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Environmental Protection
Agency

Office of Research and Development
Office of Environmental Information
Washington, DC 20460

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September 2000
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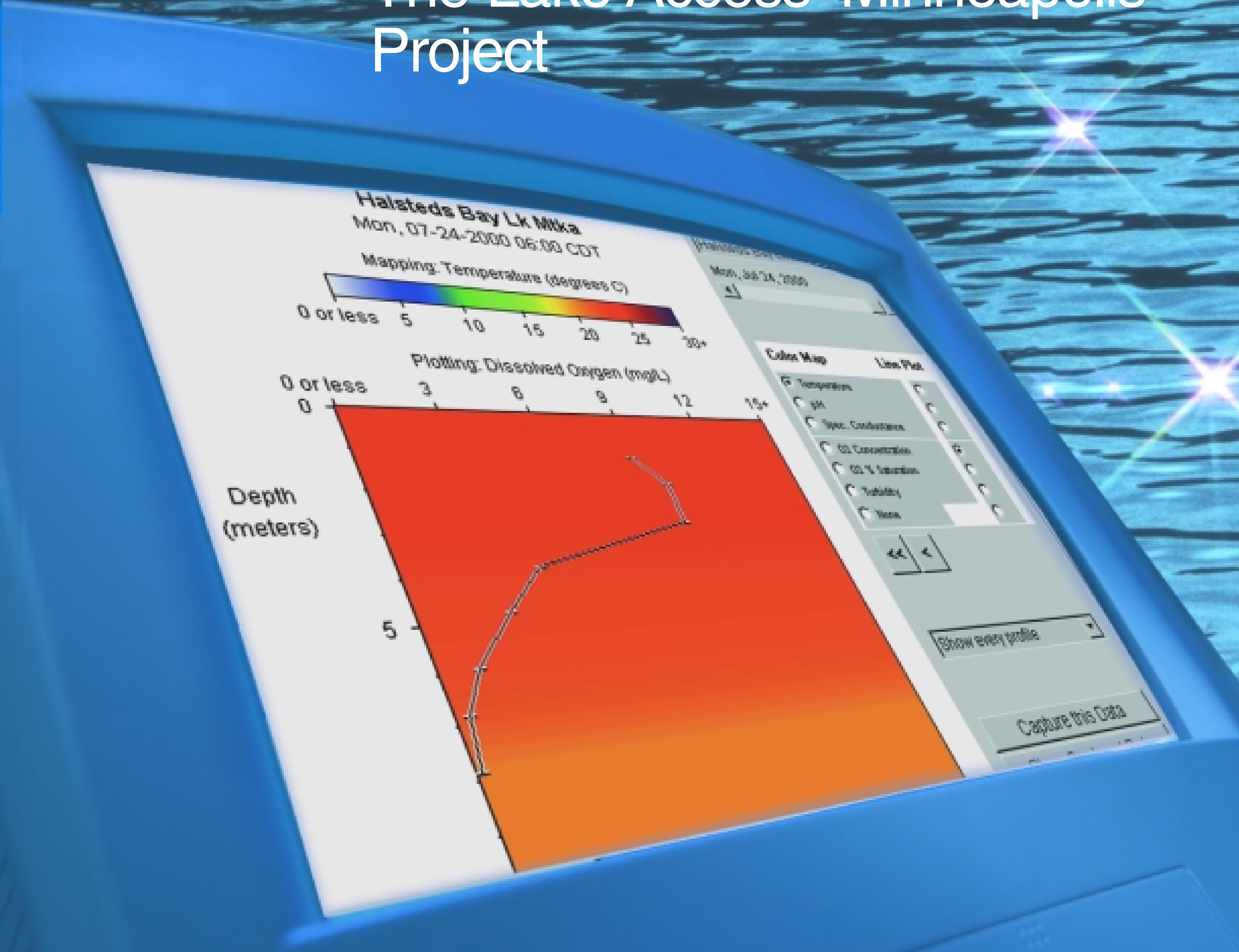
EPA

# Delivering Timely Water Quality Information to Your Community

## The Lake Access–Minneapolis Project




EMPACT

Environmental Monitoring for Public Access & Community Tracking

## Disclaimer

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## The Lake Access–Minneapolis Project

United States Environmental Protection Agency
National Risk Management Research Laboratory
Office of Research and Development
Cincinnati, OH 45268

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# 1. INTRODUCTION

People who spend time in, on, or close to lakes in and near your community can use timely and accurate information about lake water quality to help make day-to-day decisions about lake use and lake issues. For example, swimmers can use information about fecal coliform levels to protect their health when levels of these bacteria near swimming beaches are high. Anglers can use water quality information (e.g., temperature and oxygen levels) to help them decide where and when to go fishing. Time-relevant information can help recreational lake users, businesses, resource managers, lakeshore residents, and other landowners located farther from the lakeshore understand how a lake's water quality is affected by land use practices within its watershed.

This handbook offers step-by-step instructions about how to provide time-relevant water quality data to your community. It was developed by the U.S. Environmental Protection Agency's (EPA's) EMPACT program. EPA created EMPACT (**E**nvironmental **M**onitoring for **P**ublic **A**ccess and **C**ommunity **T**racking) in 1996, at President Clinton's direction. The program takes advantage of new technologies that make it possible to provide time-relevant environmental information to the public.

EMPACT is working with the 86 largest metropolitan areas of the country to help communities in these areas:

- Collect, manage, and distribute time-relevant environmental information.

- Provide residents with easy-to-understand information they can use in making informed, day-to-day decisions.

To make EMPACT more effective, EPA is partnering with the National Oceanic and Atmospheric Administration and the U.S. Geological Survey. EPA will work closely with these federal agencies to help achieve nationwide consistency in measuring environmental data, managing the information, and delivering it to the public.

To date, environmental information projects have been initiated in 84 of the 86 EMPACT-designated metropolitan areas. These projects cover a wide range of environmental issues, including groundwater contamination, water quality, smog, ultraviolet radiation, and overall ecosystem quality. Some of these projects were initiated directly by EPA. Others were launched by EMPACT communities themselves. Local governments from any of the 86 EMPACT metropolitan areas are eligible to apply for EPA-funded Metro Grants to develop their own EMPACT projects. The 86 EMPACT metropolitan areas are listed in the table at the end of this chapter.

Communities selected for Metro Grant awards are responsible for building their own time-relevant environmental monitoring and information delivery systems. To find out how to apply for a Metro Grant, visit the EMPACT Web site at http://www.epa.gov/empact/apply.htm.

One such Metro Grant recipient is the Lake Access–Minneapolis project. The project provides the public with time-relevant and historical water quality data for lakes within the largest, most populated watershed districts in Minnesota.

The Lake Access Project team is using Remote Underwater Sampling System (RUSS) devices to collect time-relevant water quality data from three locations—two in Lake Minnetonka and one in Lake Independence. The Lake Access team has developed an Internet interface for the RUSS units that allows data from the RUSS sensors to be displayed in near-real time on the Lake Access Web site at http://www.lakeaccess.org. The project is a cooperative effort of the Suburban Hennepin Regional Park District, the Minnehaha Creek Watershed District, the University of Minnesota Water on the Web Investigators (i.e., the Natural Resources Research Institute, the University of Minnesota–Duluth Department of Education, and Minnesota Sea Grant), and Apprise Technologies, which holds the license to RUSS technologies. The project team also collects data from monitoring stations established as part of other monitoring programs. The team integrates data supplied by these non-RUSS sites with RUSS-generated data to track conditions in area lakes. Many of the project Web site's key features, such as the Limnology Primer and the Data Visualization Tools, were developed under a grant from The National Science Foundation's Advanced Technology Education Program.

The Technology Transfer and Support Division of the EPA Office of Research and Development's (ORD's) National Risk Management Research Laboratory initiated development of this handbook to help interested communities learn more about the Lake Access Project. The handbook also provides technical information communities need to develop and manage their own time-relevant lake water monitoring, data visualization, and information dissemination programs. ORD, working with the Lake Access Project team, produced this handbook to maximize EMPACT's investment in the project and minimize the resources needed to implement similar projects in other communities.

Both print and CD-ROM versions of the handbook are available for direct on-line ordering from EPA's Office of Research and Development Technology Transfer Web site at http://www.epa.gov/ttbnrmrl. You can also download the handbook from the Lake Access—Minneapolis Web site at http://www.lakeaccess.org. You can also obtain a copy of the handbook by contacting the EMPACT program office at:

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We hope you find the handbook worthwhile, informative, and easy to use. We welcome your comments, and you can send them by e-mail from EMPACT's Web site at http://www.epa.gov/empact/comments.htm.

### EMPACT Metropolitan Areas

Albany-Schenectady-Troy, NY
Albuquerque, NM
Allentown-Bethlehem-Easton, PA
Anchorage, AK
Atlanta, GA
Austin- San Marcos, TX
Bakersfield, CA
Billings, MT
Birmingham, AL
Boise, ID
Boston, MA-NH
Bridgeport, CT
Buffalo-Niagara Falls, NY
Burlington, VT
Charleston-North Charleston, SC
Charleston, WV
Charlotte-Gastonia-Rock Hill, NC-SC
Cheyenne, WY
Chicago-Gary-Kenosha, IL-IN-WI
Cincinnati-Hamilton, OH-KT-IN
Cleveland-Akron, OH
Columbus, OH
Dallas-Fort Worth, TX
Dayton-Springfield, OH
Denver-Boulder-Greeley, CO
Detroit-Ann Arbor-Flint, MI
El Paso, TX
Fargo-Moorhead, ND-MN
Fresno, CA
Grand Rapids-Muskegon-Holland, MI
Greensboro-Winston Salem-High Point, NC
Greenville-Spartanburg-Anderson, SC
Harrisburg-Lebanon-Carlisle, PA
Hartford, CT
Honolulu, HI
Houston-Galveston-Brazoria, TX
Indianapolis, IN
Jackson, MS
Jacksonville, FL
Kansas City, MO-KS
Knoxville, TN
Las Vegas, NV
Little Rock-North Little Rock, AR
Los Angeles-Riverside-Orange County, CA
Louisville, KY-IN
Memphis, TN-AR-MS
Miami-Fort Lauderdale, FL
Milwaukee-Racine, WI
Minneapolis-St. Paul, MN
Nashville, TN
New Orleans, LA
New York-Northern New Jersey-Long Island, NY-NJ-CT-PA
Norfolk-Virginia Beach-Newport News, VA-NC
Oklahoma City, OH
Omaha, NE-IA
Orlando, FL
Philadelphia- Wilmington-Atlantic City, PA-NJ-DE-MD
Phoenix-Mesa, AZ
Pittsburgh, PA
Portland, ME
Portland-Salem, OR-WA
Providence-Fall River-Warwick, RI-MA
Raleigh-Durham-Chapel Hill, NC
Richmond-Petersburg, VA
Rochester, NY
Sacramento-Yolo, CA
Salt Lake City-Ogden, UT
San Antonio, TX
San Diego, CA
San Francisco-Oakland-San Jose, CA
San Juan, PR
Scranton-Wilkes-Barre-Hazleton, PA
Seattle-Tacoma-Bremerton, WA
Sioux Falls, SD
Springfield, MA
St. Louis-E. St. Louis, MO-IL
Stockton-Lodi, CA
Syracuse, NY
Tampa-St. Petersburg-Clearwater, FL
Toledo, OH
Tucson, AZ
Tulsa, OK
Washington-Baltimore, DC-MD-VA-WV
West Palm Beach-Boca Raton, FL
Wichita, KS
Youngstown-Warren, OH

# 2. HOW TO USE THIS HANDBOOK

This handbook provides you with step-by-step information on how to develop a program to provide time-relevant water quality data to your community, using the Lake Access Project in the Minneapolis-St. Paul, Minnesota, area as a model. It contains detailed guidance on how to:

Design, site, operate, and maintain a system to gather time-relevant water quality data.

→

Design, operate, and maintain a system to retrieve, manage, and analyze your time-relevant water quality data.

→

Use data visualization tools to graphically depict these data.

→

Develop a plan to communicate the results of your time-relevant water quality monitoring efforts to residents in your community.

- **Chapter 3** provides information about water quality monitoring—the first step in the process of generating time-relevant information about water quality and making it available to residents in your area. The chapter begins with an overview of water quality monitoring in freshwater systems and then focuses on the remote time-relevant water quality monitoring conducted as part of the Lake Access Project. It also provides step-by-step instructions on how to install, operate, and maintain the Remote Underwater Sampling Station (RUSS) units used by the Lake Access Project team to gather time-relevant water quality data.
- **Chapter 4** provides step-by-step instructions on how to operate and maintain an automated system to transmit, store, retrieve, and analyze the water quality data collected from the remote time-relevant water quality monitors. The chapter focuses on the software used by the Lake Access Project team from their RUSS units to their base station, and it also contains information on data quality assurance and control.
- **Chapter 5** provides information about using data visualization tools to graphically depict the time-relevant water quality data you have gathered. The chapter begins with a brief overview of data visualization. It then provides a more detailed introduction to selected data visualization tools developed by the Lake Access team. You might want to use these software tools to help analyze your data and in your efforts to provide time-relevant water quality information to your community.
- **Chapter 6** outlines the steps involved in developing an outreach plan to communicate information about water quality in your community's lakes. It also provides information about the Lake Access Project's outreach efforts. The chapter includes a list of resources to help you

develop easily understandable materials to communicate information about your time relevant water quality monitoring program to a variety of audiences.

This handbook is designed for decision-makers considering whether to implement a time-relevant water quality monitoring program in their communities and for technicians responsible for implementing these programs. Managers and decision-makers likely will find the initial sections of Chapters 3, 4, and 5 most helpful. The latter sections of these chapters are targeted primarily at professionals and technicians and provide detailed "how to" information. Chapter 6 is designed for managers and communication specialists.

The handbook also refers you to supplementary sources of information, such as Web sites and guidance documents, where you can find additional guidance with a greater level of technical detail. Interspersed throughout the handbook are text boxes that describe some of the lessons learned by the Lake Access team in developing and implementing its time-relevant water quality monitoring, data management, and outreach program.

# 3. WATER QUALITY MONITORING

This chapter provides information about water quality monitoring—the first step in the process of generating time-relevant information about water quality and making it available to residents in your area.

The chapter begins with a broad overview of water quality monitoring (Section 3.1). It then focuses on the remote time-relevant water quality monitoring conducted as part of the Lake Access Project. It also provides information about installing, operating, and maintaining the equipment used by the Lake Access Project team to gather time-relevant water quality data. Section 3.2 discusses factors to consider when designing a remote time-relevant water quality monitoring project. Sections 3.3, 3.4, and 3.5 explain how to select remote time-relevant monitoring frequencies, parameters, and equipment. Section 3.6 describes how to select the locations of your remote time-relevant water quality monitoring stations. Sections 3.7, 3.8, and 3.9 explain how you can install, operate, and maintain the remote time-relevant water quality monitoring equipment used by the Lake Access Project. The chapter concludes with a brief overview of other water quality monitoring projects conducted in the Twin Cities area (Section 3.10).

Readers primarily interested in an overview of water quality monitoring might want to focus on the introductory information in Sections 3.1 and 3.2. If you are responsible for the actual design and implementation of a monitoring project, you should review Sections 3.3 through 3.9. They provide an introduction to the specific steps involved in developing and operating a remote time-relevant water quality monitoring project and information on where to find additional guidance.

## 3.1 Water Quality Monitoring: An Overview

Water quality monitoring provides information about the condition of streams, lakes, ponds, estuaries, and coastal waters. It can also tell us if these waters are safe for swimming, fishing, or drinking. The Web site of the U.S. EPA Office of Water (http://www.epa.gov/owow/monitoring/) is a good source of background information on water quality monitoring. (The information presented in the following paragraphs is summarized from this Web site.)

Water quality monitoring can consist of the following types of measurements:

- *Chemical* measurements of constituents such as dissolved oxygen, nutrients, metals, and oils in water, sediment, or fish tissue.
- *Physical* measurements of general conditions such as temperature, clarity, flow, and water color.
- *Biological* measurements of the abundance, variety, and growth rates of aquatic plant and animal life in a water body or the ability of aquatic organisms to survive in a water sample.

You can conduct several kinds of water quality monitoring projects, such as those:

- At fixed locations on a continuous basis
- At selected locations on an as-needed basis or to answer specific questions
- On a temporary or seasonal basis (such as during the summer at swimming beaches)
- On an emergency basis (such as after a spill)

Many agencies and organizations conduct water quality monitoring, including state pollution control agencies, Indian tribes, city and county environmental offices, the U.S. EPA and other federal agencies, and private entities, such as universities, watershed organizations, environmental groups, and industries. Volunteer monitors—private citizens who voluntarily collect and analyze water quality samples, conduct visual assessments of physical conditions, and measure the biological health of waters—also provide increasingly important water quality information. The U.S. EPA provides specific information about volunteer monitoring at http://www.epa.gov/owow/monitoring/vol.html.

Water quality monitoring is conducted for many reasons, including:

- Characterizing waters and identifying trends or changes in water quality over time.
- Identifying existing or emerging water quality problems.
- Gathering information for the design of pollution prevention or restoration programs.
- Determining if the goals of specific programs (such as the implementation of pollution prevention strategies) are being met.
- Responding to emergencies such as spills or floods.

EPA helps administer grants for water quality monitoring projects and provides technical guidance on how to monitor and report monitoring results. You can find a number of EPA's water quality monitoring technical guidance documents on the Web at http://www.epa.gov/owow/monitoring/techmon.html.

In addition to the U.S. EPA resources listed above, you can obtain information about lake and reservoir water quality monitoring from the North American Lake Management Society (NALMS). NALMS has published many technical documents, including a guidance manual entitled *Monitoring Lake and Reservoir Restoration.* For more information, visit the NALMS Web site at http://www.nalms.org. State and local agencies also publish and recommend documents to help organizations and communities conduct and understand water quality monitoring. For example, the Minnesota Lakes Association maintains a Web site (http://www.mnlakesassn.org/main/resources/waterquality/index.cfm) that lists resources for water quality monitoring and management. State and local organizations in your community might maintain similar listings. The University of Minnesota–Duluth's Water on the Web site also maintains a list of links for water quality information and resources, including sampling and monitoring methods, at http://wow.nrri.umn.edu/wow/under/links.html. (The Water on the Web project provides on-line, time-relevant lake data as a tool for teaching basic and environmental science.)

In some cases, special water quality monitoring methods, such as remote monitoring, or special types of water quality data, such as time-relevant data, are needed to meet a water quality monitoring program's objectives. *Time-relevant* environmental data are data collected and communicated to the public in a time frame that is useful to their day-to-day decision-making about their health and the environment, and relevant to the temporal variability of the parameter measured. Monitoring is called *remote* when the operator can collect and analyze data from a site other than the monitoring location itself.

### Remote Time-Relevant Water Quality Monitoring: The Lake Access Project

The Lake Access Project helps community lake management and research organizations learn more about the characteristics of lakes in the Minnehaha Creek Watershed District (MCWD) and the Suburban Hennepin Regional Park district (Hennepin Parks) through remote time-relevant monitoring of lake water quality. In turn, the data gathered through the Lake Access Project are used to communicate time-relevant information about lake water quality to the local public.

The Lake Access Project team conducts remote time-relevant monitoring at two locations in Lake Minnetonka and at one location in Lake Independence. At each location, the project team operates a remote underwater sampling station (RUSS™) unit, manufactured by Apprise Technologies, Inc. The RUSS unit consists of a mobile underwater monitoring sensor tethered to a buoy and featuring an onboard computer, batteries, solar panels, telemetry equipment, and other optional monitoring equipment. Four times daily, each RUSS unit raises and lowers a tethered multiprobe water quality sensor manufactured by Yellow Springs Instruments© (YSI©) to collect a profile in 1-meter intervals from the lake surface to the lake bottom. The RUSS unit measures the following parameters:

- Temperature
- pH
- Dissolved oxygen
- Electrical conductivity
- Turbidity
- Depth

The Lake Access Project team uses a land-base station to communicate with the RUSS units via cellular connection. Time-relevant data are remotely downloaded from the RUSS units daily.

The diagram on page 10 illustrates some of the basic RUSS unit components, and it shows how the RUSS unit communicates with the land-base station. This diagram was taken from the RUSS System Manual, which is available from Apprise Technologies. For more information about Apprise Technologies and the RUSS unit, visit http://www.apprisetech.com.

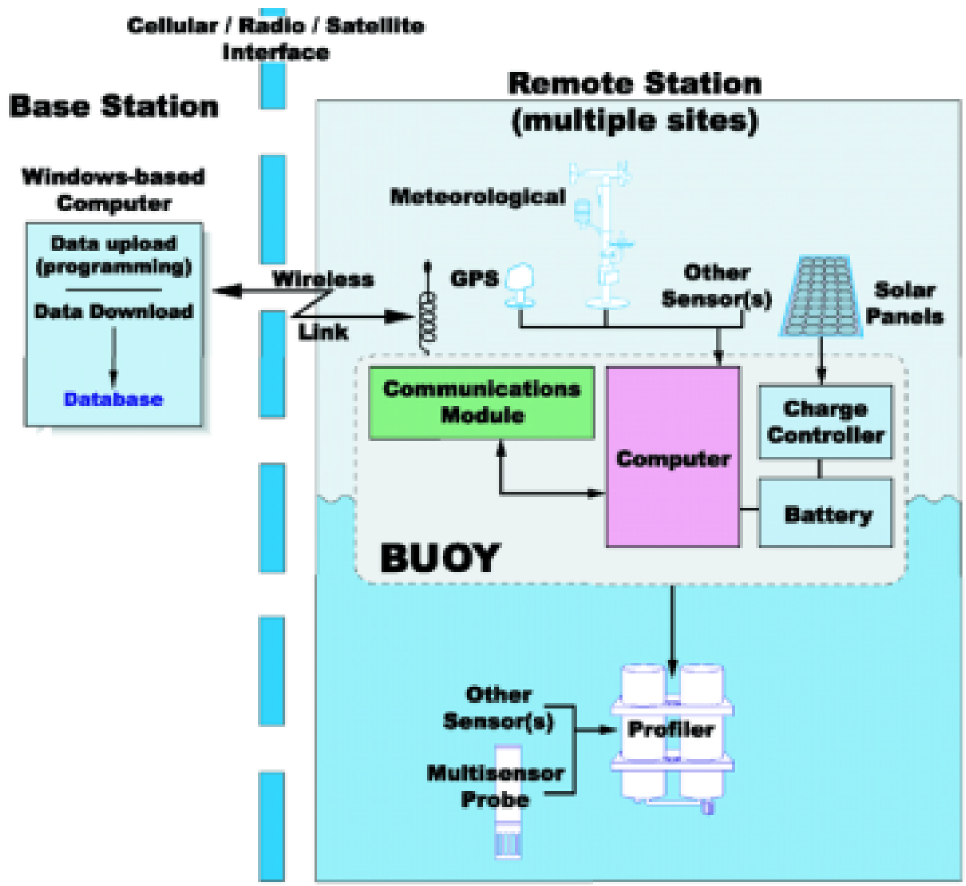



**Diagram showing some of the RUSS unit components and illustrating the communication between the RUSS unit and the land-base station.** (Taken from the RUSS System Manual, available from Apprise Technologies at http://www.apprisetech.com.)

The remainder of this chapter highlights the Lake Access Project. The text box below provides some background information on the characteristics of the lakes studied in the Lake Access Project, and it introduces some important technical terms relevant to the study of these lakes. The information in this text box was taken from the Lake Access Web site, which provides extensive online information about lake ecology. For more information, visit these Web pages at http://www.lakeaccess.org/ecology/lakeecology.html.

## 3.2 Designing a Time-Relevant Water Quality Monitoring Project

The first step in developing any water quality monitoring project is to define your objectives. Keep in mind that remote time-relevant monitoring might not be the best method for your organization or community. For example, you would not likely require a remote time-relevant monitoring capability to conduct monthly monitoring to comply with a state or federal regulation.

## Lake Stratification and Lake Mixing

This text box provides some basic information about the effects of seasonal temperature variations on the types of lakes studied by the Lake Access Project team.

Lakes are directly influenced by fluctuations in seasonal air temperature. The following figure shows the seasonal activities and characteristics of lakes, such as Lake Minnetonka and Lake Independence in the Minneapolis area, with an annual pattern of two seasonal mixing periods. (Lakes with this pattern of mixing are known as *dimictic* lakes.)

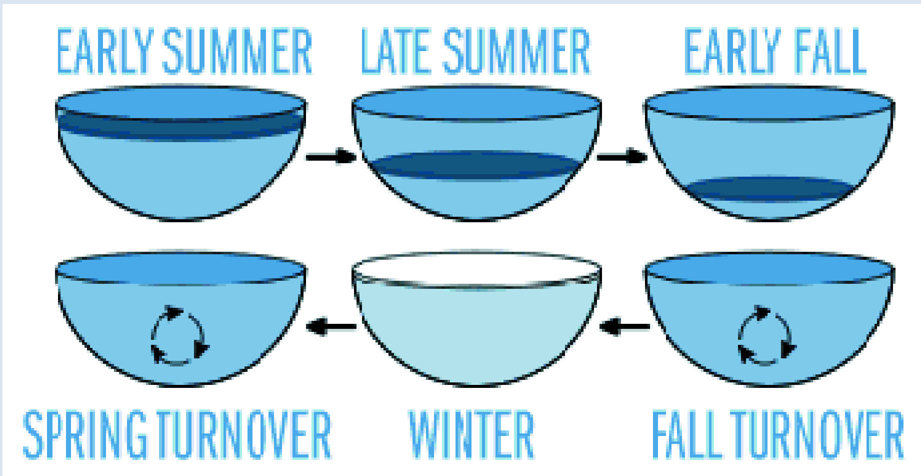



**Figure showing the activities and characteristics of the types of lakes studied through the Lake Access Project.** (Taken from the Lake Access Web site at http://www.lakeaccess.org/ecology/lakeecologyprim4.html).

Seasonal air temperatures directly affect lake temperatures. Lake temperatures, in turn, affect lake water densities. Water is most dense at about 4°C and becomes less dense at higher and lower temperatures. The typical seasonal lake temperature and density characteristics seen in dimictic lakes are described below:

**Summer.** During the summer, the lake surface is warmed by the sun, while the lake bottom remains cold. These differing temperatures affect lake water density, causing the water in deeper lakes to separate into layers. This process of separation is called stratification. The figure on page 12 shows the following three layers of a typical stratified lake:

- The *epilimnion* is the upper layer. It is warm, well-mixed, and rich in dissolved oxygen.
- The *metalimnion* is also called the *thermocline* region. The *thermocline* is the point of maximum temperature change within the metalimnion. In this layer, water temperature declines and density increases rapidly with depth. The drastic density change in this layer prevents the epilimnion and hypolimnion from mixing.
- The *hypolimnion* is the bottom layer of cold water. Because this layer is isolated from the atmosphere and the epilimnion, it becomes *anoxic* (i.e., the water does not contain any dissolved oxygen). Anoxic conditions can result in many events, including the release of phosphorus, a nutrient, from the lake bottom sediment into the hypolimnion.

Stratified layers develop different physical and chemical characteristics, and support different types of aquatic life. Lake stratification usually persists until the fall.

*(continued on next page)*

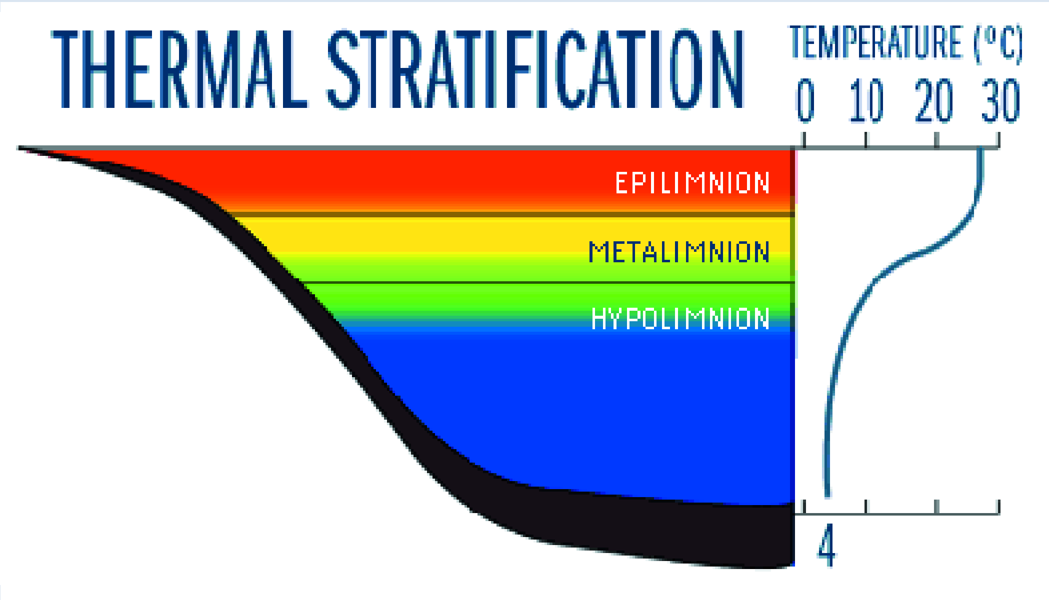



**Figure showing the three distinct layers of a typical stratified lake.**
(Taken from the Lake Access Web site at http://www.lakeaccess.org/ecology/lakeecologyprim4.html).

**Fall.** As air temperatures cool in the fall, the water temperature in the epilimnion cools and water density increases. Fall winds mix the lake to greater depths, and the thermocline deepens. Then, when the temperature and density of the epilimnion approach the temperature and density of the hypolimnion, fall winds mix the entire lake. This mixing event is called a *turnover*.

**Winter.** During the winter, the water temperature in the epilimnion cools even further, until a layer of ice forms on the lake surface. Under the ice, the lake again stratifies. Winter stratification differs from summer stratification because the temperature in the epilimnion is lower than that of the hypolimnion, which stays at about 4°C throughout the winter. The stratification is also less stable than in the summer, because the temperature and density differences between the layers is not large. Because the ice isolates the lake from wind mixing, however, stratification usually persists throughout the winter. Anoxia occurs at the bottom of most lakes during the winter.

**Spring.** During the spring, the water in the epilimnion is heated. As the temperature approaches 4°C, the density increases. When the temperature and density of the epilimnion approach that of the hypolimnion, very little wind energy is needed to mix the lake. After this turnover, the temperature and density of the water in the epilimnion continue to increase until this layer becomes too warm and too buoyant to mix with the lower layers.

Here are some questions to help determine if remote time-relevant monitoring is appropriate to meet your monitoring objectives:

- **What types of questions about water quality would you like to answer, and do you need time-relevant data to answer these questions?** For example, do you want to know more about how rapid events, such as urban or agricultural runoff from rainstorms, might affect water quality in your area by stimulating algal blooms?
- **If you already have other water quality monitoring projects in place, how would the addition of time-relevant data enhance them?**

For example, would the frequent review of time-relevant data allow you to tailor your other monitoring projects to yield more representative water quality data or conserve your organization's labor and analytical resources?

- **How would your community or organization benefit from a time-relevant monitoring project?** For example, would time-relevant data provide you with a better opportunity to communicate water quality issues to your community?

### Designing the Lake Access Project

The Lake Access Project team's decision to collect time-relevant water quality data using RUSS units grew out of an interest to learn more about rapid, weather-related mixing events in Lake Minnetonka. To do so, Minnehaha Creek Watershed District (MCWD) and Hennepin Parks required time-relevant water quality data and the capability to collect these data remotely. The box on page 14 provides more information on the design of the Lake Access Project.

## 3.3 Selecting Your Sampling Frequency

The sampling frequency you select for your remote time-relevant water quality monitoring project depends upon your project's objectives. For example:

- If you want to determine the effects of storm-related nonpoint sources on water quality in your area, you could tailor your monitoring frequency to collect data during storm events.
- If you want to study a water body affected by tidal flow, you could tailor your monitoring frequency to collect data during tidal events.

It is appropriate to experiment with different monitoring frequencies to optimize your ability to fulfill your project's objectives.

### Lake Access Project Monitoring Frequency

The Lake Access Project team typically programs its RUSS units to collect lake profile samples four times daily. This monitoring frequency enables team members to observe short-term changes in lake stratification and water quality, and to document day-to-night differences for the purpose of teaching basic and environmental science through the Water on the Web curriculum. In order to provide a high-quality data set for understanding and managing the lakes, the data's accuracy needs to be certified. See the box on page 15 for more information.

The Lake Access Project team can adjust the RUSS unit monitoring frequency from the land-base station. For example, to allow for a more detailed analysis of rapid lake mixing, Lake Access team members can program the RUSS unit to collect samples at a greater frequency during severe storm or wind events.

With frequent review of the time-relevant data, the project team has been able to tailor the frequency of its manual water quality monitoring projects to yield more representative data. For example, the team can conduct manual monitoring in

### Using Remote Time-Relevant Monitoring to Study Rapid Lake Mixing

The remote time-relevant monitoring conducted using RUSS units has provided the Lake Access Project team with new opportunities for data collection and analysis.

During several years of water quality monitoring, Minnehaha Creek Watershed District (MCWD) and Hennepin Parks personnel learned that water quality conditions in Twin Cities Metropolitan Area (TCMA) lakes varied on an annual basis. Although MCWD and Hennepin Parks personnel weren't particularly surprised by this finding, they were quite surprised that the data showed no correlation between water quality in TCMA lakes and the characteristics of runoff from surrounding watersheds. Instead, the data showed that mixing events occurring within TCMA lakes seemed to have a more significant impact on lake water quality than the effect of watershed runoff.

In addition, water quality data collected from Lake Minnetonka during several summers showed highly variable phosphorus concentrations at the lake bottom. Typically, lake-bottom phosphorus concentrations increase steadily throughout the summer as decreased oxygen levels at the hypolimnion cause phosphorus to be released from bottom sediment. At first, MCWD and Hennepin Parks personnel assumed their highly variable data were caused by sampling error. If they had accidentally hit the lake bottom during manual sampling, they could have inadvertently collected sediment with high phosphorus concentrations. However, several years of highly variable phosphorus data convinced them of the improbability of making the same sampling mistake year after year!

MCWD and Hennepin Parks personnel began to suspect that weather events, such as strong winds or storms, were causing rapid lake mixing events. They suspected these mixing events were similar to seasonal mixing that typically occurs in the spring and fall, but that these events were occurring very rapidly—often in one or two days. As a result, the phosphorous concentration near the lake bottom decreased, and the phosphorous concentration in the upper layer of the lake, where sunlight penetrates, increased, thereby promoting algae growth.

MCWD and Hennepin Parks personnel realized they could not test the validity of their theory using their "traditional" methods for monitoring water quality for the following reasons:

- Rapid lake mixing events typically occur during strong winds or storms. Field personnel could not collect manual water quality samples to document these rapid mixing events because of safety concerns associated with working on lakes during severe weather.
- Lake mixing events can occur rapidly, and algae growth can double in one day under prime conditions. MCWD and Hennepin Parks could not provide the laboratory or analytical resources to conduct water quality monitoring at the short intervals required to fully document these types of rapid events.

As you will read in this chapter, remote time-relevant monitoring has allowed the Lake Access Project team to document and study rapid lake mixing events in Lake Minnetonka.

Halsteds Bay immediately after documenting a rapid mixing event with time-relevant data. The team can then use the data collected through manual monitoring to determine the effect of the mixing event on the lake.

## 3.4 Selecting Water Quality Parameters for Monitoring

Your selection of time-relevant monitoring parameters depends on your project's objectives and on the remote time-relevant technologies available to you. To satisfy the objectives of the Lake Access Project, the project team chose to monitor

## Data Quality Assurance and Quality Control (QA/QC)

QA/QC procedures ensure that data are accurate, precise, and consistent. QA/QC involves following established rules in the field and in the laboratory to ensure that samples are representative of the water you are monitoring, free from contamination, and analyzed following standard procedures. (Chapter 4, section 4.4, provides additional information on standard QA/QC analysis procedures used by the Lake Access Project.)

The Lake Access Project uses two types of water quality data:

1. Time-relevant data collected with a YSI multiprobe water quality sensor controlled by the RUSS unit.
2. "Conventional" data collected by trained field staff, including manual measurements with a YSI multiprobe water quality sensor, as well as the collection of water samples analyzed at a laboratory.

Many state and federal monitoring projects use YSI multiprobe or similar water quality sensors. To ensure the QA/QC of data collected with these sensors, the Lake Access Project team follows manufacturer's instructions for sensor calibration and maintenance. (See Section 3.9 for more information on the calibration and maintenance procedures followed by the team.) To ensure the QA/QC of "conventional" data, the Lake Access Project team follows guidelines set forth by the U.S. EPA and American Public Health Association, in addition to those set forth by the Minnesota Department of Health.

The team also has several years of experience identifying systematic errors associated with sensor deterioration, or biofouling, that occurs when algae, bacteria, and fungi grow on the sensor while it is continually submerged in water beneath the RUSS unit.

The Lake Access Web site provides more information about the team's QA/QC procedures at **http://www.lakeaccess.org/QAQC.html**. EPA's publication *The Volunteer Monitor's Guide to Quality Assurance Project Plans* provides more information on QA/QC plans for monitoring projects. For more information on this guide, visit **http://www.epa.gov/owowwtr1/monitoring/volunteer/qappexec.htm.**

five basic water quality parameters on a time-relevant basis: temperature, pH, dissolved oxygen, electrical conductivity, and turbidity.

The Lake Access Project team uses time-relevant measurements of temperature, dissolved oxygen, and electrical conductivity as indicators of lake stratification and rapid mixing events. When summer lake stratification is stable, parameter measurements typically show the following:

- Temperature at the lake surface is about 4° to 5° warmer than temperature at the lake bottom, and a thermocline region exists with a temperature gradient of greater than 1° C per meter.
- Dissolved oxygen in the upper mixed layer is nearly saturated. Below the thermocline, dissolved oxygen decreases very rapidly and most of the hypolimnion is completely anoxic until fall overturn.
- Electrical conductivity tends to be higher below the thermocline, and it increases as the summer progresses due to the release of carbon dioxide and other ions from decomposing organic matter.

Immediately after a rapid lake mixing event, time-relevant measurements of temperature, dissolved oxygen, and electrical conductivity are nearly identical at the lake surface and the lake bottom. In addition, the Lake Access Project team usually observes increased turbidity measurements in the lake's upper layer, where sunlight penetrates as algae growth increases because of the additional phosphorus mixed into the upper layer. The project team will often collect manual samples for laboratory analyses of additional parameters immediately after a mixing event to learn more about the effects of the event on the lake.

The Lake Access Web site at http://www.lakeaccess.org/russ/ contains descriptions of time-relevant water quality parameters measured through the Lake Access project and the significance of their measurements. The descriptions are briefly summarized in the box on page 17.

**Making the Most of Your Time-Relevant Water Quality Data**

Currently, your organization will find a limited number of cost-effective time-relevant monitoring technologies available. Also keep in mind that time-relevant data might not be as accurate, precise, or consistent as "conventional" laboratory analytical data. You will want to carefully consider how your project will use time-relevant data and make the most of the time-relevant monitoring parameters you select.

In designing your program, think about how you could use time-relevant measurements of certain parameters as indicators of the phenomena you wish to document. For example, depending on your water body's characteristics and the location of your monitoring equipment, you could use turbidity and dissolved oxygen measurements as indicators of an algae bloom. Then you could learn more about the bloom by conducting manual monitoring of parameters that might not currently be available to you on a cost-effective, time-relevant basis (e.g., chlorophyll-a, phosphorus, nitrogen). Another example might involve using time-relevant measurements of turbidity and electrical conductivity to trace the influx of streams laden with higher loads of particulate (as indicated by turbidity) and dissolved solids (as indicated by electrical conductivity).

## 3.5 Selecting Monitoring Equipment

Your selection of remote time-relevant water quality monitoring equipment depends on your project's objectives. When selecting monitoring equipment, you should also consider equipment lifetime, reliability, and maintenance requirements.

### Lake Access Equipment Selection

The Lake Access Team selected the RUSS unit to provide the capability to collect time-relevant water quality data remotely. This capability has provided the Lake Access Project team with new opportunities for data collection and analysis:

- The daily collection of multiple depth profiles enables personnel to view characteristics of lake stratification and metabolism on a daily basis.
- Because the remote equipment can collect and analyze water samples over frequent time intervals and during severe weather conditions, the Lake Access Project team can document lake mixing episodes. In some instances, some bays of Lake Minnetonka can completely mix in a 24-hour period. Scientists had discussed the potential for this type of rapid

mixing to occur, and other organizations had attempted to document these events by conducting monitoring on a daily basis, but Lake Access is the first project to successfully measure and document this phenomenon in Lake Minnetonka.

### Lake Access Time-Relevant Water Quality Parameters

**Temperature.** Temperature has a direct effect on biological activity and the growth of aquatic organisms because most aquatic organisms are "cold-blooded" (i.e., they cannot regulate their core body temperatures). Temperature also affects biological activity by influencing lake water chemistry. For example, because warm water holds less oxygen than cold water, it might not contain enough oxygen to support some types of aquatic life.

**pH.** pH is a measure of the acidity of the water. A pH of 7 is neutral. Values lower than 7 are acidic and higher than 7 are basic. Many important chemical and biological reactions are strongly affected by pH. In turn, chemical reactions and biological processes (e.g., photosynthesis and respiration) can affect pH. Lower pH values can increase the amount of dissolved metals in the water, increasing the toxicity of these metals.

**Dissolved oxygen.** The concentration of dissolved oxygen in water determines the number and type of aquatic organisms that can live in the water. Dissolved oxygen must be present at adequate concentrations to sustain these organisms.

**Electrical conductivity.** Electrical conductivity is an estimator of the amount of total dissolved salts or total dissolved ions in water. Many factors influence the electrical conductivity of lake water, including the watershed's geology, the watershed's size in relation to lake's size, wastewater from point sources, runoff from nonpoint sources, atmospheric inputs, evaporation rates, and some types of bacterial metabolism. Electrical conductivity is also a function of temperature; therefore, RUSS data are "standardized" to 25° C.

**Turbidity.** Turbidity describes the clarity of water. Turbidity increases as the amount of total suspended solids in the water increases. Increased turbidity measurements might have several adverse effects on lakes, including the following:

- If light penetration is reduced significantly, growth of aquatic plants and organisms can decrease. Reduced photosynthesis can result in decreased daytime releases of oxygen into the water.
- Particles of silt, clay, and other organic materials can settle to the lake bottom, suffocate eggs and/or newly hatched larvae, and fill in potential areas of habitat for aquatic organisms.
- Turbidity can affect fish populations. Increased turbidity can reduce the ability of predators, such as northern pike and muskellunge, to locate prey—shifting fish populations to species that feed at the lake bottom.
- Fine particulate material can affect aquatic organisms by clogging or damaging their sensitive gill structures, decreasing their resistance to disease, preventing proper egg and larval development, and potentially interfering with particle feeding activities.
- Increased inputs of organic particles, either produced from plant growth in the lake or washed in from the watershed, can deplete oxygen as the organic particles decompose.
- Increased turbidity raises the cost of treating surface water for the drinking water supply.

The RUSS unit, developed through a cooperative effort between Apprise Technologies and the University of Minnesota, performs remote water quality monitoring using commercially available monitoring sensors. The sensors

### The Lake Access Project: A Success Story

Prior to initiation of the Lake Access Project, a feasibility study was conducted to identify methods for improving Halsteds Bay's water quality. The study concluded that a $5.5 million project focusing on watershed restoration and improvement was necessary to accomplish this task. (This restoration project was not implemented.) Since that study, the Lake Access Project has shown that rapid weather-related mixing events cause the release of approximately 10 times more phosphorus to the epilimnion than runoff events from the surrounding watershed. The sediments are providing a reservoir of phosphorus from historical pollution that will take decades to flush out.

The Lake Access Project has provided valuable information—watershed management alone will not improve the water quality of Twin Cities Metropolitan Area lakes in all cases. With a greater understanding of the characteristics and causes of phosphorus concentrations in these lakes, the Lake Access Project team can apply appropriate lake management and water treatment strategies to improve water quality, and apply them with a much higher potential for success.

transmit time-relevant water quality data to a computer onboard the unit. Using wireless communication, the RUSS unit can both receive programming and transmit data to a land-base station.

The RUSS unit consists of a mobile underwater monitoring sensor tethered to a module that floats on the water surface. The flotation module contains batteries; solar panels; telemetry equipment; and a Remote Programming, Data Acquisition, and Retrieval (RePDAR) unit. A diagram of the RUSS unit is presented on page 19. This diagram, which shows the flotation module, tethered profiler, and three-line unit anchoring system, was taken from the RUSS System Manual. For more information about Apprise Technologies and the RUSS unit, visit http://www.apprisetech.com.

*RePDAR Unit.* The RePDAR unit allows for remote water quality monitoring sensor operation, data storage, and data transmission. Each RePDAR unit contains a central processing unit (CPU), power supply charging controls, and telemetry modules enclosed in a watertight resin case. The RePDAR unit enables the user to:

- Collect, process, and store data at user-specified intervals.
- Transmit data to the land-base station via wireless communication systems, including cellular, radio, satellite, or 900 MHz.
- Program the RUSS Unit from the land-base station.
- Operate the RUSS Unit in the field with a portable computer.
- Call the land-base station or an emergency telephone number when a water quality monitoring sensor parameter exceeds a user-specified range.

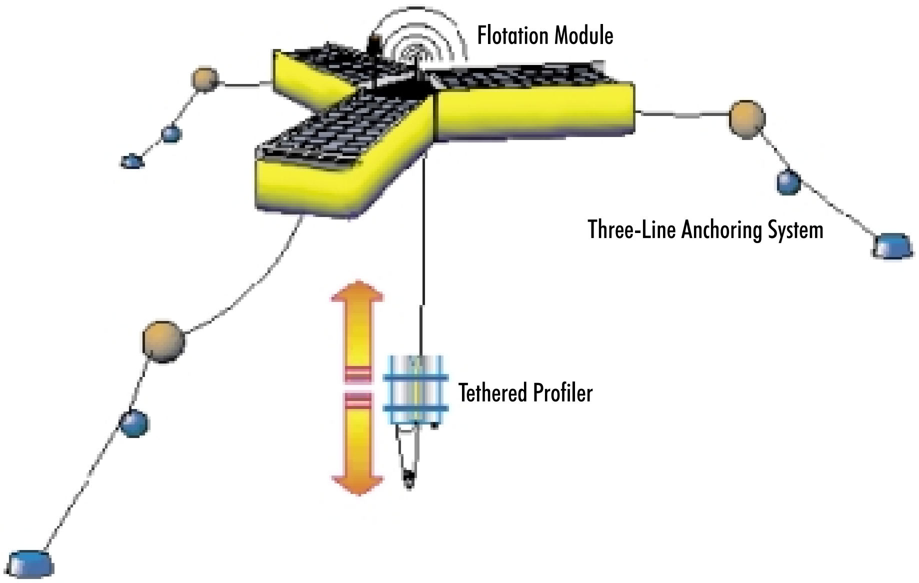



**Diagram of RUSS unit, showing the flotation module, tethered profiler, and three-line anchoring system.** (Taken from the RUSS System Manual, available from Apprise Technologies at http://www.apprisetech.com.)

*Flotation module.* The flotation module is a yellow, three-armed, floating buoy.

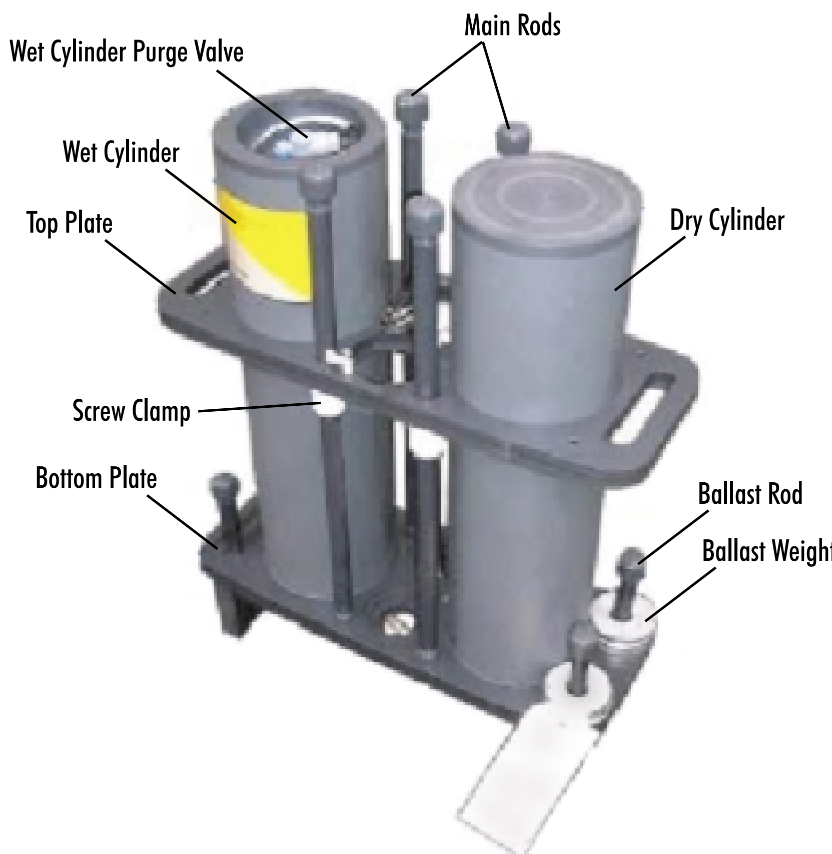
*Profiler.* The RUSS unit profiler is controlled by the RePDAR unit. The profiler carries the water quality monitoring sensor to multiple depths within the water column beneath the flotation module. A special profiler cable transmits power and buoyancy-control protocols from the RePDAR unit to the profiler and transmits data from the water quality monitoring sensor to the RePDAR unit.

An illustration of the profiler is presented on page 20.

*Field controller.* The field controller is used during the field service mode of operation. With the field controller, you can manually move the profiler and connect a portable computer to the water quality monitoring sensor and the RePDAR unit without removing the electronics hatch cover. The field controller consists of a small patch box with a receptacle for the profiler cable and a connector plug for the electronics hatch cover.

*Software.* The RUSS unit can be operated with two Apprise Technologies software programs:

- RUSS-Base, which allows you to operate the RUSS unit remotely using a computer at your land-base station. (See Chapter 4 for information about using RUSS-Base software.)
- CONSOLE, which allows you to operate the RUSS unit using a portable computer in the field.




**RUSS unit profiler.** (Taken from the RUSS System Manual, available from Apprise Technologies at http://www.apprisetech.com.)

## 3.6 Siting Monitors

You should select monitoring locations that best fulfill the objectives of your remote time-relevant water quality monitoring project; however, you will need to consider several factors when making your final siting decisions. Consider the checklist of questions on page 21 when choosing your location:

### Siting the Lake Access Project Monitoring Locations

The Lake Access Project team selected three locations for siting RUSS units:

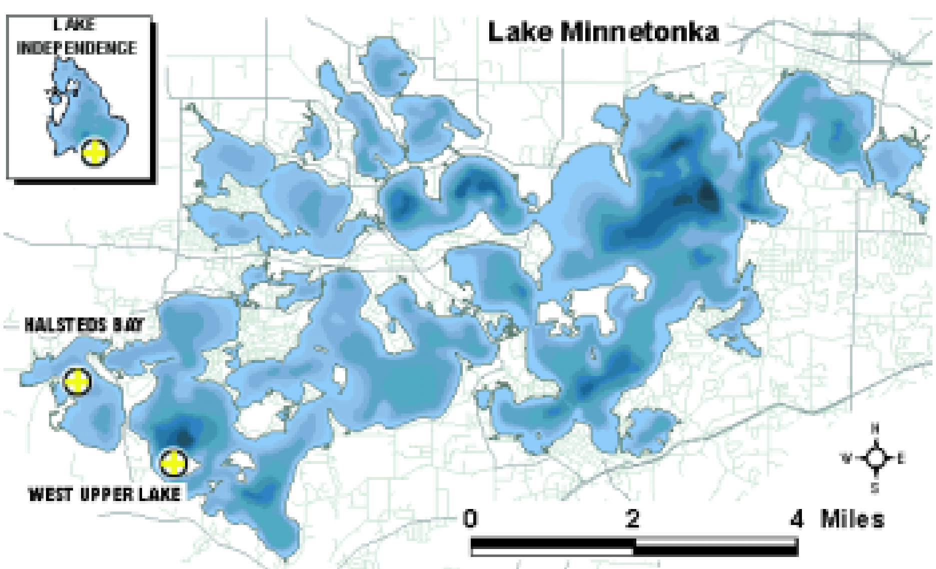
- Halsteds Bay in Lake Minnetonka, which receives runoff from a large watershed of both agricultural and urban residential land use. Because of nutrient loading from the runoff, the water quality in Halsteds Bay is poor. Halsteds Bay is subject to rapid weather-related mixing during the summer because of its relatively shallow depth (about 9-10 meters).
- West Upper Lake in Lake Minnetonka, which is much deeper than Halsteds Bay and has much better water quality. This basin receives runoff only from the area immediately adjacent to its shoreline. Because it is deeper than Halsteds Bay and has lower algal growth, West Upper Lake does not experience the same types of rapid weather-related mixing events.

## Monitoring Site-Selection Checklist

- ☐ Are the time-relevant data you collect at these locations likely to fulfill your project's objectives? Specifically, what questions will you be able to answer with your data, and how will the answers assist you with fulfilling your objectives?
- ☐ Will people in your community support equipment installation and remote time-relevant monitoring at your locations?
- ☐ Will monitoring equipment at your locations pose a potential danger to the people in your community? For example, are your monitoring locations near heavily trafficked areas of the water body?
- ☐ Will monitoring equipment be safe at your locations? In other words, will equipment be especially susceptible to vandalism, tampering, or damage?
- ☐ What local, state, or federal regulations will you need to consider when choosing your locations?
- ☐ Is flexibility important to your project? Would you like the option to move your monitoring equipment to different locations, or would you like to monitor at several locations concurrently?
- ☐ Do you foresee any site-specific problems with installing, operating, and maintaining your monitoring equipment at these locations? Do these locations pose any safety hazards to your personnel?
- ☐ Can you adequately survey and assess your locations? What equipment-specific considerations will you need to make?

- Lake Independence, which lies within the metropolitan region but receives primarily agricultural runoff. The water quality conditions in Lake Independence are intermediate to the conditions in Halsteds Bay and West Upper Lake.

The map below shows the locations of these three monitoring stations.



The Lake Access Team selected these three locations for the following reasons:

- The team can study data spanning the range of water quality conditions typically seen in Twin Cities Metropolitan Area (TCMA) lakes.
- MCWD conducts manual monitoring of the runoff to Halsteds Bay. The combination of these data, historical watershed-based land use and cultural data, and the Lake Access time-relevant water quality data from Halsteds Bay allows MCWD to study the link between land use patterns and bay water quality.
- Data from Halsteds Bay allow the Lake Access team to study the rapid weather-related mixing events that transport phosphorus from the lake bottom to the lake's upper layer.
- By comparing data from Halsteds Bay and West Upper Lake, the Lake Access team is able to determine how differences in lake basin shape and depth can produce dramatic differences in lake water quality, which in turn affect watershed and lake management decisions.

Before making final siting decisions, the Lake Access Project team met with community members to ensure their approval of proposed monitoring locations. The team decided against one proposed location because community members had concerns that monitoring equipment might interfere with lake recreational opportunities or adversely affect the lake's appearance.

The team also met with local agencies to ensure that the proposed monitoring locations complied with local regulations. To comply with boater safety regulations, the Lake Access team could not locate RUSS units in main lake traffic areas. As a result, the locations are closer to shore than the project team would have preferred. The Lake Access Project team was required to obtain navigational buoy permits from the county-level sheriff's office before installing the RUSS units.

The team also considered siting requirements specific to the RUSS units. The RUSS System Manual provides guidance on properly siting these units. Before installation, the manual recommends a site characterization survey consisting of the following:

- ***Maximum depth measurement.*** You will need to make these measurements when installing the RUSS unit profiler. The manual recommends several depth measurements within a 6-meter radius of the deployment location to account for local depth variations. If the water body you are monitoring fluctuates in depth, you must update the maximum depth in the profiler program. The profiler will sustain damage from repeated contact with the bottom of the water body.
- ***Depth contour assessment.*** Depth contour measurements will assist you with deploying the RUSS unit anchoring system. The manual recommends depth measurements in concentric circles surrounding the deployment location to generate a rough contour map of the anchoring site.

- ***Bottom type assessment.*** You might need to assess the material at the bottom of the water body to ensure proper anchoring of the RUSS unit. Different types of anchor designs are available for different bottom types.

- ***Signal strength assessment for the data telemetry device.*** You will need to ensure that cellular signal strength is reliable or radio telemetry is possible at the location.

- ***Temporary site marking.*** You should mark the assessed location to ensure that the RUSS unit is deployed in the proper location.

**The Lake Access Project: Looking Ahead**

Hennepin Parks would like to conduct future remote time-relevant monitoring with a RUSS unit in a shallow area of Lake Minnetonka where boating occurs. Lake Minnetonka is one of the most heavily used lakes for boating in the United States. Hennepin Parks would use the time-relevant data to study the magnitude at which boat traffic stirs up bottom sediments and the impact these events have on the lake's water quality. If data indicate that boat traffic adversely affects lake water quality, Hennepin Parks would advocate no-wake zones in near-shore areas to maintain ecosystem health.

## 3.7 Installing RUSS Units

This section summarizes some of the basic RUSS unit installation procedures. These procedures were taken from the RUSS System Manual, available from Apprise Technologies at http://www.apprisetech.com. You will need to consult this manual for detailed step-by-step installation guidance.

### Unpacking and inspecting the RUSS unit

The first step to installing a RUSS unit is unpacking and inspecting the unit. You should follow these procedures when receiving the unit:

1. Remove the packing material surrounding the flotation module. Take care when removing the packing material, as some items might have shifted during shipment.

2. Remove the solar panels and solar panel blank (if included) from each arm of the flotation module.

3. Remove the electronics hatch cover to access the dry compartment inside one arm of the flotation module, and remove all items located in the compartment.

4. Using the enclosed packing slip, perform an inventory of all items. If you are missing any items, contact Apprise Technologies.

5. Conduct a thorough visual inspection of all items. If you observe any damage, contact Apprise Technologies and the carrier.

### Preparing and assembling the RUSS units

You will need to conduct a series of preparation and assembly activities on land, on shore, and at the RUSS unit deployment location. Complete the following activities on land:

- Ensure your battery(ies) is charged.
- Assemble and connect the arms of the flotation module.
- Install the light and antenna.
- Attach the barrier float anchoring cables.
- Secure an appropriately sized line for towing the unit to the deployment site.
- Calibrate your water quality monitoring sensor according to manufacturer's instructions.
- Install the Apprise Technologies RUSS-Base software program on your land-base station computer.
- Install the Apprise Technologies CONSOLE software program on your field portable computer.

Once you have completed the on-land assembly of the RUSS unit, you will need to transport it to a shore-side location suitable for working on the unit. Complete the following activities on shore:

- Position your battery(ies) and the RePDAR unit within the dry compartment.
- Position and connect the two solar panels.
- Assemble the electrical system.
- Connect the RePDAR unit to the electrical system.
- Connect the profiler.
- Place the unit in the field service mode of operation and perform electrical testing. For more information on the field service mode of operation, see section 3.8.

When you have completed your electrical tests, you should disconnect the profiler and field controller and install your remaining solar panel or solar panel blank on the arm with the dry compartment. You are now ready to tow the RUSS unit to your monitoring location. When you tow the unit, take the water quality monitoring sensor, the profiler (with its ballast weights), and the field controller with you in the boat.

### Anchoring the RUSS unit

When you reach the deployment location, you will anchor your RUSS unit. Your anchoring system must meet the following requirements:

- The system must maintain the flotation module in a fixed location and prevent excessive drifting.
- Anchoring lines must maintain proper tension in all water conditions.
- Anchoring lines should not enter the water column below the flotation module (i.e., the working area of the profiler).

Apprise Technologies recommends a three-line anchoring system to provide dynamic control of the flotation module while maintaining proper orientation at the deployment location. A diagram of the recommended anchoring system's components is presented below.

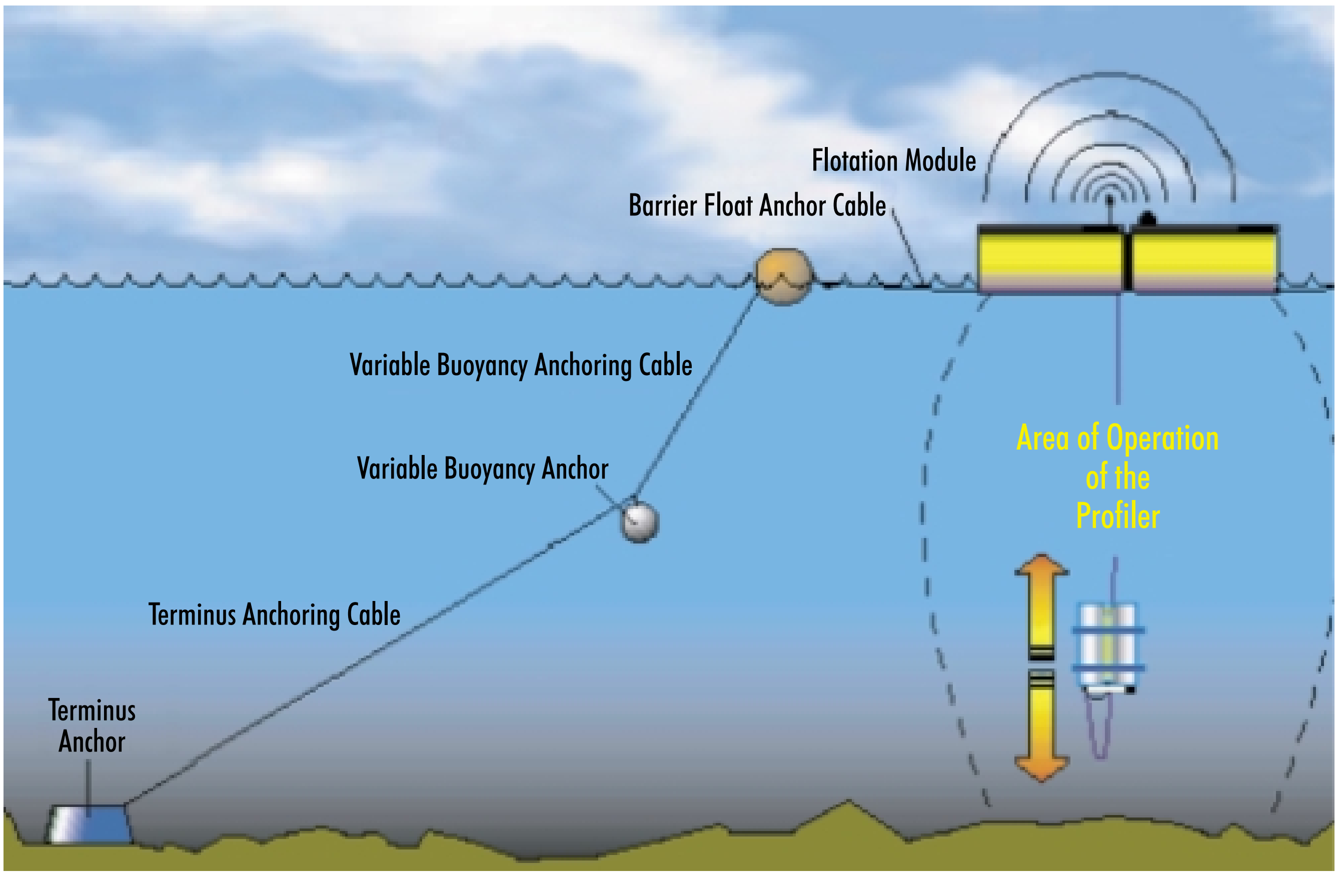



**Diagram of the recommended anchoring system components (only one of the three lines is illustrated).** (Taken from the RUSS System Manual, available from Apprise Technologies at http://www.apprisetech.com.)

Each anchoring line of the recommended system contains the following components:

- Barrier float anchoring cable—A 5-foot stainless steel cable of 3/16-inch diameter or greater connecting the flotation module to the barrier float.
- Barrier float—A small flotation buoy connecting the barrier float anchoring cable and the variable buoyancy anchoring cable. The three barrier float buoys (one on each line) can be essential for locating the RUSS unit during rough wave conditions.

- Variable buoyancy anchoring cable—A cable connecting the barrier float to the variable buoyancy anchor.
- Variable buoyancy anchor—Located between the barrier float and the terminus anchor. The variable buoyancy anchor provides tension in both the variable buoyancy anchoring cable and the terminus anchoring cable.
- Terminus anchoring cable—A cable connecting the variable buoyancy anchor to the terminus anchor.
- Terminus anchor—A device used to fix the end of the terminus anchoring cable to the bottom of the water body. The type of terminus anchor you use depends on the type of material at the bottom of the water body. As part of the survey and assessment of the monitoring location you conduct before installation and deployment, you determine this type of material and select a suitable anchor.

### Anchoring the Lake Access Project RUSS Units

The Lake Access Project team experienced difficulty with its RUSS unit anchoring system during the first year the units were deployed. The system allowed the RUSS units to drift, and the anchoring lines tangled with one another and with the profiler unit. In addition, the terminus anchors were too heavy to move by hand, so field personnel had to use a barge and crane to move and retrieve them. As a solution, the team installed a three-line anchoring system.

The Lake Access Project team is pleased with the current recommended three-line anchoring system. RUSS unit drifting has been minimized. The anchor lines remain tense and have not tangled with one another or interfered with the profiler operation. In addition, the terminus anchors are sized so team members can move them by hand. The Lake Access Project team has also replaced the steel anchoring cables with suitably sized rope because personnel have cut their hands on the steel cables while moving the anchors.

## Deploying the profiler

When your RUSS unit is anchored, you will connect your water quality monitoring sensor to the profiler and deploy the profiler by following these general steps:

1. Measure the length of profiler cable to match the maximum depth of the deployment site plus two meters. As part of your survey and assessment of the monitoring location before installation and deployment, you will have determined the maximum depth. If the water body fluctuates in depth, you must update the maximum depth in the profiler program. The profiler will sustain damage from repeated contact with the bottom of the water body.

2. Connect the profiler cable to the profiler and the electrical system.

3. Fill the profiler's wet cylinder with water and place ballast weights on the ballasting rods to achieve zero profiler buoyancy and vertical suspension.

4. Place the unit in the field service mode of operation and test the profiler movement. For more information on the field service mode of operation, see section 3.8.

Once your profiler testing is complete, your RUSS unit is ready for operation!

## 3.8 Operating RUSS Units

Although RUSS units are designed for remote operation from a land-base station, you can also operate them in the field. (See Chapter 4, section 4.2, for more information about communicating with your RUSS unit from the land-base station.) This section summarizes the basic procedures for operating your RUSS unit in field service mode. These procedures were taken from the RUSS System Manual, available from Apprise Technologies at http://www.apprisetech.com. You will need to consult this manual for detailed step-by-step field service operation guidance.

### Field service operation

The RUSS unit's field service mode of operation allows you to monitor the unit during deployment and in emergency situations. You will need the following equipment to operate your RUSS unit in field service mode:

- The key to the RUSS unit's electronics hatch cover
- The field controller
- A portable computer running Apprise Technologies CONSOLE software
- A null-modem computer cable

Follow these steps to enter the field service mode of operation:

1. Connect the field controller to the RePDAR unit.

2. With the null-modem cable, connect your portable computer to the field controller.

3. Set the field controller rotary switches to enable communication between the RePDAR unit and your portable computer, and to enable automatic movement of the profiler.

4. Turn the electronics hatch cover key to SERVICE to provide power to the RePDAR unit.

Your portable computer, with the CONSOLE software running, will act as your window to the RePDAR unit. Shortly after you provide power to the RePDAR unit, it will initialize. You will notice a 10-second pause after the initialization. You have two options during this pause:

Option 1. If you need to perform an emergency download of data in the RePDAR unit's memory, you can press *M* during the pause. (You will not need a password for this emergency download, but you will need to send the binary data file to Apprise Technologies or an authorized service site to have the file converted to standard format.)

Option 2. You can press *L* to log in during the pause. If you do not provide a password, you will be able to perform only deployment and hardware setup functions. If you enter the Level 1 password, you will have access to stored data. If you enter the Level 2 password, you will be able to make changes to the profiler and telemetry setup. If you do not log in during the pause, the software will prompt you for the appropriate password when you try to access any protected information.

After the 10-second pause, the RePDAR unit will enter the *Main Setup* menu. In this menu, you can access, review, and enter the following information:

- Current time and date
- Profiler schedule and depth
- Water quality monitoring sensor type
- RS-232 baud rate
- Modem baud rate and initialization strings
- RUSS unit call sign and location
- Data access and programming passwords

Under the main menu's *Data Access* option, press *A* to see a screen display of the stored data. As you view this display, the CONSOLE software will automatically capture these data to a file identified by the RUSS unit's call sign.

Under the main menu's *Proceed to Hardware Init* option, you can initialize the RUSS unit hardware according to the configuration you selected. When the initialization is complete, you will see a brief status report for each RUSS unit subsystem (e.g., the profiler, the water quality monitoring sensor, the modem) on your portable computer screen. The status report screen will allow you to do the following:

- View the programmed configuration, including the time, date, and the RUSS unit's call sign and location.
- View the battery voltage.

- View the results of the RePDAR unit's attempts to establish a link with the water quality monitoring sensor.
- Test profiler operation by pressing *(P)ark, (S)tart profile, or (H)alt.*
- View modem information and test commands.
- Test the modem link quality by calling a preprogrammed telephone number. You will be able to view a modem status message of the call's progress.

### Setting up the water quality monitoring sensor

In addition to properly calibrating your water quality monitoring sensor according to manufacturer's instructions, you will need to take the following steps to ensure your equipment operates properly:

- In the RUSS unit field mode of operation, confirm the programmed water quality monitoring sensor type and proper units of measurement and ensure that sensor operation is enabled.
- You should set the interval between sampling to a minimum of 3 seconds to ensure reliable profiler operation.
- Water quality monitoring sensors usually have two distinct modes of operation: the menu system is used for calibration and setup, and the data string mode is used during monitoring. You will need to make sure your sensor is in the proper operation mode.

### Lake Access Project RUSS unit operation

The Lake Access Project team programs its RUSS units to collect sample profiles at 1-meter intervals four times daily. Profiles begin at the lake surface at 12:00 p.m., 6:00 p.m., 12:00 a.m., and 6:00 a.m. Data are typically transferred to the land-base station each morning.

Apprise Technologies has altered the internal program for the Lake Access Project RUSS units to allow for a 5-minute delay between profiler movement and sample collection. This delay allows the YSI multiprobe water quality sensor to equilibrate to the different water temperature and dissolved oxygen conditions at each depth. Once the sensor has equilibrated, parameter measurement takes about 3 minutes.

When the sampling profile is complete, the profiler parks at a depth programmed by the Lake Access Project team. Parking depth is selected to place the sensor in the area of lowest light without placing it in the anoxic water layer.

## 3.9 Maintaining RUSS Units

You will likely focus most of your scheduled equipment maintenance on cleaning and calibrating your water quality monitoring sensors to meet your project's QA/QC protocols. The required effort and frequency for this maintenance will depend on the types of sensors you use and the water quality conditions at your monitoring locations. In addition to water quality monitoring sensor cleaning and calibration, you might need to perform scheduled maintenance on your RUSS unit. Required maintenance will depend on factors specific to your project, your community, and your monitoring locations.

## Lake Access Project Maintenance Activities

Lake Access Project maintenance activities include cleaning and calibrating the YSI multiprobe water quality sensors, maintaining a RUSS-unit bird deterrent system, removing the RUSS units during lake freezing and thawing conditions, reinstalling the units following these conditions, and repairing damaged or vandalized RUSS units.

### *Monitoring sensor maintenance and calibration*

The Lake Access Project team cleans and calibrates the YSI multiprobe water quality sensors on the three RUSS units every 1 to 4 weeks. The accuracy and precision of data derived from water quality monitoring instruments depend on sound instrument calibration procedures. (*Accuracy* is the extent to which measurements represent their corresponding actual values, and *precision* is a measurement of the variability observed upon duplicate collection or repeated analysis.)

Sensor cleaning and calibration is a multistep activity that begins with the following steps:

1. Traveling to the monitoring location.
2. Collecting a manual water quality profile near the unit using a YSI multiprobe water quality sensor identical to the one used on the RUSS unit.
3. Placing the RUSS unit in the field service mode of operation and manually moving the profiler to collect a water quality profile.
4. Manually moving the RUSS profiler to the surface.
5. Removing the sensor from the profiler and manually moving the profiler to its parking depth.
6. Transporting the sensor to the laboratory.

At the laboratory, a set of known parameter standards are measured with the sensor. By comparing these sensor measurements with the known standards and by comparing the two manual water quality measurements taken in the field, the Lake Access Project team can more accurately estimate the amount of error associated with recent sensor measurements and determine the quality of recently collected data.

Lake Access Project personnel clean, calibrate, and inspect the multiprobe sensors according to detailed instructions provided by YSI. The sensors are carefully and thoroughly cleaned to remove algae and other organisms that cause sensor biofouling. The pH, conductivity, and turbidity meters are calibrated against known standard solutions. To ensure accurate calibration, the team selected these standards in ranges at which the parameters are typically detected in the field. The temperature meter is calibrated against the temperature in the laboratory. The dissolved oxygen meter is calibrated using a YSI calibration cup. The depth probe is calibrated out of water to a depth of zero.

☞ **Tip.** Although cleaning and calibration activities can occur in the field, Lake Access Project personnel prefer to calibrate the monitoring sensors within the laboratory's controlled environment. Because of temperature changes in the field, the sensors can take a long time to equilibrate—even if they are submerged in a bucket of water. Overall, the Lake Access Team has found that the entire cleaning and calibration activity takes longer in the field than in the laboratory.

Lake Access personnel complete the cleaning and calibration activity by:

1. Traveling to the monitoring location.
2. Placing the unit in the field service mode of operation and manually moving the profiler to the surface.
3. Connecting the sensor to the profiler, placing the RePDAR unit in the ON position, and removing the key to the electronics hatch cover. When the key is removed, the RePDAR unit will move the profiler to its parking position and resume normal RUSS unit operation.

Lake Access Project personnel are able to complete sensor cleaning and calibration activities on the three RUSS units on Lake Minnetonka and Lake Independence in 1 day, unless a sensor component requires repair or replacement.

### Resolving Calibration Issues

Because of water quality conditions in Lake Minnetonka and Lake Independence, the Lake Access Project team has had some difficulty maintaining the calibration of the units' dissolved oxygen meters. During summer months, the team noticed significant errors in dissolved oxygen measurements. Sometimes the team had to calibrate the dissolved oxygen meters every 7 to 10 days.

The Lake Access Project team had typically parked the RUSS unit profilers at 5 meters deep—below the sunlit layer of the lake—to reduce the rate of algae growth and subsequent biofouling of the sensors. Lake stratification can make Twin Cities Metropolitan Area (TCMA) lakes anoxic below 3 meters deep. In the anoxic area, the level of hydrogen sulfide in the water increases. Lake Access team members began to suspect that the hydrogen sulfide in the anoxic zone was reacting with the potassium chloride in the dissolved oxygen probe, causing the calibration to rapidly decay. The team raised the profiler parking depth to 3 meters—out of the anoxic zone, but still deep enough to reduce the rate of sensor biofouling during the summer months.

During the winter, the Lake Access Project team typically reprograms the profilers to park at 5 meters deep because, during these months, this level of the lake is dark but remains well oxygenated.

### *Bird deterrence*

Some birds love to land on RUSS units! So many birds landed on the Lake Access Project units that guano covered the solar panels, preventing adequate battery charging. Team members sometimes had to clean the solar panels daily.

To prevent this nuisance and ensure adequate battery charging, the Lake Access Project team experimented with bird deterrent systems. First, the team placed coiled wires over the solar panels. Although the wires stopped birds from landing on the solar panels, they prevented field personnel from working comfortably with the RUSS units. The team replaced the coiled wires with chicken-wire covers that fit over the solar panels. The chicken wire is easier to handle and keeps birds off the panels just as well.

### *Lake freezing and thawing conditions*

The Lake Access team temporarily removes its units from the lakes during freezing conditions in the late fall and thawing conditions in the early spring because the units could be severely damaged if left on the ice during these conditions.

*Freezing conditions.* Just prior to lake freezing conditions, the team removes the RUSS units from the lakes. The team retrieves all portions of each unit (including the buoys, anchors, and anchoring lines), brings the profiler to the surface and detaches it, and tows the unit to shore. The RUSS units are stored intact in a large shed. When the lakes have frozen over, the project team erects an ice house at each monitoring location. The team does not use the RUSS unit flotation module during the winter months. The solar panels are mounted on top of the ice shed, which is oriented to allow for maximum solar exposure and angled to minimize snow accumulation. The RePDAR unit and batteries are stored inside the ice shed, and the profiler is deployed through a hole in the ice.

*Thawing conditions.* Just prior to lake thawing conditions, the Lake Access Project team removes the icehouses and the RUSS unit components. During winter monitoring, the ice hole cut for the profiler freezes around the cable. Although the ice does not adversely affect the operation of the profiler, personnel have to chip through the ice to remove the cable and the profiler. When the lakes have thawed completely, the project team redeploys the complete RUSS units at the monitoring locations.

## 3.10 Other Local Monitoring Efforts

This section provides information about additional water quality monitoring efforts being conducted in the Minnehaha Creek Watershed and Hennepin Parks district. Minnesota researchers and natural resource managers are conducting these projects to learn more about the characteristics of Twin Cities Metropolitan Area (TCMA) lakes, detect water quality trends and recreational use impairments, develop lake management strategies and determine their effectiveness, and ensure the safety and health of lake users. Some of these monitoring methods might help satisfy your community's water quality monitoring objectives. For example, there may be times when you are unable to conduct remote time-relevant monitoring (e.g., due to equipment malfunction; during lake freezing and thawing conditions; when remote time-relevant monitoring technology is not available for a particular location or analytical parameter; or when required resources are insufficient). In these instances, you could use the data collection methods described in these projects to supplement time-relevant data.

Specific monitoring efforts conducted by Minneapolis community lake management and research organizations include:

- Monitoring for water quality trends
- Nutrient budget monitoring
- Health and safety monitoring
- Project-specific monitoring

### Monitoring for Water Quality Trends

For more than 5 years, MCWD and Hennepin Parks have conducted water quality monitoring on approximately 15 lakes throughout the two districts and on nearly 20 bays in Lake Minnetonka. By measuring four water quality parameters (chlorophyll-a, total and soluble reactive phosphorous, and nitrogen), MCWD and Hennepin Parks personnel can determine how changes in lake nutrient concentrations affect the growth of algae and how the growth of algae affects lake water quality:

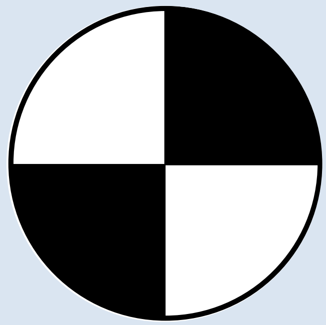
- Chlorophyll-a measurements show how much algae is present in the water.
- Total and soluble reactive (i.e., dissolved) phosphorus measurements indicate the amount of phosphorus available for algae growth. Very little phosphorus is needed to dramatically change lake water quality; one pound of phosphorus entering a lake from the surrounding watershed can grow 300 to 500 pounds of algae in the lake.
- The relationship between the amounts of nitrogen and phosphorus in a lake can help personnel determine whether phosphorous or nitrogen is the limiting nutrient for algae growth.

Collectively, MCWD and Hennepin Parks staff use these data to detect water quality trends. These trends can indicate if impacts such as recreational use or urbanization are impairing water quality, or if management initiatives such as public education or stream, lake, and wetland restoration are leading to improved water quality.

MCWD and Hennepin Parks staff travel to each monitoring location biweekly to collect water quality samples. Before collecting samples, personnel determine Secchi disk depth (see the box on page 34) and use a YSI multiprobe water quality sensor to gather time-relevant data on temperature, pH, dissolved oxygen, electrical conductivity, and depth in a profile of 1-meter intervals from the surface to the bottom of the lake. Personnel use these data in the field to determine the water depth and locate the lake's thermocline.

### What is a Secchi Disk?

A Secchi disk is a tool used to measure the water's clarity. It is a weighted, round metal plate about 8 to 12 inches in diameter with an alternating black-and-white pattern like the one shown below.



Field personnel lower the disk into shaded water (because sunlight can affect the measurement) until it is no longer visible. Then they raise the disk until it is barely visible. The average of these two depths is the Secchi disk depth, which provides a measure of the water's clarity or transparency.

(For more information on Secchi disks, see the Lake Access Web site at **http://www.lakeaccess.org/russ/index.html.**

Staff collect a 2-meter surface composite sample, a grab sample at the thermocline depth, and a grab sample one-half meter from the bottom. The table below summarizes the purposes and techniques for collecting these types of samples.

## Nutrient Budget Monitoring

Each year, MCWD and Hennepin Parks conduct nutrient budget monitoring in two to three streams that feed Lake Minnetonka. This type of monitoring includes analyses for the following parameters:

- Total phosphorus
- Total nitrogen
- Total suspended solids
- Total solids
- Soluble reactive phosphorus
- Ammonia
- Nitrate
- Temperature
- pH
- Electrical conductivity

| Sample Type | Purpose | Collection Technique |
|---|---|---|
| Two-meter surface composite | This type of sample represents the strata of biological activity (e.g., algae growth) in the lake's upper layer, where sunlight penetrates. MCWD and Hennepin Parks collect 2-meter surface columns because sunlight typically penetrates the upper 2 meters of TCMA lakes. This is also the standard surface water sampling protocol used by the Minnesota Pollution Control Agency. | Samples are collected using a PVC pipe 3 inches in diameter and 2 meters long. Field personnel submerge this pipe vertically to collect a column of water from the upper 2 meters of the water body. Each composite sample is brought to the surface, poured into a composite container, mixed, and divided into subsamples for laboratory analyses. |
| Thermocline grab | A lake thermocline typically deepens during the summer as the upper, wind-mixed layer of the lake (the epilimnion) rises in temperature. The thermocline grab sample indicates how much phosphorus will be available to algae if storms mix the lake below the thermocline depth. | Using a rope, personnel lower a special sampling device (typically a Van Dorn or Kemmerer water bottle) to the thermocline depth. The sampling device consists of a tube with spring-loaded closures on each end. When the device has reached the thermocline depth, personnel send a weight (called a messenger) down the rope. When this weight contacts the sampling device, the spring-loaded closures seal both ends of the tube. The grab sample is brought to the surface and divided into subsamples for laboratory analyses. |
| Bottom grab | This sample indicates how much phosphorus is located at the lake bottom (and how much phosphorus would be available to algae if the lake were to mix completely). | Field personnel collect the bottom grab by lowering the same type of sampling device used for the thermocline grab to a depth of one-half meter from the bottom. The grab sample is brought to the surface and divided into subsamples for laboratory analyses. |

By measuring these parameters, MCWD and Hennepin Parks can characterize total annual nutrient loading from the monitored stream into a lake.

Total phosphorus and total nitrogen measurements indicate the amounts of phosphorus and nitrogen—in particulate and dissolved forms—that enter the lake from the inflow stream.

Measurements of total solids and total suspended solids help MCWD and Hennepin Parks determine the amounts of phosphorus and nitrogen that exist in particulate form. Best management practices (BMPs) such as sediment detention ponds or constructed wetlands are typically designed to remove nutrients in particulate form.

The soluble reactive phosphorus measurement indicates the amount of phosphorus dissolved in the water. The nitrate and ammonia measurements describe the major forms of nitrogen available to algae that are present in the water. These measurements are important because they indicate how much phosphorus and nitrogen are present in the forms most available for algal growth and most difficult to remove by BMPs.

Temperature, pH, and electrical conductivity measurements further describe water quality of the inflow stream. (See Section 3.4 for more information about monitoring for these parameters.)

To conduct nutrient budget monitoring, field personnel install automated flow meters on lake inflow streams to measure and electronically log flow. Automatic samplers are linked to the flow meters to collect flow-weighted composite samples. Composite samples are made up of individual volumes collected over time. At a predetermined stream-flow interval, the flow meter sends a signal to the sampler to collect each volume of the composite sample. At the conclusion of the composite period (which typically spans a storm event, plus one hour), field personnel retrieve, mix, and divide composite samples into subsamples for analysis at the Hennepin Parks water quality laboratory.

### Health and Safety Monitoring at Swimming Beaches

Hennepin Parks manages nine swimming beaches. At three of these beaches, Hennepin Parks uses rubber beach curtains that encompass 1 to 1.5 acres of lake area for swimmers and restrict water movement between the swimming area and the lake. These curtains reduce the volume of lake water Hennepin Parks must manage for swimmers. For example, algae blooms can be quite severe on some lakes, but Hennepin Parks has several options for managing blooms within beach curtains. These include pumping fresh water into the swimming area, using fountains to prevent buildup of algae scum on the water surface, and applying aluminum sulfates (alum) to remove phosphorous and algae within the swimming area.

During the swimming season, personnel monitor swimming waters to ensure they are safe for the public. Lifeguards determine the Secchi disk depth of swimming waters three times daily. By comparing Secchi disk depths in water within the beach curtain to water outside the curtain, Hennepin Parks can demonstrate that the beach curtains provide the public a better swimming experience.

Hennepin Parks monitors recreational waters for fecal coliform bacteria weekly. Samples are analyzed at the Hennepin Parks water quality laboratory. Hennepin Parks adheres to national and state guidelines to maintain fecal coliform counts lower than 200 colonies per every 100 mL of water. Studies have shown that the probability of human health risk is minimal if fecal coliform counts are kept below this level. When Hennepin Parks personnel detect coliform levels greater than the guideline level, they immediately analyze a water sample for the bacterium E. coli. This tells personnel what percentage of fecal coliform can actually pose a health risk to swimmers. Fecal coliform bacteria data are posted weekly the Web at http://www.hennepinparks.org.

### Making Lake Waters Safe for Swimmers

Hennepin Parks personnel take immediate action to reduce fecal coliform levels when they exceed the guideline level for human health and safety. Typically, high fecal coliform levels in Twin Cities Metropolitan Area lakes can be directly attributed to local goose populations. Each morning, lifeguards patrol the beaches with strainers to remove goose droppings. If a few geese have become particularly fond of a swimming beach, lifeguards attempt to chase the geese away. If a large number of geese descend upon a swimming beach, Hennepin Parks uses a border collie service to herd the geese off the beach.

When fecal coliform sources have been minimized, Hennepin Parks treats the swimming water, if necessary. Personnel have used the following strategies to lower the fecal coliform level in swimming waters:

- Flushing the swimming area within the beach curtain with city drinking water, which contains a small amount of chlorine for disinfection.
- Flushing the swimming area with fresh ground water.
- Raising sections of the beach curtain at deep swimming sites to pull in lake water to flush the swimming area. Lake water is pulled from the bottom to minimize the amount of algae and swimmer's itch organisms pulled into the swimming area.
- Because fecal coliform bacteria are typically associated with solids, using small amounts of aluminum sulfate to settle any solid material in the swimming area can reduce health risks.

If every available strategy has been used and fecal coliform levels are still above the guideline for 2 to 3 consecutive days, Hennepin Parks closes the beach until the waters reach safe levels again.

## Project-Specific Water Quality Monitoring

MCWD and Hennepin Parks also conduct water quality monitoring on project-specific bases. A few examples of these projects are described below.

*Monitoring Sediment Detention Pond Effectiveness.* When one district lake's water quality began to decline, Hennepin Parks monitored the effectiveness of a sediment detention pond designed to remove nutrients from the lake's inflow stream. Hennepin Parks personnel suspected the sediment detention pond had filled with too much sediment to remain effective. To confirm this suspicion, personnel used the nutrient budget monitoring method to measure flow and collect samples at monitoring locations located upstream and downstream of the sediment detention pond. By comparing the parameters measured at each monitoring location, Hennepin Parks determined that the sediment detention pond was not effectively removing nutrients from the inflow stream. The pond was dredged of excess sediment, and Hennepin Parks conducted additional monitoring to ensure that the dredging increased the pond's effectiveness.

*Lawn Fertilizer Runoff Study.* Hennepin Parks conducted a series of lawn fertilizer runoff studies. To determine the number of lawns requiring phosphorus fertilizer, Hennepin Parks collected and analyzed soil samples from approximately 200 suburban lawns. Although most suburban home owners use fertilizers with phosphorus, Hennepin Parks found that only about 15 percent of the lawns actually required the addition of phosphorus for healthy turf.

Using sampling devices designed by the U.S. Geological Survey, Hennepin Parks monitored runoff from about 30 suburban lawns, some of which were fertilized and some of which were not. Each sampling device consisted of two 5-foot long, 1-inch diameter PVC pipes with slits cut lengthwise. These pipes were placed horizontally on each lawn to form a "V" pointing down the lawn's slope toward its storm water drainage area. Where the pipes met, personnel attached a cup and placed an 8-inch long, 6-inch diameter PVC pipe (vertically) into the cup. In this pipe, personnel placed a sample bottle. During a rainfall event, runoff water flowed into the slits, through the "V" pipes, and into the sample bottle.

Because most of the monitored lawns were small and because most district rain events are brief, the samplers typically collected all runoff from each rainfall event. By comparing the concentrations of phosphorus measured in the runoff from fertilized and unfertilized lawns, personnel determined that much of the phosphorus fertilizer applied to the lawns not needing additional fertilizer runs off.

*Golf Course Runoff Study.* To determine the characteristics of runoff that TCMA lakes typically receive from golf courses, Hennepin Parks conducted runoff studies using the nutrient budget monitoring method. In addition to these parameters, personnel also analyzed samples for any pesticides and fungicides used by the golf course.

Hennepin Parks and many community golf courses are cooperating to help improve the quality of local lakes. During the past several years, district golf courses have saved money, maintained suitable turf, and improved the quality of runoff water to TCMA lakes by using the following management strategies:

- Reducing the use of all fertilizers, especially those containing phosphorus.
- Reducing the use of pesticides and fungicides by eliminating preventative treatments. District courses now use these agents to treat only problem areas.

## Using Monitoring to Help Meet Lake Water Quality Goals

### *Minneapolis Park and Recreation Board*

The Minneapolis Park and Recreation Board (MPRB) conducts a variety of water quality monitoring projects in Minneapolis lakes. The MPRB undertakes some of this monitoring to measure progress toward meeting water quality goals set by the Minneapolis Chain of Lakes Citizen Committee. In 1993, the Committee developed water quality goals for Lake Calhoun, Lake Harriet, Cedar Lake, and Lake of the Isles. The Committee hopes, over the long term, to restore the water quality of these lakes to conditions as close as possible to those that existed before urbanization. To achieve its goals, the Committee has recommended reducing in-lake phosphorus concentrations and managing influent pollutant loads to each lake with a unique scheme of in-lake manipulations and watershed best management practices (BMPs). The MPRB uses monitoring data to measure changes in water quality and evaluate the effectiveness of the BMPs used. The MPRB also conducts monitoring in other Minneapolis lakes to measure long-term water quality trends, establish water quality goals and lake management plans, and compare the water quality trends in these lakes with trends measured in the Chain of Lakes.

### Lake Water Quality Monitoring

The Environmental Operations Section of the MPRB conducts long-term water quality monitoring in Minneapolis lakes. The MPRB plans to conduct this type of monitoring for about three to five years to ensure that water quality changes in city lakes are not masked by annual variations in weather patterns. The long-term monitoring program includes analyses for the following parameters:

- Dissolved oxygen
- pH
- Conductivity
- Temperature
- Total phosphorus
- Total dissolved phosphorus
- Soluble reactive phosphorus
- Total nitrogen
- Silica
- Alkalinity
- Chloride
- Hardness
- Chlorophyll
- Phytoplankton
- Zooplankton

The MPRB selected these parameters to allow for a detailed characterization of the in-lake processes that affect water quality. The MPRB's year-round sampling frequency increases during the lake growing season (May through September), when in-lake conditions are rapidly changing.

Field personnel from the MPRB's Environmental Operations section conduct water quality monitoring at the deepest point of each lake. These points are determined using bathymetric maps and located using shoreline landmarks and depth sounding equipment.

At each monitoring location, field personnel use a Hydrolab© sensor to conduct field measurements of dissolved oxygen, pH, conductivity, and temperature at 1-meter intervals through a vertical column of water. Field crews also collect manual samples for total phosphorus, total dissolved phosphorus, and soluble reactive phosphorus at predetermined intervals in the water column. Personnel collect zooplankton samples by hauling a net vertically through the water column at a rate of 1 meter per second and washing the net with distilled water to remove the contents for preservation and analysis. Surface composite samples for all other parameters are collected in a column of water from the upper two meters of the lake. Personnel also determine Secchi disk depth and perform a survey of vascular plants during sampling.

*(continued on next page)*

## Storm Water Runoff and Best Management Efficiencies Monitoring

The MPRB conducts monitoring of stormwater runoff and best management efficiencies to determine the actual pollutant removal achieved through the use of structural BMPs (e.g., wetlands, street cleaning, and grit chambers) and to study long-term pollutant loading trends in Minneapolis lakes. These monitoring data are used to determine if changes in BMPs are required. Monitoring locations are selected based on the following requirements:

- The location should be influenced by only one BMP
- No area of the watershed should drain to a sanitary treatment system
- The location should not be affected by a major sewer or street construction project
- The entire watershed should fall within Minneapolis city limits

This type of monitoring includes analyses for the following parameters:

- Total suspended solids
- Total phosphorus
- Dissolved phosphorus
- Total nitrogen

Field personnel use automated flow meters and samplers to conduct stormwater runoff and best management efficiencies monitoring. Automatic flow meters allow personnel to record continuous flow measurements at each monitoring location. Automatic samplers provide the following three sampling options:

- Time-weighted composite sampling, where composite samples are made up of individual volumes collected over a predetermined interval of time.
- Flow-weighted composite sampling, where the automatic sampler is electronically linked to a flow meter. At a predetermined flow interval, the flow meter sends a signal to the sampler to collect each volume of the composite sample.
- Time- or flow-weighted discrete sampling, where the automatic sampler is retrofitted to collect 12 samples in individual bottles at a predetermined time or flow interval.

Because the monitoring equipment cannot be operated in below-freezing conditions, the MPRB installs the equipment as early as possible in the spring and removes the equipment as late as possible in the fall to prolong monitoring time and avoid freezing conditions.

# 4. COLLECTING, TRANSFERRING, AND MANAGING TIME-RELEVANT WATER QUALITY DATA

To effectively assess the water quality of a lake or river, it is necessary to collect representative field samples over a time span that takes into account as many influences on the water body as possible. However, conducting a comprehensive manual sampling program that covers different times of the day, as well as different seasons and seasonal events, presents distinct challenges. As a result, many water quality monitoring programs, such as the Lake Access Project, rely on automated systems in which remote water sampling units collect data at programmed intervals and then transmit the data to a land-based station for storage, retrieval, and analysis.

Using the Lake Access Project as a model, this chapter provides you and your community with "how-to" instructions on how to operate and maintain such data collection systems. If you are responsible for or interested in implementing this system, you should carefully read the technical information presented in the sections on setting up and using RUSS-Base software for data collection and transfer, and managing the data at the base station (Sections 4.2 through 4.5). Readers interested in an overview of the system should focus primarily on the introductory information in Section 4.1 below.

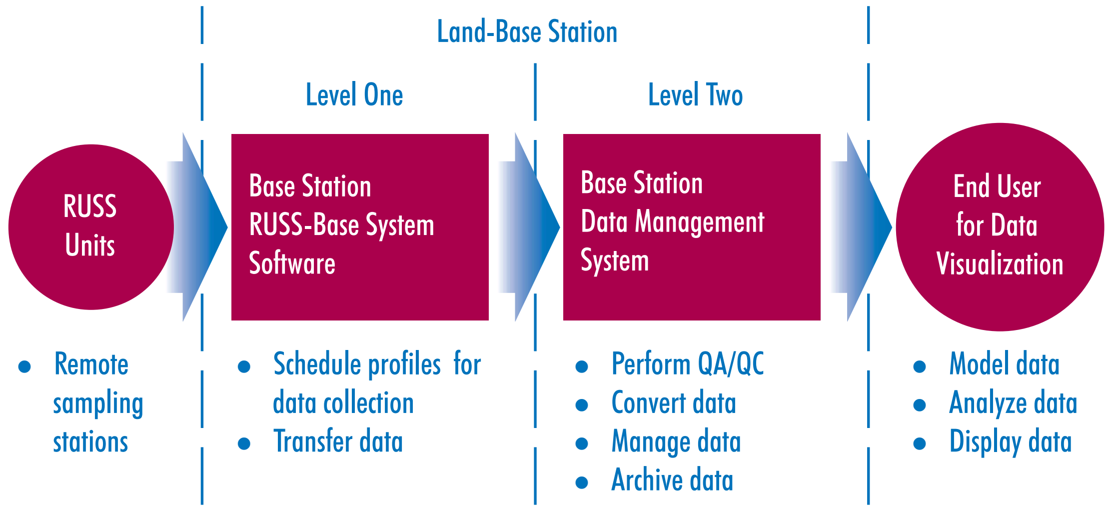
## 4.1 System Overview

A data collection, transfer, and management system can benefit your community in two ways: It enables you to automate the collection of water quality samples, and it enables you to control the resulting data flexibly and easily. By using the system's software, you can program your remote in-water sampling units (in this case, RUSS units) to collect water quality data at specified intervals. Then you can call the sampling units as needed for data transmission or program your system to call for transmissions of data at specified times. Once the data arrive, the information can be formatted and stored or otherwise prepared for export to another database, or it can be analyzed using geographical information system (GIS) or data visualization software.

The data collection, transfer, and management system used in the Lake Access project consists of two main parts (see the figure on the following page):

- *Remote Underwater Sampling Station (RUSS) units,* which are deployed in the water and programmed to collect water quality data in the water column at specified depths and intervals.
- *A land-based station,* which is basically a computer equipped with two main parts:
    - *RUSS-Base software.* You use this software to create profile schedules of sampling parameters and to communicate with the RUSS units to transmit schedules and receive sampling data.

- *A database management system.* You use this system to format, quality check, and store collected data.




The RUSS units and the base station computer are equipped with communications hardware featuring either a modem/cell phone or modem/radio transceiver. This equipment allows the RUSS units and computer to "talk" to each other over long distances. Because of this communication ability, each RUSS unit becomes part of a remote data acquisition system controlled from the land-base station. At the base station, an operator runs the RUSS-Base software to connect to the RUSS units for data collection and transfer.

The system's flexibility enables you to establish sampling and data transfer protocols based on your specific monitoring needs. For example, you might program your RUSS units to sample every 4 hours, 7 days a week, to monitor general trends. You might also want to conduct sampling specific to certain events, such as storms or heavy rainfalls, during which you might monitor water quality at a single depth on an hourly basis.

The system can collect and store data for future use, or it can retrieve and transmit collected data in near-real time. Each RUSS unit stores collected data in its on-board computer (RePDAR), making the data available for download on demand by the base station. The RUSS unit can hold up to 3 weeks of collected data (assuming average sampling intervals) in its on-board computer. The unit also can serve as a temporary archive by retaining a copy of all transmitted data files. Once the unit runs out of space, it will overwrite data as necessary, beginning with the oldest files.

A single base station can control an array of RUSS units, and an individual RUSS unit can transmit data to more than one base station.

The remainder of this chapter provides information on how to program a data collection and transfer system and how to manage the collected data, using the system used by the Lake Access project as an example.

### How often should data be collected?

The Lake Access team generally collects samples every 4 to 6 hours to observe daily changes in water quality parameters (see Chapter 3, section 1). The RUSS units collect samples at 6:00 a.m., 12:00 noon, 6:00 p.m. and 12:00 midnight, and the data are transmitted to the land-based station at 7:30 a.m. the following morning. The team also collects intermittent samples to determine the effect of storm events on lake stratification and nutrient mixing.

## 4.2 Getting Your Equipment and Software in Place

In addition to deploying your RUSS units for data collection and transfer, you will need to assess whether your base station computer equipment meets minimum technical requirements. Once you have determined that it does, you will be ready to obtain and install the software needed to communicate with your RUSS units. Before you receive the software from Apprise Technologies, you will need to determine which type of telemetry equipment should be used on the RUSS units.

### Minimum Requirements

To use a land-based computer as a base station, you will need:

- An IBM-compatible PC with a Pentium II processor (300 megahertz [MHZ])
- Windows 95, 98, or 2000 or Windows NT
- 16 megabytes of RAM
- 10 megabytes of free disk space
- An industry standard internal or external dial-up modem

### Telemetry Equipment

As a next step, you will need to determine what kind of data communication or telemetry equipment to install on your RUSS units. Telemetry equipment enables data to be transferred from a remote sampling station (i.e., the RUSS unit) to a receiving station (i.e., the base station). You can choose between a cellular telephone modem (CTM) and a 900-MHZ transceiver. To make this choice, you should consider the following factors:

- The initial expense associated with CTM units is relatively low. (They generally cost about $1,000 each.) However, CTM unit connection costs can be somewhat higher than transceiver unit connection costs. In contrast, the up-front costs for transceiver units is relatively high (generally about $3,000 each), but connection costs are likely to be much lower. In addition, maintenance costs tend to be lower for transceivers.

- Establishing a connection between a CTM unit and RUSS units can be problematic at times if local circuits are overloaded or if tower-switching issues arise.

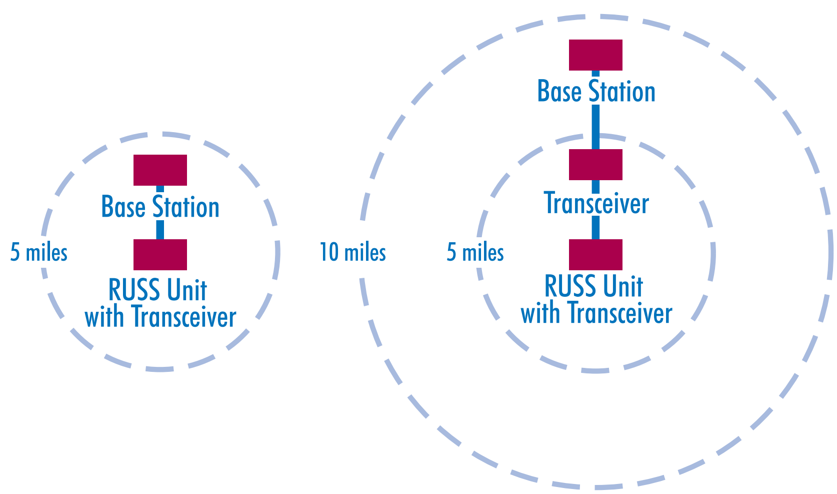
Even when a connection is established, the signal strength might not be strong enough to allow data transmission. A signal strength of less than 50 MHZ is usually too weak, while a signal strength between 50 and 60 MHZ is marginal.

**Tip.** To test the connection between a CTM unit and a RUSS unit, you can call the test line maintained by Apprise Technologies, which is usually pre-programmed into the CTM. (Before you dial, be sure to switch the unit to the proper pre-programmed number by using the key pad.) On certain CTMs, you can call the test line by pressing "C" on the key pad. The status of the call will be displayed in the phone's message window, as follows:

- "No service" indicates insufficient signal strength
- "System busy" indicates overloaded local cell capacity
- "No carrier" or "busy" or "dropped call" indicates call interruption
- "Connect" indicates successful connection

(Note: Apprise Technologies does not guarantee the accessibility of its test line.)

- Transceiver unit communications can be affected by radio interference on the transmission channel. The channel's path also can be inadequate to maintain the connection. In such cases, it might be possible to switch to a different channel. Using a dedicated or leased line can help ensure the reliability of data transmission.
- Depending on the distance between the land-based station and a RUSS unit, you may need to deploy a sequence of transceivers. Transceivers can transmit and receive over a distance of no more than 5 miles. The figure below shows different transceiver deployment configurations based on the distance between the land-based station and the RUSS unit.



## Installing Level 1 Base Station Software

Once you have determined that your computer meets minimum technical requirements and you have selected and set up your telemetry system, you are ready to obtain and install RUSS-Base, the level 1 base station software. RUSS-Base enables you to create profile schedules with sampling parameters, transmit the schedules to your RUSS units, and receive transmissions of sampling data. Additional software (discussed below) allows you to run RUSS-Base automatically.

### *RUSS-Base Software*

RUSS-Base, a DOS-based software program available from Apprise Technologies, is provided as part of a RUSS unit's data collection and transfer system.

To install RUSS-Base:

1. Copy *R-Base.exe* from the disk or CD-ROM to a directory on your computer.
2. Double click on the executable file. This will load the program onto your computer and create an icon to access RUSS-Base from your desktop. It will also create two directories on your hard drive. One directory, *C:\RUSS,* contains the RUSS-Base program. The other directory, *C:\RUSSdata,* is the default directory in which downloaded data from the RUSS unit will be automatically placed.
3. Verify that the RUSS-Base program is working by double clicking on the desktop icon or navigating to the *C:\RUSS* directory and double clicking on *R-Base.exe.*

Note that Apprise Technology provides customers with update notifications by telephone or e-mail and delivers the actual updates via e-mail, disk, or CD-ROM. We suggest that you implement these updates as you receive them.

### *Additional Software*

ClockerPro and Clocker are personal/network program schedulers for use on the Windows platform. They are designed to schedule programs (or reminders)—such as the upload and download of data from RUSS units—to run at specified times. Registration for a single copy of these schedules costs $24.95.

To obtain and install ClockerPro or Clocker:

1. Download ClockerPro and Clocker from http://www.winnovation.com/clocker.htm.
2. Click on the file *clkpr311.zip* (for ClockerPro) or c*lk2403.zip* (for Clocker) and save it to a temporary directory on your computer (such as *C:\tmp*).
3. Navigate to the location of *clkpr311.zip* or *clk2403.zip.*
4. Run *setup.exe* and follow the instructions provided. For instructions on using ClockerPro or Clocker, select *Help* from the software's main screen.

*Anticipating Support Needs*

As with any computer system, you will need to ensure the availability of technical support to attend to software, hardware, and security needs. A staff person who is familiar with providing general computer support should be able to maintain your system. You should enlist the services of a technical support person before you deploy the system so that guidance is available when you need it.

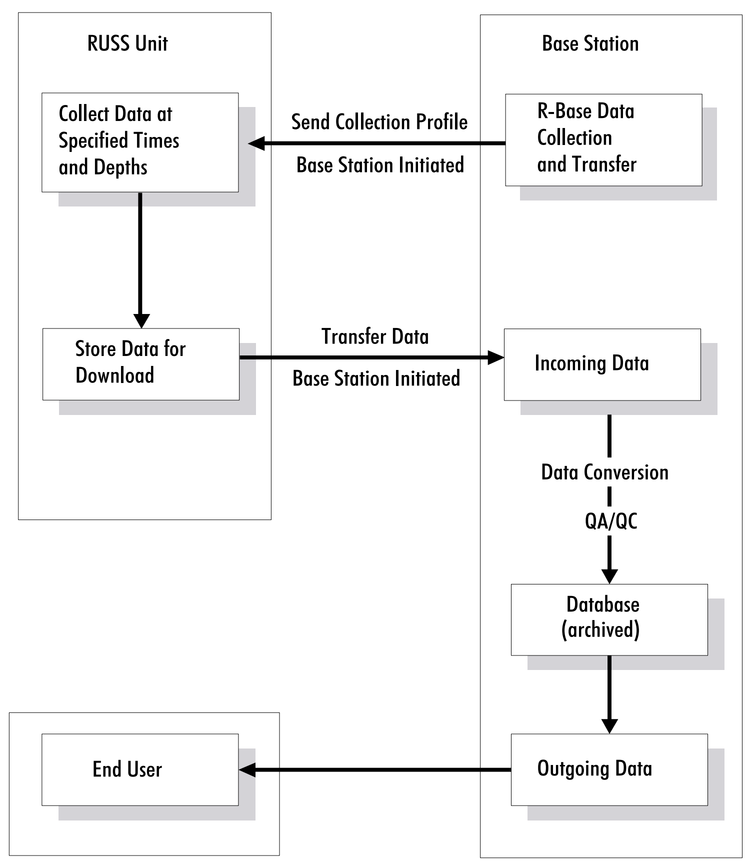
## 4.3 Programming Your System for Scheduled Transfers of Data

Now that the components of your system are in place, you are ready to program the system components for data collection and transfer using RUSS-Base software and Clocker/ClockerPro. The RUSS-Base software application is relatively easy to use, particularly if you have some experience with DOS programs and telemetry equipment. This section focuses primarily on:

- Using RUSS-Base to program your RUSS units for sample collection.
- Programming your land-base station to automatically call the RUSS units for scheduled data feeds.

The first time you perform these functions, you will need to be attentive to a variety of details. Once you have established the appropriate protocol, however, implementing these functions should be quick and easy.

The figure below provides an overview of the data collection and transfer process.

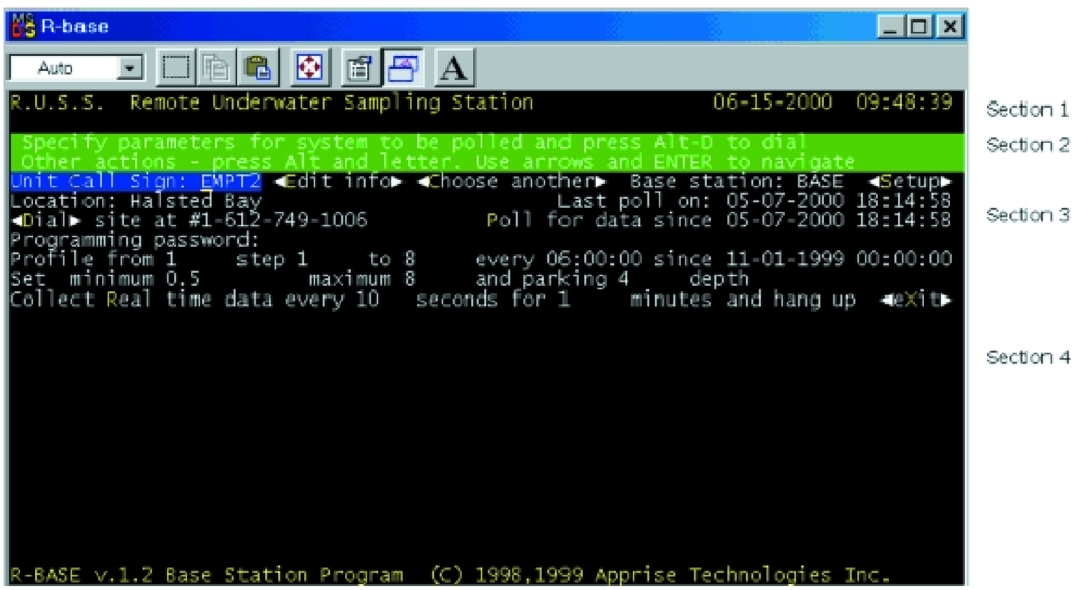


The following instructions provide an orientation to the system using a combination of screen shots and descriptive information.

### Getting Familiar with the RUSS-Base Startup Screen

With RUSS-Base installed on your land-based computer, you can launch the program by double clicking on either the desktop icon or the *R-base.exe* file in the *C:/RUSS* directory. This will open the program to the startup screen, which serves as the gateway to program functions.

The startup screen orients you to the overall format of screens throughout the program. The screen content is organized into four main areas, as shown in the screen below and described in the legend that follows.




**Legend**

Section 1: Displays the header, date, time, and error messages

Section 2: Presents information on navigating the program (highlighted in green)

Section 3: Presents the main menu of functions

Section 4: Displays component-specific information (e.g., water quality sample values)

Using the main menu on the startup screen (Section 3 in the screen shown above), you will select and use a variety of RUSS-Base program functions. For reference, these include:

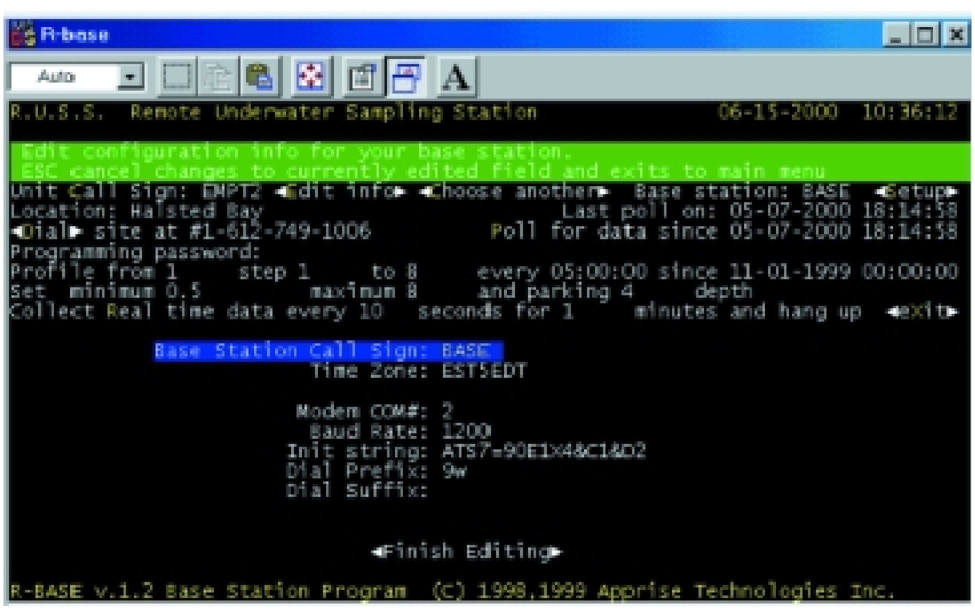
| Function | Short Cut Key | Screen Name | Description |
|---|---|---|---|
| Setup | Alt-S | RUSS-Base Setup | Enter base station call sign, time zone, parameters of your modem, and data collection information |
| Real-time data | Alt-R | RUSS-Base Setup | Enter "real-time data" parameters |
| Poll for data since | Alt-P | RUSS-Base Setup | Enter "poll for data since" parameters |
| Call sign | Alt-C | RUSS Unit Setup | Enter the call sign |
| Edit info | Alt-E | RUSS Unit Setup | Enter information for each RUSS unit including call sign, location, modem connection, password, and data folder |
| Choose another | Alt-C | RUSS Unit List | Select one or more RUSS units from a list of RUSS units |
| Dial | Alt-D | Dialing Status | Dial the RUSS unit for profile upload and data download<br>Display dialing status |
| Exit | Alt-X | | Exit RUSS-Base |

Before you proceed, we suggest that you view the startup screen and locate these functions so you will be ready to select them as directed in the section below.

### Setting Up Your Base Station

You are now ready to use RUSS-Base to configure your base station to communicate with your RUSS units. In doing so, you will initialize your modem and dial-up specifications and create profile schedules for water quality sampling performed by individual RUSS units. (You will create a configuration file for each RUSS unit in your system.)

To start, select *Setup* from the main menu or press Alt-S on your keyboard. The Setup screen (reproduced below) will appear on your computer screen.



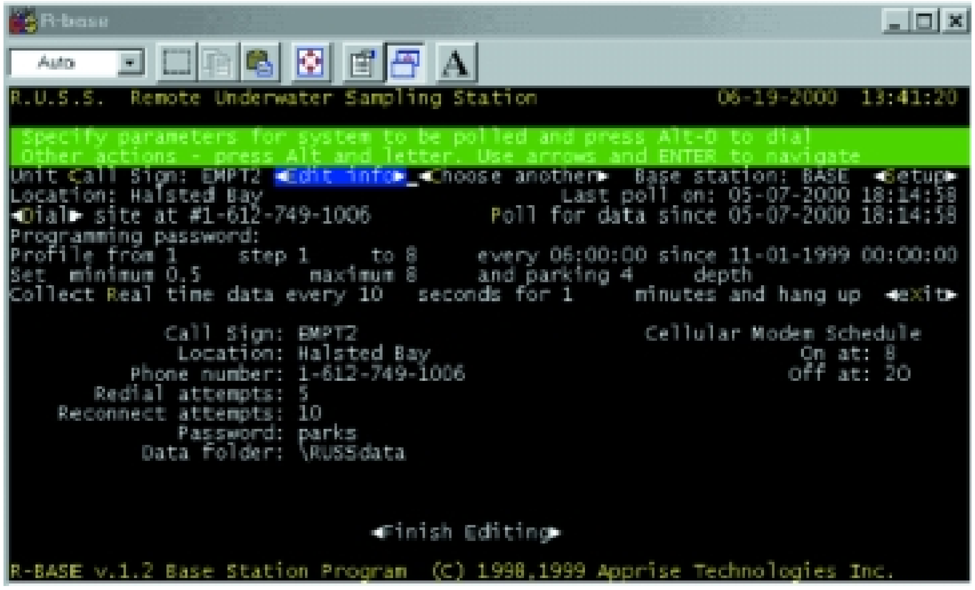
On the Setup screen, enter the information requested for various parameters, explained in the table below:

| Parameter | Description |
|---|---|
| Base station call sign | Enter name of the base station computer. This function will track which computer is calling a RUSS unit. |
| Time zone | Enter in Standard UNIX format: EST5EDT for Eastern time, CST6CDT for Central time, MST7MDT for Mountain time, and PST8PDT for Pacific time. |
| Modem CDM# | Enter modem CDM#. The default value will work with most modems. |
| Baud rate | Enter the proper baud rate for your modem: 1200, 2400, 4800, 9600, 19200, or 38400. The default value will work with most modems. |
| Init string | Enter the initialization string for your modem. The default value will work with most modems. |
| Dial prefix | If necessary, enter a dial prefix. For example, your organization might require you to dial "9" to reach an outside line. |
| Dial suffix | If necessary, enter a dial suffix. For example, your organization might require you to enter a project charge code. |
| Last poll on | This date and time tells you the last time your base station called data from a particular RUSS unit. It also keeps track of the last data point downloaded from the RUSS unit, so only new data will be downloaded. |
| Profile from... | This sets the depth and time at which the RUSS unit will collect data. The screen shot on page 48 shows the following profile:<br>*Profile from 1 Step 1 to 8 every 05:00:00 since 11-01-99 00:00:00*<br>This means that data will be collected from 1 to 8 meters at 1-meter intervals. The RUSS unit will collect data every 5 minutes from November 1, 1999, starting at midnight.<br>*Note:* The more frequently the data are collected, the more battery power is used by the RUSS unit. To conserve battery voltage, you might want to limit sampling frequency. |
| Collect real time data... | This sets the time when real-time data will be downloaded from the RUSS unit to the base station. The screen shot on page 48 shows the following parameters:<br>*Collect Real Time data every 10 seconds for 1 minute and hang up.*<br>In this example, real-time data will be sent by the RUSS unit every 10 seconds for 1 minute. This process provides the base station operator with a sample of real-time data measurements and the ability to QA/QC the data. |
| Poll for data since | This sets the time when both stored and real-time data will be downloaded from the RUSS unit to the base station. The screen shot on page 48 shows the following parameters:<br>*Poll for data since 05-07-2000 18:14:58*<br>Data will be downloaded from May 7, 2000 at 6:14 p.m. (and 58 seconds) to the present time. |
| Set minimum...<br>maximum...<br>and parking depth | This sets the minimum and maximum depths of the profiler in the lake or river. It also sets the parking depth at which the profiler will remain when inactive. The screen shot on page 48 shows the following parameters:<br>*Set minimum 0.5 maximum 8 and parking 4 depth*<br>In this case, the profiler will not ascend above 0.5 meters and will not descend below 8 meters. When inactive, it will hold at 4 meters. The minimum and maximum depths are a fail safe method for preventing potential accidents. For example, suppose you accidentally programmed the profiler to collect data from 1 to 1000 meters. If you had entered 10 meters as the maximum depth that the profiler can descend to, the system will catch this error and the profiler will remain inactive. |

☞ **Tip.** Before sending the profile information to a RUSS unit, you must first enter an authorized programming password in RUSS-Base. The RUSS unit operator will have previously programmed this password into the RUSS unit, and you will enter this same programming password into RUSS-Base. The RUSS unit will reject the profile unless this programming password has been entered in RUSS-Base.

## Setting Up Your RUSS Unit

Now that you have set up a configuration file, you need to provide additional information for each deployed RUSS unit. To enter this information, access the RUSS unit setup screen shown below, by selecting *Edit Info*, or by hitting Alt-E.



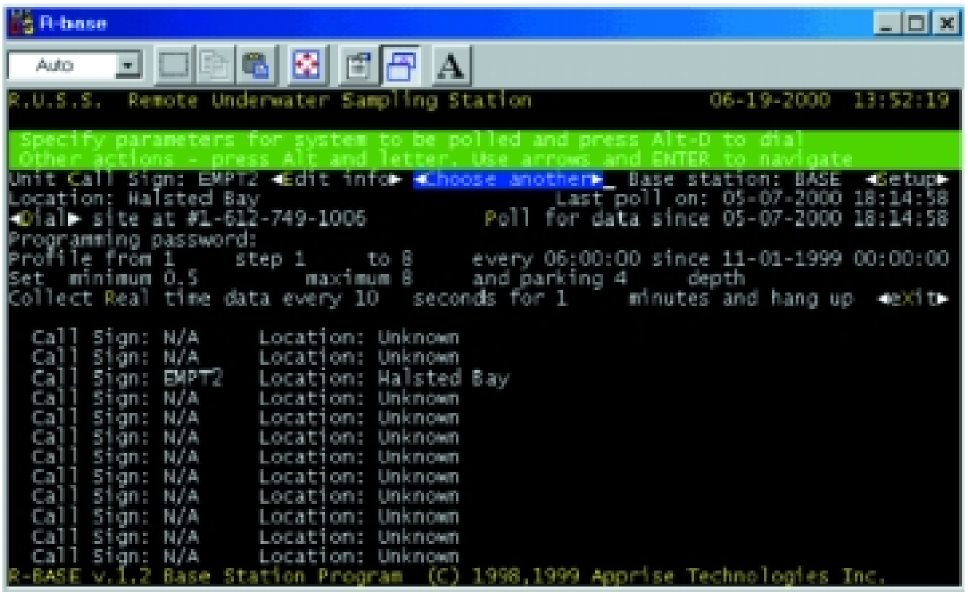

Using this RUSS unit Setup screen, enter information about the various RUSS unit parameters:

| Parameter | Description |
|---|---|
| Call sign | Name of the RUSS unit. |
| Location | Location of the RUSS unit. |
| Phone number | The phone number previously programmed in the RUSS unit cellular phone or transceiver. The base station phone number is not required if your system is not configured for calls initiated by remote stations. |
| Redial attempts | The maximum number of "Redial attempts." This value specifies how many times the base station will try to redial the programmed phone number until a connection is established. |
| Reconnect attempts | The maximum number of "Reconnect attempts." If the RUSS unit answers but connection is broken before all stored data are downloaded, the base station will hang up and call the unit again. |
| Password | This password allows a caller to establish a remote connection with the RUSS unit and download real-time and stored data. (Level 1 access priority.) |
| Data folder | The name of the folder that the RUSS data will be downloaded to on the base station computer. You can also use the default directory *C:\RUSSdata* originally created when you installed RUSS-Base. |
| Cellular modem schedule | The time when the cellular telemetry is turned on and off. This is to promote power conservation. |

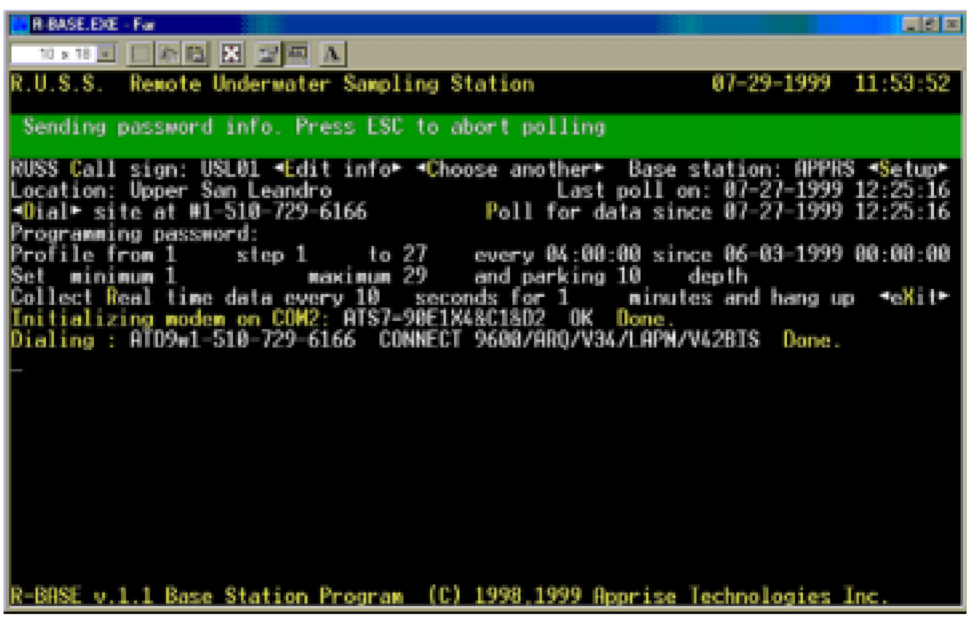
You have now set up your system with profile schedules and RUSS unit information—so that you can control your RUSS unit data collection activities. You are now ready to direct your RUSS units to collect data according to the profile schedules and to transfer back the collected data.

## Uploading the Profile Schedule and Downloading Data

To direct your RUSS units to collect data, you must upload your sampling profile schedules to your RUSS units. To do this, use the unit list screen (shown below) to select a unit for profile upload. Access the unit list screen by selecting *Choose another* or Alt-C on your keyboard. After selecting a unit from the list, call the unit for profile upload.




To call the unit, select dial (Alt-D), which initiates the call and accesses the screen shown below.



If the connection established is too weak for transmission, RUSS-Base will disconnect and redial. If the modem initialization fails, terminate the connection attempt by pressing the ESC key and check to see if another program is using the modem.

☞ **Tip.** Using ClockerPro or Clocker software, you can automatically schedule RUSS-Base to call RUSS units in a predetermined order at different times. These software programs are personal/network program schedulers for Windows designed to schedule programs (or reminders)—such as the upload and download of data from the RUSS unit(s)—to run at specified times. Use the instructions provided with these programs to run the desired schedules.

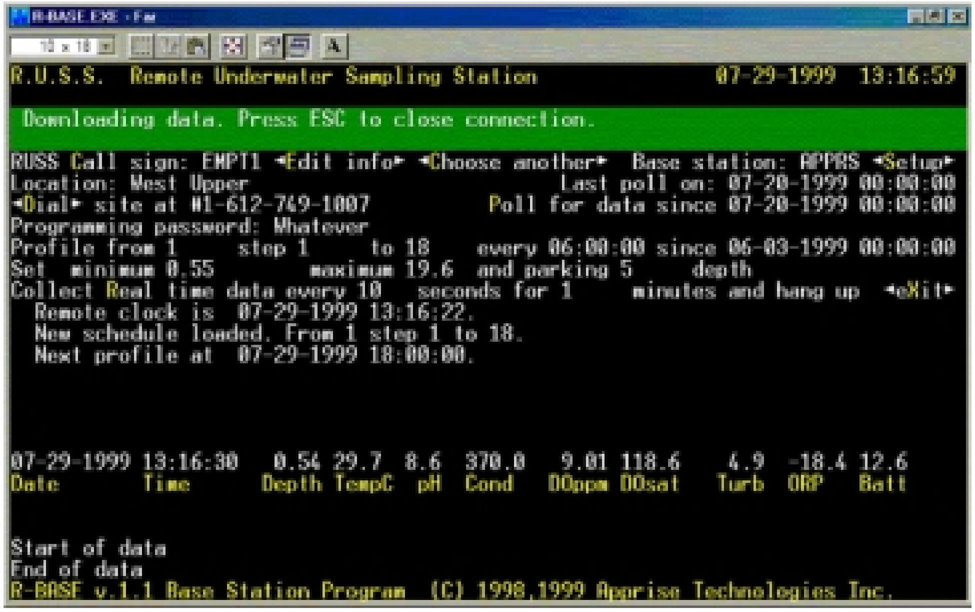
Once a connection is established, the RUSS unit will first validate the programming password if you are loading a new profile schedule. If the programming password is valid, the RUSS unit will report back the time of the next scheduled sample collection and data transmission, as well as profile parameters.

After the unit receives the new profile, its on-board computer will run a validation routine on the profile, checking for logic errors or any conflicts with existing programs. If any questionable data elements are found, the system will prompt you to review and resolve the issue. Once any issues concerning the profile are addressed, the unit will store the profile parameters and implement sampling based on the profile's schedule information. You can then proceed in a similar fashion through the unit list screen to upload profiles to other units in your system.

When collecting a water quality sample, the RUSS unit deploys a device called a Profiler to a specified depth in the water column below the unit. Before data are collected, the sensors will stabilize at the correct depth, which can take 3 to 5 minutes. Collected information is then transmitted to the unit's on-board computer via an underwater cable. The computer has the capacity to store up to 3 weeks of collected data (assuming average sampling intervals).

The collected monitoring information is then automatically transmitted from the RUSS units to the base station at intervals specified in unit-specific profile schedules. After this transmission, you can access the data as needed for analysis.

Even when the system is set up to automatically transmit collected data, you can implement manual downloads using the unit list screen to connect with specific RUSS units (as discussed above). To avoid downloading duplicate data, RUSS-Base tracks the last data point for data transmitted from each unit. In addition, you can download near real-time data from a unit at the same time the unit is transmitting data from a scheduled sampling. As information is transmitted, it will display on screen (as shown in the screen shot on page 53). An "End of data" message will be displayed when the transmission is complete.




## 4.4 Managing Data at the Base Station

This section provides you with background information on managing data at the base station. It describes the base station's data functions, including data formatting, QA/QC, management, retrieval, and storage.

### Data Format

As data are automatically transferred from the RUSS units, the data files are automatically downloaded into the *C:\RUSS* directory on your base station hard drive. The raw data are formatted as a simple string of comma-delimited ASCII text.

The data format and file name will be slightly different depending on whether you are downloading real-time data or stored data. The following table displays near real-time data obtained from the EMPT2 Russ unit in Halsteds Bay. The file is called *EMPT2506.RTD*. EMPT2 is the unit call sign, 2506 is the date, and the extension RTD indicates real-time data.

| Date | Time | Depth | Temp°C | pH | Cond | DOppm | DOsat | Turb | ORP | Batt |
|---|---|---|---|---|---|---|---|---|---|---|
| 05-06-2000 | 07:31:19 | 4.40 | 15.0 | 7.8 | 410.0 | 7.05 | 70.0 | 53.4 | 48.6 | 13.0 |
| 05-06-2000 | 07:31:28 | 4.40 | 15.0 | 7.8 | 410.0 | 7.08 | 70.3 | 51.9 | 31.4 | 12.9 |
| 05-06-2000 | 07:31:37 | 4.40 | 15.0 | 7.8 | 410.0 | 7.09 | 70.4 | 67.3 | 44.0 | 12.8 |
| 05-06-2000 | 07:31:49 | 4.40 | 15.0 | 7.8 | 410.0 | 7.11 | 70.6 | 54.2 | 48.9 | 12.8 |
| 05-06-2000 | 07:31:58 | 4.40 | 15.0 | .8 | 410.0 | 7.11 | 70.6 | 52.6 | 48.4 | 12.8 |
| 05-06-2000 | 07:32:07 | 4.40 | 15.0 | 7.8 | 410.0 | 7.11 | 70.6 | 45.4 | 48.9 | 12.8 |

The following table displays stored data obtained from the EMPT2 Russ unit in Halsteds Bay. The file is called *EMPT2725.DAT* where the extension *DAT* refers to stored data.

| Date | Time | Depth | Temp°C | pH | Cond | DOppm | DOsat | Turb | ORP |
|---|---|---|---|---|---|---|---|---|---|
| 7/25/00 | 0:02:13 | 1.17 | 24 | 8.4 | 382 | 8.23 | 97.8 | 31.2 | 11.9 |
| 7/25/00 | 0:03:40 | 1.89 | 24 | 8.4 | 382 | 8.49 | 100.9 | 38.2 | 9.7 |
| 7/25/00 | 0:05:07 | 2.83 | 23.9 | 8.4 | 383 | 8.37 | 99.4 | 32.8 | 11.9 |
| 7/25/00 | 0:06:22 | 3.86 | 23.8 | 8.4 | 384 | 7.92 | 93.8 | 50.8 | 13.8 |
| 7/25/00 | 0:08:13 | 4.97 | 23.5 | 8.2 | 388 | 6.17 | 72.7 | 20.8 | 20 |
| 7/25/00 | 0:09:40 | 5.89 | 22.6 | 7.6 | 396 | 0.83 | 9.6 | 27.8 | 36.8 |
| 7/25/00 | 0:11:31 | 6.81 | 22.1 | 7.4 | 409 | 0.11 | 1.2 | 23.3 | 48.2 |
| 7/25/00 | 0:13:34 | 7.85 | 20.5 | 7.2 | 457 | 0.11 | 1.2 | 57.1 | 57 |
| 7/25/00 | 6:02:16 | 1.16 | 23.8 | 8.4 | 383 | 7.6 | 90 | 41.4 | 13.5 |
| 7/25/00 | 6:03:55 | 1.92 | 23.8 | 8.4 | 382 | 8.29 | 98.2 | 113.3 | 8.8 |
| 7/25/00 | 6:05:07 | 2.88 | 23.8 | 8.4 | 382 | 8.19 | 97 | 96.1 | 13 |
| 7/25/00 | 6:06:34 | 3.9 | 23.7 | 8.3 | 384 | 7.4 | 87.4 | 56.5 | 14.7 |
| 7/25/00 | 6:08:37 | 4.88 | 23.5 | 8.1 | 387 | 6.45 | 75.9 | 55.5 | 19.6 |
| 7/25/00 | 6:09:52 | 5.84 | 22.9 | 7.7 | 393 | 2.36 | 27.5 | 38.2 | 30 |
| 7/25/00 | 6:11:55 | 6.86 | 22.1 | 7.4 | 409 | 0.13 | 1.5 | 47.2 | 43.6 |
| 7/25/00 | 6:13:46 | 7.84 | 21 | 7.3 | 444 | 0.11 | 1.2 | 64.4 | 52.6 |
| 7/25/00 | 12:02:40 | 1.14 | 23.9 | 8.4 | 382 | 8.01 | 95 | 233.5 | 11.3 |
| 7/25/00 | 12:08:15 | 2.18 | 23.8 | 8.4 | 382 | 7.96 | 94.2 | 108.3 | 11.2 |
| 7/25/00 | 12:10:51 | 2.85 | 23.7 | 8.4 | 383 | 7.76 | 91.8 | 108.3 | 8.5 |
| 7/25/00 | 12:12:18 | 3.91 | 23.5 | 8.3 | 384 | 7.06 | 83.1 | 97 | 16.1 |
| 7/25/00 | 12:13:57 | 4.82 | 23.3 | 8.1 | 386 | 6.13 | 71.9 | 103.9 | 21.8 |
| 7/25/00 | 12:15:36 | 5.89 | 22.8 | 7.7 | 394 | 2.52 | 29.3 | 93.5 | 36.3 |
| 7/25/00 | 12:17:51 | 6.9 | 21.8 | 7.3 | 423 | 0.12 | 1.4 | 120.4 | 46 |
| 7/25/00 | 12:19:18 | 7.83 | 20.8 | 7.2 | 450 | 0.12 | 1.3 | 111 | 54.1 |
| 7/25/00 | 18:06:42 | 0.99 | 24.5 | 8.6 | 380 | 9.71 | 116.4 | 92.4 | 2.6 |
| 7/25/00 | 18:08:33 | 1.96 | 24.5 | 8.6 | 380 | 9.85 | 118.1 | 112.4 | 3.8 |
| 7/25/00 | 18:10:12 | 2.86 | 24.4 | 8.5 | 381 | 9.58 | 114.7 | 109.3 | 6.2 |
| 7/25/00 | 18:11:51 | 3.81 | 23.7 | 8.3 | 386 | 7.15 | 84.5 | 90.9 | 13.7 |
| 7/25/00 | 18:13:30 | 4.8 | 23.3 | 8 | 388 | 5.79 | 68 | 113.9 | 24.4 |
| 7/25/00 | 18:14:57 | 5.81 | 22.8 | 7.5 | 395 | 2.81 | 32.7 | 96.8 | 40.9 |
| 7/25/00 | 18:17:00 | 6.83 | 21.7 | 7.3 | 423 | 0.15 | 1.7 | 123.7 | 49.6 |
| 7/25/00 | 18:18:51 | 7.95 | 20.8 | 7.2 | 449 | 0.12 | 1.4 | 113.3 | 52.3 |

## Checking for Data Quality

After your data have been delivered, you will want to make sure that they meet acceptable quality criteria. The Lake Access team uses both automated and manual data quality checks to ensure accurate and representative measurements of water quality parameters. At all stages of data management, the information is subjected to previously established and documented quality assurance protocols.

Performing quality checks on Lake Access data can take from a few days to weeks or months, depending on the amount of data streaming into the project's base station. The Lake Access team's data quality checks focus on subtle trend differences, data that are out of range, data with unusual rates of change, outliers, data gaps, and the data's consistency with weather patterns and season. An overview of these checks is provided below. For more detailed information, refer to the Lake Access Quality Assurance Protocols document, which is available on the Lake Access Web site at http://www.lakeaccess.org/QAQC.html.

The Lake Access team performs QA/QC on the data using the methods outlined below:

- The team compares manually collected samples with RUSS unit data prior to recalibrating the RUSS unit. This check provides assurance that the previous period's data are accurate. If the data pass for the previous period, they are considered acceptable. If the data do not pass, team members examine the results in the context of their understanding of the individual lake's limnology and other data (e.g., nutrients, chlorophyll, trends). They then decide to either delete the data from the database and/or save the information in a different place. The team is especially careful not to delete anomalous data that might reveal actual dynamic changes in lake water quality.

- The team generally performs routine, biweekly maintenance and calibration of the sensors. At the same time, the team also conducts manual sampling with an independent instrument. The following table provides information on quality assurance criteria for the RUSS unit sensors.

| Sensor | Relative Percent Difference (RPD) | Delta |
|---|---|---|
| Temperature | < 5 percent | < 0.2°C |
| Dissolved Oxygen | < 10 percent | < 0.5 $mgO_2/L$ |
| EC (25° C) | < 10 percent | < 5 uS/cm |
| pH | < 10 percent | < 0.2 units |
| Turbidity | < 10 percent | < 5 NTUs |

  See Chapter 3, Section 3.9 for detailed information on calibration and quality assurance of the RUSS sensors.

- The team has developed sophisticated data visualization programs that allow quick review of the data as they are transmitted from RUSS units. These programs enable the team to identify problems almost immediately. Using the data visualization tools described in Chapter 5, the team can visually inspect the graphical displays to ensure that the data flow in categorical increments and accurately reflect changes in water quality. The team also can visually check for data gaps and outliers. An example of questionable data might be a reading that is inconsistent with the lake's depth. Additionally, the Profile Plotter and Color Mapper tools described in Chapter 5 contain calibration flags that allow the user to keep track of calibration dates as the data stream is being viewed.

- Once the data are transferred to the base station, they are run through an importer program. This program converts the data to a standard format and also checks for errors. (The importer program is described in more detail in the following subsection on converting and managing data.)

The Lake Access team uses data from manual sampling to fill in data gaps and address anomalous data. If the team determines that the anomalies are large and cannot be resolved, or if large amounts of data are missing, the data will not be used or released to the public. If the team determines that the data meet QA/QC requirements, the data are considered valid and reportable.

### Converting and Managing the Data

After you collect data from the RUSS units, you must convert it to the correct format for input into your data management system and visualization tools (described in Chapter 5). The Lake Access team uses an importer program to convert the RUSS unit data to a standard format. This program reads data files that have been created or changed since the last time the program was run. It then converts the data to the format required by the visualization tools and checks the data for integrity.

The importer first tests the RUSS unit's name, site name, and column descriptions to ensure they correspond to the anticipated parameters for that unit. If they do not correspond, the importer generates an error and no further action is taken with the data file. For example, an error will be generated if a data file from Halsteds Bay was accidentally placed in the Lake Independence directory.

The importer then reads each individual data line and converts it to a reading that presents measurements taken at the same depth at the same time. A set of readings is combined to form a "profile" in the database. The importer also flags and rejects data that fall outside a specified range. The following table shows the correlation between water quality parameters and unacceptable data ranges.

| Parameter | Unacceptable data range |
|---|---|
| Temperature | $< -1$ or $> 35°$ Celsius |
| pH | $< 5$ or $> 10$ |
| EC at 25° C | $< 1$ or $> 600$ uS/cm |
| Dissolved Oxygen (DO) | $< -1$ or $> 20$ mg$O_2$/L |
| DO percent Saturation | $< -5$ or $> 200$ percent |
| Turbidity* | $< -5$ or $> 1000$ NTU |

*Turbidity values between -5 and 0 are set to equal 0.

After the importer has read the data, it stores the information in an object-oriented storage format. In this format, each line of text represents an object. The conversion method you employ will depend on the type of system you use for data storage or visualization. However, the Lake Access importer program is recommended for ease of use, compatibility with RUSS unit data, and for its ability to conduct quality checks. For additional information on the importer program, please read the Lake Access Quality Assurance Protocols document on the Lake Access Web site at http://www.lakeaccess.org/QAQC.html.

### Retrieving the Data

As you set up your system, you can develop your own protocols for retrieving data. To retrieve its data, the Lake Access team directly links its data visualization tools (DVTs) described in the next chapter to its object-oriented database. If you decide to store your data instead in MS Access or another database management system, you can develop simple queries to access data. If you decide to store the data in an Oracle database, you might want to develop a user-friendly interface to retrieve the data. For example, you could make use of drop-down lists to select time periods, check boxes to choose parameters, radio buttons to select output file format, or graphical versus text displays.

### Storing and Archiving the Data

It is recommended that you store and archive all sample records, raw data, quality control data, and results. A variety of media are available for archiving data (e.g., CD-ROMs, Zip disks, floppy diskettes, and hard copy). The server storing the data should also be backed up daily to prevent data loss.

## 4.5 Troubleshooting Q&A

This section contains information about common troubleshooting issues.

Q: *Is technical support available for hardware and software installation?*

A: Apprise Technologies will work with each client to ensure that the RUSS units and associated software are properly installed. Also, the company can tailor system setup to individual customers. Additionally, Apprise technologies offers telephone and onsite support. Apprise also offers onsite training on topics such as assembling and disassembling RUSS units, deploying the units, installing and operating RUSS-Base software, and system troubleshooting.

Q: *Is technical support available for operating the data collection, transfer, and management systems?*

A: Apprise Technologies offers telephone and on-site support for its systems. Many communities take advantage of on-site training, which includes sessions focused on data collection, transfer, and management.

Q: *What should I do when the data will not download?*

A: If you are unable to download data, your communications protocol or RUSS unit battery power might have failed. As a first step, make sure that your RUSS unit has enough battery power to transfer the data. Review the data file you downloaded previously, because this file will contain information about the battery voltage.

Voltage should be in the range of 12.5 to 14.5 Volts during daytime hours. Lower voltages indicate that the RUSS unit solar panel is not recharging the battery due to excessive power drain, loose cables, or a shadowed or damaged panel. A RUSS unit will be fully functional with battery power as low as 11.5 Volts. The more frequently the data are collected, the more battery power is used by the RUSS unit. To conserve battery voltage, you might want to consider limiting sampling frequency.

Q: *What should I do when I cannot log in or connect to the RUSS unit from the base station?*

A: If you are unable to connect to the RUSS unit, first check that your password entry is correct. For example, be sure not to include leading or trailing spaces. If you cannot determine the cause of the failure, place a test call to Apprise Technology's computer (see Section 4.3) to test the communications system and ensure that it is working properly.

Q: *Can I automatically collect data without being present at the base station?*

A: Using ClockerPro or Clocker software, you can automatically schedule RUSS-Base to call RUSS units in a predetermined order at different times without anyone being present. (See Section 4.3 for additional information about Clocker and ClockerPro software.)

Q: *How can I adjust the time interval that the profiler maintains at each sampling depth?*

A: If you would like to adjust the time interval, contact Apprise Technologies and they will program a new time interval for you. Apprise Technologies originally programs the RUSS-Base software to allow for between 3 to 5 minutes at each sampling depth. For example, if your profiler is programmed to collect measurements every meter for 20 meters, it will remain at each meter depth for between 3 and 5 minutes. This interval allows sufficient time for the profiler to stabilize at the given depth. Intervals greater than 6 minutes can drain the RUSS unit battery power too quickly.

# 5. DEPICTING TIME-RELEVANT WATER QUALITY DATA

Now that your water quality monitoring network is in place and you have collected the resulting data, you can turn to the next step in providing your community with time-relevant water quality information: using data visualization tools to graphically depict this information. By using the types of data visualization tools described in this chapter, you can create graphic representations of water quality data that can be used on Web sites, in reports and educational materials, and in other outreach and communication initiatives.

Section 5.1 provides an overview of data visualization. Section 5.2 contains an introduction to selected data visualization tools used by the Lake Access Team. If you are interested in a basic introduction to data visualization, you might only want to read the initial section. If you are responsible for choosing and using data visualization software to model and analyze data, you should also consult Section 5.2.

## 5.1 What is Data Visualization?

Data visualization is the process of graphically depicting data in ways that are meaningful to you. When data are visualized effectively, the resulting graphical depictions can reveal patterns, trends, and distributions that might otherwise not be apparent from raw data alone. This enables you to "see" and "understand" the data much more easily and meaningfully. The results of your efforts can then be communicated to a broader audience, such as residents in your community.

Data visualization can be accomplished with a variety of software tools, ranging from standard spreadsheet and statistical software to more advanced analytical tools such as:

- Two- and three-dimensional graphic plotters
- Animation techniques
- Geographic Information Systems
- Simulation modeling
- Geostatistical techniques

By applying these tools to water quality data, you can help your community's residents gain a better understanding of factors affecting water quality in area lakes and streams. Once you begin using data visualization tools, you will immediately be impressed with their ability to model and analyze your data for a variety of purposes, from making resource management decisions to supporting public outreach and education efforts. For example, you can use data visualization tools to:

- Explore links between land use patterns within watersheds and the type and magnitude of nonpoint pollutant sources affecting local streams and lakes.

- Calculate acreage of the various land uses within your watershed, and use this information, in conjunction with models, to predict sediment and phosphorous loadings to lakes from inflow streams and nonpoint sources.
- Create daily, monthly, and annual lake water quality profiles.

As explained in Chapter 3 of this handbook, the Lake Access team is using data collected by Remote Underwater Sampling Station (RUSS) units and manual sampling to determine the impact of pollutant loadings on Lake Minnetonka and Lake Independence. The raw data collected from the RUSS units provide information about current water quality conditions and short- and long-term water quality trends. The Lake Access team then uses a number of data visualization tools to analyze and convey information about water quality data. The Lake Access team is using data visualization and interpretation techniques to analyze water quality data and provide information to support resource management and land use planning decisions within the watershed.

A variety of commercially available data visualization tools exist that allow you to graphically represent real-time data, manipulate variables, compare temporal trends, and even depict changes over time. Section 5.2 focuses on the following data visualization tools listed in the table below.

| Tool Group | Tools | Primary Uses |
|---|---|---|
| DVT Data Visualization Tools | Lake Access Live: Near Real-Time Display of Numeric Data; Profile Plotter; Color Mapper; Depth versus Time (DxT) Profiler | • Explore lake data as it varies with depth and over time<br>• Create animated water quality profiles<br>• Feed real-time data to Internet site<br>• Investigate correlations between water quality variables and trends |
| Spreadsheet Programs | Microsoft Excel; Lotus 123 | • Display raw data<br>• Investigate correlations between water quality variables and trends<br>• Create summary graphs of data |
| Geographic Information Systems | Several, including ArcInfo; ArcView; GeoMedia; and MapInfo Professional | • Integrate and model spatial data (e.g., water quality and land use)<br>• Develop Internet mapping applications |

## 5.2 Data Visualization Software

This section provides information about the three data visualization software groups described in Section 5.1:

- DVT data visualization tools
- Spreadsheet programs
- Geographic Information Systems

After reviewing this section, you should have a good idea when and why you might want to use these tools and what you need to do to obtain, install, and use them.

### DVT Data Visualization Tools

DVT data visualization tools are user-friendly, interactive programs that the Lake Access team uses to depict and manipulate water quality profiles collected by RUSS units and from manual sampling. The four tools listed below were developed originally for the team's Water on the Web project and are designed to work with data sets generated by RUSS technology, but they could also be adapted to work with other data sets from other water quality monitoring systems your community chooses to put in place. These tools are:

- Lake Access Live: Near Real-Time Display of Numeric Data
- Profile plotter
- Color mapper
- Depth versus Time (DxT) Profiler

These tools provide the ability to:

- Feed real-time data to the Web for data sharing.
- Compare water quality profiles over time and depth.
- Create animations of profiles to illustrate how water quality parameters change daily, monthly, and annually.

You can obtain the DVT tools by contacting Apprise Technologies at 218-720-4341. They are available individually, or as a package called the DVToolkit. The tools are easy to install and are appropriate for a wide variety of platforms, including Windows 95/98/NT, Unix/Linux, and Macintosh. You can run these applications directly from your computer or over the Web.

For additional information on these tools, consult the Lake Access Web site at http://www.lakeaccess.org and the article *Interactive Technologies for Collecting and Visualizing Water Quality Data,* co-authored by the Water on the Web team and Apprise Technology. This article is published in the journal of the Urban and Regional Information Systems Association (URISA) and is available on the Web at http://www.urisa.org/Journal/accepted/host/interactive_technologies_for_collecting_and_visualizing_water_quality_data.htm (Host et al., 2000).

The subsections below present brief overviews of each DVT tool, focusing mainly on what each is used for (i.e., when/how you might use each tool). This will help you decide if you want to obtain and employ these tools.

### *Lake Access Live: Near Real-Time Display of Numeric Data*

This is a simple program that can be used to provide near real-time data feeds, such as oxygen level and temperature, to Web sites for public access and data sharing. The program automatically retrieves water quality data from your database, embeds the data in a GIF (Graphics Interchange Format) image, and posts the image to a Web site. The screen below, taken from the Lake Access Web site, shows how this program is used to display near real-time data.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Lake Minnetonka, Halsteds Bay | Wed 09/13/00 06:00 | Depth: | 1 m ( 3 ft)<br>8 m (26 ft) | Temperature: | 68 °F<br>68 °F | Oxygen: | 6.0 mg/L<br>4.8 mg/L |
| Minnetonka, West Upper Lake | Mon 09/11/00 06:00 | Depth: | 1 m ( 3 ft)<br>8 m (26 ft) | Temperature: | 70 °F<br>69 °F | Oxygen: | 6.9 mg/L<br>6.1 mg/L |
| Lake Independence | Wed 09/13/00 06:00 | Depth: | 1 m ( 3 ft)<br>8 m (26 ft) | Temperature: | 68 °F<br>68 °F | Oxygen: | 7.7 mg/L<br>7.8 mg/L |

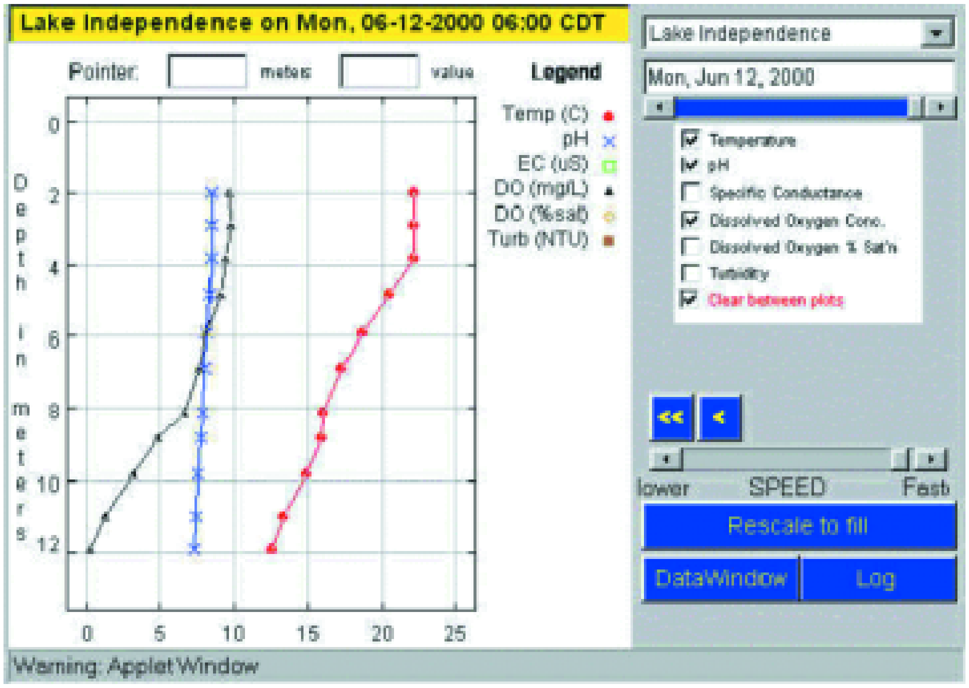
### *Profile Plotter*

The Profile Plotter program enables users to create static and animated line plots of the profiles of lakes and other water bodies revealing how water quality variables change over time and depth. Animated profiles help users observe how lake profiles change daily, monthly, and annually. Users can choose from a number of different variables to plot. For example, the screen at the top of page 63 shows how users can select from a variety of water quality parameters (i.e., temperature, pH, specific conductance, dissolved oxygen, and turbidity) to plot and animate. This particular graph displays temperature, pH, and dissolved oxygen concentrations at various depths in Lake Independence at 6:00 a.m. on June 12, 2000, in the form of a lake profile line plot. By plotting temperature as a function of depth, you can show how the thermocline location varies with time, and you can illustrate events such as spring and winter turnover.

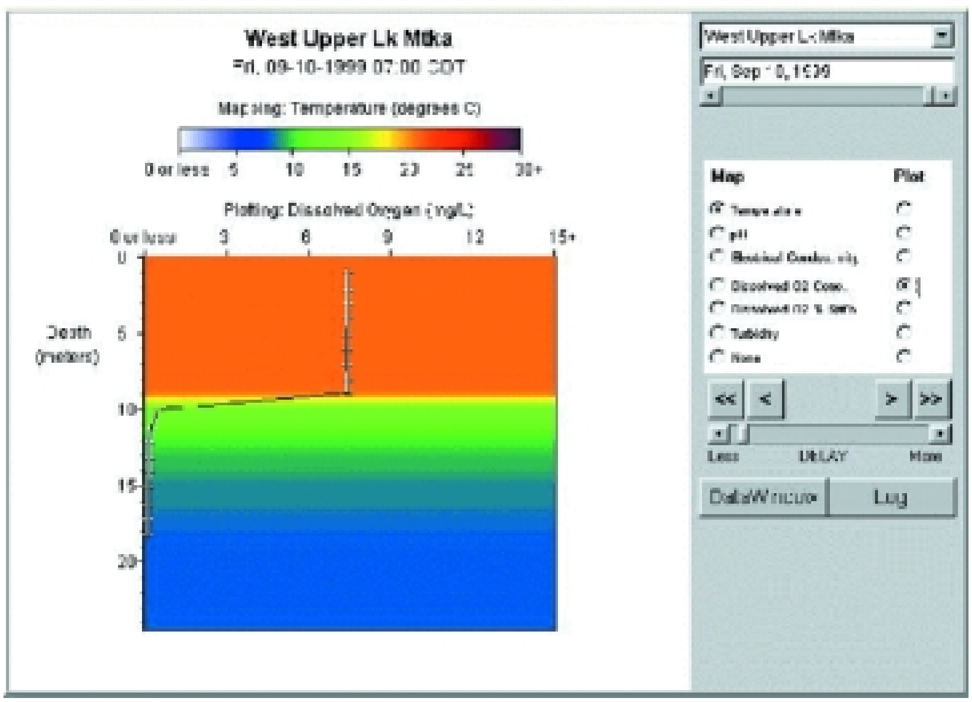
### *Color Mapper*

The Color Mapper is similar to the Profile Plotter, except that it enables you to map two water quality variables simultaneously. A user interested in understanding the correlation between two variables might want to use this tool.

Using Color Mapper, you can map one parameter as color contours and then overlay another variable over the color contours in the form of a line plot. For example, in the graph shown below, the background depicts temperature using color contour, and a superimposed line plot shows oxygen concentrations. This display shows that oxygen is depleted below the thermocline.




**Profile Plotter**



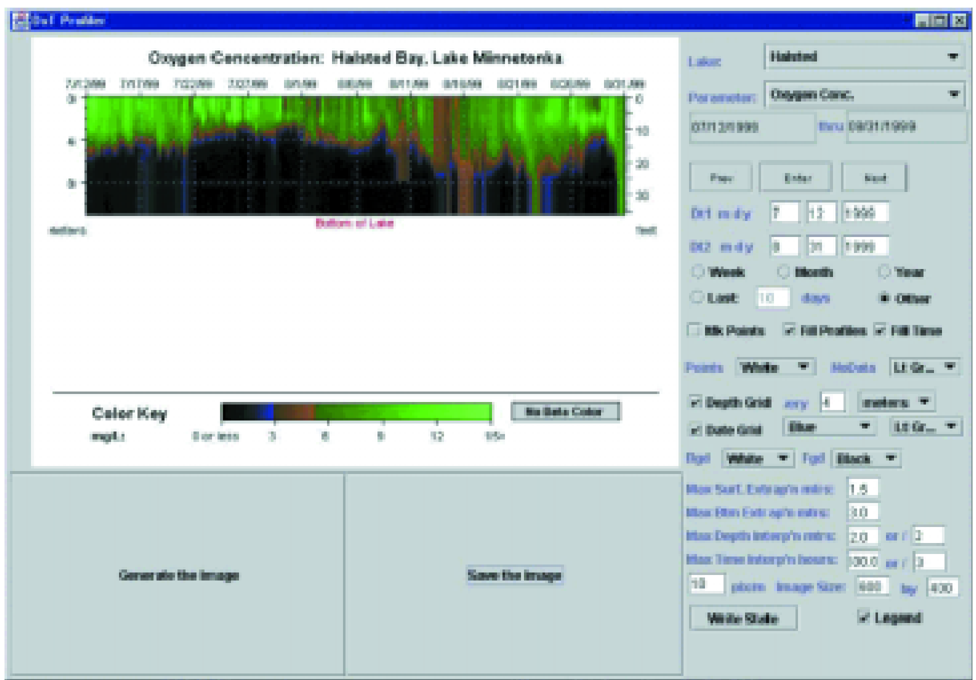

**Color Mapper**

The temperature data shown in the screen above was originally collected by the RUSS units as point data. To display the data as color contours, the Color Mapper estimates temperatures in areas where there are no measurements (i.e., in the areas between point samples). This process of estimating measurements—in this case, temperature—is called interpolation.

Once the data have been interpolated, the Color Mapper automatically draws color contours representing a range of temperatures. These ranges and colors are chosen based on predetermined break points keyed to changes in temperature. In this case, the red colors represent warmer temperatures and the blue colors represent cooler temperatures.

### *Depth Versus Time (DxT) Profiler*

This program graphically depicts how the lake data collected by RUSS units change over time. The DxT Profiler allows users to display and analyze data in two or three dimensions. As shown in the display below, this program allows you to select the time period for which you want to display data; select the parameter you wish to analyze or illustrate; add grid lines; show the actual data points; and interpolate data by depth and time. You can also output the graphs in GIF format to post to Web sites or incorporate into reports.

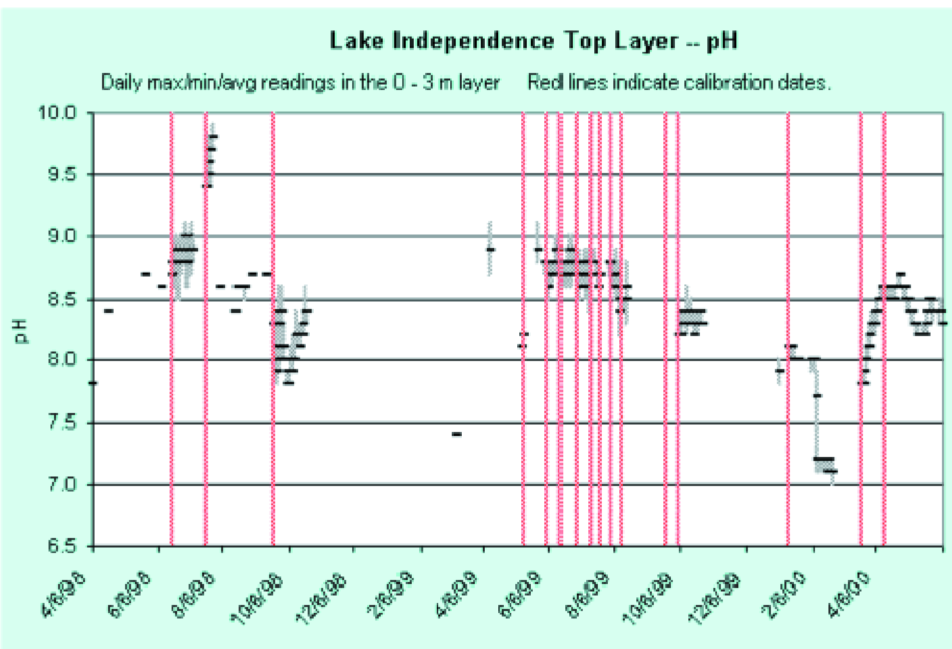



The screen above shows the changes in oxygen concentrations over time in Halsteds Bay, which is highly eutrophic. The color contours used to display oxygen are based on biological breakpoints that are important to fisheries management. The green colors represent acceptable oxygen levels for fish populations. The change from dark green to brown (at approximately 5 mg/L oxygen) shows the point at which oxygen levels are too low to support cold-water fish populations. The map's colors change from blue to black (at approximately 1 mg/L oxygen) to indicate the break point at which oxygen concentrations are too low to support *any* fish populations.

## Spreadsheet Programs

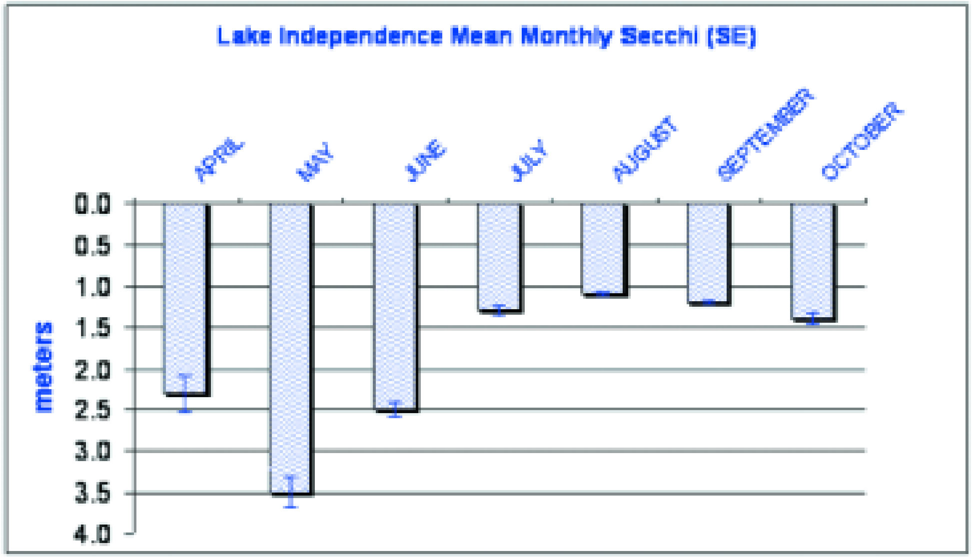
Simple spreadsheet programs such as Microsoft Excel and Lotus 123 can also be used to visually characterize lake data. These programs can be used to create graphs and tabular summaries of various water quality parameters plotted over time or versus depth. The resulting graphs and tables can be used to help analyze surface trends, heat and oxygen budgets, water chemistry, and morphometry. Because these software programs are readily available and easy to use, they can be used effectively in the classroom to introduce students to the basics of modeling and interpreting data. Both Microsoft Excel and Lotus 123 can be purchased at most stores that sell computer equipment and software, and they are easy to install. Both run on a variety of operating systems, including Windows 3.1, 95, 98, 2000, and NT.

For example, the screen below shows how the Lake Access Team uses Microsoft Excel to illustrate the surface trends of lake parameters using RUSS unit data. The screen presents a time course plot that shows the average pH values in Lake Independence's surface layer (the upper 3 meters of the water column), for the period beginning April 6, 1998, and ending April 6, 2000. The vertical bars straddling each data point represent the range of values measured for that particular day.




**Note: The pH data shown in the graph above are still undergoing several rounds of quality assessment by the Lake Access team. As a result, some of these data might be subsequently modified.**

You can also create other types of graphics using spreadsheet programs. For example in the screen shown below, the Lake Access team has used Microsoft Excel to show the Secchi depth data for Lake Independence over a 7-month period. (See page 34 for a detailed explanation of Secchi depth data.)




## Geographic Information Systems (GIS)

GIS is a software and hardware system that helps scientists and other technicians capture, store, model, display, and analyze spatial or geographic information. This technology offers powerful tools for analyzing and visualizing spatial patterns and trends in environmental data. (The U.S. Geological Society's (USGS's) Web site contains a user-friendly introduction to GIS at http://info.er.usgs.gov/research/gis/title.html.

GIS includes a varied range of technologies. To choose, obtain, and use them, you will need to understand the various technologies available and which might be appropriate for your needs and situation. By using GIS technology, you can produce a wide range of graphical outputs, including maps, drawings, animations, and other cartographic products. To create these outputs, you can use GIS to perform a range of powerful functions, including:

- Interactive visualization and manipulation of spatial data
- Integration of spatial analysis and environmental modeling
- Integration of GIS and remote sensing
- Simulations modeling
- Creation of two and three-dimensional models
- Internet mapping

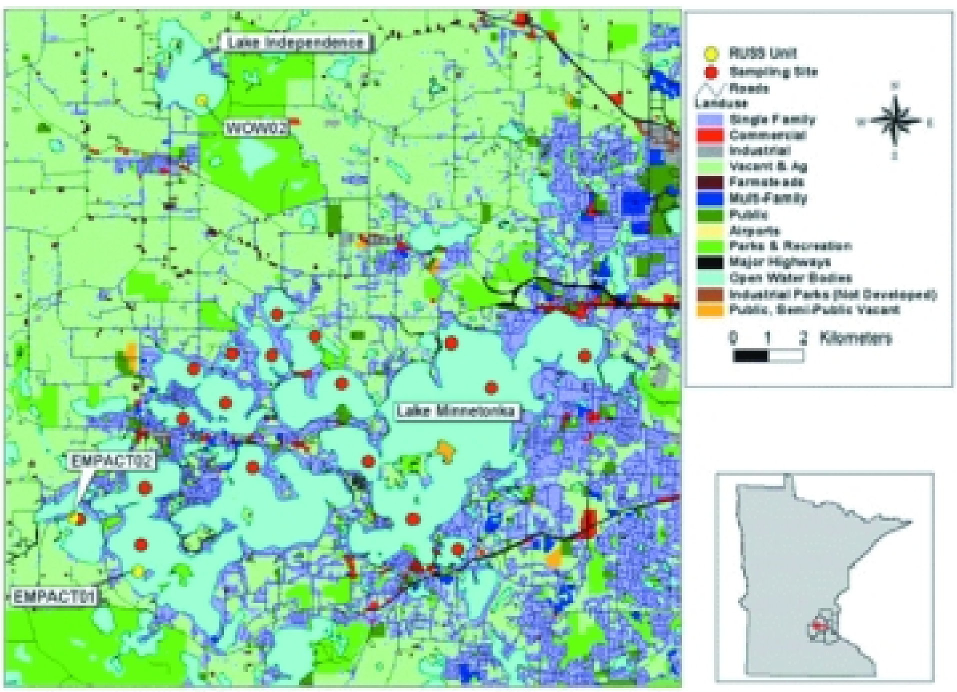
To choose, obtain, and use GIS software, you will need to understand the various technologies available and which might be appropriate for your needs and situation. For more information on specific GIS software packages, you can consult manufacturers' Web sites, including:

- ESRI (http://www.esri.com), whose suite of tools includes ArcInfo, ArcView, and ArcIMS internet mapping software

- Intergraph (http://www.intergraph.com/gis/), whose software includes GeoMedia and GeoMedia Web Map
- MapInfo (http://www.mapinfo.com/), whose products include MapInfo and MapInfo Xtreme (an Internet mapping software)

Although GIS is more complex and expensive than other data visualization tools described in this chapter, it also provides more power and flexibility—both in terms of the data you can use and what you can do with the data. You can use GIS technologies from data originating from a variety of sources, including satellite imagery, surveys, hardcopy maps, and environmental readings on variables such as water depth or chemistry. Key data layers in the Lake Access project include RUSS data, manual sampling data, land use data, transportation data, watershed boundaries, elevation, and hydrography. Having these data, you can use GIS to illustrate how land use changes affect water quality. You might also want to use GIS to model the relationships between watershed characteristics and lake water quality. By using GIS, you can combine different types of data layers to predict how quickly sediments or contaminants might move through a stream system.

The following graphic was created by the Lake Access team using ArcInfo software to display land use in the Lake Independence and Lake Minnetonka watersheds. The map is color coded to distinguish the land uses surrounding the lake (e.g., agricultural, residential, commercial, industrial, forest, and wetland).



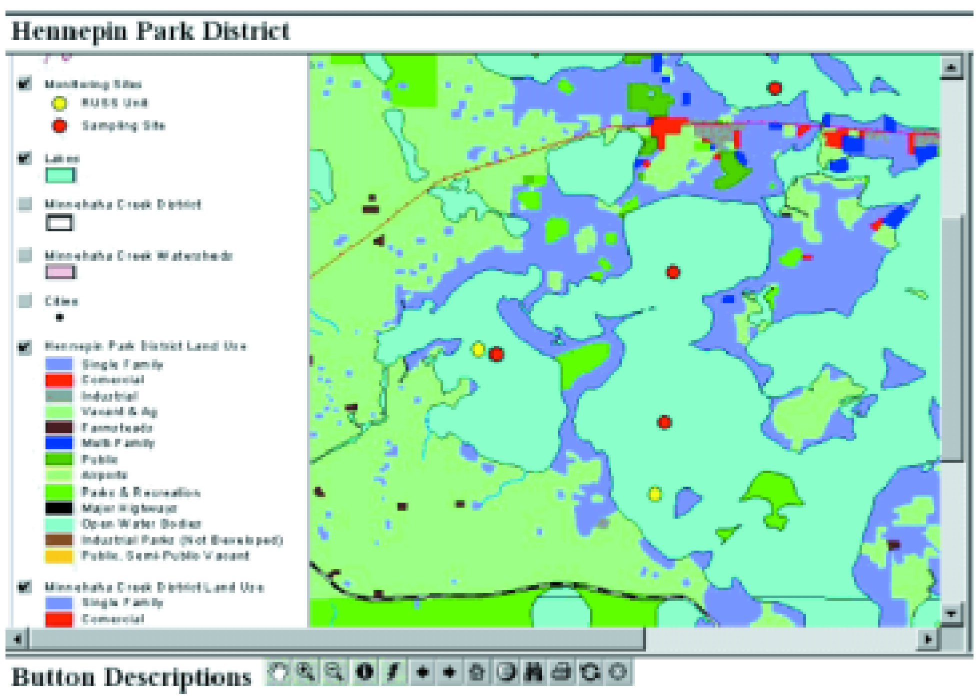

Maps of this type can help inform the public and local officials about connections between local water conditions and current land uses in their communities.

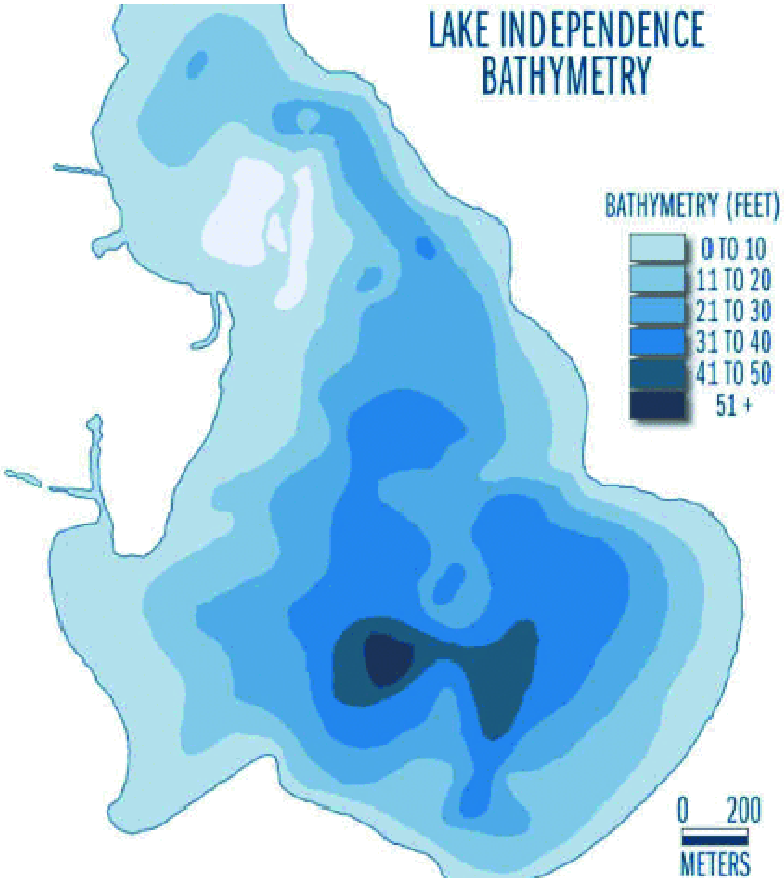
*GIS Features on the Lake Access Web site.* The Lake Access team has developed a user-friendly and engaging map-based product for the land use page of its Web site at http://www.lakeaccess.org/landuse.html. This Web-based capability is a powerful way to distribute GIS data, allowing thousands of interested parties to simultaneously display and access data. Maps are displayed on the Web site using the ARCVIEW Internet Map Server (IMS) developed by ESRI. Users can zoom in and out of maps and perform queries to gather information about different map elements. Site visitors can generate maps, query data, and retrieve information by simply clicking on the map feature. IMS allows the user to turn different kinds of map layers (e.g., roads, land use, water bodies) on or off to create their own customized maps. For more information on using IMS, visit the ESRI Web site at http://www.esri.com/software/arcview/mapcafe/index.html.

The screen below shows the IMS display for land use in the Lake Independence watershed. The screen has three primary sections:

- A toolbar for performing various map operations
- An interactive legend that allows different layers to be turned on or off
- A map viewing frame that shows the map itself

The status bar at the bottom of the screen provides information about map coordinates, a map scale, a link to a help site, and information on the status of current operations.






The Lake Access Project also creates other GIS products, including two-dimensional representations of various lake parameters. For example, depth (i.e. bathymetry) is shown in the graphic above.

GIS and other data visualization tools offer the ability to better support and communicate observations, conclusions, and recommendations to resource managers, the public, students, and regulators. These audiences can then use displays and analyses to help make day-to-day decisions that can affect the quality of their lakes and streams.

# 6. COMMUNICATING TIME-RELEVANT WATER QUALITY INFORMATION

As your community develops its time-relevant water quality monitoring and reporting systems, you will want to think about the best ways to communicate the information these systems will yield. This chapter of the handbook is designed to help you do so:

- It outlines the steps involved in developing an outreach plan.
- It profiles the outreach initiatives implemented by the Lake Access Team.
- It also provides guidelines for effectively communicating information and includes resources for water quality monitoring and promoting awareness, which you can incorporate into your own communication and outreach materials.

## 6.1 Creating an Outreach Plan for Time-Relevant Water Quality Reporting

Outreach will be most effective if you plan it carefully, considering such issues as: Who do you want to reach? What information do you want to disseminate? What are the most effective mechanisms to reach people? Developing a plan ensures that you have considered all important elements of an outreach project before you begin. The plan itself provides a blueprint for action.

An outreach plan does not have to be lengthy or complicated. You can develop a plan simply by documenting your answers to each of the questions discussed below. This will provide you with a solid foundation for launching an outreach effort.

Your outreach plan will be most effective if you involve a variety of people in its development. Where possible, consider involving:

- A communications specialist or someone who has experience developing and implementing an outreach plan.
- Technical experts in the subject matter (both scientific and policy).
- Someone who represents the target audience (i.e., the people or groups you want to reach).
- Key individuals who will be involved in implementing the outreach plan.

As you develop your outreach plan, consider whether you would like to invite any organizations to partner with you in planning or implementing the outreach effort. Potential partners might include shoreline and lakeshore property owner associations, local businesses, environmental organizations, schools, boating associations, local health departments, local planning and zoning authorities, and other local or state agencies. Partners can participate in planning, product development and review, and distribution. Partnerships can be valuable mechanisms for leveraging resources while enhancing the quality, credibility, and success of outreach efforts.

Developing an outreach plan is a creative and iterative process involving a number of interrelated steps, as described below. As you move through each of these steps, you might want to revisit and refine the decisions you made in earlier steps until you have an integrated, comprehensive, and achievable plan.

## Whom Are You Trying To Reach?

### *Identifying Your Audience(s)*

The first step in developing an outreach plan is to clearly identify the target audience or audiences for your outreach effort. As illustrated in the sample goals above, outreach goals often define their target audiences. You might want to refine and add to your goals after you have specifically considered which audiences you want to reach.

Target audiences for a water quality outreach program might include, for example, the general public, local decision makers and land management agencies, educators and students (high school and college), special interest groups (e.g., homeowner associations, fishing and boating organizations, gardening clubs, and lawn maintenance/landscape professionals). Some audiences, such as educators and special interest groups, might serve as conduits to help disseminate information to other audiences you have identified, such as the general public.

Consider whether you should divide the public into two or more audience categories. For example: Will you be providing different information to certain groups, such as citizens and businesses? Does a significant portion of the public you are trying to reach have a different cultural or linguistic background from other members? If so, it likely will be most effective to consider these groups as separate audience categories.

### *Profiling Your Audience(s)*

Outreach will be most effective if the type, content, and distribution of outreach products are specifically tailored to the characteristics of target audiences. Once you have identified your audiences, the next step is to develop a profile of their situations, interests, and concerns. This profile will help you identify the most effective ways of reaching the audience. For each target audience, consider:

- What is their current level of knowledge about water quality?
- What do you want them to know about water quality? What actions would you like them to take regarding water quality?
- What information is likely to be of greatest interest to the audience? What information will they likely want to know once they develop some awareness of water quality issues?

- How much time are they likely to give to receiving and assimilating the information?
- How does this group generally receive information?
- What professional, recreational, and domestic activities does this group typically engage in that might provide avenues for distributing outreach products? Are there any organizations or centers that represent or serve the audience and might be avenues for disseminating your outreach products?

Profiling an audience essentially involves putting yourself "in your audience's shoes." Ways to do this include consulting with individuals or organizations who represent or are members of the audience, consulting with colleagues who have successfully developed other outreach products for the audience, and using your imagination.

### What Are Your Outreach Goals?

Defining your outreach goals is the next step in developing an outreach plan. Outreach goals should be clear, simple, action-oriented statements about what you hope to accomplish through outreach (For example, a goal might be to encourage the public to improve its shoreline management practices.) Once you have established your goals, every other element of the plan should relate to those goals.

### What Do You Want To Communicate?

The next step in planning is to think about what you want to communicate. In particular at this stage, think about the key points, or "messages," you want to communicate. Messages are the "bottom line" information you want your audience to walk away with, even if they forget the details.

A message is usually phrased as a brief (often one-sentence) statement. For example:

- The Lake Access Web site allows you to track daily changes on Lake Minnetonka and Lake Independence.
- You can improve water quality in area lakes by reducing the amount of fertilizer you apply to your lawn.

Outreach products will often have multiple related messages. Consider what messages you want to send to each target audience group. You might have different messages for different audiences.

### What Outreach Products Will You Develop?

The next step in developing an outreach plan is to consider what types of outreach products will be most effective for reaching each target audience. There are many different types of outreach: print, audiovisual, electronic, events and novelty items. The table below provides some examples.

| Outreach Products | | |
|---|---|---|
| Print | Brochures<br>Educational curricula<br>Newsletters<br>Posters<br>Question-and-answer sheets | Editorials<br>Fact sheets<br>Newspaper and magazine articles<br>Press releases<br>Utility bill inserts or stuffers |
| Audiovisual | Cable television programs<br>Exhibits and kiosks | Public service announcements (radio)<br>Videos |
| Electronic | E-mail messages<br>Web pages | Subscriber list servers |
| Events | Briefings<br>Fairs and festivals<br>One-on-one meetings<br>Public meetings | Community days<br>Media interviews<br>Press conferences<br>Speeches |
| Novelty Items | Banners<br>Buttons<br>Floating key chains for boaters<br>Magnets | Bumper stickers<br>Coloring books<br>Frisbee discs<br>Mouse pads |

The audience profile information you assembled earlier will be helpful in selecting appropriate products. A communications professional can provide valuable guidance in choosing the most appropriate products to meet your goals within your resource and time constraints. Questions to consider when selecting products include:

- How much information does your audience really need to have? How much does your audience need to know now? The simplest, most effective, most straightforward product generally is most effective.
- Is the product likely to appeal to the target audience? How much time will it take to interact with the product? Is the audience likely to make that time?
- How easy and cost-effective will the product be to distribute or, in the case of an event, organize?
- How many people is this product likely to reach? For an event, how many people are likely to attend?
- What time frame is needed to develop and distribute the product?
- How much will it cost to develop the product? Do you have access to the talent and resources needed for development?
- What other related products are already available? Can you build on existing products?
- When will the material be out of date? (You probably will want to spend fewer resources on products with shorter lifetimes.)
- Would it be effective to have distinct phases of products over time? For example, a first phase of products designed to raise awareness, followed

at a later date by a second phase of products to encourage changes in behavior.

- How newsworthy is the information? Information with inherent news value is more likely to be rapidly and widely disseminated by the media.

### How Will Your Products Reach Your Audience?

Effective distribution is essential to the success of an outreach strategy. There are many avenues for distribution. The table below lists some examples.

| Examples of Distribution Avenues |
|---|
| Your mailing list |
| Partners' mailing list |
| Phone/Fax |
| E-mail |
| Internet |
| Journals or newsletters of partner organizations |
| TV |
| Radio |
| Print media |
| Hotline that distributes products upon request |
| Meetings, events, or locations (e.g., libraries, schools, marinas, public beaches, tackle shops, and sailing clubs) where products are made available |

You need to consider how each product will be distributed and determine who will be responsible for distribution. For some products, your organization might manage distribution. For others, you might rely on intermediaries (such as the media or educators) or organizational partners who are willing to participate in the outreach effort. Consult with an experienced communications professional to obtain information about the resources and time required for the various distribution options. Some points to consider in selecting distribution channels include:

- How does the audience typically receive information?
- What distribution mechanisms has your organization used in the past for this audience? Were these mechanisms effective?
- Can you identify any partner organizations that might be willing to assist in the distribution?
- Can the media play a role in distribution?
- Will the mechanism you are considering really reach the intended audience? For example, the Internet can be an effective distribution mechanism, but certain groups might have limited access to it.

- How many people is the product likely to reach through the distribution mechanism you are considering?
- Are sufficient resources available to fund and implement distribution via the mechanisms of interest?

### What Follow-up Mechanisms Will You Establish?

Successful outreach might generate requests for further information or concern about issues you have made the audience aware of. Consider whether and how you will handle this interest. The following questions can help you develop this part of your strategy:

- What types of reactions or concerns are audience members likely to have in response to the outreach information?
- Who will handle requests for additional information?
- Do you want to indicate on the outreach product where people can go for further information (e.g., provide a contact name, number, or address, or establish a hotline)?

### What Is the Schedule for Implementation?

Once you have decided on your goals, audiences, messages, products, and distribution channels, you will need to develop an implementation schedule. For each product, consider how much time will be needed for development and distribution. Be sure to factor in sufficient time for product review. Wherever possible, build in time for testing and evaluation by members or representatives of the target audience in focus groups or individual sessions so that you can get feedback on whether you have effectively targeted your material for your audience. Section 6.3 contains suggestions for presenting technical information to the public. It also provides information about online resources that can provide easy to understand background information that you can use in developing your own outreach projects.

## 6.2 Elements of the Lake Access Project's Outreach Program

The Lake Access team uses a variety of mechanisms to communicate time-relevant water quality information—as well as information about the project itself—to the affected public in Hennepin County and the nearby area. The team uses the project Web site as the primary vehicle for communicating time-relevant information to the public. Their outreach strategy includes a variety of mechanisms—among them, a brochure, kiosks, and teacher training—to provide the public with information about the Lake Access project. Elements of the project's communication program are highlighted below.

**Bringing together experts.** As a first step, project coordinators brought together a group of naturalists, museum officials, teachers, and other experts to discuss ways to implement the Lake Access Project's outreach efforts. The group identified target audiences, discussed the key points and messages that they felt needed to be communicated, the types of outreach products they thought should be developed, and what mechanisms should be used to distribute the information.

**Designing attractive, user-friendly brochures.** The team developed an attractive 2-page, 4-color brochure, entitled *Seeing Below the Surface,* which features basic, easy-to-follow information about the Lake Access project. The target audience is the general public. A reproduction of the brochure is contained in Appendix B.

**Survey.** Before moving further ahead with project outreach, the Lake Access team needed to know how much general knowledge the public had about water quality and land use issues in the Hennepin County area. To do so, they conducted a survey intended to help the team target its outreach efforts and tailor products to be most useful to lake users and community residents. The survey included a cover page that provided easy-to-understand information about the Lake Access project, and it contained questions about lake use, level of concern about lake water quality, interest in learning more about local lakes, and preferred mechanisms for receiving Lake Access project information. Appendix C contains the entire survey text.

Hennepin County Taxpayer Services provided the team with 450 randomly selected addresses throughout the county. The team sent surveys to these addresses, along with a cover letter, the project brochure, and a postcard that residents returned if they wanted to participate in a focus group. They sent the surveys out again to those who did not initially respond, and in the end, approximately 40 percent of recipients completed the surveys. The survey results revealed a general concern and curiosity about the lake, as well as interest in many aspects of water quality.

**Web site.** The Lake Access Web site, http://www.lakeaccess.org, is the Project's centerpiece for conveying time-relevant water quality data to the public. The site is organized to present information to four target audiences: swimmers, boaters, anglers, and land owners. Users can retrieve water quality data in various forms, as well as background information on water quality. The site's design includes a rolling banner that presents time-relevant information from the three RUSS unit sites in Lake Minnetonka and Lake Independence. The Web site includes an interactive GIS mapping capability (described in Chapter 5, Section 5.2) as well as other user-friendly features, such as a "Frequently Asked Questions" page and a "What's New" page.

In addition, one of the project's partners, Water on the Web (WOW), http://wow.nrri.umn.edu, has created an interactive educational Web site with National Science Foundation funding. The site provides teachers with online lessons on water quality issues and provides high school and college students with study guides on various water quality subjects.

**Kiosks.** The Lake Minnetonka Regional Parks Visitor's Center, the Eastman Nature Center, the Science Museum of Minnesota, and the Great Lakes Aquarium in Duluth have installed touch-screen computer kiosks that feature the same information as the Lake Access project Web site. Kiosk users can access time-relevant water quality data from the three Lake Access Project RUSS units.

Kiosks provide a mechanism for people without ready access to the Internet to view the time-relevant data generated by the project.

**Training teachers.** The project team trained a group of local school teachers on the RUSS unit and the project through a number of workshops, including a two-week summer workshop held at the lake.

**Piggybacking on existing events.** The team found it simple and efficient to promote the project in conjunction with pre-existing events. The team has found that one of the most effective ways to reach a large number of people is to promote the project at local summer festivals, which attract large crowds.

## Developing the Lake Access Web Site

### Experience Gained and Lessons Learned

The Lake Access Web site, **http://www.lakeaccess.org,** is the principal vehicle the Lake Access team uses to disseminate the time-relevant water quality data gathered by the RUSS units. The site's development was initiated through a partnership with Water on the Web, and for the most part, the same people were involved in developing both sites. So by the time the Lake Access Project Web site was designed, many team members had learned valuable lessons from their work on the Water on the Web site **(http://wow.nrri.umn.edu).**

Team members started from scratch when they developed the Water on the Web site. Using Microsoft FrontPage (a website development and management software tool), they designed and built the site's first release and maintained it for 18 months. Eventually, the team decided to hire a graphic designer to help "spruce up" some of the site's design features. Nine months later, they launched a completely redesigned and rebuilt Water on the Web site. With many individuals working simultaneously to rebuild the structure and content of the site, the team learned that they needed to frequently back up the site to another computer to avoid accidentally overwriting one another's content.

The team followed a very similar process to create the Lake Access Web site. They started with an initial "shell" that has emerged into the full structure and content of the current site. The project team feels that the best features of the site are the time-relevant data it conveys, the solid information base it provides, including the limnological primer, and the data visualization tools it features. (These are described in detail in Chapter 4.) Now that the Web site is fully up and running, the Lake Access Project team plans to add "focused" studies to the site. In other words, the team plans to take portions of time-relevant and manually collected water quality data and, using data visualization tools, explain what lake activity the data are illustrating and what they mean in the context of lake management. The team hopes that these focused studies will help community members become more aware of the factors that affect lake water quality.

The Lake Access Project team recommends having a graphic designer on hand, if your project's resources allow, from the onset of your Web site design and construction process. Using any number of Web-based applications, an experienced Web designer can help you design, develop, and maintain a Web site that most effectively communicates your time-relevant data and the associated messages you want to convey.

## 6.3 Resources for Presenting Water Quality Information to the Public

As you begin to implement your outreach plan and develop the products selected in the plan, you will want to make sure that these products present your messages and information as clearly and accurately as possible. You also might want to review the available resources on the Internet to help you develop your outreach products, or serve as additional resource materials (e.g., fact sheets).

### How Do You Present Technical Information to the Public?

Environmental topics are often technical in nature, and water quality is no exception. Nevertheless, this information can be conveyed in simple, clear terms to nonspecialists, such as the public. Principles of effective writing for the public include avoiding jargon, translating technical terms into everyday language the public can easily understand, using the active voice, keeping sentences short, and using headings and other format devices to provide a very clear, well-organized structure. You can refer to the following Web sites for more ideas about how to write clearly and effectively for a general audience:

- The National Partnership for Reinventing Government has developed a guidance document, *Writing User-Friendly Documents,* that can be found on the Web at http://www.plainlanguage.gov/.
- The Web site of the American Bar Association (http://www.abanet.org/lpm/writing/styl.html) has links to important online style manuals, dictionaries, and grammar primers.

As you develop communication materials for a specific audience, remember to consider what the audience members are already likely to know, what you want them to know, and what they are likely to understand. Then tailor your information accordingly. Provide only information that will be valuable and interesting to the target audience. For example, environmentalists in your community might be interested in why dissolved oxygen levels are important to aquatic life. However, it's not likely that school children will be engaged by this level of detail.

When developing outreach products, be sure to consider any special needs of the target audience. For example, if your community has a substantial number of people who speak little or no English, you will need to prepare communication materials in their native language.

The rest of this section contains information about online resources that can provide easy to understand background information that you can use in developing your own outreach projects. Some of the Web sites listed contain products, such as downloadable fact sheets, that you can use to support your education and outreach efforts.

## Federal Resources

### *EPA's Surf Your Watershed*

http://www.epa.gov/surf3/

EPA provides this service to locate, use, and share environmental information on watersheds. One section of this site, "Locate Your Watershed," allows the user to enter the names of rivers, schools, or their zip code to learn more about the water resources in their local watershed. Users can also access the Index of Watershed Indicators (IWI) from this site. The IWI is a compilation of information on the "health" of aquatic resources in the U.S. The index uses a variety of indicators that point to whether rivers, lakes, streams, wetlands and coastal areas are "well" or "ailing."

### *EPA's Office of Water Volunteer Lake Monitoring: A Methods Manual*

http://www.epa.gov/owow/monitoring/volunteer/lake/

EPA developed this manual to present specific information on volunteer lake water quality monitoring methods. It is intended both for the organizers of the volunteer lake monitoring program and for the volunteer who will actually be sampling lake conditions. Its emphasis is on identifying appropriate parameters to monitor and setting forth specific steps for each selected monitoring method. The manual includes quality assurance/quality control procedures to help ensure that the data collected by volunteers are useful to States and other agencies.

### *EPA's Non Point Source Pointers*

http://www.epa.gov/owow/nps/facts/

This Web site features a series of fact sheets on nonpoint source pollution. The series covers topics including: programs and opportunities for public involvement in nonpoint source control, managing urban runoff, and managing nonpoint pollution from various sources (e.g., agriculture, boating, households).

### *EPA's Great Lakes National Program Office*

http://www.epa.gov/glnpo/about.html

EPA's Great Lakes National Program Office Web site includes information about topics such as human health, monitoring, pollution prevention, and visualizing the lakes. One section of this site (http://www.epa.gov/glnpo/gl2000/lamps/index.html) includes the Lakewide Management Plans (LaMPs) for each of the Great Lakes. A LaMP is an action plan to assess, restore, protect and monitor the ecosystem health of a Great Lake. It is used to coordinate the work of all the government, tribal, and non-government partners working to improve the Lake ecosystem. The program uses a public consultation process to ensure that the LaMP is addressing the public's concerns. LaMPs could be used as models to assist interested parties in developing similar plans for their lakes

***U.S. Department of Agriculture Natural Resource Conservation Service***

http://www.wcc.nrcs.usda.gov/water/quailty/frame/wqam/

Go to this site and click on "Guidance Documents." The resources there include a simple tool to estimate water body sensitivity to nutrients, a procedure to evaluate the conditions of a stream based on visual characteristics, plus information on how to design a monitoring system to observe changes in water quality associated with agricultural nonpoint source controls.

## Education Resources

***Project WET (Water Education for Teachers)***

http://www.montana.edu/wwwwet/

The goal of Project WET is to facilitate and promote awareness, appreciation, knowledge, and stewardship of water resources by developing and disseminating classroom-ready teaching aids and establishing state and internationally sponsored Project WET programs. This site includes a list of all the State Project WET Program Coordinators to help you locate a contact in your area.

***Water Science for Schools***

http://wwwga.usgs.gov/edu/index.html

The U.S. Geological Survey's (USGS's) Water Science for School Web site offers information on many aspects of water quality, along with pictures, data, maps, and an interactive forum where students can give opinions and test their water knowledge.

***Global Rivers Environmental Education Network (GREEN)***

http://www.earthforce.org/green/

The Global Rivers Environmental Education Network (GREEN) helps young people protect the rivers, streams, and other vital water resources in their communities. This program merges hands-on, scientific learning with civic action. GREEN is working with EcoNet to compile pointers on water-related resources on the Internet. This site (http://www.igc.apc.org/green/resources.html) includes a comprehensive list of water quality projects across the country and around the world.

### *Adopt-A-Watershed*

http://www.adopt-a-watershed.org/about.htm

Adopt-A-Watershed is a K-12 school-community learning experience. Adopt-A-Watershed uses a local watershed as a living laboratory in which students engage in hands-on activities. The goal is to make science applicable and relevant to students' lives.

### *National Institutes for Water Resources*

http://wrri.nmsu.edu/niwr/niwr.html

The National Institutes for Water Resources (NIWR) is a network of 54 research institutes throughout the U.S. They conduct basic and applied research to solve water problems unique to their area and establish cooperative programs with local governments, state agencies, and industry.

## Other Organizations

### *North American Lake Management Society (NALMS) Guide to Local Resources*

http://www.nalms.org/resources

This is a one-stop resource for local lake-related resources. NALMS's mission is to forge partnerships among citizens, scientists, and professionals to foster the management and protection of lakes and reservoirs. NALMS's Guide to Local Resources contains links to state and provincial agencies, local offices of federal agencies, extension programs, water resources research centers, NALMS chapters, regional directors, and a membership directory.

### *The Watershed Management Council*

http://watershed.org/wmc/aboutwmc.html

The Watershed Management Council is a nonprofit organization whose members represent a broad range of watershed management interests and disciplines. Membership includes professionals, students, teachers, and individuals whose interest is in promoting proper watershed management.

### *Great Lakes Information Network (GLIN)*

http://www.great-lakes.net

The Great Lakes Information Network (GLIN) is a partnership that provides online information about the bi-national Great Lakes-St. Lawrence region of North America. GLIN provides data about the region's environment, including issues related to water quality, diversion of water out of the Great Lakes basin, and the introduction of nonindigenous species and airborne toxins into the basin.

# APPENDIX A
# GLOSSARY OF TERMS

## A

**Algae:** Simple single-celled, colonial, or multi-celled aquatic plants. Aquatic algae are (mostly) microscopic plants that contain chlorophyll and grow by photosynthesis. They absorb nutrients from the water or sediments, add oxygen to the water, and are usually the major source of organic matter at the base of the food web in lakes. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Algal blooms:** Referring to excessive growths of algae caused by excessive nutrient loading. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Aluminum sulfate:** A compound, $Al_2(SO_4)_3$, used in water purification and sanitation that adsorbs phosphate and small silt and algal particles that settle to the lake bottom.

**Anoxia:** Condition of being without dissolved oxygen ($O_2$). (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Anoxic:** Completely lacking in oxygen. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

## B

**Baud:** A unit of speed in data transmission equal to one bit per second.

**Best Management Practices (BMPs):** Methods that have been determined to be the most effective, practical means of preventing or reducing pollution from non-point sources.

**Biofouling:** The deterioration of instrumentation when it becomes covered with organisms. For example, biofouling of the RUSS unit sensors occurs when algae, bacteria, and/or fungi grow on the sensor while it is submerged in water beneath the RUSS unit.

## C

**Chlorophyll:** Green pigment in plants that transforms light energy into chemical energy in photosynthesis. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Clarity:** Transparency, or light penetration. Clarity is routinely estimated by the depth at which you can no longer see a Secchi disk. The Secchi disk is a weighted metal plate 8 inches in diameter with alternating quadrants painted black and white. The disc 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. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Clocker/ClockerPro:** Software designed to schedule programs (or reminders) to run at specified times (e.g., the upload and download of data from the RUSS units).

**Color Mapper:** A data visualization tool that enables the user to map one parameter as color contours and then overlay another variable over the color contours in the form of a line plot.

**CONSOLE**: Software that enables operation of a RUSS unit using a portable computer in the field.

**CTM:** Cellular telephone modem. Can be used to transfer data from the RUSS unit to the land-base station.

## D

**Depth versus Time (DxT) Profiler:** A data visualization program that allows users to display and analyze data in two or three dimensions.

**Dimictic:** A type of lake that has two mixing periods, typically in spring and fall. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Dissolved oxygen (DO):** The concentration of oxygen dissolved in water, usually expressed in milligrams per liter, parts per million, or percent of saturation (at the field temperature). Adequate concentrations of dissolved oxygen are necessary to sustain the life of fish and other aquatic organisms and prevent 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. Levels above 5 milligrams per liter (mg $O_2$/L) are considered optimal and most fish cannot survive for prolonged periods at levels below 3 mg $O_2$/L. Levels below 1 mg $O_2$/L are often referred to as *hypoxic* and when $O_2$ is totally absent *anoxic* (often called anaerobic which technically means *without air*). (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Dissolved oxygen profile:** A graph of the amount of dissolved oxygen per unit depth, where the depth is on the z (vertical) axis and dissolved oxygen is on the x (horizontal) axis. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**DVT data visualization tools:** A suite of four interactive data visualization programs used by the Lake Access team to depict and manipulate water quality profiles collected by RUSS units and from manual sampling, specifically, Lake Access Live: Near Real-Time Display of Numeric Data; Profile Plotter; Color Mapper; and Depth versus Time (DxT) Profiler.

## E

***E. coli:*** A bacteria *(Escherichia coli)* normally found in the gastrointestinal tract and existing as hundreds of strains, some of which can cause diarrheal disease. *E. coli* can be a water-borne pathogen.

**Electrical conductivity:** A measure of the water's ability to conduct an electrical current based on its ion content. It is a good estimator of the amount of total dissolved salts or total dissolved ions in water. The electrical conductivity in a lake is influenced by many factors, including the watershed's geology, the watershed's size in relation to lake's size, wastewater from point sources, runoff from nonpoint sources, minor atmospheric inputs, evaporation rates, and some types of bacterial metabolism. Lake Access Project values are standardized to values that would be measured at 25° C to correct for the effect of temperature. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**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. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Eutrophic lake:** A very biologically productive type of lake due to relatively high rates of nutrient input that cause high rates of algal and plant growth. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Eutrophication:** The process by which lakes and streams are enriched by nutrients (usually phosphorus and nitrogen) which leads to excessive plant growth. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

## F

## G

**Geographic Information System (GIS):** A computer software and hardware system that helps scientists and other technicians capture, store, model, display, and analyze spatial or geographic information.

**GIF (Graphics Interchange Format):** A common format for image files, especially suitable for images containing large areas of the same color.

**Guano:** A substance composed mostly of the dung of sea birds.

## H

**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. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

## I

**Inflow:** Water flowing into a lake. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

## J

## K

## L

**Lake Access Live: Near Real-Time Display of Numeric Data:** A data visualization program used to provide near real-time data feeds, such as oxygen level and temperature, to Web sites.

**Lake profile:** A graph of a lake variable per depth, where the depth is on the z-axis (vertical axis) and the variable is on the x-axis (horizontal axis). Depth is the independent variable and the x-axis is the dependent variable. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Limnology:** The study of the life and phenomena of fresh water systems, especially lakes and ponds; freshwater ecology; a limnologist is to lakes as an oceanographer is to oceans.

## M

**Metalimnion:** The middle or transitional zone between the well mixed epilimnion and the colder hypolimnion layers in a stratified lake. This layer contains the thermocline, but is loosely defined depending on the shape of the temperature profile. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Modem:** A device that converts data from one form into another (e.g., to a form useable in telephonic transmission).

**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, shoreline development, depth versus volume, and surface area curves. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

## N

**Nonpoint source:** Diffuse source of pollutant(s); not discharged from a pipe; associated with agricultural or urban runoff, contaminated groundwater flow, atmospheric deposition, or on-site septic systems. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Nutrient loading:** The discharge of nutrients from the watershed into a receiving water body (lake, stream, wetland). Expressed usually as mass per unit area per unit time (kg/ha/yr or lbs/acre/year). (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

## O

**Organic:** Substances that contain carbon atoms and carbon-carbon bonds. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Outflow:** Water flowing out of a lake. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Outliers:** Data points that lie outside of the normal range of data. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

## P

**Parameter:** Whatever it is you measure—a particular physical, chemical, or biological property that is being measured. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**pH scale:** A scale used to determine the alkaline or acidic nature of a substance. The scale ranges from 1 to 14 with 1 being the most acidic and 14 the most basic. Pure water is neutral with a pH of 7. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Phosphorus:** Key nutrient influencing plant growth in lakes. Soluble reactive phosphorus ($PO_4^{-3}$) is the amount of phosphorus in solution that is available to plants. Total phosphorus includes the amount of phosphorus in solution (reactive) and in particulate form. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Photosynthesis:** The process by which green plants convert carbon dioxide ($CO_2$) dissolved in water to sugars and oxygen using sunlight for energy. Photosynthesis is essential in producing a lake's food base and is an important source of oxygen for many lakes. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**ppb:** Parts-per-billion; equivalent to a microgram per liter (ug/l). (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**ppm:** Parts-per-million; equivalent to a milligram per liter (mg/l). (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Profile:** A vertical, depth by depth characterization of a water column, usually at the deepest part of a lake. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Profile Plotter:** A data visualization tool that enables users to create static and animated line plots of the profiles of lakes and other water bodies.

**Profiler:** A component of the RUSS unit that carries the water quality monitoring sensor to multiple depths within the water column beneath the RUSS Unit flotation module. The profiler is controlled by the RePDAR unit.

## Q

**Quality Assurance/Quality Control (QA/QC).** QA/QC procedures are used to ensure that data are accurate, precise, and consistent. QA/QC involves following established rules in the field and in the laboratory to ensure that samples are representative of the water you are monitoring, free from contamination, and analyzed following standard procedures.

## R

**RUSS-Base:** Software that enables the user to remotely operate the RUSS unit using a computer at the land-base station. RUSS-Base creates profile schedules of sampling parameters and communicates with the RUSS unit via telemetry equipment to transmit schedules and receive sampling data.

**Remote Underwater Sampling Station (RUSS™):** Monitoring equipment used to remotely collect time-relevant water quality data. The RUSS unit, manufactured by Apprise Technologies, Inc., consists of a mobile underwater monitoring sensor tethered to a  a buoy and featuring an onboard computer, batteries, solar panels, telemetry equipment, and other optional monitoring equipment.

**RePDAR (Remote Programming, Data Acquisition, and Retrieval) unit.** A component of the RUSS unit that allows for remote water quality monitoring sensor operation, data storage, and data transmission. Each RePDAR unit contains a central processing unit (CPU), power supply charging controls, and telemetry modules.

## S

**Secchi disk:** A disk, typically 8 inches in diameter, divided into 4 equal quadrants of alternating black and white colors. (Some states use totally white Secchis.) 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 a measure of the water's clarity. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Sedimentation:** The process of settling inorganic and organic matter on the lake bottom. This matter may have been produced within the lake or washed in from the watershed. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Solubility:** The ability of a substance to dissolve into another. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Spring turnover:** Period of complete or nearly complete vertical mixing in the spring after ice-out and prior to thermal stratification. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Stormwater discharge:** Precipitation and snowmelt runoff from roadways, parking lots, and roof drains that collects in gutters and drains; a major source of nonpoint source pollution to water bodies. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Stratification:** An effect where a substance or material is broken into distinct horizontal layers due to different characteristics such as density or temperature. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Stratified:** Separated into distinct layers. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Swimmer's itch:** An itching inflammation of the skin caused by parasitic larval forms of certain schistosomes that penetrate into the skin, occurring after swimming in infested water.

**Substrate:** Attachment surface or bottom material in which organisms can attach or live within; such as rock substrate or sand or muck substrate, or woody debris. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Suspended solids:** (SS or Total SS [TSS]). Very small particles that remain distributed throughout the water column due to turbulent mixing exceeding gravitational sinking. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

## T

**Telemetry:** The science of automatic measurement and transmission of data by wire, radio, or other methods from remote sources.

**Temperature profile:** A graph of the temperature per depth; where the depth is on the z-axis (vertical axis) and temperature is on the x-axis (horizontal axis). (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**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. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Thermocline:** The depth at which the temperature gradient is steepest during the summer; usually this gradient must be at least 1°C per meter of depth. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Topography:** Configuration of physical surface of land; includes relief imprints and locations of all man-made and natural features. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Total dissolved solids (TDS):** The amount of dissolved substances, such as salts or minerals, in water remaining after evaporating the water and weighing the residue. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Turbidity:** The degree to which light is blocked because water is muddy or cloudy. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Turnover:** Fall cooling and spring warming of surface water act to make density uniform throughout the water column. This allows wind and wave action to mix the entire lake. Mixing allows bottom waters to contact the atmosphere, raising the water's oxygen content. However, warming may occur too rapidly in the spring for mixing to be effective, especially in small sheltered kettle lakes. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

## U

## V

## W

**Water column:** A conceptual column of water from lake surface to bottom sediments. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

**Watershed:** All land and water areas that drain toward a river or lake. (Adapted from Water on the Web at http://wow.nrri.umn.edu/wow.)

## X

## Y

**YSI multiprobe water quality sensor:** The component of the RUSS unit, manufactured by Yellow Springs Instruments (YSI), that is raised and lowered to collect a water quality profile in specified intervals from the lake surface to the lake bottom.

## Z

# APPENDIX B
# LAKE ACCESS BROCHURE

# Seeing Below the Surface

## Lake Data Comes Alive in Minnesota!

Thanks to technological advances, all of us, not just scientists, can see below the surface!

**Lake Access allows you to:**

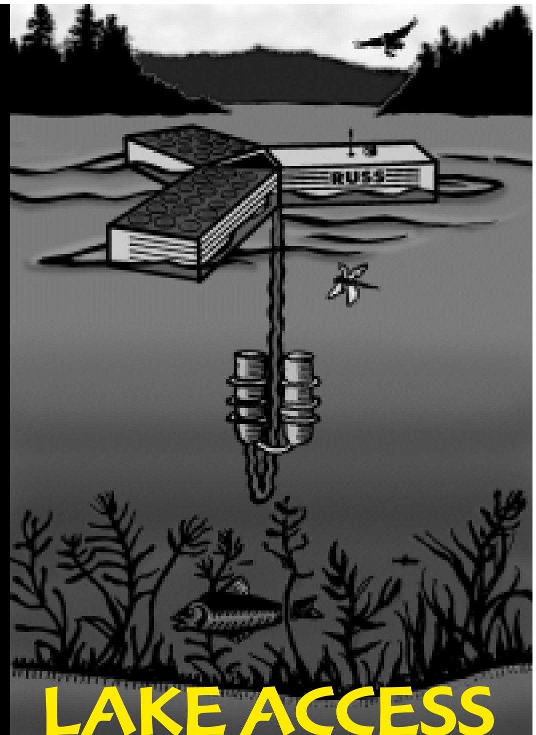
- Track daily changes on Lake Minnetonka and Lake Independence.
- Study how choices we make on the shoreline and in the water affect the health of our lakes.
- Witness the way storms and seasonal changes mix lake water and impact fish and fishing.
- Gauge how our lakes have changed over time.

Lake Access was made possible by a two-year grant from the U.S. Environmental Protection Agency's EMPACT (Environmental Monitoring for Public Access and Community Tracking) initiative. Lake Access partners include: Hennepin Parks, the Natural Resources Research Institute, UM-Duluth Department of Education, University of Minnesota Sea Grant, the Minnehaha Creek Watershed District, Minnesota Science Museum, and Apprise Technologies, Inc.

Lake Access cooperators welcome your comments and suggestions.
For more information contact: George Host, (218) 720-4264, Natural Resources Research Institute, ghost@sage.nrri.umn.edu.

**www.nrri.umn.edu/empact**

Please check out the Web site at: www.nrri.umn.edu/empact




## Seeing Below the Surface

Remote Underwater Sampling System (RUSS) units are the yellow platforms anchored in Lakes Minnetonka and Independence. Beneath the platform, an underwater sensor package cycles between the surface and the lake bottom to gather data on turbidity, acidity, conductivity, dissolved oxygen, and temperature.

## Transmitting Daily Data

Every six hours, RUSS units transmit the data they have gathered to an on-shore base station over a cellular phone.

## Accessing Information

You can access the continual stream of data from the RUSS units over the World Wide Web site: www.nrri.umn.edu/empact. Soon, Lake Access kiosks linked to the RUSS units will be constructed at Lake Minnetonka Regional Parks Visitor's Center, Richardson Nature Center, and other locations around Minneapolis.

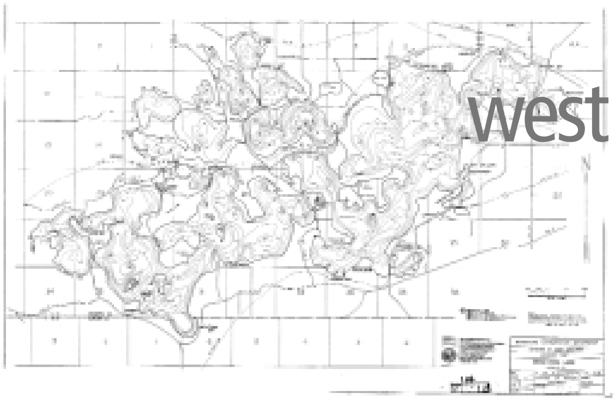
## Understanding the Data

The Lake Access Web site and kiosks will contain interactive tools and informational links that allow you to interpret easily data through maps, graphics, and text.

## Making a Difference

What you and resource professionals learn from the RUSS units could change the way we manage our shorelines. Lake Access information may encourage lakeshore owners to landscape with more native plants and fewer chemicals. City planners may use RUSS information to develop lake-friendly practices. You may decide how deep to fish or when to swim based on the day's data.

# APPENDIX C
# LAKE ACCESS SURVEY



# west metro lake survey

**SEEING BELOW THE SURFACE OF LOCAL LAKES**

**This is a survey to find out your perceptions, uses and ways you get information about your local lakes. Please help us find the best way to reach you with the facts you need to enjoy your favorite West Metro lakes.**

**WEST METRO RESIDENT:**

Do you know what is happening in your favorite lake? We would like to tell you, but we don't know the best way to reach you and your neighbors. Please help us by filling out the enclosed, 7-minute survey about your use of West Metro lakes, your perceptions about their "health," and the best ways to reach you with new information.

**WHAT IS LAKE ACCESS?**

The goal of Lake Access is to provide you with timely, accurate and understandable information about your local lakes. We want to supply you with the facts you need to make informed, day-to-day decisions about your West Metro lakes.

**WHO ARE WE?**

Partners in this project include Minnesota Sea Grant, Hennepin Parks, Natural Resources Research Institute, University of Minnesota Duluth Department of Education, Apprise Technologies Inc., and the Minnehaha Creek Watershed District. The U.S. Environmental Protection Agency funds Lake Access through their Environmental Monitoring for Public Access and Community Tracking Initiative.

**WHY YOU?**

We randomly selected your name as part of a small group of people to complete this confidential survey. We value your answers, time and privacy.

**WHY FILL IT OUT?**

This is your chance to make Lake Access easily available, understandable and useful to you and your neighbors in the West Metro.

**FOR MORE INFORMATION**

See the enclosed brochure and browse our Web site at: **http://www.nrri.umn.edu/empact**.

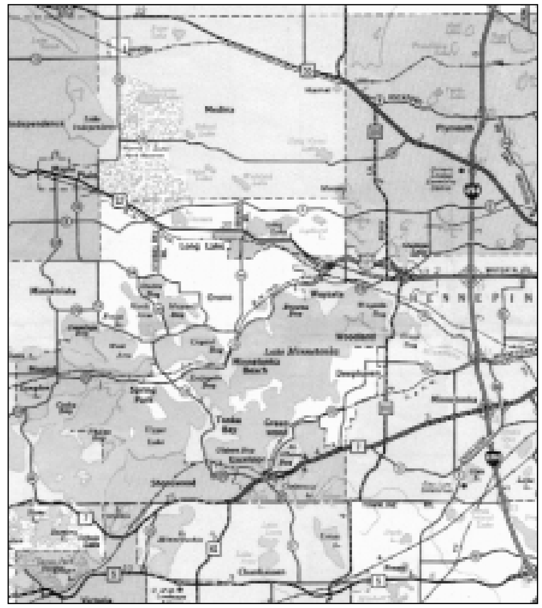
Thank you in advance for your time and effort in completing this survey.

return survey **by november 22**

## survey

**1** Approximately how many days per year do you use lakes in the West Metro area? (see map)

- [ ] 0
- [ ] 1–5
- [ ] 6–10
- [ ] 11–20
- [ ] >21



**IF YOU DO NOT VISIT WEST METRO LAKES, PLEASE GO TO QUESTION 6.**

**2** Please check the ONE West Metro lake you currently use most.

- [ ] Auburn
- [ ] Bryant
- [ ] Christmas
- [ ] Cleary
- [ ] Eagle
- [ ] Fish
- [ ] Forest
- [ ] Independence
- [ ] Hyland
- [ ] Langdon
- [ ] Libbs
- [ ] Little Long
- [ ] Long
- [ ] Medicine
- [ ] Minnetonka
- [ ] Minnewashta
- [ ] Parley
- [ ] Rebecca
- [ ] Sarah
- [ ] Schutz
- [ ] Spurzem
- [ ] Steiger
- [ ] Stone
- [ ] Virginia
- [ ] Waconia
- [ ] Weaver
- [ ] Zumbra
- [ ] OTHER SPECIFY ______

**3** In your opinion, which THREE items have the greatest impact on water quality in the lake you currently use most?

- [ ] Failing septic systems
- [ ] Aquatic plant removal
- [ ] Shoreland plant removal
- [ ] Lawn fertilizers and chemicals
- [ ] Urban, road or parking lot runoff
- [ ] Livestock manure
- [ ] Damage to aquatic plants and lake bottom by watercraft
- [ ] Introduction of exotic species invasions (Eurasian water milfoil)
- [ ] Agricultural fertilizers and chemicals
- [ ] Municipal waste water discharges
- [ ] Fuel leakage from motorized watercraft
- [ ] Soil erosion from building or road construction sites
- [ ] OTHER SPECIFY ______

**4** Please check your impression below for the West Metro lake you currently use most.

| | EXCELLENT | GOOD | FAIR | POOR | DON'T KNOW |
|---|---|---|---|---|---|
| OVERALL BEAUTY/AESTHETIC VALUE | | | | | |
| OVERALL HEALTH OF LAKE | | | | | |
| QUALITY OF FISHING | | | | | |

**5** Please mark your opinion below for the West Metro lake you currently use most.

| | TOO FEW | JUST ABOUT RIGHT | TOO MANY | DON'T KNOW |
|---|---|---|---|---|
| NUMBER OF LAKE USERS | | | | |
| NUMBER OF CABINS/ HOMES | | | | |

**6** How concerned are you about the quality of lakes and shoreland areas in the West Metro area?

- [ ] Very concerned
- [ ] Somewhat concerned
- [ ] Not concerned

**7** Please estimate your level of general knowledge about the following subjects.

**A** Lake water quality
- [ ] High
- [ ] Medium
- [ ] Low

**B** Proper care of shoreline property
- [ ] High
- [ ] Medium
- [ ] Low

**8** Are you interested in learning more about lakes in the West Metro area?
- ☐ Yes
- ☐ No

**9** Please check the item(s) you would like to learn more about West Metro lakes.
- ☐ Effects of weather on lakes
- ☐ Fisheries
- ☐ Control of algae
- ☐ Control of aquatic plants
- ☐ User conflict resolutions
- ☐ Nutrient levels (nitrogen/phosphorus)
- ☐ Change in water quality over time
- ☐ Actions that improve lake water quality
- ☐ Factors that influence lake water quality
- ☐ Water conditions for swimming
- ☐ Shoreland restoration with native plants
- ☐ Basic understanding of how lakes work
- ☐ Non-native plant control efforts
- ☐ Real time lake measurements (oxygen profiles, mixing depths, lake temperature)
- ☐ OTHER SPECIFY ____________

THE INTERNET IS AN ELECTRONIC COMMUNICATIONS NETWORK THAT CONNECTS COMPUTER NETWORKS AND FACILITIES AROUND THE WORLD.

**10** Would you use the Internet to learn more about West Metro lakes?
- ☐ Yes
- ☐ No

**11** Please check the item(s) below that would make it worth your time to visit our Web site, http://www.nrri.umn.edu/empact.
- ☐ Live camera coverage of lakeshore conditions
- ☐ Information about the bacterial contamination of swimming beaches
- ☐ Current water temperature
- ☐ Current dissolved oxygen levels
- ☐ Water clarity measurements
- ☐ Regional weather
- ☐ Weekly fishing reports
- ☐ OTHER SPECIFY ____________
- ☐ I do not have computer access

AN INTERACTIVE KIOSK IS AN INFORMATION BOOTH WITH A COMPUTER TOUCH SCREEN.

**12** Would you use an interactive kiosk to learn more about lakes in the West Metro area?
- ☐ Yes
- ☐ No

**13** Please check the THREE most convenient locations for you to use a kiosk?
- ☐ Beach
- ☐ Grocery store
- ☐ Library
- ☐ Mall
- ☐ Museum
- ☐ School
- ☐ Visitor center
- ☐ Boat launch
- ☐ OTHER SPECIFY ____________

**14** As new facts become available about West Metro lakes, which TWO ways would be most convenient for you to access in-depth news and information about your lakes?
- ☐ Classes/workshops
- ☐ Interactive kiosk
- ☐ Organizations
- ☐ Internet
- ☐ OTHER SPECIFY ____________

**15** Please check TWO ways you would most likely notice a brief announcement about West Metro lakes.
- ☐ Signs
- ☐ Public radio
- ☐ Commercial radio
- ☐ Network television
- ☐ Cable television
- ☐ Direct mail
- ☐ St. Paul Pioneer Press
- ☐ Minneapolis Star-Tribune
- ☐ Other newspapers SPECIFY ____________
- ☐ Newsletters SPECIFY ____________
- ☐ Magazines SPECIFY ____________

PLEASE **CONTINUE**

THE NEXT SECTION OF THIS SURVEY WILL HELP US FIND GENERAL PATTERNS.
REMEMBER THAT YOUR ANSWERS ARE STRICTLY CONFIDENTIAL.

**16** Do you care for a lawn?
- ☐ Yes
- ☐ No

IF YES

**A** Have you ever had your soil tested?
- ☐ Yes
- ☐ No

**B** How many times per year do you add fertilizer?
- ☐ 0
- ☐ 1–2
- ☐ 3–4
- ☐ >5

**C** What do you do with your grass clippings and leaves?
- ☐ Burn
- ☐ Compost
- ☐ Leave on lawn
- ☐ Place in trash bin
- ☐ Put in gutter
- ☐ OTHER SPECIFY ____________________

**17** Do you own/lease shoreland property?
- ☐ Yes
- ☐ No

IF YES

**A** What is the name of the lake where you own or lease shoreland property?

SPECIFY ____________________

**B** Which best describes your property at the edge of the water?
- ☐ Concrete, steel or wood retaining wall
- ☐ Mowed lawn
- ☐ Natural landscape
- ☐ Rock/rip-rap added for stabilization
- ☐ Sand beach
- ☐ OTHER SPECIFY ____________________

**C** If you have a private septic system, how frequently do you inspect and maintain it?
- ☐ Once a year
- ☐ 1–3 years
- ☐ >3 years
- ☐ Do not know

**18** What is your zip code? ____________________

**19** What is your gender? ☐ Female ☐ Male

**20** What is your age group?
- ☐ <25
- ☐ 25–45
- ☐ 45–65
- ☐ >65

SEQUENCE NUMBER

THANK YOU FOR TAKING THE TIME AND EFFORT TO COMPLETE THIS SURVEY.
**PLEASE TAPE THE SURVEY CLOSED AND DROP IN THE MAIL.**

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