Developing a Lake Management Plan

Prepared by the Interagency Lakes Coordinating Committee

Contributing agencies:

Minnesota Board of Water and Soil Resources
Minnesota Department of Natural Resources
Minnesota Pollution Control Agency
Minnesota Department of Agriculture

With participation by

Minnesota Lakes Association
Metropolitan Council
Hennepin Parks

August 1996

Foreward

Thank you for wanting to know how to better manage your lake. Lake management must be a collaborative process involving all interested parties —along with quite a few technical specialists— to be successful. This publication is designed to help you be successful in your lake management efforts.

"Developing a Lake Management Plan" is a companion document to the Minnesota Lake and Watershed Data Collection Manual, published by Minnesota's Environmental Quality Board Lakes Task Force. The goal of "Developing a Lake Management Plan" is to help you develop a lake management plan that has specified goals for local, county and state governmental units and organizations. It is likely that the lake management plan will become a critical tool in focusing limited public attention and resources for your lake.

Since every lake management plan demands good data on which to base sound decisions, the Data Collection Manual should be read first. Data collection should be well under way before attempting to prepare a lake management plan.

We also would appreciate your comments and suggestions on how to improve this manual, or any lake-related management services. Your input is very important to us. Please address your comments to: Chair, Minnesota Interagency Lakes Coordinating Committee, and send to any of the following:

Commissioner, Minnesota Department of Natural Resources
500 Lafayette Road
St. Paul MN 55155

Commissioner, Minnesota Pollution Control Agency
520 Lafayette Road.
St. Paul MN 55155

Executive Director, Minnesota Board of Water and Soil Resources
One West Water Street, Suite 200
St. Paul MN 55107

Commissioner, Minnesota Department of Agriculture
90 West Plato Boulevard
St. Paul MN 55107

Chair, Metropolitan Council
230 East 5th Street
St. Paul MN 55101

The Interagency Lakes Coordinating Committee (ILCC) has guided the work on this manual. The ILCC was formed by a memorandum of agreement between the Minnesota Department of Natural Resources (MDNR), the Minnesota Pollution Control Agency (MPCA), the Minnesota Board of Water and Soil Resources (BWSR), the Minnesota Department of Agriculture (MDA) and the Metropolitan Council (Met Council) in 1993 to improve the coordination of lake management and planning activities of these agencies. The Minnesota Lakes Association (MLA) has also been an active ad hoc participant in the ILCC. The ILCC formed committees to work on both the Lake and Watershed Data Collection Manual and this planning manual. In October 1994, the EQB Lakes Task Force merged with the ILCC and is continuing to implement the recommendations of the Lake Management Forum (started in 1991).

This document represents a collaborative effort among the aforementioned parties and does not necessarily reflect the policies of the individual agencies or divisions within an agency.

The committee is grateful to all the agency staff, local units of government staff and lake association members whose encouragements, hard work and support contributed to this project. The BWSR deserves special acknowledgment for their work editing and printing the document. We are hopeful that such teamwork will continue as lake management planning moves forward to protect and enhance the qualities of Minnesota lakes.

The Minnesota Interagency Lakes Coordinating Committee

August 1996

For additional copies, contact the Minnesota Board of Water and Soil Resources, One West Water Street, Suite 200, Saint Paul, MN 55107 (612) 296-3767.

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I. Introduction

Water... Lakes... Fishing... Swimming... Canoeing... Cabins.... these words bring to mind the fundamental Minnesota experience. We take the abundance and diversity of our lakes, rivers and wetlands for granted.—and with good reason: Minnesota has more than 15,000 lakes that are 10 acres or larger. More than 5,000, covering more than three million acres, are actively managed for their fisheries. Many others are used for boating, waterskiing, hunting and swimming, and just plain appreciated for their beauty.

The excitement of the walleye opener, a week-long vacation at the cabin, the solitude in the Boundary Waters Canoe Area, or the relaxation from a walk around a lake in a city park all speak to the special relationship Minnesotans have with lakes. Thanks to them, travel and tourism is our second largest industry. With 208,000 miles of shoreline, Minnesota offers more waterfronts than the states of California, Florida and Hawaii combined!

In 1986, the 28 million visitors who traveled to and through the state generated nearly $7 billion in revenues. About 73 percent were vacationers, with outdoor activities rated high on their lists of preferred activities.

Keeping our lakes clean directly relates to Minnesotans' ability to compete with regional lake centers such as northern Wisconsin, Ontario and Michigan for these related industries and income sources, which in turn contribute to local schools, roads, health programs, social services and law enforcement services and infrastructures.

Lakes cannot manage themselves.

In order to maintain these beneficial uses, lakes need help. With ever increasing recreational use and growing populations residing near and along waterways, lakes can suffer from small and large cumulative impacts and cannot manage themselves. We affect our lake by our actions within the lake, along its shorelines and well up into the lake's watershed or drainage basin. Even distant areas can be connected to the lake by the downstream flow of waters which, in turn, carry pollutants, sediments and nutrients into the lake over time. We all are part of the problem, but we all can do something, no matter how apparently insignificant (e.g., recycling of household materials), to help our lakes. Lakes need to be systematically and purposefully managed over time if we are to sustain their long-term health and viability.

II. Planning: a model framework for lake management plans

Lake management plans help protect natural resource systems, including the water quality of the lake and the associated fish, vegetative and wildlife communities. A lake management plan:

- Encourages partnerships between concerned citizens, including lakeshore owners, watershed residents, resource management agencies and special interest groups.
- Identifies the concerns that the people feel are important to address.
- Sets realistic goals, objectives and actions.
- Identifies needed funds and personnel.

The planning process starts with the formation of a citizen steering committee that organizes a lake management planning advisory group, with membership from all legitimate lake and watershed groups.

Lake management planning must include members representing diverse interests and perspectives to reduce the risk of failing. The activities of the citizen steering committee require that its members have the time to dedicate to make the effort successful; many groups have formal rules of attendance for voting and participation.

The typical lake management steering committee member may need to dedicate one to three years (or more) toward the effort. Attending meetings once or twice a month is an important aspect of being a steering committee member.

A. Getting Started

Appoint a citizen steering committee.

The job of the steering committee is to define the citizen advisory group's concerns, to educate themselves and the larger community on the sources and dimensions of the concerns, and to identify, study and recommend possible solutions. The work of the steering committee must be fair, objective and impartial for it to be accepted and put into action by the larger community.

The size of the steering committee may vary, but it needs to be workable. Include representatives appointed from local and county governments. Designate a chairperson who is well respected by diverse groups and able to forge partnerships. The committee should choose when and where it will meet. It is a good idea to set target completion dates for committee work so that there is a defined time commitment for members. In addition, a separate technical committee may be established to advise the steering committee.

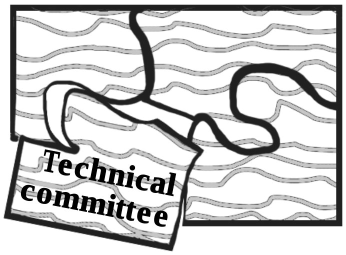
Form an advisory group.

Identify the parties interested in the management of the lake and the lake's watershed. Invite all legitimate groups with an interest in the lake resource to participate in a citizen advisory group. It is particularly important to include people or organizations that may not believe there is a need to develop a lake management plan.

While it may make initial contacts or meetings more difficult, considering all sides will lead to better solutions and implementation. Excluding some interests and viewpoints may lead to a future sabotage of the plan and can keep good resources or ideas away.

Assemble a technical committee.

Formally request assistance from local, regional, state and federal governmental groups to appoint staff to a technical committee. The technical committee will advise and assist the steering committee on all technical issues.



Suggested contacts for technical assistance

State Agencies such as MPCA and MDNR regularly collect information on water quality, fish populations and other natural resources. Contact your area or regional office.

Local Units of Government (LGUs) including counties, soil and water conservation districts and watershed districts, may also collect land and watershed information and have land use, ownership and tax information.

Successful Steering Committees

Focus on the concerns identified, rather than assigning blame.

Resolve from the beginning to work toward common goals and understanding.

Are willing to set aside differences while working on areas where solutions seem possible.

Treat all members of the committee with respect.

Recognize that resource damage of the past and present are often unintentional, and often result from lack of knowledge or information.

Work for consensus, so that everyone will be committed to the actions proposed.

Make field trips and site visits to clarify problems and solutions and increase team cohesion.

Focus on specific, constructive actions that work, not on global environmental problems.

Know that nothing inspires people like success— they get a few decisions made as soon as possible.

Have some fun—and appreciate the contributions of all involved in a tangible way.

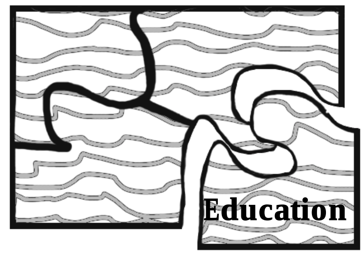
Local lake associations and volunteers.

Federal Agencies such as the Natural Resources Conservation Service (NRCS).

Private consulting services and commercial enterprises.

Educate the steering committee.

Effective planning starts with an understanding of the technical, social, economic and demographic factors influencing a lake. Understanding the historical and current conditions, along with projected future conditions, will also help establish effective goals and objectives and identify the appropriate actions to address the interest group's concerns.



Review all pertinent **resource plans** before beginning to develop a lake management plan. These plans will provide some of the data needed, andy may identify goals, objectives and actions appropriate for the lake. Resource plans include, but are not limited to,

- ✓ local land use plans (zoning controls);
- ✓ comprehensive local water management plan;
- ✓ lake assessment studies;
- ✓ MDNR fisheries management plans;
- ✓ watershed district plans; and
- ✓ soil and water conservation district comprehensive plans.

(Please refer to appendix A for information on how to contact local County Water Planners, DNR Area Fisheries and Area Wildlife Offices, and MPCA state and regional offices.)

Plan on the education phase extending over a six- to 12-month period. Mandatory attendance at the educational meetings is necessary in order to effectively identify the challenges and opportunities to be addressed by a lake management plan**.**

B. Gather Information

Lake management planning entails gathering data about the lake and the watershed, including the physical features, land use and social trends. Please refer to *The Minnesota Lake and Watershed Data Collection Manual* for specific instructions on gathering information. Important data typically includes:

1. Physical, chemical and biological characteristics

a. Delineate the watershed boundary. Calculate the watershed to lake surface area.

b. Identify the watercourses within the watershed. Include streams, drainage ditches, tile lines and city storm water or sewer lines that drain into and out of the lake.

c. Identify the soil types and slopes within the watershed.

d. Identify the lake size, depth, bottom contours, structures and surrounding groundwater levels.

e. Identify fish populations.

f. Identify the aquatic vegetation.

g. Identify exotic plant species within the watershed.

h. Identify endangered, threatened or rare plants, animals or natural communities (see *Reference Section–Other* for information on requesting data from the Minnesota Department of Natural Resources).

2. Land use characteristics

a. Historical: Determine the presettlement drainage patterns, wetlands and vegetation.

b. Current: Identify areas where presettlement conditions still exist. Identify agricultural lands, urban and residential lands and recreation lands, and any other pertinent uses.

c. Future: It is important to plan for activities that are likely to develop in the future.

3. Social and demographic trends

Look at the economic activities taking place within the watershed and consider how they can be sustained, or even improved, with successful lake and watershed management. Also learn about the attitudes of people living in (or using the resources of) the lake's watershed. Do the majority perceive a resource problem? What is the present and projected population of the watershed, and where is it concentrated?

C. Identify concerns, set priorities.

Most efforts to improve the quality of a lake begin with an identified concern or problem. These concerns must be articulated as clearly as possible to motivate citizens to take the actions needed.

Have the advisory group members identify and list all concerns regarding the watershed's natural resources and economic trends that have an impact on quality or use.

Following are examples of concerns that can be identified through a survey. The number in the parenthesis indicates how often the concern was identified by the 108 stakeholders surveyed:

Fish harvest has been declining over the last decade (42).

The lake is frequently covered with scum (32).

The watershed is contributing large amounts of nutrients and sediment to the lake (24).

Private septic systems are a problem (20).

Jet skis are ruining the lake (17).

Farmers in the watershed must be able to make a living (12).

Have the advisory group members **assess and prioritize the concerns.** Use criteria such as:

Is the group able to change the situation?

Is the group motivated enough to address the concerns?

Will the costs outweigh the benefits?

Use the inventory information to determine the critical areas in need of management. Target the management efforts to the areas that will benefit the most and where the group's input will make the biggest difference.

After the concerns have been identified and prioritized, **develop a vision statement.**

Sample vision statement:
The natural watershed process and functions are being restored to reduce nutrient and sediment loads delivered to Great Lake by at least 60 percent. The health and quantity of aquatic plant community in the lake are good and getting better and covers 75 percent of the lake shoreline. The lake is attracting anglers and other water recreational activities.

D. Develop goals, objectives and actions

Once the problems are identified and prioritized, set goals and objectives to address the high priority problems. Finally, identify actions to achieve the goals and objectives. Staff and budget constraints may affect the number of goals established for the lake management plan.

1. Establish goals, objectives and actions.

a. Goals are general statements relating to what the group hopes to accomplish over the long term. They are achievable.

Examples: Protect and improve the water quality of Great Lake by reducing the nonpoint pollution entering the lake from the watershed.

Reduce in-lake phosphorous concentrations.

b. Objectives convey what the group hopes to accomplish in the near term to make progress toward the goal. They are specific and measurable.

Examples: By the year 2000, nutrient and sedimentation delivery rates to Great Lake will be reduced by 40 to 60 percent from current levels.

By the year 2004, the in-lake phosphorous level will be reduced to 30µg/ (+/- 10µg/l.)

c. Actions are the specific steps that will be taken to accomplish the objective. They are realistic and results-oriented.

Examples:

1. Identify land parcels in the watershed where the estimated erosion rate annually exceeds twice the tolerable soil loss limit (T).

2. Identify land parcels adjacent to streams and tributaries where erosion exceeds the tolerable soil 2. loss limit.

3. Identify the owners of the parcels identified in actions 1 and 2.

4. Develop farm management plans on 80 percent of the acres identified in action 1.

5. Implement best management practices (for water quality) to control erosion within T on 75 percent of the acres planned.

6. Retire 75 percent of the acres identified in actions 1 and 2 from row-crop production.

7. Develop grazing management plans for all acres identified in actions 1 and 2 that are being pastured or will be converted to pasture land.

8. Identify steep slopes and bluffs and any known erosion problems.

9. Identify areas unsuitable for development and work with the county planning and zoning office to restrict development of these areas.

10. Inventory existing septic systems on shoreland property.

11. Identify existing shoreland development by types (e.g., permanent residence, seasonal residence, business, etc . . .).

E. Implementing and monitoring progress

Prioritize actions based on the likelihood that they can be accomplished within the specified timeframe, and their importance in achieving identified objectives.

Identify who is responsible for coordinating and completing each action. Include the timeframe for completion and the estimated cost for the action.

Seek and secure required funds.

Determine appropriate measurements to use to monitor progress.

Report progress that has been made to the interested parties identified in section I of this outline.

Frequently review and update the lake management plan.

III. Overview: factors influencing lake management

A. Regional patterns

Minnesota brings to mind pristine lakes inhabited by loons, bountiful populations of walleyes and canoe-traveling visitors, but this picture does not reflect the natural variability of lakes found across the state. They range from the cold, deep waters of the northern boreal forest to the warm, shallow lakes of the southwest prairies. The northeast region's rocky landscape, nutrient-poor soils, forest cover and frequent rainfall have resulted in lakes with clear water, while the lakes of southern Minnesota have evolved in nutrient-rich soils. These southern lakes receive considerably less rainfall than their northern counterparts and are often murky.

Recognition of regional patterns and limitations helps put the characteristics and conditions in a particular lake and watershed into perspective. More than 30 years of monitoring by state agencies and citizen volunteers gives us a good understanding of the regional patterns in Minnesota's lake water quality. Seven ecoregions have been identified in the state based upon land use, soils, geology and natural vegetation patterns. Four of the seven ecoregions include 98 percent of the state's lakes (see below: Northern Lakes and Forests (NLF); North Central Hardwood Forests (NCHF); Northern Glaciated Plains (NGP) and the Western Corn Belt Plains (WCBP).

Minnesota's ecoregions

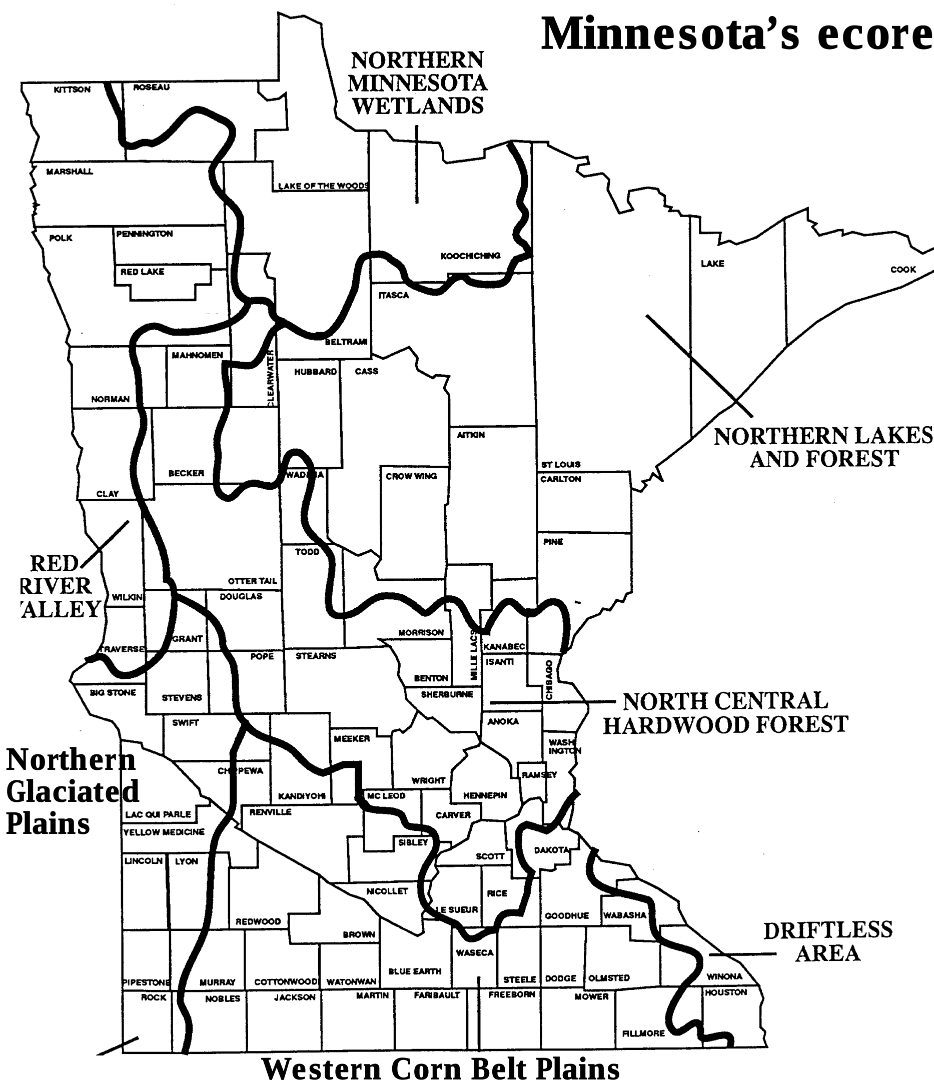


Table 1: Land use patterns by ecoregion. Percent of 40 acre parcels with land use characteristics. Based on 1968-1969 land use data from the State Planning Information Center.

Land Use	%NLF	%NCHF	%WCBP	%NGP
Cultivated	4.6	49.3	82.9	83.7
Forested	75.2	15.9	3.5	0.7
Water and Marsh	10.6	8.1	1.7	2.9
Pasture and Open	7.3	21.4	10.0	11.4
Developed	1.9	5.2	1.8	1.2

Developed by Heiskary and Wilson (1989; 1990)

Soils, geology, land cover, the intensity of land use and other factors determine the amount of sediments and nutrients lost in runoff waters per acre of land. Forested and wetland areas generally retain sediments and nutrients quite well. In contrast, urban and agricultural areas can have the greatest loss rates unless reasonable corrective measures are established. Looking at broad ecoregion areas, the loss rate of phosphorous varies from about 0.1 kilogram phosphorus per hectare per year (or about 0.1 pounds per acre per year) in the NLF to about 0.8 kilogram per hectare per year (or about 0.7 per acre per year) in the WCBP. The impact of these loss rates on a lake can be considerable, as one pound of phosphorous can generate up to 300 or more pounds of aquatic plants within the lake basin. Excessive plant and algae growths (the small microscopic plants that can color water green) are generally a primary focus of lake user complaints and concerns.

B. The lake-watershed connection

Lakes are simply depressions in the landscape that are continually filled with water from melting snow or rainfall and groundwater. These depressions were created through glaciation from the last ice-age.

The water quality of a lake depends largely on the conditions and dynamics of the watershed. Every watershed is unique and several factors interact to define a lake basin's characteristics.

Watershed Size

In the simplest terms a watershed can be defined as the area of land that drains into a lake or river. One of the very first steps in lake management planning is to understand the relative size and characteristics of the watershed. The *Minnesota Lake and Watershed Data Collection Manual* provides information on watershed delineation.

The following terminology is often used when describing various watershed management units:

Watershed Mgmt Unit	size range (approx.)
Catchment	0.5 - 1 sq. mi.
Sub-watershed	1 - 10 sq. mi.
Watershed	10 - 100 sq. mi.
Sub-basin	100 - 1,000 sq.mi.
Basin	1,000 - 10,000 sq. mi.

Most local watershed planning is done at the sub-watershed and watershed level.

Watershed hydrology

The hydrology of a watershed is defined as the route the precipitation takes on its way to the lake. Some precipitation will fall directly on the lake surface, some will runoff the adjacent land surface into the lake and some infiltrates into the land surface recharging the groundwater. As water flows over the surface of the land or beneath the ground it can pick up nutrients, minerals and organic matter and deliver them to the lake where they will influence the lake's characteristics. A basic understanding of the watershed's hydrology is important to lake management because modifications in the watershed, such as farming, development, draining of wetlands and the loss of forests can increase how much and how fast water reaches the lake. Increases in either the rate or quantity of surface water runoff can escalate the transport and delivery of sediment and attached nutrients to the lake, and can increase flooding and erosion of streambanks along watercourses flowing to the lake.

Many factors influence watershed hydrology, including the physical characteristics described below—precipitation, soils and the use of the land. Layers of sand, gravel and clay deposited by glaciers created the groundwater flow patterns that affect lakes. Depending on the patterns and the climate, a lake may either receive water from or discharge water into the groundwater system.

Precipitation

The frequency, intensity and time of year that rainfall or snowmelt events normally occur within a watershed will influence the lake. Precipitation has the ability to detach soil particles (sediment) and transport them to a receiving water body.

The potential for precipitation to cause soil erosion and to transport pollutants to a lake depends on the land use, and on rainfall—when, how much and how intense it is. Precipitation is very different, depending on where you are in Minnesota. Total precipitation varies from a low of 20 inches/year in northwestern Minnesota to a high of 32 inches/year in southeastern Minnesota. The average annual surface runoff is greatest in southern and southeastern Minnesota and the lowest in northwest and west-central Minnesota along the border with the Dakotas. Generally, the potential for raindrops to erode soil and transport the sediment and attached pollutants to a lake is greater in southern and eastern Minnesota than in northern and western Minnesota.

Soils

Understanding soil types found in the watershed is important, because they influence surface water runoff, both how much gets to the lake, and its quality. Soils in Minnesota fall into two broad groups: mineral and organic. Mineral soils are made up of varying ratios of sand, silt and clay particles. Soils made primarily of sand absorb precipitation quickly and are naturally low in available phosphorus and nitrogen. In contrast, soils made of primarily silt and clay generally have lower absorption rates and are generally high in available phosphorus and nitrogen.

Organic soils are made up of more than 50 percent organic materials, such as peat. Generally, they are not subject to erosion by water because of their position in the landscape (swales) and their high water holding capacity. The tannic acid produced by some organic soils can make the water appear brown or stained.

A basic understanding of soils helps target watershed protection programs to sites that will maximize available resources. For example, if there are two subwatersheds of similar size, it may be wise to target soil erosion control practices to the one with a high percentage of silt and clay, because these soils will have a higher potential to negatively impact the lake.

Landscape Features

Features on the landscape, both natural and resulting from human activity, greatly influence the characteristics of a lake. Converting land from its natural vegetation state (prairie, wetlands or forest) to cropland or urban uses almost always increases surface water runoff. Surface runoff from cropland and urban land often has nutrients (such as phosphorous) and toxins (such as pesticides) attached to the sediment. If natural filters such as wetlands are not present on the landscape, the sediment and pollutants can be transported to the lake.

The concentration of the nutrients from fertilizer on cropland or urban land depends on many factors, including the application method, the time of application in relation to rainfall and the solubility of the nutrients. Animal feedlots, pastures and home septic systems can also add nutrients to the lake. The sediment itself can degrade fish habitat and threaten plantlife.

Lakes that are hydrologically connected to other lakes and large open-water wetlands often have unique characteristics that must be acknowledged when developing a lake management plan. For instance, if water entering a lake has flowed through other water bodies, the land use practices and in-lake water chemistry in the upstream lake(s) or wetland(s) will affect the target lake.

Modifications to the natural hydrology, such as the construction of ditches and storm sewers, can significantly alter the rate and quantity of surface water runoff. If either the rate, quantity or quality of surface water runoff from a lake's contributing watershed is determined to be a problem, understanding the watershed hydrology will be the first step in identifying appropriate goals and objectives in the lake management plan.

C. Lake water quality monitoring and assessment

Measuring the lake's chemical, biological and physical composition is essential to understanding how the lake works and to identifying appropriate lake management options. Initial measurements will establish parameters that can characterize the trophic* status and overall ecology of the lake.

The *Minnesota Lake and Watershed Data Collection Manual* provides detailed information on what needs to be collected, along with how to collect it.

1. Common lake sampling procedures

A good way to gather lake water quality data is to sample surface water parameters on five to 10 occasions from May to September. Collect samples at one or more preselected mid-lake locations. Lakes with distinct bays need more sampling sites than round ones. Given the considerable differences in summer weather dry to wet patterns, it will take a minimum of three to five years of data collection to be able to statistically define "average" conditions.

The parameters most often used to describe the trophic status of a lake are total phosphorus, Secchi transparency and chlorophyll-a. Since concentrations of total phosphorus and chlorophyll-a are usually expressed in parts-per-billion ranges (µg/L), analytical labs must be equipped to accurately measure these extremely small concentrations.

As land uses vary by ecoregion, so do lake water quality patterns (table 2). There are distinct differences in water quality between ecoregions. Average regional concentrations of total lake phosphorus vary from 24 µg/L in the Northern Lakes and Forests ecoregion to more than 100 µg/L in the Western Corn Belt Plains and the Northern Glaciated Plains ecoregions. Ranges in algae (chlorophyll-a) and transparency followed the same pattern.

2. Common stream sampling procedures

Since lake water quality depends on the volume and quality of the waters it receives from its watershed, inflowing streams must also be sampled. Usual time periods are sometime in March through November. The point is to gauge stream flows with either a staff gauge, a metal yard stick or a continuous recording device such as a small computer (these cost about $1,500 to $2,500 per installation). Streams are then sampled by hand, called "grab samples," or by sophisticated automated samplers that require professional installation and cost $3,000 or more.

Generally, smaller watersheds need to rely more on automated sampling, because surface water runoff tends to peak quickly and is of very short duration. Typically, at least 15 total phosphorus measurements per station per year are needed to reasonably define phosphorus concentrations along with a continuous record of daily average flows. Other core parameters needed include total suspended solids and total nitrogen. Analytical laboratories must be able to accurately detected low concentrations of these parameters.

Similar to lakes, distinct differences in average concentrations have been noted by ecoregion for streams. Average regional concentrations of total phosphorus varied

Table 2: Summer mean lake water quality measures by ecoregion with interquartile in the parenthesis (i.e., 25th and 75th percentile)

Factor Considered	NLF	NCHF	WCBP	NGP
Total Phosphorus (µg/L)	24 (16-33)	60 (35-118)	135 (97-220)	179 (140-404)
Secchi Transparency (feet)	8.9 (5.9-12.8)	4.6 (2.6-7.2)	1.6 (1-3)	2.0 (1-4)
Transparency noted for swimming impaired (feet)	< 6.7	< 5.0	< 3.3	< 3.3

Developed by Heiskary and Wilson (1989; 1990)

* *"Trophic status" refers to the nutrients in the lake—what kind and how much.*

Table 3: Average annual stream quality measures in parts per billion (μg/L) by ecoregion with general middle ranges in the parenthesis (i.e., 25th and 75th percentile)

Factor Considered	NLF	NCHF	WCBP	NGP
Total Phosphorus (μg/L)	40 (20-50)	90 (60-150)	240 (160-330)	160 (90-250)
Total Suspended Solids	3,300 (1,800-6,000)	8,800 (4,800-16,000)	27,000 (10,000-61,000)	34,000 (11,000-63,000)
Nitrate+Nitrite Nitrogen	30 (10-90)	100 (40-260)	3,900 (1,400-7,400)	140 (10-510)

Developed by McCollor and Heisary (1993)

from 40 μg/L in the Northern Lakes and Forests to more than 240 μg/L in the Western Corn Belt Plains. There were similar increases over the ecoregions for total suspended solids and nitrate+nitrite nitrogen as well as depicted in table 3.

3. Fish community structure as an indicator of water quality

The fish community can also be a reliable indicator of water quality (Schupp and Wilson, 1993). Trout have the most critical requirements for good water quality. They need well-oxygenated water and prefer temperatures of 50 to 65 degrees Fahrenheit. Oxygen must be present below the thermocline in midsummer—a condition usually found only in oligotrophic lakes and occasionally in some mesotrophic lakes.

The closely related whitefish and cisco (tullibee) are more widespread than trout and more tolerant of higher temperatures. These two species are often found in high numbers in mesotrophic waters (see Carlson Tropic Status Index, Appendix B).

Most members of the sunfish family also reach their highest abundance in clear, clean waters. Where small- or largemouth bass, rock bass, bluegill and pumpkinseed sunfish are common, the lake is likely to be in good condition. Of these, sunfish, smallmouth and rock bass are usually associated with the highest quality.

Two other members of the sunfish family, the black and white crappie, are more tolerant of a wide range of conditions. Both reach higher abundances in turbid water than in clear water. However, the presence of black crappies should not be taken as a sign of poor water quality.

Walleye reach their highest abundance in large, mesotrophic lakes. These lakes frequently have relatively moderate to low water clarity, have few rooted aquatic plants and phosphorus that can lead to algal blooms. Walleye usually do not do well in small lakes with clear water, the kind favored by bluegill and largemouth bass.

Trout have the most critical requirements for good water quality...

Northern pike and yellow perch are the most widespread species in Minnesota. Northern pike are generally more abundant in clear water because vision is an important factor for feeding pike. The highest perch populations are usually found in mesotrophic waters and are associated with walleye. Perch are more tolerant of extremes in trophic state than the walleye.

...perhaps the best fish indicators of water quality are yellow and black bullheads.

Perhaps the best fish indicators of water quality are two of the three bullhead species found in Minnesota: yellow and black bullheads. Yellow bullheads are found in the highest numbers in lakes with clear water. In contrast, black bullheads reach their greatest abundance in very turbid, eutrophic waters. Where both species are present, the ratio of black to yellow bullheads can serve as an additional indicator of water quality. In moderately eutrophic lakes, black bullheads outnumber yellow five to one. A ratio of two black bullheads to one yellow is about normal for a mesotrophic lake and in very clear water yellow bullheads usually outnumber black bullheads. (Appendix B contains several graphs that ilustrate the above information.)

IV. Lake management focus areas

A. Water quality

The water quality of a lake is often the focus of citizen concerns because it is directly related to recreation, fisheries, aquatic vegetation and surface water uses. It is often a good place to begin when setting lake management goals and objectives.

The primary agency responsible for managing the water quality of Minnesota Lakes is the **Minnesota Pollution Control Agency**. The MPCA provides:

(1*) statewide monitoring and characterization of quality* - diagnostic and problem assessments. For example, the statewide lake monitoring effort works cooperatively with numerous agencies and hundreds of volunteers (the Citizens Lake Monitoring and the Lake Assessment Programs) to characterize the water quality of about 2,000 of the state's lakes.

(2) *regulatory controls* for point and nonpoint sources of pollution. Regulation involves continual refinement of performance standards for industries, municipalities, individiual sewage treatment systems, feedlots and other areas to prevent, control or abate water pollution as defined by state and federal laws.

(3) *agreements, grants and loans* for prevention and control of water pollution sources. Grants and loan programs play in an important role in improving our water resources. Since 1988, the Clean Water Partnership grant and loan program has awarded $7.34 million in investigation and remediation grants and $12 million in loan projects (septic tanks, alum treatments etc.) to about 47 different lake, stream and ground water projects.

(4) *technical assistance, education and technology transfer* for the control of point and nonpoint sources of pollution. The MPCA also offers extensive technical assistance to local units of government, citizen groups, local steering committees, and other resource management groups and agencies ranging from the Lake Assessment Program to acid rain and heavy metal pollution remediation to watershed corrective actions in the Clean Water Partnership with local units and citizen groups. Assistance with the preparation of lake management plans is provided from the MPCA's five regional and St. Paul offices (see Appendix A for locations and phone numbers.)

Include water quality goals in the lake management plan.

Lake management plans should establish specific short- and long-term numeric indicators of desired water quality. These will be performance goals against which actual water quality can be assessed. It is essential to collect water quality data as directed in the *Minnesota Lake Data Collection Manual.* The measured average summer total phosphorus and Secchi transparency can then be compared against "benchmark" in-lake ecoregion values, with due consideration by the Technical Committee to factors such as mean depth and water flow-through volumes.

Lake water quality goals are usually aimed at either protecting the current desired uses or improving the lake through a combination of watershed best management practices and lake conditions rehabilitation techniques. Protecting current uses has often been addressed through goals such as "maintain the lake's existing water quality, allowing for reasonable year-to-year variabilities caused by climate." Such a goal can be reinforced with numeric objectives such as an average summer Secchi transparency and the measured variability. It is normal to see fluctuation of the long-term average transparency of plus or minus 20 percent (for an example average summer transparency goal of 5.5 feet +/- 1.1 feet).

Lake water quality goals are usually aimed at either protecting the current desired uses or improving the lake.

Goals for improving water quality are often identified where there is measured or perceived deterioration of water quality. Steering committees may wish to adopt short- and long-term objectives of for water quality tied to specific watershed corrective actions. The approach is to fix what can be reasonably fixed and then to monitor in-lake water quality progress against the benchmarks. (See appendix C for water quality benchmarks and phosphorus criteria based on ecoregion.) In general, reservoirs (lakes with very large watersheds) or shallower lakes (less than about 35 feet maximum depth), may be expected to have greater nutrient concentrations and lower transparencies.

Case Study: Lake Shaokatan Restoration Project

Lake Shaokatan is a shallow prairie lake in west central Lincoln County, Minnesota. Its water quality deteriorated severely in the 1980s due to excessive nutrient loading associated with watershed land use practices. Nuisance algal blooms dominated the open water season and had occasionally produced algal toxins resulting in the death of dogs and cattle. An extensive data gathering effort began in 1991to understand watershed nutrient loading and lake response dynamics.

Through the use of seven state-of-the-art stream measurement sites, water and mass loading estimates were obtained and lake system balances determined. The basic approach was to manage the lake water quality by determining and managing the lake nutrient budget to achieve an average in a lake total phosphorus goal of 90 µg/L (as suggested by the ecoregion information summary in Appendix C).

Lake Shaokatan has a surface area of 1,018 acres and a mean depth of 7.3 feet and receives water from an 8,054-acre watershed. A Clean Water Partnership project begun in 1990 found extremely elevated total phosphorus (average summer value of 270 µg/L). Chlorophyll-a concentrations were episodic with concentrations noted to exceed 100 µg/L with summer means of 20-30 µg/L.

After completion of the monitoring effort, a detailed watershed restoration program was initiated in late 1991, consisting of:

a) Diversion of a stream away from a swine operation;
b) Rehabilitation of the feedlot impacted wetland;
c) Buy out of a swine operation and elimination of this as a nutrient source to the lake;
d) Upgrading of another dairy feedlot operation;
e) Upgrading of shoreline septic systems; and
f) Rehabilitating four wetland complexes in the watershed.

These implementation actions resulted in excess of a 58 percent reduction in phosphorus loading to the lake costing about $3 to $11 per kilogram of reduced phosphorus. All actions had been implemented by late 1995.

In-lake response to these steps was immediate. Significant as stream nutrient and sediment losses to the lake were reduced by about 90 percent. Concurrently measured average summer total phosphorus concentrations were noted to drop from 270 to 89 µg/L by 1994. There was an increase in 1995 to 160 µg/L due to internal recycling of P within the lake, which is believed to have been a short-term event resulting from large changes that have occurred in this system. Concurrently, there has been measured a reduction in the intensity and duration of seasonal algal blooms with all values less than 20 µg/L. These trends are expected to continue as the Yellow Medicine River Watershed District and the local management groups continue to implement additional watershed actions.

B. Fisheries

Sportfishing is a vital part of the economy and the overall quality of life enjoyed in Minnesota. Each year, two million anglers take to the water in pursuit of their favorite species. The 1991 National Survey of Fishing, Hunting and Wildlife-Associated Recreation estimated that sportfishing contributes $846 million to the state’s economy annually (United States Fish and Wildlife Service, 1991). Wise management of our aquatic resources is essential to sustaining our rich sportfishing heritage and the quality of life in Minnesota.

The best way to protect and improve fish populations is to protect and improve fish habitats.

The primary agency responsible for managing Minnesota’s fish resources is the **Minnesota Department of Natural Resources, Fisheries Section**. There are 28 area fisheries offices and six regional offices located in outstate Minnesota (see appendix A for locations and phone numbers). Area fisheries managers can provide a wealth of information pertaining to relative fish populations and historical lake information. Each year the MDNR Fisheries Section conducts 500 - 600 fisheries lake surveys. The survey data is used, along with angler input, to prepare formalized fisheries management plans for individual waters.

Consider fisheries in a lake management plan.

The goal of fisheries management is to protect and restore of fish habitats. The DNR guidelines for preparing a fisheries management plan include *Fisheries Management Planning Guide for Streams and Rivers* and the *Lake Management Planning Guide* (see reference section). Area fish managers work closely with individual lake associations when developing fish management plans.

First an **inventory** of the fishery resources and aquatic habitats is conducted. Then the fisheries manager, in consultation with established groups interested in the management of the lake (e.g., lake association), develops realistic **management goals**. These goals are based on the inventory data, historical information and the ecological potential of the lake or stream. Then an **operational plan** is developed that identifies the actions that will be taken to achieve the management goals identified. Actions may include such things as habitat protection and improvement, stocking, experimental regulations or public access development. Finally, the management goals and operations plan are **evaluated** to determine if they need to be adjusted to build upon what has been learned. For example, evaluation of fish stocking in Minnesota has provided insight about its success in different types of lakes. Fisheries management is a dynamic process that must be continually evaluated and refined.

Fish management plan:
- ✓ **Inventory resources**
- ✓ **Set goals**
- ✓ **Identify actions**
- ✓ **Evaluate plan**

Associations, clubs and local units of government have many avenues to participate in fisheries management. Sharing your interests and concerns with the fisheries manager is important in the development of the fisheries management plan. Consulting with the area fisheries manager will help target the most important fish-related activates to undertake.

Some examples of fish management related activities include:

Inventory. Angler information on fish populations can be important in understanding the status of a population. For example, angler diaries can provide valuable information on muskellunge and largemouth bass populations.

Habitat protection/restoration. This is the primary area where the long-term health of fish communities can be ensured. Groups that fully implement strategies to improve water quality will aid fish habitat protection. Critical shorelines can be protected or restored through good landowner management or public ownership. Other activities include aquatic plant restoration, aeration of winterkill-prone lakes, and removal of dams that limit fish access to important habitats.

Stocking. When the fisheries manager determines that stocking is necessary, groups can help with cost-sharing rearing pond expenses, forage costs or equipment needs.

Regulations. Support of regulations to improve fishing quality is critical to the success of maintaining good fishing. This includes limiting the introduction of exotic species that may harm fish habitats (see Exotic Species).

Contact the DNR Area Fisheries Manager for an example of a fish management plan.

C. Aquatic Vegetation

Rooted aquatic plants are a natural part of most lake communities and provide many benefits to fish, wildlife and people. They are one of the primary producers in the aquatic food chain, converting the basic chemical nutrients in the water and soil into plant matter that becomes food for other aquatic and terrestrial life.

Aquatic plants have many other important functions, including:

improving **water quality** by trapping nutrients;

protecting **shorelines and lake bottoms** by decreasing wave action; and

improving **aesthetics** by adding to the biodiversity of the lakeshore.

While aquatic plants perform these important functions, they can also interfere with various uses of the lake if their growth is profuse. Control of aquatic plants is appropriate when reasonable access to, and the use of the water is impeded.

Aquatic plant management is defined as those activities intended to alter an aquatic plant community, either to reduce or increase the abundance of plants in a specified area (e.g., through harvesting or planting).

Generally, the aquatic vegetation section of a lake management plan becomes more important as the lake's shoreline becomes heavily developed.

A strategy for lake-wide management of aquatic plants has been particularly helpful where:

1. Lakes have a large littoral zone with **extensive beds of submerged aquatic plants.** These lakes usually have a long history of extensive aquatic plant control projects and lakeshore owners complain that not enough control is allowed for them to fully utilize the lake's water surface.

2. Lakes have **stands of bulrush, wild rice, cattail** and other emergent vegetation that are in jeopardy of being lost due to shoreline development. Lakeshore owners, as well as fish and wildlife managers, are concerned with the loss of these important habitat types and wish to do something to preserve them.

3. Lakes have **floating bog problems.** When pieces of bog break loose due to fluctuating water levels or illegal removal activities, they can destroy property and can be a hazard to navigation.

The primary agency responsible for managing aquatic plants in Minnesota is the **Minnesota Department of Natural Resources, Division of Fish and Wildlife, Section of Fisheries.** Aquatic plants growing in public waters below the ordinary high water level belong to the state and there are limits placed on the type and amount of control lakeshore owners can do. Many aquatic plant management activities require a permit. For example, permits are required for activities that control emergent vegetation, such as cattails, wild rice or bulrush, or any time aquatic pesticides are used in public waters. The Section of Fisheries also surveys aquatic plants when they prepare fisheries management plans. Contact the Area Fisheries Manager for information about a lake's vegetation or other characteristics.

Consider aquatic plant management in a lake management plan.

When developing a lake management plan there are several types of aquatic vegetation to consider. Management of each type is different. There are four categories:

Algae have no true roots, stems or leaves, and range in size from tiny, one-celled organisms to stringy filamentous types. Plankton algae, which consist of free floating microscopic plants, grow throughout both the littoral zone and the well-lit surface water of an entire lake.

Submerged plants have stems and leaves that grow entirely underwater, although some may also have floating leaves. Flowers and seeds on short stems that extend above the water may also be present. Submerged plants grow near shores to the deepest part of the littoral zone and display a wide range of plant shapes. Depending on the species, they may form a low-growing "meadow" near the lake bottom, grow with lots of open space between plant stems, or form dense stands or surface mats.

Floating-leaf plants are often rooted in the lake bottom, but their leaves and flowers float on the water surface. Water lilies are a well-known example. Floating leaf plants typically grow in protected areas where there is little wave action.

Emergent plants are rooted in the lake bottom, but their leaves and stems extend out of the water. Cattails, bulrushes and other emergent plants typically grow in wetlands and along the shore where the water is less than 4 feet deep.

In many cases a small amount of control to allow access by individual landowners is all that is required to deal with aquatic vegetation issues. However, when issues become more complex and involve many, if not all, property owners, then it is time to develop an aquatic vegetation section for the lake management plan.

To develop an aquatic plant management section for a lake management plan, contact the MDNR area fisheries office. The fisheries manager or aquatic plant specialist will work cooperatively with representatives of other agencies (e.g., MPCA, SWCD), lakeshore owners and other concerned groups from the community to develop this section. Many of these representatives will have valuable information about the lake, including the amount and types of vegetation present, fisheries, bottom types, shoreline development, water clarity and other information that may help to identify trends or changes in the lake environment. The fisheries manager will also be able to identify important habitat and other sensitive areas in the lake. Including an aquatic vegetation section in the lake management plan provides an opportunity to protect the future health of the lake as well as allow for multiple recreational uses.

Case study; Big Birch Lake

Big Birch Lake in Todd County is a good example of how a Lake Vegetation Management Plan (LVMP) can be used to address lake management issues. Big Birch is highly developed. The northwest shoreline and an area called Hunter's Bay have a band of cattails 100 to 300 feet wide and bulrushes extending into the deeper water. Members of the lake association were concerned that the cattails and bulrush were being illegally destroyed as these areas were being developed. The lake association met with the aquatic plant specialist and cooperatively developed an LVMP that will help protect aquatic vegetation and the lake environment. The lake association is using the plan and information from the DNR to educate other shoreline property owners about the value of aquatic vegetation and the appropriate ways to obtain access to the lake.

D. Wildlife

Minnesota's lakes are home to many species of wildlife. From our famous loons and bald eagles to muskrats, otters and frogs, wildlife is an important part of our relationship with lakes. In fact, Minnesota's abundant wildlife can be attributed largely to our wealth of surface water. From small marshes to large lakes, these waters are essential to the survival of wildlife.

The most important wildlife habitat begins at the shoreline. The more natural the shoreline, with trees, shrubs and herbaceous vegetation, the more likely that wildlife will be there. Just as important is the shallow water zone close to shore. Cattail, bulrush and wild rice along the shoreline provide both feeding and nesting areas for wildlife. Loons, black terns and red-necked grebes are important Minnesota birds that are particularly affected by destruction of this vegetation. Underwater vegetation is also important to wildlife for many portions of their life cycle, including breeding and rearing of their young.

The primary agency charged with the management of Minnesota's wildlife is the **Department of Natural Resources, Division of Fish and Wildlife, Wildlife Section**. DNR Area Wildlife Managers and Regional Nongame Wildlife Specialists are located across the state. (Please refer to Appendix A for the location and telephone number of regional and area offices.)

Incorporate wildlife in a lake management plan.

Lake management plans are a valuable tool for considering the future of the wildlife resources in and around your lake and its watershed. The DNR can provide advice on how to identify and inventory the existing wildlife. This inventory of wildlife, and the habitat areas they use, will help set lake management goals that protect and enhance this important resource. Wildlife population goals are best achieved by creating and protecting critical habitat areas on your lake.

Wildlife will also benefit from efforts to improve the lake's watershed. Like the lake itself, wildlife considerations extend beyond the water's edge. Aquatic wildlife often spend part of their time in streams, wetlands and upland areas some distance from the lake. In many cases, the availability of this habitat is critical to their survival. The buffer areas along the edges of inlet streams and upstream lakes and wetlands provide travel corridors for wildlife. These corridors are particularly important for song birds, frogs and turtles. Protection and restoration of wetlands is critical to both fish and wildlife as well as to improving the quality of water flowing into the lake.

Shallow lakes occurring in the watershed are important wildlife areas and are often spawning areas for fish. These lakes suffer from the same factors as the downstream lakes they contribute to. The restoration and protection of aquatic vegetation in these areas is key to improving their quality and the quality of the runoff that ends up downstream. The DNR Wildlife Section will help to evaluate these shallow lakes and recommend management ideas. These lakes can even be designated as wildlife management lakes through a public hearing process if conditions warrant.

Some examples of actions to accomplish wildlife goals and objectives in the lake management plan include:

Establishing no wake zones or seasonal sanctuaries will help to control disturbances to nesting wildlife in critical areas.

Adding artificial nesting structures for loons, and houses for other species will help to preserve the lake's wildlife resource.

Work to preserve areas by entering into landowner agreements or conservation easements with landowners in the watershed.

Explore the possibility of helping the state acquire land for Aquatic Management Areas or Wildlife Management Areas.

Contact the DNR Area Wildlife Manager for actions tailored to the local resources.

Case study: Big Sugar Bush Lake, Kabekona Lake

The peninsula on Big Sugar Bush Lake in Becker County was popular with lakeshore owners who enjoyed the wildlife using the area. Its 18 acres of maple, basswood and aspen were interspersed with a number of century-old white pines. The Big Sugar Bush Lake Association purchased the area and donated it to the DNR as a wildlife management area. The donation not only protects this undeveloped lakeshore for osprey, wood ducks, loons and other wildlife, but was matched with the Reinvest in Minnesota Critical Habitat program to provide funds to help protect other areas. The lake association is currently working with the DNR Nongame Wildlife Specialist to establish a wildlife interpretive project on the peninsula.

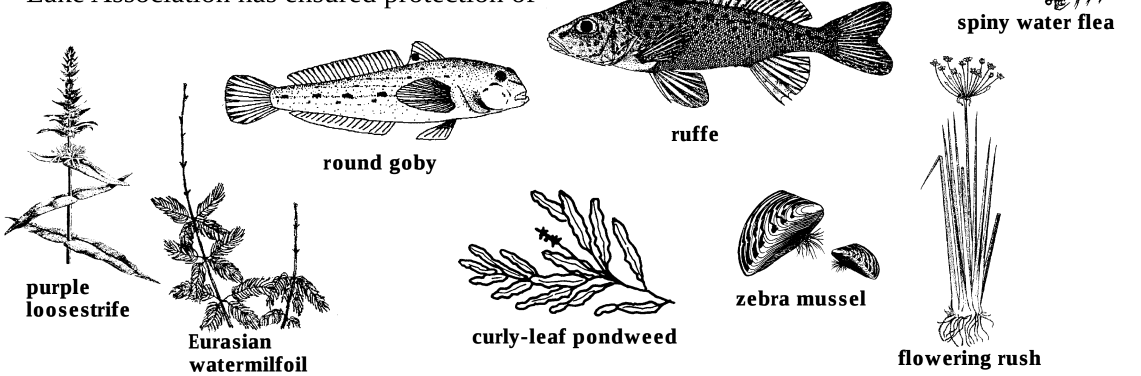
On the north shore of Kabekona Lake in Hubbard County are 3 acres of natural shoreline near a bald eagle nest. Bulrushes in the shallow water provide both fish and wildlife habitat, while behind an ice ridge, the tamarack, spruce, ash and dogwood provide warblers and other songbirds with nesting and feeding areas. The Kabekona Lake Association has ensured protection of this area by working through the Reinvest in Minnesota Critical Habitat program with matching funds. As a state-owned Aquatic Management area, the shoreline will be managed by DNR- Fisheries. The lake association has continued its efforts by working with the DNR Nongame Wildlife Specialist to erect nesting platforms for ospreys and loons, as well as nesting boxes for wood ducks, goldeneyes, and hooded mergansers.

E. Exotic Species

For the purposes of this manual, the term "exotic species" means a plant or animal not native to Minnesota, or one that was introduced to Minnesota after 1800.

Many aquatic exotic species present in Minnesota are the result of intentional introductions. The brown trout, rainbow trout and chinook salmon were introduced to provide a unique fishing experience to Minnesota anglers. Although there is some debate, the introduction of these species is generally perceived as beneficial. The common carp, another introduced species, was originally thought to be a boon for anglers because it could tolerate degraded habitat conditions, grew rapidly and was easy to catch. The carp, established in most of the major watersheds of North America, is now often considered a pest, and is blamed for degradation of habitat in marshes, lakes and streams.

Harmful exotic species may also be introduced unintentionally into Minnesota's lakes and rivers. For example, the spiny water flea, zebra mussel, ruffe and white perch were all probably introduced into the Great Lakes from ballast water discharged from ships travelling from European ports. Eurasian watermilfoil, an exotic water plant, has spread from coast to coast on boats, trailers, bait buckets and perhaps even by waterfowl. How this aquatic plant arrived in the U.S. is uncertain.



Introducing species accidentally or intentionally from one habit to another is risky business. Freed from the predators, parasites, pathogens and competitors that keep their numbers in check, species introduced into new habitats often overrun their new home and crowd out native species. In the presence of enough food and a favorable environment, their numbers will increase rapidly. Once established, exotics are rarely eliminated.

Exotic species have the potential to cause several problems. They can reduce the abundance of native species by out-competing them for food or space. Wildlife that depends on native species for food, cover and nesting sites may be faced with habitat of lower, if not unacceptable, quality. Initially, the impact of exotic species on native plant and animal communities are unclear; it may take years for it to become fully apparent. Exotic species also affect recreation and economic activities.

The primary agency responsible for managing exotic aquatic species in Minnesota is the **Minnesota Department of Natural Resources, Division of Fish and Wildlife,** which manages the Harmful Exotic Species Management Program. They can provide information on exotic species, and their ecology, biology, and on the location of existing populations in Minnesota. They also have information on current exotic species laws and rules and on control of species such as purple loosestrife and Eurasian watermilfoil. Much of this information is summarized in the *Exotic Species Handbook* listed in the reference section of this manual.

Consider exotic species in a lake management plan.

The first step in designing exotic species control for a lake management plan is to complete an assessment of the current level of infestation. Depending on the phase of infestation in a particular lake, there are several actions that can be identified in the lake management plan:

Phase I - No known infestations of exotic species. When no harmful exotic species have been observed, the focus of the exotics component of a lake management plan should be education aimed at prevention. This includes training on the identification of exotic species, the risks involved in their introduction and how to prevent their spread. Regular monitoring to identify an exotic introduction is also recommended

Phase II - Intensive Management. Consider these management strategies where a new exotic species has been recently identified and the possibility of containing or eliminating the population still exists. In this situation, the lake management plan would likely identify three actions:

1. Implement control measures in coordination with the DNR;
2. Keep lake residents and users informed of the changing situation and special regulations that may apply; and
3. Monitor the effectiveness of control efforts in coordination with the DNR.

Phase III - Maintenance management. If harmful exotic species are already well established, outline strategies to reduce the recreational, economic or ecological magnitude of their impacts in the lake management plan. These efforts will often be concentrated where exotics cause the most problems, interfere with the lake use, or can be easily spread. The DNR's Harmful Exotic Species Management Program can provide assistance with these management activities.

Case study: Bay Lake

Bay Lake in Crow Wing county is a good example of how exotic species management can be implemented cooperatively by local and state interests. In the fall of 1992, a lakeshore resident spotted a suspected Eurasian watermilfoil plant and contacted the DNR Regional office in Brainerd. A DNR aquatic plant management specialist inspected the site, and within one week the plant was positively identified as Eurasian watermilfoil. It was confined to a small portion of the lake, which was treated with herbicide. In 1993, the lake was inspected several times by the aquatic plant management specialist and the lake association; only one Eurasian watermilfoil was found, and it was removed. In 1994, milfoil was found on several sites, and during 1995 spread to about 10 sites occupying nearly 100 acres, most of which were treated with hericide. The DNR trained the lake association in aquatic plant identification and survey techniques, and the association organized their own lake monitoring program. Association members were also trained on how to conduct public awareness events at the public access to prevent further introductions of exotic species.

F. Land Use and Zoning

The amenities associated with living on a lake, including many recreational opportunities and aesthetic rewards, place lakeshore property in high demand for home sites and certain commercial businesses such as resorts and marinas. However, not all lands surrounding a lake may be suited for such development. Proper planning is essential to ensure that development will occur in a safe and orderly fashion, and with minimal impact on the lake.

The state Shoreland Management Act establishes a set of minimum development standards specifically for shoreland areas. Shorelands are defined as lands located within 1,000 feet of a lake, pond or flowage, and within 300 feet of a river. Shoreland standards are adopted and administered by local governments and are commonly incorporated into their overall zoning controls. Like zoning controls, shoreland standards set permissible uses and specify minimum requirements for newly created lots. Shoreland standards may also limit physical alterations to shoreland property, and may control the placement of structures, roads and other improvements to minimize impacts on the adjoining lake.

The primary agency responsible for land use controls and zoning in Minnesota is **local units of government such as counties, municipalities or townships.** They have the authority to administer land use zoning controls for areas within their boundaries. Local zoning controls generally apply to all lands in the government unit's jurisdiction, including lakeshore. These controls may identify a list of uses that are permissible or non-permissible for given areas or "zones." They also may specify minimum design standards for newly created lots, onsite sewer systems and wells, subdivision plats, planned unit developments and for construction in general.

Most local governments also administer regulations pertaining to the use of floodplain areas. Floodplain regulations specify minimum elevation requirements for structures and access roads and limit certain types of uses in floodplain areas. Such controls are particularly important on lakes with large watersheds, or lakes which exhibit extreme water level fluctuations. Generally, if a local government is administering floodplain regulations, then floodplain areas along some lakes and rivers have been mapped. Copies of Flood Insurance Rate Maps are available from the county or municipal zoning offices or the DNR Area Hydrologist.

Consider land use controls and zoning regulations in a lake management plan.

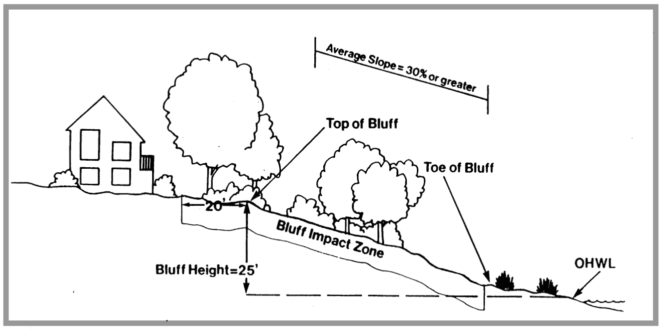
Since local governments have the legal authority to adopt land use regulations, the planning process begins with a contact to the local planning and zoning administrator. The lake management planning group, with the help of the administrator, should use the list of planning considerations to determine the best suited uses for a particular zone or district (e.g., planned development vs. open space for wildlife).

Shoreland standards are adopted and administered by local governments and are commonly incorporated into their overall zoning controls.

Before designing a set of land use controls for a lake it is important to inventory the landscape features that influence the lake's water quality and its ability to sustain fish and wildlife. While shoreland standards generally apply only to lands within 1,000 feet of a lake, planners might want to consider the entire watershed of the lake in their planning efforts since activities anywhere within the watershed have the potential to impact the lake. Some of the resources that should be inventoried include:

Wetlands. Wetlands serve as filters to remove nutrients and sediments from surface runoff before they reach the lake. They also provide important habitat for many species of wildlife. Wetland vegetation along a lakeshore provides habitat for fish and wildlife and protects the shore from erosion caused by wave action. Wetlands are also protected by various federal, state or local laws. Wetlands have been mapped on a series of National Wetland Inventory Maps. These maps may be viewed at the local Natural Resources Conservation Service office or at the soil and water conservation district office.

Bluffs and steep slopes. Lands characterized by bluffs and steep slopes can become a serious erosion threat if they are disturbed by grading, filling or vegetation removal. Bluffs are already protected from intensive removal of vegetation and grading or filling involving more than 10 cubic yards of material by local shoreland management ordinances. Bluffs rise at least 25 feet above the lake at an average slope of 30 percent or greater and can generally be identified from topographic maps the U.S. Geological Survey (USGS) Quadrangle Maps. Such maps can be obtained from the USGS or may be viewed at County or Municipal offices (Zoning or Land Department) or at local offices of the DNR.



Shallow groundwater or bedrock. The presence of the groundwater table or bedrock at or near the soil surface limits certain construction activities, particularly onsite sewage disposal systems.

Soils. Some soils have poor drainage or stability characteristics that affect their ability to support development of roads, buildings or onsite sewage disposal systems. In most Minnesota counties, soils have been mapped as part of the County Soil Survey. These surveys classify the soil types and explain the limitations of each type for development purposes. They also provide information on seasonal high groundwater levels and shallow bedrock. They surveys are available from the county soil and water conservation district office or the USDA Natural Resources Conservation Service.

Important habitat areas. Areas that support high quality fish or wildlife habitat or rare plants and animals generally need buffer areas surrounding them where disturbances will be minimized. Therefore, the locations of such areas should be determined and their protection should be reflected in land use plans. Information on these resources can be obtained from the MDNR Area Fisheries and Wildlife Manager.

Cultural and historic sites. These include sites of known archeological significance, unplatted cemeteries and historic structures. Shoreland areas are generally more likely to have sites of historic cultural significance than non-shoreland areas. Information on known sites or the potential for such sites to exist in an area can be obtained from the Minnesota Historical Society or the office of the State Archeologist.

Additional areas that should be considered when examining land use in a watershed are: public accesses, parks, marinas, highways adjacent to lakes, private septic systems and municipal sewage discharges and float-plane airports.

The inventory can be used to determine the best uses for individual tracts of shoreland or other critical areas identified. A set of written standards can be developed to guide future use of these lands. Generally, this entails the designation of land use districts or zones around the lake and the preparation of a list of permissible, conditional and prohibited uses for each district. The districts must be shown on the zoning maps of the local government and district boundaries must be definable to a specific feature (e.g., property line, highways, government lot line, etc.).

For each district or zone, it is necessary to develop a specific list of performance standards. These will establish minimum guidelines for development and may include such things as minimum lot sizes and building and sewage system setbacks from the lake. When the intended uses for the land have been determined and the performance standards defined, these documents are presented in draft at a public hearing conducted by the local planning commission or board to determine if there is any need to add, amend or eliminate portions of the plan. After the plan has cleared the hearing process, it becomes part of the zoning ordinance and has the force and effect of law.

Possible sources of funding for land use planning activities may include the local government or the soil and water conservation district. Active lake associations may also have an operating budget to fund certain aspects of the process

The shoreland management program's goal is for each newly created lot in shorelands to be suited in its natural state for the intended use. If that use is for development of a homesite, then each lot should have enough land that is free of limiting factors such as wetlands and bluffs to accommodate the placement of all proposed structures, an onsite water supply well and sewage disposal system and a site for future replacement of the sewage system. In addition, the property should be accessible by road. The presence of bluffs, wetlands or other surface water features may restrict the ability to extend roadways into certain areas.

G. Managing water

surface use conflicts

The goal of lake management is to ensure that the lake can continue to provide the benefits that attract homeowners and users. However, conflicts among uses arise almost invariably. Successful resolution of conflicts lies in the ability of the users to work collaboratively to arrive at acceptable compromises.

The primary agency responsible for managing surface water use conflicts is the **Minnesota Department of Natural Resources, Bureau of Information and Education**. The **Boat & Water Safety Section** within the Bureau oversees surface water use and is in charge of administering the Water Surface Use Management (WSUM) program. The goal of this program is to enhance the recreation use, safety and enjoyment of the water surfaces in Minnesota and to preserve these water resources in a way that reflects the state's concern for the protection of its natural resources.

Consider surface use management in a lake management plan.

Any governmental unit may formulate, amend or delete controls for water surface use by adopting an ordinance. Submit the ordinance for approval by the MDNR Boat and Water Safety Coordinator 1-800-766-6000, or in the metro area 296-3336.

The ordinance must:

✓ where practical and feasible, accommodate all compatible recreational uses;

✓ minimize adverse impacts on natural resources;

✓ minimize conflicts between users in a way that provides for maximum use, safety and enjoyment; and

✓ conform to the standards set in WSUM Rules.

The WSUM rules establish standards to promote uniformity of ordinances or rules on the use of watercraft throughout the state. In addition, they encourage compliance and ease of enforcement. It is not required that all the WSUM standards be included in the ordinance, only those necessary to reduce the conflict. The governmental unit may select from the following standards:

Watercraft type and size. Controls may be formulated for the type and/or size of watercraft permissible for use on the surface of the water body or portion of the water body.

Motor type and size. Controls on the maximum total horsepower of motor(s) powering watercraft will utilize one or more of the following options: 25 hp; 10hp; electric motors; no motors.

Direction of travel. Directional controls, if used, will mandate watercraft to follow a counterclockwise direction of travel.

Speed Limits. Controls concerning the maximum watercraft will utilize one or more of the following miles-per-hour cutoffs: slow no wake, 15 mph or 40 mph.

Effective time. Controls must use one or more of the four time periods specified in the rules.

Area zoning. Controls will clearly specify which portion of the water body is affected by the control.

The formal review process begins when the local unit of government submits the following information to the DNR Bureau of Information and Education for review and approval, prior to adopting an ordinance as required by the rules:

✓ water surface worksheet with a map of the lake highlighting the areas to be regulated;

✓ a statement evaluating whether the information reveals significant conflicts and explains why the particular proposed controls were selected (i.e., provide adequate justification for the adoption of the controls);

✓ the proposed ordinance; and

✓ description of the public hearing held concerning the proposed controls, including an account of the statement of each person who testified.

If more than one governmental unit is involved in adopting the ordinance, all the governmental units with jurisdiction over the particular water body must agree with the ordinance and develop a joint powers agreement. If for some reason the DNR denies the proposed ordinance, the denial will be in the form of a letter which will explain the reasons for denial. The governmental unit may amend the proposed ordinance and resubmit the proposed ordinance for a second review by the MDNR.

The DNR will notify the governmental unit in writing of approval or denial within 120 days after receiving all of the above information. Failure of the DNR to notify the governmental unit will be considered approval. The governmental unit adopting an ordinance must provide for notification of the ordinance to the public, which involves placing signs at public watercraft launch sites outlining essential elements of the ordinance.

H. Public water access

Research has shown that Minnesotans rely heavily upon public access sites to access lakes and rivers. A 1988 boater survey conducted by the University of Minnesota showed that three-fourths of the state's boat owners launch a boat at a public water access site at least once a year. In addition, over 80 percent of boat owners report using public water access sites for recreation activities other than boating.

The primary agency responsible for public water accesses in Minnesota is the **Minnesota Department of Natural Resources Trails and Waterways Unit.** They are responsible for the acquisition, development and management of public water access sites. The DNR either manages them as individual units or enters into cooperative agreements with county, state and federal agencies, as well as local units of government such as townships and municipalities.

The DNR's efforts to establish and manage public water access sites are guided by Minnesota Statutes and established written DNR policy. The goal of the public water access program is free and adequate public access to all of Minnesota's lake and river resources consistent with recreational demand and resource capabilities to provide recreation opportunities.

Consider public access sites in a lake management plan.

The DNR is also on the alert for properties that are being sold that may be used as a boat access. Site usability is based upon a set of criteria designed by the DNR. The pricing is based upon fair market value. When developing a lake management plan, it would be wise to identify sites that may be suitable for a public access.

If a desirable site is identified, construction is usually performed by a local contractor according to DNR specifications. There are several criteria that the public access must meet to be approved by the DNR. Contact the local DNR Trails and Waterways office in St. Paul for more information on the construction and design of public accesses.

The DNR routinely works with interested parties in the design of access sites from the initial concept stage through final design. This cooperative process does not end with the construction of the access site. After the access is developed, the Trails and Waterways Unit will continue to work with the community and neighbors on issues regarding maintenance and operation procedures.

Lakes are a very important part of Minnesotans' well being and economic diversity. One

V. Conclusion

of the state's most important products is the "water experience" and it directly influences property values, recreation, tourism and related activities. As in any product, quality is important and Minnesota competes for limited discretionary dollars with Wisconsin, Michigan and Canada. People will go elsewhere if our product is not competitive.

The quality of our lake resources is the cumulative result of the people and their activities within the lake's drainage basin. And, with ever increasing pressures upon our lakes, they cannot be expected to assimilate all impacts forever. The need to manage lakes as a limited resource requiring purposeful planning and action is real and immediate. Lake management requires the collective resources of citizens, local, county and state governments and commercial enterprise. Neglect often results in negative impacts, water quality declines, lost fisheries and ultimately lost revenues and a degraded quality of life. Lake rehabilitation is a ***very*** costly venture with an uncertain outcome.

Citizen-initiated steering committees havebeen an effective method for developing specific lake and watershed management plans. These efforts may be expected to require a year or more to prepare and up to several subsequent years to enact changes in the daily lives of watershed residents. Cooperation, collaboration and a willingness to change are the prime ingredients of the successful ventures. Finger pointing and recrimination will quickly ruin the best of intentions.

Formalized lake plans should be acknowledged by and incorporated into county, township, watershed district or other units of government operations—particularly those of the planning and zoning departments. Chipping away at the problems does work and everyone can do something, no matter how small the efforts may seem. It all adds up and makes a difference over time!

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Appendices

Appendix A – Water quality indices

Carlson Trophic Index

Fish Community Structure Graphs

Appendix B – Lake water quality benchmarks based on ecoregion

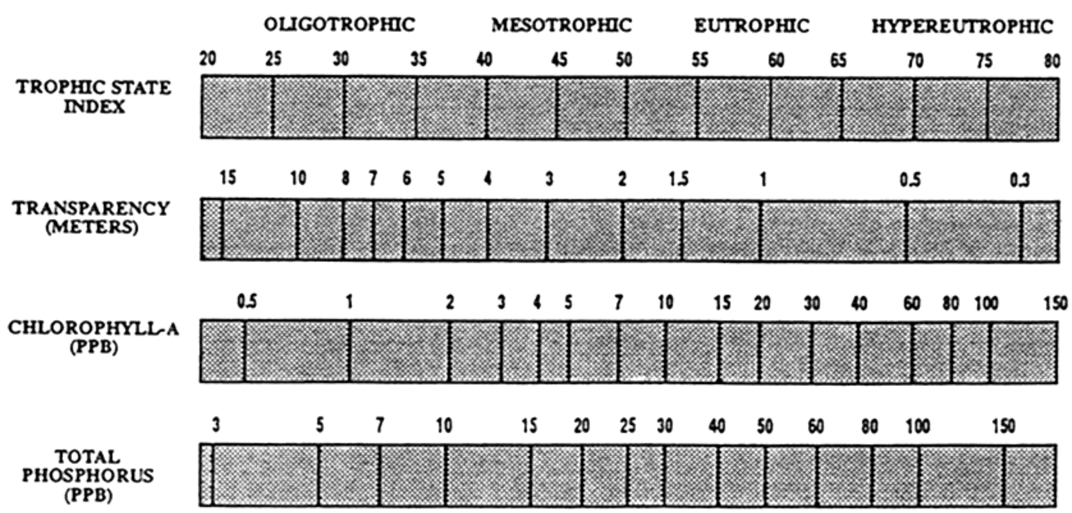
CARLSON'S TROPHIC STATE INDEX VALUES

TSI Relationships based on mean summer data for 1991.

Changes in the Biological Condition of Lakes With Changes in Trophic State

R.E. Carlson

TSI < 30	Classical oligotrophy: Clear water, oxygen throughout the year in hypolimnion, salmonid fisheries in deep lakes.
TSI 30 - 40	Deeper lakes still exhibit classical oligotrophy, but some shallower lakes will become anoxic in the hypolimnion during the summer.
TSI 40 - 50	Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.
TSI 50 - 60	Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimnia during the summer, macrophyte problems evident, warm-water fisheries only.
TSI 60 - 70	Dominance of blue-green algae, algal scums probable, extensive macrophyte problems.
TSI 70 - 80	Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypertrophic..
TSI > 80	Algal scums, summer fish kills, few macrophytes, dominance of rough fish.



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Water quality benchmarks based on ecoregion

Ecoregion Reference Lakes - One means for placing lake water quality information in perspective is to compare summer mean values to those found in reference lakes from the same ecoregion in which the lake is located in. Ecoregions were mapped for the United States from information on soils, landform, potential natural vegetation, -and land use by the U.S. Environmental Protection Agency. For Minnesota, within-region similarities in terms of quality and lake morphometric characteristics have been noted. Reference lakes, deemed to be representative and minimally impacted by man (e.g., no point source wastewater discharges, no large urban areas in the watershed, etc.) were sampled in each ecoregion by the MPCA from 1985 through 1988. The reference lake data base consists of approximately 90 lakes distributed as follows among the four ecoregions with the majority of Minnesota's lakes: Northern Lakes and Forests - 30, North Central Hardwood Forest - 38, Western Corn Belt Plains - 12, and Northern Glaciated Plains - 10. Data from the reference lakes can be used as a "yardstick" to compare other data against. Table I provides a range of summer mean values for each parameter and each ecoregion. These values were taken from the "inter-quartile range" (25th to 75th percentile) of the reference lakes for each region. By using these values, we have excluded the very low values (lower 25 percent) and the very high values (upper 25 percent) and thus, have a range of values which represent the central tendency of the reference lake's water quality. If your lake is near the transition zone of two ecoregions is often useful to make comparisons to reference lakes from both ecoregions.

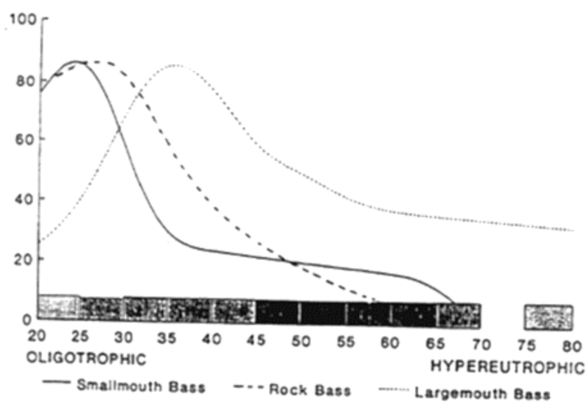
Table 1. Ecoregion Lake Data Base Water Quality Summary.
Summer Average Water Quality Characteristics for Lakes by Ecoregion*

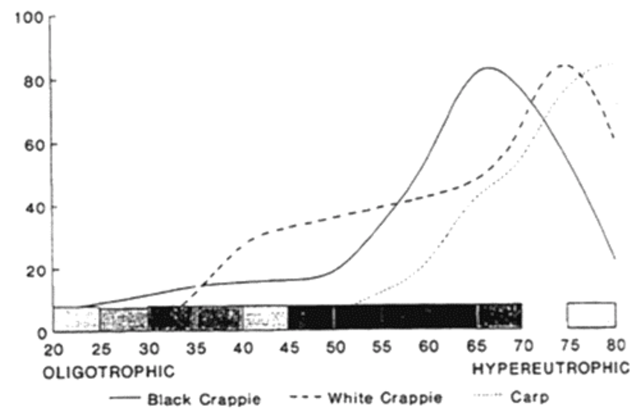
Parameter	Northern Lakes and Forests	North Central Hardwood Forests	Western Corn Belt Plains	Northern Glaciated Plains
Total Phosphorus (ug/l)	14 - 27	23 - 50	65 - 150	130 - 250
Chlorophyll mean (ug/l)	< 10	5 - 22	30 - 80	30 - 55
Chlorophyll maximum (ug/l)	< 15	7 - 37	60 - 140	40 - 90
Secchi Disk (feet) (meters)	8 - 15 (2.4 - 4.6)	4.9 - 10.5 (1.5 - 3.2)	1.6 - 3.3 (0.5 - 1.0)	1.0 - 3.3 (0.3 - 1.0)
Total Kjeldahl Nitrogen (mg/l)	< 0.75	< 0.60 - 1.2	1.3 - 2.7	1.8 - 2.3
Nitrite + Nitrate-N (mg/l)	<0.01	<0.01	0.01 - 0.02	0.01 - 0.1
Alkalinity (mg/l)	40 - 140	75 - 150	125 - 165	160 - 260
Color (Pt-Co Units)	10 - 35	10 - 20	15 - 25	20 - 30
pH (SU)	7.2 - 8.3	8.6 - 8.8	8.2 - 9.0	8.3 - 8.6
Chloride (mg/l)	<2	4 - 10	13 - 22	11 - 18
Total Suspended Solids (mg/l)	< 1 - 2	2 - 6	7 - 18	10 - 30
Total Suspended Inorganic Solids (mg/l)	< 1 - 2	1 - 2	3 - 9	5 - 15
Turbidity (NTU)	< 2	1 - 2	3 - 8	6 - 17
Conductivity (umhos/cm)	50 - 250	300 - 400	300 - 650	640 - 900
TN:TP ratio	25:1 - 35:1	25:1 - 35:1	17:1 - 27:1	7:1 - 18:1

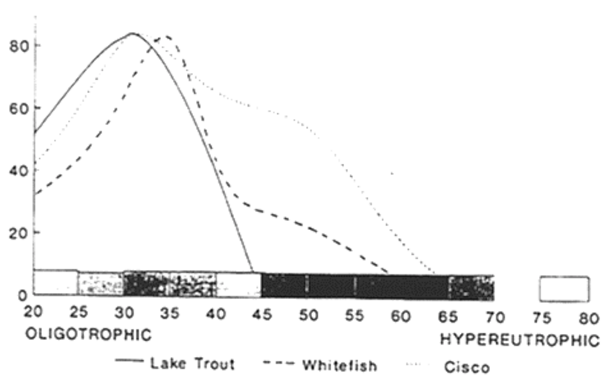
*Based on interquatile range (25th - 75th percentile) for ecoregion reference lakes. Derived in part from Heiskary, S. A. and C. B. Wilson (1990).

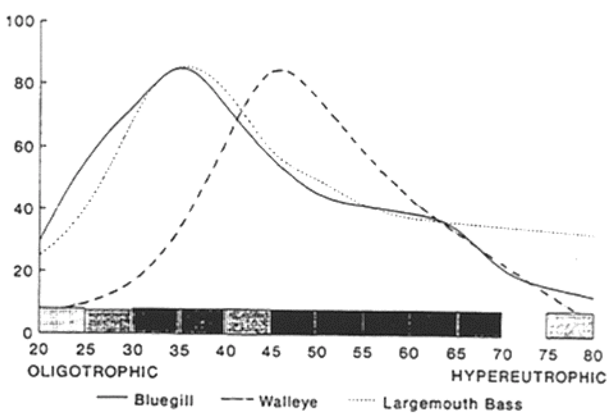
Fish Community Structure Graphs

Relative fishery abundance (vertical axis) versus
lake water quality TSI (horizontal axis)









Minnesota Lake Phosphorus Criteria Development- Because of regional diversity in lake and watershed characteristics, it was unlikely that a single total phosphorus value could be adopted as a statewide criterion for lake protection in Minnesota (Heiskary et al. 1987). Rather, a methodology was needed for developing lake water quality criteria on a regional or lake-specific basis.

The methodology for establishing lake water quality criteria in Minnesota considered the following (from Heiskary and Walker, 1988):

1. *phosphorus impacts on lake condition* (as measured by chlorophyll a, bloom frequency, transparency, and hypolimnetic oxygen depletion;

2. *impacts on lake user* (aesthetics, recreation, fisheries, water supply, etc.); and

3. *attainability* (as related to watershed characteristics, regional phosphorus export values, lake morphometry, etc.).

Previous papers (Heiskary et al. 1987) have described the range in the trophic status of lakes in Minnesota and the utility of the ecoregion framework in explaining some of this variability. Ecoregion maps, as developed by EPA ERL-Corvallis, are based on land use, soils, land form, and potential natural vegetation (Omernik, 1987). Recognizing patterns in lake trophic status between these regions has permitted the development of some generalized lake management strategies (Heiskary and Wilson, 1988).

Minnesota is characterized by seven ecoregions (Figure 1). However, over 98 percent of Minnesota's lakes are found in four of the state's seven ecoregions (Heiskary et al. 1987). Typical land use varies from the forests in the north to the primary cultivated land and pastures to the south. A more detailed presentation of the information may be found in Heiskary and Wilson (1988 and 1990).

The ecoregion framework provides a regional perspective on the uses of lakes in each part of the state and allows for the definition of "most sensitive uses" in each region. The MPCA has defined the "most sensitive use" of a lake as that use (or uses) which can be affected or even lost as a result of an increase in the trophic status of the lake. Two examples include drinking water supplies and cold water fisheries. In the case of drinking water supplies, eutrophication can increase water treatment costs (Walker, 1985), contribute to taste and odor problems (Walker, 1985), and increase production of trihalornethanes during the treatment process (Palmstrom et al. 1988). In a cold water fishery, increased nutrient loading will reduce oxygen in the hypolimnion (Walker, 1979), and cold water species may die off as these populations are driven into warmer surface waters (Colby and Brooke, 1969).

Table 2 presents some of the most sensitive lake uses for each ecoregion. Lakes corresponding to some of these categories have been specifically identified in Minn. R. ch. 7050.0470, subp. 1-8 (1980), and include designations for the following:

1. Domestic consumption (as defined in Chapter 7050.0220, subp. 2.1); and

2. Fisheries and recreation (as defined in Chapter 7050.0220, subp. 3.2), whereby Class A specifically refers to waters designated for the propagation and maintenance of warm or cold water fish, with lake trout lakes specifically identified in Chapter 7050.0420.

Once uses have been defined for a lake, in a given region, appropriate management strategies may be developed. The management strategy for maintaining a given use (phosphorus goal) may vary between regions and should reflect user expectations and regional variations in attainable lake trophic state.

For example, drinking water supplies in the Northern Lakes and Forests ecoregion are typically characterized as oligotrophic to mesotrophic in nature. The cost of treating these waters to produce potable water is much less than water obtained from eutrophic lakes in central and southern Minnesota. These treatments have included extensive in-lake application of copper sulfate to reduce algal blooms and the use of potassium permanganate and activated carbon in the treatment plants to reduce taste and odor (Walker, 1985; Hanson and Stefan, 1984). Even with these treatments, taste and odor complaints are common among users of these water supplies. Management strategies for water supplies should focus on decreasing the frequency and intensity of algal blooms.

Regional patterns and user perceptions must be considered when managing lakes for primary contact recreation and aesthetics. For example, a lake in the Western Corn Belt Plains ecoregion with Secchi transparency in the 1.5 to 2.0 meter range would be considered to have only "minor aesthetic problems", and would support swimming. In contrast, a lake in the Northern Lakes and Forests ecoregion with this transparency range would be deemed "swimming im-paired." Using this information in conjunction with regional patterns in lake trophic state, morphometry, and so forth, appropriate phosphorus management goals may be set. For the Northern Lakes and Forests, an appropriate phosphorus goal to fully support swimmable uses would be less than 30 µg/L, while in the Western Corn Belt Plains a phosphorus goal of 40 µg/L would be required. However, only a few lakes in the WCBP can achieve a phosphorus concentration less than 40 µg/L and thus, a more reasonable goal may be "partial support" of swimmable use which corresponds to a phosphorus concentration less than 90 µg/L.

The phosphorus criteria provide a basis for goal setting and prioritization. For example, lakes currently at or below the criteria for their ecoregion will typically support the specified use. These lakes should be protected from increases in phosphorus concentration, beyond natural variability, since even small increases in phosphorus concentration can lead to increased algae blooms and decreased transparency in these lakes. In most cases, these changes will be measurable and noticeable to long-time users of the resource. For those lakes above the criteria, the criteria can serve as goals for restoration. In fact, the recently revised Clean Water Partnership rule (Ch. 7 076.0240 Subp. 4c) notes for lakes in the CWP Program ...'*for lakes, an in-lake phosphorus goal defined relative to the ecoregion phosphorus criteria.*" In this case, the phosphorus criteria become the cornerstone for setting goals in these projects. This does not mean that the goals are simply applied as written, but goals are developed through the Phase I process and in conjunction with local steering committees. This work is done in an ecoregion context and goals are set accordingly.

Table 3. Minnesota Lake Phosphorus Criteria (Heiskary and Wilson, 1988).

Ecoregion	Most Sensitive Use	P Criteria
Northern Lakes and Forests	drinking water supply cold water fishery primary contact recreation and aesthetics	< 15 µg/L < 15 µg/L < 30 µg/L
North Central Hardwood Forests	drinking water supply primary contact recreation and aesthetics	< 30 µg/L < 40 µg/L
Western Corn Belt Plains	drinking water supply primary contact recreation (full support) (partial support)	< 40 µg/L < 40 µg/L < 90 µg/L
Northern Glaciated Plains	primary contact recreation and aesthetics (partial support)	< 90 µg/L