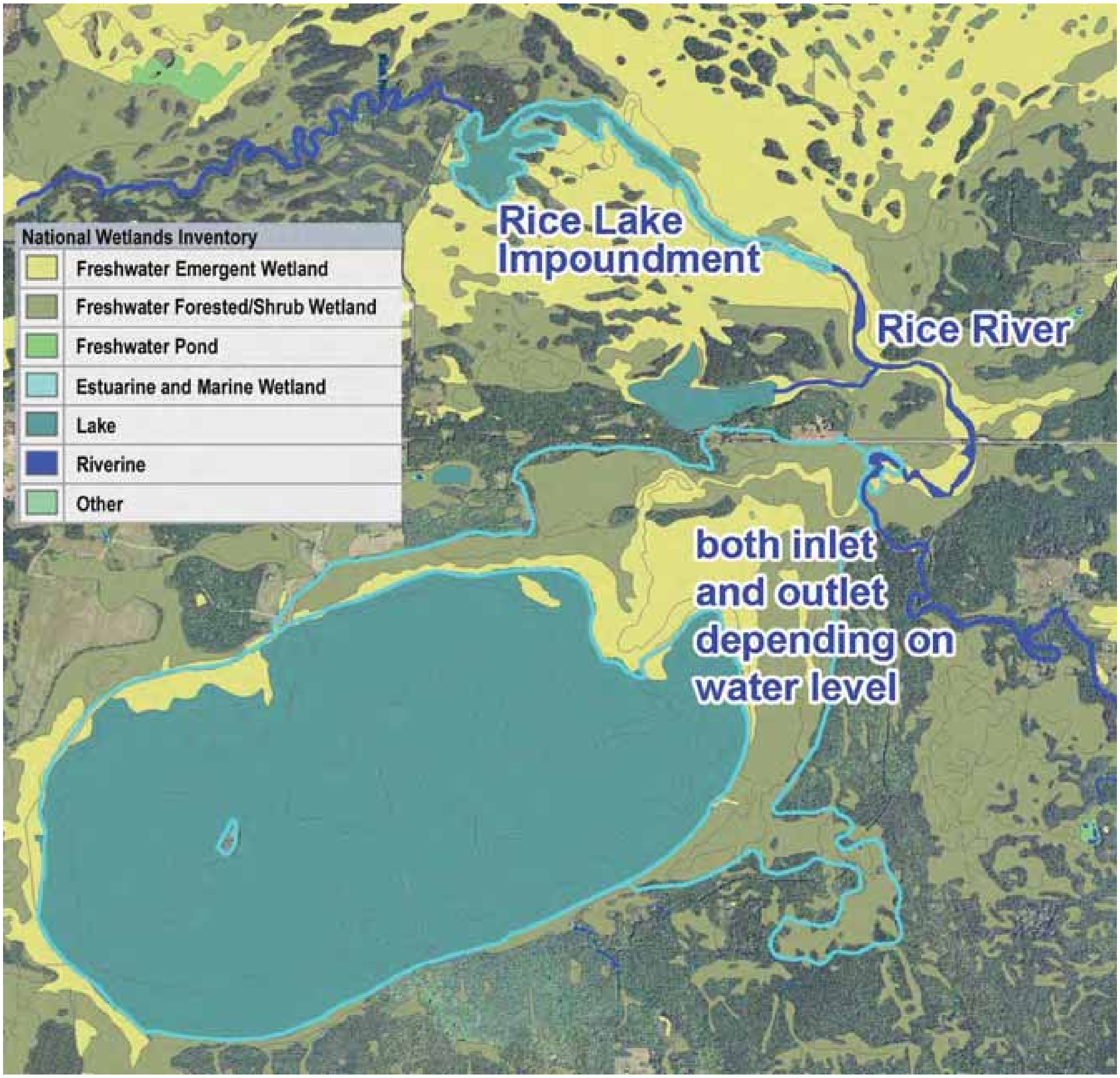


Figure 1. Map of Rice Lake with aerial land use and National Wetlands Inventory.

Rice Lake water levels are controlled by a structure. The water either flows into our out of Rice Lake into the Rice River depending on water levels. The water levels are regulated for wild rice growth and wildlife habitat. Over the season water levels vary greatly for Rice Lake, and much of the surrounding area is freshwater emergent wetland. In just 2007, Rice Lake depth ranged from 6.23 ft to 2.8 ft.

The information below describes all available chemical data for Rice Lake up to 2008. The data set is limited, and all parameters are means for just 1941, 1968, 2005-2006 data.

Minnesota is divided into 7 ecoregions based on land use, vegetation, precipitation and geology. The MPCA has developed a way to determine the "average range" of water quality expected for lakes in each ecoregion. For more information on ecoregions and expected water quality ranges, see page 10.

Parameter	**Mean**	**Ecoregion Range[1]**	**Impaired Waters Standard[2]**	**Interpretation**
Total phosphorus (ug/L)	30.8	14 - 27	> 35	Due to the shallow nature of the lake (max depth 4.5 ft), it is not beneficial to compare Rice Lake to the Ecoregion averages for total phosphorus and secchi depth.
[3]Chlorophyll *a* (ug/L)	3.5	4 - 10	> 12	
Chlorophyll *a* max (ug/L)	4	<15		
Secchi depth (ft)	1.1	7.5 - 15	< 4.5	
Dissolved oxygen				Rice Lake is shallow and polymictic (mixes all summer). Dissolved Oxygen levels are below 5 much of the summer, which means it is inhospitable to game fish.
Total Nitrogen (mg/L)	0.9	-		-
Alkalinity (mg/L)	40	40 - 140		Rice Lake lies midway between a soft water and medium hard water lake. Rice Lake alkalinity indicates a low sensitivity to acid rain and a good buffering capacity.
Color (Pt-Co Units)	-	10 - 35		The DNR surveys indicate the presence of "bog staining" from drainage from surrounding wetland areas.
pH	-	7.2 - 8.3		-
Chloride (mg/L)	-	0.6 - 1.2		-
Total Suspended Solids (mg/L)	2.7	<1 - 2		The TSS for Rice Lake indicate clear water.
Total Suspended Volatile Solids (mg/L)	-	<1 - 2		-
Conductivity (umhos/cm)	106	50 - 250		Conductivity is within the expected range for the ecoregion.
Total Nitrogen :Total Phosphorus	28:1	25:1 – 35:1		Indicates the lake is phosphorus limited, which means that algae growth is limited by the amount of phosphorus in the lake.

Data Source: DNR Fisheries Surveys, 1941, 1968; Rice Lake National Wildlife Refuge, 2005-2006

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

Water Quality Characteristics - Historical Means

Years monitored: 1968, 2005

Parameters	
Total Phosphorus:	**30.8**
Number of Observations:	4
Chlorophyll *a* Mean:	**3.5**
Number of Observations:	2
Secchi Depth Mean:	**1.1**
Secchi Depth Min:	0.3
Secchi Depth Max:	3
Number of Observations:	17

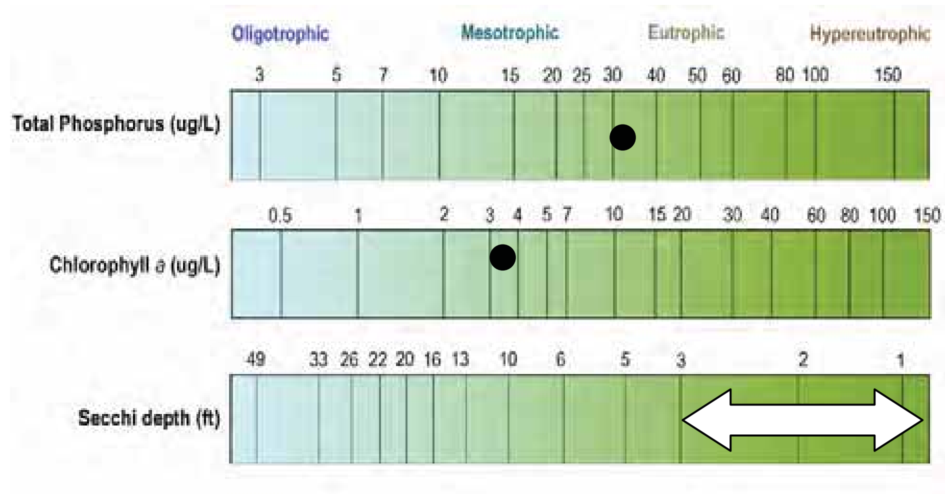


Figure 2. Rice Lake total phosphorus, and transparency historical ranges. The arrow represents the range and the black dot represents the historical mean. Figure adapted after Moore and Thornton, [Ed.]. 1988. Lake and Reservoir Restoration Guidance Manual. (Doc. No. EPA 440/5-88-002)

Transparency (Secchi Depth)

Transparency is how easily light can pass through a substance. In lakes it is how deep sunlight penetrates through the water. Plants and algae need sunlight to grow, so they are only able to grow in areas of lakes where the sun penetrates. Water transparency depends on the amount of particles in the water. An increase in particulates results in a decrease in transparency.

Rice Lake Secchi data is not representative of the lake water quality since it was clear down to the bottom of the lake. The maximum depth at the sample site was 3 feet and the secchi depth was also 3 feet. Using total phosphorus and chlorophyll a data to characterize the lake will be more representative of in-lake conditions.

Trophic State Index

The Trophic State Index is not useful for describing Rice Lake. The shallow nature of the lake (max depth 4.5 feet) would suggest that it does not behave like a typical lake of its size in northern Minnesota. In shallow lakes there are different dynamics occurring than deep lakes, and total phosphorus, chlorophyll *a* and secchi depth are not as closely related.

Ecoregion Comparisons

Minnesota is divided into 7 ecoregions based on land use, vegetation, precipitation and geology. The MPCA has developed a way to determine the "average range" of water quality expected for lakes in each ecoregion. From 1985-1988, the MPCA evaluated the lake water quality for reference lakes. These reference lakes are not considered pristine, but are considered to have little human impact and therefore are representative of the typical lakes within the ecoregion. The "average range" refers to the 25th - 75th percentile range for data within each ecoregion.

Rice Lake is in the Northern Lakes and Forests (NLF) Ecoregion. The mean total phosphorus and transparency (secchi depth) for Rice Lake are above the expected ecoregion ranges.

The shallow nature of the lake (max depth 4.5 feet) would suggest that it does not behave like a typical lake of its size in northern Minnesota. In addition, over the season water levels vary greatly for Rice Lake. In just 2007, Rice Lake depth ranged from 6.23 ft to 2.8 ft.

In addition, the data for Rice Lake are limited and outdated. The Rice Lake total phosphorus is from 1 data point collected in 1941 and 3 data points collected in 2005. Chlorophyll a data are from 2 data points collected in 2005, and the secchi depth is from data collected in 1968 and 2005.

Parameter	Rice Lake Mean	Ecoregion Range
Total phosphorus (ug/L)	30.8	14 - 27
Chlorophyll *a* (ug/L)	3.5	4 - 10
Chlorophyll *a* max (ug/L)	4	<15
Secchi depth (ft)	1.1	7.5 - 15

Inlet/Outlet Data Assessment

A 1968 DNR Fisheries survey includes some inlet and outlet characteristics. The outlet consists of a ditch that runs 1 mile to the Rice River. The ditch was an average of 10 feet wide, 2 feet deep, and had a velocity of 0.25 feet per second. There is a stoplog dike control at the outlet as a barrier to fish movement.

The Rice Lake National Wildlife Refuge monitors the lake and river water levels using a gauge at the lake side and river side.

Assessment/Findings Recommendations

Transparency
Transparency is not a good indicator of water quality in Big Rice Lake because the secchi disk can be seen clear to the bottom of the lake.

There is limited data available between 1990-2005 from the University of Minnesota Remote sensing satellite imagery; however, this data does not appear to be accurate. These remote sensing results show that the mean transparency is 2-2.5 meters (6.6-8.2 feet), whereas the maximum depth of Rice Lake is only 4.5 - 8 feet. Therefore, these data were not used in this assessment.

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. Rice Lake is not listed as impaired for mercury in fish tissue.

As of the date of this report, the Rice Lake data set is insufficient for Impaired Waters Assessment for eutrophication. A data set of 10 data points each of total phosphorus, chlorophyll *a*, and secchi depth over a two-year period in the past 10 years is required for eutrophication assessment. Scheduling two years of chemical data collection would complete this assessment data set (see standards on page 3).

Aquatic Recreational Use Assessment 305(b)
In the 2008 MPCA Aquatic Use Assessment (305(b)), Rice Lake did not have enough data to be included this assessment.

Organizational contacts and reference sites

Rice Lake National Wildlife Refuge	http://www.fws.gov/midwest/ricelake 218-768-2402
Aitkin Soil and Water Conservation District	130 Southgate Drive, Aitkin, MN 56431 (218) 927-6565, http://www.aitkincountyswcd.org/
DNR Fisheries Office	1200 Minnesota Avenue South, Aitkin, MN 56431 (218) 927-3751, http://www.dnr.state.mn.us/lakefind/index.html
Regional Minnesota Pollution Control Agency Office	7678 College Road, Suite 105, Baxter, MN 56425 (218) 828-2492, http://www.pca.state.mn.us
Regional Board of Soil and Water Resources Office	1601 Minnesota Drive, Brainerd, MN 56401 (218) 828-2383, http://www.bwsr.state.mn.us

Rice Lake Lakeshed Assessment

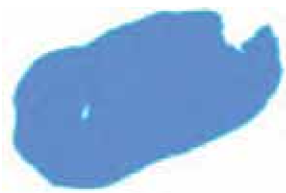
The lakeshed vitals table identifies where to focus organizational and management efforts for each lake. Criteria were developed using limnological concepts to determine the effect to lake water quality.

Lakeshed Vitals		**Rating**
Major Basin	Upper Mississippi River	descriptive
Major Watershed	Mississippi River - Brainerd	descriptive
Minor Watershed	10020	descriptive
Lakeshed	Rice Lake - Rice River (1002101)	descriptive
Ecoregion	Northern Lakes and Forests	descriptive
Lake Area	3,698 acres	descriptive
Miles of Shoreline	11.3	descriptive
Miles of Stream	18.7	descriptive
Miles of Road	17.4	descriptive
Lake Max Depth	4.5 - 8 ft. (1.4 - 2.4 m)	descriptive
Lake Mean Depth	2.5 ft. (0.76 m)	-
Water Residence Time	NA	NA
Municipalities	None	+
Sewage/Storm Water Management	No septic systems present	+
Public Drainage Ditches	None	+
Lake Management Plan	Refuge-wide comprehensive conservation plan approved December 2007	+
Lake Vegetation Survey/Plan	Refuge-wide comprehensive conservation plan approved December 2007	+
Forestry Practices	None	+
Development Classification	Natural Environment	+
Shoreline Development Index	1.3	+
Total Lakeshed to Lake Area Ratio (total lakeshed includes lake area)	5.1:1	x
Public Lake Accesses	None	+
Inlets	Some small seepage creeks	x
Outlets	1 – Logging ditch to Rice River	x
Feedlots	3	-
Agriculture Zoning	1,737 acres > 200 ft. from lake	x
Public Land : Private Land	1.6:1	+
Wetland Coverage	34%	+

Lakeshed Vitals		Rating
Lake Transparency Trend	NA	NA
Exotic Species	None	+

Rating Key:
\+ *beneficial to the lake*
\- *possibly detrimental to the lake*
x *warrants attention*

Lakeshed



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.

Rice Lake is found within the **Upper Mississippi River Basin**, which includes the **Mississippi River - Brainerd Major Watershed** as one of its sixteen major watersheds (Figure 1). The basin covers 20,000 square miles, while the Mississippi River - Brainerd Watershed covers 1,687 square miles (approximately 1,079,950 acres). Rice Lake falls within **minor watershed 10020**, one of the 126 minor watersheds that comprise the Mississippi River - Brainerd Major Watershed (Figure 2).

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. Rice Lake falls within the **Rice Lake - Rice River (1002101) lakeshed**, covering 18,983 (includes lake area) (Figure 3). Even though Rice Lake occasionally receives water from minor watersheds 10002, 10021, 10001, and 10022, for the purpose of this assessment it is decided that only the immediate lakeshed be inventoried and assessed.

Rice Lake Lakeshed Water Quality Protection Strategy

Each lakeshed has a different makeup of public and private lands. Looking in more detail at the makeup of these lands can give insight on where to focus protection efforts. The protected lands (easements, wetlands, public land) are the future water quality infrastructure for the lake. Developed land and agriculture have the highest phosphorus runoff coefficients, so this land should be minimized for water quality protection.

Although the majority of Rice Lake's lakeshed is made up of public land, private forested uplands should be the focus of development and protection efforts in the lakeshed.

	Private (29%)					26%	Public (45%)		
	Developed	Agriculture	Forested Uplands	Other	Wetlands	Open Water	County	State	Federal
Land Use (%)	1%	6%	16%	-	6%	26%	1%	18%	26%

Runoff Coefficient Lbs of phosphorus/acre/ year	0.45 - 1.5	0.26 - 0.9	0.09		0.09		0.09	0.09	0.09
Description	Focused on Shoreland	Cropland	Focus of develop-ment and protection efforts	Open, pasture, grass-land, shrub-land	Protected				
Potential Phase 3 Discussion Items	Shoreline restoration	Restore wetlands; CRP	Forest stewardship planning, 3rd party certification, SFIA, local woodland cooperatives		Protected by Wetland Conservation Act		County Tax Forfeit Lands	State Forest	National Forest

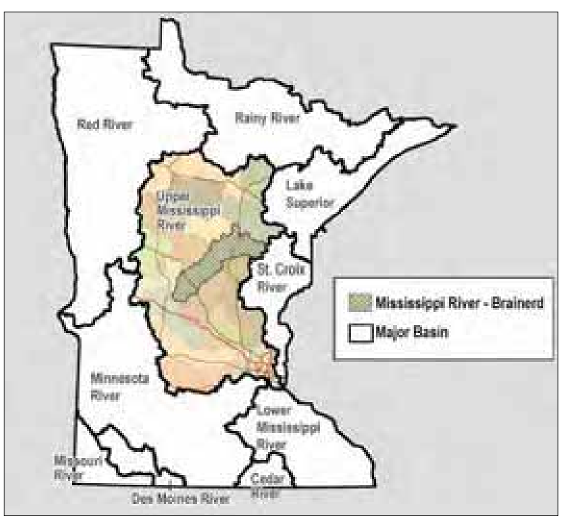


Figure 1. Upper Mississippi Basin and the Mississippi River – Brainerd Watershed.

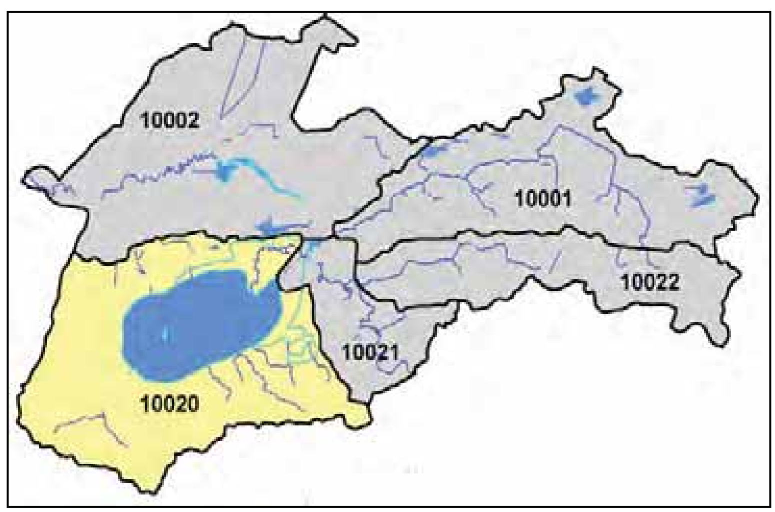


Figure 2. Minor Watersheds 10020, 10002, 10021, 10001, & 10022 contribute water to Rice Lake.

Figure 3. The Rice Lake - Rice River (1002101) Lakeshed (Aerial Imagery 2008 1M).

Land Cover / Land Use

The activities that occur on the land within the lakeshed can greatly impact a lake. Land use planning helps ensure the use of land resources in an organized fashion so that the needs of the present and future generations can be best addressed. The basic purpose of land use planning is to ensure that each area of land will be used in a manner that provides maximum social benefits without degradation of the land resource.

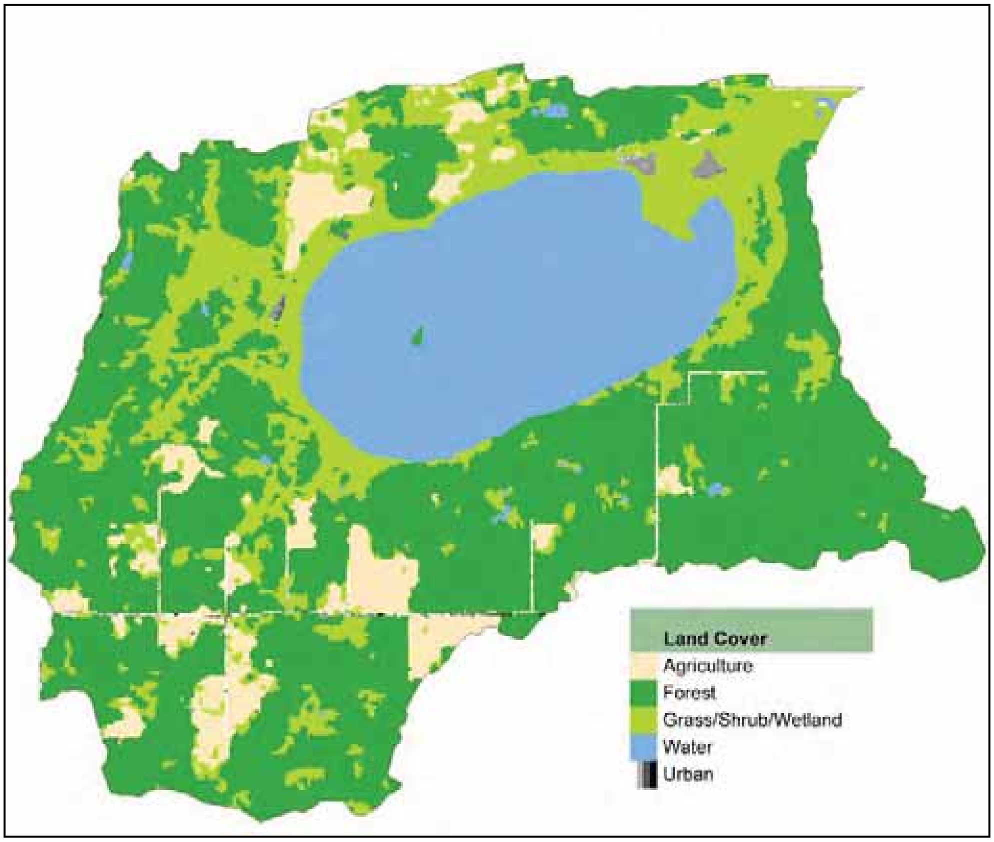


Figure 5. The Rice Lake - Rice River (1002101) lakeshed land cover (http://land.umn.edu).

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

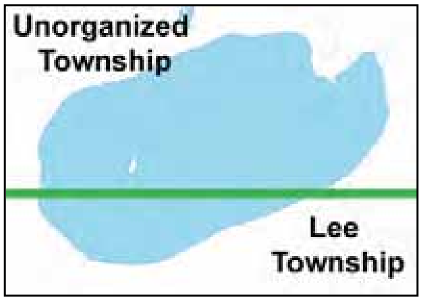
Phosphorus export, which is the main cause of lake eutrophication, depends on the type of land cover occurring in the lakeshed. Figure 5 depicts Rice Lake's lakeshed land cover.

The University of Minnesota has online records of land cover statistics from years 1990 and 2000 (http://land.umn.edu). Table 1 describes Rice Lake's lakeshed land cover statistics and percent change from 1990 to 2000. Due to the many factors that influence demographics, one cannot determine with certainty the projected statistics over the next 10, 20, 30+ years, but one can see the transition within the lakeshed from agriculture, water, and grass/shrub/wetland acreages to forest and urban acreages. The largest change in percentage is the decrease in grass/shrub/wetland (41.8%); however, in acreage, forest cover has increased the most (2,210 acres). In addition, the impervious intensity has increased, which has implications for storm water runoff into the lake. The increase in impervious intensity is consistent with the increase in urban acreage.

Table 1. Rice Lake's lakeshed land cover statistics and % change from 1990 to 2000 (http://land.umn.edu).

	1990		2000		% Change
Land Cover	**Acres**	**Percent**	**Acres**	**Percent**	**1990 to 2000**
Agriculture	1,329	7	1,088	5.73	18.1 % Decrease
Forest	10,095	53.18	12,305	64.82	21.9 % Increase
Grass/Shrub/Wetland	3,663	19.3	2,131	11.23	41.8 % Decrease
Water	3,686	19.42	3,215	16.94	12.8 % Decrease
Urban	209	1.1	244	1.29	16.8 % Increase
Impervious Intensity %					
0	18,840	99.25	18,813	99.1	0.1 % Decrease
1-10	46	0.24	79	0.42	71.7 % Increase
11-25	79	0.42	77	0.41	2.5 % Decrease
26-40	12	0.06	12	0.06	No Change
41-60	2	0.01	1	0.01	50.0 % Decrease
61-80	2	0.01	0	0	100.0 % Decrease
81-100	0	0	1	0.01	100.0 % Increase
Total Area	18,983		18,983		
Total Impervious Area (Percent Impervious Area Excludes Water Area)	23	0.15	21	0.13	8.7 % Decrease

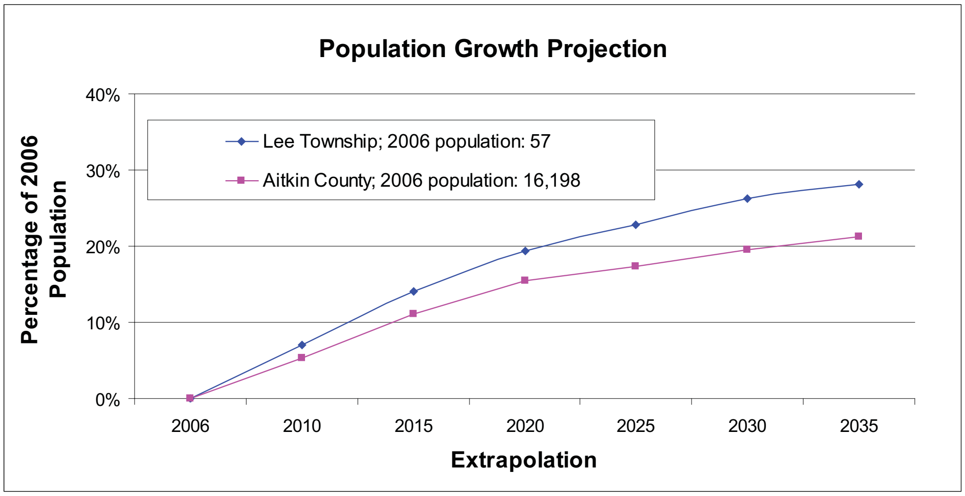
Demographics



Rice Lake is classified as a natural environment lake. Natural environment lakes usually have less than 150 total acres, less than 60 acres per mile of shoreline, and less than three dwellings per mile of shoreline. They may have some winter kill of fish; may have shallow, swampy shoreline; and are less than 15 feet deep.

Aitkin County records indicate that the population in Lee Township increased 0-50% from 1990-2000. The Minnesota Department of Administration Geographic and Demographic Analysis Division extrapolated future population in 5-year increments out to 2035. These projections are shown in Figure 6 below. Lee Township has a higher extrapolated growth over the next 30 years than Aitkin County as a whole.

Figure 6. Population growth projection for Lee Township and Aitkin County. Figure excludes one unorganized township that lacks individual population data. (source: http://www.demography.state.mn.us/resource.html?Id=19332)



Status of the Fishery (USFWS, 07/17/2008)

Commonly Caught Fish Species
Northern Pike, Yellow Perch, Bullhead, Buffalo Fish, Walleye, Panfish

Season Dates
Refuge fishing areas are open in accordance with Minnesota season dates. Anglers must possess a valid Minnesota fishing license and fish in accordance with all applicable state and refuge fishing regulations.

Special Conditions
Fishing is permitted only in Twin Lakes, Mandy Lake and the Rice River. Rice Lake is closed to fishing. Boats without motors or boats with electric motors are permitted on all fishing areas. Vehicles must travel on established roads and park in designated parking areas. Overnight camping and open fires are prohibited. The refuge is open for day use only. Ice fishing is permitted on Mandy Lake only. Ice fishing shelters are permitted but must be removed from the ice at the end of each day.

Appendix I: Lakeshed Assessment Reference Material

The purpose of the assessment is to develop an inventory and assess the resources within each lakeshed to be used as a tool to assess 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.

This reference material includes both references and explanations for features in the individual lake reports.

Lakeshed Vitals Rating Criteria

The lakeshed vitals table (page 1 of individual lake reports) identifies where to focus organizational and management efforts for each lake. Criteria were developed using limnological concepts to determine the effect to lake water quality. The table below contains an explanation of each item and the criteria used in the rating process.

Major Basin	Description A basin (or drainage basin) is the area of land drained by a river or lake and its tributaries. Minnesota has 10 major drainage basins. Each drainage basin is made up of smaller units called watersheds, which correspond to the drainage of a tributary or lake system.
Major Watershed	Description A major watershed is the smaller unit within a major basin. The major watershed corresponds to the drainage of a tributary or lake system.
Minor Watershed	Description A minor watershed is the smaller unit within a major watershed. The minor watershed drains directly into a lake through an inlet.
Lakeshed	Description A lakeshed is defined as the land area that drains into a lake.
Ecoregion	Description An ecoregion is a relatively large expanse of land containing a geographically distinct collection of plants, animals, natural communities and environmental conditions. There are seven of them in Minnesota.
Lake Surface Area	Description Lake surface area is the size in acres of the lake's surface. Large lakes (>1000 acres) can behave differently than smaller lakes.
Miles of shoreline	Description Miles of shoreline describes the distance around the lake shore. Lakes with more miles of shoreline have more area for potential shoreline impacts to occur.

Miles of Stream	<u>Description</u> Zero, first and second order streams account for most of the total stream miles within any watershed and cumulatively provide much more habitat for aquatic organism than large rivers. Small streams are also highly productive systems, owing to their relationships with adjacent upland habitats. These areas of high productivity are often used for spawning and nursery habitat by fish that normally inhabit larger waterways as adults. Even intermittent and very small perennial streams play an important role in transporting invertebrates, detritus, and other organic matter that fuel downstream food webs. Small streams provide important summer habitat for cold-water fish that move up into headwater streams to escape unfavorably warm conditions in ponds and rivers. In addition to providing critical habitat for fish, small streams support many animals that do not occur in larger streams and rivers. These include species of stream salamanders and crayfish, and probably countless other invertebrate species. On the other hand, streams are also major sources of nutrients and suspended solids to lakes. It is important that lake residents keep riparian areas natural with vegetated buffers in order to protect the lake and the stream.
Miles of Road	<u>Description</u> Roads are considered impervious surface; they fragment the landscape for wildlife habitat and lead to increased development.
Lake Max Depth	<u>Description</u> The maximum depth of the lake corresponds to the deepest hole in the lake bottom.
Lake Mean Depth	<u>Description</u> The mean or average depth of a lake is calculated by dividing the lake's volume by its area. The mean depth is one of the best indicators of the morphology of a lake, and it tells a great deal about its limnology or water quality characteristics. If the mean depth is shallow (<20 ft), the lake water will mix from the surface to the bottom on windy days. The bottom sediments may be a source of nutrients, which will cause algae blooms when mixed to the surface water, potentially reduce dissolved oxygen levels, and thereby contribute to the risk of winterkill or summerkill. <u>Criteria</u> **"-"** for mean depth of 20 feet or less, "+" if greater than 20 feet
Water Residence Time	<u>Description</u> For lakes having longer residence times (a year or more), long-term average pollutant loadings become more important to overall lake water quality. Lakes that have a residence time of more than 5 years have a capacity of retaining about 60% of the phosphorus loading that occurs and is not lost via outflow. This characteristic requires that the longer the water residence time, the longer the time frame needed for in-lake observations to detect any response to loading reduction. <u>Criteria</u> **"-"** for residence time greater than 5 years, "+" if 4 years or less

Municipalities	Description Municipalities adjacent to a lake are areas of dense population and impervious surface. Stormwater runoff from streets, parking lots, roofs and storm gutters can contribute nutrient and pollutant loading to a lake. In addition, road salt used in the winter can increase the salinity and conductivity in a lake. Criteria **"-"** if present due to storm water runoff issues, "+" if not present
Sewage Management	Description If properly maintained, septic systems can be an effective way to manage sewage waste near a lake. If improperly maintained, septic systems can leech into the groundwater and/or lake water and contribute harmful bacteria and nutrients. The excess nutrients can fuel plant and algae growth in front of the property. Criteria **"-"** if comprehensive septic inspections around the lake not completed in last 10 years, "+"if comprehensive septic inspections around the lake completed in last 10 years
Public Drainage Ditches	Description Public drainage ditches can contribute nutrient enriched runoff to lakes during heavy rain events and spring thaw. Channelized streams or constructed ditches effectively increase the slope of the watershed and reduce the time it takes water to reach the lake. Criteria If present, "warrants attention" due to nutrient loading, "+" if not present
Lake Management Plan	Description A lake management plan is an excellent way to get lakeshore owners involved in evaluation and future planning for the lake. The planning process can set goals for lake management and give property owners a reason to practice stewardship in the future. Criteria "warrants attention" " if no plan, "+" if plan exists
Lake Vegetation Survey/Plan	Description Native lake vegetation is crucial to healthy fish and wildlife habitat, tying up nutrients that would otherwise be in the water column, and stabilizing lake sediments. A lake vegetation survey describes the current vegetation in the lake and identifies any invasive species. A lake vegetation plan is a way to move forward for management of native and invasive species in a way that benefits the lake and its habitat quality. Criteria "warrants attention" if no survey/plan, "+" is survey/plan exists

Forestry Practices	Description Properly planned and managed forestry will have little impact on lake water quality; however, clear-cutting along a tributary or in the lakeshed can accelerate erosion and runoff. Criteria "-" if clear-cutting is occurring in lakeshed, "+" if no clear-cutting is occurring in the lakeshed
Shoreland Development Classification	Description Minnesota's lakes range from the sterile, rock basin lakes of the Arrowhead region to the naturally fertile, shallow lakes of the southwest prairie region. These different types of lakes require different shoreland development standards. A classification system was developed so that the appropriate development standards could be applied. Lakes are divided into the following classes based on a combination of factors. Natural Environment Lakes usually have less than 150 total acres, less than 60 acres per mile of shoreline, and less than three dwellings per mile of shoreline. They may have some winter kill of fish; may have shallow, swampy shoreline; and are less than 15 feet deep. Recreational Development Lakes usually have between 60 and 225 acres of water per mile of shoreline, between 3 and 25 dwellings per mile of shoreline, and are more than 15 feet deep. General Development Lakes usually have more than 225 acres of water per mile of shoreline and 25 dwellings per mile of shoreline, and are more than 15 feet deep. Criteria "-" General Development Lake "x" Recreational Development Lake "+" Natural Environment Lake
Shoreline Development Index	Description The shoreline development index is the ratio of the length of shoreline to the circumference of a circle with an area equal to the lake area. As the index value increases from 1, it indicates a more irregularly shaped shoreline. An index value of 1 is the smallest possible value and indicates a lake that is perfectly circular. Lakes with an index value of approximately 2 are more elliptical in form, while elongated or dendritic-shaped lakes can have values greater than 4. The shoreline development index is an important morphological parameter to consider because it can give an idea of a lake's susceptibility to the impacts of shoreline development. Lakes with high index values are more susceptible to the impacts of development because there is more shoreline to be developed compared to a more regularly shaped (round) lake with a similar surface area. (Wetzel 2001) Criteria "-" if greater than 2, "+" if less than or equal to 2

Total Lakeshed to Lake Area Ratio (total lakeshed includes lake area)	The lakeshed to lake area ratio shows how much land area drains into the lake compared to the size of the lake. "+" if less than 2 "warrants attention" if over 2
Public Lake Accesses	<u>Description</u> Public lake accesses enable the public to use the lake for fishing and recreation. They are also one of the main locations for the spread of aquatic invasive species. All public lake accesses should have signs that identify any invasive species present in the lake. Boaters should be aware of invasive species and inspect their boat before and after entering the lake. <u>Criteria</u> "warrants attention" due to potential spread of exotic species
Inlets	<u>Description</u> Inlets are the #1 source of nutrient loading in most lakes; however, they are also important in decreasing the lake residence time and "flushing" the lake. Inlets can also be a source of invasive species from lakes upstream. Lake Associations should be familiar with lake conditions upstream from their own lake and know the locations of all tributaries entering the lake. <u>Criteria</u> Any inlets "warrant attention" due to invasive species and nutrients
Outlets	<u>Description</u> If there is a controlled structure at an outlet, it can affect water levels and manipulate water levels artificially. If this control structure were to fail or wash out, water levels would drop significantly in the lake. In addition, outlets can be a source of invasive species to the lake from downstream lakes. Lake Associations should be aware of downstream lake conditions and whether or not they have an outlet control structure. <u>Criteria</u> "warrants attention"
Shoreland Conservation Potential (% shoreland identified for conservation potential)	<u>Description</u> Conservation efforts to limit or slow down the development process can only assist in the preservation of the lakeshed and inevitably the water quality of water bodies found within. Parcels within the lakeshed that are large enough to warrant the investigation of parcel conservation practices and purchase will slow future development on the lake. <u>Criteria</u> "-" if there is no shoreland identified for conservation potential, "+" if there is shoreland identified for conservation potential

Feedlots	Description Feedlots are sources of concentrated nutrients that can enter a lake during a storm event and spring runoff. Any feedlots within the lakeshed should be investigated for their land and manure practices. Criteria "-" if feedlots found within lakeshed, "+" if no feedlots present
Agriculture Zoning	Description Agriculture practices along a lakeshore should have a proper buffer to filter and absorb nutrient runoff and prevent it from entering the lake. Agriculture practices within the lakeshed should have a proper buffer along any tributaries to the lake. Criteria "-" if zoning within 200 ft of lake, "warrants attention" if in lakeshed but greater than 200 from lake, "+" if no agriculture zoning present
Public Land : Private Land	Description Public land is protected, and therefore additional development cannot occur in those areas. Private land that is undeveloped has the potential to be developed unless there are wetlands present that are protected by the Wetland Conservation Act. Criteria "-" if the ratio is less than 1:1, "warrants attention" if 1:1, "+" if the ratio is more than 1:1
Wetland Coverage	Description Wetland protection is a critical component for the long-term protection of water quality and recharge of groundwater. Historically, wetlands were drained for various land-use practices. Today, environmental awareness and increased stewardship has lead practices to restoration. All wetlands in the National Wetlands Inventory are protected by the Wetland Conservation Act and cannot be developed. The more land tied up in protected wetlands around a lake, the less development and impact there will be on the lake water quality. Criteria "-" if less than 1% of the lakeshed area is wetlands "warrants attention" if 1-2% of the area is wetlands "+"if greater than 2% of the lakeshed area is wetlands

Lake Transparency Trend	Description For detecting trends, a minimum of 8-10 years of data with 4 or more readings per season are recommended. Minimum confidence accepted by the MPCA is 90%. This means that there is a 90% chance that the data are showing a true trend and a 10% chance that the trend is a random result of the data. Only short-term trends can be determined with just a few years of data, because there can be different wet years and dry years, water levels, weather, etc, that affect the water quality naturally. The data was analyzed using the Mann Kendall Trend Analysis. For more details on individual lake trend analyses, see the individual lake reports. Criteria "-" if there is a declining trend in transparency "+" if there is no trend or an improving trend in transparency
Exotic Species	Description Species that have been introduced by human activities to a location where they do not naturally occur are termed "exotic," "nonnative," and "alien". When nonnative species cause ecological or economic problems, they are termed "invasive" or "harmful exotic species." Minnesota's natural resources are threatened by invasive species such as the zebra mussel, Eurasian watermilfoil, purple loosestrife, and curly-leaf pondweed. These species, along with new invasive species, could be easily spread within the state if citizens, businesses, and visitors don't take necessary steps to contain them (MN DNR). Criteria "-" if exotic invasive species are present "+" if no exotic invasive species are present

Geospatial Information and Mapping

Most all of the listed GIS layers are also viewable from a single source at RMB Environmental Laboratories' interactive mapping tool (http://gims.eorinc.com/pmapper/map.phtml?config=rmb). Here a user can overlay various geospatial layers to better understand the interaction and relationship of each informational data set. Cass County also has a very complete listing of geospatial information on its interactive mapping website (http://www.co.cass.mn.us/cassmnpublic/Default.aspx).

When investigating development or conservation potential of parcels within the lakeshed, individuals must consider the relationships between each land attribute. Below is a quick reference listing of available geospacial layers

Land Use / Land Cover

www.land.umn.edu

The information at the University of Minnesota shows land cover and impervious surface information. See page 6 in the individual lake report for analysis.

Soils

http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx
http://www.co.cass.mn.us/cassmnpublic/Default.aspx

It is important to understand the soil types surrounding the lake because they can affect the effectiveness and location of septic system drainfields. In addition, hydric soils can be restored to wetland conditions.

Aerial Imagery

http://www.dnr.state.mn.us/airphotos/search.html
http://gims.eorinc.com/pmapper/map.phtml?config=rmb
http://www.co.cass.mn.us/cassmnpublic/Default.aspx

Comparing aerial imagery from past to present can identify changes in land use, especially forestation and agriculture.

Topographical

http://www.dnr.state.mn.us/maps/tomo.html?x=468087.0000&y=5160799.0000&size=3&layer=24k

Topographical information is important for determining the location of escarpments, which are steep slopes adjacent to the lake. Escarpments are areas where natural vegetation is crucial for bank stabilization and prevention of erosion.

Wetland Inventory

http://www.co.cass.mn.us/cassmnpublic/Default.aspx
http://gims.eorinc.com/pmapper/map.phtml?config=rmb

Wetland protection is a critical component for the long-term protection of water quality and recharge of groundwater. Historically, wetlands were drained for various land-use practices. Today, environmental awareness and increased stewardship has lead practices to restoration. Overlaying soil, topographic, and wetland inventory GIS layers help identify areas where wetland restoration as well as protection is possible. Identifying areas with hydric soils that are not included in the wetland inventory have restoration potential. Landowners can work with the SWCD on wetland banking/restoration projects.

Parcel Information
http://gims.eorinc.com/pmapper/map.phtml?config=rmb

Parcel information can be analyzed along with other layers to see the impact that development has on sensitive lakeshore. By overlaying parcels with wetlands, soils or topographical information, one can determine areas that need special attention and protection.

Zoning Information
http://www.co.cass.mn.us/cassmnpublic/Default.aspx

Zoning information is helpful for locating areas that are available for commercial or residential development.

Land Cover

The information at the University of Minnesota shows land cover and impervious surface information. The information below describes the different land cover classes and what they include. See page 5 in the individual lake report for analysis and lakeshed map.

Land Cover Classes Key (http://land.umn.edu)

Classification categories attempt to group land cover into classes based on structure, taxonomy, or function. There can be many "levels" of complexity to a classification. The land cover classifications are all considered "level one" or fairly simple categorically.

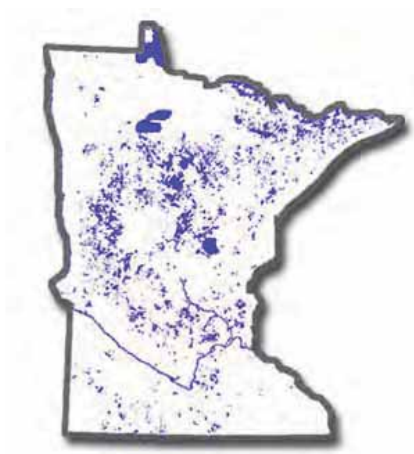
Land Cover Class	Description
Agriculture	Agricultural cropland including row crops, forage crops and small grains. Examples: corn, soybeans, alfalfa, oats, wheat, barley and sugarbeet.
Forest	Land covered with trees reaching a mature height of at least 6 feet tall with a definite crown. Examples: white pine, red pine, black spruce, fir, mixed conifer, aspen, maple, oak, and mixed deciduous.

Grassland	Golf courses, lawns, sod fields, upland areas covered by cultivated or non-cultivated herbaceous vegetation predominated by grasses, grass-like plants and forbs. Examples: pasture and dry prairie.
Shrubland	An upland or lowland area with vegetation that has woody stems, generally with several basal shoots, low growth of less than 20-feet height, and fairly uniformly distributed throughout and moderate to high density. Examples: alder, willow, buckthorn, hazel, sumac, and scrub oak.
Wetland	A lowland area with a cover of persistent and non-persistent herbaceous plants standing above the surface of wet soil or water. Examples: cattails, march grass, sedges and peat.
Water	Permanent open water, lakes, reservoirs, streams, bays and estuaries.
Urban	Residential, commercial, industrial, transportation, industrial and commercial, mixed urban or build-up land, other urban or built-up land.

Appendix II: 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.

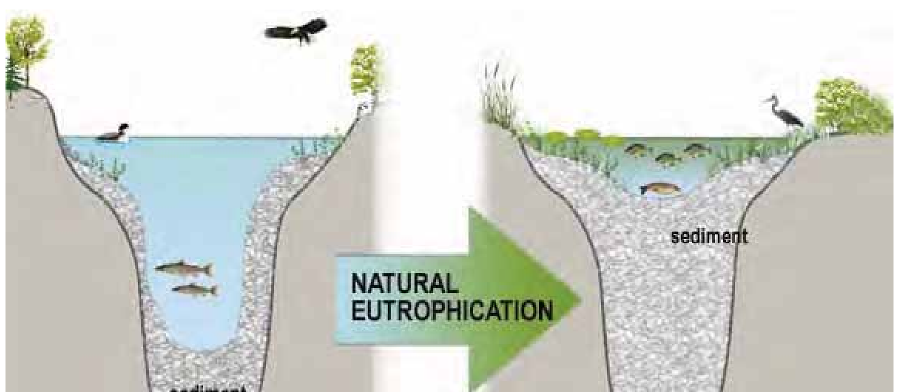
Another major factor affecting lake condition is the size of its watershed and where the lake sits within the watershed. A watershed is an area of land where all the water drains into the same river system. These watershed areas are defined by topography, or ridges of elevation. Therefore, watersheds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

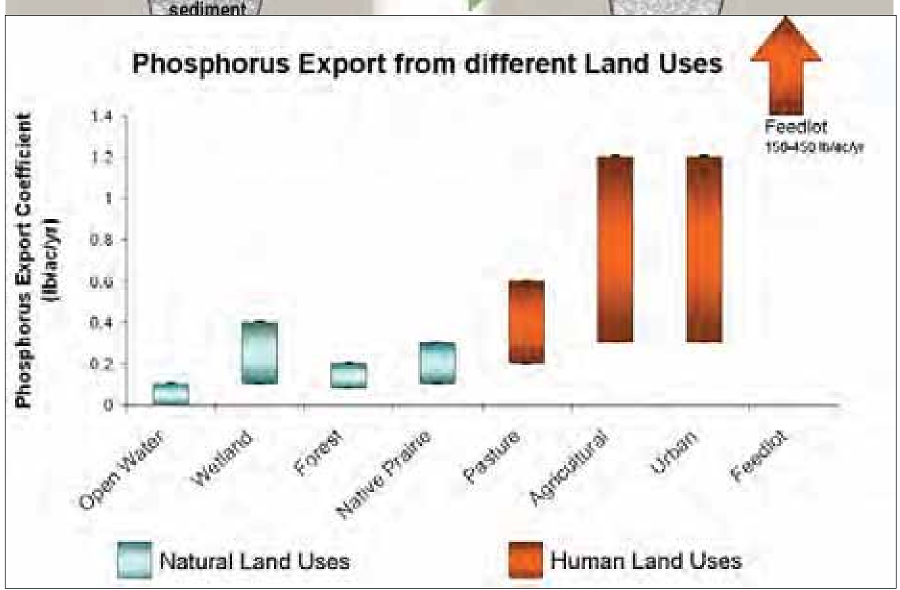
If a lake has a very small watershed or is at the top of a watershed (in topography terms), the lake usually has better water clarity than a lake at the bottom of a large watershed. As water flows downhill through a watershed it picks up sediment from erosion and nutrients from runoff. This sediment 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 III: 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)
  - Limit the use phosphorus fertilizer on lawns
  - Surface water onsite management (rain gardens, drainage, etc.)

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

Phosphorus

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

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

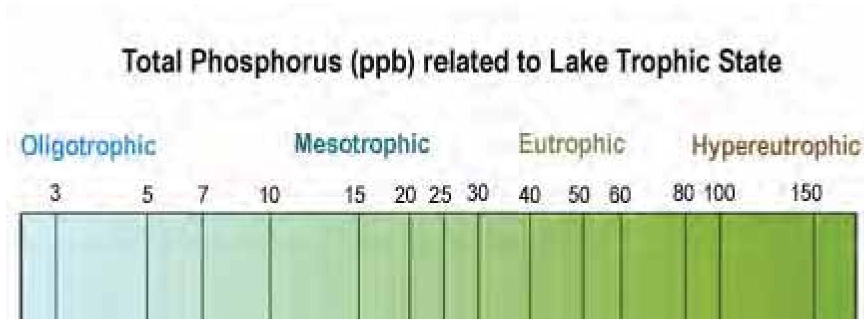
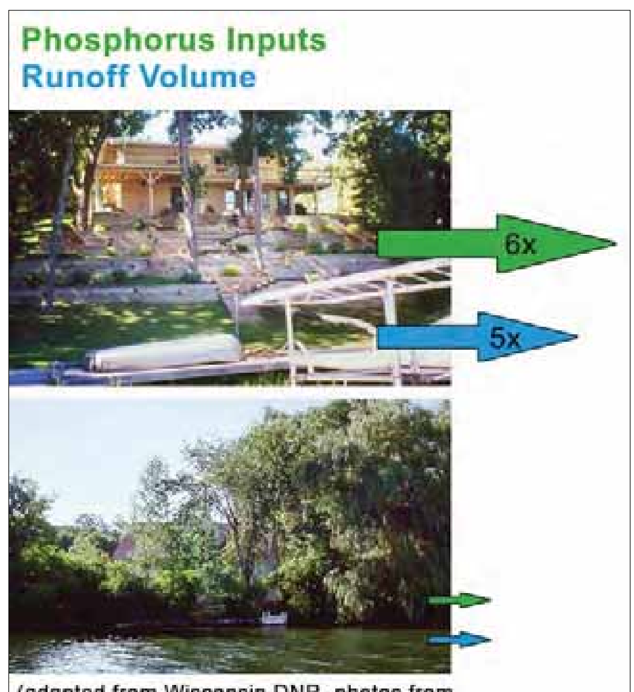


Figure 1. Phosphorus concentration (ppb) related to lake trophic state.

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

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

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



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

Figure 3. The effects of development on the amount of phosphorus and total runoff from a shoreland property. A large landscaped lot with a manicured lawn, a beach, and a retaining wall can increase

total runoff volume by 500% and the phosphorus inputs to the lake by 600% (University of Wisconsin–Extension and Wisconsin Department of Natural Resources. 2002).

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Appendix IV: 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.

Educational Summary

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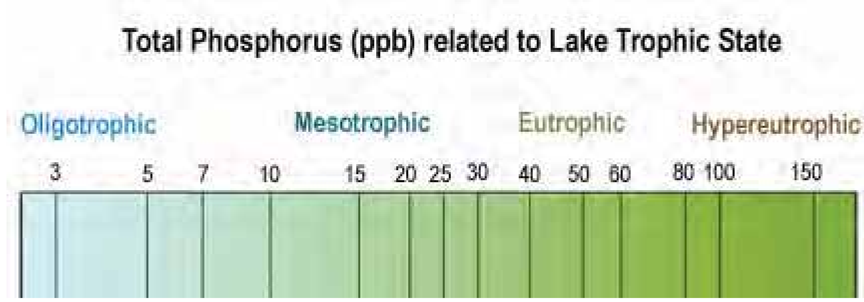

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If phosphorus inputs are decreased or eliminated, less plants and algae are able to grow and water quality can improve.

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.

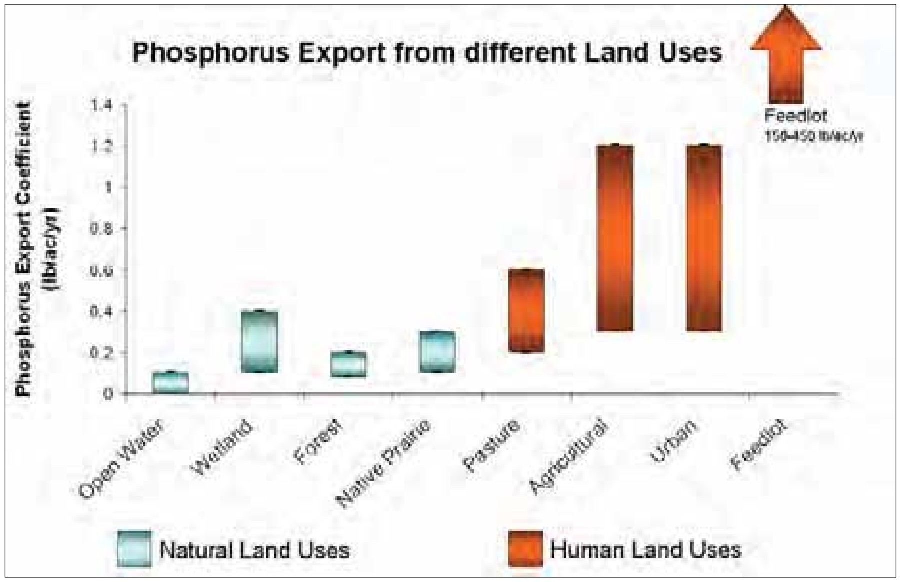
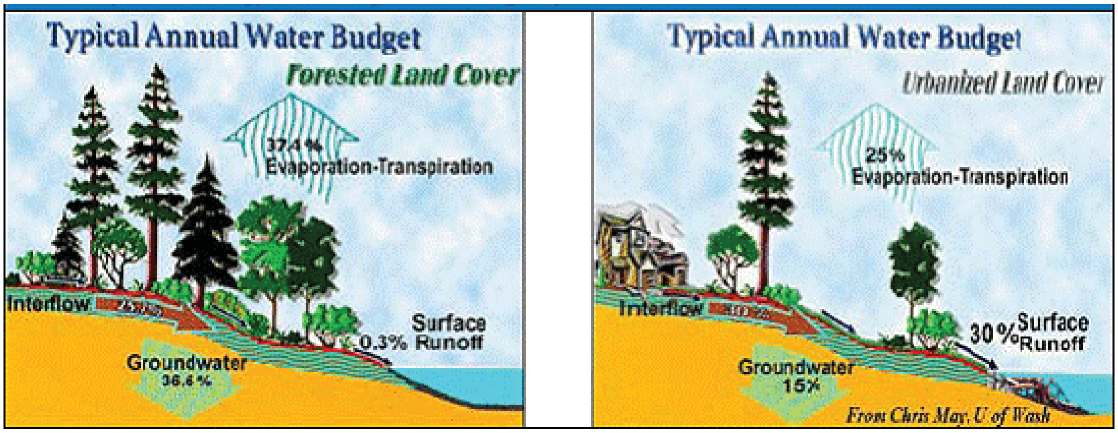


Figure 2. Phosphorus export coefficient for natural vs human land uses.

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).



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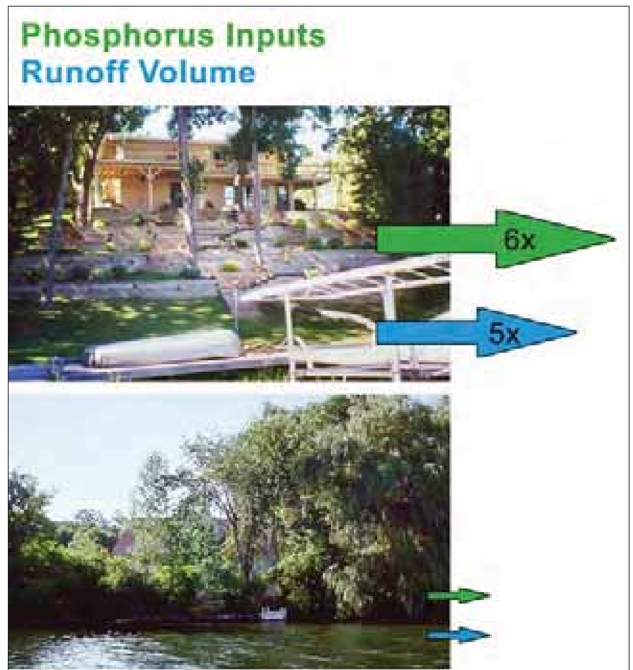

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Section IV. Historical and Current Data

AITKIN COUNTY COMPREHENSIVE LOCAL WATER MANAGEMENT PLAN

As a task force decision this portion of our third generation Water Plan was retained as a section Note: A brief history of the plan follows. This information is included so that the reader understands how and when the Water Planning Process was started, as well as who was involved. It is interesting and a little sad to remember the Task Force members who are no longer with us. Recent losses from the Task Force membership are John (Barney) Janzen and Tom Sandberg who passed away since our 1995 update. Both Barney and Tom were active and knowledgeable members and are missed.

Introduction

The first generation Comprehensive Local Water Plan started in November 1987. Prior to that date, the Mississippi Headwaters Board (MHB) applied for a grant through the Legislative Commission on Minnesota Resources (LCMR), for all of the counties within their jurisdiction. These eight counties (including Aitkin) were approved for funding to assist with the preparation of the plan. MHB Administrator Molly MacGregor, contacted the Aitkin County Board of Commissioners and the Aitkin County Soil and Water Conservation District to encourage them to formulate a Water Plan. The manager of the Soil and Water Conservation District (SWCD), Steven Hughes, was asked by the County Board of Commissioners to attend informational meetings and report to the Commissioners.

The Aitkin County SWCD then proposed to the Board of Commissioners that a plan should be formulated for Aitkin County. At that time the District volunteered to be the coordinating agency for the plan. A Resolution dated November 1987 delegated the responsibility for the plan to the SWCD with a requirement that the District report quarterly as to their progress.

District Manager Hughes, became County Project Coordinator and began organizing a committee that would serve as the Water Planning Task Force. Approximately 25 persons were contacted by letter and by telephone and asked if they would be willing to serve on the task force. A list of task force members and whom they represented is included just before the goals and objectives section of this plan.

The first task force meeting was held November 20, 1987 for the purpose of introducing the planning process to the task force members. The discussion began with a summary of the