2003

MINNESOTA POLLUTION CONTROL AGENCY

Volunteer Surface Water Monitoring Guide

"You've got to protect the natural resources for the benefit of the state for years and years ahead of us…not just for my generation but for many, many future generations."

—*Willard Munger*

How this guide was developed

The Minnesota Legislature passed a citizen-monitoring bill in 2002 to encourage the use of volunteers for water monitoring. The bill also directed the Minnesota Pollution Control Agency (MPCA) to collaboratively develop guidance for volunteer water monitors. Based on that direction, the MPCA convened a group of interested stakeholders to develop this guide.

This guide was developed through the collaborative efforts of many stakeholders interested in volunteer water monitoring activities in the state of Minnesota. In the fall of 2002, the MPCA initiated the guidance development by inviting about 110 stakeholders to attend a kickoff meeting and participate in the development process. From this group, 19 agreed to serve on the Work Group, which provided direction to consultants who wrote the guide. Two members of the Work Group, in turn, served on the Project Planning Committee, with the consultants, to manage the flow of work in the committees.

The Work Group met eight times, while the larger stakeholder group came together in three plenary sessions.

The guide is considered an "iterative" document and will be revised and updated as new information is received.

This publication can be made available in other formats, including Braille, large type, computer disk or audiotape, upon request.

(651) 296-6300
toll-free/TDD (800) 657-3864

www.pca.state.mn.us

Minnesota Pollution Control Agency

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St. Paul, Minnesota 55155

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Icons

Throughout the guide, you will see boxes with an icon at the top indicating the type of information that is in the box. The icon is meant to help you decide if you want to read the supplementary information included in the boxed text.

More Information: Adds information to make text more understandable, or to add an interesting note to the text.

Link: Indicates a link to more information that is available on the Internet.

Technical: When you see this icon, you will find information that is more technical than the text as a whole. More advanced technical readers may be interested in this information as well as non-technical readers who want to learn more.

Example: Indicates a story of volunteers in action doing water monitoring activities; often shows how they have obtained results using various methods or processes.

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Work Group Members

Randy Anhorn, Metropolitan Council
Angie Becker Kudelka, Rivers Council of Minnesota
Mark Briggs, Minnesota Department of Natural Resources
Joel Chirhart, Minnesota Pollution Control Agency
Mary Gullickson, Volunteer Stream Monitoring Partnership
Keith Hanson, Minnesota Chamber of Commerce/Minnesota Power
Jamie Harper, Mississippi River Revival
Louise Hotka, Minnesota Pollution Control Agency
John Hines, Minnesota Department of Agriculture
Daniel Huff, Dakota County Environmental Education Program
Bruce Kleven, agricultural commodity groups
Mary Kay Lynch, Minnesota Wetland Health Evaluation Program
Joe Martin, Minnesota Farm Bureau Federation
Deb McDonald, Minnesota Agricultural Education Leadership Council
Bruce Paakh, Minnesota Pollution Control Agency
Jenny Schaust, Hennepin County Conservation District
Amy Trisko, Sauk River Watershed District
Paula West, Minnesota Lakes Association

Project Planning Committee

Keith Hanson
Angie Becker Kudelka
Diane Lynch, Lynch Associates
Paul Nelson, Sustainable Watershed Strategies
Betty McMahon, Z Communications
Shannon Lotthammer, Minnesota Pollution Control Agency

Consultants

Facilitator: *Diane Lynch*, Lynch Associates
Facilitator/writer: *Paul Nelson*, Sustainable Watershed Strategies
Writer: *Betty McMahon*, Z Communications

MPCA staff resources

Shannon Lotthammer, project manager, Environmental Outcomes Division
Patricia Engelking, production coordinator, Environmental Outcomes Division
Paul Hoff, supervisor, Environmental Outcomes Division
Gaylen Reetz, manager, Environmental Outcomes Division

Additional contributors

Jesse Anderson, Myriam Beaulne, Todd Biewen, Cassie Champion, Keith Cherryholmes, Dave Christopherson, Geoff Dates, James Fallon, Roger Fisher, Patrick Ganey, Lee Ganske, Wayne Goeken, Sheila Grow, Dick Hecock, Steve Heiskary, Judy Helgen, John Helland, Dan Helwig, Don Hickman, Greg Johnson, Kent Johnson, Jen Klang, Barb Liukkonen, Molly MacGregor, Howard Markus, Dave Maschwitz, Sylvia McCollor, Gary Montz, Lynn Nelson, Donna Perleberg, John Peterka, Wayne Pikal, Bob Potocnik, Kevin Proescholdt, Kay Rezanka, Pete Rzepecki, Mike Sandusky, Eric Silvola, Sol Simon, Mel Sinn, Kristen Soderlund, Laurie Sovell, Greg Spoden, Isis Stark, Jeff Stevens, Howard Stewart, Dan Stoddard, Darcy Tatham, Bill Thompson, Paul Wymar, David Wright

Section 1:

Introduction

"You've got to protect the natural resources for the benefit of the state for years and years ahead of us ... not just for my generation but for many, many future generations."

– ***Willard Munger***

Volunteer citizen water monitoring is a critical component in understanding and educating Minnesotans about water quality issues. This guide provides information so you as a volunteer can play an important role in monitoring and protecting Minnesota's water resources.

A few decades ago, U.S. waters were becoming alarmingly impaired by pollutants. Then, in 1972, responding to citizens' pressure to clean up U.S. waters, Congress passed the Clean Water Act (CWA), with a mandate to protect and restore the physical, chemical, and biological integrity of our nation's water. That legislation gave agencies, local governments, environmental groups, universities, citizens and other organizations the clout to create legislation to implement and enforce the Act.

Progress has been made, but there is still a long way to go, especially in states like Minnesota, which has more surface water than any other state in the lower 48.

One of the challenges still facing water resource managers is a lack of the data necessary to understand the

Volunteer monitors supplement work of scientists

In Minnesota, volunteers have responded generously and enthusiastically with their time and energy. Information provided by volunteer water monitors, for example, helps scientists to use high-tech satellite imaging to determine how clear Minnesota lakes are. Computer researchers take digital satellite pictures of Minnesota and measure the light that's reflected off the lakes. But the information they gather from the satellite pictures would not be usable without the data provided by volunteer monitors. These volunteers lower a simple measurement device called a Secchi disk into the water at scheduled periods and report their findings to scientists at the University of Minnesota. Using these volunteer readings, the scientists can "ground-truth" the satellite results.

Source: ***http://www.water.umn.edu***

quality of Minnesota's surface water resources. There are not nearly enough organizations to monitor the health of all the waters in Minnesota. If every professional organization used its staff full time, every day, to monitor the waters, there would still not be enough to adequately do the job. That makes your work as a volunteer water monitor very important.

Volunteers have taken an active role in monitoring Minnesota's water resources since the 1970s. In recent years, volunteer monitoring has gained attention as the state has struggled with the task of adequately monitoring and assessing Minnesota's water resources given the limited staff and funding available for monitoring.

Point and non-point sources of pollution

Point sources are those that have a known discharge point, such as a pipe, including:

- Industrial and municipal wastewater treatment plants that discharge directly to a stream
- Urban stormwater discharge

Non-point source pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, eventually depositing them into lakes, rivers, wetlands, coastal waters and even our underground sources of drinking water. These pollutants include:

- Excess fertilizers, herbicides and insecticides from agricultural lands and residential areas
- Oil, grease, and toxic chemicals from urban runoff and energy production
- Sediment from improperly managed construction sites, crop and forest lands and eroding stream banks
- Salt from roadways, irrigation practices and acid drainage from abandoned mines
- Bacteria and nutrients from livestock and inadequate household waste disposal systems

What do volunteer water monitors do? They identify healthy waters and put strategies in place to protect them. They identify problem waters and see what they can do to fix them. They do this by collecting and analyzing water samples, conducting visual assessments of physical conditions and measuring the biological health of waters. Efforts to resolve the problems may take decades, especially when the sources of contamination are many and hard to pinpoint.

Finally, and most important, volunteer monitors help raise overall community awareness about the health of (and threats to) water resources. Through monitoring, individuals gain a better understanding and appreciation for the workings of the ecological system. This helps build awareness of how their (and their community's) actions impact the environment and what steps can be taken to minimize those impacts. This understanding, which can be shared with others in the community, in turn helps volunteers participate in and influence resource management decisions made at the local and state level. In this way, the activity of volunteer monitoring – and the greater understanding it creates – can be just as important as the data generated.

How can you participate in this important task? You can initiate water monitoring projects yourself. Or you can augment the work of scientists and other professionals by working with various water monitoring organizations. Through these partnerships, you become an important resource to supplement the work of organizations and agencies.

Volunteer monitoring in Minnesota

Rivers Council survey provides insight into Minnesota monitoring activities

In summer 2002, the Rivers Council of Minnesota conducted a survey to better understand groups that used citizen monitors and the organizations that provide resources (or services) to these monitors.

The resulting report, *An Evaluation of Citizen Volunteer Water Quality Monitoring in Minnesota,* represents responses from citizen monitors across the state. It represents citizens who work with local governments, nonprofit groups and some of the dozens of schools that are monitoring our waters. Although it is difficult to accurately track the work of all volunteers, based on responses the Rivers Council received, we assume there are at least 4000 volunteers engaged in monitoring the state's waters.

What volunteer monitors do

As a volunteer monitor, you can contribute to the quality of waters in Minnesota by raising community awareness of water-quality issues and providing valuable data that can be used to influence decisions. Depending on your level of involvement, you can:

- Learn about your resources and what you can do to protect them
- Experience a water ecosystem firsthand
- Promote a better understanding of natural resources
- Gain valuable technical skills and expertise
- Investigate problems with waters in your own neighborhoods
- Initiate community action projects based on your findings

Volunteers typically monitor water temperature, precipitation, dissolved oxygen, pH, macroinvertebrates, phosphorus, nitrogen, chlorophyll-*a*, flow/water level, turbidity, habitat, bacteria, land use and Secchi transparency (Source: *Directory of Volunteer Environmental Monitoring Programs, 5th ed.*). You may decide to monitor for one or many of these water resource characteristics or parameters.

Using various procedures, you can discover problems in streams, lakes and wetlands that otherwise may not be brought to the attention of natural resource profession-

Do volunteers make a difference?

The Cannon River Watershed Partnership organized the Citizen Stream Monitoring Program (CSMP) to monitor the Straight and Cannon Rivers. Forty volunteer monitors are assigned to specific areas of the Cannon River Basin watershed. Half of these volunteers were added in 2002. In 2001, 59 gauge readings were made in 183 days of monitoring, but with the additional volunteers in 2002, 350+ gauge readings were made in 183 days. Thanks to the help of volunteers, the CSMP has nearly met its goal of securing monitoring sites in each minor watershed in the Basin.

Watershed Watcher (Citizen Stream Monitoring Program, Northfield, MN) Jan. 2003, p. 4,5.

als and policy makers. You can also highlight the need to protect water bodies that are still healthy ecosystems. And you can join others who have provided data to understand the long-term changes that occur in lakes and streams as a result of growth and development.

Once volunteer data is collected, it can be entered into water quality databases, where it becomes accessible to citizens, local governments, consultants, agencies, etc. for retrieval. In this manner, the data you collect can be widely distributed.

How groups use volunteer data

At a minimum, your monitoring program will help educate yourself and others about water quality problems and will promote awareness and stewardship. But you may choose to go beyond education/awareness/stewardship and seek a role in shaping policy and management decisions.

Groups typically use citizen-collected data, in addition to education, to:

- Compare regions of the state
- Measure progress toward goals
- Document water quality conditions
- Develop public policy
- Determine where to direct limited resources
- Diagnose/analyze how and why a water body is changing over time

Volunteer data supports water resources management

Local, state, federal and non-governmental agencies and organizations benefit greatly from volunteer data that complements their monitoring programs. Many organizations and agencies have a long record of promoting volunteer monitoring. Some efforts include:

MPCA's new monitoring strategy specifically includes volunteers

In late 2002 the MPCA developed a condition monitoring strategy designed to increase the number of surface waters monitored across the state. The intent of this three-pronged strategy – detailed assessment, satellite remote sensing and volunteer monitoring – is to provide a more comprehensive understanding of the quality of the state's water resources, both in the number of waters assessed and the frequency of monitoring.

The strategy, which will be implemented in the future, is as follows:

- MPCA staff will visit each monitoring site at least once every 10 years and collect enough samples during the year to meet the federal requirement of "current" data necessary for assessments.
- Every five years, the MPCA will supplement its more intensive monitoring with remote sensing overviews (satellite imagery to identify water clarity), which would provide "snapshot" information on many hundreds of lakes and streams.
- Annual volunteer monitoring at each monitoring site will help fill in gaps in the MPCA monitoring frequency and alert the community and the MPCA of any changes that occur between assessments. Even relatively simple volunteer efforts such as Secchi disk or transparency tube measurements provide valuable indications of any year-to-year changes at sites, and will provide early warning of potential or threatened impairments.

The MPCA views each of these three pieces as critical in ensuring that the approach will build sufficient understanding of the quality of Minnesota's surface water resources.

- The Department of Natural Resources (DNR) and State Climatologists Minnesota Climatological Network for precipitation monitoring
- The DNR's lake gauge monitoring program
- The Metropolitan Council's Citizen Assisted Monitoring Program (CAMP) for lakes.
- MPCA's Citizen Lake Monitoring Program (CLMP) and Citizen Stream Monitoring Program (CSMP)
- Volunteer Stream Monitoring Partnership (VSMP)

The uses and value of volunteer monitoring will continue to evolve as a result of the citizen monitoring bill that was passed by the Minnesota Legislature in 2002 and as efforts by other organizations are implemented. This evolution has already started. One example is how volunteer monitoring is reflected in the MPCA's new monitoring strategy.

Quality is key

As a volunteer, you may feel that sloshing around in a muddy stream to collect stoneflies or midges is not a worthwhile endeavor. And, indeed, collecting these organisms may meet your own goals to simply learn more about the environment.

But, if you add one element to your activity, you can elevate your monitoring efforts to a scientific level. That element is to spend some time up front and design your monitoring activity according to quality standards, or protocols. In other words, instead of picking up a net and heading to a stream to capture organisms, you first decide what you intend to accomplish and what it will take to make your results credible to those who will use the data to make decisions.

When you design a process that has appropriate methods built into it, your data will then have the "rigor" to establish scientific credibility. That data can then be entered into an environmental database and used for making decisions.

Appropriate methods range from relatively simple ones to more complex ones, depending on the monitoring activity and the ultimate data user. For example, you can measure pH (acidity) concentration in a stream with a simple test strip, which will meet basic standards for data collection. On the other end of the spectrum, you can measure pH concentrations with a pH meter to provide a more accurate chemical analysis that would be accepted by a wider range of data users.

How this guide applies to you

Some organizations have existing manuals to teach monitoring methods for rivers, streams, lakes or wetlands. This guide is intended to create an "overall framework" that addresses issues such as monitoring plan design, data storage, data quality and data management and to help you think through why you want to monitor and how you want the data to be used. The guide is expected to help you in decision-making; it is not a methodology manual.

Once you know the path you want to follow, you can pursue that path in several ways:

Possible paths	How this guide can help
Proceed with your own independent data collection efforts.	Help you determine your monitoring purpose and goals and data quality needs; help you design your monitoring effort, introduce you to data management and interpretation and show you where to find more information.
Join one of the many existing volunteer monitoring programs coordinated by public and private organizations across the state.	Describe and provide contacts for many existing monitoring programs (see *Appendix A*). Help you understand the design of these existing programs. *Section 2: Monitoring purpose, data uses and goals*, can also help you determine your goals so you can make an informed choice and contribute your time and effort toward the program that best matches your goals.
Develop a group volunteer monitoring program.	Help you determine your monitoring purpose and goals, data quality needs; help your organization design your effort, introduce you to data management and interpretation and show you where to find more information.
Enhance existing monitoring programs to fulfill data requirements for state and local governments and other data users.	Help you sort through the process of setting data quality objectives and quality assurance and quality control sampling. *Appendix D* provides a summary of data quality requirements for MPCA use of data for Clean Water Act decisions.

How to use this guide

We have developed this guide to help you understand the basics involved in designing and implementing a volunteer monitoring program in your community. It is meant to give you an overview of the process and to direct you to resources that can help with details that you need in your specific program.

This process and associated sections of the guide are displayed in Exhibit 1-1.

Exhibit 1-1: Volunteer monitoring process

Setting goals
Section 2: Monitoring purpose, data uses and goals

Monitoring plan development
Section 3: Data quality
Section 4: Design your monitoring effort
Section 5: Data management

Implementation plan
(Data collection)

Data assessment and program evaluation
Section 6: Converting data to information
Section 7: Evaluating monitoring program performance

We recommend you use the guide as follows:

Read or scan all seven sections so you get a feeling for the context of your program in the greater scale of volunteer water monitoring. As you read, you will begin to understand the scope of your potential project and the implications for the resources involved in making it a reality.

Each of the Sections guides you through the steps it takes to implement a successful volunteer water monitoring program. Pay particular attention to *Sections 2* and *3*, where you are led through the process of determining your monitoring purpose and associated data quality considerations. The more time you spend thinking through what you want to accomplish and setting the foundation to make it happen, the more successful your program will be.

Section 4 describes the core of a monitoring program, guiding you through the steps of designing the actual program. This will go much faster and easier if you have done your homework from *Sections 2* and *3*. You may find that many organizations you work with already have the program designed for you.

The basic principles of data management and assessment, described in *Sections 5* and *6*, may require more expertise to implement than you have. Much of this work may be done by organizations of which you are a part. It will benefit you, however, to read through the Sections so you are aware of what will be expected of you to make sure the data you collect is credible and usable.

Section 7 will help you to evaluate your program once you complete it. You may have created a very simple monitoring program designed to create awareness and provide education on the process. Or you may have completed one year of a complex program. In either case, it will be helpful to evaluate what you accomplished and what you may change in future efforts to make your program even more successful.

The appendices include a wealth of information regarding other resources available to help make your monitoring effort successful and provide more details about information that is presented in the first seven Sections of the guide.

Section 2:

Monitoring purpose, data uses and goals

This Section will show you how to:

- **Sort out the reasons you are monitoring.**
- **Think through who your primary data users may be.**

A successful monitoring effort requires up-front consideration of the why, who, what, when, where and how of monitoring – especially *why* you want to monitor, *what* you hope to accomplish and *who* you want to use the data. Often people involved in monitoring jump right into the "how" (i.e., the methods) before developing a clear monitoring plan that includes purpose, desired use of the data, etc. This Section covers the questions of why you want to monitor and who you want to use the data. *Section 4: Design Your Monitoring Program* covers how to combine all of these questions into a comprehensive monitoring plan.

Why are you monitoring?

You may have an idea of why you want to monitor. Perhaps you want to discover:

- What lives in the wetland near you.
- Whether the water in your stream or lake meets designated uses (such as fishing, swimming, drinking, aesthetics).
- Whether water quality is improving or diminishing.
- If swimming in the lake is a health risk.
- The impact land and water use activities are having on ecological conditions and human uses.
- If the various strategies in protecting and restoring ecological integrity and human uses have been effective.

Know what questions you want to answer

Taking time to think through the reasons you want to monitor will help you:

- Focus your project and collect the most useful information efficiently
- Select appropriate protocols and parameters
- Evaluate later if you have met your objectives and answered your questions
- Design a monitoring program that is credible to the primary data users

The first step is to make your monitoring project part of the bigger scientific picture by formulating your plans into a purpose. Your purpose may fall into one or more of the following categories:

- To promote community *education and awareness*
- To provide *water body characterization and assessment* (i.e., condition monitoring)
- To support *problem investigation* including regulatory investigation
- To evaluate the *effectiveness* of management decisions

For example, if you want to find out what lives in a wetland near you, your "purpose" could be "to promote awareness." Or if you want to find out if swimming in the lake is a health risk, your purpose may be "to provide data that can be used to characterize and assess" the lake in question.

Decide what questions you want to answer and what your purpose is. Clearly document them so you can revisit them later to see if you accomplished what you set out to do.

Square Lake gets remedial help

Monitoring efforts at Square Lake provide an example of the different monitoring purposes, and how monitoring purpose may change over time. While the Square Lake example includes all the purposes, your project does not need to cover them all. You can start with a single purpose in mind, and, like the example, the purpose may change.

Square Lake, in northeastern Washington County, is one of the clearest lakes in the state. Volunteers began collecting Secchi transparency readings on Square Lake through the MPCA's Citizen Lake Monitoring Program (CLMP) in the early 1970s. To broaden the lake's water quality database, the Metropolitan Council started routinely monitoring the lake in 1980, adding phosphorus, nitrogen, chlorophyll and plankton parameters to Secchi transparency readings. Since 1993, in-lake water quality data have been collected through the Metropolitan Council's Citizen-Assisted Monitoring Program (CAMP). In the mid-1990s, the lake association, in an effort to get some baseline loading data, began periodically collecting water quality samples from the lake's tributaries. Data collected through all the programs were used for baseline *water body characterization and assessment*.

Then trend analysis on the lake's historical (1970-2000) Secchi transparency database revealed a statistically significant decline in water clarity. Evaluating the lake's water quality database and listening to lake-user concerns that the lake was being degraded for recreational use led to increased *awareness* and the formation of a committee*. The committee submitted a proposal for a Clean Water Partnership (CWP) to conduct a more intensive in-lake and watershed-based study to *diagnose and investigate* potential problems, help set goals for desired in-lake conditions and protect the lake's exceptional water quality.

The results of this 1998 study have lead to remedial projects such as gully erosion control, road wetland rehabilitation, homeowner education, storm water runoff regulations, septic system surveys, and continued monitoring and evaluation. Volunteers continue to work with the Washington County SWCD, MPCA, MDNR and Met Council to further diagnose problems and assess the *effectiveness* of the implementation plan. Besides Secchi transparency and water samples, volunteers are currently collecting zooplankton samples to evaluate potential trends in the lake's *Daphnia* populations, as well as better understand the lake's predator-prey relationship between trout that are stocked in the lake and *Daphnia* numbers.

* *Partnering in this volunteer-aided project were: Square Lake Association, Marine on St. Croix Watershed District, Washington Soil and Conservation District, May Township, Minnesota Pollution Control Agency, Metropolitan Council, Minnesota Department of Natural Resources, Science Museum's St. Croix Watershed Research Station, Wilder Nature Center, and Minnesota Chapter of Trout Unlimited.*

Who will use the data?

Whatever monitoring project you select, you will be generating some kind of data. That data can range from counting stream organisms to measuring chemical concentrations.

To make sure data will be usable for its intended purpose, identify in advance how you will use the data you collect.

Potential data users include:

- Monitoring program participants
- Students and teachers
- Watershed residents
- Local decision makers (e.g. cities and counties)
- Landowners and shoreline residents
- Environmental and business organizations
- Soil and Water Conservation Districts
- Watershed Management Organizations
- District, Regional, State and Federal Agencies
- Volunteer programs and organizations
- Nonprofit organizations

Programs have varying data requirements

Data quality and rigor that will ensure credibility varies with the use and the user. You may set up a volunteer monitoring program designed primarily to educate participants regarding the value of local surface waters. If your primary purpose is education and constituency-building, you may adopt simple, easy-to-use assessment methods and may not need to develop stringent quality assurance protocols. You might find that an interest in and understanding of monitoring and the resources being monitored increases over time.

Your program may attempt to identify actions you can take to protect or prevent damage to water resources. Or to help build scientific study skills by getting involved in data collection and analysis.

Any of these programs can assist in building bridges among various governmental agencies, businesses and organizations and create a constituency to protect local waters that promotes personal and community stewardship and cooperation.

Data for decision-making

If you want the data to be used for research, decision-making or regulatory programs, your data will have to meet data quality objectives set by those who will ultimately use the data.

Citizen phosphorus monitoring leads to change in local ordinance

Citizen water quality data on Pelican Lake, collected as part of the Pope County Coalition of Lakes Associations (COLA) water monitoring program, showed steady increases in phosphorus and decreases in water clarity over a four-year period.

The water quality was more degraded than most of the lakes in the region. Volunteer data was presented to the County Board to show the cause and effect between water quality and agricultural development in the watershed. The citizens requested mandatory inspections and upgrades on all feedlots in the Trappers Run watershed. The Board passed a resolution requiring inspections of the existing feedlots within two years and used the data to apply, and receive, federal 319 grant funding for upgrades along the creek such as buffer strips, dikes, and more to prevent further nutrient contributions from erosion and runoff.

Source: Minnesota Lakes Association

Learn what it takes to be credible

We strongly encourage you to contact primary data users and decision makers to determine what information they need. A good way to approach them is to ask them to review your monitoring plan (*Section 4* will show you how to build your monitoring plan). You may also decide to develop a Quality Assurance Project Plan (QAPP). A QAPP is a written document that outlines the procedures a monitoring project will use to ensure that the samples participants collect and analyze, the data they store and manage, and the reports they write are of high enough quality to meet the desired data uses. A QAPP is required for all U.S. Environmental Protection Agency (USEPA) funded monitoring programs and provides a tool for engaging the data users and defining credible protocols at the beginning of the project. *Section 3: Data quality*, provides additional information on developing a QAPP.

Some monitor for individual purposes

A farmer near Austin, MN is using a transparency tube just like the one these students are using to track the effectiveness of best management practices (BMPs) he is implementing on his land. Committed to land and environmental stewardship, this farmer is completing a series of wetland restorations and other BMPs to minimize erosion and flooding, and thereby improve water quality on (and coming from) his land. He uses transparency-tube measurements to track stream water clarity before and after the BMP installations and to help him decide where to place additional BMPs.

(Source: MPCA)

Directories for local decision makers and organizations

Some on-line directories include:

Board of Water and Soil Resources (BWSR): ***http://www.bwsr.state.mn.us/directories/index.html***
This site contains contact information for Watershed Districts, Watershed Management Organizations, County Local Water Planners, Wetland Conservation Act LGUs, and Soil and Water Conservation Districts

Minnesota Association of Watershed Districts (MAWD): ***http://www.mnwatershed.org*** This site contains contact information for Watershed Districts.

Minnesota Association of Conservation Districts: ***http://www.maswcd.org/SWCDs_On_The_Web/swcds_on_the_web.htm***.
This site contains links to Soil and Water Conservation Districts across the state.

A list of organizations involved in volunteer monitoring is also attached in *Appendix A*.

Section 3:

Data quality

This Section will show you how to:

- **Plan so your data can be used by others, based on your specific purpose.**
- **Interface with primary data users to establish your data collection strategies.**

This Section may also be of value to you if you want to enhance an education program by teaching the importance of quality assurance and quality control (e.g., learning the value of duplicate field samples, teaching scientific processes or understanding variability of results).

Collecting credible data

Assuring data credibility is the primary challenge you may face if you want your data to be used by others. It's also a primary challenge to show how to do this in one guide, because there are as many different approaches for quality assurance and quality control (QA/QC) as there are different types of monitoring. Keep in mind that the level of data quality you need is relative to *your* purpose and the uses of *your* data. Data used for one purpose is not "higher quality" than for another purpose; you should select a level of data quality that is appropriate for *your* particular purpose.

This Section is about building QA/QC into your project, or how to ensure the data you collect is usable. If you are spending time and resources to make the effort to collect data, you want to be sure you don't compromise the results by not following basic accepted procedures. If you expect decisions to be made based on the data you collect, the data will need to meet criteria accepted by the ultimate users. Remember, collecting data is time sensitive. In other words, if you make a mistake, you can't go back and correct it, as conditions will never be the same at any

MPCA Guidelines for 305b and 303d Assessments

See *Appendix D* for a copy of the Minnesota Pollution Control Agency's Monitoring Guidelines to meet the Clean Water Act's 305b (use-support assessments) and 303d (list of impaired waters) requirements. This document is a compilation of information from various resources at the MPCA.

other time. If you don't do it right the first time, the data may not be usable for your purposes.

It is important to note, too, that the data you collect will undergo greater scrutiny as the use moves from awareness to regulation and also with the number of people and institutions affected.

Communicating with data users

The best way to ensure you will collect usable data is to *check with the primary data user who will use your information*. We cannot emphasize this too strongly. You can waste time and resources putting together a water monitoring project, only to discover that you did not use appropriate methods or equipment that will make your data usable. Some users may not require rigorous data, but the level of rigor needed rests with the ultimate user.

It is important to note that in this context "data user" refers to the *primary* user of your data, whom you identify up-front and consult while developing your monitoring plan. Once you finish your monitoring effort and the data is public, there may be many other groups and individuals who wish to use your data. For these "secondary" users, it's up to them to decide if your monitoring purpose and QA/QC practices meet their needs. It would be impossible to plan for all the potential uses of your data. What you *can* do is identify up-front who *you* want to use your data and then consult with that primary data user to ensure the data you collect meet their needs.

General QA/QC concepts

In this guide, we will discuss the concepts of building QA/QC into any volunteer water monitoring project and the general parameters that scientists look for when setting up QA/QC objectives. If you set data quality objectives and/or develop a Quality Assurance Project Plan *before you begin monitoring*, you can help ensure all your data is usable for its intended purpose. Building QA/QC into your project, up front, will put you on the right track from the beginning.

Your project may include some or all of these parameters. Again, *talk to your primary data user* to see which ones are appropriate for your project. And remember, too, when you are establishing QA/QC objectives, there are many professionals available to help you. If you are working with an organization, for example, it is likely that the group has QA/QC objectives already established.

Help your data user

Your data users may not be sure of the monitoring protocols and QA/QC procedures they need to be able to use your data. If that is the case, the following are some things to consider that will help you and your primary data users determine acceptable protocols:

- If the primary data users are not sure about data quality needs and QA/QC protocol, try phrasing the question differently and ask what their data quality concerns might be for the parameters you are considering. Then use this Section and the examples to identify QA/QC protocols that address those concerns. You can then present suggested QA/QC protocols to the users to assess their comfort level.

- If the data uses are potentially controversial or involve resource management decisions with significant financial implications, you want to have especially high confidence in your data. In this case, the protocols and QA/QC procedures in *Appendix D* may be a good model. In general, these protocols have been reviewed and recognized by scientists.

- Consider your audience or the people who must accept the credibility of the data. In general, people will be more likely to accept results that come from accepted methods or protocols. In other words, do some research and find out the generally accepted scientific methods for sampling the parameters you are interested in, and then reference the source of your methods. *Section 4* of this guide provides some references for specific methods and sampling design considerations for Minnesota.

- Consider the variability of parameters you are monitoring. For example, bacteria counts in streams can vary widely and bacteria sampling can be easily contaminated. So you will probably want to have some QA/QC samples, such as field or sampler blanks that help determine whether or not accuracy has been compromised by contamination.

- You might choose to use QA/QC sampling to assess laboratory accuracy and precision with field kits as well as for use with a contract lab. It is always good practice to run standards and duplicates when using field kits. You can complete duplicates for assessing the precision of physical parameters such as temperature or stream flow. Taking duplicate Secchi disk readings only takes a few minutes.

- Consider the questions you might get regarding the data you are collecting. Then use this Section and the examples to identify QA/QC protocols that address those questions.

- When in doubt, reach for the highest level of quality you can and build into your program all the QA/QC protocols you can afford. Err on the side of more/better data, using the highest level of QA/QC you can.

Another option is to look for existing volunteer monitoring efforts that are tackling questions similar to the one(s) you hope to address, and ask participants about the procedures they follow and who uses their data. If you can bring an example to your potential primary data user of how similar data has been gathered and used elsewhere in Minnesota, you may be able to build a level of understanding and confidence that will allow you to work through data quality questions.

There are many examples of local individuals and organizations using volunteer monitoring data for a variety of purposes (see examples in *Appendix H*). No one magic formula will ensure your data will be used for local decision-making. However, by clearly identifying your monitoring purpose, talking through data quality questions with your intended primary data users and sharing examples from other parts of the state, you will be well on your way to assuring yourself and your primary data users that the data you generate will be usable for the intended purpose.

Quality assurance/quality control

Quality assurance refers to the overall management system, including the organization, planning, data collection, quality control, documentation, evaluation and reporting activities.

Quality control refers to the routine technical activities that help you minimize errors. Together, establishing QA/QC helps you produce data of known quality, enhances the credibility of your monitoring activities and ultimately saves time and money. To ensure quality data, both sample collection and laboratory analysis have QA/QC responsibilities.

You must collect samples according to the needs of primary data users and the Standard Operating Procedures (SOPs) you have selected, being aware of:

- sample containers (sizes and materials)
- preservation
- sample holding times
- sampling methods
- documenting methods and materials used
- sample handling before and after use to eliminate contamination

The lab must also follow the analytical SOPs and assure that:

- it is using proper analytical procedures
- it is documenting calibration procedures/results, analytical results and lab QA/QC analyses
- its instruments are calibrated according to manufacturers' direction and tested with known standards; calibrations should be recorded on lab sheets

The primary data user has the final responsibility of determining validity based on the monitoring program and analytical QA/QC procedures.

Setting data quality objectives

There are two basic ways to establish data quality objectives: 1) from your primary data users; and/or 2) from experimentation. Keep in mind that if you fail to meet your objectives, you can learn and improve, change your methods or change your data use goals. Five major parameters are typically used to measure the quality of your monitoring results and to use in building your data quality objectives.

- **Precision –** How closely repeated measurements of the same characteristic agree. You determine precision by calculating the difference between samples taken from the same place at the same time. Minimizing human error plays an important part in assuring precision.

- **Accuracy –** How close your results are to a true or expected value. You determine accuracy by comparing your analysis of a known standard or reference sample to its actual value.

- **Representativeness –** How closely samples represent the true environmental condition or population at the time a sample was collected.

- **Completeness –** Whether you collect enough valid, or usable, data (compare what you originally planned to collect with how much you actually collected). For example, if 100 samples were to be collected, but only 90 were actually collected, then 90% completeness is documented.

- **Comparability –** How data compares between sample locations or periods of time within a project, or between volunteers.

Precision is usually assessed with field and/or laboratory duplicate samples. Field duplicates are made by collecting two or more samples from the same place at the same time. This simply means you collect a duplicate sample in the exact same manner as the first sample (using the normal sampling equipment, cleaning procedures, etc.). Each duplicate is analyzed and the results theoretically should agree. Results not in reasonable agreement suggest a quality problem in the field. Laboratory duplicates consist of running analyses twice from one particular sample. Results not in reasonable agreement for laboratory duplicates suggest a quality problem in the laboratory.

How many duplicate samples do you have to collect to ensure you meet the precision parameter? *It is typically 5% to 10% of the samples collected.*

Here's how precision enters into whether your data is credible: you typically calculate the relative percent difference (RPD) (a calculation based on the percent difference of the samples) between the samples. The smaller the RPD, the more precise your measurements are. Based on the data quality objective set for the parameter you are measuring, a decision will be made about whether the data is usable or not.

Accuracy reflects how close your results are to a true or expected value. For the purposes of volunteer water monitoring, you will use procedures to determine whether or not your equipment is giving accurate results, or if contaminants are being introduced in the sampling and analysis process that may bias results and provide less than accurate results.

Accuracy in water chemistry monitoring.
QA/QC sample analyses often include blanks and spikes, as follows:

- **Sampler blanks (analyzing a blank sample with a zero value)** A sampler blank (sometimes called rinsate blank or equipment blank) is a sample of distilled or deionized water that is rinsed through the sampling device and collected for analysis. Results will determine if equipment was properly rinsed or decontaminated from one site to the next and if equipment was properly handled in the field.

Calculating relative percent difference

Data quality objectives for precision are typically expressed as the relative percent difference (RPD). Relative percent difference is calculated using the following equation:

RPD = (Result 1 – Result 2)/((Result 1 + Result 2)/2) x 100

EXAMPLE:
On May 9, 2002 the Prior Lake-Spring Lake project staff collected a field duplicate at site CD-1 on County Ditch 13, which was analyzed for Total Phosphorus (TP) with the following results:

Duplicate 1 = 0.271 mg/L TP
Duplicate 2 = 0.276 mg/L TP

RPD = (0.271 – 0.276)/((0.271 +0.276)/2) x 100 = 1.8%

This meets the field precision objective set by the project of ± 30%.

If significant concentrations of the water quality parameter being measured are found in sampler blanks, it could suggest that field equipment is not being properly cleaned between sites. In this case, you will need to determine whether to change/improve field procedures, and whether or not the problem could have affected results of other samples collected that day.

- **Field blanks** Field blanks are "clean" samples produced in the field. They are used to test for problems with contamination from the time of sample collection through analysis at the laboratory. A field blank is created by filling a clean sample container with distilled or deionized water in the field using the same procedures used to collect the site water samples. When the field blank is analyzed, it should be at least a factor of 5 below all sample results (i.e., little of the substance being analyzed should be found in the field blank sample).

- **Spiked samples (also known as matrix spikes)** One way to assess accuracy of water chemistry samples in the laboratory is to add a known concentration of the parameter to a portion of the sample to get a "spiked sample." The difference between the original measurement of the parameter in the sample and the measurement of the spiked sample should equal (or be close to) the added amount. The difference indicates your ability to obtain an accurate measurement.

- **Method blanks** A method blank consists of deionized water that is run through the normal analytical method. The method blanks should be clean water and the water quality parameters being assessed should not be detected above the reporting limits. If the water quality parameter being analyzed for is detected in this "clean" water sample, it may suggest that the analytical equipment is not accurate since it did not read the true value.

Using field blanks

In 1999 and 2000, citizen volunteers from the Vermillion River Watch Council worked with state and local agencies to monitor fecal coliform bacteria levels in the Vermillion River, Dakota County, as part of a Total Maximum Daily Load (TMDL) Study. Agencies provided training, sampling protocols, clean buckets and distilled water for rinsing.

Volunteers collected weekly samples from various sites, along with occasional field blanks. Samples were kept on ice and immediately delivered to a central location where a contract laboratory picked them up for timely analysis. By analyzing the field blanks against the samples taken from the site, they were able to assess potential contamination from the sampling method, shipping and laboratory process. Bacteria were not found in any of the field blanks, which increased the confidence that the accuracy of the measurements on the river water samples was not compromised by bacteria contamination from other sources.

**Partnering with the Vermillion River Watch Council for this project were: Dakota County, Dakota Soil and Water Conservation District, Dakota County Environmental Education Project and the Minnesota Pollution Control Agency.*

Accuracy in biomonitoring.
For biological (plant and animal) monitoring, accuracy is commonly assessed during sample processing and identification.

Processing: Typically, samples are processed in a laboratory, after they have been collected and preserved. In the lab, organisms are removed from the excess sediment or vegetation that was collected during sampling. Usually a lab technician will use a microscope to sort through samples, but most volunteer monitors pick through samples with the naked eye. To ensure that the final group of identified organisms accurately reflects the sample, an independent person should check the matrix of sorted material to ensure all organisms were found. Ideally, you will find 95 percent of the target organisms.

Identification: Usually all volunteers' invertebrate identifications must be verified by an expert. Typically, an expert verifies entire samples, but as the volunteers' skills increase, they can assemble a "voucher collection" to use as a primary means for verification. A voucher collection is a collection of invertebrates, all verified by an expert, that is preserved for use a "true value" to which taxonomic comparisons can be made. Even with the use of a voucher collection, there will always be difficult organisms that must be checked by an expert.

Repeat sample: To ensure that the individual or individuals responsible for collecting the field sample are doing so properly and consistently, two samples should be taken at a minimum of 10 percent of all sites sampled. The second sample can be collected concurrently with the first sample, or within a relatively short time from the collection of the first sample (i.e., one to three weeks). Wetland and stream samples can generally be collected concurrently, but care must be taken to collect the second sample in an area that was not disturbed while taking the initial sample. If concurrent sampling is not possible, take

Matrix spike calculations

Percent recovery for matrix spikes is calculated with the following equation: **% recovery = (C1 – C2) /C3) x100**
C1 = Concentration of spiked sample **C2** = concentration of unspiked sample **C3** = Concentration of spike added

Assessment of laboratory accuracy for the Prior Lake–Spring Lake Improvement Project

The contract laboratory used for this project included the following results in their laboratory report for May 9, 2002 samples. Review shows that these results meet data quality objectives, since concentrations were not detected in the method blanks and the matrix spike percent recovery results were within the guidelines of 90 to 110 percent.

Analyte/Parameter	*Method Blank Results*	*Matrix Spike Results*
Ortho Phosphate as P	<0.006 mg/L	98% recovery
Phosphate as P, Total	<0.010 mg/L	99% recovery

spring samples at a close interval, as this is a time when the invertebrate community can change rapidly in a short time frame (i.e., one week). Fall samples can be spaced up to three weeks apart.

Representativeness. A number of factors may affect the extent to which measurements actually represent the true environmental condition or population at the time a sample was collected. For example, data collected from a backwater area of a stream may not be representative of the primary flow in the stream. Making sure the data you collect is representative of the water body is typically addressed with sampling program design (see *Section 4: Designing Your Monitoring Program*).

Completeness is a measure of the number of samples you originally determined you would need, compared to how many you actually collected. For example, if your monitoring purpose is *problem investigation* with the intent to provide data to the MPCA for assessing the impairment status of a lake, you need to meet MPCA's data needs. That means, if you were assessing the narrative eutrophication standard, you would need to collect 12 total phosphorus samples, 12 chlorophyll-*a* samples and 12 Secchi disk measurements. If, at the end of your project, you had collected only 10 measurements of each parameter, it would mean you did not meet your data quality objective for completeness. Since there are many reasons why samples are not collected as planned, a general rule of thumb is to plan to collect more samples than you actually need.

Comparability is the extent to which data can be compared between sample locations or periods of time within a project, or between projects. This is a useful data quality check that essentially asks how your data compares with data that others have found for the same site or for similar conditions. It is good practice when reporting your data to include comparisons with other data.

Other data quality considerations

Although incorporating the above parameters will help ensure credible data, you will also need to do the following: follow instructions; provide documentation; inspect, maintain and calibrate equipment; and manage data.

Following instructions. It's easier to follow instructions that are developed using clear Standard Operating Procedures (SOPs) (the detailed procedures for the methods you will use). You should develop SOPs for your project before you go to the field. Many SOPs are already available for sampling and analytical procedures. Section 4 of this guide references a number of existing methods manuals, which include SOPs.

"Comparability" in action

For a quality check, the Metropolitan Council, as part of its Citizen-Assisted Monitoring Program (CAMP), routinely has a professional limnologist on its staff collect samples from the same lakes at approximately the same date that volunteers are monitoring. This professionally collected quality check is compared with CAMP volunteer collected data. Data generated by the CAMP program has been accepted by the MPCA and used as part of its impaired waters assessments.

Reporting laboratory QA/QC results

Data quality objectives are typically established for both field and laboratory efforts.If you decide to use a contract laboratory, we suggest making the reporting and assessment of laboratory QA/QC parameters a required part of the laboratory report. Guidance for retaining laboratory services is included in *Appendix B*.

Documentation. It is important to use and completely fill out data sheets. The same holds true for sample bottle labels, lab sheets (if applicable) and sample drop-off sheets (e.g., chain of custody).

Inspecting, maintaining and calibrating equipment. Keep field and laboratory equipment in good working condition. You should regularly inspect equipment and perform maintenance as suggested by the manufacturer. You should calibrate equipment before each use according to manufacturers' directions and test with known standards.Record all calibrations on lab or field sheets.If equipment is used to collect analytical samples, decontaminate the equipment between sample collections and analyses.

Data management. The subject of managing data is covered in detail in *Section 5*. As you collect data, it is a good idea to check it against your data quality objectives throughout the project, so if corrective actions are necessary they can be made before the end of the project. Try to identify a QA/QC project manager who can review the data and compare it with the data quality objectives. No data should be entered into a database before the QA/QC manager approves it. If data does not meet the data quality objectives set for your project, a decision needs to be made regarding its use and if it should be flagged when it is entered into a database.

Using data quality parameters in the field

The Dakota County Wetland Health Evaluation Project (WHEP) demonstrated the use of data quality parameters in a project to sample plant and invertebrate (true bugs, beetles and crustaceans) communities in the county's wetlands.

In the project, adult citizen volunteers worked under the direction of local teachers or nature center staff. In 2001, 10 teams (representing 10 cities) sampled 41 wetlands. To implement the program, they held three training sessions for the citizen monitoring teams. At least one experienced person on each team served as the team leader. The teams relied on spot checks to ensure they were adhering to data quality parameters.

- Each city evaluated one wetland in another city, as a means of providing a duplicate analysis and assessing whether repeated measurements agree (i.e., are precise).
- A technical expert spot-checked 10% of the wetlands sampled to assess accuracy, representativeness and completeness.

The expert reviewed the vegetation sample plot already evaluated by the citizen team to check if it was *representative* of the wetland and the vegetation was *accurately* identified. The expert also reviewed the insects collected by the team to check for *accuracy* of identification and to ensure they completely filled out the data collection sheets.

Taking the next step: developing a Quality Assurance Project Plan (QAPP)

A QAPP is a written document that outlines the procedures you would use to ensure that the samples you collect and analyze, the data you store and manage and the reports you write are of high enough quality to meet the desired data uses. A QAPP is a plan required for all USEPA- funded monitoring efforts.

A QAPP is very thorough and detailed, with elements prescribed and formatted to meet the needs of reviewers and provide some standardization across the county. A QAPP has the following elements:

1. Title and Approval Page
2. Table of Contents
3. Distribution List
4. Project/Task Organization
5. Problem Identification/Background
6. Project/Task Description
7. Data Quality Objectives for Measurement Data
8. Training Requirements/Certification
9. Documentation and Records
10. Sampling Process Design
11. Sampling Methods Requirements
12. Sample Handling and Custody Requirements
13. Analytical Methods Requirements
14. Quality Control Requirements
15. Instrument/Equipment Testing, Inspection, and Maintenance Requirements
16. Instrument Calibration and Frequency
17. Inspection/Acceptance Requirements for Supplies
18. Data Acquisition Requirements
19. Data Management
20. Assessment and Response Actions
21. Reports
22. Data Review, Validation, and Verification Requirements
23. Validation and Verification Methods
24. Reconciliation with Data Quality Objectives

A QAPP can be extremely valuable to you and the data users to ensure that the data collected is of a certain confidence and meets the objectives of the project. You can use the QAPP to make sure you are following proper procedures and collecting data that meet the project objectives and will be credible to decision-makers.

The ability to reference a QAPP and show how it was followed can also help you answer questions from other groups concerned about the reliability of your data. However, QAPPs are not necessary in every situation, and it does take some time to put one together. Unless you are required to do a QAPP, you may want to start with a monitoring plan (see *Section 4*). And, once you have completed a study design, it's easier to move up to a QAPP, as most of the elements required by a QAPP will be a part of your study design.

For more on QAPPs

For additional information on Quality Assurance Project Plans, see *The Volunteer Monitor's Guide To Quality Assurance Project Plans* by the USEPA, Doc. number EPA 841-B-96-003

http://www.epa.gov/owow/monitoring/volunteer/qappcovr.htm

and *The Massachusetts Volunteer Monitor's Guidebook to Quality Assurance Project Plans*, Doc. number DWM-CN61.0

Section 4:

Design your monitoring effort

This Section will show you how to:

- **Translate your monitoring purpose and objectives into a plan of action.**

Map out your monitoring journey

Probably the most critical step in developing a successful monitoring effort is designing a plan in advance. Designing your monitoring project up front will keep you from spending time and money unproductively.

You've already decided where you want to go (purposes and objectives). Now, with a design plan, you will document where you are starting from and what it will take to accomplish your goals.

Involve data users

A good reason for putting your monitoring plan down on paper is that you can have the plan reviewed by your primary data users. Determining who they are and involving them early in your process will ensure that the data you collect will be credible and usable. Ultimately, the primary data user is responsible for ensuring accuracy through review of QA/QC procedures.

Build your design

This guide provides general information to help you decide how to design a basic monitoring program for lakes, streams and wetlands. The guide does not include detailed step-by-step descriptions of field and laboratory methods, because there are many existing manuals that provide good descriptions. Some of these are listed in *Appendix C*; others are listed, when appropriate, in this Section.

Determining your monitoring purpose and your data quality needs are important first steps in developing a monitoring plan. In fact, a purpose statement and your data quality objectives should be documented in your plan. Learning how to develop a monitoring purpose is covered in *Section 2* and working with data quality is covered in detail in *Section 3*. Your plan should also give thought to managing the data you collect and converting this data to information. Managing data is discussed in *Section 5*, and converting data to information in *Section 6*. In *Section 6* you will find a series of questions to help assess whether data collected was influenced by natural conditions or the monitoring design. These questions should also be considered during design to help assure you are collecting representative data.

You will build your monitoring design by considering the following, in addition to the materials in the other Sections:

- Learning about your water body or watershed
- Determining what, how, when and where you will monitor (the core of your plan)
- Documenting your monitoring activities
- Considering safety issues
- Ensuring data QA/QC procedures are followed

These items are the focus of this Section, but keep in mind that you need to consider and document decisions made with respect to the topics discussed in the other Sections of this guide.

I. Learn what is already known about your water body or watershed.

A water monitor's starting point is not from a particular lake or stream, but from the watershed that the water body is part of. Collect as much background information about the watershed as possible, depending on your particular purpose and intended data use. Some purposes will require a great deal of detail; others will require little detail. You may want to include information such as: geologic and soils information, land uses, watershed boundaries and drainage patterns, water quality and biota, locations of point source discharges such as wastewater treatment plants, rainfall records, groundwater-surface water interactions, and streamflows and lake levels.

The following discussion provides sources and guidance for finding:

- Available maps
- Hydrologic information
- Information on past and current monitoring efforts and studies
- Fish and aquatic plants
- Wetlands
- Lakes
- Basin information

You can obtain a lot of this information from your local municipality, County Water Planners, Soil and Water Conservation Districts and Watershed Management Organizations (see *Section 2* for a list of on-line directories for local government decision makers and organizations). Area MDNR and regional MPCA personnel are also good sources for finding existing information. More sources of information are listed in the pages that follow.

After you have collected and reviewed available background information, you may want to revisit your monitoring purpose and the original questions you wanted to answer (see *Section 2: Monitoring Purpose, Data Uses and Goals*). Ask yourself if the background information answered your question(s), or changed the question(s) you want answered.

Be prepared to change objectives

Organizers of the Bois Forte Reservation monitoring program (tribal government) refined their original monitoring program objectives down from the numerous parameters they had decided to monitor and chose instead to monitor fewer parameters and focus more on nitrogen and phosphorus.

Source: *An Evaluation of Citizen Volunteer Water Quality Monitoring*

Map sources

As a result of the Minnesota Lakes Association's Sustainable Lakes Project, a set of 21 Geographic Information System (GIS) maps for all 7,000 minor watersheds in Minnesota is available for viewing or purchase at the John R. Borchert Map library in the Wilson Library on the West Bank of the University of Minnesota. The user-friendly program allows you to determine which boundaries you want mapped, view the data on the computer screen and print the maps for a modest charge. The maps can also be viewed anytime without purchasing. The Map Library's phone numbers are: 612-624-4549; fax, 612-626-9353.

Each map set includes the following 21 resource maps for each minor watershed in Minnesota:

1.. Government political boundaries
2. Pre-settlement vegetation
3. Shaded relief
4. Slope
5. Area roughness
6. Geomorphology
7. Public ownership
8. Water features
9. Land use
10. Forest cover
11. Soils
12. Septic tank suitability
13. Groundwater contamination potential
14. Erosion (runoff) susceptibility and water orientation
15. Scenically attractive areas
16. Scenically attractive private land within π mile of a road (e.g. likely development areas)
17. Scenically attractive public land within π mile of a road (e.g. potential recreational development)
18. Scenically attractive public land over π mile from a road
19. Possible agricultural irrigation areas on private land with less than an 8% slope (areas where irrigation is likely to cause groundwater contamination)
20. Aerial photography
21. United State Geological Survey

Additional map sources include:

- Minnesota Geographic Data Clearinghouse ***http://www.lmic.state.mn.us/chouse/index.html***
- Datafinder interactive maps ***http://www.datafinder.org/maps.asp***
- Metropolitan Council ***http://gis.metc.state.mn.us***
- Counties and SWCDs
- University of Minnesota Terra Sip ***http://terrasip.gis.umn.edu/projects/***
- Minnesota River Basin Data Center ***http://mrbdc.mankato.msus.edu***
- Metro GIS ***http://www.metrogis.org***
- Lake depth maps – Minnesota Department of Natural Resources (MDNR) Lake Finder web page (***http://www.dnr.state.mn.us/lakefind/index.html***).

- Wetland maps, including those in the National Wetland Inventory and MDNR Protected Waters Inventory – part of the atlas of maps available from the Science Museum, the Minnesota Geographic Data Clearinghouse

- Information on point source discharges – MPCA Data Access web page **http://www.pca.state.mn.us/data/eda/index.html**

Hydrologic information

- Historic rainfall records for many locations across the state are available from the Minnesota Climatological Network **http://climate.umn.edu/doc/historical.htm.**

- Flow records for many Minnesota streams and rivers are available from the USGS at **http://www.usgs.gov** or **http://mn.water.usgs.gov** or **http://waterdata.usgs.gov/mn/nwis/sw**.

- The MDNR has a lake level network comprised of approximately 900 stations. Look at the Lake Finder web page, referenced previously, to find out if there is a record for your lake.

Information on past and current monitoring efforts and studies

MPCA Water Quality Database

A good place to start for historical water quality information is the MPCA Water Quality Database. A web-based system with links to this database is available as of July 2003 at **http://www.pca.state.mn.us/data/eda/index.html**. The MPCA's website also includes information about the extent to which waters of the state support their designated water quality uses as identified in state water quality standards. Current use-support information for lakes and rivers in Minnesota can be found at **http://www.pca.state.mn.us/water/basins/305blake.html**, and **http://www.pca.state.mn/water/basins/305briver.html.**

In addition, every two years the MPCA completes a list of waters designated as "impaired" as required by section 303(d) of the federal Clean Water Act. These waters are slated for remedial action via the completion of a plan to restore the waters. Information on TDMLs and the most recent list of impaired waters (completed in 2002) is available at **http://www.pca.state.mn.us/water/tmdl.html**.

Other databases

- Minnesota River Basin Data Center **http://mrbdc.mankato.msus.edu**

- Metropolitan Council's Environmental Information Management System (EIMS) web address under development; contact Metropolitan Council at 651-602-1056

Local programs

Not all programs and studies are included in these databases. Additional local information can often be uncovered by talking with local water planners and other local staff. The Minnesota Water Resources Center, **http://wrc.coafes.umn.edu**, and USGS, **http://www.usgs.gov**, have completed numerous studies across Minnesota and may have data available for your lake, stream or wetland.

Fish and aquatic plants

- MDNR Fishery Surveys are available at the Lake Finder web page.

- USGS also has data available on fish communities across the nation at **http://water.usgs.gov/nawqa/data**.

- County biological surveys may also be a good source of information on rare, threatened or endangered species and unique natural communities.

Wetlands

The MPCA, in collaboration with the DNR and the Board of Water and Soils Resources (BWSR), is developing approaches for monitoring and assessing the health of Minnesota wetlands. This monitoring effort will take into account the features that make wetlands unique from lakes and streams. The MPCA is focusing on developing indexes of biological integrity for depressional wetlands based on invertebrates and plants.

Some wetland information is available from the MPCA (through its Water Quality Database) based on past studies. Many communities have completed Comprehensive Wetland Management Plans under the State of Minnesota Wetland Conservation Act, where you may be able to find information on the current functions and values of particular wetlands. Several Dakota and Hennepin County communities are participating in the Wetland Health Evaluation Project (WHEP), a citizen wetland assessment program based on the MPCA's development of biological methods and criteria for wetlands. ***http://www.mnwhep.org.***

Lakes

- DNR Lake Finder website ***http://www.dnr.state.mn.us/lakefind/index.html***
- MPCA Lake Water Quality Assessment Program web page ***http://www.pca.state.mn.us/pca/lkwq95search.html***
- The Metropolitan Council has developed a system that assigns a "grade" (A through F) to lakes monitored through the CAMP program and an annual report is produced covering the monitored lakes.

Basin Information

Basin information documents are produced by the MPCA for major water basins in the state. See ***http:// www.pca.state.mn.us/water/basins/index.html*** for current status of the reports and contact information.

II. Determine *what*, *how*, *where* and *when* you will monitor.

This is the heart of your monitoring design plan – deciding what, how, where and when you will monitor.

General determinations for lakes, streams and rivers, and wetlands

This guide is organized to provide general considerations on what and how to monitor that are common to lakes, streams and rivers and wetlands. Then, considerations that are specific to lakes, streams and rivers and wetlands are covered, including where and when to monitor.

Where and when to monitor varies significantly among the three media. However, carefully selecting the best monitoring site is important to ensure the data you collect is representative of the water body and the condition you want to characterize. Remember, *many of the state's water resources are bordered by private property. Always contact landowners and receive permission before entering or crossing private property.* You may also want to have a liability waiver, signed by volunteers, to present to landowners to make them more comfortable about allowing access.

What to monitor

Include in your monitoring plan a list of the data you are going to collect. Following are the most frequently used monitoring parameters for lakes, streams and rivers, and wetlands (list is not exhaustive). Exhibits 4-1 and 4-2 organize these parameters into types of water quality problems and pollution sources. Use these tables and the following parameter descriptions as guidance for choosing parameters to monitor.

Exhibit 4-1 Sources and associated pollutants for volunteers to consider monitoring

Source	Associated pollutants and conditions
Cropland	Turbidity, nutrients (phosphorus, nitrite + nitrate), temperature, total suspended solids, changes in the biological community (macroinvertebrates, fish, plants)
Construction	Turbidity, temperature, dissolved oxygen, total suspended solids, changes in the biological community
Forestry harvesting	Turbidity, temperature, total suspended solids, changes in the biological community
Grazing and feedlots	Fecal bacteria, turbidity, nutrients (phosphorus, nitrite + nitrate), total suspended solids, temperature, changes in the biological community, stream bank stability
Industrial discharge	Temperature, conductivity, total suspended solids, pH, changes in the biological community
Property development/ lakeshore urbanization	Total suspended solids, total phosphorus, changes in shoreline vegetation, changes in aquatic vegetation
Septic systems	Fecal bacteria, nutrients (phosphorus, nitrite + nitrate), dissolved oxygen, conductivity, temperature, changes in the biological community
Sewage treatment plants	Dissolved oxygen, turbidity, conductivity, nutrients (phosphorus, nitrite +nitrate), fecal bacteria, temperature, total suspended solids, pH, changes in the biological community
Urban runoff	Turbidity, nutrients (phosphorus, nitrite + nitrate), temperature, conductivity, dissolved oxygen, changes in the biological community

Exhibit 4-2 Water quality problems and monitoring parameters for volunteers to consider[1]

Problem/concern	Water body type	Parameters
Eutrophication (i.e., nutrient enrichment)	Lakes and streams	Nutrients (phosphorus and nitrogen), Secchi transparency (lakes), turbidity/transparency tubes (streams), chlorophyll-*a*, dissolved oxygen, temperature, flow, and changes in the biological community (fish, plants, macroinvertebrates, etc.)
Habitat loss	Lakes, streams and wetlands	Macroinvertebrate biosurveys, habitat, temperature, aquatic plant surveys, shoreline surveys and flow
Low oxygen levels	Lakes and streams	Dissolved oxygen, nutrients (phosphorus, nitrogen), temperature, chlorophyll-*a*, flow and macroinvertebrate biosurveys
Sedimentation	Streams and wetlands	Total suspended solids, turbidity/transparency tubes, habitat, macroinvertebrate biosurveys and flow

[1] Additional advanced parameters may be helpful for characterizing some problems such as biochemical oxygen demand and ammonia for diagnosing low oxygen levels.

Nutrients

Phosphorus and nitrogen are essential plant nutrients that stimulate the growth of algae and other aquatic plants. Algae are microscopic plants that, when overabundant, turn surface waters green and scummy. Of the two plant nutrients, phosphorus is often considered to be the nutrient that regulates the production of algae in most lakes and is also the most amenable to control.

Numerous forms of phosphorus and nitrogen can be measured in a laboratory or with a field kit.

- Total phosphorus represents dissolved phosphorus and phosphorus attached to particles (i.e., soil) in the water. It is the single most important nutrient analysis to complete for a lake.

- Ortho-phosphorus represents the reactive phosphorus in the water. It is a measure of the phosphorus that is readily available for use by algae, and is important to consider in comprehensive lake and watershed studies.

The forms of nitrogen of most interest in surface water studies are total Kjeldahl (TKN), which includes ammonia-N and organic-N, and nitrite + nitrate N. TKN plus nitrite + nitrate N represents total nitrogen (TN). Nitrite + Nitrate N are very soluble in water and are readily used by algae. Concentrations of nitrite and nitrate are frequently so low that they are at or below the ability of a laboratory to detect them in a sample (detection limit). Of the forms of nitrogen discussed, TKN is the most important to measure for lakes. In some cases ammonia-N is also important to measure because ammonia at elevated levels in the un-ionized form is toxic to aquatic life.

Solids

A variety of parameters provide information on the amount of dissolved and suspended material in lake water. Suspended materials influence the transparency, color and overall health of an aquatic ecosystem.

The total suspended solids parameter (TSS) is the most common measure of the amount of suspended solids in water. TSS is the mass of solids per unit volume of water. TSS is measured by weighing a container, filling it with a known volume of water, evaporating the water in an oven, completely drying the residue, and then weighing the container with the residue. TSS measurement cannot be done in the field. TSS is an important parameter to consider if you suspect sediment and water clarity are issues.

Transparency and turbidity

Turbidity is a measure of light scattering properties of suspended materials. Transparency is the depth to which light penetrates the water column. In theory, the more suspended material exists, the more light scattering (i.e., turbid), and hence, the less transparent.

Secchi disk, turbidity meters and transparency tubes are commonly used to measure these parameters. Secchi transparency is a measurement of water clarity, and is considered an indirect measurement of algae or suspended sediment in the water. As one of the three measures used to characterize the trophic status of a lake (others are chlorophyll-*a* and total phosphorus), it is essential to any lake monitoring program.

Transparency tube data helps determine where to place grassy buffers

Volunteers in the MPCA's Citizen Stream-Monitoring Program (CSMP) use transparency tubes to determine water clarity in streams once a week, plus after significant rainfall events, from April through September. The Big Birch Lake Association (BBLA), which is part of CSMP, relies on CSMP transparency data to help decide where grassy buffers should be planted to filter agricultural runoff. When a monitor found that a downstream site had much lower transparency, it was traced to a drainage ditch that empties into the creek between his two monitoring sites. The BBLA worked with the landowner to install buffers along the ditch.

Source: *Volunteer Monitor*, Summer '02

Secchi transparency is measured using a Secchi disk, which is a white, or white and black circular metal plate, six to eight inches in diameter, attached to a calibrated rope. The disk is lowered into the water until it disappears and then raised until it reappears, and the depth is recorded. It is probably the least expensive and easiest-to-use tool in lake water quality monitoring. Turbidity is generally measured by using a turbidity meter, or samples can be sent to a laboratory for analysis. A transparency tube is 60 cm long, with a colored disk on the bottom into which the sample water is poured until the colored disk is no longer visible. Transparency tubes are generally used with stream monitoring and can indicate problems with water clarity, and/or suspended sediment.

Alkalinity

Alkalinity is a measure of the buffering capacity of the water. It is typically reported as total alkalinity, which you determine by measuring the amount of acid (i.e., sulfuric acid) needed to bring the sample to a pH of 4.2 standard units (s.u.) You can do this with field kits or in a laboratory. Lakes and streams in regions of the state with thick soil cover and some limestone will have moderate to high alkalinities. Lakes and streams in regions with thin soils, or lakes on bedrock, such as those in northeastern Minnesota, may have very low alkalinities. Alkalinity is not a pollutant itself, but indicates sensitivity to acid rain. Acid rain impacts may be a concern for lakes with alkalinities less than 5 milligrams per liter (mg/L).

Chlorophyll-*a*

Chlorophyll-*a*, a plant pigment necessary for photosynthesis, is used as a surrogate measure/indicator of algae (phytoplankton) biomass in water. If algae populations are dense, water becomes noticeably green with a lower-than-normal transparency and greater chlorophyll-*a* concentrations. The preferred measure is chlorophyll-*a*, corrected for pheophytin *a*. Pheophytin *a* is a common degradation product of chlorophyll-*a* that can interfere with the measurement of chlorophyll-*a*. Chloroplyll-*a* is often measured using a fluorometer. Chlorophyll-*a*, as one of the three parameters used to assess lake trophic state (the other two are total phosphorus and Secchi disk transparency), is important to measure for lake studies.

Conductivity

Conductivity is a measure of the ability of water to pass an electrical current. It is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Conductivity is also affected by temperature. For this reason, conductivity is reported as conductivity at 25 degrees Celsius.

Waters with high alkalinity often have high conductivity and vice versa. Lakes with low conductivity would be considered “soft,” and high conductivity, “hard.” Streams tend to have a relatively constant range of conductivity that, once established, can be used as a baseline for comparison with regular conductivity measurements. Significant changes in conductivity could then be an indicator that a discharge or some other form of pollution has entered the stream. Conductivity can be measured with a field meter.

More advanced monitoring parameters

Information on other parameters that also can be monitored by volunteers, such as ammonia nitrogen, or dissolved phosphorus can be found in professional references, such as the Minnesota Lake and Watershed Data Collection Manual available at the Minnesota Shoreland Management resources guide website, ***http://www.shorelandmanagement.org.***

Dissolved oxygen

Dissolved oxygen (DO) is measured to characterize the amount of oxygen available for aquatic life. At low DO concentrations, sensitive animals may move away, weaken or die. It also influences decomposition rates and the composition and cycling of other water quality parameters. Low dissolved oxygen concentrations indicate either high demand for oxygen or limited reaeration from the atmosphere. Dissolved oxygen can be measured with field meters or test kits.

Temperature

The rates at which biological and chemical processes progress depend on temperature. Aquatic organisms, from microbes to fish, are dependent on certain temperature ranges for their optimum health. If temperatures are outside this optimal range for a prolonged period of time, organisms are stressed and can die. Measuring temperature in lakes is also important for characterizing thermal stratification. Thermal stratification occurs when water at different temperatures forms in layers, and is important because it affects vertical mixing and the distribution of chemical and biological characteristics.

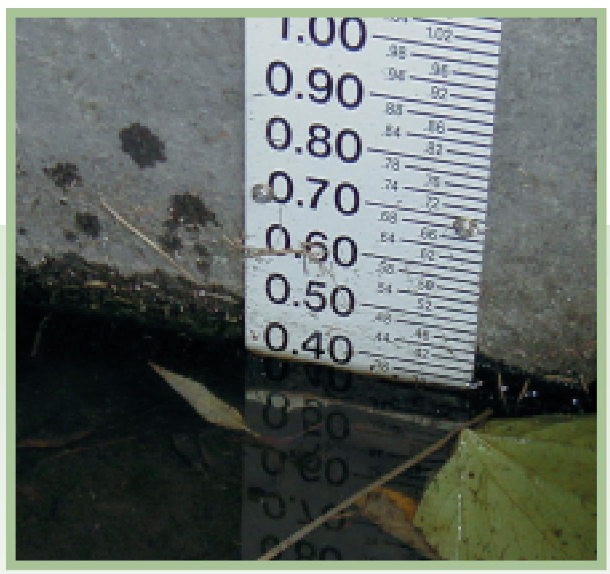
Temperature is measured in degrees Fahrenheit (F) or degrees Celsius (C). Temperature can be measured with either thermometers or meters, but must be measured in the field. Temperature is an important part of any surface water study.

pH

The acidity of water, as measured by pH, is a concern to aquatic life. A desirable range is between 6.5 and 9.0 standard units (s.u.). pH is not an indicator of a particular pollutant; however, it affects many chemical and biological processes in water. For example, low pH can allow toxic elements and compounds to become mobile and "available" for uptake by aquatic plants and animals. pH can be measured with paper strips, field kits, and meters in the field or in a laboratory.

Flow

Stream flow, or discharge, is the volume of water that moves past a specific point per unit of time. It is usually expressed as cubic feet per second (cfs or ft^3/sec). Flow is a function of water volume and the speed at which it is traveling (velocity). It is important because it impacts water quality and the habitats and living organisms in



Getting data on flow

Flow is a critical part of stream and river monitoring efforts. You may be able to take advantage of existing flow stations or get assistance from professionals to develop a stage discharge curve, which relates the various stages or heights of the stream to flow. For example, the USGS operates a gauge station on the Crow River at Rockford (USGS Station 05280000). If you were monitoring at or near this station, instead of taking your own flow measurement, you could either: 1) read the river stage off the Station's staff gauge, call the Station for its stage discharge curve and determine the flow; or, 2) go to its website ***http://waterdata.usgs.gov/mn/nwis/sw*** and see what the flow is either right before or after you monitor. The point is that if you have an established stagedis charge relationship, you only need to record the stage or elevation reading off a post in the river or on a bridge, to get an estimate of flow. Real-time flows are available in several places on the Web.

the stream. Fast-moving streams have higher dissolved oxygen concentrations than slow-moving streams because they are more turbulent and better aerated. High flows can dilute dissolved pollutants, and at the same time, increase the amount of particulate pollutants such as silt and sediment suspended in the water, compared to low flow. Flow in rivers and streams is dynamic, increasing during rainstorms, decreasing during dry periods, and changing with seasons of the year. Since it is very dynamic and influences many of the water quality parameters likely to be monitored, as well as living organisms, measuring stream flow is an essential part of any stream or river monitoring effort.

Some monitoring groups rely on qualitative estimates of flow (e.g. "high," "normal," or "low") to provide a general idea of stream conditions. Other groups measure flow using relatively sophisticated equipment and methods. Keep in mind that flow data may already be available from a local, state or federal agency for the stream you are sampling (see box, "Getting Data on Flow"). Because of the complexity of flow monitoring, if you decide to include quantitative (i.e., numeric, rather than descriptional) flow monitoring in your plan, it is a good idea to consult a professional to help with initial design. The level of effort (and detail) you put towards flow measurement will depend on the purpose of your monitoring and how you want your data to be used.

Lake level

Similarly to flow monitoring for streams, lake level measurements provide information about the hydrologic conditions of a lake (i.e., if the lake is experiencing high water levels, low water levels, etc.). To monitor lake level, first install a lake gauge either on a fixed structure (such as a bridge abutment) or on a metal pole driven into the lake bottom. Then take lake level measurements on a periodic basis (often weekly) and after major rainstorm events. Lake level data help volunteers and water resource managers interpret other monitoring data, model lake water quality characteristics and understand the natural fluctuations of the lake. Find more information on lake level monitoring, including how to get involved in the DNR's volunteer lake level monitoring program, at the DNR's Lake Level Minnesota web page at ***http://www.dnr.state.mn.us/volunteering/lakelevelmn.html.***

Precipitation

Volunteers often collect precipitation (rainfall) data along with other parameters. Precipitation monitoring provides information that is critical to properly interpret other water quality data. For example, if you find unusually high sediment concentrations in a stream one day, knowing that it rained two inches the night before would provide helpful clues as to the reason for the excess sediment. You can do precipitation monitoring with a simple rain gauge placed in your yard or on your deck, particularly if your house is close to your monitoring site(s). Do more complex monitoring through the use of an automatic weather station installed at the sampling site. Or, you may be able to rely on other volunteers if there is a precipitation monitor close to your sampling site(s).

Habitat

The type and quality of habitat in streams and rivers have a significant influence on living organisms. Some organisms prefer fast moving water; others, quiet pools. Where degraded, poor habitat conditions may impair aquatic communities and frequently will be a greater stressor to the aquatic community than pollutants measured by chemical monitoring. Habitat assessments are an essential part of studies assessing aquatic life and stressors to aquatic life in streams and rivers. You can assess levels of habitat in several ways, ranging from visual observations recorded during stream walks to detailed measurements compiled into numerical indices.

Bacteria

Fecal coliform bacteria are indicators of possible sewage contamination because they are commonly found in human and animal feces. Large numbers of coliform bacteria suggest that other pathogenic microorganisms found in human and animal waste might also be present and swimming may be a health risk. You will need sterile equipment to monitor for fecal coliform bacteria. It has a short holding time between when the sample is collected and when it needs to be analyzed and requires care when collecting to prevent sample contamination. Fecal coliform bacteria can be measured using kits or a laboratory. Both approaches require some method of incubating and counting the bacteria colonies.

Macroinvertebrates

Macroinvertebrates are organisms that are large (macro) enough to be seen with the naked eye and lack a backbone (invertebrate). (*Volunteer Stream Monitoring: A Methods Manual*, EPA, 1997). They are a frequent part of stream monitoring efforts and more recently have been a part of wetland assessments. They inhabit all types of waters, from clear fast-flowing streams to slow-moving muddy rivers, to wetlands. Examples include insects, crayfish, clams, snails, leeches and worms.

Aquatic macroinvertebrates are good indicators of stream and wetland quality because:

- They are affected by the physical, chemical, and biological conditions of the stream or wetland.
- They have limited mobility and most can't escape pollution; therefore, they show the effects of short- and long-term pollution events.
- They display a wide range of sensitivities to many forms of impairment and may show the cumulative impacts of pollution.
- They may show the impacts from habitat loss not detected by traditional water quality assessments.
- Some are very intolerant of pollution.
- They are relatively easy to sample and identify to a level that provides meaningful information about stream and wetland health.

Fecal coliform data used to post swimming risks

Using fecal coliform data, the Mississippi River Revival (private organization) helped organize the Mississippi Corridor Neighborhood Coalition (nonprofit) and partnered with area parks to create and post signs along shore. The signs are updated to indicate when bacteria levels are over the state water quality standard, and used to recommend to the public not to swim in the water.

Source: *An Evaluation of Citizen Volunteer Water Quality Monitoring*

Volunteers evaluate best management practices

Some Dakota County participants in the Wetland Health Evaluation Project are teaching scientists a thing or two about wetland restoration. Volunteers are monitoring the plant and invertebrate communities of Cedar Pond in Eagan "before" and "after" the installation of best management practices (BMPs) designed to enhance and restore wetland vegetation and improve water quality. The initial monitoring was completed in 2000, and the project partners installed the BMPs in 2001. Follow-up monitoring will continue by volunteers for at least five years to evaluate the success of the restoration project.

Source: *Dakota Wetland Health Evaluation Project: 2001 Field Season Summary*

The basic principle behind the use of macroinvertebrates in monitoring is that some are more sensitive to disturbance than others. Therefore, if a site is dominated by a group of organisms that are tolerant of human disturbance and the less tolerant organisms are missing, an impairment is likely.

For example, stonefly nymphs are aquatic insects that are very sensitive to pollution that affects dissolved oxygen and cannot survive if a stream's dissolved oxygen falls below a certain level. If a biosurvey shows that no stoneflies are present in a stream that used to support them, a hypothesis might be that dissolved oxygen has fallen to a point that keeps stoneflies from reproducing, or the lack of dissolved oxygen has killed them outright.

The advantage of a macroinvertebrate biosurvey is that it tells us when the stream or wetland ecosystem is impaired, or "sick," due to pollution or habitat loss. It is not difficult to realize that a stream full of many kinds of crawling and swimming "critters" is healthier than one without much life. It is easier to assess community impairment when macroinvertebrate biosurveys are combined with information about other biological assemblages (such as fishes, algae or plants), and monitoring of physical and chemical information (such as habitat or dissolved oxygen). The two types of monitoring, physical/chemical and biological, provide complementary information. Characterizations of plants and wetland types are important supporting data for wetland macroinvertebrate biosurveys.

Macroinvertebrate data can be used to assess streams and wetlands at several levels. Invertebrates collected and identified by trained professionals can allow for the calculation of an Index of Biotic Integrity score, where you can compare the stream's or wetland's biological community to a regional "index" or reference for similar streams or wetlands to see how the stream compares. Biosurveys you conduct can serve as useful screening tools, which can be followed up with a more detailed biosurvey later if the screening indicates a potential problem. If you want to interpret which conditions and parameters are affecting the invertebrate community, you should also collect information on upstream land use, general chemistry, physical parameters and habitat conditions.

Biosurvey methods vary from relatively simple collection techniques (with family level keys and identification protocols) for education purposes, to more rigorous collection methods and sophisticated analytical techniques. You typically conduct biosurveys when you remove macroinvertebrates from the stream by disturbing the substrate (stream bed materials, plants, woody debris) that harbors the target organisms. You generally will use some form of net (kicknet, dipnets or surber samplers) to collect them as the current washes them downstream. Then, either count and identify the organisms along the stream or wetland (for screening purposes), or preserve them in alcohol and bring them back to the lab for identification and counting (for more detailed assessment). You can store properly preserved macroinvertebrates for several years prior to identification.

Flora (plants)

For wetland monitoring, it is particularly important to identify plants and plant communities. One of three characteristics that define a wetland is the presence of hydrophytic (water-loving) vegetation, which varies depending on the type of wetland. Similarly to the macroinvertebrate community, the wetland plant community can indicate degradation or impairment. For example, the absence of submerged plants in a wetland where they would be expected, the presence of exotic species, or dominance by a single species could indicate stresses or pollution problems.

Identify plant communities and species with simple methods such as noting the presence or absence of communities and species, or with more complex surveys that map out communities and species for the entire area or at representative plots/transects.

You can also monitor to characterize the rooted aquatic plant community in Minnesota lakes. Things such as water clarity and chemistry, the shape and depth of the lake can influence the amount of plants in a lake, the soils found on the lake bottom and the climate. Impacts to the lake can also affect the plant community. For example, increased nutrient loading from the watershed may spur some plants to more abundant growth, while harming other plants.

You can sample plants in a variety of ways, ranging from simply watching for the appearance of exotic species, such as Eurasian water milfoil, to surveying the types and abundance of plants growing in the lake. One relatively simple way to measure changes in the plant community is to measure the maximum depth where vegetation roots in the lake. In general, the clearer the water, the deeper plants can grow.

Find additional information about aquatic plant monitoring at ***http://www.wes.army.mil/el/aqua/apis/apishelp.htm*** (in the index, go to "Ecology" and then to "Plant Sampling.")

How to monitor

Include in your monitoring plan detailed descriptions of how you will collect and analyze environmental data. This means developing and including Standard Operating Procedures (SOPs) for all field sampling and field/laboratory analytical methods. SOPs are step-by-step directions, including calibration and maintenance procedures for field and laboratory analytical instrumentation. A number of existing manuals provide detailed methods descriptions, SOPs and even field data sheets. Some of these are listed in *Appendix C*. This subsection will not repeat these detailed methodologies, but will help you decide how you will monitor.

Water chemistry monitoring

If you plan to measure water chemistry parameters, you must decide whether to use test kits, field meters or a contract laboratory. Your decision will be based on how you want the data used. For example, if you want the data used for 305(b) or 303(d) impaired waters assessments, you will need to use USEPA-approved methods, listed in *Appendix D*. Other factors to consider are cost, ease of use and volunteers' time and expertise.

Use of laboratory

The most expensive option – and in some ways the easiest – is to send samples to a lab for analysis. *Appendix B* provides guidance for selecting and using a contract laboratory and *Appendix G* includes an example price list for common parameters. You will

Consider cost and storage

When deciding whether to use USEPA- approved methods and a contract laboratory, you will need to consider cost (field kits, e.g., are generally cheaper than contracting with a lab) and whether or not you want to deal with sample preservation and holding time issues. For example, samples collected for analysis of total phosphorus need to be preserved by adding H_2SO_4, refrigerated to 4 degrees Celsius and analyzed within 28 days.

also need to use a Minnesota Department of Health Certified Laboratory if you want your data used for impaired waters assessments. These laboratories will typically have already developed laboratory SOPs for the analytical methods and Quality Assurance/Quality Control plans. A list of certified laboratories is maintained by the health department at ***http://www.health.state.mn.us/divs/phl/cert.html***. When sending samples to a laboratory, pay close attention to holding times and sample preservation methods. We suggest including a table of holding times, acceptable bottle types, and sample preservation methods in your monitoring plan. You can request this information from the laboratory based on the parameter to be analyzed and the method used.

Use of field meters

Another option you can use is to purchase and use field meters. Using field meters for some parameters is acceptable for most efforts, including impaired waters assessments. However, you will need to calibrate meters each time you use them and record all calibration results. Parameters for which meters are frequently used include: dissolved oxygen, temperature, pH, conductivity and turbidity. It is also important to realize that temperature must be measured immediately in the field since it would change during shipping to a laboratory or off-site facility. While there are ways to preserve dissolved oxygen, it is also frequently, and probably best, done in the field for the same reason.

Use of field kits

The final option you can use to monitor water chemistry is field kits. These kits generally involve prepackaged containers of chemicals that are used in the field to analyze water samples for particular chemicals. Some field kits involve relatively simple tests that provide general results, while others are more precise. While the use of field kits tends to be less expensive than sending samples to a laboratory, they do require that you spend extra time in the field completing the analysis. In addition, just as with a contract laboratory, confidence with field kits results increases with the use of QA/QC procedures. In particular, accuracy can be assessed with known standards and precision with replicate analysis of samples.

Some things to consider when deciding whether or not to use a field kit (and which one to choose) include:

- What range of concentrations can the kit detect? Some kits detect presence or absence of a chemical; others can measure within a range of concentrations.
- How much time are you willing to spend in the field? With field kits, not only do you collect a sample, but you analyze it too. The use of field kits, however, does avoid the need to transport samples to a lab.
- If you want the data you collect to be used by others, what is their view of field kits? Some data users may require that a laboratory analyze samples, or that field kits meet certain requirements for the data to be acceptable.
- Would the use of field kits enhance your experience as a volunteer? Because you are actually doing the analysis, field kits can help build a better understanding of the water resource and scientific principles.
- How much of an issue is cost? If it's critical that costs be kept to a minimum and if the data is viewed as acceptable, field kits can be a good option because they are often easier on the budget than laboratory analysis.
- Keep in mind that sometimes the chemicals used in field kits are hazardous to the environment and must be disposed of properly following analysis.

These are just a few of the considerations that go into deciding how to analyze the samples you collect. Local water resources officials, state agencies and other volunteer groups are all great sources of advice and guidance on making this decision. In addition, you can find information on test kits, meters and laboratory analysis in the various monitoring manuals referenced throughout this Section, particularly the USEPA lake and stream monitoring manuals.

Here is some guidance to consider when choosing laboratories, meters or field kits:

- Develop and follow standard operating procedures (available from many methods manuals).
- Thoroughly document your efforts.
- Make sure the kits, meters and/or laboratories you are using have appropriate measurement ranges. Depending on your objectives, you may or may not want to use kits, meters, or methods that cover the full range of expected values. Even when using a contract laboratory, you should specify detection limits and measurement ranges before the project starts, to ensure the laboratory has the necessary equipment and methods to achieve the project's detection limits. Consult Exhibits 6-5 and 6-6 in *Section 6* for a list of reference measurement ranges for Minnesota lakes and streams.

Sampling equipment

Sampling equipment needed for the various parameters is described in the detailed methodologies included in the manuals listed in *Appendix C*. *Appendix E* lists some vendors where you can find equipment and supplies.

Morrison County chooses a screening approach for sample analysis

Morrison County chose to use a screening approach for water quality analysis, an approach that uses a non-certified laboratory. County staff has confidence in the data and their primary purpose is for local use. This local use consists of screening for problem spots identified by the monitoring. In these cases, hot spots are followed up with a site visit, a talk with the landowner, and in many cases solved without further monitoring. Another option is that hot spots are put on a list to monitor further, possibly with analysis at a certified laboratory.

Source: Minnesota Rivers Council, and Chuck Forss, Morrison County Water Planner

Citizens and students monitor the Vermillion River

As part of the Vermillion River Watch Program, students from six schools are gathering information on physical habitat and macroinvertebrates (aquatic insects) at ten sites on the river. The Minnesota Department of Natural Resources, working in conjunction with Dakota Environmental Education Program, provides funding and technical support to the schools.

Recently, the Vermillion River Council formed to learn more about the river and to give guidance to the Vermillion River Watch Program. As a result of the meetings, four citizens that live along the river and staff from the Dakota County Soil and Water Conservation District are participating in a research project to monitor the river for fecal coliform. Portions of the river are in violations of fecal coliform standards and the monitoring should help identify sources of the pollution. Both the student and citizen volunteer monitors are following protocols and quality measures designed by their partnering state agencies.

Source: Dakota County Environmental Education Program

Biological monitoring

Macroinvertebrates

Macroinvertebrate monitoring methods range from visually surveying habitat conditions to collecting and identifying organisms in the field to bringing organisms back to the lab for more detailed identification. In general, you collect macroinvertebrates by wading into streams or wetlands and using nets to capture the organisms. The specific collection method depends on the objectives of the study and the habitat type being sampled. Dip nets are useful in sampling multiple habitats (rocks, woody debris, vegetation) from fast-flowing, rocky streams, slow-moving, muddy streams and wetlands, while surber samplers, or kick nets, are often used when sampling is directed specifically at shallow, rocky substrates in streams. You can also use artificial substrates (multi-plate, bag or screen-cage samplers) to collect invertebrates where conditions prevent efficient sampling by hand (e.g., due to depth of the stream or wetland), where adequate invertebrate habitat is lacking or when a consistent quantitative sample is desired.

Sample aquatic plants by identifying and counting the types of plants found in a particular sampling plot placed randomly in the vegetated area, or by identifying and counting the plants along a straight line of a fixed length (a transect) through the habitat. Another relatively simple measurement for lakes is to map out the areas where aquatic plants grow and the maximum depth (or distance from shore) of aquatic plant growth.

One question you will need to answer as you plan a biological monitoring program is the taxonomic level (genus, family, etc.) to which the organisms will be identified (or classified). This decision will depend on your skill in spotting differences between similar organisms, the amount of time you wish to spend on training and the purpose of your monitoring. For example, a relatively simple classification into major groups (orders) is sufficient for increasing awareness about what lives in a stream and acquiring a general understanding of the stream conditions. But you will find identification to the genus level (i.e., very detailed classification) is required for some regulatory uses of the data.

Sampling methods, including the equipment needed and the suggested level of classification, are detailed in the manuals available from the resources identified in *Appendices A* and *C*, and throughout this Section.

Resource-specific consideration (including when and where to monitor)

Lakes

Physical and chemical parameters most frequently measured for lakes include: nutrients (phosphorus and nitrogen), solids, Secchi transparency, alkalinity, chlorophyll-*a*, dissolved oxygen and temperature, and pH. Biological parameters can include aquatic plant communities and types of algae (microscopic plants) or zooplankton (microscopic animals) found in the lake.

In many natural lakes in Minnesota, it is sufficient to sample at one primary site, typically where the lake is the deepest. Lakes with complex basin morphologies (numerous bays) and reservoirs frequently need monitoring at multiple sites. Conduct surveys of aquatic plants along the shoreline, often in a series of paths or "transects" from the shore out towards the deep part of the lake to the point where rooted aquatic plants are no longer found.

Collect most lake parameters from the warm surface waters (epilimnion). Temperature and dissolved oxygen, however, are frequently taken as a depth profile (i.e., taken at 1-meter intervals from the surface to the bottom) and used to assess stratification and vertical mixing of the lake. In addition to surface samples of total phosphorus, it is often advisable to collect samples from the deeper, cooler waters (hypoliminion) during the summer. These measurements will help evaluate whether substantial amounts of phosphorus are being released by the sediments.

Lake sampling is most often done during the growing season, roughly from May through September. More detailed monitoring plans may involve sampling year-round, even during the winter through holes cut in the ice. Aquatic plant surveys should be completed when the plants are vigorously growing, generally between mid-June and mid-July. However, some aquatic plants (most notably curly-leafed pondweed) die off partway through the summer. In this case, a survey should be completed in June when the plant is growing vigorously and later in the summer after the die-off is complete.

Detailed methodologies and SOPs for lakes are available in:

- *The Citizen Lake Monitoring Handbook*, produced by the MPCA and available at **http://www.pca.state.mn.us**
- *The Minnesota Lake and Watershed Data Collection Manual*, available at **http://www.shorelandmanagement.org**
- *The Handbook for the Citizen-Assisted Lake Monitoring Program*, by Randall J. Anhorn, 2000, which is available from the Metropolitan Council, Mears Park Centre, 230 East Fifth Street, St. Paul, MN 55101-1634
- *Volunteer Lake Monitoring: A Methods Manual*, by USEPA 1991, Document USEPA 440/4-91-002 available at **http://www.epa.gov/owow/monitoring/volunteer**

Exhibit 4-3 provides a summary of suggested lake monitoring parameters and sample frequencies.

Exhibit 4-3: Lake monitoring parameters and frequency of sampling

(Adapted from: Minnesota Lake and Watershed Data Collection Manual)

PARAMETER	SITE		PRIORITY	COST	FREQUENCY	
	Primary	Secondary			Minimum	Recommended
Epilimnion (surface) Nutrients						
- total phosphorus	X	X	High	Mod.	Monthly	Biweekly
- total nitrogen	X	X	High	Mod.	Monthly	Biweekly
Secchi disk	X	X	High	Very low	Monthly	Weekly
Chlorophyll-*a*	X	X	High	Mod.	Monthly	Biweekly
General Chemistry - total suspended solids, pH, alkalinity, conductivity, turbidity, nitrate+nitrite N	X		Mod./Low	High/ Low	Monthly	Biweekly
Dissolved oxygen and temperature profiles	X	X	High	High/Low	Monthly	Weekly
Field Observations						
- Precipitation			High	Low	Each Storm Weekly	Weekly
- Lake Level			High	Low		
Rooted aquatic plants (macrophytes)	Shoreline		Mod.	Low	Every 2 to 3 years	Annually*

* More often (i.e. twice during the summer) if community changes throughout the season.

Rivers and streams

Do river/stream sampling at a point where the water is well mixed and is most likely to represent the water quality of the reach that is to be assessed. The goal is to get a sample that represents the overall characteristics of the stream at that site.

Physical and chemical parameters most frequently measured for streams and rivers include many of the same parameters described previously for lakes (i.e., nutrients, solids, dissolved oxygen and temperature, turbidity and pH), as well as flow and physical conditions such as habitat. You may also frequently measure biological parameters such as fecal coliform bacteria and macroinvertebrates for streams and rivers.

When monitoring for general chemical, physical or biological parameters, it is generally a good idea to monitor flow. Flow monitoring can involve qualitative observations of relative flow (i.e., high, medium/average, low), or actual measurements of the velocity of the water. Measuring flow accurately, however, can be fairly involved and, at high flow, a significant safety risk. We strongly encourage you to involve a professional for quantitative flow monitoring.

To be representative of the stream or rivers, complete your monitoring activities over a range of conditions. For general chemical parameters and physical parameters such as temperature, this means collecting samples to represent a range of flows and seasons. Biological communities are an indicator of longer-term conditions, so you may not need multiple samples within a single season or year to represent conditions at a specific location. You may want to complete surveys at the same location over time, say annually, to track long-term trends. However, for biosurveys, you need to recognize that different organisms are naturally found in different microhabitats, such as rocky areas, undercut banks, or on woody debris. So, take composite samples that represent different microhabitats, or the same location/habitat type to compare between locations or assess trends.

It is important to determine what your sampling goals are and to take the proper type of sample based upon the habitats available. If you want to collect a quantitative riffle sample, then the stream you are sampling should have riffle-run-pool morphology with ample flow characteristic of the habitats in which riffle-dwelling organisms are present. If you want a quantitative multihabitat sample, take a composite sample that represents different microhabitats present in the stream. You generally conduct stream monitoring during the “open water” season, roughly from March through November. Macroinvertebrate monitoring is conducted in spring, while a large portion of the macroinvertebrate community is mature and near emergence, or in the late summer or early fall during low-flow conditions, when the community is stressed and more susceptible to impairment.

Exhibit 4-4 provides guidance as to minimal and desirable stream and river sampling program designs for eutrophication monitoring.

Exhibit 4-5 provides this information for biological monitoring (both streams and wetlands). *Appendix D* provides sampling frequency and considerations for 303(d) and 305(b) assessments.

Exhibit 4-4 Minimal and desirable designs for eutrophication monitoring programs

(Adapted from Walker, 1996 and *Minnesota Lake and Watershed Data Collection Manual,* 1994)

Feature	Duration of water and nutrient monitoring
Minimal design	One water year (Oct. – Sept).
Desirable design	Three water years
Comments	Determined partially by extent of year-to-year variability in hydrology and nutrient loadings

Feature	Flow monitoring
Minimal design	Daily or with each sample event
Desirable design	Continuous monitoring

Feature	Water quality components
Minimal design	Instantaneous flow, transparency tube, total phosphorus, total Kjeldahl nitrogen, nitrite plus nitrate nitrogen, total suspended solids, dissolved oxygen and temperature
Desirable design	Add: ammonia nitrogen, bacteria, chloride, and turbidity

Feature	Sampling frequency
Minimal design	15 samples per site per year; either weight at higher flows or supplement with rain event sampling
Desirable design	15 to 20+ samples per site per year; continuous storm event monitoring; either weight at high flows or supplement with rain event sampling
Comments	Characterize annual and seasonal loadings; adjust sampling frequencies as more is learned about range of flows and flow concentration dynamics

Exhibit 4-5 Minimal and desirable designs for biological monitoring programs

Feature	Stream invertebrates
Minimal design	One mulithabitat or one riffle sample per year during spring emergence periods (April – May) or at base flow conditions (Mid August – Early October); family level identification
Desirable design	Genus level identification verified by a professional taxonomist
Comments	Sampling during base flow conditions can give a better indication of stress; spring samples should not be compared to fall samples, and not used with the assessment tools being developed by the MPCA

Feature	Qualitative stream habitat and other parameters
Minimal design	One habitat assessment done at the same time and place as invertebrate assessment
Desirable design	Supplement habitat information with instantaneous flow, transparency tube, total phosphorus, total Kjeldahl nitrogen, nitrite + nitrate nitrogen, total suspended solids, dissolved oxygen and temperature

Feature	Wetland invertebrates
Minimal design	One sample per year during spring emergence period (late May – June); sample should include a dipnet and 6 bottle trap samples; family to species level identifications
Desirable design	Sample should include 2 dipnets and 10 bottle traps; Genus and species level identification verified by a professional taxonomist
Comments	Sampling in the fall should be avoided as invertebrates have dispersed and may not be found in their water body of origin, which can lead to misleading assessments

Feature	Wetland plants
Minimal design	One sample per year during period of maximum flowering/fruiting (late June – early August); species level identification
Desirable design	Species level identification verified by a professional taxonomist
Comments	Sampling outside of this index period will lead to a larger proportion of plants that are difficult for volunteers to identify due to the absence of visible reproductive structures

Detailed methodologies and SOPs for streams are available in:

- *Volunteer Stream Monitoring: A Methods Manual*, by USEPA 1997 Document USEPA 841-B-97-003 available at **http://www.epa.gov/owow/monitoring/vol.html.**
- *Guide To Volunteer Stream Monitoring*, developed by the Volunteer Stream Monitoring Partnership available from the University of Minnesota Water Resources Center 173 McNeal Hall, 1985 Buford Avenue, St. Paul, MN 55108 **http://www.vsmp.org**
- *River Monitors Manual*, developed by the Rivers Council of Minnesota
- *The Minnesota Lake and Watershed Data Collection Manual*, available at **http://www.shorelandmanagement.org**

Wetlands

Unlike lake and river monitoring, assessing wetland conditions incorporates some of the monitoring and assessment techniques used for forests, meadows and other upland areas. Wetlands require a broad spectrum of surveying and monitoring techniques because they are the transitional areas between aquatic and upland environments and because they exist in a great variety of forms. There are many different types of wetlands, and each type hosts a distinct community of flora and fauna (plants and animals). Because physical and chemical conditions create such a variety of biological conditions in wetlands, measuring nutrients, pH, dissolved oxygen, turbidity and solids give a limited picture of a wetland's health.

Parameters

Wetland parameters often measured by volunteers include:

- **Dominant vegetation type.** Measurement requires some training, is often conducted using sample plots located on transects and is a principal means of detecting change in a wetland.
- **Adjacent impervious surface** (e.g., pavement, roofs). Estimate using maps or visual observations in the field; can be an important indicator of stresses to wetlands.
- **Hydrology.** Timing, frequency and duration of water inputs can be critical to wetland health. Measure water fluctuations by installing and reading a staff gauge.
- **Exotic plant species encroachment**. Uses some of the same methods used for measuring dominant vegetation types; can point to the need for eradication of exotic species.

- **Amphibian migration counts.** A variety of methods are used to count amphibians. Amphibian counts can provide insight into the effects that land use or other stressors might have on wetland health.

- **Macroinvertebrate taxa richness.** The presence or absence of certain macroinvertebrate taxa can provide strong indications of wetland quality.

- **Physical and chemical parameters.** Nutrients, pH, dissolved oxygen, turbidity and solids.

- **Bird sighting.** Recognizing and counting birds and their calls takes training; can be a good screening mechanism in assessing risk or determining a wetland's connection to migratory corridors.

- **Wetland appearance/footprint** (through photographs or maps). This very simple information-gathering method is not scientifically rigorous but can help supplement other data and "freeze" a picture of a wetland's condition at a certain time.

(Source: *Volunteer Wetland Monitoring: An Introduction and Resource Guide*, USEPA 2001)

Equipment and timing

The equipment needed for wetland monitoring is relatively simple; much can even be constructed from ordinary household materials. Macroinvertebrate sampling is generally completed in late spring/early summer (i.e., late May to June) in the shallow, near-shore area of the wetland, close to (or in) any vegetation. Vegetation monitoring generally occurs in mid-summer (i.e., late June to early August). Exhibit 4-5 lays out minimal and desirable biological monitoring designs for wetlands (and streams).

Find additional information on wetland monitoring from:

- *Volunteer Wetland Monitoring: An Introduction and Resource Guide*, by USEPA 2001 Document EPA 843-B-00-001 available at ***http://www.epa.gov/owow/monitoring/volunteer***

- *A Citizen's Guide to Biological Assessment of Wetlands: The Macroinvertebrate Index of Biotic Integrity (IBI) Field and Laboratory Protocols, Pictorial Keys to Wetland Invertebrates*, 2002, available from the Minnesota Pollution Control Agency

The second reference covers a macroinvertebrate IBI developed for assessing the condition of wetland types 3, 4 and 5 specifically for Minnesota. This method is the basis of the Wetland Health Evaluation Project (WHEP) being completed by citizen volunteers in Dakota and Hennepin Counties. Additional information and reports about WHEP are available on the web at Dakota County ***http://www.extension.umn.edu/county/dakota/Environment/wetlands/wetld.html*** and ***http://www.mnwhep.org***.

III. Document your monitoring activities.

Making sure data are credible depends on good documentation. Take the following into consideration as you design documentation into your monitoring plan:

Use a well-designed field sheet

Field data collection sheets are an essential part of your monitoring plan. Many are available from existing methods manuals, so you will not have to design one yourself. *Appendix G* provides some examples of existing field sheets. Field sheets should include simple instructions and examples for calculation and should provide ample space for the following:

- Site name and exact location (including sample depth)

- Time and date of sampling

- Volunteer's name and phone number
- Weather conditions (recent as well as current)
- Name and model number of equipment or test kits used
- Actual readings, including duplicate readings (don't just provide space for the final answer). For example, for dissolved oxygen titrations, record the actual number of milliliters titrated as well as the final concentration of dissolved oxygen.
- Space for comments. Leave room to record anything unusual you see (spills, new construction, dead animals, etc.) as well as any problems you may have in performing the tests.
- Site conditions

If you are using field kits or meters, be sure to include spaces to record and document results of the tests. If you are using a contract laboratory, it will typically have its own lab sheets.

Record data in the field

Once you leave the monitoring site, the field sheet(s) is the only record of your efforts. No matter how carefully the tests were performed, the data will only be as useful as what's written on the form. Therefore, be sure you understand instructions on how to carefully fill out forms.

- Record any unusual conditions at the site. (When in doubt, write it down.)
- Record the presence of any tributaries, dams, bridges or anything else that may affect results.
- Record all instrument or kit readings, including units, on the form.
- Do not report a value of zero for water chemistry parameters. Instead report "less than ___," filling in the blank with the lowest value that can be read with the equipment.

  Example: If the range of a test is 0 –1 mg/L, the smallest increment is 0.02 mg/L, and the test result is zero, report "less than (<) 0.02 mg/L.

Rounding out numbers

Number of Decimal Places/Rounding example:

- Measured value Y = 7.7
- Measured value X = 5.32
- Constant value C = 12

*Calculation formula is (Y * X) / C*

Report the answer as 3.4, not 3.41 or 3.413 (because the measured value with the least decimal places is Y, which has one decimal place).

- If calculations are performed, show all formulas, calculations and units.

- When reporting results of calculations, do not report excess decimal places. Use the following rule of thumb: look at all the values that were used in the calculation, and find the measured value with the fewest decimal places. The final answer should have that same number of decimal places.

- Be sure to state the number of sample replicates; this is likely to vary depending on the test and the data retrieved.

- Be sure to record observations on habitat, recreational suitability, etc. if that is part of your sampling routine.

- Record field procedures, including calibration and documentation procedures.

Keep a copy

If data sheets are to be mailed in, keep a copy in case the originals are lost in the mail. Having a reference copy also comes in handy if the program coordinator calls with questions. Your best strategy may be to e-mail your data sheets to the database you are using or data user (e.g., MPCA) you are working with. Be sure to have another person (a "buddy") check the numbers before you send them in (Quality Control).

IV. Consider safety issues.

In any monitoring activity, you run the risk of injury or incurring a lawsuit. Never put yourself at risk to obtain a measurement or observation. Part of your monitoring plan should cover safety considerations and should be covered in any training provided.

Take the following into consideration in developing the safety portion of your plan to protect your safety: (The following is a guide only and should not be construed as a comprehensive safety plan.)

- Describe the safety issues and risks involved with your particular type of monitoring.

- Describe the safety precautions for your particular type of monitoring. For example, in stream monitoring, describe the flow velocities and depths at which volunteers should not enter the stream.

- Include emergency contact information for all volunteers.
- Include locations and directions to local emergency care providers.

Additional safety considerations are covered in Section 2.3 in *Volunteer Stream Monitoring: A Methods Manual*, by USEPA 1997 (Document Number EPA 841-B-97-003).

Buddy system

You may also wish to implement a "buddy"' system policy where certain field efforts require two or more people present.

Liability waivers

Organizations that coordinate volunteers may want to use liability waivers and/or have some coverage for liability and for possible injuries. You may be able to cover volunteers with worker's compensation or by obtaining insurance through funding agencies or partners. Liability waivers are essentially signed documents (i.e., contracts) in which the signers promise not to sue. A carefully worded waiver, signed by an adult, can protect you if you're sued for negligent (i.e., unintentional) acts. Most waivers fail because they do not adequately describe the risks of the activity and the consequences of signing. Everyone signing a waiver must be clearly informed about the dangers so they can make informed decisions about signing.

Additional information is available from The Nonprofit Risk Management Center, 1001 Connecticut Ave., NW, Suite 900, Washington, DC 20036: 202-785-3891; fax 202-833-5747. Two publications from the Nonprofit Risk Management Center may be of particular interest: *No Surprises: Controlling Risks in Volunteer Programs*, and *Insurance Assurance for Volunteers*.

V. Ensure data quality.

Working with data quality and how to set objectives are discussed in detail in *Section 3*. Your monitoring plan should document those decisions and describe your data quality program. The following information should be included:

- The types of QA/QC samples you will take to assess precision and accuracy.
- Your goals for the number of QA/QC duplicate samples to be collected (i.e., some percentage of total samples collected, typically 5% or 10%).
- Your field and laboratory precision and accuracy objectives for the types of QA/QC samples to be collected and parameters analyzed. For example, give precision objectives for field duplicate samples analyzed for TSS, which is typically ± 30%. These objectives can be presented in tables.
- Procedures for inspecting, maintaining and calibrating field equipment.

Head for the field

Now that you have your monitoring plan completed, here are a few additional elements to consider and coordinate:

- Finding a laboratory (if needed). See *Appendix B* for guidance on choosing a laboratory.
- Purchasing equipment. See *Appendix E* for a list of equipment vendors.
- Recruiting and organizing volunteers.
- Training. Whenever possible, we suggest training and a practice run.
- Considering safety, procuring a first aid kit and waivers.
- Getting property owner permission.
- Timing for sample analysis. If you collect samples on a Friday or before a holiday, be sure you or your laboratory will be available over the weekend to accept samples and run the parameters with short holding times.
- Determining methods for data transfer and management. See *Section 5* for a detailed discussion of data management.

There are a lot of things to remember. We suggest using an overall checklist in addition to the field data collection sheets to help you organize your day and ensure you have all your equipment before heading out to the field.

Section 5:

Data management

This Section will show you how to:

- **Organize and keep track of the data you collect**

Managing data

By now you know that volunteer water monitoring requires attention to detail and precision at every step of the way. If you have been following the Sections in this guide, you have determined the reason you are monitoring (your purpose). You have set your QA/QC objectives and you have designed a plan. You are now ready to start collecting data and recording it in a format that is eventually usable to yourself and others. What, exactly does this entail?

To get the most out of this part of your monitoring program, it is critical that you set up a data management program before you actually begin monitoring. By setting it up in advance:

- You eliminate/minimize errors in recording and transferring data.
- You don't lose data.
- You can go back to the original data sheets if there are problems or questions.
- You can easily access and use data once you've stored it.
- You can format it in a way that will be useful and acceptable to others.

Decide your data management needs

The extent of data management you will need depends upon the purpose for which you are gathering data. If you are collecting information that may be used for enforcement, for example, you will need a more rigorous program than if you are collecting data to determine what organisms are in the wetland in your back yard.

The Golden Rule of data transfer

Keep the number of times data is transcribed to a minimum. The more times you transcribe data (from one sheet to another), the more chance of errors.

Based on your own specific purpose, use the following guidelines to set up your own program: You do not have to follow each one of the guidelines below, nor do you have to follow them sequentially.

- Develop or use already-developed data collection sheets and checklists. This will ensure uniform collection and recording of results in both the field and the laboratory. If you are working with an organization, you will probably use sheets and checklists developed by the organization's program.

- Continually review the data sheets and checklists as you collect data to ensure the information is complete. To do this, you may have a signature line for a sampling team captain or third party to indicate the data sheet was checked or approved. If there are problems, this reviewer will contact any sampler whose field sheets contain significant errors or omissions.

- If using a laboratory, use a Chain of Custody form (or transmittal letter) to document the transmittal of samples. You can get these from most laboratories.

- If using a laboratory, the laboratory manager should review the QA/QC parameters used and include the results with the laboratory report.

- Review field and laboratory QA/QC results and determine if data quality objectives (set in *Section 3*) have been met. Make a decision whether to keep the data or not. Many times, even though the data does not meet QA/QC objectives for a particular purpose, it will meet objectives for another purpose and may still be usable. In such cases, data may be "flagged" to indicate how it did not meet its original QA/QC objectives.

- Enter data that meets the data quality objectives into a spreadsheet or database. If you plan to send data to a central database, such as the MPCA's Water Quality Database, check in with the database managers to find out how to organize the data for submittal. Then set up your data management system (spreadsheet or database) in a way that is compatible with the database requirements. If you are using a contract laboratory, you can require the lab to provide results in an electronic format that is compatible with database requirements.

- Have a second individual review the entered data.

- Program the database to screen data for errors or review the data manually by checking to see that results are within an acceptable range. For example, pH can only range from 1 to 14 standard units (s.u.). A pH of 16 s.u. is not possible.

Use field data sheets and laboratory reports

Collecting raw data, both field and laboratory, is discussed in detail in *Section 4: Design Your Monitoring Effort*. A few existing data collection sheets are included in *Appendix G*.

Develop a database or spreadsheet

Decide in advance how data sheets will be handled, and how and where they will be stored and then archived.

We suggest you use a computer to store and access data in either a database or spreadsheet. Unless you have a lot of data, spreadsheets will generally be easier to use.

When setting up a spreadsheet, first check the format of the database you may use in the future and pattern your spreadsheet after it by creating similar fields.

When you're entering data, check it, and check it again. Then have an outside individual review it yet again. Make certain that you have a record of individuals who check the results and also record the dates they were reviewed.

Be wary of releasing an electronic form of data to users before the numbers are checked and rechecked or before all data is entered.

Watch out for these data entry errors

- Entering data in the wrong units (entering concentrations as micrograms/liter instead of milligrams per liter)
- Reversing numbers
- Misplacing decimal points
- Entering in the wrong row or column

To prevent multiple versions of a database from being circulated:

1. Wait to release the results until all data has been entered and checked (i.e., resist the temptation to release draft databases).
2. Include a field for dates and initials of the last update or approval so that you can easily tell if you are working with the most current version. Also, to avoid losing your data, make a backup copy and store it at another location.

Make data available to others

Entering data from coordinated programs

If you participate in an organized volunteer monitoring program, the project sponsor may enter your data into one of its databases. Following are some possibilities:

- Data from the Citizens Lake Monitoring Program (CLMP), the Citizens Stream Monitoring Program (CSMP) and the Citizen- Assisted Lake Monitoring Program (CAMP) are all entered into the MPCA Water Quality Database.
- CAMP data is also entered into the Metropolitan Council's Environmental Information Management System (EIMS).
- The Volunteer Stream Monitoring Partnership (VSMP) has an agreement to house its data on the Metropolitan Council's EIMS in the future. (***http://www.vsmp.org***).
- The Department of Natural Resources (DNR) and the State Climatologist maintain a database for volunteer precipitation monitoring collected by volunteers in the Climatological Network (***http://www.climate.umn.edu/doc/historical.htm***).
- The DNR also houses a database for volunteer lake gauge readings, which is online at ***http://www.dnr.state.mn.us/lakefind/results.html***.

Entering data independently collected

If you have developed your own local program, you may want to deposit your data into one of the state or regional databases. Submitting data to a state or regional database increases the chances that federal, state and local agencies and organizations are aware of, have access to and use the data you've collected. To do so, follow the protocols established by the database manager(s). Some databases to consider to house your data are:

- MPCA Water Quality Database (formerly known as STORET). Administered by the USEPA and coordinated by MPCA, this database is linked to a web-based access system that is online, effective July 2003 (***www.pca.state.mn.us/data/eda/index.htm***l).

- Met Council Environmental Information Management System (EIMS) is designed to house data from the Twin Cities metropolitan area. Web-based access is under development. For more information, call 651-602-1056.

- The Minnesota River Basin Data Center (MRBDC) at Mankato State University houses a lot of data, including water quality information on the Minnesota River and its tributaries (***http://mrbdc.mankato.msus.edu***). Contact is MRBDC, Mankato State University, 184 Trafton Science Center South, Mankato, MN 56001; 507-389-5492; mrbdc@mnsu.edu.

- Local governments may also house water quality databases. Contact Soil and Water Conservation Districts, Watershed Management Organizations and County Water Planners for more information. Online directories for these organizations are provided in *Section 2*.

The following tables identify the information that must be submitted for data to be loaded into the Water Quality Database. Keep in mind that it is important to contact the MPCA as you are setting up your data management system (i.e., before you begin entering data into your spreadsheet or database system) to ensure it is compatible with the database. This will minimize steps needed to load your data into the database.

Send complete information

Note that it is generally not sufficient to simply send in the monitoring data for inclusion in a database. You must also send information about the data, such as the monitoring location, field sampling procedures, equipment used, analytical laboratory, lab methods, etc. This information is known as meta-data.

Appendix F includes meta-data descriptions and requirements for the MPCA Data Quality Database.

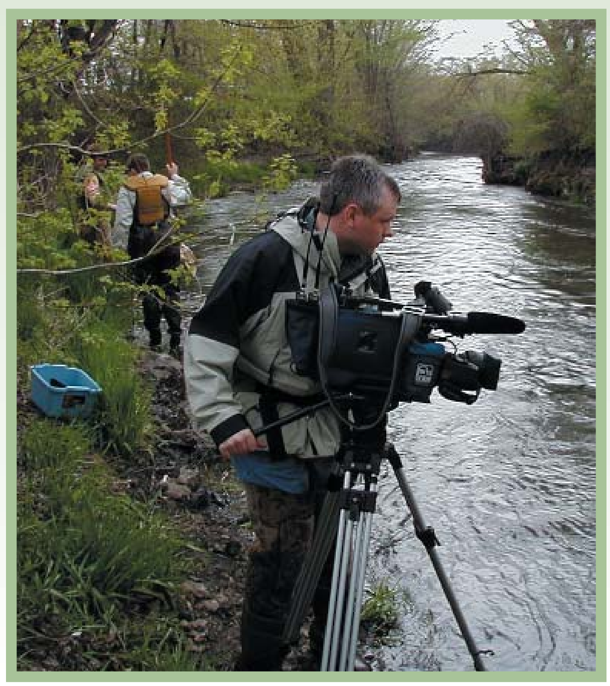


Exhibit 5-1 Information that must be submitted for MPCA Water Quality Database

Meta-data element	Required?	Notes
Project Information		
Name Purpose Start date & duration Lead organization Contact information Laboratory info. (if one is used) Sampling methods & equipment Sample medium Sampling station information	Yes, for all monitoring efforts	Only needs to be supplied once, when the project data is first submitted for inclusion in the database
QAPP summary or citation (i.e. where to find project QAPP)	For data submitted for 305(b) or 303(d) use (in addition to info. required for all projects)	
Laboratory Information		
Name Contact information Analyses and methods Parameter name and reporting units Lab certified for parameter? Comparable Standard Method	Yes, for all monitoring efforts where a lab is used	Only needs to be supplied once, when the project data is first submitted for inclusion in the database (or if the lab changes)
Detection limit	For data submitted for 305(b) or 303(d) use (in addition to info. required for all projects)	
Monitoring Station Information		
Name Type Description Ecoregion (optional) Travel directions Latitude-longitude or UTM Method and reference (datum) for determining lat.-long. or UTM HUC code; RF1 reach (optional)	Yes, for all monitoring efforts (except as noted)	Only needs to be supplied once, the first time data is provided for a particular station
Data (sampling results) Information		
Project ID Station ID Date and time Lab ID (as applicable) Depth Methods QA sample type (as applicable) Measurement (i.e., result) and units Project personnel Remarks (as needed)	Yes, for all monitoring efforts	Required every time data is submitted to the database
Lab sample temp. (as applicable) Time of sample	For data submitted for 305(b) or 303(d) use (in addition to info. required or all projects)	

Section 6:

Converting data to information

This Section will show you how to:

- **Work with graphs and tables to interpret your data.**
- **Work with graphs, tables and charts to report your data.**
- **Use common assessment methods, benchmarks and indices for lakes, stream and rivers, and wetlands.**

The payoff for all your hard work

The goal of your monitoring program may be to make the results available to others – fellow volunteers, the community where you are monitoring or regulatory agencies. But pages of raw data have no meaning until you transfer the numbers into a format and context everyone can understand.

Some data is quite simple to interpret. For example, Secchi disk readings are easy to correlate with chlorophyll-*a* data to determine whether or not algae are the primary factors affecting water transparency. But other numbers will require more expertise. You may be able to do some of the work yourself, especially if you have some background in science, or the patience to learn. Or you may decide to work with an agency or organization that will interpret the numbers for you.

Interpreting data

This Section will introduce you to the basics of data interpretation and reporting. Specific procedures for interpreting data for use with 303(d) and 305(b) impaired water assessments are available in the *MPCA 2003 Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment*, available at **http://www.pca.state.mn.us/water/tmdl.html#publications.**

Think of data interpretation as a process in which you ask a series of questions that lead you to *findings and conclusions.*

Findings are objective observations about your data. *Conclusions* are how you explain why the data look the way they do. For example, say you are monitoring a lake to determine its condition. Your *findings* can indicate nutrient concentrations, or relationships between chlorophyll-*a* concentrations and water clarity. Based on those *findings*, you can draw *conclusions* as to whether or not excessive nutrients are causing algae blooms and high chlorophyll-*a* concentrations, and in turn problems with water clarity.

See article "Interpreting Your Data," *The Volunteer Monitor*, Vol. 7, No. 1, Spring 1995, by Geoff Dates.

Determining findings

Questions like the following can help you arrive at findings:

- Which sites consistently did not meet the water quality goals? By how much?
- Are there seasonal differences in results?
- Did flow or rainfall affect results?
- Do results change in a consistent manner upstream or down?
- Do changes in one parameter coincide with changes in another? For example, is there an inverse relationship between Secchi transparency readings and chlorophyll-*a* measurements?

Create graphs

To assess findings, first graph your data to visually display results. This will help you compare parameters. The following table lists graphs you can consider creating. (More on creating graphs is covered later in *Section 6*.)

Reaching conclusions

Once you've organized your data into findings, you can start to assess whether or not you can answer your monitoring questions, address your study purpose and make conclusions. Then, once you develop conclusions, you can organize them into a presentation. Good presentation of information is essential to effectively communicate and gain credibility for your results.

Graphs and comparisons to consider when assessing data

Graph	Comment
Flow vs. any parameter	May show non-point source pollution effects or dilution of dissolved parameters at high flows
Date vs. observed values/concentrations	May show trends or seasonal variation
Precipitation vs. any parameter	May show how parameters respond to rainfall and/or non-point source pollution effects
Secchi transparency readings vs. chlorophyll-*a* measurements	May show that algae blooms are the primary factor affecting transparency, or suggest that non-algae turbidity or color is affecting transparency
Chlorophyll-*a* measurements vs. phosphorus measurements	May indicate that phosphorus is the controlling factor for algae growth
Secchi transparency readings vs. total phosphorus	Shows relationship between primary nutrient and water clarity
Dissolved oxygen and temperature depth profiles	May show stratification or mixing status in lakes
Parameters vs. numerical standards/criteria	May indicate problem areas
Bacteria vs. total suspended solids or turbidity	May indicate that bacteria are associated with solids, and reductions in bacteria could be achieved with technologies that trap solids
Observed values or biometrics vs. river mile/station (to see upstream-to-downstream trends)	May show trends by location or points/locations where major changes are noticeable

In reducing your data down to usable information, the key is to make conclusions that your data support. One conclusion may be that additional data is needed. That's an acceptable conclusion. You may arrive at a conclusion that others disagree with. But do the following and you will be in a strong position to defend your conclusions:

- Follow a logical process that has a scientific basis.
- Get help from other knowledgeable people. Most professionals and scientists enjoy reviewing and assessing data sets.
- Document your assumptions and your assessment process.

To begin this process, go back to the original questions upon which you based your monitoring plan. If you can answer them, your work is done. You've answered your basic study questions.

It is more likely, however, that you will only partly answer your questions, or find some additional questions. In other words, you may want to assess whether findings and conclusions can be explained by natural conditions, human alterations, and/or errors in sampling and analysis.

Natural conditions or human alterations factors affecting findings and conclusions

Consider some of the following questions to help you decide if human alterations or natural conditions can explain your results.

- Might natural upstream-to-downstream changes in the river account for your results? Your benthic macroinvertebrate results might be explained by natural shifts in the macroinvertebrate community composition from headwaters to mouth.

- Does weather appear to influence your results? For example, do problem levels coincide with intense rainstorms? Might elevated temperature levels be caused by unusually hot weather?

- Do problem levels coincide with rising flow? For example, are elevated bacteria counts only present during storm flows, which would indicate non-point runoff sources? Or are they only present during low flows, which might suggest point discharge sources?

- Does the presence of specific sources explain your results? For example, can you attribute increased bacteria levels to a wastewater treatment plant or a failing septic system?

- Do changes in one parameter appear to explain changes in another? For example, could low dissolved oxygen be explained by high temperature?

- Do your visual observations explain any of your results? Did your volunteers report any strange pipes, eroding banks or dry weather seeps from storm drains?

- For multiple years of data, are there overall trends? For example, did the macroinvertebrate community improve or deteriorate over time? The former could be explained by improved pollution control; the latter, by new pollution sources.

- If you are monitoring the impact of a pollution source, are there other upstream impacts that might be influencing and confusing your results? For example, if there is no riparian vegetation for shade upstream of an outfall, it might be difficult to figure out which, or which combination of factors, is causing elevated temperatures.

Sampling and analysis factors affecting findings and conclusions

Your results may also be explained by the way you collected and analyzed samples, rather than in the resource itself. To determine if this is the case, consider the following questions:

- Could flaws in your field and/or laboratory techniques explain your results? Could high concentrations be due to contamination or sampling error? Double check your QA/QC sample results to confirm data quality.

- Was your sampling representative of the resource and range of conditions observed? For example, was your sampling primarily conducted when river flows were low? Did you catch storm-related runoff or just base flow? Plot sample times against continuous stream flow records, if available, to check which parts of the flow regime were sampled.

- Was your analytical method sensitive enough to detect levels of concern?

- Did the time of day you sampled affect your results? For example, dissolved oxygen is typically lowest in the morning and highest in the late afternoon.

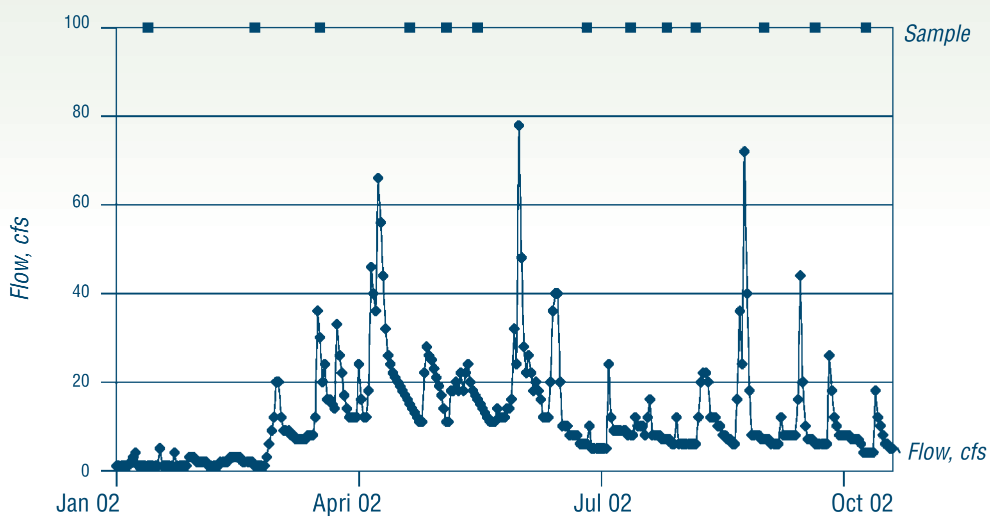
Understanding variability

Variability happens. Even with rigorous data collection methods and QA/QC protocol, all monitoring data will have variability. Natural systems are inherently variable, and through sample handling and analysis, we introduce additional variability. Uncertainty, in turn, compounds variability. Uncertainty arises because there is no such thing as a truly exact measurement, and we can't collect samples continuously, forever. Instead, we *periodically* collect samples to represent an environment that is *continuously changing over time and space*. And we analyze these periodic samples using methods that have limits in resolution, precision and accuracy.

(Much of the information on variability is taken from the article, "Variability Happens: Basic Descriptive Statistics for Volunteer Programs," by Julie Rector; *The Volunteer Monitor*, Vol. 7, No., 1, Spring 1995.)

Example graph shows that samples were generally collected at lower flows and may not be representative of conditions under high flow events

Rocky River 2002 Hydrograph and Sample Dates



Working with statistics

Statistics is the science of making decisions in the face of uncertainty. We cannot eliminate uncertainty and variability, but we can use statistics to estimate their contribution to our observed results and make informed decisions based on the data. Statistical methods and a number of assessment methods and indices have been developed to help with water quality data interpretation. According to Ms. Rector, volunteer monitoring programs generally use statistics for three main purposes:

- to summarize and report monitoring results
- to evaluate QA/QC data
- to help interpret data and draw conclusions

The most frequently used descriptive statistics are those that *describe central tendency* and those that *describe the distribution or variability*. The following examples illustrate these processes as they are used for lakes, streams and wetlands monitoring. Other statistical analyses, such as *trend analysis*, can also be completed. However, they may require years of data and/or more advanced statistical techniques. If you are interested in more advanced techniques, see references such as *Statistical Methods for Environmental Pollution Monitoring* by R.O. Gilbert, 1987, Van Mostand Reinhold Co., New York.

Measures of central tendency

Commonly used measures of central tendency include averages (i.e., arithmetic means), geometric means, and medians.

- **Average** is calculated by adding all the values and dividing by the number of values. Averages are representative or typical of all the sample observations. A problem with averaging can occur when you have very high or very low numbers that distort results.

- **Geometric mean** reduces the influence of very high and very low numbers in a data set. Geometric mean is commonly used to summarize bacteria data. To calculate geometric mean:
  1. Take the logarithm of each result.
  2. Average the transformed values.
  3. Transform the value back to the original unit (i.e., take the antilog of the average).

- **Median** is the value that divides the distribution into two halves. In other words, 50% of the values are above the median and 50% are below. Medians are meant to be a value representative or typical of the data set. The median is not affected by outliers (values that are extremely low or high) and is frequently more representative of data than the average. This is particularly true when the data set contains one or two very high or very low numbers. Consider the following example.

Central tendency calculation example

Consider the following set of total suspended solids (TSS) concentrations:

Date 1: 6 mg/L	Date 4: 15 mg/L	Date 7: 12 mg/L
Date 2: 8 mg/L	Date 5: 7 mg/L	Date 8: 7 mg/L
Date 3: 10 mg/L	Date 6: 13 mg/L	Date 9: 85 mg/L

The *median* of these numbers is 11 mg/L (values were ranked from lowest to highest and 50% of values were above and 50% below the number 11); the *geometric mean* is 12 (the logarithmic value of each number was calculated then summed to get 9.67, which was divided by 9 to get 1.0945 and the antilog taken [10X on calculators] to get 11.8 mg/L); and the *average* is 18 (total of 163 divided by 9). In this case, the median and geometric mean are much more representative of the data set than the average, as the average is greater than all but one of the observed TSS concentrations.

In general, it is appropriate to use the *average* when data sets are normally distributed around a mean value with no outliers. It is better to use the *median* if the data is skewed and/or if there are outliers. The only time volunteers typically use *geometric mean* is for bacteria monitoring.

Measures of distribution

Commonly used measures of distribution include range, quartiles and confidence interval/standard deviation.

- **Range** is defined as the difference between the maximum and minimum values of your data set. If you have a wide range, it means there is a lot of variation in your data. A small range indicates low variability and, therefore, greater likelihood that the average (i.e., arithmetic mean) is representative of the data set.

- **Quartiles** are the values below which lie the 25%, 50% and 75% of the values in a data set. The median is the 50% quartile and shows you the typical value in your data set. The other two show you the spread of your data. Another way to look at the quartiles is that 50% of your data, or the interquartile range, lies between the 25% and 75% quartiles. If these quartiles are far apart, it means there is a lot of variability in your data. If they are close together, it means your data set is relatively consistent and is clustered about the median.

- **Confidence interval and standard deviation.** Confidence interval is a group of continuous values that tends to include the true value a predetermined portion of the time. For example, if we say the 95% confidence interval for parameter "y" is 6 to 26, we are saying that we are confident that 95% of the time the true value of parameter "y" is between 6 and 26. The standard deviation describes a population's deviation from the mean. For a normally distributed population, the mean plus or minus one standard deviation represents a 66% confidence interval. Confidence intervals and standard deviations will be larger when there is a lot of variability. Most scientific calculators have a function for calculating standard deviation, and some will perform confidence intervals.

Deciding which measure to use depends upon the type of data you are summarizing. In general, we recommend the following summaries for the different indicators, but you should check historical data sets to see how they have been summarized:

Exhibit 6-1: Suggested statistical summaries for general chemical and physical parameters

Exhibit 6-1 is adapted from *Data to Information: A Guide Book for Coastal Volunteer Water Quality Monitoring Groups in New Hampshire and Maine*, by Dates and Schloss, (University of Maine Cooperative Extension and University of New Hampshire/Maine Seas Grant Extension, 1998).

Parameter	Statistical summary
Total suspended solids	Average Median Flow-weighted average[1] Range Quartiles Confidence intervals or standard deviation
Temperature (water or air)	Seasonal average Seasonal median Maximum Range Quartiles
Dissolved oxygen (as mg/l)	Seasonal median Minimum Quartiles
Turbidity	Median Maximum Quartiles
Nutrients (e.g. nitrite plus nitrate or total phosphorus)	Seasonal average[2] Flow-weighted average[1] Median Quartiles Confidence intervals or standard deviation
Conductivity	Average Median Quartiles

Parameter	Statistical summary
pH	Median or average[3] Quartiles Minimum
Alkalinity	Median Quartiles Minimum
Chlorophyll-*a*	Seasonal average[1] Range Maximum and minimum Median Quartiles Confidence intervals or standard deviation
Flow	Average Maximum and minimum Median Quartiles
Water clarity/transparency	Seasonal average[1] Seasonal median Maximum and minimum Range Quartiles Confidence intervals or standard deviation
Bacteria (water contact safety)	Geometric mean Quartiles

[1] Flow-weighted means are used for stream or river monitoring to represent concentrations weighted by flow. Flow-weight means account for concentration flow relationships.

[2] For lakes typically presented as growing season (loosely defined as mid-June through mid-September in Minnesota) average.

[3] The average is acceptable in well-buffered systems where fluctuations are not extreme. It also is acceptable if you measure pH to the nearest 0.1 unit. If you measure to the nearest 1.0 unit, then use the median.

"Load" in water monitoring

Load refers to the total mass of a parameter delivered to a point per unit of time (i.e., kilograms per year) such as the mass of phosphorus delivered by a stream to a lake each year. Loads are important to consider for water bodies such as lakes and wetlands that are sensitive to longer-term inflow or recycling of pollutants. In monitoring programs, we sample a mix of high and low flow events, but the arithmetic average concentration may not represent the true concentration that reflects the load distribution across the range of flows observed. Consider the following example:

Flow-weighted mean calculation example

Event	Total Phosphorus mg/L	Flow cfs
1	0.330	2
2	0.290	7
3	0.450	16
4	0.350	4
5	0.550	25

The arithmetic average concentration for these samples is 0.394 mg/L, and the median 0.350 mg/L total phosphorus. The flow-weighted average as shown below using a very simple approach is:

Total Phosphorus mg/L		x Flow cfs		
0.330	x	2	=	0.66
0.290	x	7	=	2.03
0.450	x	16	=	7.20
0.350	x	4	=	1.40
0.550	x	25	=	13.75
Total		**54**	=	**25.04**

25.04/54 = 0.464 mg/L, which is much higher than either the average or median would suggest.

When to consider flow-weighted means

Flow-weighted means are important to consider when doing loading studies such as determining the magnitude of pollutant loads discharged to a lake's tributaries. Calculation of flow-weighted means are generally more complex than presented in the above example because you also need to consider flow occurring between the sampled events and how concentrations can be represented for this unmonitored flow. In Minnesota the FLUX model *Simplified Procedures for Eutrophication Assessment and Prediction: User Manual* (Walker, William W. 1999, USACE Report w-92-2) is frequently used for this type of analysis. We suggest if you use this, that you get help from an experienced professional.

In Minnesota, you will also need to consider the influence of snowmelt when monitoring runoff in tributaries, streams and rivers. Snowmelt runoff can be significantly different with respect to pollutant concentrations than other runoff events because pollutants that accumulate over the winter are mobilized with the snowmelt. If snow melt concentrations are high compared to other events, we suggest calculating your statistics with and without the snowmelt values to test the sensitivity of the result. Median may also be a better measure of central tendency than average when considering snowmelt.

Other parameters may vary over other continuous periods, such as ice-free periods or periods when the water body stratifies. In any case, you must be sure that you're comparing data sets that are for the same period, seasonal or otherwise.

Specific considerations for water monitoring statistics

When calculating lake parameters, it is general practice to calculate growing season average. In Minnesota, the growing season is loosely defined as mid-June through mid-September.

Central tendencies for pollutants in runoff from tributaries, streams and rivers are frequently summarized as flow-weighted mean concentrations. Flow-weighted mean concentrations take into account the fact that concentrations of some parameters vary with flow. For example, concentrations of particulate pollutants (TSS, TP) may be higher at higher flows, which have more energy to suspend and transport particles. This higher concentration, combined with the higher flow, means that a disproportionate amount of the load of that particulate pollutant is transported during high flow events.

Finally, you should have at least five data points to calculate averages, geometric means, medians and quartiles.

Common assessment methods, benchmarks and indices

In addition to descriptive statistics, there are some fairly common assessment methods, benchmarks and indices used by scientists that tell use a lot about surface water quality. This subsection provides a general overview of some of these common assessment methods and indices. You can find additional information from the many manuals cited throughout this guide. For more information on lakes, refer also to the *Sustainable Lakes Planning Workbook: A Lake Management Model*, by the Minnesota Lakes Association, May 2000. It includes a comprehensive appendix called the *Lake Data Assessment Guide*.

Specific assessment methods, benchmarks and indices described in this Section include:

- Determining the mixing status of your lake
- Determining the trophic status of your lake
- Comparing to ecoregion reference lakes and streams
- Comparing to water quality standards
- Using biometrics for assessing streams, rivers and wetlands
- Using habitat indices for streams and rivers

I. Determining the mixing status of your lake

Mixing status refers to the frequency of vertical (i.e., top to bottom) mixing of water in lakes. Mixing can be characterized as:

- Dimictic – mixes spring and fall
- Intermicitic – mixes intermittently during the summer with short periods of thermal stratification
- Polymicitic – mixes from top to bottom throughout the summer

These characteristics can significantly influence the quality of a lake. For example, in lakes where sediments release significant amounts of phosphorus, concentrations of phosphorus in bottom waters can become very high. In dimictic lakes where mixing only occurs in the spring and fall, these bottom phosphorus-rich waters are not brought to the surface during summer months. However, in intermictic and polymictic lakes, this mixing of bottom water can be a significant source of phosphorus.

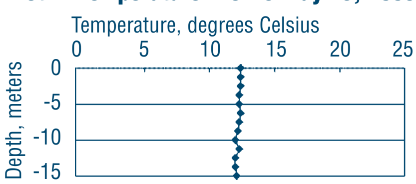
Vertical mixing is controlled by the presence or absence of thermal stratification. Thermal stratification occurs when layers of water with different temperatures form a thermal density gradient that resists the energy of wind and makes it more difficult for waters to mix. To assess mixing and stratification, temperature measurements are taken by lowering a probe to specified depths (typically every meter from surface of the lake to the bottom) and recording the temperature at each depth. These measurements are frequently complemented with dissolved oxygen recordings to characterize oxygen gradients from the surface to bottom. Conducting this sampling at defined intervals (monthly or weekly) from spring through fall should allow for a characterization of the mixing status of the lake.

Analysis of mixing is best done visually with graphs. You can complete the analysis by graphing each sample date separately as shown in Exhibit 6-2. With a series of these graphs covering the monitoring season, you can determine when the lake was well mixed vertically as in Plot A, versus Plot B, where temperature drops 10 degrees Celsius in five meters, indicating the lake is thermally stratified.

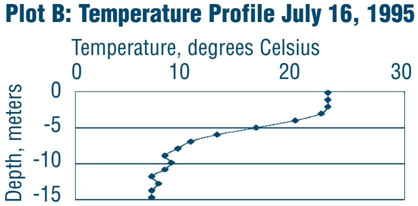
Exhibit 6-2: Temperature Plots

Plot A, well mixed vertically; Plot B, stratified

Plot A: Temperature Profile May 23, 1995



Plot B: Temperature Profile July 16, 1995



II. Determining the trophic status of your lake

Total phosphorus, Secchi transparency and chlorophyll-*a* measurements are the basic parameters that go into characterizing the "trophic status" of a lake.

Carlson's *Trophic State Index* (TSI) is used as the basis for estimating the trophic status of Minnesota lakes (Exhibit 6-3). Trophic status ranges from oligotrophic to hypereutrophic (and is viewed as a continuum) on this scale. Carlson's TSI is based on the interrelationships of TP, chlorophyll-*a* and Secchi transparency measurements.

To figure out your lake's trophic status, calculate the growing season average for these parameters, find the corresponding bar in the graph and the average, and draw a line upward to intersect with the top bar to read the TSI. For example, say from your data set you calculated the following growing season averages: total phosphorus 0.030 mg/L, Secchi transparency 2.1 meters, and chlorophyll-*a* 0.009 mg/L. First, convert the concentrations to parts per billion (ppb) – 30 ppb total phosphorus and 9 ppb chlorophyll-*a*. Note that Secchi transparency in meters is already in the correct units for use in the graph.

Then draw lines upward to the top bar to get the following TSI values:

- TSI_{secchi} = 48
- TSI_{chl-a} = 52
- TSI_{TP} = 52

You will find that the lake is right at the boundary of mesotrophic to eutrophic. TSI values can also be calculated for each of the variables using the following formulas:

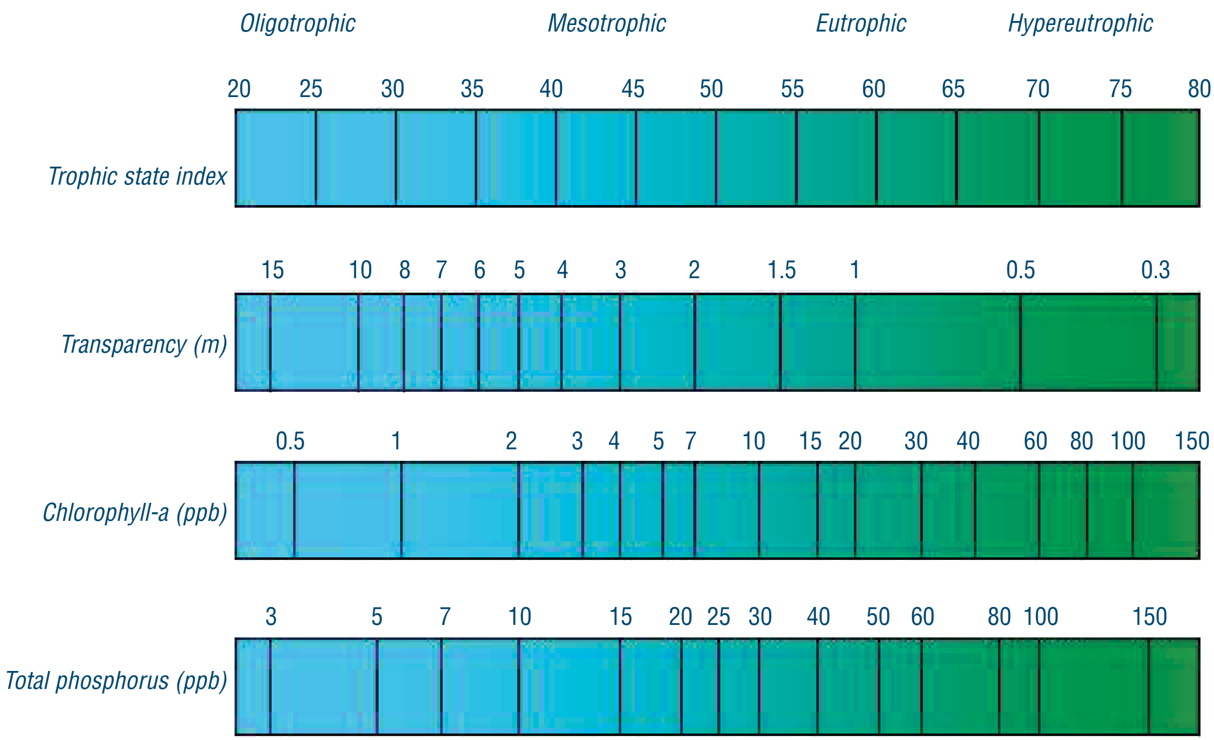
Total Phosphorus TSI (TSI_{TP}) = 14.42 ln(TP) + 4.15
Chlorophyll-*a* TSI (TSI_{chk-a}) = 9.81 ln(Chl-*a*) + 30.6
Secchi disk TSI (TSI_{Secchi}) = 60-14.41 ln(SD)

Note that TP and chlorophyll-*a* values are in mg/L and Secchi disk transparency is in meters. The "ln" in the formula stands for "natural log" and is a function on many scientific calculators.

If the TSI values agree fairly well for your lake, the three parameters are closely related (as is common for most Minnesota lakes), and it may be safe to assume that given data for one parameter, e.g., Secchi transparency, you should be able to estimate the others and, ultimately, be able to track changes in trophic state over time.

Exhibit 6-3 Carlson's trophic state index R.E. Carlson

TSI < 30	Classical oligotrophy: Clear water, oxygen throughout the year in the 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 hypereutrophic.
TSI > 80	Algal scums, summer fish kills, few macrophytes, dominance of rough fish.



After Moore, 1. And K. Thornton, [Ed.]1988. *Lake and Reservoir Restoration Guidance Manual.* (Doc. No. EPA 440/5-88-002.)

If the index values do not agree closely for your lake, there may be other factors affecting the relationship among the three parameters. If you carefully assess these differences, you should be able to diagnose what is going on. For example, Secchi TSI values in highly colored waters (bog-stained waters) may be higher than the other parameters. This is because the dark coloration may limit the amount of algae produced, keeping chlorophyll-*a* concentrations low. In this case, color is limiting transparency rather than algae turbidity.

In addition, lakes dominated by large colonial algae, such as *Aphanizomenon sp*. (look like clumps of grass clippings), may have high transparencies (low TSI) relative to the phosphorus concentration. This is because these colonies of algae may form "rafts" or scums at the surface of the water, which are easily displaced by wind or lowering of a Secchi disk and, hence, Secchi readings may be deeper than if the algae were dispersed evenly throughout the water column.

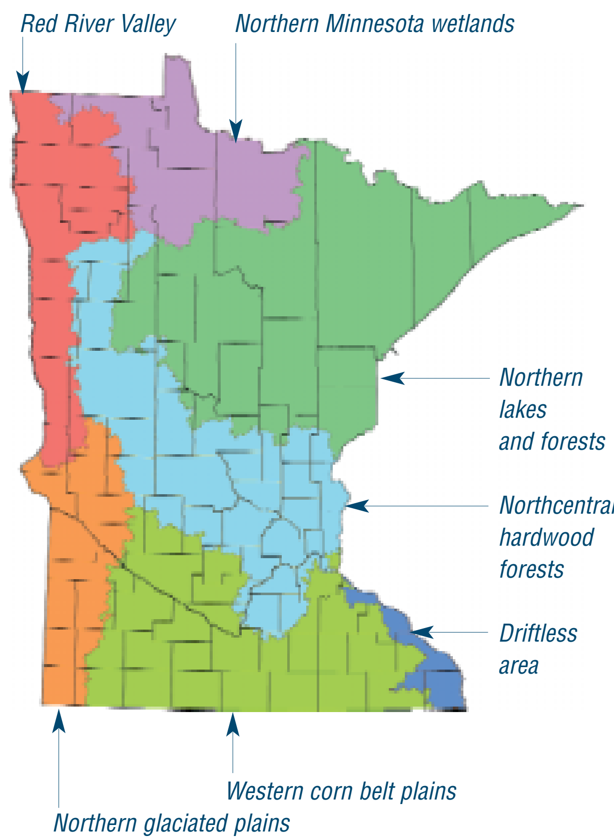
Lakes with extensive macrophyte (rooted submergent and emergent plants) growth may have higher transparency and lower chlorophyll-*a* (lower TSIs) than expected, based on the phosphorus concentration. These plants may compete with algae for available nutrients like phosphorus.

III. Comparing to ecoregion reference lakes and streams

One means for placing lake or stream 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 or stream is located (Exhibit 6-4). (An ecoregion is an environmental area characterized by a specific land use, soil types, land surface form and potential natural vegetation.) The U.S. Environmental Protection Agency mapped ecoregions for the United States from information on soils, landform, potential natural vegetation and land use.

For Minnesota, within-ecoregion similarities in lake chemistry and lake morphometry (depth and surface area) have been documented by scientists. Reference lakes, deemed to be representative and minimally impacted by human influences (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 to develop ecoregion ranges in Exhibit 6-5. The reference lake database consists of approximately 90 lakes distributed as follows among the four ecoregions with the majority of Minnesota's lakes:

Exhibit 6-4: Minnesota ecoregions



Data from the reference lakes can be used as a "yardstick" to compare other data against. Exhibit 6-5 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 that represent the central tendency of the reference lake's water quality. If your lake is near the transition zone of two ecoregions, it is often useful to make comparisons to reference lakes from both ecoregions.

Similar ecoregion summary data is also available for reference streams that can be used as a "yardstick" to compare other data against. Exhibit 6-6 provides a range of summer-mean values for each parameter and each ecoregion.

Exhibit 6-5. Ecoregion lake data base water quality summary

(Summer average water quality characteristics for lakes by ecoregion)[1]

Parameter	*Northern Lakes and Forests*	*North Central Hardwood Forests*	*Western Corn Belt Plains*	*Northern Glaciated Plains*
Total Phosphorus (mg/l)	14 - 27	23 - 50	65 - 150	130 - 250
Chlorophyll mean (mg/l)	4 - 10	5 - 22	30 - 80	30 - 55
Chlorophyll maximum (mg/l)	< 15	7 - 37	60 - 140	40 - 90
Secchi Disk (feet)	8 - 15	4.9 - 10.5	1.6 - 3.3	1.0 - 3.3
Total Kjeldahl Nitrogen (mg/l)	0.4 – 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 (s.u.)	7.2 - 8.3	8.6 - 8.8	8.2 - 9.0	8.3 - 8.6
Chloride (mg/l)	0.6 – 1.2	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 (mmhos/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

Exhibit 6-6 Water quality summary of reference streams, by ecoregion

Based on interquartile range (25th-75th percentile) and 5th – 95th percentile range for ecoregion reference streams (summer data, 1970-1992)*

Parameter	*Northern Lakes and Forests*	*North Central Hardwood Forests*	*Western Corn Belt Plains*	*Northern Glaciated Plains*
Total Phosphorus (mg/l)	30 - 50	70 - 170	210 - 350	160 - 290
Nitrite +	0.10 – 0.03	0.03 – 0.12	0.89 – 6.50	0.01 – 0.43
Nitrate-N (mg/L)	0.01 – 0.09	0.01 – 0.18	0.01 - 12	0.01 – 2.5
Fecal Coliform	20 - 50	80 - 700	130 - 1200	110 - 790
Bacteria	4 - 130	20 - 10000	40 - 9200	28 - 7900
pH (s.u.)	7.5 – 7.9	8.0 – 8.4	8.0 – 8.3	8.1 – 8.3
	7.0 – 8.1	7.5 – 8.6	7.8 – 8.5	7.8 – 8.5
Temperature (°C)	15 – 22	20 - 24	18 - 24	20 - 25
	11.1 – 25.0	14 - 27	14 - 28	13 - 29
Total Suspended Solids (mg/l)	2 – 6	8 - 18	26 – 76	37 - 89
	0.8 - 13	4 - 45	12 - 200	12 - 180
Turbidity (NTU)	1 - 4	5 - 10	14 – 27.0	20 - 37
	0.9 – 7.5	2.3 - 18	6.3 – 54.0	9.1 - 77
Conductivity (mmhos/cm)	120 - 260	250 - 310	530 - 810	760 - 990
	41 - 290	170 - 350	320 - 940	510 - 1300

*Derived from McCollor and Heiskary (1993).

IV. Comparing to water quality standards

You may want to compare your data to water quality standards – the fundamental benchmarks by which the quality of surface waters is measured. Water quality standards are used to determine impairment and assess whether a water body is meeting its beneficial use. However, keep in mind that exceedances of standards do not automatically mean there is impairment that will immediately place the water body on the 303(d) and 305(b) lists. There are specific procedures and data requirements (see *Appendix D* for data requirements) for developing these lists, including public debate through hearings.

Standards were first adopted into Minnesota administrative rules (Minnesota R. ch. 7050) beginning in the late 1960s. Assessing water quality standards and impairment is very specific since there is a regulatory component. This subsection provides a brief overview of water quality standards. Specific procedures for interpreting data for use with 303(d) and 305(b) impaired water assessments are available in the MPCA *2003 Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment* available at **http://www.pca.state.mn.us/water/tmdl.html#publications.**

Water quality standards are both numeric and narrative and apply to water bodies depending on their beneficial use classification.

Beneficial use classes for surface waters

All waters in Minnesota have been classified according to their beneficial use. Minnesota R. ch. 7050 identifies seven beneficial uses for which surface waters are protected, as listed below. The use class numbers 1 – 7 are not intended to imply a priority rank.

Use Class	Beneficial Use
Class 1	Drinking water
Class 2	Aquatic life and recreation
Class 3	Industrial use and cooling
Class 4A	Agricultural use, irrigation
Class 4B	Agricultural use, livestock and wildlife watering
Class 5	Aesthetics and navigation
Class 6	Other uses
Class 7	Limited resource value waters (not fully protected for aquatic life due to lack of water, lack of habitat or extensive physical alterations)

Water quality standards vary depending on beneficial use classification

Applicable numeric water quality standards may be different for different use classifications. For example, the numeric fecal coliform standard for:

- **Class 2A** (trout streams and lakes) waters – a monthly geometric mean[1] of 200 organisms per 100mL of water with less than 10% of samples having a maximum[2] greater than 400
- **Class 2Bd, 2B, 2C** (nontrout/warm) and 2D (wetlands) waters – a monthly geometric mean of 200 organisms per 100mL of water with less than 10% of samples having a maximum greater than 2,000
- **Class 7** (limited resource value waters) – a monthly geometric mean of 1,000 with less than 10% of samples having a maximum greater than 2,000

[1] Not to be exceeded as the geometric mean of not less than 5 samples in a calendar month

[2] Not to be exceeded by 10% of all samples taken in a calendar month, individually.

Class 2 waters are further divided into subclasses as follows:

Class 2A	Cold water fisheries, trout waters
Class2Bd	Cool and warm water fisheries; in addition, these waters are protected as a source of drinking water
Class 2B	Cool and warm water fisheries (not protected for drinking water)
Class 2C	Indigenous fish and associated aquatic community
Class 2D	Wetlands

All Minnesota surface waters, including lakes, rivers, streams and wetlands, are protected for aquatic life and recreation (i.e., should be "fishable and swimmable") where these uses are attainable, *unless* the water body has been individually assessed and reclassified as a limited resource value water. Protection of aquatic life means the maintenance of healthy, diverse and successfully reproducing populations of aquatic organisms, including invertebrates as well as fish. Protection of recreation for all surface waters, except wetlands and limited resource value waters, means the maintenance of conditions suitable for swimming and other forms of water recreation. Recreation in wetlands means boating and other forms of aquatic recreation for which they may be usable (this does not preclude swimming if that use is suitable). Limited resource value waters (Class 7) do not support swimming, but they may support wading, nature study or other forms of recreation that do not involve immersion in the water. Class 7 waters support a very limited fishery and aquatic community due to lack of water, habitat and usually extensive human alternations.

Both Class 2 and Class 7 waters, i.e., *all surface waters of the state*, are also protected for industrial (Class 3A, B & C), agricultural (Class 4A & B), aesthetic and navigation (Class 5) and other uses (Class 6). For example, the St. Croix River, from the dam in Taylor Falls to its mouth, is classified as 1C, 2Bd, 3B, 4A, 4B, 5 and 6. It is therefore protected for all uses defined by these use classes. If a pollutant has numeric standards for more than one beneficial use class, the most stringent applies.

Numeric Water Quality Standards

A numeric water quality standard is a safe concentration of a pollutant in water, associated with a beneficial use. Numeric standards are associated with all use classes except Class 6 (other uses). Ideally, if the standard is not exceeded, the use will be protected. Specific standards can be found in Minnesota Rules chapter 7050.

Narrative Water Quality Standards

A narrative water quality standard is a statement that prohibits unacceptable conditions in or upon the water, such as floating solids, scums, visible oil film or nuisance algae blooms. Narrative standards are sometimes called "free froms" because they keep surface waters free from very fundamental and basic forms of water pollution. More specifically, these standards also protect surface waters and aquatic biota from:

- Eutrophication (nutrient enrichment, particularly for lakes)
- Impairment of the biological community
- Impairment of fish for human consumption

The association between the standard and beneficial use is less well defined for narrative standards than it is for numerical standards; however, most narrative standards protect aesthetic or aquatic life beneficial uses. Because narrative standards are not quantitative, the determination that one has been exceeded typically requires a "weight of evidence" approach to data analysis showing a consistent pattern of violations.

V. Using biometrics for assessing wetlands, streams and rivers

Biometrics are used to analyze and interpret biological data by grouping organisms into meaningful biological assemblages. These groups, or metrics, represent various aspects of the biological community and are typically chosen to express meaningful biological endpoints such as species diversity, trophic structure, evenness, and tolerance or intolerance of various forms of human disturbance. If you used the Wetland Health Evaluation method detailed in *A Citizen's Guide to Biological Assessment: The Macroinvertebrate Index of Biotic Integrity (IBI)* (available from the Minnesota Pollution Control Agency) or one of the more intensive stream biosurvey methods, you should be able to use metrics to help assess your data. (See VSMP and Minnesota River Watch for more information.)

Wetlands

The Wetland Health Evaluation method uses six metrics to develop an overall Index of Biotic Integrity (IBI) score. (IBI is a synthesis of diverse biological information that numerically depicts associations between human influence and biological attributes. It is composed of several biological attributes or 'metrics' that are sensitive to changes in biological integrity caused by human activities.)

The term taxa (plural for taxon), used below, refers to the specific taxonomic groupings to which organisms have been identified. The six metrics used for the citizen invertebrate IBI are (Wetland Health Evaluation Method):

1. **The Leech Taxa Metric.** The number of kinds of leeches found in dipnet and bottletrap samples is greater in healthier wetlands. One kind of leech tends to increase in relative numbers in more polluted wetlands, but overall, the more leech taxa identified, the fewer disturbances.

2. **The Corixidae Proportion Metric.** All aquatic beetles and most true bugs are predators, mostly feeding on other invertebrates. Many of the corixid bugs feed on algae and detritus that tend to increase in polluted wetlands. The corixid bugs tend to increase in proportion to the total count of individuals of beetles and bugs found in the bottletrap samples. This is the only metric that relies only on data from bottletrap samples and the only one that counts the number of individuals.

3. **The Dragonfly-Damselfly Taxa Metric.** The number of kinds of dragonfly and damselfly (*Odonata*) larvae found in dipnet and bottletrap samples tend to be higher in healthier wetlands. These insects are predators at all stages, and have somewhat longer life cycles than other invertebrates. Dragonflies pump water in and out of their posterior end, which could expose them to pollutants. Some odonates lay their eggs on stems of plants, so if the plants are lost, they lose their egg-laying sites.

4. **The ETSD Taxa Metric.** This metric adds the total number of taxa of mayfly larvae (Ephemeroptera) and caddisfly larvae (Trichoptera) and to this is added a "one" for the presence of dragonfly larvae (D) and "one" for the presence of fingernail clams (S, for fingernail clam family Sphaeriidae) from bottletrap and dipnet samples. Mayflies, caddisflies and fingernail clams are sensitive to pollution. Mayflies and caddisflies are gill breathers, allowing them to take in pollutants directly from the water. Fingernail clams filter small particles from the water, allowing direct intake of pollutants, but also making them more vulnerable to siltation in the water. See the "Dragonfly-Damselfly Taxa Metric" for a description of dragonflies and damselflies.

5. **The Snail Taxa Metric.** Most snails in wetlands are air breathers. Sometimes you will see snails hanging upside down under the water surface film. They are breathing and may be feeding on the film. Snails are herbivores and feed on plants and the algae coating surfaces of plants, sticks and substrates. The number of taxa of snails is greater in higher-quality wetlands than in disturbed wetlands. Algae and plants can accumulate contaminants, so snails could be exposed to pollutants through their feeding. Also, if the vegetation is lost, there will be less food for snails.

6. **The Total Taxa Metric.** The total number of invertebrate taxa is usually one of the strongest indicators of the health of wetlands. The total taxa metric sums the total number of leech taxa, dragonfly and damselfly taxa, mayfly and caddisfly taxa, snail taxa and presence of fingernail clams. In addition, the number of macrocrustacean taxa is added to the total taxa. These are crustaceans that are visible to the eye such as crayfish, isopods, amphipods, fairy shrimp and clam shrimp. Smaller crustaceans like water fleas (*Daphnia*), ostracods and other zooplankton (copepods) are not counted. The Dipteran or true fly taxa are also included in the total taxa metric. Mosquito larvae, Chaoborus (the phantom midge), the midges (Chironomidae), the biting midges (Ceratopogonidae) and soldier flies are some examples of some of the Dipteran taxa that might occur in wetlands.

The seven metrics used for the plant IBI are (Wetland Health Evaluation Method):

1. **Total number of vascular plants.** It is a general ecological principle that integrated and stable natural communities typically have more different kinds of organisms (i.e., greater richness). Based on this principle, this metric measures the richness of vascular plant genera within a wetland.

2. **Total number of nonvascular plants.** This metric is similar to the preceding one in principle. Nonvascular plants, such as mosses liverworts and macroscopic algae (*Chara and Nitella*), depend on a healthy aquatic environment for reproduction and propagation and are extremely sensitive to changes in this environment. With the exception of bluegreen and green filamentous algae, which are not counted in this metric, this group of plants will quickly disappear under stressed wetland conditions.

3. **Total number of grass-like plants.** This metric is also similar to the other two in principle. It measures the richness of three specific groups of vascular plants: the grasses, sedges and true rushes (collectively called grass-like plants). They are a very common and important component in wetland communities. A variety of grass-like plants may grow in a wetland or the wetland can be dominated by only one or two of them. A healthy wetland will typically support several grass-like plants.

4. **Cover of sedge (*Carex*).** Sedges (grass-like plants) are very important components in the wetland community. They are especially sensitive to changes in wetland hydrology. This metric score is based on the extent of the sample plot covered by sedges – the greater the extent, the higher the score.

5. **Presence of *Utricularia*.** Bladderwort is a carnivorous plant that feeds on microinvertebrates. Its absence indicates there are stresses to wetland plants and animals. Bladderwort's presence in a wetland suggests good health.

6. **Cover of "Aquatic Guild" plants.** Nearly all of the true aquatic plants depend on an aquatic environment to survive. Many of these plants float or are below the water's surface. They are especially sensitive to the aquatic environment. This metric evaluates the cover of the true aquatic plants – the higher the cover, the healthier the wetland.

7. **Cover of plants with persistent standing litter.** This metric measures the cover of certain plants whose leaves and stems decompose very slowly after senescence at the end of the growing season. A *high* cover value of these plants suggests slower nutrient cycling and lower diversity of both wetland plants and animals. A *low* abundance of the plants suggests rapid nutrient and mineral cycling and, therefore, a healthy wetland.

Each metric is given a score of one, three or five points. The scores for all metrics of each community are summed to give two IBI scores. The best possible IBI score for invertebrates is 30 (6 metrics x 5 points); the lowest possible score is 6 (6 metrics x 1 point). The best possible IBI score for plants is 35 (7 metrics x 5 points); the lowest possible score is 7 (7 metrics x 1 point). Then the condition of the wetland is assessed using the suggested criteria: For invertebrates: 23 to 30 is excellent condition; 15 to 22 is moderate condition; 6 to 14 is poor condition. For plants: 27 to 35 is excellent condition; 18 to 26 is moderate condition; 7 to 16 is poor condition. These criteria are based on dividing the possible range of IBI scores (6 to 30, a range of 24 points) by three.

Streams and rivers

A number of metrics can be used to calculate stream health using benthic macroinvertebrates (*Volunteer Stream Monitoring: A Methods Manual*, EPA 841-B-97-003, EPA, 1997.) Three IBIs have been developed in Minnesota for the St. Croix River Basin, the Lake Superior River Basin (excluding the St. Louis River Watershed and the Nemadji River Watershed), and an IBI from Ohio was used in the Minnesota River Basin. These IBIs were developed based on data collected by professional biologists using genus or species level taxonomic information. Many of the metrics included in these IBIs are similar to those that volunteer groups could calculate, while others are not directly transferable to data interpretation using family level data.

Independent of a regional IBI, there are several ways of looking at family level biological information that will allow for a relatively robust glimpse at the health of an individual stream. Ideally, expectations of stream biological health should be based on a regional reference condition, or minimally disturbed condition. In

many areas, a regional reference condition is not readily available and the only option for assessment is to look at the trend of data collected over three or more years. While this does not allow for a one-time snapshot of stream health, it does provide valuable information about the trend of water quality in the stream being considered.

The only tool that currently exists to allow for assessment independent of regional reference expectations is the family level Hilsenhoff Biotic Index (HBI). The HBI allows for designations of stream condition based on the tolerance values and abundances of invertebrates in riffle samples. While it is a useful tool, volunteer groups that use the HBI as a primary means of assessing stream health must be aware that this is only one way of looking at data, and that other metrics, which are intended to reveal other types of changes to stream ecosystems (such as trophic structure), should also be considered.

As described in *Appendix D*, the MPCA will be developing regional, family level IBIs to assist volunteers in stream assessment using biological data. These tools will be finished once a large enough data set is available to allow for development of the tool across a significant portion of Minnesota.

The Intensive Stream Biosurvey method 4.3 in the USEPA manual (*Volunteer Stream Monitoring: A Methods Manual*, EPA, Nov. 1997) recommends the use of four basic metrics described below. These metrics have been commonly used by monitoring agencies throughout the country and are considered robust measures of stream health. Using multiple metrics is recommended and will allow for more in-depth assessment.

1. **Number of taxa** (taxa richness) **–** a count of the number of taxa (e.g., families) found in the sample

2. **Number of EPT taxa** (EPT richness) **–** a count of the number of taxa in each of three generally pollution-sensitive orders: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).

3. **Percent dominance –** the percent composition of the most abundant family from your site. It indicates how dominant a single taxon is at a particular site.

4. **Sensitive taxa index** (modified Hilsenhoff Biotic Index) **–** calculated by multiplying the number of organisms in each taxon by the pollution tolerance value assigned to each taxon, adding these for all taxa represented in the sample and dividing by the total number of taxa in the sample.

Additional metrics used in Minnesota IBIs that could be calculated for family level information include:

- **Number of intolerant taxa –** calculated by adding the number of taxa present in a sample that have a tolerance value of 2 or less. Tolerance values are taken from Hilsenhoff. This method of addressing intolerance is similar to the HBI but looks only at richness rather than abundance.

- **Percent of tolerant taxa –** the percent composition of organisms in a sample that have a tolerance value of 8 or greater. This metric addresses the abundance of tolerant taxa in a sample.

- **Number of clinger taxa –** a count of the number of taxa in the sample that have adaptations allowing them to cling tightly to submerged substrates. This mode of existence is defined for most aquatic insects in Merritt and Cummins (Merritt, Richard W. and Kenneth W. Cummins, *An Introduction to the Aquatic Insects of North America,* 3rd ed., Kendall/Hunt Publishing [Dubuque, IA, 1996] 862 pp) and can be determined for most other organisms by considering their typical habitats and physical adaptations.

- **Number of mayfly taxa –** a count of the Ephemeroptera (mayfly) families found in a sample.

- **Number of stonefly taxa –** a count of the Plecoptera (stonefly) families found in a sample.

- **Number of caddisfly taxa –** a count of the Tricoptera (caddisfly) families found in a sample.

- **Percent Hydropsychidae of Tricoptera** (Hyd/Tri) – relative abundance of net spinning caddisflies (Hydropsychidae) to all caddisflies found in the sample. This measure is calculated by dividing the number of individual of Hydropsychidae caddisflies by the number of individuals of all caddisflies found in the sample.

- **Percent predators –** represents the percent composition of organisms in a sample that are active predators.

- **Percent gatherers –** represents the percent composition of organisms in a sample that collect their food by gathering.

Exhibit 6-7 Attributes of aquatic invertebrate community assemblages and predicted responses to human disturbance

Metric	Predicted response to disturbance
Number of taxa	Decrease
Number of EPT taxa	Decrease
Percent dominance	Increase
Modified HBI	Increase
Number of intolerant taxa	Decrease
Percent of tolerant taxa	Increase
Number of clinger taxa	Decrease
Number of mayfly taxa	Decrease
Number of stonefly taxa	Decrease
Number of caddisfly taxa	Decrease
Hyd/Tri	Increase
Percent predators	Decrease
Percent gatherers	Decrease

Other metrics are presented in the USEPA manual, along with detailed methods.

VI. Using habitat indices for streams and rivers

Completion of some form of habitat assessment is recommended to complement stream biosurveys. A quantitative method for habitat assessment is included in the USEPA manual (*Volunteer Stream Monitoring: A Methods Manual*, EPA, Nov. 1997) and the VSMP man-

ual provides data sheets for this method (***http://www.vsmp.org***). This Quantitative Evaluation Method is available for rocky and muddy bottom sampling sites. It consists of a scoring system from 0 (poor) to 20 (optimal) for the following 10 different habitat parameters:

	Rocky bottom	Muddy bottom
1	Attachment sites for macroinvertebrates	Shelter for fish and macroinvertebrates
2	Embeddedness	Pool substrate characterization
3	Shelter for fish	Pool variability
4	Channel alteration	Channel alteration
5	Sediment deposition	Sediment deposition
6	Stream velocity and depth combination	Channel sinuosity
7	Channel flow status	Channel flow status
8	Bank vegetative protection	Bank vegetative protection
9	Condition of banks	Condition of banks
10	Riparian zone width	Riparian zone width

Total scores are summed to get the quantitative assessment. The total value and the individual parameter values can be compared to biosurvey results and biometrics. This will help identify causes of impairment shown by the biometrics. For example, if the percent dominance metric shows a very high value indicating dominance by one or two taxa, but the quantitative habitat evaluation shows optimal conditions for all parameters, a likely conclusion is that water quality, rather than habitat, may be stressing the aquatic community. Future studies should perhaps focus on water quality parameters.

Reporting your information

If you have spent the time to collect data, you will probably want to share your experience and the data you have collected with others. At the very least, as a basis for any presentations, produce a written report that summarizes your work and the results for your most rigorous audience. Once you have this report prepared, you can prepare different presentations for different audiences. A presentation you make to county commissioners, for example, may be very different from a report you make for your staff.

Make an annual report

In your report, summarize your monitoring activities and results, state your findings and conclusions and make recommendations for actions to address problems or changes to your sampling program, if needed. You may produce an annual "state of the watershed or water body" report that highlights trends, cleanup progress, new trouble spots, etc.

Here is a generic format you can follow:

1. **Introduction** (describe the area and your specific program, including maps of your monitoring location)

2. **Project description** (summarize your study design)

3. **Results** (how data were analyzed, findings, conclusions, recommendations)

4. **Acknowledgments** (who made your program possible)

5. **References** (information sources used to prepare your report)

6. **Appendices** (any other information you wish to include but that would detract from your narrative report)

Once you have your basic report prepared, share your experience and the data you have collected with others.

- Participate in the distribution of information to and with other agencies.

- Write and distribute technical reports, describing what you learned – current water-quality conditions, source, cause, transport, and effects of contaminants to humans, aquifers, and ecosystems, as appropriate.
- Communicate with multiple audiences, by writing reports or executive summaries for nontechnical audiences.
- Write articles for local weekly newspapers or magazines.
- Present lessons to peers, elementary school classes or after-school clubs.
- Create a display or booth.
- Make presentations to your watershed district, city council or community forum to assist the public in understanding the significance of your results.
- Provide basic data for other data users as requested.

Use tables and graphs

This Section explains how your results can be displayed in tables and graphs to help visualize and interpret them. You do not have to include all of your graphs and tables in reports or the main body of the report. Only include the ones that help you tell your story. Others, particularly raw data tables, can be included in appendices.

Tables. Sometimes a table is not considered "exciting," but it is an important tool for organizing data, and can present information more precisely than graphs. Use tables sparingly in presentations because they are difficult for the audience to read unless they are very simple.

Graphs and charts. Line graphs, bar graphs (including scatter plots) and pie charts are the three main types of graphs you will use. You can create these types of graphs from spreadsheets. An MPCA document, *Charting Lake Data: Applications for Spreadsheets in Lake Assessments* (1996), provides step-by-step instructions for charting total phosphorus, Chlorophyll-*a*, and Secchi transparency graphs and dissolved oxygen and temperature profiles ***(http://www.pca.state.mn.us/water/charting.html)***.

Line graphs are good for displaying relationships between points. A line graph displays the data points as points on the graph connected by a line. They often illustrate trends in data. For use with water quality data, time or space is usually displayed along the x-axis (horizontal) and water quality parameters along the y-axis (vertical). Exhibit 6-2, earlier in this Section, shows the use of line graphs for temperature profiles (e.g., for displaying the relationship between lake depth and temperature).

When using a line graph, you must be careful that you have enough data points so that the trend implied is valid. This may or may not be the case depending on the variability of the data. For example, if graphing dissolved oxygen concentrations against location (mileage) along a river, it may be appropriate to connect a line through several points that are only a short distance apart and taken at about the same time of day. But it would not be appropriate for sites miles apart or where readings were taken at different times of the day.

Bar graphs put more emphasis on the individual points or summary statistics. They are useful for comparing biosurvey results, the level of a pollutant at one station over time or at several stations at one time and for displaying summarized data. Exhibit 6-7 shows a bar chart used to compare Index of Biotic Integrity (IBI) scores from different wetland sites and volunteer team results and quality control check results.

Pie charts (and stacked column charts) are different ways to display the same data and show data as proportions of a whole. They're easy for the general public to understand, but can only be used for data that can be expressed in terms of proportions, or percentages, of a whole. For example, they can show the percent of phosphorus loads to a lake (Exhibit 6-8), or taxonomic groups (Exhibit 6-9).

Create a good table

A good table has:

- Readable, logical data placement
- Clear column and row headings
- Title at the top
- Reporting units

Dates and Schloss, 1988

Create a good graph

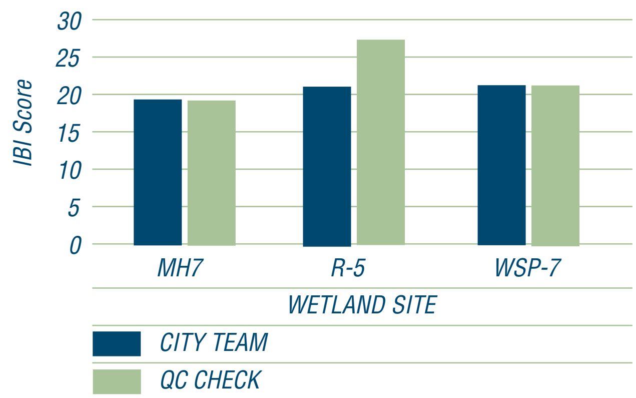
A good graph has:

- A clear title
- Simple clear labels on each axis
- A scale that reveals trends
- A legend that explains the elements of the graph
- Clearly shown reporting units
- A story that is apparent from the graph
- Information that allows the reader to get the point (e.g., example, levels of concern)
- The minimum number of elements to tell the story (avoid clutter)

Dates and Schloss, 1988

Exhibit 6-7 Example bar graph

2001 Invertebrate Quality Control Check



(Source URS, 2002. Dakota Wetland Health Evaluation Project: 2001 Field Season Summary)

Exhibit 6-8 Example pie chart

Percent phosphorus contributions to Round Lake 1996

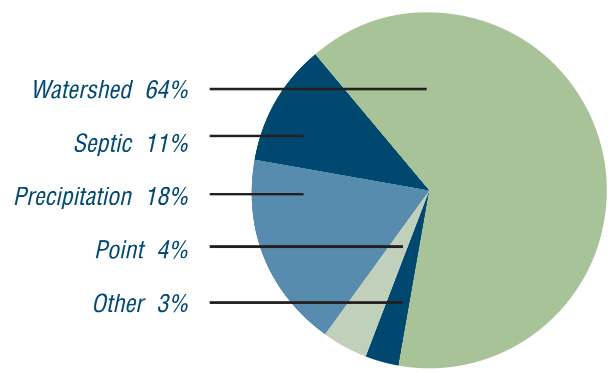
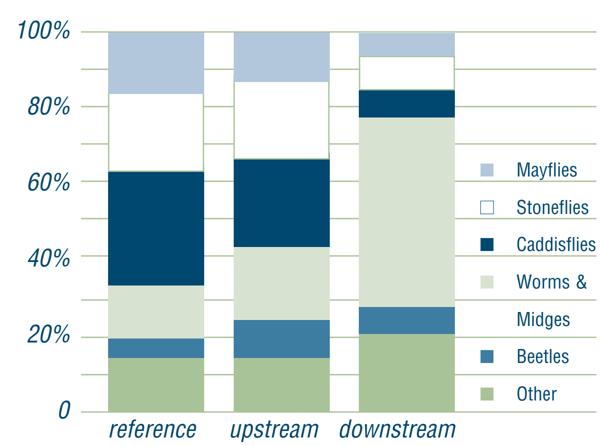


Exhibit 6-9 Example stacked column chart

Composition of selected macroinvertebrate groups



Section 7:

Evaluating monitoring program performance

This Section will show you how to:

- **Determine if your monitoring program's goals and objectives were met.**
- **Decide how to proceed in the future.**
- **Stay engaged in the ongoing monitoring program.**

Take stock and plan for the future

We've emphasized how important it is to continually evaluate and review how you are performing against the goals and objectives you set early in your program. But once your project is finished – or at the very least, on an annual basis – you should evaluate the performance of your overall monitoring program. Doing so could be the most important step in the design and review process. That's because evaluation procedures can resolve whether the information you developed was sufficiently precise and scientifically usable. If there is anything you could be doing better, to gain more credible and useful data, you will often uncover it in the evaluation process.

Having good field notes will make the process of evaluation go more smoothly. If you have an ongoing record of activities, changes you made during the program, etc., it will help you remember what occurred during the monitoring effort.

Keep in mind, too, that it may take a few years of monitoring before it is possible to fully analyze and interpret your data, so take that into consideration as you routinely evaluate your program.

You generally review and evaluate in order to measure the effectiveness of the monitoring actions and programs you implemented, and to provide essential information that can be used to redirect and refocus your design plan.

To evaluate your program, follow these basic guidelines:

- Determine if your monitoring program's goals and objectives were met.
- Identify successes/what worked in your monitoring program.
- Identify any monitoring problems associated with your project.
  - Collecting and analyzing samples
  - Storing, disseminating, and interpreting data
  - Reporting the information to managers and the public
  - Identifying gaps and inefficiencies
- Evaluate the costs of the monitoring program relative to other costs, such as clean-up, lost environment and results realized.
- Provide feedback.

1. Determine if goals and objectives were met

Evaluating your actual results against original goals and objectives (see *Section 3*) will help determine if the program should be modified by adding, deleting or expanding monitoring components.

Suppose, for example, that your goal was to collect at least 24 water samples per site monthly to measure fecal coliform bacteria, dissolved oxygen, total phosphorus, temperature, pH and total acidity. Upon evaluation, you realize you were able to collect an average of 18 samples. You may decide the samples collected were actually good enough to meet the objective, or you may realize you need more volunteers or need to use the volunteers you have more often.

An evaluation may also reveal that to meet your goal, you need to add an alternative sampling strategy to fulfill the objective. It may become obvious, for example, that you should also be sampling for nitrates. Based upon this, you may decide to add the procedure, or determine that it is beyond the scope of your particular project.

Whatever you decide, you will then use this information to update your monitoring design plan before you proceed to the next level.

2. Identify successes

You are going to have some successes, regardless of the data objectives you set. Even if you missed a particular goal, what you did accomplish may meet a lesser goal. For example, you may have set out to establish baseline data for your neighborhood watershed, but you were not able to collect enough information to meet your objectives. You did, however, raise community awareness and promote community education. Celebrate that success as you redesign your project for the next phase.

3. Identify problems

Problems may have been identified as the monitoring program was in progress or you may uncover new ones that show up on final evaluation. At this stage, you can make note of the problems and determine

how to incorporate changes in your updated design plan to avoid these problems the next time. You may find you need to enhance your QA/QC procedures. Or you may find that your original goal or purpose has changed based on the information you have.

4. Evaluate costs

Costs in monitoring programs vary widely – from expenses involved in purchasing equipment to costs associated with actually carrying out the program (meeting, transportation, volunteer hours spent). In order to protect this considerable investment, evaluate your sampling strategies to be sure you have selected the most effective monitoring components and variables, and that you have optimized your overall monitoring effort.

5. Provide feedback

Use results of your evaluation to identify current and future needs and activities of your group and data users.

Typical problems identified in monitoring program evaluations:

- Monitoring programs did not clearly define monitoring objectives and apply available design tools.
- Monitoring group did not check with potential data users to determine types of data to collect.
- There was a lack of communication and coordination among the people in the program.
- They needed to adopt standardized sampling and QA/QC procedures to ensure data comparability.
- The results of the monitoring program were not presented in a form that is useful to interested stakeholders. It is essential to link data management strategies and data analysis methods to the objectives of the monitoring effort. It is also necessary to devise a plan for effectively communicating monitoring results to the identified audience.

Develop partnerships and connections

Because environmental sampling can be costly and resources will often be limited, it makes sense to leverage your resources as much as possible.

Other organizations with similar goals and objectives may have developed procedures or training materials that can streamline your particular project. Databases may already include information that you can use to build on. The city where you live no doubt has resources that you can use. You will often find regional conferences will be a big help in providing information and motivation for your volunteers.

Here are a few ways you will benefit from making connections:

- Receive funding or learn about funding sources.
- Obtain technical assistance.
- Receive on-site supervision of volunteer projects.
- Get help from speakers, field trips and telephone or e-mail support.
- Obtain materials, videos, curricula, posters, public education flyers and displays.
- Receive loans or gift equipment from interested parties.
- Obtain maps and data on water quality, native species, soil types, wetlands, history, etc.
- Track the status and progress of other programs in situations similar to yours.
- Learn how you can improve your own programs by learning about other current and emerging programs.
- Learn about programs that are working well.
- Put your own program in a framework or context of water monitoring as a whole.
- Learn how to present your findings to elected officials and the public about the progress you have made.

Most agencies, organizations and governmental bodies are eager for the help that volunteers provide. Ask these questions to evaluate whether an agency/organization fits into your monitoring goals:

- Are its goals compatible with your goals and objectives?
- What do you hope to get from the agency?
- When do project activities take place?
- Does the organization provide training?
- How does the organization use volunteers in its projects?
- Will the agency help with transportation, liability issues and supervision?
- Will support staff be available to help you in person or by phone/e-mail? Are they responsive and reachable?

Throughout this guide, we have referenced guidance manuals and organizations that provide excellent resources for volunteer water monitors. These references only scratch the surface of information that is available to you. Take advantage of it so you can leverage the resources you have in the most effective way possible.

Stay motivated and engaged

You, and others on your team, may have joined the monitoring effort for any number of reasons.

- To have an impact
- To be part of a team
- To meet people and make friends
- To learn something
- To gain experience
- To build a resume
- To gain fulfillment
- To feel needed and appreciated
- To have fun
- To use a skill
- To give back to the community

Joining the team took effort on someone's part and following through to implement the program took commitment on everyone's part. The challenge is to

Students produce data that will help clean up St. Louis River estuary

Students in the St. Louis River River Watch program collect chemical, physical, and biological data twice per year at river sites located throughout northeastern Minnesota. The data are compiled, evaluated and shared among all schools, as well as with the state and local communities in a variety of ways. For example, an environmental engineering company recently requested the program's water temperature data to help model temperature fluctuations in the St. Louis River sediment. These models will help advance clean-up efforts at a Superfund site in the St. Louis River estuary. In these and many other ways, student-gathered data are used to protect and manage the St. Louis River ecosystem (from St. Louis River Watch web site:
http://www.fdl.cc.mn.us/ei/rw/data.html)

stay interested in your monitoring project. A study about why volunteers leave, prepared by *Florida Lakewatch* in 1998, may help you understand how to stay motivated yourself and to motivate others on your team.

Some volunteers will leave for reasons such as health problems and life changes, or taking a more time-consuming job, or moving out of the area. Others may leave because they are left to maintain their own motivation, with little or no encouragement, interaction or reporting of results.

You may find the following ideas that *Lakewatch* created to address the challenge of keeping volunteers motivated may help your group as well. Encourage your group to try some of the following suggestions if you feel they will help your group move forward:

Improve feedback

- Hold more meetings, at least one general meeting per year, so everyone has a sense of connection to a group and to offer opportunities to deal with any questions and concerns.

- Speed turnaround time between data collection and feedback.
- Improve data report format.
- Produce a variety of types of feedback (videos, brochures, in-person presentations).
- Produce a newsletter at least twice a year.
- Hire regional coordinators to maintain closer touch with volunteers.

Add new challenges

- Take training in monitoring additional parameters, such as bacteria levels, bird populations or aquatic plant levels.
- Perform training, if you are an experienced volunteer.
- Get everyone involved in fundraising and recruiting.

Create rewards

Probably the best reward volunteer monitors can receive is to see their data being used. This is often accomplished when you present your data in a public venue. In so doing, you will feel more like a necessary part of your organization. And, last but not least, say "thank you" over and over again. Some ways organizations have said "thank you":

- Hold a picnic, barbecue or party.
- Take volunteer leaders out to lunch.
- Hold a banquet that is a fundraiser and awards ceremony.
- Write personal letters expressing your appreciation for everyone's contribution.
- Profile volunteers in a newsletter.
- Present appreciation awards – certificates, pins, caps, mugs, etc.
- Give scholarships.
- Send regular memos keeping everyone up to date on activities and the status of the project.
- Plant a tree honoring your project.

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http://www.bwsr.state.mn.us/directories/index.html

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http://www.datafinder.org/maps.asp

Massachusetts volunteer water monitoring
http://www.state.ma.us/dep/brp/wm/files/qapp.pdf

Metro GIS
http://www.metrogis.org

Metropolitan Council
http://www.gis.metc.state.mn.us

Minnesota Association of Conservation Districts
http://www.maswcd.org/swcds

Minnesota Association of Watershed Districts (MAWD)
http://www.mnwatershed.org

Minnesota Climatological Network
http://www.climate.umn.edu/doc/historical.htm

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http://www.deli.dnr.state.mn.us

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http://ga.water.usgs.gov/edu/wetstates.html

USGS at
http://www.usgs.gov or
http://www.mn.water.usgs.gov

Volunteer Stream Monitoring Partnership
http://www.vsmp.org

Volunteer Monitor
http://www.epa.gov/owow/volunteer/vm_index.html

Note to readers: *This guide provides dozens of internet references for further information from a variety of sources. They are current and live as the guide goes to press; however, over time some links may become inactive.*

Photos

The majority of the photos in the publication were provided by the Dakota County Environmental Education Program, the Minnesota Wetland Health Evaluation Program, Cannon River Watershed Partnership and St. Louis River Watch.

Appendices

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Appendix A:

Resources

This Appendix describes water monitoring resources and programs available through various websites. The list is not intended to be comprehensive.

Resources are broken down into four categories: volunteer monitoring programs, other monitoring programs, water education resources and professional organizations. Some resources could fit into multiple categories, given the various programs offered.

Volunteer monitoring programs

These organizations provide monitoring through the use of volunteers.

Cannon River Watershed Partnership (CRWP)

http://www.crwp.net

CRWP was founded in 1990 to protect the surface and groundwater resources and natural systems of the Cannon River Watershed, a 1,460-square-mile area covering parts of six counties in southeast Minnesota. CRWP is involved in outreach, monitoring and on-the-ground conservation projects. The CRWP began its citizen stream-monitoring program in 2000 and had 22 volunteer monitors involved. Modeled after the MPCA program, the organization recruited a network of citizen volunteers to perform basic water quality testing throughout the watershed. This network will provide long-term water quality data for many parts of the watershed that were previously untested. Water quality and stream flow at several sites on the Straight River will be used in a Total Maximum Daily Load (TMDL) project for the Straight River in an effort to reduce bacteria pollution levels in the Straight and the Cannon Rivers.

COLA Lake Monitoring Program

MPCA, Detroit Lakes Regional Office, 218-846-0747

The COLA Lake Monitoring Program was initiated in 1993 by the Becker County Coalition of Lake Associations. It is a citizen volunteer lake monitoring program that was drafted and developed by the MPCA – Detroit Lakes Regional Office. The program was developed to collect reliable total phosphorus and chlorophyll-*a* data in conjunction with the MPCA - Citizen Lake-Monitoring Program Secchi data, to better understand the trophic condition of regional lakes. The cooperative program links county resource officials, coalitions of lake associations (COLAs), lake associations and the MPCA for lake water quality assessment goals. Citizen volunteers are trained to collect, preserve, and ship samples to a certified contract laboratory. Eight counties have implemented the program with over 250 lakes involved. Cooperators gain an improved understanding of the participating lakes and of general limnological principles. Resource managers have current information for management decisions and have built strong relationships with the COLAs and lake associations. Lake residents have developed an understanding about the phosphorus - chlorophyll - Secchi relationship and pass this information to others on the lake and within the watershed. Lake stewardship concepts and programs have an increased level of importance when residents understand the fertility level of their lake and how their shoreland activities affect lake nutrient levels. The user-friendly program has successfully generated credible data in each of the counties where implemented. The data are used for 303(d) water quality assessment purposes.

Metropolitan Council

http://www.metrocouncil.org

The Metropolitan Council is the regional planning agency serving the Twin Cities seven-county metropolitan area (TCMA). It provides essential services to the region, such as collects and treats wastewater, engages communities and the public in planning for future growth and provides forecasts of the region's population and household growth.

Noteworthy resources available:

- **Lake Monitoring and CAMP.**
  The Metropolitan Council has conducted water quality monitoring of the TCMA lakes since 1980. Both Metropolitan Council Environmental Services (MCES)

staff and citizen volunteers have been obtaining the monitoring data. The MCES Citizen-Assisted Monitoring Program (CAMP) has been very successful at involving citizens in lake monitoring efforts and greatly expanding the number of lakes with water quality data. Biweekly, each volunteer collects a surface water sample for laboratory analysis of total phosphorus (TP), total Kjeldahl nitrogen and chlorophyll-*a,* obtains a Secchi transparency measurement and provides some user perception information about the lake's physical and recreational condition.

Special lake monitoring is conducted on individual lakes to help answer specific questions.

- **Stream Monitoring.**
  In 1973, MCES began monitoring the water quality of the Mississippi, Minnesota and St. Croix Rivers in the TCMA. These rivers are regularly monitored for a wide variety of water quality variables that help document long-term changes in water quality. This program led to the creation of the Stream Monitoring Program, which began in 1988. Twenty-six automated stream monitoring stations are now located around the TCMA and six stations in the Mankato area. These stations monitor portions of the Minnesota, St. Croix and Mississippi River Basins. Some of these stations are cooperatively operated between the MCES and local governments. The diverse range of variables analyzed allows for characterization of the streams that are being monitored and are leading to the development of target pollutant loads.

- **Wastewater Treatment Plant (WWTP) Monitoring.**
  MCES monitors the quality of treated wastewater that is discharged from its eight wastewater treatment plants into the TCMA rivers. Groundwater monitoring is also conducted at several WWTPs.

Minnesota Department of Natural Resources (MDNR)

http://www.dnr.state.mn.us

The MDNR's mission is to work with citizens to protect and manage the state's natural resources, to provide outdoor recreation opportunities and to provide for commercial uses of natural resources in a way that creates a sustainable quality of life.

Noteworthy resources available:

- **Lake Hydrology Program.**
  Collects and provides data on lake levels and other characteristics that are needed to effectively carry out the DNR Water's statutory responsibilities and management programs. Includes the development and maintenance of the *Lake Level Minnesota* monitoring network and the Lakes-DB computer database. In the Lake Level Minnesota program, volunteers and cooperative organizations collect and report lake levels throughout the state. Each spring, DNR Waters employees travel throughout the state and reset the survey lake gages. These gages are used to measure the change in water levels throughout the open water season. A map of the locations is provided.

- **Project Wet.**
  http://www.dnr.state.mn.us/projectwet/index.html
  Project Wet (Water Education for Teachers) is an international, interdisciplinary water science and education program for formal and non-formal educators of K-12 students. Educators can obtain the basic K-12 activity guide focused upon all aspects of water, or other guides focused upon water quality, wetlands, water conservation and cultural attitudes about water. It is designed to teach children reading, writing, math and other subjects by exploring water and water-related environmental issues. There is a WET curriculum guide.

- **Water on the Web.**
  http://wow.nrri.umn.edu/wow/
  Water on the Web's primary goal is to train students to understand and solve real-world environmental problems. WOW offers unique opportunities for high school and first-year college students to learn basic science through hands-on science activities (in the lab and in the field) and by working with state-of-the-art technologies accessible through a free web site. It is a collaboration of MDNR, the Natural Resources Research Institute, Minnesota Sea Grant, University of Minnesota Duluth, Lake Superior College and Apprise Technologies Inc.

- **Exotic Species Monitoring.**
  http://www.dnr.state.mn.us/volunteering/index.html
  There are a number of volunteer monitoring opportunities available for review on this website.

- **State Climatology Office (SCO).**
  http://climate.umn.edu
  This office manages, analyzes and disseminates climate information to ensure a contiguous and continuous supply of high-quality climate data. It maintains a number of data sets and develops products from those data sets, such as: weekly maps of snow depth or precipitation, current and long-term summaries of floods, temperature and precipitation and other products resulting from high spatial resolution daily precipitation data sets and special data sets. The Office works with Soil and Water Conservation Districts, the National Weather Service, the Metropolitan Mosquito Copntrol District, DNR Forestry, Watershed Districts and others to recruit volunteers, distribute monitoring equipment and forms, and assure that the data are delivered to the State Climatology Office. The office receives data from more than 1400 volunteer participation monitors each year.

Minnesota Lakes Association (MLA)

http://www.mnlakes.org
lakes@mnlakes.org

MLA is a nonprofit organization that promotes citizen stewardship of Minnesota's waters and influences public policy for water resource protection. MLA participates in water quality and lake-oriented studies and meetings, represents lakeshore property owners on government committees, prepares training and reference materials on lake management issues, publishes a bi-monthly newsletter and e-mail bulletin and assists lake associations and coalitions of lake associations around the state. MLA also represents the voice of lakeshore property owners across the state at the state legislature.

The MLA website contains a bibliography of more than 600 lake management resources, including the Sustainable Lakes Workbook for lake management planning. MLA is working in collaboration with the Rivers Council of Minnesota to design and implement a statewide citizen monitoring network to enhance volunteer education and training and provide resources for volunteer monitoring. It also publishes and promotes a Lake Ecology curriculum for 5th and 6th graders that is being widely used throughout Minnesota.

Minnesota Pollution Control Agency (MPCA)

http://www.pca.state.mn.us

The MPCA was created to protect Minnesota's environment through monitoring environmental quality and enforcing environmental regulations.

Noteworthy resources available:

- **The Lake Water Quality Assessment Program.**
  http://www.pca.state.mn.us/water/lakequality.html
  This program assesses 2,235 lakes in Minnesota. The assessment was first required by the Federal Water Quality Act of 1987. The MPCA chooses to update the assessment each year. Lake quality assessment information is useful to anyone involved in lake management in Minnesota – from lakeshore owners to lake associations. It provides lake and water quality criteria.

- **Citizen Lake-Monitoring Program (CLMP).**
  Participants take weekly transparency measurement readings on lakes and record their perceptions of the physical appearance and recreational suitability of that lake during the summer months. The MPCA enters the participants' data into a database called STORET, the United State Environmental Protection Agency's (USEPA) national water quality data bank. CLMP data help teach citizen volunteers about water quality interactions in lakes and provides important information for assessing trends in the quality of Minnesota lakes.

- **Citizen Stream-Monitoring Program (CSMP).**
  The CSMP, which began in 1998, was designed to give Minnesotans the opportunity to become involved in a stream-monitoring program that provides data management and interpretation. The CSMP uses a collaborative approach to stream monitoring by partnering with citizen volunteers who live on or near a stream and who are interested in water quality. Sites are monitored weekly from April to September and an annual report is completed that summarizes data collected by volunteers statewide and is sent to volunteers and other interested parties.

- **Environmental Data Access.**
  http://www.pca.state.mn.us/data/eda/index.html
  The goal of the Environmental Data Access project is to create an interactive, web-based system for retrieving environmental data and assessments. The system will be compatible with Geographic Information Systems

(GIS) so that monitoring data can be displayed geographically. A first iteration of the web-based system, focused on surface water monitoring data, is accessible on the MPCA's web site as of June 30, 2003. Future versions will include all environmental data, not just surface water.

- **Lake Assessment Program (LAP).**
  A LAP is a cooperative study of a lake, involving MPCA staff and local citizens, such as a lake association or municipality. The MDNR and Soil and Water Conservation Districts also cooperate on many of the studies. LAP studies characterize a lake's condition and provide some basic information regarding the interaction of the lake and its watershed. A detailed individual report is written for each LAP project. These reports provide valuable information for the local group, the MPCA and others interested in protecting or improving the quality of the lake.

- **Regional and Trend Analysis.**
  The MPCA began a monitoring effort in 1985 to better understand regional patterns in lake conditions. The monitoring was based upon an ecoregion framework developed by the EPA. Most of the work was carried out between 1985 and 1989. More recently, MPCA's monitoring has emphasized trend assessment. Typically, MPCA samples 30 to 50 lakes per year on three or four occasions during the summer months for the purpose of adding to its regional database or for trend assessment. Combining several years of data from CLMP with chemical and biological data provides a good basis for assessing trends. Individual case studies that attempt to explain observed trends in water quality are included as part of this database.

- **Clean Water Partnership Program and Clean Lakes Program.**
  These programs provide matching grants to local units of government to protect and improve lakes, streams and groundwater that are affected by non-point source pollution. The monitoring conducted under the Clean Lakes and Clean Water Partnership projects provides a detailed characterization of in-lake water quality and information to develop a detailed nutrient and water budget for the lake. It also includes a comprehensive assessment of conditions in the lake's watershed.

- **Biological Monitoring Program.**
  http://www.pca.state.mn.us/water/biomonitoring
  The biological monitoring program is responsible for the biological assessment of streams, rivers and wetlands throughout Minnesota. Primary goals are to develop tools for assessment in the form of indexes of biotic integrity (IBIs), and then to apply those tools through condition monitoring, problem investigation monitoring and effectiveness monitoring.

Outdoor Corps

http://www.outdoor-corps.org

The Outdoors Corps program trains students to meet environmental stewardship needs in the community. It trains them in the operation and management of a small business, with services, such as: water quality monitoring, aquatic plant identification and mapping, forest management services, living snow fence design and installation, wildlife surveys and management services and natural history interpretation services. In 2002, the Outdoor Corps provided water quality monitoring services for 10 lake associations. Monitoring services include monitoring for total phosphorus, chlorophyll-*a*, Secchi disk measurements, temperature, dissolved oxygen profiling, exotic species monitoring, algae community analyses and aquatic plant surveys. The Outdoor Corps is made possible through support by the University of Minnesota Extension Service and the Initiative Foundation.

Rivers Council of Minnesota (RCM)

http://www.riversmn.org

RCM is a statewide nonprofit organization that works to help Minnesotans improve, protect and enjoy the state's 92,000 miles of rivers. RCM is committed to building a strong network of River Sentinels – people and organizations that monitor river health and take action to improve and protect the rivers. The three main program areas include: Resources for Rivers (developing tools and resources to support and empower River Sentinels to successfully understand, improve and protect Minnesota rivers); River Voices (building awareness of Minnesota rivers and river conservation through newsletters, website, and presentations); and River Sentinels Network (building and forging strong ties for taking action to improve and protect rivers). RCM works with both citizen groups and local governments to build successful, locally led programs.

River Network

http://www.riverwatch.org

The River Network's mission is to help people understand, protect and restore rivers and their watersheds. The original concept of the River Network was to provide support to the hundreds of grassroots organizations (river guardians) across the country that are working to conserve their local rivers. In 1998, River Watch Network and River Network merged. River Watch provides river activists with tools to measure the health of their river and River Network's programs help activists turn concern and information into action.

Through River Watch, participants learn such things as whether their streams are clean and healthy and how to identify watershed problems and their sources. Through River Protection and Restoration Tools, River Watch helps people learn about techniques, programs and laws to protect and restore their rivers and watersheds. The River Source Information Center has an extensive reference library.

River Watch programs

There are a number of River Watch programs around the state; some programs are not associated with the River Network program or the Izaak Walton League. Here are a few programs:

St. Louis River Watch

http://www.fdl.cc.mn.us/ei/rw/

This program is a river monitoring program for high school students in northeastern Minnesota. The 10-year-old program currently includes 25 schools. It has started to develop a formal QA/QC plan, but for the most part the group's primary goal is youth education and stewardship.

Red River Basin Monitoring Project

wrg@gvtel.net

http://www.ndsu.nodak.edu/tricollege/watershed/

With the support of a Minnesota Board of Water and Soil Resources Challenge Grant, the project began in 1995 with four schools on the Sand Hill River. The program has grown to involve more than 30 schools monitoring more than 100 sites on waterways throughout northwest Minnesota. Monitoring sites are selected in consultation with local watershed district and soil and water conservation district managers to represent different reaches of rivers and tributaries. Schools conduct monthly monitoring of from three to seven sites – generally from April or May through October or November, inclusive of summer months.

Mississippi Headwaters Board (MHB) River Watch

http://www.mhbriverwatch.dst.mn.us

The MHB was formed as an alternative to designation of the river into the National Wild and Scenic River system and works to protect and preserve the first 400 miles of the Mississippi River in Minnesota. It is a joint powers board of the counties of Clearwater, Beltrami, Cass, Itasca, Aitkin, Crow Wing and Morrison and works in conjunction with the Chippewa National Forest and Leech Lake Indian Reservation. It promotes water quality monitoring, education and stewardship activities. The River Watch program was started in 1989 and assesses the health of the Mississippi headwaters through nine indicators of chemical and physical tests.

Sauk River Watershed District

http://www.mnwatershed.org/sauk.htm

The Sauk River Watershed District monitors 17 sites throughout the watershed district, from Osakis on the west to Cold Spring on the east and from Little Birch Lake on the north end to Eden Valley on the south side.

Save Our Streams (SOS)

http://www.izaakwaltonleague.org

SOS is a national watershed education and outreach program developed by the Izaak Walton League (IWL) more than 30 years ago. Individuals and groups adopt a stream and agree to become its guardian for at least one year. Stream adopters check water quality, look for signs of trouble and take action to help resolve the problems. It can be used in the classroom or in youth and civic organizations. The IWL put together an SOS kit that contains survey forms, macroinvertebrate identification cards and a teacher's manual on integrating SOS into the classroom and includes lessons on water monitoring, watershed dynamics and land use planning. The manual comes with IBM- compatible software for managing water monitoring data.

Soil and water conservation districts (SWCDs)

http://www.bwsr.state.mn.us (Board of Soil and Water Resources)

http://www.maswcd.org (Minnesota Association of Soil and Watershed Districts)

Soil and water conservation districts are local units of government that help to manage and direct natural resource programs. They are based upon county lines; 91 soil and water conservation districts exist in the state. A board of five supervisors who are elected in the general state election governs each district. The districts work primarily on a one-on-one basis with landowners and work closely with key partners, such as the Natural Resources Conservation Service and the University of Minnesota Extension Service. The soil and water conservation districts were authorized under Minnesota Statutes Chapter 103C. The Minnesota Association of Soil and Water Conservation Districts provides information on conservation issues, lobbying, policy development, coordination of training for district personnel, convention coordination and conservation education materials.

Each individual SWCD office is involved with monitoring in a variety of ways.

Volunteer Stream Monitoring Partnership (VSMP)

http://www.vsmp.org

VSMP works to support, strengthen and coordinate volunteer stream monitoring throughout the metropolitan area. VSMP offers programs monitoring chemistry, benthic macroinvertebrates, bacteria and physical habitat to assess the health of streams. VSMP has several resources to help volunteers get involved in monitoring at the appropriate level for their project goals, commitment and experience. Monitoring programs can be customized for educational purposes or to meet quality assurance/ quality control checks for data verification. VSMP works with local partners to support and promote volunteer monitoring by providing training; standardized protocols; quality assurance and quality control measures; data management, storage, and analysis; and a network of partners to assist in all types of monitoring.

Watershed districts

http://www.mnwatershed.org (Minnesota Association of Watershed Districts)
http://www.bwsr.state.mn.us (Minnesota Board of Water and Soil Resources)

Watershed districts are local units of governments whose boundaries follow the natural watershed. A Board of Managers that is appointed by the applicable county board of commissioners governs Minnesota's 45 watershed districts. They receive their authority from Minnesota Statutes Chapter 103D. They are authorized to monitor surface waters, wetlands and groundwater; manage drainage systems; establish, record and maintain hydrological data; regulate, conserve and control the use of surface water within the district and other water resource activities. Watershed districts collect data on many lakes and streams within their boundaries. This data is generally available for use by monitoring programs and is frequently shared with other agencies. Watershed districts use data from volunteer monitors to evaluate the need for further monitoring of certain areas. The website identifies watershed district locations. Watershed districts work in partnership with state, local and regional water planning and management activities. The Minnesota Association of Watershed Districts provides administrative, lobbying, convention coordination and district support services.

Many watershed districts have water monitoring programs.

Other monitoring programs

Staff and other professionals conduct monitoring in these programs.

Center for Watershed Protection

http://www.cwp.org

The Center for Watershed Protection provides local governments, activists and watershed organizations around a county in which it is located with technical tools for protecting streams, lakes and rivers. It has developed and disseminated a multi-disciplinary strategy to watershed protection that encompasses watershed planning, watershed restoration, storm water management, watershed research, better site design, education and outreach and watershed training.

Noteworthy resources available:

- **Urban/rural watershed in St. Mary's County in Maryland.**
  Illustrated the use of a field stream assessment and current and future impervious cover as watershed planning tools.

- **Chesapeake Bay Region.**
  Provides technical training to three watershed groups that focus upon protection and restoration skills, rapid stream assessment, delineating subwatersheds, GIS training, storm water retrofitting and watershed education.

- **Rapid Stream Assessment Technique (RSAT).**
  RSAT allows for a simple, rapid reconnaissance-level assessment of stream quality conditions. The RSAT synthesizes USEPA, Izaak Walton League's Save Our Streams, USDA and CWP stream survey techniques.

Land Stewardship Project (LSP)

http://www.landstewardshipproject.org

The LSP was founded in 1982 to foster an ethic of stewardship for farmland, to promote sustainable agriculture and to develop sustainable communities. LSP developed The Monitoring Toolbox with the Minnesota Institute for Sustainable Agriculture, along with its companion video, *Close to the Ground*. The project is known nationally for its unique integration of soil testing, water analysis, quality of life analysis and gauging of finances to create a well-rounded system for measuring the success of a farm. LSP also provides information on aquatic invertebrates, how to select a protocol and how to construct an invertebrate (invert) key.

Minnesota Department of Agriculture (MDA)

http://www.mda.state.mn.us

The MDA is Minnesota's designated state lead agency for the enforcement of federal and state pesticide laws. As part of these responsibilities, the MDA monitors the state's surface and underground waters for the presence of pesticides and pesticide break-down products. Ground water monitoring at the MDA began in 1985 and surface water monitoring started in 1990. Annually in March, the results of pesticide water quality monitoring are published on the MDA web page. The state's pesticide water resources pesticide management plan is the responsibility of the MDA and includes the development, promotion and implementation of best management practices (BMPs) for the protection of the state's water resources. The MDA also collects information on the use of pesticides in the state.

Water Resources Education

Bridges

http://www.bridges.state.mn.us

This website provides direct access to state environmental information.

Cairn and Associates

612-722-5806

Cairn and Associates educates the community through youth stewardship by organizing environmental service projects, storm drain stenciling, erosion prevention, etc. It designs community-based education on water quality, reduction and other issues and assists in creating community-based environmental grants programs.

Among the many resources available on the CGEE website (see below), Cairn and Associates developed a list of "Curricula Supporting Water Quality Projects Aligned with Minnesota Graduation Standards" for primary and secondary grades. It analyzes the following resources: *Environmental Resource Guide*, Project WET, The Water Sourcebook*, Save Our Streams, Aquatic Project Wild and Full Option Science System*. See the CGEE website (below) for more information.*

Center for Global Environmental Education (CGEE)

http://www.cgee.hamline.edu

CGEE provides training and educational resources for K-12 teachers and creates community education initiatives that motivate citizens for environmental leadership. CGEE, WaterShed Partners and Cairn & Associates collaborated on the website.

Noteworthy resources available:

- **The WaterShed Partners.**
  http://cgee.hamline.edu/watershed/Exhibit/TheShed.htm
  A coalition of more than 40 public, private and non-profit organizations in the Twin Cities Metropolitan Area (TCMA) that collaborate on educational outreach. The WaterShed Partners created the WaterShed Exhibit. Its interactive exhibits provide learning opportunities about metropolitan watersheds and the impacts of individual actions. The *WaterShed* is available on loan for events.

- **WaterShed Action.**
  Many service-learning projects are outlined.

- **Water Quality Curricula.**
  Water quality curricula are identified for teachers. A list of curricula is included, such as: "Give Water a Hand," "Water on the Web," etc. There are specific resources identified for monitoring.

- **Pollution Prevention Project Guide.**
  Provides details of several pollution prevention projects including water quality monitoring. An overview of water quality monitoring topics is included such as: choosing a site, types of monitoring, reporting and quality control and lake monitoring resources. A Resource Directory is included.

- **Rivers of Life.**
  An interactive video program that provides projects and resources to help K-12 teachers and students learn about their watershed.

- **Waters to the Sea.**
  These media-rich explorations reveal how humans have changed the rivers of the Upper Mississippi watershed. Three virtual river journeys, led by historic guides, take viewers from prehistoric times up to the present through prairie, deciduous forest and coniferous forest ecoregions. Videos, QuickTime VR movies and engaging multimedia activities examine a variety of land-use themes in each watershed. Visits to a virtual water quality lab correlate land uses with water quality.

Counties

http://www.mncounties.org (Association of Minnesota Counties)
http://www.state.mn.us (Minnesota North Star)
Many counties in the state have strong water resources programs. Some of them, such as Dakota County's Environmental Education program, are coordinated programs. Dakota County has specific information regarding wetland monitoring. See the websites for lists of counties and links to other sites. County water planners are good resources for water monitoring information.

Some counties have chosen to coordinate the management of water resources with other counties through programs and financing and have formed "joint powers boards," such as the Mississippi Headwaters Board (see Volunteer Monitoring Programs).

Dakota County Environmental Education Program

http://www.extension.umn.edu/county/dakota
The Dakota County Environmental Education Program is a coordinated program between the Dakota County Soil and Watershed District, Office of Planning, Department of Environmental Management and the University of Minnesota Extension Service, Dakota County. The goal of the program is to promote consistent messages countywide about water resources protection. It sponsors the River Watch program in the Vermillion River and coordinates student monitoring of local lakes, streams and rivers.

Fortin Consulting Inc.

763-478-3606
FCI's mission is to provide project design and coordination that will unite citizens, environmental organizations and industry in the common goal of improving rivers, lakes and wetlands. FCI works with private individuals and companies, watershed management organizations, lake associations, schools and governmental agencies to provide environmental education, project management and implementation, surface water and wetland monitoring and landscape design and planting.

Friends of the Minnesota Valley

952-888-0706
The Friends' mission is to support conservation and management of the natural and cultural resources of the Lower Minnesota River Watershed and promote environmental awareness. The Friends created the Minnesota River Watershed Initiative to develop an integrated, long-term sustainable communities conservation effort. They are collaborating with local, state and federal agencies, businesses, educators and community groups on this effort. The Friends work closely with the Minnesota Valley National Wildlife Refuge to accomplish their goals of stewardship, biological monitoring and education. Other programs include the Heritage Registry, Corporate Partners for Conservation and the Blufftop Bookshop.

Friends of the Mississippi River (FMR)

http://www.fmr.org
Through active leadership and education, FMR seeks to preserve and restore the river's fish and wildlife, its vital floodplains and scenic bluffs and its natural and cultural treasures. FMR provides support for the Volunteer Stream Monitoring Partnership and the Shoreland Buffers Pilot Program. It developed a "Landscaping for Water Quality Workshop" for urban residents and conducts storm drain stenciling. With funding from the Metropolitan Council, FMR works with landowners along the Vermillion River to improve the quality of their riverfront land through the installation of vegetative buffers that reduce erosion and runoff, filter out nutrients and improve the health of the river.

Minnesota Audubon

http://www.audubon.org/chapter/mn/mn/wetlands.html
Minnesota Audubon has three programs to protect wetlands: advocating for strong wetland laws, wetland and watershed restoration and neighborhood protection of wetlands. The American Rivers Project provides water quality education such as an in-stream flow restoration toolkit.

Minnesota Board of Water and Soil Resources (BWSR)

http://www.bwsr.state.mn.us

BWSR is the state's administrative agency for 91 soil and water conservation districts, 43 watershed districts, 27 metropolitan watersheds and 80 county water management organizations. In partnership with the University of Minnesota Extension, BWSR supports local governments, conservation organizations and BWSR staff in:

- Developing education strategies that assist offices, agencies and organizations in reaching water and soil resources goals
- Designing and implementing education events
- Designing and producing educational materials
- Evaluating the effectiveness of educational efforts

Minnesota Environmental Partnership (MEP)

http://www.mepartnership.org

MEP is a coalition of local and statewide nonprofit organizations. A list of all the partners is included on the website. "Healthy Waters," a multi-year commitment by MEP, includes a collaborative initiative to improve public policies, as well as education and outreach efforts. In 2002, MEP organizations successfully urged the State Legislature to pass the nation's first phosphorus-free lawn fertilizer law and assisted in the passage of legislation for developing a guidance manual and training for volunteer water monitoring.

Minnesota North Star

http://www.state.mn.us

Official website of the State of Minnesota. Especially helpful for "Environment" and "Government" information.

Minnesota Office of Environmental Assistance (MOEA)

http://www.moea.state.mn.us

MOEA is a non-regulatory agency that works to improve the environment through partnerships, technology transfer, technical assistance, education, research and matching grants.

Noteworthy resources available:

- **Green Print for Minnesota: The State Plan for Environmental Education.**
  Offers guidance to individuals, organizations and agencies that deliver or support environmental education in Minnesota.
- **Education Clearinghouse.**
  Provides curricula, training and listing of environmental books for students, including videos and other resources. Central location provides materials free or on loan. Provides an extensive library of videos, such as: Mississippi Headwaters River Watch (how to help monitor), *1997 Environmental Education Teacher Preparation Project* (implementation of environmental education in classrooms), *50 Simple Things Kids Can Do to Save the Earth* (Part 1: Water and Resources), etc.
- **Source Index.**
  Provides an extensive listing of resources locally and around the country.

Natural Resources Conservation Service (NRCS)

http://www.nrcs.usda.gov and http://www.mn.nrcs.usda.gov

NRCS assists private landowners with conserving their soil, water and other natural resources and provides technical assistance to local, state and federal agencies. NRCS primarily works with local partnerships to help people conserve, maintain and improve natural resources and the environment and is a program of the United States Department of Agriculture. The Environmental Quality Incentives Program (EQIP) was established in the 1996 Farm Bill and provides technical, financial and educational assistance to farmers and ranchers who face serious threats to soil, water and related natural resources.

Seek

http://www.seek.state.mn.us

Website provides a directory of environmental education resources.

Water Laws

http://www.waterlaws.com

This is an interactive water resources journal of water law, policy and commentary that is sponsored by the Water Resources Group of Smith Parker P.L.L.P.

Water Resources Center (WRC)

http://wrc.coafes.umn.edu/index.html

WRC is a multifaceted center with active programs in research, outreach and education. It coordinates volunteer programs that provide opportunities for citizens to learn about, monitor and restore local water bodies, such as Shoreland Volunteers.

Shoreland Volunteers serves as a resource to communities by answering questions about lakes and rivers, monitoring water quality and restoring shorelines. It leads community action projects and gets involved in local land-use decision-making.

Wetland Health Education Program (WHEP)

http://www.extension.umn.edu/county/dakota/Environment/wetlands/wetld.html
http://www.mnwhep.org
WHEP uses trained, volunteer "citizen biologists" to collect macroinvertebrate and vegetation measures from selected wetlands to measure the relative health of the wetland. Using an "index of biotic integrity" (IBI) developed by the MPCA, WHEP teams follow a simplified protocol used by professionals in the field. The IBI uses counts of macroinvertebrates (bugs, crustaceans, leeches, etc.) to come up with a single score. It relies on detecting critters or plants that are sensitive to pollution (or not) or an overabundance of pollution-tolerant species. WHEP is conducted in both Dakota and Hennepin counties.

University of Minnesota Extension Service

http://www.extension.umn.edu
The University of Minnesota Extension Service offers a broad array of water quality programming and materials dealing with issues of water quality, safe drinking water, septic systems and the rehabilitation of the Minnesota River. The Extension Water Quality Program is an outreach arm of the Water Resources Center. The White Earth Reservation Science and Math Summer Program provide a natural resources curriculum that includes water quality monitoring.

United States Geological Survey (USGS)

http://water.usgs.gov
The USGS investigates the occurrence, quantity, quality, distribution and movement of surface and underground waters and disseminates the data to the public, state and local governments, public and private utilities and other federal agencies involved with managing water resources.

The USGS has collected water resources data at approximately 1.5 million sites across the United States, Puerto Rico and Guam. The types of data collected are varied but generally fit into the broad categories of surface water and groundwater. Water quality data are available for both. The NWISWeb provides current and historical data (***http://waterdata.usgs.gov/nwis***). Data can be retrieved by category and by geographic area.

Professional Organizations

Following are some professional organizations for individuals within the water resources field:

North American Lake Management Society

http://www.nalms.org
NALMS has a number of programs that are designed to improve the quality and management of lakes and reservoirs, such as "science and management" that presents research and management studies, peer review, public policy updates and initiatives, emerging lake issues identification and chapter grassroots advocacy.

Society for Ecological Restoration International (SER)

http://www.ser.org
SER is a nonprofit organization of scientists, planners, administrators, ecological consultants, first peoples, landscape architects, teachers, engineers, natural area managers, volunteers and others. Its mission is to "promote ecological restoration as a means of sustaining the diversity of life on Earth and re-establishing an ecologically healthy relationship between nature and culture."

Water Environment Federation (WEF)

http://www.wef.org
http://www.cswea.org
WEF was created more than 75 years ago to continually assess and study the quality of our global water environment by commissioning studies about the sources and causes of pollution, examining each new water treatment procedure and educating the general public and water quality professionals on new techniques and solutions. Water quality focus areas for WEF include: watershed management, wastewater, industrial wastewater and biosolids. The regional chapter, The Central States Water Environment Federation (CSWEA) provides a Water Environment Federation (WEF) organization for Illinois, Minnesota and Wisconsin and offers multiple opportunities for the exchange of water quality knowledge and experiences among its members and the public.

Appendix B:

Considerations for selecting and using a contract laboratory

The following is list of things to consider when choosing and using a laboratory. Not all of the items in the following table need to be considered for all projects; it depends on your purpose and anticipated data uses.

Laboratory considerations

Bottles and preservatives	Ask if they will provide appropriate bottle types with preservatives.
Cost	Consider cost not only of the sample analyses, but also of shipping. Tell them the number of samples you anticipate. You may be able to get a better price for large orders.
Certification	You may want to require that the laboratory be certified with the Minnesota Department of Health. See *www.health.state.mn.us/divs/phl/cert.html* for a list of certified laboratories, or you may want to ask for a copy of their certificate.
Chain of custody	If chain of custody is important for your monitoring purpose, ask for a description of their chain of custody procedures and copies of their chain of custody forms.
Consistency	If you have a long-term project, consider a laboratory you know will be around for the length of the project. Staying with the same laboratory for the duration of the project will help minimize variability between laboratories/analysts.
Delivery and shipping	Ask if they have a delivery service and whether or not this cost is included in the cost per sample analysis. Some labs allow sample drop-off to satellite locations, which avoids shipping costs.
Detection limits	Make sure that the laboratory can achieve the detection limits you need for your project. Ask if they have the necessary equipment to achieve these limits.
Hours of operation	Make sure the laboratory will be able to receive samples at the times you anticipate collecting and be able to complete analyses within specified holding times.
Methods	Specify the methods you want used. Ask if the laboratory has experience with these methods and if they have Standard Operating Procedures already prepared for these methods. If so, you may want to ask for copies.
QA/QC	Ask for a copy of the laboratory's Quality Assurance/Quality Control Manual. Check to make sure that the laboratory's data quality objectives are consistent with your project objectives and needs.
Reporting	Tell them in what format you want the results reported (i.e., paper report, electronic). Ask them to include results of laboratory QA/QC efforts for precision and accuracy and to note if data quality objectives were met in the reports.

Appendix C:

Summary matrix of existing manuals (not all-inclusive)

Existing manuals

Minnesota manuals

Guide to Volunteer Monitoring
Minnesota Lake and Watershed Data Collection Manual
Handbook for Citizen-Assisted Lake Monitoring Program (CAMP)
Minnesota's Citizen Lake Monitoring Program (CLMP) Handbook
Training Program for CLMP+: Expanding Minnesota's CLMP Program
Citizen Stream-Monitoring Program Instructions
Sustainable Lakes Planning Workbook
A Citizen's Guide to Biological Assessment of Wetlands
River Monitors Manual

Federal manuals

National Field Manual for the Collection of Water-Quality Data
Volunteer Lake Monitoring, A Methods Manual
Volunteer Stream Monitoring, A Methods Manual
Volunteer Wetland Monitoring: An Introduction and Resource Guide
Starting Out in Volunteer Water Monitoring
The Volunteer Monitor's Guide to Quality Assurance Project Plans

National non-profit manuals

River Monitoring Study Design Workbook
Testing the Waters: Chemical and Physical Vital Signs of a River
Living Waters: Using Benthic Macroinvertebrates and Habitat to Assess Your River's Health

Other states' manuals

A Citizen's Guide to Understanding and Monitoring Lakes and Streams
Virginia Citizen Monitor's Methods Manual
Texas Watch Monitoring Plan Guide
Volunteer Stream Monitoring Training Manual
Designing Your Monitoring Program: A Technical Handbook for Community-Based Monitoring In Pennsylvania

Minnesota manuals

TITLE	TARGET USERS / GEOGRAPHIC AREA	QA/QC	DATA MANAGEMENT	MEDIA	DATA USES	METHODS	STUDY DESIGN/ PROCESS
Guide to Volunteer Monitoring 2002, by Volunteer Stream Monitoring Partnership (VSMP) **http://www.vsmp.org**	Volunteers in the VSMP program / Twin Cities Metro Area	Emphasizes importance of QA/QC and i.d.'s necessity of QA for the intended use and inclusion in VSMP database; includes some QA protocols; mainly refers to other manuals	Discusses how to use data collected for each activity; does not cover data mgmt.; VSMP intends to keep a central database	■ Streams ■ Physical, Chemical, Biological	■ Awareness and education ■ Condition / trend ■ Problem investigation	Describes activities, general methods and data collection Refers to other manuals for details	Discusses importance of determining why, what, where, when, who and how to monitor; suggests contacting a VSMP coordinator or local resource professional for help
Minnesota Lake and Watershed Data Collection Manual 1994, Lakes Task Force (EQB); written by several agencies **http://www.shorelandmanagement.org/depth/index.html**	State, county, lake associations, consultants (broad audience) / Statewide	Some discussion of lab considerations – detection limits and field techniques	Discusses how to analyze, chart and present data; has various tables to assist reporting	■ Lakes, Stream loading ■ Chemical, Biological	■ Awareness and education ■ Condition / trend ■ Problem investigation ■ Local decision-making	Detailed methods for sampling, analysis and data presentation; integration of lake and watershed data; collecting societal and development data	Discusses proper collection techniques, useful appendices, how to use data
Handbook for Citizen-Assisted Lake Monitoring Program (CAMP) 2001, Metropolitan Council **http://www.metrocouncil.org/environment/RiversLakes/Lakes/campLakes2001.htm**	CAMP volunteers / Twin Cities Metro Area	Brief mention of QA/QC, which is handled by the Met Council's analytical lab	Data management is handled by Met Council; data is entered into MPCA Water Quality Database	■ Lakes ■ Physical, Chemical	■ Awareness and education ■ Condition / trend ■ Local decision-making ■ Impaired waters assessment and listing	Provides detailed descriptions of general methods and data collection	Gives detailed background into how methods were selected, discusses why program was formed

TITLE	TARGET USERS / GEOGRAPHIC AREA	QA/QC	DATA MANAGEMENT	MEDIA	DATA USES	METHODS	STUDY DESIGN/ PROCESS
Minnesota's Citizen Lake Monitoring Program (CLMP) Handbook 2000, MPCA **http://www.pca.state.mn.us/water/pubs/clmp-handbook.pdf**	CLMP Volunteers / Statewide	Addresses QA/QC issues	MPCA Water Quality Database	■ Lakes ■ Physical	■ Awareness and education ■ Condition / trend ■ Problem investigation ■ Local decision-making ■ Statewide decision-making ■ Impaired waters assessment and listing	Provides standard operating procedures for the CLMP; includes SOPs for the program	NA
Training Program for CLMP+: Expanding Minnesota's CLMP Program 2002, MPCA **http://www.pca.state.mn.us/publications/clmp/clmp-trainingmanual.pdf**	Volunteers in the CLMP Program / Statewide	Addresses QA/QC issues	MPCA Water Quality Database	■ Lakes ■ Physical, Chemical	■ Awareness and education ■ Condition / trend ■ Problem investigation ■ Local decision-making ■ Statewide decision-making ■ Impaired waters assessment and listing	Provides standard operating procedures for the CLMP Plus; includes SOPs for the specific program	NA
Citizen Stream-Monitoring Program Instructions 2002, MPCA Available from MPCA	Volunteers in CSMP (individuals, school groups, watershed groups like CWP, county networks) / Statewide	Incorporated into program	Done by MPCA – no information included in document	■ Perennial streams ■ Physical	■ Awareness and education ■ Condition / trend ■ Problem investigation ■ Local decision-making ■ Statewide decision-making ■ Impaired waters assessment and listing	Provides standard operating procedures for the CSMP; includes SOPs for the specific program	Briefly discusses when & where to sample; add'l background and process info. provided in intro. to annual reports

TITLE	TARGET USERS / GEOGRAPHIC AREA	QA/QC	DATA MANAGEMENT	MEDIA	DATA USES	METHODS	STUDY DESIGN/ PROCESS
Sustainable Lakes Planning Workbook 2000, Minnesota Lakes Association **http://mnlakes.org/ main_dev/workbook. cfm**	Lake associations, community planners working with water resource mgmt. agencies / Statewide	Provides program contacts, rather than specific methods QA/QC guidance; Appendix D is a guide for data analysis and assessment and it offers guidance for data management QC	NA	■ Lakes ■ Physical, Chemical, Biological	■ Awareness and education ■ Condition / trend ■ Local decision-making ■ Impaired waters assessment and listing	Community organizing, effective use of agency resources, geophysical landscape measures, in-lake physical-chemical-trophic state measures and data analysis	Provides complete context for long term, multifaceted lake watershed planning; includes uses of water clarity and geophysical data in this process, as well as MN-specific programs & resources
A Citizen's Guide to Biological Assessment of Wetlands 2002, MPCA Available from MPCA	Citizens interested in biological assessment of wetlands; developed for Wetland Health Evaluation Project-WHEP / MN depressional wetlands	QA/QC issues not specifically addressed; WHEP uses a Twin Cities consulting firm to provide QA/QC	Not addressed in guide; data generated by WHEP is managed by the contract consulting firm	■ Wetlands ■ Biological	■ Awareness and education ■ Condition / trend ■ Problem investigation ■ Local decision-making	Provides detailed descriptions of how to collect & analyze a wetland invertebrate sample and how to generate an assessment score	Discusses when and where to sample; addresses the importance of using biological data for wetland assessment; gives brief background into IBIs and biological indicators
River Monitors Manual Mississippi Headwaters Board/Rivers Council of Minnesota, 1997 Available from the Rivers Council of Minnesota 320-259-6800	Citizens interested in understanding and monitoring the health of a river or stream / Minnesota rivers and streams	Explains concepts and methods for various parameters; also references other manuals (mainly River Watch manuals)	Not much on management (some info. on spreadsheets); does cover reporting and interpreting results	■ Streams ■ Physical, Chemical, Biological	■ Awareness and education ■ Condition / trend ■ Problem investigation ■ Local decision-making ■ Statewide decision-making	Provides detailed methods for physical, chemical and biological monitoring of rivers; in some cases descriptions reference River Network manuals for specific details	Teaches the basic concepts of river ecology, fundamentals of monitoring river water quality, how to interpret results and take actions to protect your river; helps volunteers choose the level of monitoring that is appropriate for the resources they have available

Federal manuals

TITLE	TARGET USERS / GEOGRAPHIC AREA	QA/QC	DATA MANAGEMENT	MEDIA	DATA USES	METHODS	STUDY DESIGN/ PROCESS
National Field Manual for the Collection of Water-Quality Data 1998, USGS **http://water.usgs.gov/owq/pubs.html**	USGS Field Personnel / United States	Provides USGS organizational structure supporting QA aspects for USGS water programs and constitutes SOPs for USGS	NA	■ Surface and ground waters ■ Physical, Chemical, Biological	■ Awareness and education ■ Condition / trend ■ Problem investigation ■ Local decision-making ■ Statewide decision-making ■ Impaired waters assessment and listing ■ Regulatory action	Provides USGS SOPs for water & sediment sampling, selected field physical-chemical meas., and bacteria counts; other books address other SOPs such as lab methods	Provides individual SOPs for elements of a study; does not address overall study design
Volunteer Lake Monitoring, A Methods Manual 1991, US EPA **http://www.epa.gov/owow/monitoring/lakevm.html**	Volunteers and organizers of volunteer monitors / United States	QA concepts and elements are described	NA	■ Lakes ■ Physical, Chemical, Biological	■ Condition / trend ■ Local decision-making	Sampling algae, aquatic plants, sediment and bacteria and meas. DO	Conventional description of planning process based on QA principles; detailed, but general guidance for program development
Volunteer Stream Monitoring, A Methods Manual 1997, US EPA **http://www.epa.gov/owow/monitoring/volunteer/stream/**	Volunteer monitoring program mgrs / United States	QA concepts and elements are described; additional details for physical-chemical meas.	Provides technical advice for good organization and QA	■ Streams and watershed ■ Physical, Chemical, Biological	■ Awareness and education ■ Condition / trend ■ Problem investigation ■ Local decision-making ■ Statewide decision-making ■ Impaired waters assessment and listing ■ Regulatory action	Watershed survey, macroinvert. & habitat assessment, in-stream water physical-chemical meas.; data mgmt. & analysis	Conventional description of planning process based on QA principles; detailed, but general guidance for program development

TITLE	TARGET USERS / GEOGRAPHIC AREA	QA/QC	DATA MANAGEMENT	MEDIA	DATA USES	METHODS	STUDY DESIGN/ PROCESS
Volunteer Wetland Monitoring: An Introduction and Resource Guide 2000, US EPA ***http://www.epa.gov/owow/wetlands/monitor/volmonitor.html***	Citizens and organizations interested in wetland monitoring / U.S.	The importance of having a quality QAPP is heavily emphasized; QA/QC procedures are not specifically addressed	Discusses the importance of good data management	■ Wetlands ■ Physical, Chemical, Biological	■ NA	References methods manuals; does not give detailed methods; more of a process document; does a very good job of outlining why/how to effectively implement wetland volunteer monitoring	Discusses the process for designing a wetland study; addresses key issues such as target audience, data quality, and data objectives
Starting Out in Volunteer Water Monitoring 1998, US EPA ***http://www.epa.gov/owow/monitoring/volunteer/startmon.html***	Volunteers and organizers of volunteer monitors / U.S.	NA	NA	■ Surface waters ■ NA	■ NA	4-page factsheet offering first-step guidance for individuals interested in beginning a monitoring effort	Guide to planning a volunteer monitoring effort, with references to helpful EPA guidance
The Volunteer Monitor's Guide to Quality Assurance Project Plans 1996, US EPA ***http://www.epa.gov/owow/monitoring/volunteer/qappcovr.htm***	Volunteer monitoring program planners / U.S.	Complete and technical guidance for quality assurance design	Addresses QA considerations for data management	■ Surface and ground waters ■ NA	Useful to all: ■ Awareness and education ■ Condition / trend ■ Problem investigation ■ Local decision-making ■ Statewide decision-making ■ Impaired waters assessment and listing ■ Regulatory action	NA	Detailed guidance for QA in program development; the QA concept encompasses all aspects, including successful design and reporting

National non-profit manuals

TITLE	TARGET USERS / GEOGRAPHIC AREA	QA/QC	DATA MANAGEMENT	MEDIA	DATA USES	METHODS	STUDY DESIGN/ PROCESS
River Monitoring Study Design Workbook River Network Available from River Network at **http://www.rivernetwork.org/marketplace/category.cfm?Category=25**	Volunteer monitoring program planners / U.S.	Covers how to set up a quality assurance program	Not included	■ Streams ■ Physical, Chemical, Biological	■ NA	Does not include specific monitoring methods; focus is on how to design a monitoring effort	Discusses the process for designing a stream monitoring effort, including determining the purposes of the monitoring program; selecting appropriate water quality indicators, methods and sites; deciding who to involve and setting a schedule
Testing the Waters: Chemical and Physical Vital Signs of a River River Network Available from River Network at **http://www.rivernetwork.org/marketplace/category.cfm?Category=25**	High school teachers and community groups interested in volunteer monitoring of stream water chemistry and physical characteristics / U.S.	NA	Some discussion of how to manage data that is generated	■ Streams ■ Physical, Chemical	■ NA	Each indicator chapter (physical survey, temperature, turbidity, dissolved oxygen, pH, alkalinity, phosphate, nitrate and conductivity) has background information and measurement procedures	Covers nine water quality indicators, information needed to design a study and deal with the data once it's carried out, and how to use the information to take action
Living Waters: Using Benthic Macroinvertebrates and Habitat to Assess Your River's Health River Network Available from River Network at **http://www.rivernetwork.org/marketplace/category.cfm?Category=25**	Citizens interested in volunteer monitoring of stream water biology and habitat / U.S.	NA	NA	■ Streams ■ Biological		Describes four options for monitoring benthic macroinvertebrates, the detailed procedures for each option and how to interpret and present results	Describes how to design and carry out a river study using benthic macroinvertebrates; includes background information about macroinvertebrates and the role they play in the river ecosystem

Other states' manuals

TITLE	TARGET USERS / GEOGRAPHIC AREA	QA/QC	DATA MANAGEMENT	MEDIA	DATA USES	METHODS	STUDY DESIGN/ PROCESS
A Citizen's Guide to Understanding and Monitoring Lakes and Streams 1991, Washington Department of Ecology	Citizens / Puget Sound area (could be applied broadly)	Discusses the importance of QA/QC; describes what good QA/QC is, defines common QA/QC terms, and describes how to implement a QA/QC plan	Does not directly address data management	■ Lakes, streams ■ Physical, Chemical	■ Awareness and education ■ Condition / trend ■ Problem investigation ■ Local decision-making ■ Statewide decision-making ■ Impaired waters assessment and listing	Gives detailed methods for collecting a variety of water quality sample parameters	Addresses many aspects of study design and process; details who, why, what, when, where, how; very good background into why various WQ parameters are used, natural variation, & expected pollution impacts
Virginia Citizen Monitor's Methods Manual 1999, Virginia DEQ ***http://www.deq.state.va.us/cmonitor/manual.html***	Citizen volunteers / Virginia (could be applied broadly)	Provides a boilerplate QA/QC plan; discusses different levels of QC for different objectives; defines QA/QC terms	Discusses the need for good data management; details not provided	■ Streams ■ Physical, Chemical, Biological	■ Awareness and education ■ Condition / trend ■ Problem investigation ■ Local decision-making ■ Statewide decision-making ■ Impaired waters assessment and listing	Provides detailed methods for all sampling methods recommended	Good intro. section on developing a monitoring plan; primarily a methods manual rather than a process manual
Texas Watch Monitoring Plan Guide Texas Watch, San Marcos, TX 78666 ***http://www.texaswatch.geo.swt.edu/formsx.htm***	Volunteers in the Texas Watch program / Texas	Indicates that QA/QC is important, but provides no detailed protocol; discusses the need for a QA officer and defines officer duties	Discusses the need for a data coordinator	■ Surface waters ■ Physical, Chemical	■ Awareness and education ■ Condition / trend ■ Problem investigation ■ Local decision-making	Methods not detailed; manual is intended to be used with add.'l Texas Watch material & is just a brief intro. to its program	Discusses process for setting up a monitoring program using its resources

TITLE	TARGET USERS / GEOGRAPHIC AREA	QA/QC	DATA MANAGEMENT	MEDIA	DATA USES	METHODS	STUDY DESIGN/ PROCESS
Volunteer Stream Monitoring Training Manual 2000, Indiana DNR RiverWatch ***http://www.in.gov/dnr/soilcons/riverwatch/vsm/manual.html***	RiverWatch volunteers / Indiana (could be applied broadly)	Emphasizes the need for good QA/QC; gives a decent outline of steps to be followed for different levels of QA/QC based on monitoring objectives	Indiana DNR Riverwatch program provides data mgmt. tool (an online, data entry program).	■ Streams ■ Physical, Chemical, Biological	■ Awareness and education ■ Condition / trend ■ Problem investigation ■ Local decision-making	Provides detailed methods for all recommended sampling methods	Includes a chapter devoted to study design
Designing Your Monitoring Program: A Technical Handbook for Community-Based Monitoring In Pennsylvania Pennsylvania Citizens' Volunteer Monitoring Program, Pennsylvania DEP, 2001. ***http://www.dep.state.pa.us/dep/deputate/watermgt/wc/subjects/CVMP/cvmp_HdBook.htm***	Volunteer monitors / Pennsylvania	Discusses need for good QA/QC; includes table that defines QC measures and recommends QC measures for various monitoring uses	Includes discussion of data mgmt; need to plan for this up-front as part of study design	■ Lakes, streams, ground water, watershed ■ Physical, Chemical, Biological	■ Awareness and education ■ Condition / trend ■ Problem investigation ■ Local decision-making ■ Statewide decision-making ■ Impaired waters assessment and listing	Breaks uses down, then includes list of what, why, when, where, how often (etc.); monitoring options (including examples of methods), and sources of further information by use	Key/ integral part of the manual

*The MPCA is working towards the use of CLMP monitoring in 305(b) assessments and 303(d) listing.

Appendix D:

Monitoring requirements
for MPCA 305(b) and 303(d) assessments

I. Introduction
II. Background: 305(b) and 303(d)
III. Assessment basics
- A. Rivers and streams
- B. Lakes
- C. Parameters

IV. Data requirements for assessments
V. Developing and implementing a monitoring plan for Clean Water Act assessments
- A. Location
- B. Analytical methods
- C. Water sampling methods
  - 1. Sampling for conventional pollutants and nutrients
    - a. Field Meters
    - b. Grab Sampling
      - i. Bottle and equipment preparation
      - ii. Sampling lakes
      - iii. Sampling rivers and streams
      - iv. Sample preservation and transport
  - 2. Bacteria Sampling (fecal coliform and E. coli)
- D. Biological sampling methods
  - 1. Wetlands
  - 2. Rivers and streams
    - a. Fish
    - b. Invertebrates
    - c. Laboratory sample processing
- E. QA/QC requirements
  - 1. Field quality control checks
  - 2. Lab quality control checks
  - 3. QA/QC reporting
  - 4. Data submittal

VI. Resources

I. Introduction

Many volunteer monitoring groups are interested in having the data they collect used by the MPCA for assessing water quality. To use this data in its formal assessments, you must meet certain requirements to ensure the data are accurate, precise, complete and representative of the environmental conditions. This appendix identifies the requirements for data to be used by the MPCA in 305(b) and 303(d) assessments.

The scope of this document includes monitoring methods and data requirements for assessing surface waters for the following pollutants (or "parameters"):

Pollutant category	Parameters
Those with toxicity-based standards	Un-ionized ammonia, chloride
Conventional pollutants and water quality characteristics	Dissolved oxygen, pH, turbidity (TSS can be used as a surrogate), temperature
Bacteria in surface waters	Fecal coliform bacteria, *E. coli* bacteria (in the future)
Eutrophication of lakes (effects of excess nutrients)	Total phosphorus, chlorophyll-*a,* Secchi disk transparency
Impairment of the biological community	Various metrics related to the health of the stream community, used to calculate an Index of Biotic Integrity
Supporting water quality data (These support and verify assessments based on the parameters listed above.)	Total suspended solids (TSS), total Kjeldahl nitrogen, nitrite-nitrate nitrogen, conductivity, 5-day biochemical oxygen demand, alkalinity

This document will not address the methods or requirements for sampling metals or organic pollutants (other than mentioning them in passing), as these requirements are more complicated than for the other pollutants. This does not mean that you cannot monitor for metals or organics; the MPCA simply suggests that groups interested in this sort of monitoring meet with MPCA staff to discuss the associated requirements and expectations in depth.
Also note that this Appendix will not cover flow monitoring. While flow-monitoring data is used as supplemental data to assessments, it is not required. Because flow monitoring can be complicated, if you are interested in flow monitoring, contact MPCA staff for in-depth information on setting up and maintaining a flow-monitoring station.

This Appendix will not cover wetland monitoring, since the MPCA does not currently assess wetlands under 305(b) or list wetlands on the 303(d) list of impaired waters. The MPCA is investigating including wetland assessments in the future. If the MPCA begins to assess wetlands, we will revise this Appendix to include those methods and data needs.

If you follow the requirements identified here, you can be assured that the data you collect, that meets quality assurance requirements, will be used by the MPCA for water quality assessments. This does not guarantee a specific outcome of the assessment. For example, in some cases, even though minimum data requirements are met, there may not be sufficient data available to complete a reliable assessment due to high variability or lack of representative data.

The MPCA uses all available data that meets quality assurance requirements, and also employs professional judgment as a formal step in the assessment process. Professionals include the people who take samples and measurements in the field and the biologists, hydrologists and statisticians who analyze the data. A professional review of available data can extract the most value from small data sets.

Note also that a major aspect of monitoring the MPCA must consider when reviewing data for use in assessments is the *purpose* for which the data were collected. For example, samples collected to characterize "events" such as the effects of storm runoff on a river may not be suitable, if used alone, to characterize the overall water quality of the river. It is important that data be used and interpreted correctly; the professional review process helps ensure that this happens.

Finally, someone who can represent the organization that collected the data will need to be involved in the professional review process. To appropriately interpret the data, in addition to the purpose for which data were collected, the MPCA will consider timing and magnitude of exceedances, seasonality of exceedances, flow regime, knowledge of naturally occurring conditions and known point and non-point influences in the watershed.

II. Background – 305(b) and 303(d)

The federal Clean Water Act (CWA) requires states to assess their water resources to determine if they meet designated beneficial uses. "Beneficial uses" refer to desirable uses that a lake or stream should support, such as domestic consumption, aquatic life, recreation (swimming), agriculture and wildlife, industrial consumption and aesthetics.

To determine the level of use support, the MPCA assesses monitoring data to determine if the lake or stream meets water-quality standards developed to protect the designated use in question. If sufficient data are available to make an assessment, the lake or stream is then categorized as one of the following levels:

- Fully supporting
- Partially supporting
- Not supporting

A lake or stream assessed as "fully supporting" is considered to be non-impaired, while one assessed as "partially supporting" or "not supporting" is considered impaired. In some cases, a "partially supporting" assessment triggers further analysis of the lake or stream before the MPCA determines if it is impaired or not.

The difference between a use-support assessment and a determination of impairment reflects two related elements of the CWA. Section 305(b) requires states to develop a biennial report to Congress that identifies the use-support status of all surface waters statewide. Section 303(d) requires states to identify and list impaired waters. Therefore, the purpose of the 305(b) report is to convey the use-support *status* of all surface waters statewide, while the purpose of the 303(d) list is to *identify impaired water bodies* for which a plan will be developed to remedy the pollution problem(s). Based on these distinctions, when water bodies do not meet water quality standards the term "non-support" is associated with the 305(b) report and the term "impaired" with the 303(d) list.

While Sections 305(b) and 303(d) are related, in some cases the data requirements for use-support assessments differ from the requirements for identifying/listing impaired waters and delisting those waters once they have improved. To help clarify these differences, the MPCA recently completed a guidance document detailing the relationship between the 305(b) report and the 303(d) list and their associated data requirements (see *Guidance Manual for Assessing the Quality of Minnesota Surface Waters: For the Determination of Impairment,* MPCA, January 2003; available on-line at ***http://www.pca.state.mn.us/publications/manuals/tmdl-guidancemanual.pdf***). This appendix excerpts some of the information from the Assessment Guidance and also includes information about monitoring procedures that is not found in the Assessment Guidance.

You should be aware that the United States Environmental Protection Agency (USEPA) is changing to Integrated Assessment Reporting for 305(b) and 303(d) so there will be no distinction between what is reported to EPA for these two programs. This is called Integrated Assessment Reporting. For its own purposes, however, the MPCA will continue to recognize the importance of completing screening-level use-support assessments for lakes using fewer data points than would be required for TMDL listing. The MPCA will also retain the distinction between "partially supporting" and "not supporting" as different levels of impairment.

III. Assessment basics

River and stream assessments are generally assessed based on the water's ability to support aquatic life and allow for safe swimming. "Aquatic life" assessments are based on conventional pollutants, toxic pollutants and biological community impairment. "Swimmable use" assessments are based on fecal coliform bacteria data. River and stream assessments in Minnesota are determined for river "reaches," which are typically less than 20 miles long and extend from one tributary to another.

Lake assessments are based primarily on the trophic, or nutrient enrichment, status of the lake and its relation to the ability of the lake to support primarily swimming and aesthetics. Lake assessments are based on summer Secchi transparency, total phosphorus, and chlorophyll-*a* combined with ecosystem expectations based on measurements from similar lakes. Lake assessments are generally completed for an entire lake. Assessments are also completed for streams and lakes based on fish consumption advice.

IV. Data requirements for assessment

MPCA requirements for assessment monitoring involve three general categories:

- *How much* monitoring data are needed to complete an assessment
- *How* the sampling and laboratory analysis must be conducted
- *What* quality assurances and quality control practices must be followed and documented to assure the MPCA and its stakeholders that the data is credible and its use for assessment purposes is appropriate

Table 1 identifies the quantity and timeliness requirements for assessment data and supporting water quality data. Section V then identifies the methods to follow when sampling for assessment purposes and the quality assurance and quality control requirements for assessment monitoring.

Note that while Table 1 lists the *minimum data requirements* for a water body to be considered for assessment, this is often not *enough* for an assessment to be completed. It is critical that the data used in an assessment be representative of the quality of the water body in question. To achieve this, measurements must be taken in various seasons, flow conditions, etc. This is difficult to accomplish if the monitoring effort is designed to gather minimum measurements (since it is not uncommon to miss a sampling date or two due to weather, equipment problems, lab issues, etc.).

Because of this, the MPCA designs its monitoring efforts with a target of acquiring four times the minimum number of values. This helps ensure the data are representative of the water body and that an assessment can be reliably completed. You should also design your monitoring effort to go beyond the minimum requirements.

V. Developing and implementing a monitoring plan for CWA assessments

As indicated earlier, for the MPCA to use data in CWA assessments, it is critical that the monitoring is designed to meet the 305(b) and 303(d) requirements. These requirements help ensure that the data are accurate, precise, complete and representative of the environmental conditions. The first step in fulfilling these requirements is to carefully plan out your monitoring effort, following the guidelines identified in this Appendix.

If you are interested in having your data used by the MPCA for assessment purposes, prior to beginning the sampling effort, you must complete a monitoring plan that contains all the applicable elements of a Quality Assurance Project Plan (QAPP). The QAPP is a written plan that:

- Provides background information
- Identifies objectives for your project
- Details your project's standard operating procedures in the field and lab
- Outlines project organization
- Addresses issues such as training requirements, instrument calibration and internal checks on how data are collected, analyzed, and reported

The QAPP helps ensure that the samples you collect and analyze, the data you store and manage, and any reports you write are of high enough quality to meet project and data user needs.

A QAPP is extremely valuable to the volunteer monitors, project leaders, and the data users to ensure that the data collected is of a certain confidence and meets the objectives of the project. You can use the QAPP to make sure you are following proper procedures and collecting data that meet the project objectives and will be credible to decision-makers. Also, referencing a QAPP and showing how it was followed can also help you answer questions from other groups concerned about the reliability of your data. QAPPs can vary in their level of detail, depending on the nature of the work you are doing and how you intend to use the data. Any group that is interested in and capable of monitoring for assessment purposes is capable of developing a general QAPP for their monitoring effort to document the monitoring plan and ensure that the results obtained are of the type and quality needed and expected. The QAPP should be reviewed periodically to ensure that its content continues to be valid and applicable to the program over time.

Guidance on how to complete a QAPP can be found in EPA's document, *The Volunteer's Guide to Quality Assurance Project Plans,* September 1996, EPA-841-B-96-003, available on-line at ***http://www.epa.gov/owow/monitoring/volunteer/qappcovr.htm.*** This Appendix also provides many of the elements needed to develop a QAPP for CWA assessment monitoring (e.g, the monitoring methods and quality assurance/quality control procedures necessary for assessment monitoring, later in this Section).

Table 1:
Summary of data needed for water quality assessments: 305(b) report and 303(d) list[1,2]

Pollutant category	Parameters (or steps)	Assessed for	Period of record	Minimum number of values
Pollutants with toxicity-based standards	Un-ionized ammonia (total ammonia, pH & temperature) [3], chloride	305(b)	Most recent 10 years	5, within a 3-yr. period[4]
		303(d)	Most recent 10 years	5, within a 3-yr. period
Conventional pollutants and water quality characteristics	Dissolved oxygen, pH, turbidity, temperature	305(b)	Most recent 10 years	10 (minimum of 20 for turbidity based on total suspended solids)
		303(d)	Most recent 10 years	10 (minimum of 20 for turbidity based on total suspended solids)
Fecal coliform bacteria[5]	Step 1 (screening for potential problem)	305(b)	Most recent 10 years	10
		303(d)	Most recent 10 years	10
	Step 2 – impairment determination via monthly geometric mean	305(b)	Most recent 10 years	5 per month (to calculate mean); at least 3 months
		303(d)	Most recent 10 years	5 per month (to calculate mean); at least 3 months
	Step 2 – impairment determination via individual max. values	305(b)	Most recent 10 years	10
		303(d)	Most recent 10 years	10
Eutrophication of lakes (effects of excess nutrients)	Total phosphorus (TP), chlorophyll *a,* Secchi disk transparency	305(b)	Measurements collected from June to Sept. over the most recent 10-year period	At least one TP, Secchi disk or chlorophyll *a* measurement
		303(d)	Measurements collected from June to Sept. over the most recent 10-year period	At least 12 measurements (12 separate sampling dates) for each of TP, Secchi disk & chlorophyll *a*
Impairment of the biological community	Index of Biotic Integrity[6]	305(b)	Most recent 10 years	Can be based on a single biological monitoring event on a given reach
		303(d)	Most recent 10 years	Can be based on a single biological monitoring event on a given reach
Supporting water quality data	TSS, total Kjeldahl nitrogen, nitrite-nitrate nitrogen, conductivity, 5-day biochemical oxygen demand, alkalinity, stream TP	305(b)	Most recent 10 years	As available; supports assessments
		303(d)	Most recent 10 years	As available; supports assessments

[1]For more details, including exceedance thresholds, see *Guidance Manual for Assessing the Quality of Minnesota Surface Waters: For the Determination of Impairment,* MPCA, January 2003 (MPCA Assessment Guidance).

[2]This table does not include metals or organic pollutants due to the complexity of sampling for those parameters. Those interested in sampling for metals or organics should consult the MPCA Assessment Guidance and MPCA monitoring staff.

[3]The measurement of un-ionized ammonia requires that total ammonia, temperature and pH all be measured at the site (un-ionized ammonia concentrations are then calculated based on this data).

[4]If more than one sample was taken within a four-day period the values are averaged (usually an arithmetic mean is appropriate) and the four-day average is counted as one value in the assessment.

[5]In the future, *E. coli* will replace fecal coliform as the indicator bacteria used for assessments. While that will necessitate a change in analytical methods, the sample collection methods will remain the same.

[6]For macroinvertebrate monitoring, data used for 303(d) listing must be based on identification to the genus level. Family-level identification is sufficient for use in 305(b) assessments and as *supporting* data for 303(d) listing.

A. Location

A critical initial step in planning a monitoring effort to collect data for 305(b) and 303(d) assessments is deciding where to collect samples. River assessments are conducted for river reaches and lake assessments for an entire lake (unless the lake is very complex or "bayed"). It is important to clearly identify the sampling site on a map, and collect precise locational data (e.g., global positioning system [GPS] readings) for each site so the MPCA can be sure of the exact locations.

In many natural lakes in Minnesota, it is adequate to sample at one primary site, typically the site of maximum depth. You will need to sample at multiple sample sites if the lake is "bayed" or has a complex shoreline. The MPCA applies the following criteria to determine whether a water body is a lake:

- The water is listed in Minnesota Department of Natural Resources (MDNR) Bulletin 25
- It is not listed as a wetland in the MDNR Public Waters Inventory
- It is 10 acres or larger
- It has a hydraulic residence time of at least 14 days

Collect river/stream samples at a point where the water is well mixed and is most likely to represent the water quality of the reach that is to be assessed. The goal is to get a sample that represents the overall characteristics of the stream at that site.

B. Analytical methods

Another element of up-front planning involves selecting the procedures and methods that you will use to collect and analyze the samples. All analyses must be completed according to methods approved by USEPA for your specific monitoring purpose. For example, if you are interested in sampling for total phosphorus and providing the data to the MPCA for CWA assessments, you must use an USEPA-approved method that is appropriate for the type of water you are sampling (ambient surface water), and that will be able to detect the concentrations you expect to find. Table 2 lists some of the EPA-approved methods and holding times (length of time the sample can be stored before analysis) for the parameters that you are likely to sample. This information is derived from EPA's regulation 40 CFR part 136, table IB and table II, which can be accessed online at ***http://www.access.gpo.gov/nara/cfr/cfrhtml_00/Title_40/40cfr136_00.html.***

For water quality sampling, depending on the parameter, you can collect data through the use of a field meter, field kit, or you can collect water samples and transport them to a laboratory for analysis. Note that the EPA-approved list includes methods for both laboratory analysis and field measurements. Consult with MPCA staff if you have questions about selecting an EPA-approved method for a specific parameter.

Some parameters are best measured through the use of a field meter due to the need for short (or no) holding times, or because a field meter is generally easier to use than a field kit or lab analytical method. The parameters where use of a field meter is recommended are temperature, dissolved oxygen, pH and turbidity.

Field analysis kits exist for a wide variety of water assessment parameters. The kit manufacturer provides a water analysis handbook that describes in detail how to use the kit in the field. The handbook also contains information as to whether the field analysis is equivalent to the EPA method or to a Standard Method. For example, for the analysis of alkalinity, the manufacturer's handbook may contain the following or similar information: "Scope and Application: For water, wastewater, and seawater. Adapted from *Standard Methods for the Examination of Water and Wastewater,* 2320 B. USEPA accepted."

If you will be using a laboratory for chemical analyses, the MPCA requires that the lab be certified by the Minnesota Department of Health (MDH). You will find a list of certified

A **minimum detection limit** (or reporting level) is the lowest concentration of a parameter that an analysis method can measure. For example, there are several approved methods that a lab can use to analyze total phosphorus (TP) in a water sample. One method detects concentrations of 1 mg/L or greater. Most Minnesota lakes, however, particularly those in Northeastern Minnesota, have TP concentrations lower than 1 mg/L, making this method inappropriate for these lakes.

labs and information about the certification process on MDH's web site at ***http://www.health.state.mn.us/divs/phl/cert.html***. All certified laboratories must be audited by MDH at least once every three years. The audit provides a determination on whether the laboratory is capable of analyzing each of the analytes (parameters) for which it is seeking certification. Certification assures the data user that the laboratory is capable. Without the certification, users may have less confidence in the quality of data produced. Please note that "users" can include not only the organization collecting the data, but also other organizations and individuals who use the data.

It is also important to determine that the kits, meters and/or laboratory methods you are using have appropriate measurement ranges and the minimum detection limits necessary to achieve project objectives. You will have to select appropriate field meter(s) or field kits, or contact the laboratory before you sample to ensure it has the necessary equipment and methods to achieve the project's detection limits.

Prior to sampling, you should also develop field data sheets tailored to the project objectives. Information important to the MPCA includes the collector's name, site ID, site

Table 2.
USEPA-approved[1] analytical methods suggested by the MPCA.

Parameter	USEPA method	Standard method	Preservation	Max. holding time (before analysis)
Un-ionized ammonia[2]	350.1/350.2/350.3	4500-NH_3 G	H_2SO_4 to pH < 2, Cool to 4° C	28 days
Chloride	325.2/325.3	4500-Cl E	None	28 days
Dissolved oxygen (DO)[3]	360.1/360.2	4500-O G	None	Immediately (i.e. measure in the field)
Temperature	170.1	2550	None	Immediately (i.e. measure in the field)
pH	150.1/150.2	4500-H^+ B	None	Immediately (best if measured in the field)
Turbidity	180.1	2130 B	Cool to 4 °C	48 hours (best if measured in the field)
Fecal coliform	—	9222 D	Cool to 4 °C	6 hours[4]
Total phosphorus	365.1/365.2/365.3	4500-P F	H_2SO_4 to pH < 2	28 days
Chlorophyll *a*	—	10200 H	Cool to 4°C, keep in dark	28 days (shorter if not field-filtered)
Total suspended solids	160.2	2540 D	Cool to 4° C	7 days
Total Kjeldahl nitrogen	351.2/351.3	4500 N	H_2SO_4 to pH < 2, Cool to 4° C	28 days
NO_2/NO_3 nitrogen	353.2	4500-NO_3 F	H_2SO_4 to pH < 2, Cool to 4° C	28 days
Conductivity	120.1	2510 B	Cool to 4° C	28 days
Alkalinity	310.1/310.2	2320 B	Cool to 4° C	14 days
5-day biochemical oxygen demand (BOD_5)	405.1	5210 B	Cool to 4° C	24 hours[5]

[1]From 40 CFR part 136, table IB: ***http://www.access.gpo.gov/nara/cfr/cfrhtml_00/Title_40/40cfr136_00.html***, or *Standard Methods for the Examination of Water and Wastewater*, 20th Edition, 1998, American Public Health Association.
[2]Record sample pH and temperature. Analyze for Total Ammonia nitrogen. Consult pH vs. temperature chart to determine percent of sample that is un-ionized.
[3]DO via Winkler Method: 360.2; no preservative; analyze immediately. Sample may be 'fixed' with 2-mL $MnSO_4$ + 2-mL alkali-iodode-azide + 2-mL H_2SO_4. Fixed sample may be held for 4-6 hours out of direct sunlight. Because this method requires considerable "technique," volunteer monitors are encouraged to use a field DO meter (*Standard Methods* 4500-O G) rather than the Winkler Method.
[4]For samples to be used for enforcement. Otherwise, 24 hrs.
[5]For composite samples, the 24-hour holding time begins at completion of compositing.

description, date, time, depth of sample (typically for lakes), parameters to be tested, calibration results, field notes and observations (e.g. weather, unusual conditions, land-use surrounding site and any departures from the field methods). Use these data sheets during every sampling event to ensure you collect the needed information each time.

C. Water sampling methods

Sampling involves either the in-stream or in-lake measurement of a parameter, or the collection of a sample for later analysis at a laboratory. The sampling method and size of the sample container will vary, depending on the parameter(s) to be analyzed and the lake or stream conditions (such as stream width, depth and flow rate). This section details sampling procedures for lakes and streams, including considerations for sample preservation and transport to the lab.

1. Sampling for conventional pollutants and nutrients

Two main methods for sampling water quality are: in-field measurements using field meters; and collecting samples for laboratory analyses. The following paragraphs detail methods for each sampling type.

a. Field meters

When completing an analysis in the field using a field meter (such as a dissolved oxygen, pH or turbidity meter), it is important to follow the manufacturer's instructions for calibrating the instrument. Proper calibration is essential to make sure the meter is reading accurately. Be sure to note the calibration data on the field sheet, including the instrument reading before and after calibration, to check for measurement drift (note that calibration frequency depends on the meter/parameter being measured). This will serve as a check that the calibration was done, and that the meter was functioning properly. You will also need calibration information to complete a quality assurance assessment report prior to submitting the data to the MPCA (see section E). The box below provides general information on the use of a field dissolved oxygen meter, which is the most common type of field meter used.

b. Grab sampling (for laboratory analysis)

While a few parameters can be measured using field meters (e.g., dissolved oxygen, pH, temperature), many require that you collect a sample and transport it to a laboratory for analysis. Sample collection breaks down into three general steps: bottle and equipment preparation, sampling and sample preservation and transport. Following are MPCA requirements for each of these steps.

i. Bottle and equipment preparation

Most labs will provide bottles for sample collection. If sample bottles have been precleaned by a laboratory or a manufacturer, you do not need to rinse with the sample water before collection. Always follow bottle preparation directions from the lab. If the bottles are not cleaned ahead of time by a lab, then clean them with a detergent (phosphorus-free if sampling for phosphorus) and tap water and rinse several times with distilled or deionized (DI) water. (Note: Do this only for non-metal, inorganic and nutrient parameters. Use special bottle cleaning procedures when sampling for metals or organic parameters. Contact the MPCA for guidance on cleaning procedures for metals or organics sampling.)

Dissolved oxygen meter general instructions

Meter preparation

- Inspect the probe; replace electrolyte and membrane as needed
- Turn the meter on and check the battery
- Allow the probe to stabilize for at least 60 minutes (20 min. in a pinch) before calibration

Calibration

- Calibrate meter according to manufacturer's instructions
- Enter maintenance and calibration information into the instrument's log book. Note: periodically check the probe temperature readings against a precision grade thermometer.

Testing sample

- Place probe in sample
- Turn on stirrer unit or continuously stir sample with the probe
- Record test result once the instrument's readings stabilize

Re-calibration

- Do at the end of the sampling run. If this is an all-day sampling run, do a recalibration check midway through the day.
- Follow manufacturer's calibration instructions
- Record re-calibration check data. This check will allow you to determine, if the data is reliable.

Just prior to sampling (i.e., while at the sampling site), clearly label each bottle with the site name, date, time, sample depth and collector's initials. Also record this information on the field data sheet.

Clean sampling equipment that contacts sample water (including the sampling device(s) and any container used to subdivide samples) with phosphorus-free detergent and rinse with DI water before each day's sampling if there is any visible dirt or foreign material. If the sampling equipment is visibly clean and free from dirt, then simply rinse with DI water at the beginning of the day's sampling for non-metal inorganic and nutrient parameters. Rinse the sampling equipment thoroughly three times with stream/lake water at each site before water is collected to transfer to sample bottles. Use special cleaning procedures when sampling for metals or organic parameters; contact the MPCA for more information.

ii. Sampling lakes

As indicated earlier, in many natural lakes in Minnesota it is adequate to sample at one site, unless the lake is "bayed" or has a complex shoreline. Check with the MPCA (St. Paul or regional offices) to see if there are existing monitoring sites on your lake before you begin your monitoring. Each lake sampling date, which may include data averaged together from one or more sampling sites on a lake, is considered a single sample for assessment purposes.

Typically, you collect surface water samples from the upper, well-mixed layer of water using an "integrated" sampler. This is a PVC tube with an inside diameter of 3.5 cm (1.4 inches), 2 meters long (6.5 feet), with a stopper at one end. It will fill a 2-liter bottle, and is used to collect water samples for the majority of the chemical analyses.

To collect a sample, rinse the tube three times with lake water, and then lower it vertically into the water until it submerges, and fills. Stopper the top end (think of putting your finger over the end of a straw in a glass of soda). Then pull the tube out of the lake. The pressure caused by capping the end holds the water in the sampler until it can be released into a rinsed, 2-liter sample bottle by loosening the stopper. (Note: The pressure often doesn't hold for long, so be quick in transferring the lower end of the sampler from the lake to the sample bottle.) With this procedure, you obtain an "integrated" 2-liter sample of the upper two meters of the lake, which provides a representative sample of lake water quality in the summer. Shake the sample in the 2-liter bottle and subset into individual bottles and preserve as per lab requirements for nutrient and chlorophyll-*a* analyses.

If you are going to take a bottom sample to measure phosphorus, use a discrete depth sampler (such as a Van Dorn or Kemmerer sampler). A dissolved oxygen/temperature profile and a Secchi disk reading are also recommended for lake sampling.

iii. Sampling rivers and streams

Collect stream samples at a point that is most likely to represent the water quality of the site. Because stream flow characteristics at a site change considerably from low- to high-flow conditions, you must decide on the best specific location at the site during each visit. Note the location you choose and the factors you consider in your choice.

What if you see a pollution source at the site?

If a localized source of pollution, such as sediment from a storm sewer inlet or field runoff, is visible at a sampling location it may be tempting to collect the sample in the "plume" to document the problem. It is important to remember, however, when sampling for CWA assessments that the results will be used to characterize the water quality of the stream *throughout* the reach. Sampling within the problem zone would invalidate the results because it would not be representative of the whole stream. In such a situation, sample outside the localized problem zone, in a well-mixed area that better represents the entire stream reach.

In addition, consider collecting additional samples in the problem zone. You can use this along with additional sampling or information to help characterize and resolve the problem through sharing the data and discussing solutions with landowners and local watershed officials.

The goal is to get a sample that represents the overall characteristics of the stream at that site. Sample rivers and streams at a point where the water is well mixed, in such a way as to avoid contamination from surface film or flotsam, bottom sediments and airborne particulates from sampling equipment or bridge decks. If a site is poorly mixed across the stream use a method besides a grab sample or choose another site that is well mixed. For example, if safe access to a stream prohibits sampling in a well-mixed location, consider taking multiple samples/measurements along the stream cross-section, noting the position along the stream width for each sample. Note that sampling for total suspended solids (TSS) is particularly vulnerable to effects from an inadequately mixed site, as TSS can vary considerably across a stream's width and depth.

Collect a stream grab sample at a middle depth in the water column without disturbing streambed materials or collecting floating materials from the water surface. If sample water is to be collected directly in the sample bottle, to collect the sample, lower the bottle mouth-down to a point below the water surface and then turn it upstream. Always collect the sample upstream of yourself to avoid contaminating the sample (i.e., stand with the sample bottle upstream of your body). During winter, take care to keep ice and snow out of the sample (particularly if sampling through a hole cut in the ice), since this can impact the analytical results. You can make in-field measurements of pH, dissolved oxygen, temperature, conductivity and turbidity.

In some cases the stream current is too swift or the water is too deep to safely collect a sample by wading (a general rule is that if stream depth (in feet) multiplied by its velocity (in feet per second) is greater than your height (in feet), then **DO NOT WADE!**). In this situation, you can collect a sample from shore by extending a sampling bottle connected to a pole to the well-mixed area of the stream, or by lowering a bottle or sampling device from a bridge.

iv. Sample preservation and transport

Some lab analyses, such as those for total phosphorus, require chemical preservation of the sample in the field to ensure that the sample conditions do not change between the time when the sample is collected and when it is analyzed. Other samples may require field filtration or additional treatment prior to sample transport. It is important to follow lab directions for field preservation or filtration to help ensure the validity of the analysis.

The laboratory that provides the sample bottles often also provides the sample preservative. For example, if the sample must be preserved at a pH < 2, the laboratory will provide a small vial of H_2SO_4 for this purpose. The lab will provide one vial of preservative for each sample bottle that requires it.

Most samples must also be cooled to 4°C immediately following sample collection. Do this by placing the sample bottles in a cooler full of ice. Note that some methods do allow for samples to be frozen until analysis; contact the MPCA for more information on this alternative.

Be sure to make arrangements with the laboratory prior to each sampling trip to ensure they are prepared to receive the samples. Keep in mind that certain parameters have very limited holding times within which the analysis must take place for the measurement to be valid. Establish a clear plan for transporting samples to the laboratory to ensure they arrive well before the holding time expires. In addition, use a chain-of-custody form to identify samples and record all transportation and storage information as samples are collected, transported to the lab, analyzed and disposed.

2. Bacteria sampling

Because bacteria occur naturally in and on humans, take extra care to avoid contamination during collection, preservation, storage and analysis of indicator bacteria samples (i.e., samples analyzed for fecal coliform bacteria or *E. coli*). Take these simple, but critically important, precautions to avoid contamination:

- Follow the lab's direction for sample containers
- Do not use a container that has a loose cap or any other opening
- Avoid touching the inside of the cap, bottle or bag while filling with sample water
- Ensure that the sample container is tightly closed while being transported to the lab in a cooler

Indicator bacteria in surface water can be as variable as the distribution of suspended sediment because bacteria commonly are associated with solid particles. It is very important that you collect samples in a well-mixed area of the stream to obtain representative data. As with other grab samples, collect the sample at a middle depth in the water column without disturbing streambed materials or collecting floating materials from the water surface.

If the stream is well mixed and the stream depth and/or velocity permit safe wading, collect a sample by the hand-dip method described below. While it is acceptable to collect a sample with a clean, rinsed, non-sterile water sampler and pour it into the sterile bottle, it is preferable to sample directly into the sterile bottle or bag when possible.

Hand-dip method

1. Open a sterile sample bottle. Hold the bottle near the base, with hand and arm on downstream side of bottle. If using a sterile sample bag, skip this step (the bag will be opened underwater).

2. Without rinsing, plunge the bottle opening downward, below the water surface. Allow the bottle to fill with the opening pointed slightly upward into the current. If using a bag, open, fill and close the bag below the water surface without disturbing the bed materials.

3. Remove the bottle with the opening pointed upward from the water and tightly cap it, allowing about 1 to 2 inches of headspace (empty space between the water sample and the bottle cap). This procedure minimizes collection of surface film and avoids contact with the streambed.

4. If sampling the stream from the shore or a bridge (using a sample bottle on a pole or rope), rinse the sampling device three times with stream water before collecting the sample. Avoid contacting the stream water or the inside of the sample bottle or bag when transferring the water from the sampling device to the bottle/bag.

5. Be sure to *collect a sampler blank* before taking the stream sample (see Section VII for further information on sampler blanks, including collection procedures).

Use the same sample collection procedure regardless of the type of bacteria being monitored. The laboratory performing the analysis will provide sterile sample bottles that contain sodium thiosulfate crystals to neutralize any halogen present in the sample (the presence of halogen can be lethal to any bacteria in the sample). It is critical when monitoring bacteria that you keep the sample bottle sterile. The container size you use will depend on the sample amount you need for the bacteria analysis method chosen and for other analyses. Remember to wash your hands thoroughly after collecting samples suspected of containing fecal contamination. Also, be careful not to touch your eyes, ears, nose or mouth until you've washed your hands.

D. Biological sampling methods

The MPCA uses biological monitoring in addition to chemical monitoring of pollutants, for 305(b) and 303(d) assessments. A number of volunteer groups are involved in biological monitoring and interest in it continues to grow.

This section focuses on the methods and quality assurance needs for monitoring biological communities. In general, biological monitoring involves collecting a sample of the biological community in question (i.e., fish, macroinvertebrates, plants), identifying the organisms found in that sample and comparing the organism numbers and types, habitat conditions and other characteristics (or metrics) to established indices.

A key component of this monitoring is the level of detail employed when identifying the sampled organisms. The Indices of Biotic Integrity (IBIs) currently completed or under development by the MPCA are based on genus-level identification of organisms, which is necessary for data to be used for 303(d) listing. A family-level identification method is adequate for the purposes of 305(b) assessments. Family-level monitoring results can also be used as *supporting* data in the 303(d) listing process, which means that while these data are not sufficient by themselves to result in an impairment determination, they can be used to support and verify determinations based on other parameters identified in this Appendix. In the future, the MPCA plans to develop a regional, family-level IBI that volunteer monitors in Minnesota can use. This "citizen" IBI will be developed once a large enough data set is available to allow for significant state coverage. It will be a useful tool for completing 305(b) assessments and for identifying potential candidates for 303(d) listing (which would then require follow-up monitoring).

At the time we prepared this Appendix, the MPCA was using IBIs based on fish communities in rivers and streams in water quality assessments, and developing and beginning to apply IBIs based on river and stream macroinvertebrate communities. Sampling fish communities in lakes is done by the Minnesota Department of Natural Resources (DNR) as part of their responsibility to manage a sport fishery. Sampling of stream invertebrates (mostly aquatic insects) and the development of associated IBIs are ongoing. These data have not been used in previous 305(b)/303(d) assessments, but will be included in the 2004 assessments for the St. Croix and Lake Superior Basins. In anticipation of the future use of these data, the methods for sampling invertebrates are included below.

As for wetland monitoring, the MPCA is building a database and acquiring experience in applying biological indices to wetlands to determine the health of invertebrate communities in a range of wetlands from highly disturbed to unimpacted. The MPCA plans to use wetland biological indices in future 305(b)/303(d) assessments as it gains more experience in this arena. Wetland monitoring methods and requirements will be included in future revisions of this Appendix. Additional information about biological sampling, including descriptions of the MPCA's standard operating procedures, can be found at ***http://www.pca.state.mn.us/water/biomonitoring/***.

1. Wetlands

Although the MPCA has developed sampling protocols and tools for wetlands for macroinvertebrate and plant assemblage data, it currently does not have guidance for 305(b) and 303(d) assessment of wetlands using biological data. If you have an interest in using protocols to collect and interpret invertebrate or plant data from wetlands, contact the MPCA's wetland monitoring staff at (651) 296-6300. Find additional information on wetland monitoring on the MPCA's biomonitoring web page (***http://www.pca.state.mn.us/water/biomonitoring/***). As indicated above, the MPCA is acquiring experience in the application of biological indices, and plans to include wetland biotic assessments in future 305(b)/303(d) assessments.

2. Rivers and streams

a. Sampling fish

The MPCA has guidance for the assessment of streams in Minnesota using fish assemblage data. However, this process requires expensive equipment and a permit from the DNR. If you have an interest in using MPCA protocols to collect and interpret fish assemblage data, contact the MPCA's river and stream biological monitoring staff at (651) 296-6300.

b. Sampling invertebrates

When to sample: Sample in the late summer/early fall, primarily during September. Flood and drought events can have strong effects on macroinvertebrate community structure; therefore, sample streams under stable, base flow conditions. Delay sampling in streams following high-flow events until stable conditions return. If a stream is known to have been dry at an earlier date in the sample year, do not sample it.

Sampling reach determination: It is important to collect a sample representative of the stream reach selected. Once a reach is established, walk its entire length to determine the presence and abundance of productive macroinvertebrate habitats. The reach length should be adequate to cover the entire range of hydrological and morphological conditions for the stream in the area of interest. The MPCA uses a stream reach that is 35 times the average stream width, with a maximum of 500 meters and a minimum of 150 meters, which has been determined to provide a representative characterization of most streams. It is typically not necessary to sample the entire reach for invertebrates. The important thing is that you sample all major habitat types (e.g., riffles, rocky substrates, woody debris, etc.). Collecting an adequate sample normally requires walking 150-200 meters of stream length, although sometimes you must cover a much longer distance to sample the range of available habitats.

Benthic sampling technique: The tools the MPCA is developing for stream assessment are based upon samples collected using a qualitative multi-habitat sampling technique. For data to be assessed using the invertebrate IBIs developed by the MPCA, it must be collected in a similar fashion. Data collected using a riffle-sample, hester-dendy sample or other sampling technique will be considered adequate for the purposes of listing in the future if it can be demonstrated that current assessment tools are transferable to this type of data or if new scientifically defensible assessment tools are developed.

Take a *qualitative multi-habitat (QMH)* sample at each sampling location. The only sampling gear you need is a D-Frame dip-net (D-net) with a 500-micron mesh size. Take care to ensure that as many invertebrates as possible are collected for each area sampled. Always hold the net downstream of the sampling area. When collecting a QMH sample in conditions of negligible flow, sweep the net repeatedly in upstream fashion to ensure that as many invertebrates are collected as possible.

You collect the qualitative multi-habitat sample to characterize the overall diversity of the sample reach. Sample macroinvertebrate habitats in proportion to their existence in the defined stream reach. For example, if 20 percent of the invertebrate habitat consists of woody debris, then take 20 percent of the samples from woody debris habitats. You will not sample fine sediment substrates. Collect samples in a downstream-to-upstream fashion. Collect 20 sampling efforts, or sweeps, and composite them in a 500-micron mesh sieve bucket. Label samples and preserve in 100%-denatured ethanol.

Consider these five habitats when sampling: 1) riffles or shallow, fast-flowing runs, 2) undercut banks and overhanging vegetation, 3) submerged or emergent aquatic macrophytes, 4) snags and woody debris, and 5) leaf packs.

A sampling effort is defined as taking two D-net samples in a common habitat. Take a D-net sample by placing the net on the substrate and disturbing an area equal to the square of the net width (approximately $1ft^2$) directly in front of the net opening. Each effort should cover approximately $0.18m^2$ of substrate and the total area sampled should be approximately $3.6m^2$.

This process becomes complicated when dealing with multidimensional substrates like weed beds and woody debris. Following is a description of each habitat and how to sample:

Riffle/rocky substrate. This category covers rocky substrates with fast-flowing water. Runs often have suitable rocky substrates and should not be excluded from sampling. To sample riffles, firmly and squarely place the D-net on the substrate downstream of the area to be sampled. If the water is shallow enough, disturb the area directly in front of the net with your hands, taking care to wash large rocks off directly into the net. If the water is too deep for this, it is adequate to kick the substrate in front of the net.

Aquatic macrophytes. This category includes any vegetation found at or below the water surface. This includes emergent vegetation because all emergent plants have stems that extend below the water surface, serving as suitable substrate for macroinvertebrates. You should not sample the emergent portion of these plants. Sample submerged plants with an upward sweep of the net. If the net fills with weeds, vigorously hand-wash or jostle them in the net for a few moments and then discard. Sample emergent plants with horizontal and vertical sweeps of the net until you feel that the area being swept has been adequately sampled.

Undercut banks. This category covers shaded, in-bank or near-bank habitats, away from the main channel, that typically are buffered from high flows. These banks can vary in the extent of undercutting. Many banks appear undercut, but when investigated, prove not to be. For these reasons, prod banks to determine how deeply they are undercut. Treat overhanging vegetation the same way. Sample with upward thrusts of the net, while beating the undercut portion of the bank or the overhanging vegetation to dislodge any clinging organisms.

Woody debris. This category includes any piece of wood found in the stream channel. Consider logs, tree trunks, entire trees, tree branches, and large pieces of bark and dense accumulations of twigs as snags. Root-wads are masses of roots extending from the stream bank. Use best professional judgment to determine what a "sampling effort" is. It is acceptable to approximate the surface area available for sampling for larger tree trunks or branches, while giving a "best guess" for the sample area of masses of smaller branches and twigs. Given their variable nature, there is not one best method for sampling snags. As the diameter of wood gets larger, it is easier to sample the surface area more directly using a hand or tool to gently wash the surface of the wood. As the diameter of the wood gets smaller and the density of branches becomes greater, it is more efficient to kick or beat the woody debris.

Leaf packs. Leaf packs are dense accumulations of leaves typically present in the early spring and late fall. You will find them in deposition zones, generally near stream banks, around logjams or in current breaks behind large boulders. Take a leaf pack sample near the surface of the leaf pack, since sweeping to the bottom of every leaf pack could create a disproportionately large amount of sample volume being collected for a given area. Due to the timing of the sampling (i.e., late summer/early fall), leaf packs are generally not dominant enough to be included in a sample.

Take care in areas near bridges or high pedestrian traffic to avoid sifting through shards of broken glass or sharp metal. Use a hard tool such as a screwdriver to dig through the coarse substrate when sampling in areas where sharp substances are likely to be found.

c. Laboratory sample processing

Once the sample is brought into the lab, separate the macroinvertebrates from the rest of the sample. Do this by sorting through the sample in the lab and "picking" out the macroinvertebrates. QMH samples are sub-sampled to 300 organisms. To accomplish this, remove a minimum of 300 macroinvertebrates from the sample, then remove the remaining large and/or rare organisms. Do not combine the two sub-sample components (300 organisms and large/rare organisms) until the data are analyzed.

Have 10 percent of each sample checked for "picking efficiency" by an independent stream biologist to make sure that most of the macroinvertebrates were removed for identification. Once you finish picking, the biologist will count the number of macroinvertebrates remaining in the original sample (i.e., the sample remnant). If the biologist finds the number of macroinvertebrates in the sample remnant exceeds 10 percent of the total number of macroinvertebrates you picked out, the picked sample remnant is reprocessed. When new volunteers start, check their entire samples until they are able to find 95% of all target organisms in a sample, after which they can pick independently.

All organisms are identified to the genus level (if possible) for data used for 303(d) listing. Family-level identification is acceptable for data used in 305(b) assessments; as a screening tool for 303(d) listing (follow-up monitoring is needed to collect genus-level data for rivers and streams targeted by the screening-level analysis); or as supporting data for 303(d) impairment determinations based on other parameters identified in this Appendix. Five percent of all samples identified are checked for proper taxonomic characterization by an independent stream biologist. An independent taxonomist should resolve taxonomic discrepancies. For taxonomic comparisons, maintain a reference collection that contains identified invertebrates that have been verified by an independent, professionally trained taxonomist.

E. QA/QC requirements

Data used in impairment decisions must be of reliable quality. There are many opportunities for the introduction of errors – from field sampling, to lab analysis, to data assessment and all the steps in between. Therefore, it is difficult to overstate the importance of spelling out quality assurance and quality control (QA/QC) protocols for each step along the way and the need to carefully adhere to them. This applies to the data generated by the MPCA and data used from outside parties.

This section identifies the QA/QC protocols that must be followed and documented for physical and chemical monitoring data to be considered for assessment purposes. Section V-D, above, identifies the QA/QC protocols for biological monitoring. Note that, while all data collected following the procedures identified in this Appendix, will be considered by the MPCA when developing its assessments, data that do not meet QA/QC tests may not be used in the final assessments.

1. Field quality control checks

Quality control checks serve three main purposes:

1) They provide a "feedback loop" to those performing and managing the monitoring effort. For example, unacceptable concentrations of an analyte in a sample blank signals that the sample was contaminated, which points to the need to better adhere to existing monitoring procedures or improved procedures.

2) Quality control checks allow for the assessment of the quality of the data produced by the monitoring effort. This allows those interested in using the data to determine if the data meets their quality objectives.

3) Quality control data can tell water resource managers something about the lake or stream being monitored. For example, consistent variations in duplicate samples, even with documented adherence to protocols, can indicate variability in the lake or stream conditions. This information can help interpret the data used in the assessment process.

For biological sampling, use appropriate internal quality control checks. As noted in the previous section, a 10 percent review of "picking efficiency" for new volunteers is incorporated into the sampling until competency is documented. Five percent of all samples identified are checked for proper taxonomic characterization by an independent stream biologist. An independent taxonomist should resolve taxonomic discrepancies. Maintain a reference collection containing identified invertebrates that have been verified by an independent, professionally trained taxonomist, for taxonomic comparisons.

For water samples, during each sampling season, make sure at least 10% of samples taken are sampler blanks and at least 10% are field duplicates, as specified in the paragraphs below. The more uncertainty around the data collection, the more quality control checks you should complete. For example, a sampling effort by teams of monitors (rather than a consistent sampling team throughout the sampling season) may benefit from taking additional field duplicates (beyond the 10% minimum) to document uniform data collection methods and further demonstrate data credibility. It is not required that you take sampler blanks or sample duplicates at each sampling site. The purpose of the field duplicate is to assess the reproducibility of the sampler's sampling technique and the laboratory's analytical technique. The purpose of the sampler blank is to assess the sampler's effectiveness at cleaning the sampling device.

a. Sampler blanks

A sampler blank (also commonly referred to as a rinsate blank or equipment blank) is a sample of deionized (or distilled) water that is rinsed through the sampling device and collected for analysis. Containers used to store the deionized (DI) water should only be used to store DI water to eliminate possible contamination from other uses. You can usually obtain DI water from the lab doing the sample analyses. If the DI water is not from a laboratory or provider that can assess the purity of the water, then also provide one bottle blank of the DI water with every sampling trip.

The first step in collecting a sampler blank is to decontaminate the sampling device the same way you collect your regular samples. For example, if you rinse three times with the lake/stream water, then do this in exactly the same manner with the DI water before you collect the blank. Try to eliminate as much of the rinse water from the sampling device as possible. To collect the blank, fill the sampling device with DI water and transfer the water to the appropriate collection bottles. Handle the device as close to your normal sampling procedure as possible (agitate the sampling device in the same manner, try to leave the water in the sampling device for the same amount of time and collect the same volume of water).

For bacteria sampling, collect and analyze field blanks to document that sampling equipment has not been contaminated. ***Before*** collecting the water sample, process field blanks as follows:

1. Rinse sampling equipment and containers with sterile buffered water.

2. Process DI water through sampling equipment and into sterile sample bottle. If no growth is observed when the field blank is analyzed, collect the sample using sterile procedures.

b. Field duplicates

A field duplicate is a second sample taken immediately after an initial sample in the exact same location. Field duplicates assess the sampler's precision, laboratory precision and possible temporal variability. Collect the duplicate sample in the exact same manner as the first sample, including the normal sampling equipment cleaning procedures. It is important that you clearly label field duplicates as such in the field to ensure there is no confusion once the samples are transported to the lab or after the results are received.

In the case of field water quality measurements (such as dissolved oxygen profiles or turbidity meter readings), also collect duplicate measurements at 10% of the locations. To perform a duplicate field water quality measurement, remove the meter sensor from the lake or stream for at least several minutes, so that the sensor readjusts to the lake/stream conditions once it is reinserted into the water. If the instrument readout is unstable (i.e., the reading is bouncing around), check the meter batteries and calibration before making another reading.

2. Laboratory quality control checks

All labs certified by the Minnesota Department of Health are required to develop and maintain quality control (QC) procedures and checks to ensure the credibility of the analyses they are performing. While the quality control checks are the lab's responsibility, it is important for you to understand what is required, and to require your lab to report its quality control data along with the sample analyses, so you can check on your lab's performance. Following are the *minimum* lab quality control checks that must be completed and evaluated if data is to be used for assessment purposes:

- 10% laboratory duplicates
- 10% matrix spikes
- 10% method blanks on all samples.

Monitoring laboratory performance

It is a good idea for you to periodically check your lab's QC performance as results are reported. This way, if the lab is having problems you will recognize that and ensure the problems are addressed before a whole season of data must be flagged as unreliable due to poor lab performance. You should require your lab to report the results of lab QC checks along with sample results and to note whether the data quality objectives were met. Review these reports to ensure that your lab is performing as required for the project.

3. QA/QC reporting

Write a Quality Assurance Assessment Report after the data collection is complete. Prepare the report so that the project coordinators and the data's end users know how to interpret and use the final data. Include an assessment of quality control data to determine if the data quality objectives required by the CWA assessment process were met. Also include adherence and deviation from approved field and lab protocols.

Evaluate your QA/QC data as follows:

- Sampler blanks: The concentration of the parameter being analyzed should not be detected in the blank sample at above the minimum detection limit.
- Field duplicates: Examine the results of these duplicates by calculating the relative percent difference (RPD) between the duplicate samples. The lower the RPD, the more precise the sampling performance.

  Calculate RPD using the following equation:
  RPD = (|Result 1 - Result 2|)/((Result 1 + Result 2)/2) x 100

To assist volunteer monitoring project managers with quality assurance review of datasets, Table 3 contains assessment variables and an expected maximum relative percent difference for each.

In addition to an analysis of the QA/QC data, you should also include in the Quality Assurance Assessment Report a discussion of error introduced by other factors such as sampling design (e.g., collecting too few samples or sampling over too short a time period), weather events while sampling, instrument performance issues, etc. Field notes are a valuable source of information for acknowledging and estimating additional sources of error in the monitoring results.

4. Data submittal

You can find information on submitting data for inclusion in the MPCA Water Quality Database (which the MPCA uses for assessments) on the MPCA's web site at ***http://www.pca.state.mn.us/data/eda/index.html***. Keep in mind that it is important to contact the MPCA when setting up a data management system (i.e., before beginning to enter data into a spreadsheet or database system) to ensure it is compatible with the Water Quality Database. This will minimize the steps that must be taken to load your data into the database at the end of the monitoring season or when the sampling effort is completed.

Before you enter data into the database, establish geographic and hydrographic identifiers for sampling locations. When a sampling location is established, identify the type of water body, such as lake, stream, wetland, well or treated effluent. Also, enter specific collection and lab methods associated with the data, and the results of QA/QC checks. This information allows potential users of your data to decide whether it meets their data quality objectives. See Section 5 of the Volunteer Monitoring Guide for additional information on submitting data to the Water Quality Database.

Table 3.
Water quality parameters and expected relative percent difference for use in CWA assessments.

Primary parameter	Supporting parameter	Maximum expected relative percent difference
Un-ionized ammonia		10%
Chloride		20%
Temperature		0.3° C
Dissolved oxygen (DO)		0.1 mg/L
pH		0.3 pH unit
Turbidity		30%
Fecal coliform		30%
Total phosphorus		30%
Chlorophyll-*a*		30%
Total suspended solids		30%
	Total Kjeldahl nitrogen	30%
	NO_2/NO_3 nitrogen	10%
	5-day biochemical oxygen demand (BOD_5)	30%

VI. Resources

1. *Standard Methods for the Examination of Water and Wastewater, 20th Edition,* 1998. (Note: This document is not available on-line (except through a paid service), but you can find it at college/university libraries and many state and local water management agencies).

2. USEPA, agency-wide quality system documents, ***http://www.epa.gov/quality/qa_docs.html***

3. *Water Analysis Handbook,* 4th Edition, 2002, Hach Company.

4. National Environmental Methods Index, ***http://www.nemi.gov***

5. U.S. Geological Survey, ***http://water.usgs.gov***

6. *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment 305(b) Report and 303(d) List,* Minnesota Pollution Control Agency, Environmental Outcomes Division, January 2003, ***http://www.pca.state.mn.us/publications/manuals/tmdl-guidancemanual.pdf***

7. *Field Manual for Water Quality Sampling,* ***http://www.ag.arizona.edu/AZWATER/publication/handbook/english/contents.html***

8. *Code of Federal Regulations, Title 40 – Protection of the Environment,* Chapter 1 – Environmental Protection Agency, Part 136 – Guidelines Establishing Test Procedures for the Analysis of Pollutants, ***http://www.access.gpo.gov/nara/cfr/cfrhtml_00/Title_40/40cfr136_00.html***

9. Minnesota Pollution Control Agency, Quality Assurance Program, ***http://www.pca.state.mn.us/programs/qa_p.html***

10. State of Washington, Dept. of Ecology, Water Quality Program, ***http://www.ecy.wa.gov/programs/wq/wqhome.html***

Appendix E:

Equipment and supply vendors[1]

Vendor	Phone/Fax/Web Site/E-mail
Apprise Technologies, Inc. 4802 Oneota St. Duluth, MN 55807	218-624-2800 218-624-3363 fax ***http://www.apprisetech.com*** ***http://appriseuv.com***
Ben Meadows Company PO Box 5277 Janesville, Wisconsin 53547-5277	800-241-6401 800-628-2068 fax ***http://www.benmeadows.com***
Bioquip 2321 Gladwick Street Rancho Dominquez, California 90220	310-324-0620 310-667-8808 fax ***http://www.bioquip.com***
Cabela's	800-237-4444 ***http://www.cabelas.com***
Carolina Biological Supply Company 2700 York Road Burlington, North Carolina 27215-3398	800-334-5551 ***http://www.carosci.com***
Fisher Scientific Fisher Science Education 4500 Turnberry Dr. Hanover Park, Illinois 60133	800-766-7000 800-955-0740 fax ***http://www.fishersci.com*** ***info@fisheredu.com***
Forestry Suppliers, Inc. PO Box 8397 Jackson, Mississippi 39201	601-354-3565 601-292-0165 fax ***http://www.forestry-suppliers.com*** ***fsi@forestry-suppliers.com*** catalog request
Hach Chemical Company PO Box 389 Loveland, Colorado 80539-0389	800-227-4224 970-669-0165 fax ***http://www.hach.com***
Hawkins Chemical, Inc. 3100 E. Hennepin Ave. Minneapolis, Minnesota 55420	612-331-6910
Hydrolab – Hach Company PO Box 389 Loveland, Colorado 80539-0389	800-949-3766 or 970-669-3050 970-461-3921 fax ***http://www.hydrolab.com***
Lamotte Company PO Box 329 802 Washington Avenue Chestertown, Maryland 21620	800-344-3100 410-778-6394 ***http://www.lamotte.com***
Lawrence Enterprises	207-276-5746
Water Monitoring Equipment and Supply Route 3 PO Box 344 Seal Harbor, Maine 04675	207-276-4058 fax
Tech Sales Company 8500 Pillsbury Avenue South Minneapolis, Minnesota 55420	612-888-1131 612-888-1333 fax ***info@techsalesco.com***
Twin City Bottle 1227 E. Hennepin Ave. Minneapolis, Minnesota 55420	612-331-8880
VRW Scientific	800-932-5000 ***http://www.vwrsp.com***
Wildlife Supply Company Buffalo, New York	800-799-8301 800-799-8115 ***http://www.wildco.com***
YSI Incorporated 1700/1725 Brannum Land Yellow Springs, Ohio 45387 (See Tech Sales for local Representative)	800-897-4151 or 937-767-7241 937-767-1058 ***http://www.ysi.com***

[1] List is not intended to be comprehensive. To have your company included in future editions, contact the MPCA.

Appendix F:

MPCA Water Quality Database
meta-data descriptions and requirements

Project information[1]

Meta-data element	Description	Why important	Required?
Project ID			
Project name	Name of the monitoring project	Identification	Yes
Project purpose	Reason why the monitoring is being done	To help data users understand appropriate uses for the data, and to provide context for the monitoring effort	Yes
Start date	When the project began	Understand timeframe and seasonality of the monitoring	Yes
Planned duration	Planned duration of the monitoing (i.e. 2 years, ongoing)	Context, expected length of record. Also helps answer completeness questions (e.g. Are all the data in? Are there related data?)	Yes
Lead organization name	The group that is coordinating the monitoring effort	In case a data user (or the person loading the data into the database) has questions	Yes
Project manager (with contact info.)	The individual that is coordinating the monitoring effort	In case a data user (or the person loading the data into the database) has questions	Yes
Data manager (with contact info.)	The person who manages the data for the project	In case a data user (or the person loading the data into the database) has questions	Yes, if different than the project manager
MPCA project contact	The MPCA staff person assisting with the project	In case a data user (or the person loading the data into the database) has questions	Yes, if applicable
Sampling personnel	Who is doing the sampling	Identify monitoring staff; comparability of results	No, optional
Sample medium	The nature of the sample (e.g., water, sediment, tissue)	Provides essential information about the sample	Yes

[1] This data only needs to be supplied once, when the project data is first submitted for inclusion in the database (or if there are changes).

Meta-data element	Description	Why important	Required?
Sample collection method(s) and gear(s)	The sampling methods used (grab sample, 0-2 meter integrated sample, etc.) and the gear used to collect the sample (integrated sampler, open bucket, etc.)	Understanding the methods used so the results can be properly interpreted; allows data user to decide if the methods fit with the user's objectives; also needed for comparability to other monitoring and reproducibility of the results	Yes
Field measurements - methods & instruments	The field measurement methods, and the instruments used (field meters, dry reagent kits, etc.)	Understanding the methods used so the results can be properly interpreted. allows data user to decide if the methods fit with the user's objectives; also needed for comparability to other monitoring and reproducibility of the results	Yes
Comments about data submission plans	A description of the project coordinator's plans for submitting data	Helps database coordinator understand project's intentions for submitting data (such as when, how often, in what format), and plan for data submission	Optional
Other info.: ■ Project Study Area ■ Design & sampling frequency ■ Programs associated with the Project ■ Cooperating Org.'s	Additional information about the monitoring project that can be stored in the database	Improves understanding about the project	Optional
QA plan summary/ reference	A brief summary of the project's Quality Assurance Project Plan, and information on where to obtain the full plan	The completion of and adherence to a project QAPP helps to ensure the sampling plan will meet the purpose; also helps data users understand what "the numbers" (sampling results) mean, and provides credibility to the monitoring effort	Required for data to be used for 305(b)/ 303(d); optional for all others

Laboratory establishment[1]

Meta-data element	Description	Why important	Required?
Lab ID	User-defined code for the lab	Quick way to identify lab, to be used when reporting sampling results	Yes
Laboratory name (w/ address, contact info.)	A unique name for the laboratory analyzing the samples	Clarity on who is doing the analysis; contact information in case there is a question	Yes, if applicable
Citation for lab. Manual or Handbook	Information about the manual/ handbook for the lab procedures and methods, including where/ how to obtain a copy	Understanding the methods and procedures followed so the results can be properly interpreted; allows data user to decide if the methods fit with the user's objectives; also needed for comparability to other data, reproducibility of the results, and confidence that the data is credible	Required for data to be used for 305(b)/ 303(d); optional for all others
For each type of analysis performed by the lab:			
Analyte name	Name of the parameter being measured	Identification	Yes
Sample fraction	Fraction associated with the analysis	Understanding and properly interpreting the results	Yes, as applicable

[1] This data only needs to be supplied once, when the project data is first submitted for inclusion in the database (or if there are changes).

Meta-data element	Description	Why important	Required?
Reporting units	Unit of measurement	Understanding and properly interpreting the results	Yes
Comparable standard method	Method number from *Standard Methods* that is comparable to the lab analysis method	Comparability	Yes (labs can provide this information)
Field preservation method	How the sample was preserved in the field following collection	Understanding and properly interpreting the results; confidence in the data; comparability	Yes, as applicable
Detection limit	The lowest concentration of a parameter that an analysis method can reliably measure	Understanding and properly interpreting the results; comparability; provides an indication of the quality of the method	Yes
Lab certified for analyte?	Has the lab been certified by the MN Department of Health for the particular parameter/ analytical method?	Certification provides confidence that the lab has met specific requirements to help ensure data quality	Yes/No question must be answered; lab data used for 305(b)/303(d) must be from a certified lab
Duration basis	Length of time of the analysis	Applicable to certain analytical methods that are time-dependent, such as the measurement of biochemical oxygen demand	Yes, as applicable
Temperature basis	The temperature at which the sample was maintained during analysis	Understanding and properly interpreting the results; comparability; provides an indication of whether quality control was properly maintained during analysis	Required for data to be used for 305(b)/ 303(d); optional for all others

Station information[2]

Meta-data element	Description	Why important	Required?
Project station ID	User-defined code for the sampling site. For lakes, this is the DNR lake ID	Quick way to identify station, to be used when reporting sampling results	Yes
Related station info.	Additional information about the station	Identification, understanding of the station	Optional
Station name	Stream station names and descriptions should follow this format as closely as possible: (Stream Name) AT (Road) (Distance) (Direction) OF (Nearest Town). Lake station names should follow this format: LAKE: (Lake Name) (Distance)(Direction) OF (Nearest Town)	Identification of the station	Yes

[2] This data only needs to be supplied once, the first time data is provided for a particular station/site.

Meta-data element	Description	Why important	Required?
Station type	Primary classification of the station – e.g., lake, river/stream, reservoir, storm sewer, etc.	Identification of the station; understanding and properly interpreting the results	Yes
Station description (including township, section, range)	Detailed description of the station location	Station location and identification; geographic location (i.e., latitude-longitude or UTM data) may not be specific enough.	Yes
Site ID	Unique and user-defined code for a sampling site within a lake station	Allows data users to identify and differentiate between multiple sampling sites within a single lake	Yes, for lakes
Ecoregion name	Which of the seven Minnesota ecoregions the station falls within	Station location and identification; understanding and interpreting the results	Optional
Travel directions	Narrative description of how to get to the station	Allows others to get to (and sample at) the same monitoring station, which promotes consistency and continuity of the monitoring record	Yes
Station latitude-longitude or UTM (x-y)	Geographic coordinates for the station	Allows precise location of the station on maps	Yes
Geo-positioning method	Method used for determining the geographic coordinates	Provides confidence in the geo-positioning data; allows data user to decide if the method meets the user's objectives	Yes
Datum	Reference site used in determining the geographic coordinates	Provides confidence in the geo-positioning data; reproducibility of the coordinates	Yes
Map scale	The map scale used if geo-positioning method is "Interpolation-map"	Provides confidence in the geo-positioning data; reproducibility of the coordinates.	Depends on geo-positioning method
Site lat-long	Latitude and longitude of lake sampling site	Allows data users to locate and differentiate between multiple sampling sites within a single lake	Yes, for lakes
State/county	State and county of the station	Location of the station	Yes
HUC code	The 8-digit hydrologic unit code (HUC code) for the station	Location of the station	Optional
RF1 river reach	Valid EPA RF1 reach number for the station	Location of the station	Optional

Monitoring results[3]

Meta-data element	Description	Why important	Required?
Station and site ID	Identifies exactly where the sample or measurement was taken	Location of monitoring event, understanding and interpreting results	Yes
Date	Date the sampling took place	Understanding and interpreting results	Yes

[3] This data is required every time data is submitted to the database.

Meta-data element	Description	Why important	Required?
Time	Time when the sampling occurred	Understanding and interpreting results	Required for data to be used for 305(b)/ 303(d); recommended for all others
Station ID	Database identification code for the sampling station	Location of the station that the results are associated with	Yes
Site ID	Database identification code for the sampling site within a lake sampling station	Location of the specific site within a lake that the results are associated with; allows users to differentiate between multiple sampling sites in the same lake	Yes, for lakes
Activity ID, type and category	Identifies whether the result is from a sample (grab, integrated, etc.), a field measurement, or a field quality control measure (duplicate, blank)	Understanding and interpreting results	Yes
Medium	The nature of the sample (e.g., water, sediment, tissue)	Provides essential information about the sample	Yes
Sample depth	Depth at which the sample was collected; for integrated samples, an upper and lower depth is reported	Understanding and interpreting results	Yes
Sampling personnel	Who collected the samples	Identity monitoring staff; comparability of results	Optional
Activity comments	Any comments made about the sampling event (such as information taken from the field notes)	Qualification of data; captures deviations from monitoring plan/QAPP; captures anomalies	Optional (but recommended)
Sample collection method and gear	The sampling methods used (grab sample, 0-2 meter integrated sample, etc.) and the gear used to collect the sample (integrated sampler, open bucket, etc.)	Understanding the methods used, so the results can be properly interpreted	Yes (for samples)
Sample preservation	How the sample was preserved in the field following collection	Understanding and properly interpreting the results; confidence in the data; comparability	Yes, for samples as applicable
Lab ID	Database identification code for the lab performing the analysis	Allows data user to go back and ask the lab questions if needed	Yes, as applicable
Lab sample ID	Unique identification code that lab used for the sample	Helps when communicating with the lab about a particular set of results	Optional
Lab certified?	Yes/No information as to whether the lab is certified for parameter and lab procedure at the time of analysis	Certification provides confidence that the lab has met specific requirements to help ensure data quality	Lab data used for 305(b)/303(d) must be from a certified lab
Results	Result from lab analysis or field measurement, including the units	This is the data that the monitoring is designed to generate. Units are necessary to understand the scale/magnitude of the results	Yes

Meta-data Element	Description	Why important	Required?
Field/lab ID	Valid database ID for the analytical procedure that was used to obtain the result	Understanding the methods and procedures followed so the results can be properly interpreted; allows data user to decide if the methods fit with the user's objectives; also needed for comparability to other data, reproducibility of the results, and confidence that the data is credible	Yes, as applicable
Lab sample temperature	Temperature of the sample at the time of lab analysis	Credibility of the data; helps to show that proper methods were followed	Required for data to be used for 305(b)/ 303(d); optional for all others
Remark codes	Comments about the results. Can include exceedence of holding times, QA/QC problems, deviation from established methods, etc.	Helps with understanding and interpreting the results	Yes, as needed

Appendix G:

Useful tools for monitoring

Tools/examples included (in order):

- A sample of lab analytical costs
- Conversion factors
- Example monitoring checklist
- Example field data sheets for stream, lake and biological monitoring
- Example QAPP completed for a volunteer monitoring program (Southern Red River Basin Surface Water Nutrient Loading Assessment Project)
- Sample of Monitoring Program Evaluation Form

Lab analytical costs

PARAMETER	PRICE OF ANALYSIS, PER SAMPLE[1]
Alkalinity, Total	$17.00
Ammonia Nitrogen, Total	$13.00
BOD, 5-day	$50.00
Chloride, Total	$11.00
Chlorophyll-*a* (phaeophytin corrected)	$35.00 (field filtered) $55.00 (lab filtered)
Fecal Coliform, MF	$33.00
Kjeldahl Nitrogen, Total	$27.00
Nitrate+Nitrite Nitrogen, Total	$10.00
Orthophosphate, Total	$16.00
Phosphorus, Total	$27.00 (0.01 mg/L detection limit) $33.00 (0.002 mg/L detection limit)
Suspended solids	$15.00
Turbidity	$13.00

[1]from 2003 MDH Environ. Lab Handbook

Lab analytical costs

The following table presents a sample of analytical costs for analyses performed by the Minnesota Department of Health's Environmental Laboratory. Note that costs at other labs may be slightly higher or lower than those presented here, depending on a variety of factors. This is included merely as a general guidance as to what to expect for certified lab analysis costs.

Conversions

As you enter and assess your data, it is sometimes necessary to transform the data from one unit to another. For example, you may take Secchi disk measurements in feet and later find that you need to translate them to meters to match with the data someone else has collected. The table on the next page provides conversions for common units used in water quality monitoring and analysis.

Examples:

All summer, you record Secchi disk measurements in feet. You later learn that the county also has transparency data for your lake from previous years, but the measurements are in meters. To change your measurements from feet to meters, you use the following equation:

Measurement in feet x conversion factor = Measurement in meters

Conversion factor (from table) = 0.3048

Your laboratory reports results in mg/L (ppm), but you'd like to compare those results to ecoregion reference values, which are reported in µg/L (ppb). To change your measurements, you use the following equation:

Result in mg/L x conversion factor = Result in µg/L
Conversion factor (from table) = 1000

Conversions

TO CONVERT "UNIT X"	TO "UNIT Y"	MULTIPLY VALUE IN UNIT X BY:
acres	hectares	0.4047
acre-feet	gallons	3.259×10^5
cubic feet/ second (cfs)	gallons/ minute	448.831
feet	meters	0.3048
gallons	liters	3.785
inches	centimeters	2.54
pounds	grams	453.5924
temperature in degrees F (°F)	temperature in degrees C (°C)	First subtract 32, then multiply by 5/9
milligrams/liter (mg/L or ppm – part per million)	micrograms per liter (µg/L or ppb – part per billion)	1000

Note: To perform the conversion in the reverse direction, multiply by (1/(the conversion factor)). For example, to convert from hectares to acres, multiply the value in hectares by (1/0.4047).

Note:

Keep in mind when converting between units that it is important not to report excess decimal places. Use the following rule of thumb: Look at all the values that were used in the calculation, and find the *measured* value with the fewest decimal places. The final answer should have that same number of decimal places. For example, if you measured Secchi disk transparency to the nearest tenth of a foot, after converting from feet to meters the final value should not have more than one decimal place (even though there are 4 decimal places in the conversion factor).

4.6 feet x 0.3048 (conversion factor) = 1.40208, which should be recorded as *1.4 meters*

Monitoring checklist

(example for lake monitoring)

The following example of a sampling checklist is from *Training Manual for the CLMP+ Program,* 2002.

Lake sampling equipment checklist

Below is a checklist of the equipment you'll need to bring with you IN the boat for sampling.

1. Sample bottles (one each):
   A. Nutrient plastic bottle for TP
   B. 2-liter plastic bottle for Chlorophyll-*a*
2. Sulfuric acid vial for preserving TP sample
3. Cooler (with ice provided by volunteer)
4. Integrated sampler
5. Secchi disk
6. Temperature Digital Depth Counter (Fish Hawk)
7. Lake map showing site locations, Site ID #, and MN Lake ID #
8. Watch – for recording the time of sampling
9. Permanent marker for writing on bottles
10. Ink pen
11. Field observation forms
12. Life jackets (State Law requires 1 for each person in the boat)
13. Oar or paddle in case of motor problems
14. Anchor - with rope length at least 1 1/2 times the depth at the deepest sampling site.
    Pontoon boats should carry extra rope and a second anchor to prevent sway.
15. Depth finder - optional
16. A 14-foot or larger boat is recommended with a properly matched motor. Pontoon boats work well but can be difficult to anchor in windy conditions.

Field data sheets

The following five pages contain example data sheets used for field data collection. Feel free to duplicate any of these data sheet and use them if they fit with your monitoring effort, or revise as needed for your project goals and objectives.

Example stream monitoring field sheet (p .1)

MINNESOTA POLLUTION CONTROL AGENCY / *STREAM* FIELD SHEET

FIELD INFO.	A	B	C	D	E
PROJECT ID*					
STORET ESTAB. STATION NUMBER					
FIELD CODE OR STREAM NAME*					
DATE (YYMMDD)					
TIME (military)					
SITE ID QA*					
TEMP °C					
CONDUCTIVITY @ 25 ° C (umho/cm)					
DO (mg/l) PH TURBIDITY, NTU					
W.L. GAGE (ft.)*					
W.L. GAGE TYPE*					
TRANSPARENCY* 60 cm tube (to the nearest cm)					
TRANSPARENCY* 100 cm tube (to the nearest cm)					
APPEARANCE*					
RECREAT. SUIT. *					
STREAM CONDITION*					
STREAM FLOW (cfs)*					
SAMPLING DEVICE*					
SAMPLE TYPE*					

* See back of sheet for additional instructions/information. Use codes listed on back to assure STORET entry.

FIELD OBSERVATIONS (station name/location, weather, ice condition, stream width, picture #, GPS file name, etc.)

A	
B	
C	
D	
E	

Revised 3/0

Example stream monitoring field sheet (p .2)

ADDITIONAL INSTRUCTIONS/INFORMATION (Stream Field Sheet p. 2)

PROJECT ID
Identify Project ID for sample collection (examples: MILE, UP_MISS, SWANTMDL). If project is not established, please fill out Project Establishment form.

FIELD CODE OR STREAM NAME
If this is an unestablished site and you want the site established and data entered in STORET, please supply us with GPS reading and station description/location. Note these in the field observation section and fill out Station Establishment forms.

QA: FD = Field Dup, SB = Sampler Blank, TB = Trip Blank, BB = Bottle Blank, RB = Reagent Blank

W.L. GAGE (ft.):
Water level, also called "stage", determined by reading a staff gage, recording gage, wire weight gage or by subtracting a tape down measurement to water level from a measuring point elevation. A description of the gage should be noted in "field observations", as well as any unusual conditions that affect the measurement (debris around the staff, wind catching the tape, standing waves, etc...)

W.L. GAGE TYPE	ABBREV.	DEFINITION
Tape Down	TD	Tape-down to water level subtracted from established measuring point elevation (describe in comments).
Staff Gage	S	Staff plate mounted vertically in stream.
Wire Weight	W	Weighted wire cable wound on a calibrated reel and attached to a box mounted on bridge.
Automated Stage Recorder	A	Automatic water level readout on an indoors instrument connected to water level sensor in or above stream.
Pool and/or Tailwater elev. (ie L&D)	P/TW	Pool (above dam) and tailwater (below dam) elevations, recorded in L&D station offices. (Record both; also record flow measurement if available).
Other	O	Describe in comments.

TRANSPARENCY READINGS

INSTRUCTIONS:
Make sure your back is to the sun when taking a measurement
Fill your tube until the symbol disappears
Release water until you can JUST make out the symbol. Note depth
Release a bit more water until the symbol is CLEARLY visible (can make out screw in middle of symbol). Note depth
Record the average of the two depths to the nearest centimeter
If the symbol is visible when the tube is full, record as ç>60cmé.

APPEARANCE:
1 = Clear – crystal, clear transparent water
2 = Milky – not quite clear, cloudy white or gray
3 – Foamy – naturalor from pollution
4 = Tea-colored – clear but tea-colored due to wetland or bog influences
5 = Muddy – cloudy brown due to high sediment levels
6 – Green – might indicate excess nutrients released into the stream
7 = Green <u>or</u> muddy & either extensive floating scum or strong foul odor

RECREATIONAL SUITABILITY:
1 = Beautiful, could not be better
2 – Very minor aesthetic problems: excellent for body-contact recreation.
3 = Body-contact recreation and aesthetic enjoyment slightly impaired
4 = Recreation potential and level of enjoyment of the stream substantially reduced (would not swim but boating/canoeing is okay)
5 – Swimming and aesthetic enjoyment of the stream nearly impossible

STREAM CONDITION
N=Normal, L=Low, H=High / SW=Swift, SL=Slow, MO=Moderate / C=Clear, M=Muddy, O=Other

STREAM FLOW (cfs)
Note in Field Observations if stream flow was determined by direct measurement, rating curve, L&D gate rating or other.

SAMPLING DEVICE

ABBREVIATION	STORET CONFIG ID	NAME
SIM	SIMPLE	Simple Open Plastic Bucket
ROD	ROD	Telescoping Rod with Bottle
ICE1	ICE 1	Ice Conditions Water Sampler (straight rod with bottle attached to lower through ice)
DI		Depth Integrating (USGS type)
WB	WEIGHTED	Weighted Bucket with Cover (aka triple sampler, "labline")
Other		Another type of sampler (describe in notes)
None		Sample collected directly into sample bottle
AS		Automatic Sampler

SAMPLE TYPE	ABBREVIATION	DEFINITION
Grab	G	Sampling vessel or bottle filled at one point in water column and cross section of a waterbody
Composite-F	CF	Flow-weighted with auto-sampler
Composite-M	CM	Samples from multiple locations on a waterbody, combined w/churn splitter (describe in comments)
Composite-O	CO	Composite Ö Other (describe in comments)

Example lake monitoring field sheet

Revised 3/03

Table 6.

MINNESOTA POLLUTION CONTROL AGENCY
PROFILE AND FIELD DATA SHEET

MDH FORM # 7

PROFILES

Lake Name				
Bul.25 Lake #				
[illegible] Site ID #				
** Date / Time	/		/	
[illegible] meters	*** [illegible] Temp °C	[illegible] D.O. mg/l	*** [illegible] Temp °C	[illegible] D.O. mg/l
0				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
12				
14				
16				
18				
20				
22				
24				
26				
28				
30				
[illegible] Lake Bot (M)		X		X

FIELD DATA

Site		
Secchi (M) [illegible]		
Conductivity [illegible]		
pH [illegible]		
Chlor *a* (Bottle#)		
*Chlor *a* (Filtered ml)		
Zooplankton (✓)		
Zoo. #Tows X M		
Phytoplankton (✓)		

* Data to be transferred to lab sheet
** Date / Time = (YYMMDD) / (Military)
*** Temp. to .5 °C, D.O. to .1 mg/l

OBSERVATIONS

Sampled by: ______________

Lake Elevation (ft): ________

SITES

1. WIND CONDITIONS:
DIRECTION: ________
APPROXIMATE SPEED: ________
SITES(101 ETC.) UPWIND: ____
DOWNWIND: ____

2. COLOR OF WATER: Green / Sediment / Stain / Clear

3a. PHYSICAL CONDITION: [illegible]
Crystal Clear (1)
Some Algae Present (2)
Definite Algae Present (3)
High Algal Color (4)
Severe Bloom (Odor, Scum) (5)

3b. SUITABILITY FOR RECREATION: [illegible]
Beautiful (1)
Minor Aesthetic Problem (2)
Swimming...Slightly Impaired (3)
No Swim...Boating OK (4)
No Aesthetics Possible (5)

4. LAKE USES OBSERVED: Swim / Ski / Fish / Sail or Boat

5. MACROPHYTE PROBLEMS:
Depth: ________
Inhibits: Navigation / Fishing / Swimming

6. ZOOPLANKTON (TOW):
No Zooplankton Present
Few Zooplankton Present
Abundant Large-Bodied Daphnia
Abundant Small Varieties

7. SHORELINE SOILS/GEOLOGY:
Sandy, Gravel, Rocks, Clay (Circle)
Erosion ____________ Access Problems ____________

FIELD OBSERVATIONS:

SAMPLE COLLECTION CHECK LIST

Site (s,m,b)	Time	Depth Sample	Depth Lake Bottom	Gen Chem	Nut.	Phyto

REVISED APRIL 1997

Example habitat assessment field sheet (p .1)

Habitat Assessment Field Data Sheet

Volunteer Stream Monitoring Partnership

SITE (include county)	SITE NUMBER

INVESTIGATOR	DATE	TIME

LOCAL COORDINATOR / ORGANIZATION	GPS	GPS COORDINATES
	☐ YES ☐ NO	

WEATHER

In past 24 hours:	Now:
☐ Storm (heavy rain)	☐ Storm (heavy rain)
☐ Rain (steady)	☐ Rain (steady)
☐ Showers (intermittent)	☐ Showers (intermittent)
☐ Overcast	☐ Overcast
☐ Clear/Sunny	☐ Clear/Sunny

TEMPERATURE READINGS (Take in the shade)

Water temperature: ________ Air temperature: ________

WATER APPEARANCE (check one)

☐ Clear ☐ Green ☐ Brown
☐ Blue-green ☐ Yellow ☐ Milky

WATER ODOR (check one)

☐ None ☐ Musty ☐ Septic
☐ Fishy ☐ Rotten eggs

LOCAL LAND USE

Land use in the local watershed within approx.1/4 mile of the site. Check all that apply. Circle the dominant feature.

☐ Residential	☐ Paved roads or bridges
☐ Commercial	☐ Unpaved roads
☐ Agricultural	☐ Construction
☐ Natural/Preserve	☐ Recreational use
☐ Lawns	☐ Industry
☐ Wooded	☐ Land fill
☐ Crop land	☐ Waste treatment plant
☐ Grazing land	☐ Evidence of past alteration
☐ Feed lot	

TYPE OF SAMPLING (check one)

☐ ROCKY BOTTOM

☐ MUDDY BOTTOM
Record the number of jabs taken in each habitat type:

Vegetated bank margins ________
Snags and logs ________
Aquatic vegetation beds ________
Silt/sand/gravel substrate ________

STREAM WIDTH

3 Measurements (in feet)

1 ________ Average Stream Width:
2 ________ ________
3 ________

STREAM DEPTH

Minimum of 10 measurements (in feet)

Measure the depth across the stream, from right bank to left bank in one-foot intervals for a minimum of 10 measurements.

1 ____	2 ____	3 ____	4 ____
5 ____	6 ____	7 ____	8 ____
9 ____	10 ____	11 ____	12 ____
13 ____	14 ____	15 ____	16 ____
17 ____	18 ____	19 ____	20 ____
21 ____	22 ____	23 ____	24 ____
25 ____	26 ____	27 ____	28 ____
29 ____	30 ____	31 ____	32 ____
33 ____	34 ____	35 ____	36 ____
37 ____	38 ____	39 ____	40 ____

NOTE: Conduct all habitat assessments IN THE FIELD. Complete all data sheets before leaving the site.

Example habitat assessment field sheet (p .2)

Habitat Assessment Field Data Sheet

SKETCH OF SITE

On your sketch, note features that affect stream habitat, such as: riffles, runs, pools, ditches, wetlands, dams, riprap, outfalls, tributaries, landscape features, vegetation, and roads. Include all pipes draining directly into the stream and indicate direction of flow.

Were photos taken?

FIELD NOTES

Include notable observations such as any major landscape changes (including construction projects, bridge projects, etc.) upstream or adjacent to your site.

Example vegetation survey field sheet

Minnesota Citizen Wetland Vegetation Survey Field Sheet

Observer: Site Name: Date:

Local Survey Sponsor (a city, county, wateshed etc.): Time: (circle: am or pm)

Releve dimensions (circle one): 10m x 10m or 5m x 20m = 100 meters ^{2}

Water depth in plot (meters): shallowest:__________meters deepest: _______meters

Describe any abrupt drop-offs or shelves on the wetland bottom in the Remarks section.

Is the releve typical of the entire wetland plant community? (circle one; if no explain in Remarks: yes no

Remarks

Sketch the location of your sample plot on the **Site Sketch Sheet form** or on the back of this sheet.

Please note: Numbers in ( ) refer to the metric(s) where the respective data is used.

CC	**FORBS** *(1, 5, 6, 7)*	Remarks
	Emergent/Erect *(1, 7)*	
	Submergent or Floating *(1, 6)*	
	Bladderwort (*Utricularia*) *(1, 5, 6)*	

CC	**GRASSLIKE** *(1, 3, 4, 7)*	Remarks
	Grasses & Rushes *(1, 3, 7)*	
	Sedges (*Carex*) *(1,3, 4)*	
	% Coverage for all *Carex* within the plot *(4)*:	

CC	**WOODY** *(1,6)*	Remarks
	Linear-leafed Willow :(include only those willows in water or right adjacent ot water so they always have ¢wet feet¢ *(6)*	

CC	**Mosses, lichens, algae & liverworts** *(2)*	Remarks

Comments:

Cover Value	**Cover class (CC) estimate**		**Selected Remarks Code**
5	75 – 100%	complete or nearly complete cover	DD dead
4	50 – 75%	large group, definitely more than 50% cover	DY dying
3	25 – 50%	small group of plants, near 50% cover	SP sprout/seedling
2	5 – 25%	plant is common in plot, more than 5% cover	IN insect damage
1	1 – 5 %	plant is established well, but minimal cover	LS leaf spots
0.5	< 1 %	plant is rare, insignificant cover	LD leaves discolored

QUALITY ASSURANCE PROJECT PLAN
for
Southern Red River Basin Surface Water Nutrient Loading Assessment Project

Prepared for:

Ms. Sarah Lehmann

EPA Monitoring Coordinator
USEPA, Region 5 Water Division
Water Quality Branch
77 W. Jackson Blvd. (WQ-16J)
Chicago, Ill 60604-3590

Prepared by:

Wayne R. Goeken

Monitoring Coordinator
Red River Watershed Management Board
RR 3, Box 75A
Erskine, MN 56535-9527

Sarah Lehmann
Project Manager, EPA

Tony Medrano
Quality Assurance Manager, EPA

Wayne Goeken
Red River Watershed Management Board Monitoring Coordinator

Wayne Anthofer
Director of Grants, Audits, and Procurement Program Office, EPA

Mike Vavricka
Data Quality Specialist, Minnesota Pollution Control Agency

August 2002

Example QAPP for project involving volunteer monitoring (p.2)

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DISTRIBUTION LIST

Name	Title/Affiliation	Address	Phone/e-mail
Wayne Goeken	Monitoring Coordinator, Red River Basin Monitoring Project	RR 3, Box 75A Erskine, MN 56535	218-574-2622 wrg@gvtel.com
Jon Roeschlein	Administrator, Bois de Sioux Watershed District	1002 Broadway Wheaton, MN 56296	320-563-4185 bdswd@traversenet.com
Bruce Albright	Administrator, Buffalo-Red Watershed District	PO Box 341 Barnesville, MN 56514	218-354-7710 brrwd@rrt.net
Michael Vavricka	MPCA Environmental Outcomes	714 Lake Ave Detroit Lakes, MN 56501	218-846-0494 michael.vavrika@pca.state.mn.us
Jack Frederick	MPCA Community & Area Wide	714 Lake Ave Detroit Lakes, MN 56501	218-846-7387 john.frederick@pca.state.mn.us
Molly MacGregor	Red River Basin Coordinator-MPCA	714 Lake Ave Detroit Lakes, MN 56501	218-547-3583 molly.macgregor@pca.state.mn.us
Sarah Lehmann	Project Manager, EPA Region 5	Chicago, Ill	312-353-4328 Lehmann.Sarah@epamail.epa.gov

GROUP A PROJECT MANAGEMENT

A4 PROJECT/TASK ORGANIZATION

Name	Project Title/Responsibility
Goeken	Project Manager
Vavricka	QA Officer
Goeken	Field Sampling Leader water quality
S. Lehmann	Lab Manager Leader

A5 PROBLEM DEFINITION/BACKGROUND

This project establishes a flow-weighted assessment of the Bois de Sioux, Buffalo-Red and Wild Rice River watersheds of the upper Red River Basin. These watersheds represent the main sources of the Red River of the North and provide drinking water for the cities of Fargo, N.D. and Moorhead, MN. Seventeen river reaches in these watersheds have been identified as impaired according to Section 303(D) of the Clean Water Act. Moreover, water quality monitoring information is extremely limited. This project uses existing resources from local government, including watershed districts, soil and water conservation districts, county planning and schools, to establish a locally based water quality monitoring network. Locals will establish sites, evaluate conditions and collect field samples of dissolved oxygen, conductivity, temperature and pH. They will also collect samples for lab analysis. This information will be used by local and state resource managers to establish trends, design water resource management project and evaluate the performance of mitigation measures.

The Bois de Sioux - Mustinka Rivers Watersheds represent an area of about 1,420 square miles, including areas of Traverse County (38% of the watershed), Grant County (27%), Wilkin County (14%), Stevens County (10%), Big Stone County (7%), and Otter Tail County (4%). The watershed includes the drainage basins of Lake Traverse and the Bois de Sioux River. Where the Bois de Sioux River and the Otter Tail River join is considered the headwaters of the Red River Basin. The major tributaries of the watershed include: the Mustinka River, numerous creeks in the south and east portions of the watershed, and the Rabbit River in the Northern portion of the watershed (described below).

Generally, the topography of the subbasin has little relief. A near-level glacial lake plain covers most of the western portion, and the eastern portion is characterized by gently rolling glaciated uplands. Between the rolling hills and the flat plain is the transition zone composed of a series of ridges with moderate slopes that are the former beach ridges of glacial Lake Agassiz.

Three different ecoregions are included in the watershed: The Red River Valley ecoregion, the Northern Glaciated Plains Ecoregion and the North Central Hardwood Forests ecoregion.

The Red River Valley ecoregion encompasses most of the watershed in the north, central and western portions of the watershed. The Northern Glaciated Plains ecoregion is found in the southern and eastern portion of the watershed. The northeastern portion of the watershed includes a small area of the North Central Hardwood Forests ecoregion.

The majority of glacial deposits in the watershed are till, made up of clay, silt, sand and gravel. Soils are predominantly black, limey and clayey in the central portion of the watershed, with black, loamy soils in the southwest and eastern portions of the watershed.

Historically, prairie/grassland (78%) and wetland (17%) were the dominant landcover types. As a result of the fertile soils that are present, land use and cover in the watershed is now dominated by cropland (88%), while prairie/grassland and wetlands provide only 2% and 4% of the current land cover, respectively. Land cover in the riparian areas (1,000 feet on either side of rivers) of the *watershed are mainly cultivated land (78%) and wetland (12%). Primarily to accommodate agriculture, the central portion of the watershed has been extensively drained.*

The Mustinka River is the largest tributary to the Bois de Sioux River. The Mustinka River sub-watershed comprises 850 squares miles (over one-half of the total area of Bois de Sioux Watershed). The Mustinka River sub-watershed itself occupies the upper most portion of the Red River Basin. The Mustinka River sub-watershed is typified by extremely flat gradients (with the exception of the glacial moraine portion in the east) which seldom exceed 0.5 feet or drop per mile. The soils within the watershed are generally heavy clays that when tilled are subject to wind and water erosion. The land use within the subwatershed is predominately agricultural. The Mustinka River and its watershed provide the largest portion of the hydraulic budget for Lake Traverse. Lake Traverse is a large reservoir (12th largest lake in Minnesota) which is management by the Army Corps of Engineers for flood control purposes. Water Quality sampling data collected in the mid 1990's as part of a Clean Water Partnership Phase I Diagnostic for the Lake study characterized Lake Traverse as a hyper-eutrophic lake with very high concentrations of total suspended solids and phosphorus. During that period inflows from the Mustinka River and its tributaries to the lake often exceeded concentrations of 250ug/l for phosphorus. Thus suggesting that inflows to Lake Traverse from the Mustinka River watershed system are leading contributors to the nutrification of the lake.

The main channel of the Bois de Sioux River was modified during the construction of the Reservation and White Rock Dams at Lake Traverse and Mud Lake to help improve the flow of water to the north. The Corps of Engineers built the Lake Traverse and Bois de Sioux River project from 1939 to 1941. It provided for use of Lake Traverse and Mud Lake as flood control and water conservation reservoirs and for channel modification in the river below the lakes (extending 24 miles below the main dam). In 1958, the Corps of Engineers completed a project on the Mustinka River near Wheaton, which consisted of 36.1 miles of straightening, clearing and enlarging of the Mustinka River and its tributaries.

The Bois de Sioux watershed contributes 58,200-acre feet to the Red River annually, less than 1 percent of the volume contributed from Minnesota tributaries. Flood damage is a major concern. Annual average flood damage (in 1996 dollars) in the watershed is estimated at $1,103,488 with 98% of the damages being rural. The Bois de Sioux watershed suffers 5.5% of flood damages occurring in the Red River Basin, outside of damages occurring along the main stem of the Red River.

The Bois de Sioux Watershed District oversees water management in the watershed, which has been in existence since 1988. Also, the U.S. Army Corps of Engineers oversees the operation of the outlet of Lake Traverse and is responsible for controlling lake levels.

The Rabbit River Watershed has a total drainage area of 320 square miles. It flows westerly from Upper Lightning Lake in SW Ottertail County, and Stony, Ash and Mud Lakes in NW Grant County. It has three major branches, from the northeast, from due east, a ditch from the Stony and Ash Lake area, and the South Fork which generally lies west of Highway 9; the northeast and east branches join just inside Wilkin County; the two main branches met west of Campbell. County Ditch Two flows north to the River east of Campbell and north of Tintah; Judicial Ditch 12 is a major tributary running parallel to Highway 9 and joining the main branch of the river, upstream of the South Fork, at Campbell. The drainage is very complex and it is difficult to discern the boundary between the Mustinkaës watershed to the south and the Otter Tailës to the north.

The 1994 stream water quality assessment for the Bois de Sioux subbasin showed the Rabbit River to be impaired. Non-point sources adversely affecting dissolved oxygen, ammonia, nitrogen, high pH, fecal coliform suspended solids, *nutrient levels, biological oxygen demand and agricultural chemicals are causing eutrophication, sedimentation, toxicity and turbidity.*

The survey reported the Mustinka River to be impaired. Local resource managers cited crop production, feedlots, livestock holding, agricultural chemicals, streambank modification, storm sewers, and urban runoff as causing oxygen depletion, eutrophication, bacterial contamination, sedimentation, and toxicity due to pesticides, turbidity, and habitat alteration.

The Buffalo River Watershed represents an area of about 1,189 square miles, including areas of Clay, Becker, Otter Tail and Wilkin Counties. It is the drainage basin of the headwaters of the Red River. The major tributaries of the watershed include the Buffalo River (and its tributaries, including the South Branch of the Buffalo River; and Whiskey, Deerhorn, Stoney and Hay Creeks) and Wolverton Creek -- both direct tributaries to the Red River. The Buffalo River originates in Tamarac Lake in Becker County.

The Whiskey Creek watershed drains an area of approximately 300 square miles lying exclusively in the lakebed region of the Red River Basin, characterized by level deposits of sediments up to 80 feet in thickness. This subwatershed is intensively drained by drainage ditches. The 1994 water quality assessment survey reported that crop production, livestock holding, and agricultural chemicals cause oxygen depletion, sedimentation and turbidity.

Two ecoregions comprise the watershed. The southern and western portion of the watershed lies in the Red River Valley ecoregion. The eastern portion of the basin lies in the North Central Hardwood Forest ecoregion.

Glacial deposits in the western portion of the watershed are glacial lake deposits of clay and silt from Glacial Lake Agassiz, and glacial lakeshore deposits of delta sand and gravel, along with areas of beach sand ridges separated by silty wetland depressions. The eastern portion of the watershed has primarily till glacial deposits made up of clay, silt, sand, gravel, cobble and boulders. Soils in the watershed vary moving from west to east from clayey soils of the lake plain at the mouth of the watershed, to black, limey, clayey soils; sandy soils; black, loamy soils; loamy soils and rolling wooded soils in the very uplands of the watershed.

Historic land cover in the watershed was primarily prairie/grassland (73%), wetland (14%), and forest (10%). Currently, the dominant land use is cropland (77%) with prairie/grassland having been reduced to 4% of land cover, wetlands having been reduced to 7%, and forests having been reduced to 6%. Land cover in the riparian areas (1,000 feet on either side of rivers) of rivers of the watershed is mainly cropland (67%) and wetland (15%). Primarily for agricultural purposes, wetlands have been extensively drained in the southern portion of the watershed.

A buried sand aquifer, the Buffalo aquifer, containing large amounts of ground water underlies the watershed near its mouth. Smaller quantities of ground water are available throughout the rest of the basin. An average of 2,700 acre-feet per year of ground water is pumped for municipal water supplies and crop irrigation. Ground water recharge occurs in the moraine area, while discharge occurs to the Red River, the Buffalo River and the glacial lake plain.

Nearly 300 streams miles assessed for aquatic life in 1996 found only 39 miles fully supporting aquatic life; 108 miles did not support aquatic life, and 120 miles were threatened or partially supported aquatic life. The MPCA assessed 152 stream miles for swimming in the same year and found that all monitored stream miles partially supported or did not support swimming.

Since much of the watershed lies in the Red River Valley, it is prone to flooding. Annual average flood damage (in 1996 dollars) in the watershed is estimated at $2,705,710 and is 99.5% rural damage. The watershed suffers 13.6% of flood damages occurring in the Red River Basin, outside of damages occurring along the main stem of the Red River.

The Buffalo River Watershed District oversees water management in the watershed, and has been in existence since 1960.

The Wild Rice River subbasin occupies 2080 square miles in portions of Norman, Mahnomen, Polk, Clearwater, Clay, and Becker Counties in northwestern Minnesota. The upland areas in the east are gently undulating to rugged and are covered by forests, grasslands, agriculture, and fairly large lakes. The uplands give way to an extensive beach ridge area that is mainly agricultural, but contains grassland, some lightly forested areas, and small lakes. Below the beach

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ridge is the flat plain of the Red River Valley, which is primarily agricultural. Elevations range from more than 1500 feet above sea level in the upland area to only 860 feet near the Red River of the North.

The Wild Rice River begins at Mud Lake above Lower Rice Lake in a rugged, heavily forested area of Clearwater County. It flows west through a series of Lake Agassiz beach ridges where it drops in elevation quite rapidly and then flows across the flat Lake Agassiz lake plain before it joins with the Red River of the North. Channel gradients change from drops in elevation of 10 to 30 feet per mile in the eastern portion to 1 to 2 feet per mile in the western portion. The other major tributary in the subbasin is the Marsh River, which originates just east of Ada, Minnesota. Channel changes, ditch improvements, and a diversion structure constructed at various times since the late 1800s have diverted part of the flow of the Wild Rice River to the Marsh River north and west of Ada. Some of the tributaries of the Wild Rice River are the White Earth River, Marsh Creek, South Branch Wild Rice River, Felton Ditch, Moccasin Creek, Spring Creek, Mashaug Creek, and Coon Creek. The major tributary to the Marsh River is the Spring Creek drainage area.

The 1994 water quality assessment reported that monitoring of the Wild Rice River from the mouth of Marsh Creek down to the mouth of the South Branch revealed use impairment. Nonpoint sources adversely affecting high pH, fecal coliform, suspended solids, ammonia, and nutrient levels result in nonsupport of aquatic life and overall uses and partial support of agriculture, wildlife, and swimming. The assessment survey reported impairment of the segment downstream from the South Branch confluence, on a small segment downstream from Lower Rice Lake and on both Marsh Creek and the Marsh River. The survey judged the segment of the Wild Rice River above Lower Rice Lake and from the downstream end of the short impaired segment through the City of Mahnomen to be threatened. Local resource managers cited crop production, pasture land use, feedlots, agricultural chemicals, septic systems, storm sewers, channelization, and dredging as causing oxygen depletion, sedimentation, toxicity, and turbidity. The survey also reported the White Earth River to have threatened quality. Local resource managers cited crop production, pasture land use, feedlots, livestock holding, agricultural chemicals, land development, septic systems, removal of riparian vegetation, and streambank modification as causing oxygen depletion, sedimentation, toxicity, and turbidity.

In 1999, the Wild Rice Watershed District (WRWD) published its Water Quality Management Plan. This plan was developed by dividing the watershed into fourteen river reaches that corresponded with major tributaries. Each subwatershed was evaluated using metrics or measures of water quality, including:

- *Potential sediment yield.*
- *Past exceedances of surface water quality standards.*
- *Past exceedances of fecal coliform bacteria standards for surface water.*
- *The presence of timber production.*
- *The percentage of land under cultivation.*
- *Estimated acreage with potential to be converted from permanent cover to cultivation.*
- *Index of biotic integrity.*
- *Stream stability and bank erosion.*
- *Feedlots.*
- *Presence of barriers to fish migration.*
- *Identified point sources.*
- *The condition of the stream riparian area.*
- *The condition of the drainage system riparian area.*

Data were gathered for each metric and totaled for each river reach. "Weight" or ranking assignments of low, medium, and high were identified for each metric, and the data were used to rank each river reach for implementation priorities based on the ranking assignments. A number of

specific strategies were then recommended to address problems found in subwatersheds. Implementation goals of this plan are:

- ***Understanding and making accessible existing water quality data.***
- ***Identifying specific regions and water resources within the basin that are of public concern.***
- ***Analyzing and interpreting the existing data and applying the results to the identified regions and water resources.***
- ***Prioritizing the regions and water resources based on existing data and levels of public concern.***

The WRWD is now developing a program of ambient water quality monitoring to develop a baseline of water quality for the subwatersheds of the Wild Rice Watershed and to evaluate progress in implementing and achieving the goals of the water quality management plan.

A6 PROJECT AND TASK DESCRIPTION

Red River Basin Water Monitoring Program personnel in conjunction with staff from the Bois de Sioux and Buffalo-Red Watershed Districts, Clay County SWCD, and teachers and students from the participating schools based in Climax, Hawley, Barnesville, Breckenridge, Campbell, Herman, Wheaton, and Graceville, will collect water samples once a month at a total of 40 sites located throughout the southern portion of the Red River Basin. Water samples will begin to be sent to the EPA Region V lab analytical laboratory in Chicago during the third week of August 2002 and continue through November of 2002. The samples will be packaged and shipped according to EPA standards to the EPA Region V lab for analysis of total phosphorus, ammonia, nitrate, total suspended solids and total dissolved solids. In addition, sampling personnel will collect and record ambient water quality information, including temperature, pH, dissolved oxygen (DO), turbidity, and conductivity during the course of the sampling period. In order to develop loading estimates from the various sources that will be sampled, flow data will be collected from existing USGS gaging stations where available. Flow will be calculated at those sampling sites for which there is no gaging station using velocity measurements in conjunction with the cross-sectional area of the stream through a defined structure, e.g., a culvert. Data generated by the project will be reviewed by the MPCA prior to being input into the national EPA STORET database. Project results will be incorporated into the water quality database being established for the Red River Basin. Table 1 provides a general milestone chart for the assessment.

TABLE 1. Project/Task Organization

Tasks	Aug	Sep	Oct	Nov	Dec
Personnel Training	x	x			
Collect Water Samples for EPA Analysis	x	x	x	□ x	
Conduct Ambient Water Quality Analysis (DO, temperature, conductivity, pH, general observations)	x	x	x	□ x	
Lab Analysis	x	x	x	□ x	
Data Review, Analysis, and Interpretation	xx	xxxx	xxxx	xxxx	xxxx

A7 QUALITY OBJECTIVES AND CRITERIA FOR MEASUREMENT DATA

This assessment is exploratory and will focus on evaluating baseline ambient water quality parameters and nutrient loads strategically by watershed and subwatershed in the Bois de Sioux, Otter Tail, Buffalo-Red, and Sand Hill watersheds with primary emphasis on sites in the Red River Valley ecoregion. Therefore, data quality objectives will be targeted as such. The data generated from this assessment will be treated as "screening" level data only. Data for all variables will be compared with historic data where available, to determine how well they agree with previous analytical techniques and results. One field duplicate sample and one field blank will be collected per 10 samples collected to evaluate field-sampling precision and quality control. For the 40 samples being collected this will equate into 4 sets of duplicate and field blanks collected per month which will be rotated equally among the eight schools involved in this monitoring program.

Water quality is an ongoing concern throughout the Red River Basin with special concerns in the southern portion of the basin due to a relative lack of current or historic water quality data from which to assess current conditions and base resource management decisions on. This nutrient assessment is intended to determine the relative contribution from subwatersheds of sediments and nutrients to the main stems of the Bois de Sioux, Otter Tail, Buffalo, and Sand Hill Rivers and, ultimately, these riverês like contributions to the Red River of the North. MPCA staff has established ecoregion expectations for water quality of the state (see Table 2 for ecoregion water quality expectations for northwest Minnesota). These expectations will be used, where they have been identified, to evaluate results of monitoring. One site in the southernmost portion of the project area being monitored by the Graceville school is in the Northern Glaciated Plains ecoregion with the other sites monitored by this school being on the border between the NGP ecoregion and the Red River Valley ecoregion. Otherwise all other sites being assessed by this monitoring program lie within the Red River Valley ecoregion. These two ecoregions are characterized as follows:

Red River Valley (RRV) Relatively flat; fine or clay soils dominate. Low population density. Heavily cultivated in small grains. Land use changes have increased suspended sediments (turbidity). Located in the western portion of watersheds throughout the Red River Basin.

Northern Glaciated Plains (NGP) Flat with silty soils; population density equals 19 people per square mile; agriculture is more than 83% of land use, predominately corn and soybeans; about 11% pasture and open land. Only found in the extreme southern tip of the Red River Basin.

TABLE 2. Northwest MN Ecoregion Water Quality Expectations (75percentile: 1970-85 Annual Avg)

Eco-region	Water Temp., C	Turbidity, NTU1	TSS mg/l	Conduc-tivity mS/cm	pH	Dissolved Oxygen mg/L	Ammonia N mg/L	Nitrate N mg/L	Total Phosphorus mg/L
NLF	17.5	4.3	6.4	270	7.9	5	0.2	0.09	0.052
NCH	20.0	8.5	16	340	8.1	5	0.21	0.28	0.170
RRV	19.8	23.0	56	655	8.3	5	0.29	0.20	0.322
NGP	20.5	23.5	65	1100	8.2	5	0.3	0.52	0.271
NMW	17.2	10.0	17	250	7.9	5	0.2	0.08	0.092

[1] Nephelometric turbidity unit.

Although there are no anticipated legal issues or requirements at stake concerning this nutrient assessment, the data collected will be used to establish baseline water quality conditions for the principal surface water courses. The parameters identified in the project task and description will be consistently sampled for the period of performance defined above. The completeness of this data set is expected to range from 80% to 90%. Laboratory precision and accuracy are addressed below, along with data acceptability levels.

A8 DOCUMENTATION AND RECORDS

This monitoring plan will be retained in the Red River Watershed Management Board' s Monitoring Coordinator' s office (RRWMB) and at the Detroit Lakes Regional MPCA Environmental Outcomes office. Water quality data will be transmitted to MPCA for review and entry into the national STORET database.

GROUP B – MEASUREMENT/DATA ACQUISITION

B1 SAMPLING PROCESS DESIGN

All samples to be collected for the Red River Mid-Basin surface water nutrient assessment will follow the EPA Region V Minimum Requirements for Field Sampling Activities (September 1996). Water samples will be collected for lab analysis of total phosphorus, ammonia N, nitrate N, TSS, and TDS. Field measurements will be taken for temperature, pH, DO, turbidity, and conductivity. Transparency tube and general site observations will also be recorded at all sites along with GPS coordinates if not already collected. Locations to be sampled and gaging status are identified in Table 3. Flow data will be collected from existing gaging stations where available. Flow will be calculated at those sampling sites for which there is no gaging station using velocity measurements in conjunction with the cross-sectional area of the stream through a defined structure, e.g., a culvert. These sampling sites were selected because of representativeness of the watershed or subwatershed and ease of access via bridges. Samples will be collected and velocity measurements taken at 60% of the depth below the surface at each sampling site to obtain a representative sample. Water depth and 60% depth will be determined by use of a weighted tape measure.

TABLE 3. Southern Red River Basin Sampling Site Locations and Descriptions

Site Name	Water Body	School	Site Location Description	Latitude	Longitude	Gaging
BdS 13	12 Mile Cr.-E.Fk	Graceville	2 miles S. of Dumont; 8.2 miles E			SG
BdS 19	12 Mile Cr.-W.Br	Graceville	2 miles S. of Dumont; 0.2 miles E			SG
BdS20	12 Mile Cr.-W.Br	Graceville	1.7 miles W. of Graceville			SG
BdS 18	12 Mile Cr.-W.Br-E.Fk	Graceville	2 miles S. of Dumont; 1.8 miles E			SG
BdS 15	12 Mile Cr.-W.Fk	Graceville	3 miles S. of Dumont; 4,7 miles E			SG
BdS 16	12 Mile Cr-E.Br	Wheaton	Approx. 3.4 miles E. of Dumont on CR 6			SG
BdS 5	12 Mile Cr-MS	Wheaton	Approx. 7.4 miles NE of Wheaton on CR 14			SG
BdS 34	12 Mile Cr-W.Br	Wheaton	Approx. 0.25 mile E. of Dumont on CR 6			SG
BdS 23	5 Mile Cr	Herman	Approx. 5.7 miles W. of Herman on MN 27			SG

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Tyler	Bois de Sioux R	Brecken-ridge	One mile S and E of Breckenridge on US 75; S 7.2 miles on CR 9; W .2 mile on CR 6	46.15194	-96.57980	MD
BdS26	Bois de Sioux R	Campbell	Bois de Sioux. Hwy 55 crossing 2 miles E. of Fairmount, ND			SG
BdS LkTr	Bois de Sioux R	Wheaton	MN 117 crossing at Reservoir Dam outlet(approx 8 miles SW of Wheaton)	45.76908	-96.63915	SG
BdSW RockN	Bois de Sioux R	Wheaton	8 miles N of Wheaton and 4 miles W on CR 16			SG & USGS
BufMN9	Buffalo R	Hawley	Bridge Xing on MN 9; 0.2 miles N. of Jct. MN 9 and US 10	46.87956	-96.50530	MD
Ceder-berg	Buffalo R	Hawley	Bridge Xing approx. .3 mile N of US 10 on east edge of Hawley(N of MnDOT shed)			USGS
Haw31	Buffalo R	Hawley	Bridge Xing of CR 31 S. of Hawley, approx. 1.4 miles S. of US 10	46.85590	-96.32318	MD
ManJct	Buffalo R	Hawley	2.5 miles E. of Hawley on US 10; 2 miles N. on MN 32; 0.6 miles E. on gravel road	46.90472	-96.24523	MD
Muskoda	Buffalo R	Hawley	4 miles W. of Hawley on US 10; approx. 1.2 miles S. on CR 23	46.85999	-96.40726	MD
BufDown	Buffalo R SB	Barnesville	S.Br.Buffalo R. Xing of Wilkin CR 11. Approx. 5 miles W and 4.2 miles S. of Barnesville	46.59995	-96.52991	MD
BufUp	Buffalo R SB	Barnesville	S.Br.Buffalo R. Xing of Twp road approx. 6 miles S and 3.8 miles W of Barnesville	46.57256	-96.50661	MD
BRD39	BufRed Ditch 39	Hawley	N. of Jct of MN 9 and US 10 on MN 9 for 7 miles; E. on CR 26 approx. .8 miles			MD
DeerH E	Deer Horn Cr.	Barnesville	Deerhorn Cr. Xing of Wilkin CR 52 approx. 6.5 miles SSE of Barnesville	46.57007	-96.37765	MD
DeerH W	Deer Horn Cr.	Barnesville	Deerhorn Cr. Xing of Twp road approx. 3 miles W and 5.5 miles S of Barnesville	46.57875	-96.48820	MD
BdS 11	Grant CD 8	Herman	Approx. 3.4 miles W of Herman on MN 27			SG
BdS30	Judicial Ditch 12	Campbell	JD 12 at Tintah. Sec. 3. 2nd St. Bridge			SG
BdS51	Judicial Ditch 2	Campbell	JD 2 Crossing of Hwy 55 2 miles east of Nashua			SG
BdS 01	Mustinka R	Herman	From Herman E. on MN 27 3/4 mile; N on CR 11-5 miles; E 4/N 1/E 0.4 on CR 8	47.19493	-96.58002	SG
BdS 33-PineRD	Mustinka R	Herman	From Herman E. on MN 27 3/4 mile; N on CR 11-4 miles; E 0.5 mile			SG
BdS28	Rabbit R.	Campbell	Rabbit R. 1.5 miles N of Campbell on MN 9. Sec 35, SW 1/4			SG
Brush-vale	Red R	Brecken-ridge	Approx. 7 miles N & W of Breckenridge on US 75 and one mile W. on CR 18			MD
Red 210By	Red R	Brecken-ridge	MN Hwy 210 Bypass Xing of Red River on north end of Breckenridge	46.28872	-96.59569	MD
Climax RR10	Red R	Climax	Bridge Xing over Red River approx 2.2 miles west of Climax	46.27435	-96.57995	MD
Climax Belt10	Sand Hill R	Climax	Bridge Xing over Sandhill R. on MN Hwy 9 1/2 mile S. of Beltrami	47.53543	-96.53131	MD
Climax CL 01	Sand Hill R	Climax	Bridge Xing over Sand Hill R. 3 miles east and one mile north of Nielsville	47.54271	-96.75067	MD
Climax CL10	Sand Hill R	Climax	Bridge Xing over Sandhill R. on Polk Co. 51(2.5 miles S. & 1.7 miles E. of Climax)	47.57146	-96.77965	MD
Climax CL15	Sand Hill R	Climax	Bridge Xing over Sand Hill R. on US Hwy 75 (north edge of Climax)	47.61209	-96.81482	USGS
Whisky E	Whisky Cr.	Barnesville	Whisky Creek Xing of Clay CR 25 approx. 2 miles E and 0.5 mile S of Barnesville	46.65261	-96.38337	MD
Whisky W	Whisky Cr.	Barnesville	Whisky Creek Xing of Clay CR 21: 5 miles W and 0.9 mile N of Barnesville	46.67302	-96.52583	MD
BufTrout	Wilkin CD 40	Barnesville	CoDitch 40 (Lawndale Spring) Xing of Wilkin CR 167 approx. 8 miles S of Barnesville	46.54306	-96.42480	MD

*Gaging: SG=staff gage; USGS=U.S. Geological Survey; MD=Measure Down

B2 SAMPLING METHODS REQUIREMENTS

Water quality samples will be collected using a Kemmerer or beta-bottle sampler. The sampler will be rinsed three times with the given source water before samples are taken. Clean 1-liter polyethylene bottles will be used as sample containers for shipment to the analytical laboratory. All samples will be preserved as necessary, tagged, and logged on EPA chain-of-custody forms. Table 4 outlines the necessary preservation techniques for each sample and also includes container types, analytical methods, reporting limits, and holding times. Field measurements, including water depth, pH, DO, temperature, conductivity, transparency tube, and site observations will be taken at each sampling location. The water temperature, pH, conductivity, and dissolved oxygen will be measured by use of a YSI 600QS multi-parameter probe. Turbidity will be measured by use of a Hach 2100P turbiditmeter. When necessary, stream velocity will be measured by a USGS Type AA current meter. Field measurements will be recorded on data sheets and placed in a field notebook, and probes will be rinsed with deionized water between sampling locations. Table 5 describes the quality control (QC) checks maintained for nutrient sampling.

TABLE 4. Parameters Analyzed from Wild Rice River Surface Nutrient Assessment Project

Parameter, units	Method	Container and Preservative	Holding Time	Required Reporting Limits
NH_3-N, mg N/L	EPA 350.1	1 L HDPE, H_2SO_4 to pH 2, 4°C	28 days	0.1 mg N/L
NO_3-N, mg N/L	EPA 353.2DNS	1 L HDPE, H_2SO_4 to pH 2, 4°C	28 days	0.05 mg N/L
P, mg/L	EPA 365.4	1 L HDPE, H_2SO_4 to pH 2, 4°C	28 days	0.05 mg P/L
TSS, mg/L	EPA 160.2NS	1 L HDPE, Unpreserved, 4°C	7 days	5 mg/L
TDS, mg/L	EPA 160.1	1 L HDPE, Unpreserved, 4°C	7 days	5 mg/L

TABLE 5. Quality Control Checks for Nutrient Samples

QC Check (Symbol)	Explanation	Run Frequency	Acceptance Criteria	Corrective Action
Quality Control Sample (ICV)[1]	Preferably out-of-house, critiqued standard or else a standard from different lot than calibration standards	Beginning of run to verify calibration	Historical data or 90%–110% of "true" value	Restandardize and rerun ICV
Continuing Calibration Verification (CCV)	Approximate midrange standard made from working standards stock	Every 20 samples and at end of run	Historical data or 90%–110% of "true" value	Restandardize and rerun all samples from last "acceptable" QC or check sample

Reagent Blank (RB)	Digested or extracted blank with same reagents as prepared unknown	Once per run	±PQL[2]	Investigate for contamination; if found, rerun all samples
Matrix Spike (SPK)	At historical area of interest	Every 20th sample, submitter designates sample for spiking	Historical limits or 80%–120% of expected value	Check for instrument drift, respike and retest
Duplicate Sample (DUP)	Either a field split or lab aliquot of previous sample	Same frequency as SPK	Historical limits or 20% RSD[3] for concentration	Check for instrument drift, noise, sample inhomogeneity, or contamination prior to repreparation

[1] Initial calibration verification.
[2] Practical quantitation limit.
[3] Relative standard deviation.

B3 SAMPLE-HANDLING AND CUSTODY REQUIREMENTS

Chain-of-custody procedures will follow those listed in the EPA Region V Central Research Laboratory (CRL) SOP. Wayne Goeken and/or a trained designee will be the field sample custodian and will keep records of all samples taken by field personnel. Sample bottles will be labeled with bottle number, site identification, date, and time; preservative added as needed; sealed tightly; and packed in ice at the sampling location. A chain-of-custody record including project name, samplerës signature, unique field station identification sample numbers, parameters for analysis, matrix, number and size of containers, date/time, and appropriate signatures will accompany all samples. All laboratory samples will be shipped to the EPA Region V CRL custodian within 48 hours of collection. Coolers containing samples that require ice preservation will be checked daily before shipping to ensure temperatures do not exceed 4ºC.

B4 ANALYTICAL METHODS REQUIREMENTS

Analytical methods for water samples are listed in Table 4. Methods for field measurement of pH, conductivity, temperature, turbidity, and DO will follow the EPA Chemistry Methods Manual, 1983; Standard Methods for the Examination of Water and Wastewater, 19th edition; or the EPA Region V Minimum Requirements for Field Sampling Activities, 1996.

B5 QUALITY CONTROL REQUIREMENTS

One field QC sample set for laboratory analyses, including a field blank for each sample type (unpreserved and H_2SO_4 preserved) and a grab sample duplicate, will be collected for every ten locations sampled following the grab sample collection protocol described in A7. The field blanks will be used to determine whether sampling procedures introduce contaminants in the field. Field duplicates for laboratory analyses will also be collected to determine whether duplicate grab samples produce consistent results.

Acceptance criteria for field QC samples will follow those for laboratory blanks (PQL) and duplicates (20% RSD). Laboratory personnel will notify the field sample custodian as soon as possible if field QC samples do not meet acceptance criteria. If QC samples reveal a sampling or analytical problem, field and laboratory personnel will troubleshoot the problem and attempt to identify the source of contamination or cause of failure. Upon working out a plausible solution, personnel will take necessary steps to ensure that similar problems do not arise during future sampling events. Data may need to be flagged and qualified depending upon the nature and extent of the contamination. Sarah Lehmann, EPA Region V, will assist in the review of QC data and implementing corrective measures if deemed necessary.

B6 INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE REQUIREMENTS

All equipment will be inspected and tested each day prior to use in the field. All pH probes will be checked prior to calibration for breaks or low fluid levels. Membranes on DO probes will also be inspected routinely for air bubbles. Steps will be taken to fix any problems that are noted. If any probes are beyond repair, replacement probes will be conditioned for use. Expired pH buffer solutions will be replaced with new solutions prior to the initiation of the field-sampling trip. Batteries on all meters will be replaced when meters show power-related problems. Every meter will have at least one backup available for use at all times if major problems should occur. All upkeep procedures will be documented in the meter maintenance logs or the field notebook. Global positioning system (GPS) readings will not be taken at sampling locations until signals from at least four satellites are received.

B7 INSTRUMENT CALIBRATION AND FREQUENCY

Instruments used in this project are those commonly used in most water quality studies and are widely available. Calibration of the instruments will follow manufacturers' instructions, and the calibration results will be recorded in the project log book. Electrodes for pH determinations will be calibrated with pH buffers bracketing the expected range of pH values of the ambient samples each day before tests are conducted. Thermometers used in the field will be checked with a standard calibrated thermometer that has been registered with the National Institute of Standards and Technology. Calibration of the multi-parameter YSI 600QS for pH, conductivity, and dissolved oxygen will be completed according to the manufacturer's recommended procedures prior to sample collection. The flow velocity meter consists of mechanical parts that do not require calibration. An initial calibration check will be performed prior to the first sampling event following manufacturer recommendations. If a National Geodetic Survey (NGS) benchmark is available, GPS readings will be taken at the benchmark and will be compared to the surveyed values documented on the benchmark disc.

The precision and accuracy for each laboratory parameter produced by the analytical laboratory will be determined according to the laboratory's SOPs and the EPA methods for chemical analysis of water and wastes. Precision for field measurements of pH, DO, conductivity, and temperature will be determined from statistical analysis of triplicate data collection. Accuracy expressed as maximum error by instrument manufacturers is 0.2 for pH, 0.2 mg/L DO, 0.5% for conductivity, and 0.15 C for temperature. Precision will be determined from statistical analysis of triplicate data collection.

Calibration procedures for nutrient analyses will be conducted according to manufacturer's specifications and SOPs developed by the EPA Region V laboratory. Tables 4 and 5 list the QC protocols to be followed for all laboratory analyses.

GROUP C – ASSESSMENT/OVERSIGHT

C1 ASSESSMENT AND RESPONSE ACTIONS

Wayne Goeken, RRWMB, will be responsible for all field activities, reviewing the data, reporting to the group on findings, and forwarding all data to the appropriate state regulatory agency for inspection and input into STORET. He will oversee and assess field sampling and data collection activities a minimum of two times during the project duration to make sure that the samplers are following the QAPP and all standard procedures and quality control activities. Expected oversight dates are the initial sampling event and another event four to six weeks later. The EPA Project Officer and the EPA QA Staff are also authorized to oversee the field and laboratory activities during the period of this project.

C2 REPORTS

A draft report of the Southern Red River Basin (Minnesota) findings will be prepared for the RRWMB and shared with all involved watershed districts, local resource managers, and other involved parties.

GROUP D – DATA VALIDATION AND USABILITY

D1/D2 DATA VERIFICATION REQUIREMENTS AND USABILITY

All laboratory analytical results will be cross-checked against the field notebook, sample tags, and chain-of-custody documents to ensure that the raw, computer-generated summary of the laboratory analyses were correctly assigned to the corresponding sampling stations. All analytical results will be compared to the chain-of-custody documents to ensure that the data are complete. Laboratory QC data will be reviewed for all data to ensure that those data are usable. If any of the data are found outside of the QC limits identified in Tables 4 and 5, reanalysis of the samples may be requested.

Field data and field QC sample sets will be reviewed by Wayne Goeken, RRWMB, and Mike Vavricka, MPCA, to determine if data meet the QAPP objectives. In addition, Sarah Lehmann, EPA Region V, will assist in the data review. Data found outside of the QC limits identified in B5 may be flagged or rejected. Decisions to reject or qualify data will be made by Goeken and Vavricka.

D3 RECONCILIATION WITH DATA QUALITY OBJECTIVES

Within 48 hours of receipt of results of each sampling event, calculations and determinations for precision, completeness, and accuracy will be made and corrective action implemented, if needed. If data quality indicators do not meet project specifications, data may be discarded and resampling may occur. The cause of failure will be evaluated. If the cause is found to be equipment failure, calibration/maintenance techniques will be reassessed and improved. If the problem is found to be sampling team error, team members will be retrained. Any limitations on data use will be detailed in any project-related reports and other documentation, as needed.

Sample Program Evaluation form*

Please rate how well you feel your group is doing for each item by circling the appropriate number:

Organizational Health

Clear statement of purpose and objectives

poor -great
1-------2--------3--------4-------5

A written monitoring design to achieve the goals written down and agreed upon by all leaders

poor -great
1-------2--------3--------4-------5

A multiple year budget

poor -great
1-------2--------3--------4-------5

The monitoring component is related to the activities of the group or organization as a whole

poor -great
1-------2--------3--------4-------5

The program is evaluated annually and the work for the coming year adjusted accordingly

poor -great
1-------2--------3--------4-------5

A good mix of funding from various sources

poor -great
1-------2--------3--------4-------5

Clear financial management (clear, monthly financial statements, bookkeeper)

poor -great
1-------2--------3--------4-------5

Strong organizational leadership

poor -great
1-------2--------3--------4-------5

Example QAPP for project involving volunteer monitoring (p.16)

Page 2

Active board or advisory committee
poor -great
1-------2--------3--------4-------5

Clear staff and volunteer job descriptions
poor -great
1-------2--------3--------4-------5

Overall organizational health
poor -great
1-------2--------3--------4-------5

Community Support, Outreach, and Involvement

Collaborative partnerships and networking (a broad base of groups, business, schools, agencies, individuals)
poor -great
1-------2--------3--------4-------5

Good working relationship with local decision makers
poor -great
1-------2--------3--------4-------5

Are visible in the community
poor -great
1-------2--------3--------4-------5

Cultivates and receives media coverage
poor -great
1-------2--------3--------4-------5

Have committed volunteers, with low turnover rates
poor -great
1-------2--------3--------4-------5

Provides effective support and training for volunteers (recognition, training, opportunities for advancement, feedback)
poor -great
1-------2--------3--------4-------5

Have a process for cultivating and training people for leadership roles
poor -great
1-------2--------3--------4-------5

Overall effectiveness of community outreach
poor -great
1-------2--------3--------4-------5

Example QAPP for project involving volunteer monitoring (p.17)

Monitoring Program

Do you have a technical advisory committee? (Y/N):_____. If so, how helpful has it been to your monitoring program?

poor -great
1-------2--------3--------4-------5

How well is the monitoring program integrated into other programs of your organization?

poor -great
1-------2--------3--------4-------5

Written study design that is used

poor -great
1-------2--------3--------4-------5

QA/QC plan approved by data users

poor -great
1-------2--------3--------4-------5

Clear, written manual for volunteers and training

poor -great
1-------2--------3--------4-------5

Clear data quality goals and users

poor -great
1-------2--------3--------4-------5

Good data management and reporting system

poor -great
1-------2--------3--------4-------5

Identified target users and uses for data

poor -great
1-------2--------3--------4-------5

Consistently meet data quality goals and requirements set forth in a QA Plan

poor -great
1-------2--------3--------4-------5

Involved local and regional resource people in data interpretation

poor -great
1-------2--------3--------4-------5

Presented data to interested parties and target users

poor -great
1-------2--------3--------4-------5

Target users accepted and used the data

poor -great
1-------2--------3--------4-------5

Example QAPP for project involving volunteer monitoring (p.18)

Target users or your group used data to identify problems

poor -great

1-------2--------3--------4-------5

Target users or your group used data to identify actions or policy changes to solve problems

poor -great

1-------2--------3--------4-------5

Target users or your group used data to evaluate the effectiveness of actions or policy changes

poor -great

1-------2--------3--------4-------5

Made strides in achieving watershed improvement and program goals

poor -great

1-------2--------3--------4-------5

Impact on community

poor -great

1-------2--------3--------4-------5

Progress towards stated goals-vision

poor -great

1-------2--------3--------4-------5

Overall effectiveness of monitoring program

poor -great

1-------2--------3--------4-------5

Please describe any changes you are planning in your monitoring program within the next two years. For any areas above that you rated as a 3 or less, which ones would you like to address?

Appendix H:

Examples of local data use

One question that volunteers often ask is how to get local government and other groups to use the data they have generated. Often the stumbling block for use of volunteer monitoring data – or any monitoring data – is the comfort level the data user has with the quality of the data. Section 3 of the Guide includes some considerations for working through data quality questions with your primary data user. In addition, the following examples illustrate how three Minnesota groups worked through data quality issues to facilitate local use of their data.

As you read these examples, keep in mind that there is no one magic formula you can employ to ensure that your data will be used for local decision-making. However, by clearly identifying your monitoring purpose, talking through data quality questions with your primary data users and sharing examples from other parts of the state, you will be well on your way to ensuring yourself and your data users that the data you generate will be useable for the intended purpose.

Morrison County water monitoring built on trust

When Morrison County completed its water plan and began a monitoring program, there was little discussion about data quality. This was because a member of the water planning committee who had experience and was trusted was implementing the monitoring program. Even though there was not much discussion, there is a strong emphasis on data quality and making sure the data users understand the intended purpose of the data. This emphasis on data quality is very important, since trust in the individual doing the work is based on relationships, while continued credibility of the data is a function of the quality control efforts. Through these efforts, trust in the people involved and the data quality is continually reinforced.

Efforts to assure data quality and reinforce trust involved two elements:

1) Using basic quality assurance /quality control (QA/QC) procedures
2) Reporting

Basic QA/QC procedures varied by project but generally included:

1) Split samples analyzed major parameters for comparison with backup laboratories (i.e., certified or university laboratories) at a 5 to 10% frequency
2) Split samples with other neighboring community programs
3) Spiked samples
4) Analysis of known standards
5) Field blanks
6) Duplicate samples

The last two are generally completed on >10% of samples for nitrogen and phosphorus.

Reporting included efforts to define the monitoring purpose, present quality control methods and the sample collection and analytical methods. Reports include a page on the quality control methods used, and a page describing how each parameter was analyzed. In this manner, data users have information they need to make informed decisions about whether the data meets their data quality needs.

Source: Wayne Pikal, Aqua Tech

Big Birch Lake: highlighting public/private partnerships

The Big Birch Lake project is an example of homeowner initiative and commitment, coupled with extensive benefits received from leveraging public and private partnerships.

Big Birch Lake is located in west central Minnesota. Approximately half of the lake is in Todd County and half in Stearns County. It is made up of two large basins with a watershed of approximately 9600 acres. It has experienced decreasing water clarity and increased areas of submerged aquatic vegetation since the early 1970s. In response to these problems, in 1985 the Big Birch Lake Association (BBLA), an organization of Big Birch Lake shoreland property owners, began participating in the CLMP (Citizens Lake Monitoring Program).

As part of this program, the CLMP participants were required to take weekly transparency measurement readings and record their perceptions of the physical appearance and recreational suitability of Birch Lake during the summer months. The BBLA monitored three sites in the Upper Basin and four in the Lower Basin. Secchi disk readings indicated a decline in water clarity from 1989-91, so the BBLA petitioned the Sauk River Watershed District (SRWD) for funding to complete an independent diagnostic/feasibility study of the lake. A Phase I Diagnostic Study was initiated in 1993.

Phase I

The purpose of the Phase I Diagnostic Study was:

- to monitor lake conditions during 1993
- to assess the hydrologic and nutrient budgets for the lake
- to identify problems within the lake and watershed contributing to the degradation of the lake
- to identify feasible management options to improve or protect the current lake conditions

Water quality samples were collected from three in-lake sampling locations around Big Birch Lake during summer 1993. A survey was taken of aquatic plants in the lake. The study included flow monitoring of four tributary streams that included water quality analysis, a survey of septic systems around the lake and an assessment of the current land use in the watershed. Barr Engineering, who did the sampling, sampled monthly during the open water season, testing for: total phosphorus, ortho phosphorus, chlorophyll-*a*, pH, temperature, total Kjeldahl nitrogen, nitrates, nitrites and total suspended solids. Barr developed a Quality Assurance Project Plan (QAPP) and provided strong quality control and analysis.

The study, completed in 1994, documented that Big Birch Lake experienced declining transparency. It was determined that the high phosphorus loading from Fish Creek tributary resulted from land use in the watershed, primarily agricultural activities located between Goose Lake and Big Birch Lake. Fish Creek had the highest pollutant discharge and the poorest water quality of inflows to Big Birch Lake. It was also determined that 45% of the nutrients to Fish Creek were coming from a few feedlots.

Phase II

The Sauk River Watershed District then applied for a Phase II Clean Water Partnership grant that was awarded with limited grant money but a large low-interest loan component. As part of Phase II, more than 10 cooperating federal, state and local units of government, citizen organizations and individuals sought to maintain and improve (if possible) water quality by reducing the impacts of non-point source pollution.

To accomplish this, each month the Sauk River Watershed District monitored two sites in the Upper Basin and one site in the Lower Basin and took the samples to a certified lab. For the first two years, a six foot profile and bottom samples were taken. The next year, a hyrdoprobe with a complete profile was completed. For the Phase II project, samples were tested for: chlorophyll-*a,* total phosphorus, ortho phosphorus, total suspended solids, chloride, nitrates, nitrites, total Kjehdahl nitrogen, ammonia, dissolved oxygen, pH and transparency. A QAPP was created.

Data was written in a waterproof field book with indelible ink and the date, temperature and depth of where the sample was taken was included. Samples were sent to a certified lab. The MPCA supplied the total phosphorus standards that were sent to the lab for quality assurance/quality control (QA/QC). Blind samples were sent into the MPCA and periodically, double blinds were included. The monitoring complied with the MPCA's monitoring requirements for 305(b) and 303(d) Assessments.

Phase II Implementation

In order to maintain and improve water quality (the goal of Phase II), strong action was taken to minimize pollution from feedlots and septic systems and minimize shoreline erosion.

A full subwatershed feedlot evaluation was completed in 1994 that included 18 feedlot sites. Four sites were identified as the largest contributors to phosphorus loading to the lake. The SRWD offered the feedlot owners matching funds that resulted in the owners' action to mitigate the runoff from the feedlots. The study also determined that septic systems contributed approximately 10% of the total phosphorus load and funds were provided that ultimately resulted in 98% environmentally compliant septic systems.

In order to enhance water clarity, the Big Birch Lake Association and the Sauk River Watershed District wanted to install vegetative buffer strips along ditches and along Fish Creek. When CRP funds proved too restrictive for the landowners, the BBLA created an innovative program that resulted in buffering 13.94 acres along the lower reaches of Fish Creek.

Ongoing

The BBLA provided funding to the SRWD for monthly lake sampling and tributary sampling for low flows and rain after the Phase II funds were depleted. The SRWD was awarded a second Phase II (EPA 319) grant in 2001 to continue the monitoring program and to address land use practices in the Bass Creek sub-watershed and shoreland BMPs. There are about 11-15 samples taken per year and results are sent to the MPCA.

Source: Sauk River Watershed District

Red River Basin River Watch: focusing on data quality

The Red River Basin River Watch program is another example of the use and acceptance of volunteer monitoring data. With the support of a Minnesota Board of Water and Soil Resources Challenge Grant, the Red River Basin River Watch (RRBRW) program began in 1995 with the participation of four schools on the Sand Hill River. The program has grown to involve more than 30 schools monitoring 148 sites on 53 rivers, streams, creeks and major drainage ditches throughout northwest Minnesota.

Program began with need for baseline data

The genesis of the RRBRW program is a great example of "need meeting opportunity". In the early 1990s, the Sand Hill Watershed District (SHWD) tried unsuccessfully to undertake a major water project in the watershed. According to Wayne Goeken, River Watch coordinator, a key stumbling block was a lack of baseline data to support the application for necessary permits. This experience alerted the SHWD managers of the importance of baseline monitoring data.

At the time of the unsuccessful water project, Wayne was working as the SHWD's part-time secretary. He heard about the efforts of the Mississippi River Headwaters and saw an opportunity to gather baseline data and raise residents' awareness of water quality issues. The Mississippi River Headwaters Board staff helped him sort through the monitoring purpose and goals, and they also provided initial training. Support from the SHWD managers (who saw the program as a means of obtaining the baseline data they needed for future projects) and the BWSR Challenge Grant provided the other elements needed to create the Red River Basin River Watch program.

The program was developed with two specific goals in mind:

1. To develop a baseline of data using standard scientific methods to generate reliable, quality data that is comparable between sampling organizations and rivers
2. To provide students and citizens with hands-on opportunities that will foster a greater awareness and understanding of their local watersheds and the Red River Basin in general

Considerable thought went into developing the program so it would allow its goals to be met, forethought that was extended into program implementation. As the effort is extended to additional watersheds in the Red River Basin, specific monitoring goals are set. Most often these involve providing baseline data and education/awareness opportunities for the youth of the watershed. Ongoing input is also sought from local resource professionals to help design individual sampling efforts and ensure data quality.

The program

Monitoring sites are selected in consultation with local watershed district and soil and water conservation district managers to represent different reaches of rivers and tributaries. Schools conduct monthly monitoring of three to seven sites, generally from April or May through October or November. Students take a variety of field measurements (including air and water temperature, conductivity, dissolved oxygen, pH, turbidity, river depth and width) and record general observations of vegetation and other conditions in the watershed that could influence water quality. During these monthly sample runs, water samples are also collected and sent to a certified lab for analysis of total phosphorus, nitrate+nitrite nitrogen and total suspended solids.

Focus on data quality

Assuring data quality is an important part of this effort, as the program receives considerable funding from local watershed districts that want to use the data to understand local conditions and guide their management efforts. According to Goeken, the goal of meeting watershed district data needs is one reason why the River Watch program places a strong emphasis on data quality and the collection of scientifically sound data. This commitment was reflected in the development of a Quality Assurance Project Plan (QAPP) for this effort and its approval by the USEPA Ongoing attention is also paid to ensuring data quality. All participants are trained in proper methods and a strong emphasis is placed on the hands-on participation of professionals along with the student monitors.

Historically, students collected water samples and performed the chemical analyses in the classroom. More recently, the program has moved towards the use of field meters and contract laboratories certified by the Minnesota Department of Health. This shift from student analysis to the use of certified labs was made because of the efficiencies this allows and to improve decision-makers confidence in the data and encourage its use in water quality management efforts.

Data is managed through a combination of centralized coordination and individual school efforts. The Red River Watershed Management Board maintains a master data set of all the results, which are entered into an Excel spreadsheet and returned to the participating schools for review and analysis. This allows the Board to ensure proper entry and also make adjustments necessary for more thorough statistical analysis. The data are also submitted to the MPCA for inclusion in the statewide Water Quality Database. Future plans involve creating an Access database and posting the data on two Red River Basin web sites to allow for wider access. The web sites will include interactive maps of the sampling sites, background information, monitoring data and a report card on site conditions. Some schools also maintain their own web pages that include their data along with photos of the sites and their sampling teams in action.

Local data use

Watershed district officials accept the data because they are aware of the effort that went into assuring sound science and they have confidence that the written Standard Operating Procedures, quality assurance documents and training materials developed for this program are being followed. They have also received assurances from state agencies (such as the MPCA) that the methods being followed represent sound scientific practices and are usable for watershed management decisions. As more samples are analyzed, the resulting data provide a basis of comparison for students and local resource managers, a means of beginning to assess the health of their rivers and contributing watersheds. For example, River Watch monitoring results help provide baseline information useful in assessing flood damage reduction projects being advanced in the region.

As the program evolves and builds on its premise of "sound science and citizen involvement," partnerships are strengthening at the local level. As results of initial baseline watershed monitoring are analyzed, more directed research partnerships are emerging between local resource managers and school districts to better understand specific local conditions. On a much broader scale, efforts are underway to raise awareness of how local conditions are connected to the health of the Red River Basin in total as monitoring and education linkages are being made with North Dakota and Manitoba schools and resource managers.

Source: Wayne Goeken, Red River Basin River Watch

Appendix I:

Acronyms, abbreviations and symbols

BWSR	Board of Water and Soil Resources
CAMP	Citizen-Assisted Monitoring Program (through Metropolitan Council)
CLMP	Citizens Lake Monitoring Program
CSMP	Citizens Stream Monitoring Program
CWA	Clean Water Act
CWP	Clean Water Partnership
DNR	Department of Natural Resources
DO	Dissolved Oxygen
DQOs	Data Quality Objectives
EIMS	Metropolitan Council's Environmental Information System (also known as Environmental Data Warehouse)
EPT	Ephemeroptera, Plecoptera, Tricoptera
GIS	Geographic Information System
GPS	Global Positioning System
IBI	Index of Biotic Integrity
L	Liter
LCMR	Legislative Commission on Minnesota Resources
LGU	Local Government Unit
MAWD	Minnesota Association of Watershed Districts
MCES	Metropolitan Council Environmental Services
µg	microgram
mg	milligram
MPCA	Minnesota Pollution Control Agency
MRBDC	Minnesota River Basin Data Center
NCHF	North Central Hardwood Forest Ecoregion
NGP	Northern Glaciated Plains Ecoregion
NLF	Northern Lakes and Forests Ecoregion
ppb	parts per billion
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
QMH	Qualitative Multi-Habitat
RPD	Relative Percent Difference
SOPs	Standard Operating Procedures
STORET	EPA water quality data STOrage and RETrival system
SWCD	Soil and Water Conservation District
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSI	Carlson's Trophic State Index
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
USGS	U.S. Geological Survey
VSMP	Volunteer Stream Monitoring Partnership
WCBP	Western Corn Belt Plain Ecoregion
WHEP	Dakota County Wetland Health Evaluation Project
$\geq$	Greater than or equal to
$\leq$	Less than or equal to

Appendix J:

Glossary

303(d). Part of the *Clean Water Act.* If monitoring and assessment indicate that for some uses and/or parameters, a water body or segment is not meeting water quality standards, then that water is considered "impaired" and goes on a special list called the "303(d) list," named after the section of the *Clean Water Act* that calls upon states, approved tribes, and territories to create such lists.

305(b). Part of the *Clean Water Act.* Refers to a required national water quality inventory that provides information on which pollutants (chemicals, sediments, nutrients, metals, temperature, pH) and other stressors (altered flows, modification of the stream channel, introduction of exotic invasive species) are the most common causes of impairment to water bodies and what are the most common sources of those stressors.

Accuracy. A data quality indicator that shows the extent of agreement between an observed value (the sample) and the accepted, or *true, value* of the parameter being measured.

Algae. Microscopic organisms/aquatic plants that use sunlight as an energy source.

Algal bloom. Population explosion of algae in surface waters due to an increase in plant nutrients such as nitrates and phosphates.

Alkalinity. Capacity of a lake to neutralize acid.

Analyte. A property or substance to be measured, such as pH, dissolved oxygen, bacteria and heavy metals.

Bacteria. The overall recreational value of a surface water body (river, stream or lake) can be measured partially by its suitability for swimming (all water contact activities) as determined by the presence of fecal coliform bacteria. These bacteria are found in the wastes of warm-blooded animals, such as people, dogs, cattle, etc. Bacteria levels with a monthly average below 200 bacteria colonies/100 ml of water are generally considered safe for human contact.

Benthic. Refers to being on the bottom of a lake. **Benthic fauna** are organisms attached to or resting on the bottom or living in the bottom sediments of a water body.

Biological monitoring (or biomonitoring). The use of a biological entity as a detector and its response as a measure to determine environmental conditions. Toxicity tests and biological surveys are common biomonitoring methods.

Biological survey (or biosurvey). Consists of collecting, processing, and analyzing representative portions of a resident aquatic community to determine the community structure and function.

Biological Oxygen Demand (BOD). Amount of dissolved oxygen needed to break down (oxidize) organic materials to carbon dioxide, water and minerals in a given volume of water at a certain temperature over a specified time period.

Biometrics. The automated use of physiological or behavioral characteristics to determine or verify identity.

Chlorophyll. Green pigment in plants that transforms light energy into chemical energy in photosynthesis.

Clarity. Transparency of water; routinely estimated by the depth at which you can no longer see a Secchi disk. The Secchi disk is a 20 cm (8 inch) diameter weighted metal plate with alternating quadrants painted black and white that is used to estimate water clarity (light penetration). The disk is lowered into water until it disappears from view. It is then raised until just visible. An average of the two depths, taken from the shaded side of the boat, is recorded as the Secchi depth.

Cfs. Cubic feet per second.

Clean Water Act. Growing public awareness and concern for controlling water pollution led to enactment of the Federal Water Pollution Control Act Amendments of 1972. As amended in 1977, this law became commonly known as the Clean Water Act. The Act established the basic structure for regulating discharges of pollutants into the waters of the United States. It gave USEPA the authority to implement pollution control programs such as setting wastewater standards for industry. The Clean Water Act also continued requirements to set water quality standards for all contaminants in surface waters. The Act made it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions. It also funded the construction of sewage treatment plants under the construction grants program and recognized the need for planning to address the critical problems posed by nonpoint source pollution.

Common protocol/standard protocol. See *Protocols*.

Comparability. Degree to which different methods, data sets and/or decisions agree or are similar.

Completeness. The amount of valid data obtained compared to the amount of data planned. Usually expressed as a percentage.

Compliance monitoring. A type of monitoring done to ensure the meeting of immediate statutory requirements, the control of long-term water quality, the quality of receiving waters as determined by testing effluents, or the maintenance of standards during and after construction of a project.

Composite sample. A combined water sample consisting of a series of discrete water samples taken over a given period of time and mixed according to a specified weighting factor, such as stream flow. A composite sample is often collected by an automated sampler during a runoff event.

Concentration units (mg/l or µg/l). The amount of chemical dissolved in water. Most common is milligrams per liter (mg/l) and micrograms per liter (µg/l). One milligram per liter is equal to one part per million (ppm).

Conductivity. Measures water's ability to conduct an electric current and is directly related to the total dissolved salts (ions) in the water. Called EC for electrical conductivity and is reported in micromhos per centimeter (umhos/cm) which has been recently renamed as uS/cm (microSiemans per centimeter). EC is temperature sensitive and increases with increasing temperature. Most modern probes automatically correct for temperature and standardize all readings to 25°C and then refer to the data as *specific* EC.

Contaminant. A material added by humans or natural activities that may, in sufficient concentrations, render the environment unacceptable for biota. The mere presence of these materials is not necessarily harmful.

Critical habitat. Those areas designated as critical for the survival and recovery of threatened or endangered species.

Data analysis. Using monitoring results to answer your question(s) and using your quality control data to evaluate whether you met your data quality goal and objectives.

Data quality objectives. In the context of water- quality monitoring, the characteristics or goals that are determined by a monitoring or interpretive program to be essential to the usefulness of the data. They would include, but not be limited to, the specification or delineation of the limits of precision and bias of measurements, the completeness of sampling and measurements, the representativeness of sites relative to program objectives, the validity of data and so forth.

Data users. The group(s) that will apply the data results for some purpose, such as the monitors themselves, government agencies, schools, universities, industries, *watershed* organizations and community groups.

Detection limit. The lowest concentration of a target *analyte* that a given method or piece of equipment can reliably ascertain and report as greater than zero.

Dimictic. If a lake mixes completely twice a year, in the spring and fall, it is said to be dimictic. (See *oligomictic* and *polymictic*.)

Dissolved oxygen (DO). The concentration of free (not chemically combined) molecular oxygen (a gas) dissolved in water, usually expressed in milligrams per liter, parts per million, or percent of saturation. Adequate concentrations of dissolved oxygen are necessary for the life of fish and other aquatic organisms and the prevention of offensive odors. DO levels are considered the most important and commonly employed measurement of water quality and indicator of a water body's ability to support desirable aquatic life.

Drainage area. The area contributing runoff to a single point that is enclosed by a ridgeline.

Duplicate samples. Two samples taken at the same time from, and representative of, the same site and are carried through assessment and analytical procedures in an identical manner. Duplicate samples measure natural variability and precision of a method, monitor and/or analyst. More than two duplicate samples are called replicate samples.

Ecoregion. An environmental area characterized by a specific land use, soil types, land surface form and potential natural vegetation.

Ecosystem. A system formed by the interaction of a community of organisms with each other and with the chemical and physical factors making up their environment.

Education. Using water monitoring to provide knowledge and training.

Environmental sample. A specimen of any material collected from an environmental source, such as water or macroinvertebrates collected from a stream or lake.

Epilimnion. The upper, wind-mixed layer of a thermally stratified lake. This water is turbulently mixed throughout at least some portion of the day and because of its exposure, can freely exchange dissolved gases (such as O_2 and CO_2) with the atmosphere.

Equipment or rinsate blank. Types of *field blanks* used to check specifically for carryover contamination from reuse of the same sampling equipment. Same as sampler blank.

Erosion. The process of particle detachment and transport due to the forces of wind and rain.

Eutrophic lake. A nutrient-rich lake, usually shallow, "green" and with limited oxygen in the bottom layer of water.

Eutrophication. The process by which lakes and streams are enriched by nutrients (usually phosphorus and nitrogen) which leads to excessive plant growth - algae in the open water, periphyton (*attached* algae) along the shoreline, and macrophytes (the higher plants we often call *weeds*) in the nearshore zone. This remains the biggest pollution problem for Minnesota's lakes. The extent to which this process has occurred is reflected in a lake's trophic classification: oligotrophic (nutrient poor), mesotrophic (moderately productive), and eutrophic (very productive and fertile). The less productive a lake is naturally, the more sensitive it is to increased nutrient loads from human-caused disturbances in the watershed.

Export coefficient. An estimate of the expected annual amount of a nutrient or water transported from a unit of land to a receptor. Expressed in terms of mass per area per unit of time.

Field blank. A "clean" sample (e.g. distilled water) that is otherwise treated the same as other samples taken from the field. They are submitted to the analyst with all other samples and are used to detect any contaminants that may be introduced during sample collection, storage, analysis and transport.

Flow rate. The rate at which water moves by a given point; in rivers it is usually measured in cubic meters per second (m^3/sec) or cubic feet per second (cfs).

Flow weighted mean concentration. Dividing total mass or load of a pollutant by the total flow.

Free oxygen. Oxygen in its molecular forms, O_2 (normal diatomic oxygen) or O_3 (ozone), uncombined with other elements. Free oxygen is a requirement of all aerobic organisms.

Geographic Information System (GIS). A computer system that allows for input and manipulation of geographic data to allow researchers to manipulate, analyze and display the information in a map format.

Grab sample. All of the test material is collected at one time. As such, a grab sample reflects performance only at the point in time that the sample was collected, and then only if the sample was properly collected.

Groundwater. Water contained in or flowing through the ground.

Hot spots. Area where land use or activities have generated highly contaminated runoff, with concentration of pollutants in excess of those typically found in stormwater.

Hydrograph. A graph of stream flow during a given time frame, such as seasonal or annual.

Hydrology. The study of water, especially its natural occurrence, characteristics, control and conservation.

Hypereutrophic. Refers to a lake or other body of water characterized by excessive nutrient concentrations such as phosphorus or nitrogen and resulting in high productivity. Such waters are often shallow, with algal blooms and periods of oxygen deficiency. Slightly or moderately eutrophic water can be healthful and support a complex web of plant and animal life; however, it is undesirable for drinking water and other needs.

Hypolimnion. The bottom, and most dense layer of a stratified lake. It is typically the coldest layer in the summer and warmest in the winter. It is isolated from wind mixing and typically too dark for much plant photosynthesis to occur.

Impact. A change in the chemical, physical, or biological quality or condition of a water body caused by external sources.

Impairment. A detrimental effect on the biological integrity of a water body caused by impact that prevents attainment of the designated use.

Index of Biotic Integrity (IBI). A synthesis of diverse biological information that numerically depicts associations between human influence and biological attributes. It is composed of several biological attributes or 'metrics' that are sensitive to changes in biological integrity caused by human activities.

Intermictic. If a lake mixes completely intermittently, it is said to be intermictic.

Isopleth. A line on a map connecting points with the same value for variables such as temperature or air pressure.

Kjeldahl. Kjeldhal's method is an analytical method (TKN – Total Kjeldahl Nitrogen) for determination of nitrogen in certain organic compounds. The method was developed by the Danish chemist Johan Kjeldahl (1849-1900). It involves addition of a small amount of anhydrous potassium sulfate to the test compound, followed by heating the mixture with concentrated sulfuric acid, often with a catalyst such as copper sulfate. As a result ammonia is formed. After alkalyzing the mixture with sodium hydroxyde, the ammonia is separated by distillation, collected in standard acid, and the nitrogen determined by back-titration.

Lake management. A process that involves study, assessment of problems and decisions on how to maintain a lake as a thriving ecosystem.

Land use. Type of development and use of a land area, such as agriculture or commercial.

Limnology. Scientific study of fresh water, especially the history, geology, biology, physics and chemistry of lakes.

Load. Refers to the mass of material passing through a stream during a given period. It reflects the combined contributions of surface runoff and ground water discharge from a specific watershed as measured at the monitoring station.

Macroinvertebrate. An aquatic invertebrate animal large enough to see with the naked eye, such as crayfish, snails and clams. The analysis of the types and numbers of macroinvertebrates is referred to as a "biological index" and is a useful indicator of water quality and habitat conditions.

Macrophyte. A plant large enough to be studied and observed using the unaided eye, especially an aquatic plant.

Mesotrophic. Pertains to a lake or other body of water characterized by moderate nutrient concentrations.

Metadata. Information that describes the content, quality, condition, and other characteristics of data.

Morphometry. Relating to the shape of a lake basin; includes parameters needed to describe the shape of the lake such as volume, surface area, mean depth, maximum depth, maximum length and width, shoreline length and shoreline development.

Nonpoint source pollution. A source of pollution that comes from no single identifiable point of discharge, e.g.,, pollution that results from water runoff from urban areas, construction sites and agricultural operations.

Nutrient. Element or substance such as nitrogen and phosphorus necessary for plant growth. Large amounts of these substances can become a nuisance by promoting excessive aquatic plant growth.

Nutrient budget. Measurement of the amount of nutrients coming into a lake or stream, flowing out and staying in the water and bottom sediments. Usually expressed as pounds per year.

Oligotrophic lake. A relatively nutrient-poor lake, it is clear and deep with bottom waters high in dissolved oxygen. Lakes that mix infrequently and at irregular intervals (many deep tropical lakes) are called **oligomictic** lakes. (See *dimictic* and *polymictic*.)

Outliers. Data points that lie outside of the normal range of data. Ideally, outliers must be determined by a statistical test before they can be removed from a data set.

Parameter. Whatever it is you measure, whether it is physical, chemical or biological.

Phosphorus. Key nutrient influencing plant growth in lakes. Soluble reactive phosphorus is the amount of phosphorus in solution that is available to plants.

pH. Measure of the concentration of hydrogen ions of a substance. It ranges from 1=very acid (high concentration) to 14=very alkaline (low concentration) of hydrogen ions.

Point source. A well-defined source of pollutants, such as a pipe from a municipal wastewater treatment plant, industry or a stormwater pipe.

Polymictic. A lake that does not thermally stratify in the summer but tends to mix periodically throughout summer via wind and wave action. Shallow lakes which mix frequently are called **polymictic** lakes. (See *dimictic* and *oligomictic*.)

ppm. Parts per million equal to milligrams per liter (mg/L).

Precision. Measures the level of agreement or variability among a set of repeated measurements, obtained under similar conditions. Usually expressed as a standard deviation in absolute or relative terms.

Protocols. Detailed, written, standardized procedures for field and/or laboratory operations.

Rating curve. A continuous record of stream discharge or flow can be established by developing a mathematical relationship between the water stage and discharge. To properly develop a rating curve, discharge measurements should be made at a variety of water stages, from low to high. Using a rating curve, all water stages continuously measured at the monitoring station can be converted to flows. That establishes a flow record (hydrograph) for a given time period.

QA/QC. QA is an integrated management system designed to ensure that a product or service meets defined standards of quality with a stated level of confidence. QC is the overall system of technical activities designed to measure quality and limit error in a product or service.

Quality Assurance Project Plan (QAPP). A formal written document describing the detailed quality control procedures that will be used to achieve a specific project's data quality requirements.

Relative standard deviation (RSD). The standard deviation of a parameter expressed as a percentage and used in the evaluation of precision.

Relative percent difference (RPD). An alternative to standard deviation, expressed as a percentage used to determine precision when only two measurement values are available.

Replicate samples. See *Duplicate Samples*.

Representativeness. The degree to which data accurately and precisely portray the actual or true environmental condition measured.

Retention time. Turnover rate or flushing rate. The average length of time water resides in a water body.

Sampler blank. See *Equipment or rinsate blank*.

Secchi disk. A device measuring the depth of light penetration in water, it has a 4-6 inch radius that is divided into four equal quadrants of alternating black and white colors. It is lowered into a section of shaded water until it can no longer be seen and then lifted back up until it can be seen once again. Averaging the two depths gives the clarity of the water.

Sediments/sedimentation. Soil particles that have been eroded and are transported by stormwater runoff. Sedimentation is the deposition of soil particles that have been transported by water or wind.

Spiked samples. Samples to which a known concentration of the target *analyte* has been added. When analyzed, the difference between an *environmental sample* and the analyte's concentration in a spiked sample should be equivalent to the amount added to the spiked sample.

Split sample. A sample that has been equally divided into two or more subsamples and submitted to different analysts or laboratories. Used to measure the precision of analytical methods.

Standard deviation. Used to determine precision, the most common calculation used to measure the range of variation among repeated measurements. Expressed by the positive square root of the variance of the measurements.

Standard Operating Procedures (SOPs). A written document detailing the prescribed and established methods used for performing project operations, analyses or actions.

Stratification. An effect where a substance or material is broken into distinct horizontal layers due to different characteristics such as density or temperature. (See also *Thermal Stratification*.)

Target pollutant load. A goal set to limit the amount or load of a pollutant that is being discharged from a watershed via the stream.

Taxon. (Pl. taxa) Any of the groups to which organisms are assigned according to the principles of taxonomy, including species, genus, family, order, class and phylum.

Thermal stratification. Existence of a turbulently mixed layer of warm water (*epilimnion*) overlying a colder mass of relatively stagnant water (*hypolimnion*) in a water body due to cold water being denser than warm water coupled with the damping effect of water depth on the intensity of wind mixing.

Titration. A method of calculating the concentration of a dissolved substance by adding quantities of a reagent of known concentration to a known volume of test solution until a reaction occurs.

TMDL. Total Maximum Daily Load. Refers to the Clean Water Act's 305(b) and 303(d) requirements. A calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources.

Total nitrogen. The total amount of nitrogen that is contained in the water column.

Total phosphorus. Includes the amount of phosphorus in solution (reactive) and in particulate form.

Total suspended solids. The total amount of particulate matter that is suspended in the water column.

Toxic. Lethal concentration, which may refer to conditions of a water body or concentration of a particular pollutant.

Trophic state. Eutrophication is the process by which lakes are enriched with nutrients, increasing the production of rooted aquatic plants and algae. The extent to which this process has occurred is reflected in a lake's trophic classification or state: *oligotrophic* (nutrient poor), *mesotrophic* (moderately productive), and *eutrophic* (very productive and fertile).

True value. A value that has been sufficiently well established to be used for the calibration of instruments, evaluation of assessment methods or the assignment of values to materials. Used to determine accuracy.

Turbidity. A measure of the degree to which light is scattered by suspended particulate material and soluble colored compounds in the water. It provides an estimate of the muddiness or cloudiness of the water due to clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton, and microscopic organisms.

Variance. A statistical term used to calculate standard deviation. The sum of the squares of the difference between the individual values of a set and the arithmetic mean of the set, divided by one less than the numbers in the set.

Water column. Water contained in the water body. A conceptual column of water from a lake surface to bottom sediments.

Water-quality data. Chemical, biological, and physical measurements or observations of the characteristics of surface and ground waters.

Water-quality monitoring. An integrated activity for evaluating the physical, chemical, and biological character of water in relation to human health, ecological conditions and designated water uses.

Water-quality volume. The volume needed to capture and treat 90% of the average stormwater runoff volume equal to one inch times the volumetric runoff coefficient times the site area.

Watershed. The geographic region where water drains into a particular river, stream or body of water.

Wetland. Habitat that is transitional between terrestrial and aquatic where the water table is usually at or near the land surface or land that is covered by shallow water. Wetlands have one or more of the following characteristics: at least periodically, the land supports predominantly hydrophytic plants; the substrate is predominantly undrained hydric soil; and the substrate is nonsoil and is saturated with water or covered by shallow water at sometime during the yearly growing season.

Winkler method. A method for measuring the amount of dissolved oxygen in a sample of water using reagents to fix or preserve the sample and titration to create a color change that indicates the amount of dissolved oxygen in the sample.

Minnesota Pollution Control Agency

520 Lafayette Road
St. Paul, Minnesota 55155

(651) 296-6300
toll-free/TDD (800) 657-3864

www.pca.state.mn.us