

Water Monitoring Program  
**WASHINGTON CONSERVATION DISTRICT  
STANDARD OPERATING PROCEDURE (S.O.P.) No. 1**

**Lake Monitoring**

Water Monitoring Program  
**Standard Operating Procedure No. 1**  
**Lake Monitoring**

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## **Scope and Applicability**

### **1.0 Overview of Data Management Procedures**

This S.O.P is designed to define the procedures that are performed in lake Multiple agencies collect these types of data and have specific standard procedures for their specific data collection needs. This S.O.P. specifically defines the methods used by the Washington Conservation District (WCD) and does not reflect the exact procedures used by others. Although other agency S.O.P.'s may look similar, careful investigation may reveal differences between procedures that should be taken into account.

### **2.0 Scope of the S.O.P.**

This SOP describes required procedures for data management required by flow monitoring and/or other aspects of water resource data collection using data logging technology or water sampling. This SOP describes:

- CAMP Lake Monitoring Program
- Zooplankton Monitoring
- Aquatic Plant (Macrophyte) Surveys

### **3.0 Equipment and Materials**

#### **.1 The following equipment and materials will be required:**

- A Coast Guard-approved personal flotation device
- A fire extinguisher (depending on length of boat)
- A first-aid kit
- Oars (in case of motor failure or no gas)
- Boat anchor
- Chlorophyll hand pump, flask, and filters
- Clipboard and pencils
- Cooler with ice packs (if you expect to stay out on the lake longer than a half-hour)
- Depth finder (if possible or needed)
- Thermometer/Dissolved Oxygen Meter
- Map of lake with sampling site(s)
- Sampling form or electronic sampling form
- Sampling jug
- Sampling handbook (to help remember procedures)
- Labeled sample vials
- Secchi disk

- Aluminum foil
- Tweezers (forceps)
- Wisconsin 80  $\mu\text{m}$  plankton net
- 70% ethanol solution
- Metal tined rake
- Grappling hook

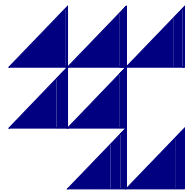
## **4.0 Procedures**

### **.1 Procedure for CAMP Lake Monitoring**

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# Handbook for the Citizen-Assisted Lake Monitoring Program

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Mears Park Centre, 230 East Fifth Street, St. Paul, MN 55101-1634

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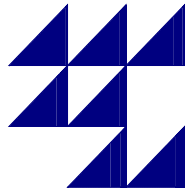
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# Handbook for the Citizen-Assisted Lake Monitoring Program

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September 2003

Randall J. Anhorn



METROPOLITAN COUNCIL  
Mears Park Centre, 230 East Fifth Street, St. Paul, MN 55101-1634

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# **Metropolitan Council**

**Mears Park Centre, 230 East Fifth Street, St. Paul, Minnesota 55101**

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***T***he mission of the Metropolitan Council is to improve regional competitiveness in the global economy so that this is one of the best places to live, work, raise a family and grow a business.

The Metropolitan Council coordinates regional planning and guides development in the seven-county area through joint action with the public and private sectors. The Council also operates regional services, including wastewater collection and treatment, transit and the Metro HRA □ an affordable-housing service that provides assistance to low-income families in the region. Created by the legislature in 1967, the Council establishes policies for airports, regional parks, highways and transit, sewers, air and water quality, land use and affordable housing, and provides planning and technical assistance to communities in the Twin Cities region.

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## **FORWARD**

This handbook has been prepared as a support manual for the volunteers involved in the Citizen-Assisted Monitoring Program (CAMP).

The majority of lakes in the Twin Cities Metropolitan Area (TCMA) and other areas throughout the United States suffer from a lack of data. Area lake and watershed managers need a broad comprehensive water quality database for regulatory and decision making purposes. Because of the lack of public funding and the large ratio of area lakes to monitoring staff, very little data exists for the majority of the lakes in the area. Therefore, local decision-makers are forced to make management decisions without possessing adequate information on which to base them.

In order to bridge the data gaps of area lakes and provide more complete databases to local decision makers, the Metropolitan Council is sponsoring a volunteer monitoring program to gather as much information on area lakes as is economically possible. Volunteer monitoring programs are being used in many states for this reason.

Previously conducted volunteer programs have shown that with the proper equipment and instructions, volunteers can be trained to produce credible water quality data. In fact, because most of the volunteers actually live near the lakes they are monitoring, they are very interested in determining any trends and/or changes in local water quality (Nichols, 1992).

Not only will volunteer involvement in the lake monitoring process substantially reduce the cost of obtaining data, but it will also enhance the volunteers' understanding of how a lake works and how its condition relates to its surrounding watershed. Additionally, through their participation and enhanced knowledge, volunteers can become more involved in water quality issues.

## **ACKNOWLEDGEMENTS**

Special thanks to the Minnesota Pollution Control Agency (MPCA) for their permission to excerpt and adapt information and illustrations from its publication *A Citizens' Guide to Lake Protection*.

# **PART I – CITIZEN-ASSISTED MONITORING PROGRAM**

## **PURPOSE OF THIS MANUAL**

This manual is designed to present the sampling methods to be used in the Citizen-Assisted Monitoring Program (CAMP). It can then be used as a reference throughout the course of the monitoring period. Additionally, the manual describes the goals of the volunteer monitoring program and briefly summarizes the basic inner workings of a lake.

## **PURPOSE OF CITIZEN-ASSISTED MONITORING PROGRAM (CAMP)**

A 1989 survey of watershed management organizations by the Metropolitan Council entitled "An Evaluation of Lake and Stream Monitoring Programs in the Twin Cities Metropolitan Area," determined that water quality monitoring in the majority of metro lakes is inadequate (Osgood, 1989a). The results also suggest that one of the first steps in protecting and managing the quality of our lakes is the formation of a reliable, comprehensive water quality database. Therefore, this suggests that lakes in the Metropolitan Area (as well as the majority of lakes throughout the state) are being managed without the proper support of a database which truly explains the workings of the lake and its watershed.

The main purpose of the Citizen-Assisted Monitoring Program is to provide lake and watershed managers with water quality data that will support them in proper management of the resources. An additional function of the monitoring program will be the volunteer's increased awareness of their lake's condition and workings throughout the summer.

## **DESCRIPTION OF THE PROGRAM**

The Citizen-Assisted Monitoring Program will involve the collection of in-lake samples by volunteers. Monitoring procedures and sample handling methods were determined during a pilot study during the summer of 1991. The pilot study was designed to evaluate the validity of data collected using several possible citizen monitoring and sample handling methods by comparing them to routine methods (Hartsoe and Osgood, 1991). A copy of the pilot study and results are presented in Appendix A.

Volunteers will collect surface water samples to be analyzed for total phosphorus (TP), total Kjeldahl nitrogen (TKN), and chlorophyll-a (CLA). In addition, they will measure surface water temperature, water transparency, and user perception. Lakes will be visited biweekly from April through October (fourteen sampling dates), and be sampled at the lake's deepest open water location. After each monitoring, samples that are collected will be submitted to the Metropolitan Council which will then forward them to an analytical laboratory for chemical analysis.

## **PROJECT ORGANIZATION AND RESPONSIBILITIES**

### **Metropolitan Council**

The Metropolitan Council will oversee the Citizen-Assisted Monitoring Program. The Council's main responsibilities include:

- ◉ Training volunteers in proper monitoring techniques.
- ◉ Picking up and delivering samples to the laboratory for analysis.
- ◉ Managing and analyzing data.
- ◉ Monitoring quality assurance/quality control (QA/QC) of the volunteer's sampling procedures and resulting numbers.
- ◉ Preparing and distributing an annual monitoring report.
- ◉ Include data in the U.S. Environmental Protection Agency's STORET database.

### **Watershed Management Organization (WMO)/Watershed District (WD)/County/City**

After determining which lakes they would like involved in the program, the sponsoring groups main obligations consist of recruiting of volunteers to monitor their lakes and setting up times and locations for training sessions. Whenever possible, the training sessions will be held at times and locations where volunteer monitors from several lakes can be trained at once.

### **Volunteer Monitors**

The volunteer monitors must have access to a boat. Their duties include collecting and labeling samples, and filling out sampling forms. A Metropolitan Council representative will pick up the samples.

### **Analytical Laboratory**

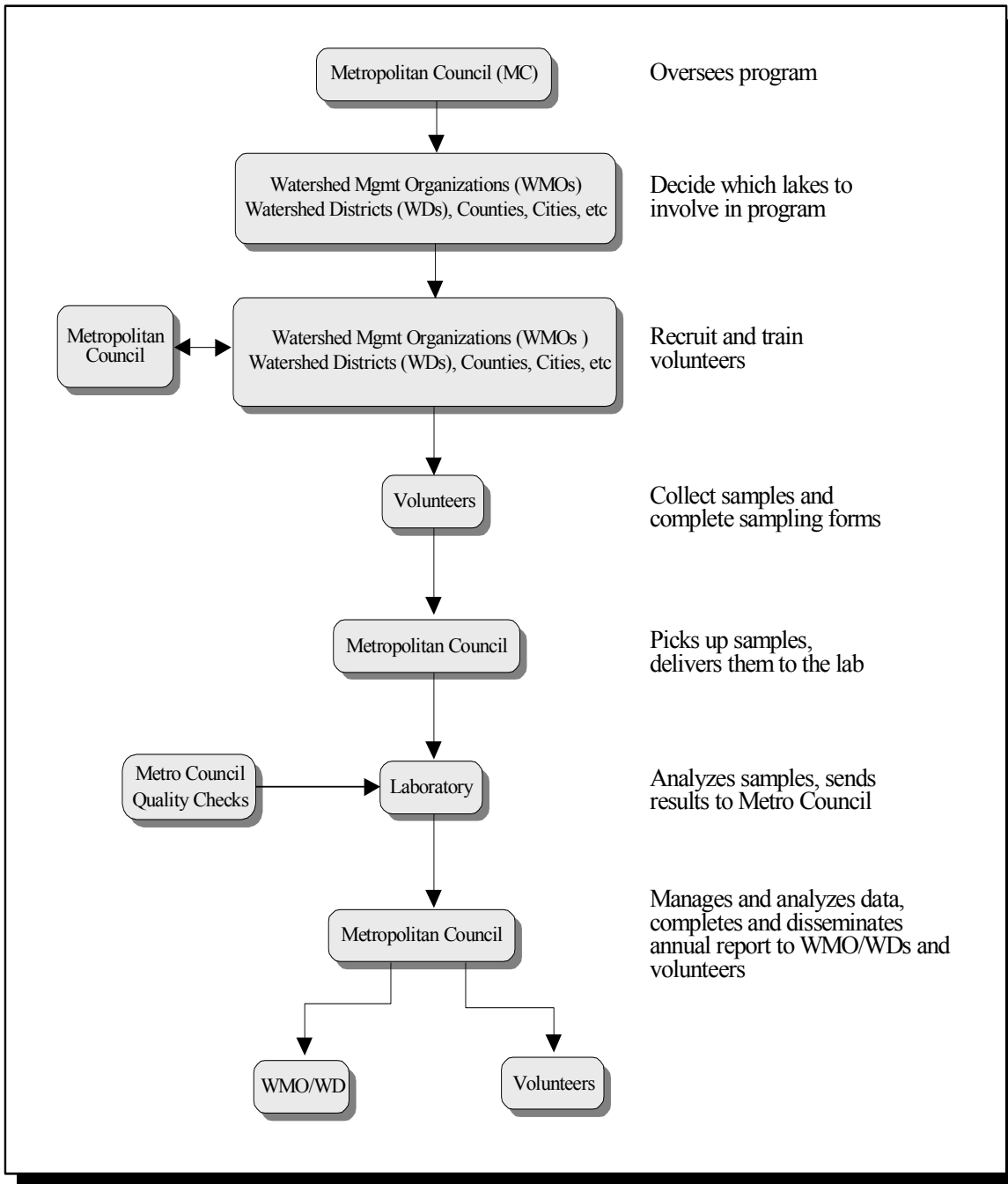
The analytical lab is responsible for the lake samples once they have been received from the Metropolitan Council representative. The lab, which has its own QA/QC program, will conduct the specified analyses (TP, TKN, and CLA) on the samples. Results from the analyses will then be sent to the Metropolitan Council. A copy of the results can also be sent to the sponsoring group if requested.

A step by step schematic showing the organization of the program is shown in Figure 1.

## **HOW DATA WILL BE USED**

Lake information collected by the volunteers will be managed and statistically analyzed by the Metropolitan Council. The data will then be used in the preparation of a year end annual report which will be sent to the participating volunteers and WMO/WDs. In addition, the data collected by the volunteers will be included in the U.S. Environmental Protection Agency's STORET data bank. This will result in the broadening of area lakes data bases available to local decision makers.

**Figure 1. CAMP Organizational Schematic**



## VOLUNTEER MONITORING PROCEDURES

### 1. Confirm sampling date and weather conditions

- a. Check the sampling date as shown on the sampling schedule.
- b. Make sure that current and forecasted weather conditions allow for safe sampling.

### 2. Boating safety equipment checklist - Before leaving the shore, make sure that the boat contains the proper safety equipment including:

- ☐ A Coast Guard-approved personal flotation device
- ☐ A fire extinguisher (depending on length of boat)
- ☐ A first-aid kit
- ☐ Oars (in case of motor failure or no gas)

### 3. Sampling equipment checklist - Verify that all the required monitoring equipment is aboard the boat. This list includes:

- ☐ Boat anchor
- ☐ Chlorophyll hand pump, flask, and filters
- ☐ Clipboard and pencils
- ☐ Cooler with ice packs (if you expect to stay out on the lake longer than a half-hour)
- ☐ Depth finder (if possible or needed)
- ☐ Thermometer
- ☐ Map of lake with sampling site(s)
- ☐ Sampling form
- ☐ Sampling jug
- ☐ Sampling handbook (to help remember procedures)
- ☐ Labeled sample vials
- ☐ Secchi disk
- ☐ Aluminum foil
- ☐ Tweezers (forceps)

### 4. Label sample vials – During each monitoring event, three sample vials/containers will be kept. Before samples are decanted or placed into their respective vial/container, the vials/containers need to be labeled (*this should be done onshore before or after the collection of the lake water*) in order to document:

- a. The lake where the sample was taken;
- b. The date of sampling; and,
- c. The parameter for which the sample will be tested (**TP** = total phosphorus, **TKN** = total Kjeldahl nitrogen, **CLA** = chlorophyll - a [additionally, the volume of water filtered for CLA analysis should also be included on the CLA label]).

Examples of the three labels needed for an individual monitoring event are shown in Figure 2. Preprinted labels are provided for each lake. If the preprinted become lost, use the template below to create new labels.

**Figure 2. Templates for the three labels needed for each monitoring event.**

<b>Lake Name</b> <b>Date</b>  <b>TP/TKN</b>	<b>Lake Name</b> <b>Date</b>  <b>TP/TKN</b>				
<table border="1" style="width: 60%; margin: auto; border-collapse: collapse;"> <tr> <td style="width: 50%; padding: 5px;"><b>Lake Name</b></td> <td style="width: 50%; padding: 5px;"><b>Date</b></td> </tr> <tr> <td style="padding: 5px;"><b>CLA</b></td> <td style="padding: 5px;">_____ <b>ml</b></td> </tr> </table>		<b>Lake Name</b>	<b>Date</b>	<b>CLA</b>	_____ <b>ml</b>
<b>Lake Name</b>	<b>Date</b>				
<b>CLA</b>	_____ <b>ml</b>				

5. **Locate lake sampling location and anchor boat** - Use the lake map provided with the volunteer materials and/or a depth finder to locate the sampling site. Anchor the boat. *(If there is not a depth finder available to locate the proper sampling location (deepest spot), the anchor rope can be used to estimate the approximate depth.)*
  
6. **Fill out the observation portion of the sampling form** - Observe lake and meteorological conditions and fill out form. An example of the sampling form is shown in Figure 3.
  
7. **Measure the Secchi transparency depth** (see Figure 4)
  - a. Make sure the disk is securely attached to the measured line.
  - b. Lower disk into the water on the shaded side of the boat.
  - c. Lower disk until it disappears, then lower a little further and slowly raise until the disk just reappears. *The point where it reappears is the Secchi transparency depth.*
  - d. Determine and record the depth using the measured line attached to the disk.
  
8. **Collecting a surface water sample** (see Figure 5) – A surface water sample is collected in a clean one-gallon plastic milk jug. (The methods outlined below were validated during a pilot study in 1991 and the findings from the study are presented in Appendix A.)
  - a. Pre-rinse the jug three (3) times with lake water.
  - b. Fill by submersing it upside down to forearm depth.
  - c. Turn jug upright while still submersed.
  - d. After collecting the water sample, prepare and test for the following parameters:

**Figure 3. Example of Sampling Form**

Lake Name and ID #: \_\_\_\_\_

Site #: \_\_\_\_\_

Sampling Date: \_\_\_\_\_

Time: \_\_\_\_\_

Name(s) of Volunteer(s):

Sample #s

\_\_\_\_\_

TP/TKN: \_\_\_\_\_

TP/TKN: \_\_\_\_\_

\_\_\_\_\_

CLA: \_\_\_\_\_

SECCHI DISK DEPTH: \_\_\_\_\_ meters

SURFACE TEMPERATURE: \_\_\_\_\_ °C

VOLUME OF FILTERED LAKE WATER (CLA) \_\_\_\_\_ ml

**GENERAL OBSERVATIONS**

(Circle)

\* Water Color

Clear    Yellow  
Green    Gray  
Brown    Blue-Green  
Comment:

\* Odor of Water

None    Rotten Egg-like    Calm  
Fishy    Septic-like  
Musty    \_\_\_\_\_  
Comment:

\* Wind Conditions

Strong  
Breezy  
Direction:

\* Water Surface

Calm    Moderate Waves  
Ripple    Whitecaps  
Small Waves  
Comment:

\* Cloud Cover

0%    75%  
25%    100%

\* Lake Level

Above Normal  
Normal  
Below Normal  
Staff Gage Reading \_\_\_\_\_

\* Amount of Aquatic Plants

None    Moderate  
Minimal    Substantial  
Slight

\* Air Temperature (F)

< 40    81-90  
41-60    > 90  
61-80

\* Unusual Conditions in the past week (storms, high winds, temp. extremes):

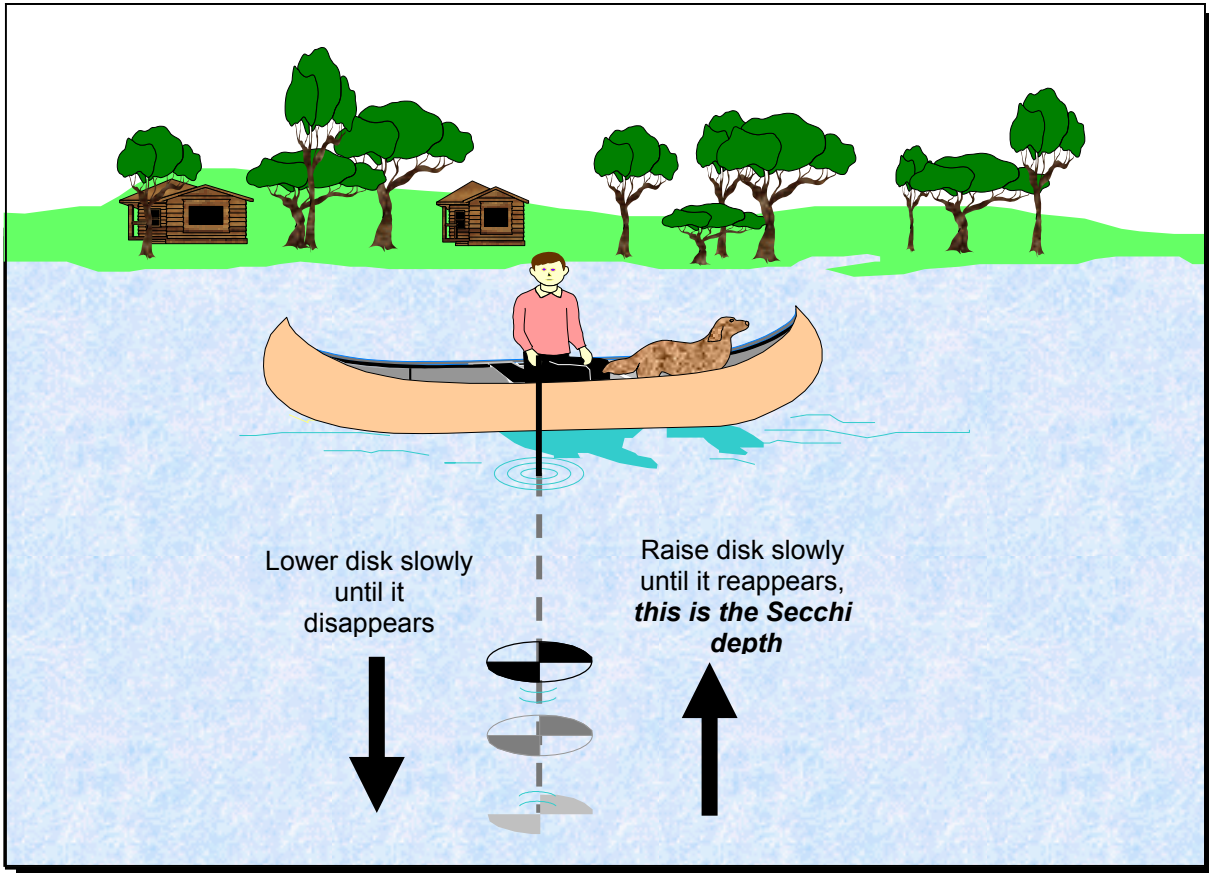
\* Physical Condition

Crystal Clear(1)  
Some Algae Present(2)  
Definite Algae Present(3)  
High Algal Color(4)  
Severe Bloom (Odor, Scum)(5)

\* Suitability For Recreation

Beautiful(1)  
Minor Aesthetic Problem(2)  
Swimming..Slightly Impaired(3)  
No Swim..Boating OK(4)  
No Aesthetics Possible(5)

Figure 4. Reading a Secchi Disk

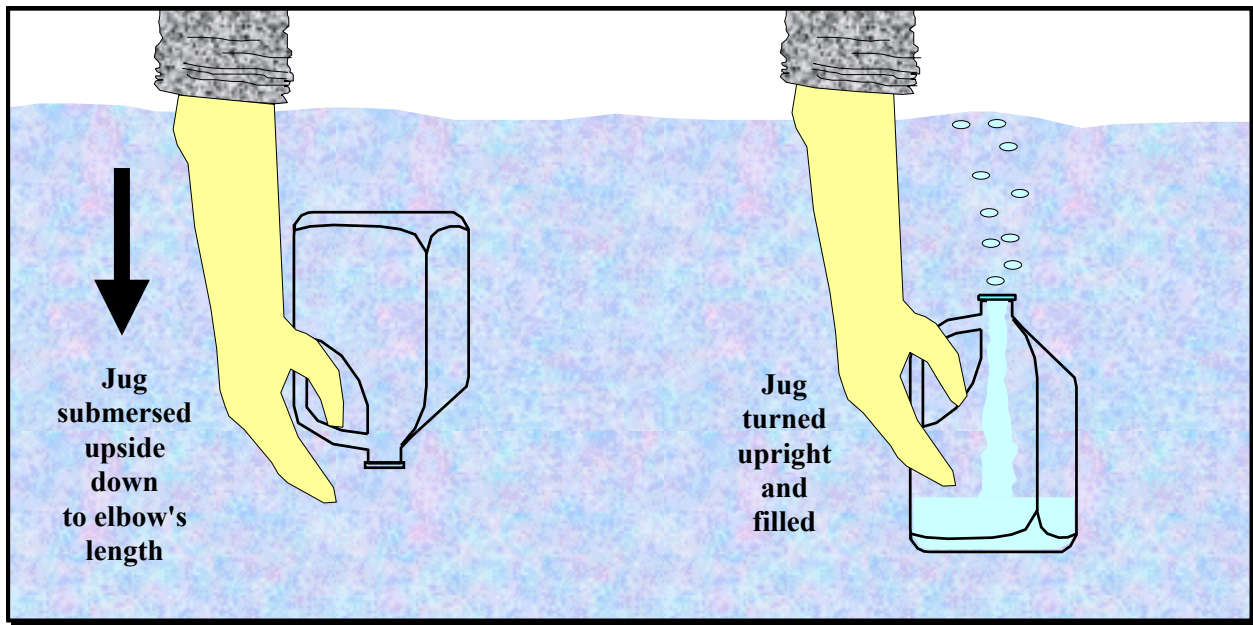


☉ **Temperature.** Surface water temperature will be measured from the volunteer's sampling jug using a dial or LCD thermometer. The temperature will be measured immediately following collection of the sample. Special care should be taken to keep the sample out of direct sunlight in order to minimize temperature change. *Every so often it may be necessary to check the accuracy of the thermometer. This can be done by comparing the temperature of some water with a more accurate kitchen thermometer. If a difference exists, the dial thermometer can be calibrated by loosening or tightening the nut underneath the dial. The LCD thermometer can not be calibrated, but it will be replaced if a discrepancy exists.*

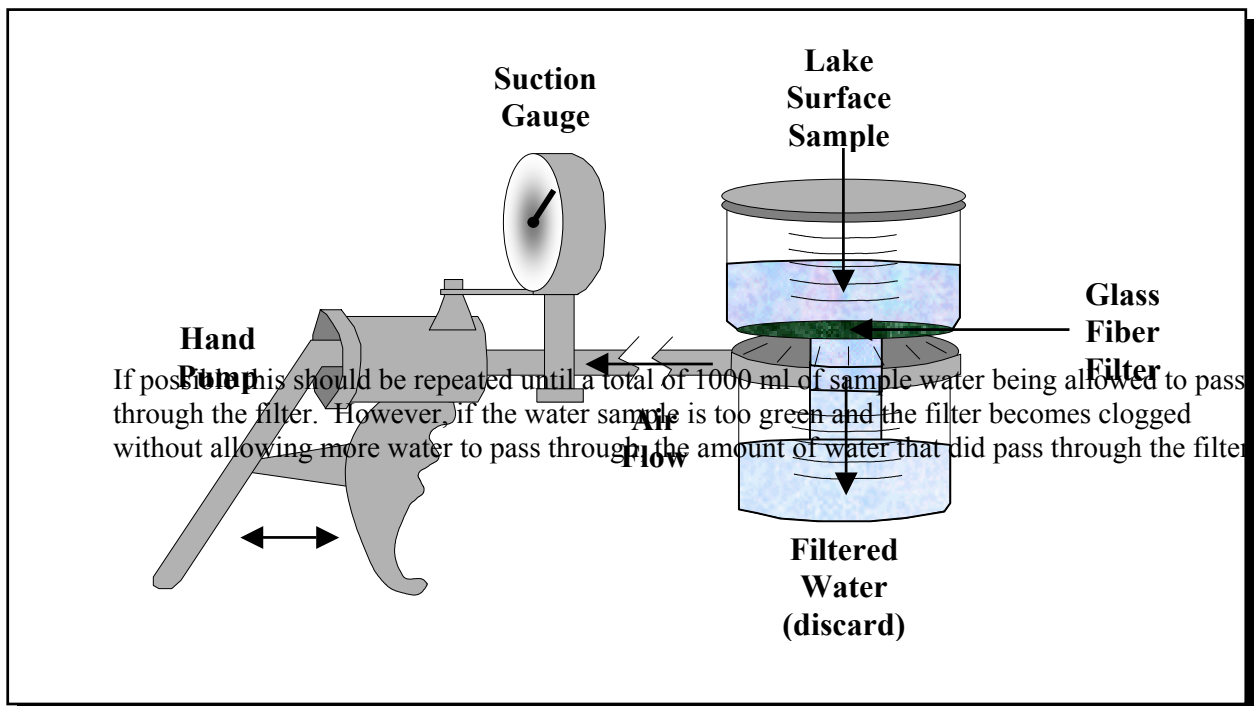
☉ **Total Phosphorus (TP) and Total Kjeldahl Nitrogen (TKN).** Two samples, one each for TP and TKN, will be decanted from the volunteer's jug in the field into their respective triple pre-rinsed, pre-labeled 50 milliliter (ml) vials. These samples can then be placed in the cooler, and taken home to be frozen for pick-up and delivery to the lab for analysis within 90 days of sample collection.

**Chlorophyll-a (CLA).** CLA samples from the volunteer's jug can either be filtered in the field or once back on shore (*out of direct sunlight*) onto a 0.45 micrometer ( $\mu\text{m}$ ) glass-fiber filter using a field filtration apparatus and a hand pump (Figure 6). Sample water is measured with a 250 ml graduated cylinder and poured into the pump reservoir. By squeezing the handle of the pump, a vacuum is created pulling the sample water through the filter leaving the associated suspended planktonic algae attached to the filter. The filtered water can then be dumped back into the lake.

**Figure 5. Taking a Surface Sample**



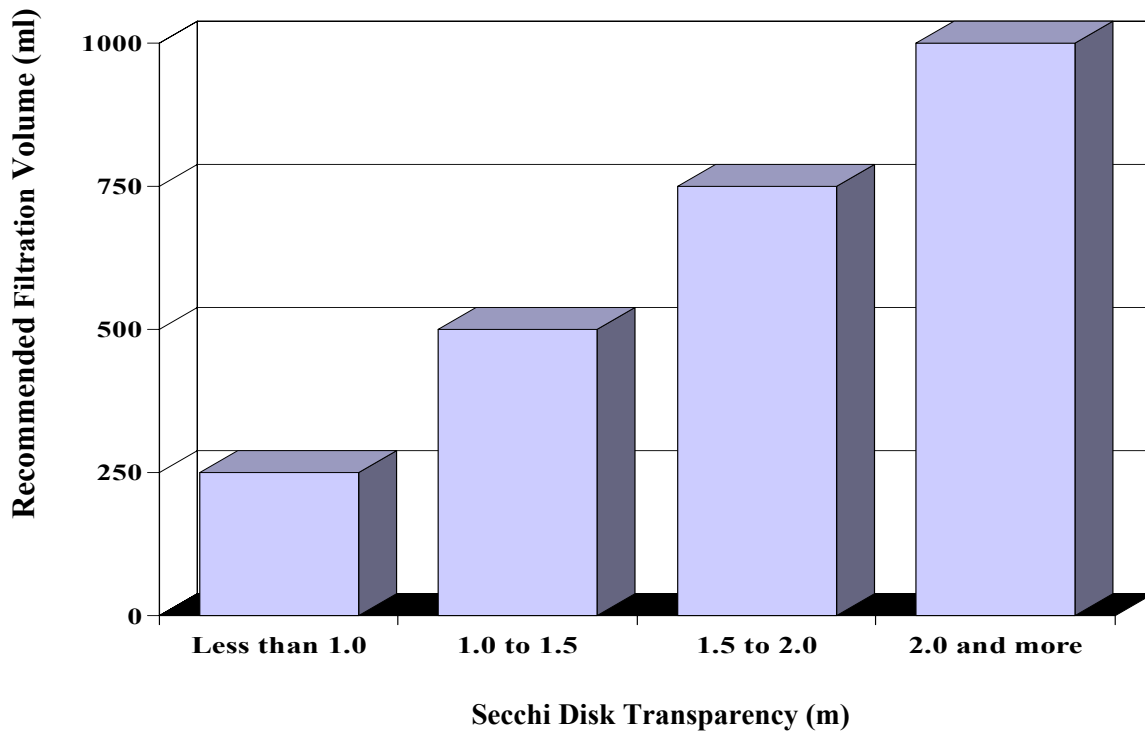
**Figure 6. Chlorophyll Filtration Apparatus**



should be calculated. The amount of water eventually filtered will relate to the lake's Secchi Transparency. The worse the transparency, the less the volume of sample water that will be. If possible this should be repeated until a total of 1,000 ml of sample water being allowed to pass through the filter. However, if the water sample is too green and the filter becomes clogged without allowing more water to pass through, the amount of water that did pass through the filter should be calculated. The amount of water eventually filtered will relate to the lake's Secchi transparency. The worse the transparency, the less the volume of sample water that will be able to be pumped through the filter.

Figure 7 graphs the recommended filtration volumes against various Secchi transparencies. The final quantity of sample water passing through the filter should be recorded on the label and the sampling form. The filters are then to be taken off the filter holder with a pair of tweezers, put in the sample container, and wrapped in aluminum foil. The sample container can then be marked with the same code and number as on the TP and TN sample vials, and frozen until pick-up and delivery to the lab (no more than 90 days after sample collection).

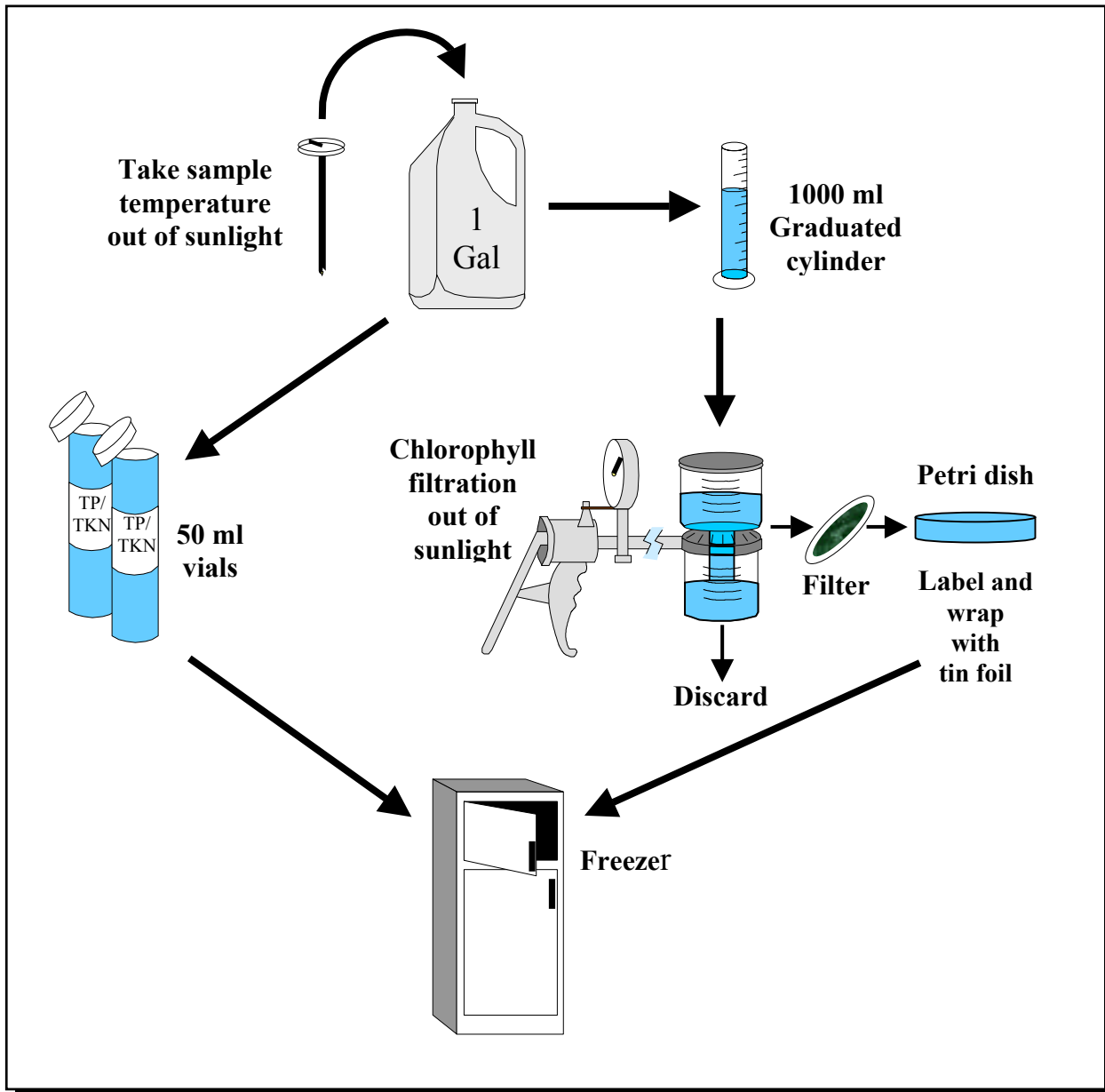
**Figure 7. Suggested Filtration Volumes for Given Secchi Transparencies**



A schematic diagram of the distribution of sample water from the sampling jug is presented in Figure 8.

9. **Cleaning up and taking care of equipment** - After all sampling procedures are completed, the sampling equipment should be rinsed with tap water, air dried, and properly stored to protect them until the next sampling date.

**Figure 8. Sample Preparation**



## PART II – A PRIMER ON LAKES

### HOW LAKES ARE FORMED

The surface of the Metropolitan Area as we know it today is the result of several glacial events that occurred from two million to 10,000 years ago. Surface features were created by the movement of large sheets of ice and by deposits of drift left behind as the glaciers retreated. Several predominant geological features created by glaciation, along with the general surface left behind, dictate how water flows through the region.

As glaciers stagnated and retreated, massive ice blocks were left behind. Most lake basins in the region are the result of these blocks of remnant ice melting into depressions formed by the weight of the ice.

If Minnesota is known as "the land of 10,000 lakes," then the Metropolitan Area could easily be referred to as "the region of 1,000 lakes." With 942 lakes larger than 10 acres in surface area located within the region, lakes are obviously one of the greatest water resources in the region. These lakes cover approximately 200 square miles, or 6.7 percent of the region.

Metro Area lakes range from 10 acres to 14,310 acres in surface area while their maximum depth range from 5 to 137 feet. About 90 percent of the lakes are less than 200 acres in size, but together they make up half of the total lake surface area. The largest lake in the region is Lake Minnetonka (14,310 acres) and the deepest is Lake Elmo (137 feet).

### PHYSICAL LOOK AT LAKES

In latitudes similar to those in Minnesota, lakes tend to become stratified into layers during summer months. Under bright summer sunshine, surface waters warm and become lighter, or of lower density, than the colder water below. The result is a stable layer of light, warm water overlying one of dense, cold water, with little mixing occurring between the two.

The upper layer of a stratified lake is called the **epilimnion**, the lower layer the **hypolimnion**, and the narrow transition zone between the two, which helps to prevent their mixing, is referred to as the **thermocline**. The epilimnion is roughly equivalent to the zone of light penetration, where the bulk of productivity, or growth (i.e. algal growth) occurs, while the hypolimnion is the zone of decomposition where plant material either decays or sinks to the bottom and accumulates.

Lakes do not remain stratified permanently, however. In most area lakes, the surface and bottom waters are recirculated twice a year. These periods of lake recirculation normally occur during the spring and fall months. In autumn the surface water cools. Eventually the temperatures, and therefore the densities of the two layers become equal. Assisted by the force of the wind upon the lake surface, water circulates, mixing the lake creating a constant temperature throughout. This process is called **fall turnover**.

During the winter months when our lakes are covered with ice, water temperatures vary from 0° C (32° F) just below the ice to 4° C (39° F) near the bottom. This is referred to as **inverse stratification**. Then

with the arrival of spring, the ice melts and surface waters warm. Because water becomes more dense as the lake's water temperature rises toward 4° C (39° F), the warmer but denser surface water sinks. Under these conditions, the entire lake is mixed vertically, assisted by the wind. This mixing is called the **spring turnover**.

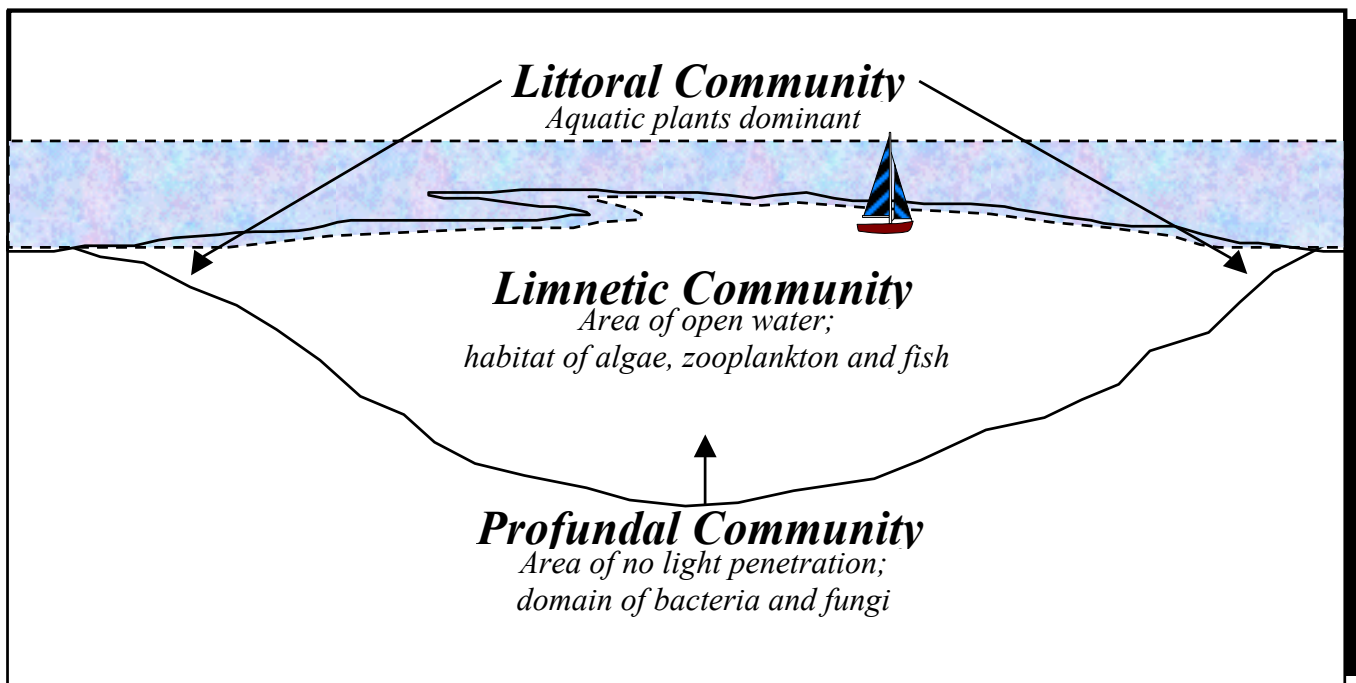
The lake turnovers are essential to the replenishing of the dissolved oxygen supply of bottom waters. Thus, turnovers help insure survival of fish that require cold water and high concentrations of dissolved oxygen. Furthermore, re-circulation brings nutrients (primarily nitrogen and phosphorus) from the bottom waters to the surface waters, thereby increasing algal productivity.

## BIOLOGICAL LOOK AT LAKES

The majority of lakes can be divided into three zones or communities: the shoreline or **littoral zone**, the open water or **limnetic zone**, and the deep-water or **profundal zone** (see Figure 9).

The littoral zone extends from the shoreline and includes the area of rooted and unrooted plants, or **aquatic macrophytes**, such as water lilies, duckweed and other emergent and submergent vegetation. This aquatic macrophyte community found in the lake's littoral zone serves an important role throughout the overall aquatic community. These macrophytes produce oxygen, and provide a diverse habitat for many different animals including insects, fish, and crustaceans.

Figure 9. Lake Communities



relatives of shrimp and lobsters which, under the microscope, look quite similar to their larger marine cousins (NYDEC, 1990).

Phytoplankton, which make up the plant component of the plankton community, are very important to the inner workings of a lake. Not only do they serve as the base of a lake's food chain, but they also convert sunlight, water, and carbon dioxide into chemical energy in the form of simple sugars and oxygen. This process is called **photosynthesis** and utilizes a pigment produced in plants (**chlorophyll**) to synthesize simple sugars from sunlight with oxygen as a by-product. Therefore, oxygen production by way of photosynthesis is limited to water depths penetrated by sunlight. This sunlight penetration depth can be measured with the use of a **Secchi disk** (an all white, or white and black disk 20 cm in diameter). The disk is lowered over the shaded side of the boat, and the depth at which the disk disappears from view is called the Secchi transparency.

Beneath the limnetic zone is a darker profundal zone where **respiration** (oxygen consumption rather than production), and decomposition (the breakdown of organic compounds such as dead plants and animals) predominate. Ideally, a compensation depth marks the place between the limnetic and profundal zones where photosynthetic processes are matched by respiratory events. In stratified lakes much of the profundal zone lies within the hypolimnion, but the two are not necessarily synonymous.

## CHEMICAL LOOK AT LAKES

The idea of lake quality is tied to a concept of aging (NALMS, 1989). The natural process of lake aging is a progression from a young (**oligotrophic**) lake with few nutrients through a middle stage (**mesotrophic**) to advanced age (**eutrophic**). As the basin fills with sediment, nutrient levels increase, and aquatic vegetation (especially algae) become more abundant (Gersmehl, Drake, and Brown, 1986). This is known as eutrophication, the process of nutrient enrichment whereby lakes become more productive.

Naturally, this process may take thousands of years. However, human activities both within the lake and in the area of land around the lake which contributes runoff to the lake (**watershed**) can greatly accelerate this aging process (see Figure 10). This accelerated aging is termed **cultural eutrophication**. Human activities, or cultural eutrophication that result in accelerated soil erosion and dumping of wastes rich in plant nutrients including wastewater and stormwater discharges, and construction site and agricultural runoff, speed up the filling-in process. These examples of pollution sources can be divided into two categories, point sources and nonpoint sources.

Point sources of pollution are the easiest to identify because they enter lakes through direct, piped and channeled discharges. Examples of point sources include wastewater and stormwater outlet discharges. Not only are point sources of pollution the easiest to identify, but they are also the easiest to control through treatment projects, and have been the focus of much of the water pollution control work to date.

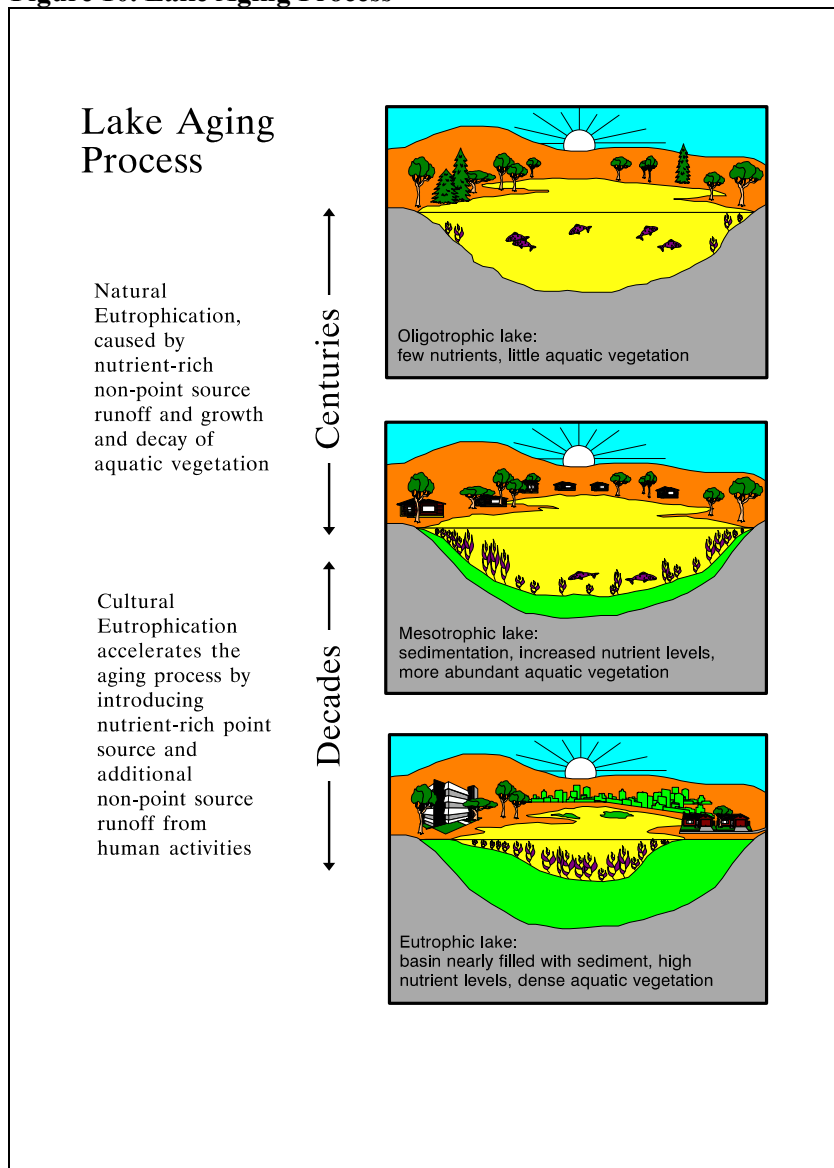
Nonpoint sources of pollution, on the other hand, are much more difficult to distinguish. Nonpoint sources are not discharged from a direct pipe or channel, rather they are washed off the land. Examples of nonpoint sources include agricultural and construction site runoff. The most typical way to control nonpoint pollution sources is through wise land use practices.

Trophic conditions in lakes are relative, not absolute. That is, there is no definitive line between oligotrophic and mesotrophic, or between mesotrophic and eutrophic. However, each trophic state has characteristic conditions.

Oligotrophic lakes have a low level of organic productivity, clear water and low nutrient levels. Deep water and steep basin walls often characterize these lakes. Water in mesotrophic lakes contains a moderate supply of nutrients and organic production. Eutrophic lakes are characterized by a very high level of nutrients which causes a significant increase in the rate of plant growth. As a result, water clarity is greatly reduced, and oxygen depletion is common during the summer months. Eutrophic lakes tend to be shallow and, typically, have elevated water temperatures (NYDEC, 1990).

Identification of a lake's trophic status is a useful way to determine its general health, from one year to the next, and to compare its trophic status with other lakes (NYDEC, 1990). While it is difficult to determine

**Figure 10. Lake Aging Process**



specific trophic classification boundaries, there are classification systems which attempt to designate a lake's trophic status by various water quality parameter concentrations and readings. Table 1 expresses traditional trophic classifications with relation to Secchi disk, total phosphorus (TP), and chlorophyll-a (CLA) values.

**Table 1  
General Trophic Classification of Lakes**

Parameter	Oligotrophic	Mesotrophic	Eutrophic
Total phosphorus ( $\mu\text{g/l}$ )	$\leq 12$	13 - 25	$> 26$
Chlorophyll-a ( $\mu\text{g/l}$ )	$< 3$	3 - 7	$> 8$
Secchi transparency (m)	$> 4$	2 - 4	$< 2$

(Modified from Wetzel, 1983 and Mahoney, 1979)

Another method of determining and comparing the lake water quality of Metropolitan Area lakes is the use of a letter grade system developed by the Metropolitan Council (Osgood, 1989b). The idea is simply that lake water quality characteristics can be ranked by comparing measured values with other Metropolitan Area lakes.

The grading curve represents percentile ranges for three water quality indicators, the summertime averages values for TP, CLA, and Secchi disk. These percentiles use ranked data from 119 lakes in the Metropolitan Area sampled from 1980-1988. Table 2 reveals the report card grading system and corresponding parameter values.

**Table 2  
Lake Quality Report Card System**

Grade	Percentile	TP ( $\mu\text{g/l}$ )	CLA ( $\mu\text{g/l}$ )	Secchi Transparency(m)
A	$< 10$	$< 23$	$< 10$	$> 3.0$
B	10 - 30	23 - 32	10 - 20	2.2 - 3.0
C	30 - 70	32 - 68	20 - 48	1.2 - 2.2
D	70 - 90	68 - 152	48 - 77	0.7 - 1.2
F	$> 90$	$> 152$	$> 77$	$< 0.7$

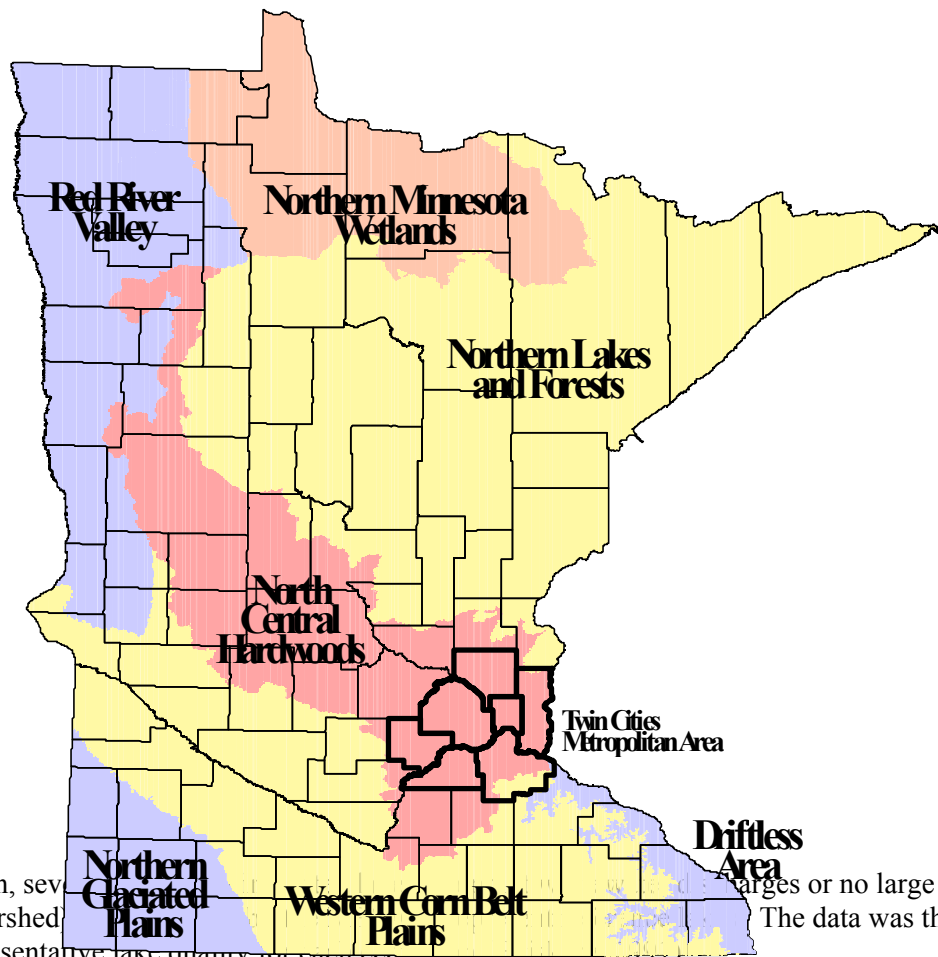
These water quality grades only characterize the open-water quality of lakes. Other nuisances, such as the abundance of aquatic macrophytes, are not indicated with these grades.

The grades also correspond to the recreational use-impairment of the lakes (Osgood, 1989c). A grade of A would correspond to no impairment, B to some impairment, C is impaired, D is severely impaired, and F indicates total impairment.

The lake quality grades are further validated when they are compared to the "inter-quartile" (25th to 75th percentile) parameter value ranges determined for the aquatic ecoregions associated with lakes in the Metropolitan Area.

The EPA mapped seven different aquatic ecoregions in Minnesota. These ecoregions represent areas with similar contributing characteristics to lake water quality. Land use, soil type, land surface form, and potential natural vegetation defined the seven ecoregions. Figure 11 shows the location of the different ecoregions throughout the state.

**Figure 11. Minnesota Ecoregions**



In each ecoregion, several representative watersheds were selected. The data was then used to illustrate representative lake quality for each ecoregion (Hornberger, 1992).

Two of the ecoregions are located in parts of the Metropolitan Area. The majority of the Metropolitan Area is within the North Central Hardwood Forest (NCHF) ecoregion, while small portions of the southern Metro Area are either within, or possibly influenced by, the Western Corn Belt Plains (WCBP) ecoregion. The inter-quartile range (25th to 75th percentile) values for TP, CLA, and Secchi transparency of the representative lakes in both ecoregions are shown in Table 3.

**Table 3**  
**Summer Average Water Quality Values of Ecoregion Lakes**

Ecoregion	Percentile	TP (µg/l)	CLA (µg/l)	Secchi Transparency(m)
NCHF	25 - 75	23 - 50	5 - 22	1.5 - 3.2
WCBP	25 - 75	65 - 150	30 - 80	0.5 - 1.0

(Heiskary, 1991)

By comparing Table 2, the percentile and lake grading system determined from the monitoring of 119 Metropolitan Area lakes, and Table 3, the "inter-quartile" ranges of the two ecoregions located in the area, it is apparent that both are supportive of one another. The NCHF ecoregion corresponds well with the top 50 percent (A - C grades) of the Metropolitan Area lakes, while the WCBP ecoregion corresponds with the lower 50 percent (C(-) - F).

There are a couple of reasons for the contrast in lake water quality between the two previously mentioned ecoregions. While the lakes in both ecoregions are generally shallow, the lakes in the WCBP ecoregion are surrounded by a higher percentage of agricultural land use and naturally fertile soils. These factors result in the majority of lakes in the WCBP ecoregion having poorer water quality (higher TP and CLA values, and lower Secchi transparency) than the majority of lakes in the NCHF ecoregion. Along with other human activities, they are primary influences causing the continual degradation in the majority of lakes in all the aquatic ecoregions.

**Eutrophication** (the degradation of lake quality), however, should not be viewed as a completely negative and irreversible process. Proper management of a lake and watershed has been demonstrated to slow and even reverse cultural eutrophication (NYDEC, 1990).

The previously mentioned grading and classification systems could possibly be used in future management processes to evaluate and make sound decisions on various management alternatives. For example, future development of a lake's watershed would not be permitted to downgrade the lake a letter grade. In other words, if a lake is currently graded B, the development of its watershed would not be allowed to add to the lake's nutrient load at a degree that would downgrade the lake to a letter grade of C.

## GLOSSARY

**Aquatic Macrophyte** - macroscopic (larger) forms of aquatic vegetation; encompasses macroalgae, liverworts, mosses, horsetail and ferns, and flowering plants.

**Chlorophyll** - the primary photosynthetic pigment in plant; a measure of the concentration of algae in lakes.

**Cultural Eutrophication** - accelerated aging, or rate of eutrophication, of a lake as a result of human activities.

**Decomposition** - the process in which organisms such as bacteria feed on the remains of plants and animals.

**Dissolved Oxygen** - the oxygen dissolved in water which is then available for respiration.

**Epilimnion** - the warm, relatively less dense top layer of water in a stratified lake.

**Eutrophication** - a natural process of nutrient enrichment whereby lakes gradually become more productive.

**Eutrophic Lake** - a lake with a high rate of nutrient cycling and thus a high level of biological productivity.

**Fall Turnover** - a mixing process that occurs in autumn in a stratified lake whereby the surface water layer mixes with the bottom water layer.

**Food Chain** - a sequence of organisms, such as green plants, herbivores, and carnivores, through which energy and materials move within an ecosystem (lake).

**Hypolimnion** - the cold, relatively dense bottom layer of water in a stratified lake.

**Inverse Stratification** - condition where warm water lies beneath colder water in a vertical temperature profile; winter stratification below ice cover.

**Invertebrate** - animals without backbones such as zooplankton.

**Limnetic Zone** - the area of open water in a lake where zooplankton and phytoplankton are found.

**Littoral Zone** - referring to the marginal region of a body of water; the shallow, near-shore region; often defined by the band from zero depth to the outer edge of the rooted plants.

**Mesotrophic Lake** - a lake with a moderate rate of nutrient cycling and biological productivity; between oligotrophic and eutrophic.

**Nonpoint Source** - pollution sources in the landscape that are not discharged from a single point, e.g. agricultural runoff.

**Oligotrophic Lake** - a lake with a low rate of nutrient cycling and a low level of biological productivity.

**Phosphorus** - a primary nutrient that is usually the limiting factor for vegetative growth in natural waters.

**Photosynthesis** - the process by which green plants transform light energy into food energy.

**Phytoplankton** - (algae) free-floating, mostly microscopic, aquatic vegetation; the base of the lakes food chain.

**Plankton** - floating organisms whose movements are more or less dependent on currents; e.g. phytoplankton and zooplankton.

**Point Source** - (pollution) specific sources of nutrient or polluted discharge to a lake or stream; discharges from a single discernible outlet; e.g. stormwater outlet.

**Pollution** - a change in the concentration of a material or form of energy, or the introduction of a material or a form of energy, that adversely affects the wellbeing of organisms.

**Profundal Zone** - the area in a lake below the limnetic zone where light does not penetrate; this area roughly corresponds to the hypolimnion layer of water and is home to organisms that break down and consume organic matter.

**Respiration** - the liberation of energy from food within an organism; using oxygen and releasing energy for growth.

**Secchi Disk** - a device used to make visual estimates of the clarity of water and the depth of light penetration in lakes.

**Spring Turnover** - a mixing process that occurs in the spring in a stratified lake whereby surface waters mix with bottom waters.

**Thermocline** - a density gradient owed to changing temperatures; the thermocline is the imaginary plane (below the epilimnion) at the depth where the rate of temperature change is the greatest in a vertical profile; during the summer months.

**Trophic Status** - the level of growth or productivity of a lake as measured by phosphorus content, algae abundance (chlorophyll content), and depth of light penetration.

**Watershed** - the geographical region that drains into a lake, river, or stream.

**Zooplankton** - weakly swimming, mostly microscopic aquatic animals found near the water surface.

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## **APPENDIX A**

### **Methods for Pilot Study**

A pilot study was designed to evaluate whether data collected using the pilot methods was comparable to data collected using the routine methods. Temperature, Secchi disk transparency, TP, TKN and CLA were evaluated in this study. Temperature and Secchi disk readings obtained by a limnologist and citizens were compared at every lake and TP, TKN, and CLA were compared from six lakes (Elmo, McCarrons, Hydes, Parley, Bryant and Riley) every fourth week for six sampling weeks. The temperature and the chemical data were measured from a surface sample collected in a clean one-gallon plastic milk jug. The jug was pre-rinsed with lake water, then filled by submersing it upside down to forearm-depth, then turned upright and allowed to fill.

#### **Secchi Disk**

Several Secchi disk readings were recorded during each sampling visit. The routine measurement was recorded using a black-and-white disk (see above) and reported in meters. The pilot disk, which was obtained through the Minnesota Pollution Control Agency's Citizen Lake Monitoring Program (CLMP), was all white and was metered in half-foot intervals. The second crew member made the pilot reading. One evaluation compares the routine Secchi disk and the pilot Secchi disk measurements. Additional evaluations include comparing the primary field persons readings with both disks and also comparing three field persons readings using the pilot disk.

#### **Temperature**

Surface water temperature was measured from the citizens jug using a dial thermometer that was readable to 0.5° C. The temperature was measured immediately following the collection of the sample. Care was taken to keep the sample out of direct sunlight in order to minimize temperature change. This temperature was compared to the 0-meter surface temperature from the routine sampling (see above).

#### **Total Phosphorus and Total Kjeldahl Nitrogen**

Four samples (two duplicate tests) for TP and TKN were decanted from the citizens jug in the field. The first set of duplicates were submitted to the lab on the same day as the routine duplicate surface samples. The second set of duplicate samples were frozen for about 60 days, then thawed overnight and submitted to the lab. All TP/TKN (routine and pilot) samples were treated identically following submission to the lab. The treatment regimes used for the comparisons in the pilot study are summarized as follows:

Treatment One: Duplicate samples from the routine sampling;

Treatment Two: Duplicate samples from the citizens jug; and

Treatment Three: Duplicate samples from the citizens jug following 60 days frozen storage.

#### **Chlorophyll a**

Nine CLA analyses, in addition to the routine analysis, were conducted for the pilot study. One analysis was a duplicate of the routine analysis. Another set of duplicates was filtered from the routine surface jug, but not treated with magnesium carbonate. These duplicates were submitted to the lab the same day. The remaining CLA analyses were taken from the citizens jug.

All CLA samples from the citizens jug were filtered in the field onto a 0.45  $\mu\text{m}$  glass-fiber-filter using a field filtration apparatus and a hand pump. The filtered samples were put into sample containers and treated as follows: one set of duplicates were submitted the same day, a second set of duplicates was wrapped in aluminum foil and frozen for 30 days before submission, and the last set of duplicates was wrapped in aluminum foil and frozen for 60 days before submission. None of the samples from the citizens' jug were treated with magnesium carbonate. The treatment regimes used for the comparisons in the pilot study are summarized as follows:

- Treatment One: Duplicate samples from routine sampling;
- Treatment Two: Duplicate samples from routine sampling without magnesium carbonate added;
- Treatment Three: Duplicate samples from the citizens jug without magnesium carbonate added and submitted the same day;
- Treatment Four: Duplicate samples from the citizens jug without magnesium carbonate added and submitted following 30 days being kept frozen and dark; and
- Treatment Five: Duplicate samples from the citizens jug without magnesium carbonate added and submitted following 60 days being kept frozen and dark.

## **Results of the Pilot Study**

The pilot study was designed to evaluate the validity of data collected using the citizen methods compared to data collected using the routine methods of water quality specialists. Temperature, Secchi disk transparency, TP, TKN, and CLA were collected by the mock citizen sampling program. These parameters are evaluated relative to their reliability in replicating the results from the routine sampling. Other more detailed analyses are possible but are not included here.

### **Temperature**

Surface temperatures were compared at every lake. The surface temperature from the field oxygen/temperature meter was compared to the temperature readings from the milk jug with the dial thermometer. The oxygen/temperature meter was readable to 0.1° C while the dial thermometer used by the citizen program was readable to 0.5° C. Comparisons for 188 paired readings were evaluated. One hundred seventy-eight of 188 (95%) were within 0.5° C. Because the dial thermometer was readable to 0.5° C, there is no measurable difference between the two methods.

### **Secchi Disk**

Secchi disk readings were compared at every lake. In all cases, lake sampling was completed by two people. The routine Secchi disk was generally measured by the same person throughout the study while the pilot Secchi measurement was assigned to the other crew member. Comparison of the routine Secchi disk to the pilot Secchi disk measurement showed that 85% of the time the two measurements were within  $\pm 0.2$  meters; 99% of the measurements were within  $\pm 0.5$  meters. Ninety percent of the measurements not within  $\pm 0.2$  feet, occurred in measurements that were greater than 4.5 meters deep.

Seasonal average Secchi disk transparencies for the six pilot lakes were not different. Comparisons of the averages showed that these values did not differ by  $>0.1$  meter, without rounding (Table A1).

**Table A1**  
**COMPARISON OF THE SEASONAL (MAY - SEPTEMBER)**  
**AVERAGE SECCHI DISK FOR SIX PILOT STUDY LAKES**

Lake	N=	TREATMENT	
		Secchi Disk - Routine (m)	Secchi Disk - Citizens (m)
Bryant	11	1.9	2.0
Elmo	11	4.1	4.1
Hydes	11	0.8	0.9
McCarrons	11	1.5	1.5
Parley	11	1.0	1.0
Riley	11	1.4	1.5

**Total Phosphorus and Total Kjeldahl Nitrogen**

The seasonal averages for the nutrient samples from the routine (Treatment One) versus the pilot (Treatments Two and Three) were not different (Table A2). A comparison of the average TP and TKN over similar intervals (n=6 for Treatment One versus Treatment Two; and n=5 for Treatment One versus Treatment Three) indicates no systematic bias. TP appeared to diminish after being frozen for 30 days (Treatment Two), but not after being frozen for 60 days (Treatment Three). Seasonal averages for TKN did not vary over either interval.

**Table A2**  
**COMPARISON OF THE SEASONAL (MAY - SEPTEMBER)**

**AVERAGE TOTAL PHOSPHORUS AND TOTAL KJELDAHL NITROGEN  
FOR THE SIX PILOT STUDY LAKES**

TREATMENT					
Lake	Parameter	N=	One	Two	Three
Bryant	TP	6	44	39	-
		5	47	36	36
	TKN	6	1.19	1.20	-
		5	1.18	1.17	1.16
Elmo	TP	6	13	11	-
		5	14	11	15
	TKN	6	0.47	0.42	-
		5	0.56	0.51	0.54
Hydes	TP	6	189	192	-
		5	180	190	178
	TKN	6	2.17	2.13	-
		5	2.18	2.09	2.23
McCarrons	TP	6	52	43	-
		5	55	48	57
	TKN	6	1.26	1.17	-
		5	1.33	1.26	1.31
Parley	TP	6	104	102	-
		5	95	94	96
	TKN	6	2.00	2.00	-
		5	1.92	1.93	1.82
Riley	TP	6	52	48	-
		5	51	48	49
	TKN	6	1.52	1.46	-
		5	1.54	1.48	1.45

**Chlorophyll-a**

There appears to be a great deal of variability between the replicate CLA samples. However, when used to compute summertime averages, these data are adequate. There is no systematic bias apparent in the seasonal averages in any CLA treatments (Table A3).

**Table A3  
COMPARISON OF THE SEASONAL (MAY - SEPTEMBER)  
AVERAGE CHLOROPHYLL-a**

**FOR THE SIX PILOT STUDY LAKES**

<b>Treatment</b>						
<b>Lake</b>	<b>N=</b>	<b>One</b>	<b>Two</b>	<b>Three</b>	<b>Four</b>	<b>Five</b>
Bryant	6	20	20	18	-	-
	4	16	14	14	13	-
	2	19	17	16	17	18
Elmo	6	4.6	5.1	4.5	-	-
	4	4.6	5.3	4.6	5.5	-
	2	6.0	7.2	6.6	8.5	6.8
Hydes	6	74	72	78	-	-
	4	72	67	80	74	-
	2	30	25	24	28	28
McCarrons	6	31	32	30	-	-
	4	36	37	34	34	-
	2	39	38	36	44	40
Parley	6	67	64	64	-	-
	4	65	58	63	53	-
	2	15	15	13	16	17
Riley	6	24	22	22	-	-
	4	24	20	22	19	-
	2	24	16	20	20	24

**Conclusions**

The pilot program has demonstrated that citizen sampling yields results comparable to our routine field methods. Due to analytical variability, we recommend that chemical samples be collected in duplicate (TP, TKN, and CLA). Frozen chemical samples (TP, TKN, and CLA) should be submitted to the lab within 30 days of sample collection, but no longer than 60 days following sample collection. We are recommending the previously described methodologies as standards for citizen lake monitoring programs.

A one-day seminar will be needed to train participating citizens on proper sampling methodologies and techniques for handling the samples. The seminar should also provide a hands-on, mock sampling experience. Quality control methods and procedures should also be stressed to produce data that is reliable and compatible to all sampling programs.

**PILOT STUDY DATA**

**Lake Identification Code**

ABNW  
BRYN  
DEMT  
EAGH  
ELMO  
GOLD  
HYDE  
JANE  
MCCR  
MEDC  
OLSN  
PARL  
RETZ  
RILE  
TWNL  
TWNM  
TWNW

**Lake Name**

Auburn  
Bryant  
Demontreville  
Eagle (Maple Grove)  
Elmo  
Golden  
Hydes  
Jane  
McCarrons  
Medicine  
Olson  
Parley  
Reitz  
Riley  
Twin - Lower  
Twin - Middle  
Twin - Upper

## ROUTINE AND PILOT TEMPERATURE READINGS (° C), 1991

WEEK OF:												
Lake Name	4/15	4/29	5/13	5/27	6/10	6/24	7/08	7/22	8/05	8/19	9/02	9/16
ABNW	6.6 -	8.7 9.0	15.7 16.0	25.8 26.0	26.2 26.0	25.1 25.5	25.6 26.0	25.7 25.5	22.1 22.5	23.2 -	22.2 22.0	13.8 13.5
BRYN	7.3 -	10.4 11.0	21.0 21.0	22.5 22.0	24.8 25.0	25.1 25.5	25.6 25.5	26.2 26.0	21.7 21.5	22.5 22.5	22.6 22.5	15.8 16.0
DEMT	6.5 -	12.0 12.0	18.9 19.0	21.5 22.0	23.5 24.0	23.5 23.5	25.1 -	28.1 28.0	23.6 24.0	22.5 22.0	23.7 24.0	20.9 21.0
EAGH	6.3 -	10.9 11.0	20.8 21.0	21.9 -	23.5 23.0	23.1 -	24.5 24.5	26.2 26.0	22.2 22.0	21.4 21.0	22.6 22.5	- -
ELMO	4.5 -	9.0 9.0	15.8 15.5	20.3 20.0	22.8 23.0	22.6 23.0	24.4 24.0	27.0 27.0	22.9 23.0	22.6 22.0	24.0 24.0	21.2 21.5
GOLD	6.2 -	10.4 11.0	22.6 22.5	22.5 22.5	24.7 24.5	23.1 23.0	24.1 25.0	25.8 25.5	21.6 21.5	22.0 22.0	22.2 22.0	14.6 14.5
HYDE	8.0 8.0	8.4 8.5	19.3 19.0	24.4 24.0	25.1 25.0	25.6 26.0	24.3 24.0	24.5 24.0	20.8 21.0	22.3 22.5	21.8 22.0	20.7 20.5
JANE	6.1 -	11.2 11.0	18.0 18.0	21.4 21.5	22.9 23.0	22.7 23.0	24.4 24.5	27.9 28.0	22.7 22.5	22.1 22.0	23.7 24.0	20.7 20.5
MCCR	5.4 -	10.7 11.0	20.1 20.0	22.3 22.5	23.7 24.0	23.5 23.5	25.0 25.5	28.4 28.0	23.7 24.0	22.9 22.5	23.9 24.0	20.7 20.5
MEDC	6.4 -	10.2 10.0	21.0 21.0	21.8 22.0	24.0 24.0	24.7 24.5	25.0 25.0	25.2 24.5	21.8 21.5	22.0 22.0	22.3 22.0	15.9 16.0
OLSN	6.4 -	12.2 12.0	19.0 19.0	21.8 22.0	23.1 24.0	23.6 24.0	24.9 25.0	28.1 28.0	23.5 23.5	22.8 22.5	24.1 24.0	20.9 21.0
PARL	8.6 9.0	8.5 9.0	15.7 15.5	24.8 24.5	25.7 26.0	26.2 27.0	24.7 24.5	25.2 25.0	21.6 22.0	22.6 22.5	22.3 22.0	13.4 13.5
RETZ	7.7 7.5	8.4 9.0	14.7 15.0	25.0 25.0	26.0 26.0	26.6 27.0	24.5 24.5	24.5 24.0	20.7 21.0	22.9 22.5	21.8 22.0	13.8 13.5
RILE	7.1 -	9.6 9.5	20.5 20.5	21.3 21.0	25.0 25.0	25.3 25.5	25.6 25.5	25.9 25.5	21.8 22.0	22.7 23.0	22.6 22.5	15.9 16.0
TWNL	6.0 -	10.8 11.0	21.4 21.5	22.6 23.0	24.1 24.0	23.4 23.5	24.6 24.5	26.5 26.0	21.9 22.0	22.1 21.5	22.5 22.5	16.0 16.0
TWNM	6.3 -	10.7 11.0	20.4 21.0	22.7 23.0	24.1 24.0	23.1 23.0	24.9 25.0	26.5 26.0	22.2 22.0	21.8 22.0	22.6 22.5	16.4 16.5
TWNU	6.1 -	9.9 10.0	21.9 22.0	22.5 22.0	24.3 24.5	23.2 23.0	24.6 25.0	26.3 26.0	21.7 21.5	21.6 21.5	22.1 22.0	13.6 13.0

\*Routine readings are listed first, citizen readings are listed second.

## ROUTINE AND PILOT SECCHI DISK READINGS (m), 1991

WEEK OF:												
Lake Name	4/15	4/29	5/13	5/29	6/10	6/24	7/08	7/22	8/05	8/19	9/02	9/16
ABNW	2.20 7.25	2.40 7.50	1.60 5.25	1.70 6.00	1.50 5.00	1.00 3.50	0.70 2.25	0.70 2.75	1.10 3.00	1.30 4.25	1.45 4.75	2.10 6.00
BRYN	0.90 3.00	1.40 5.00	1.20 5.50	2.60 8.50	3.50 10.0	2.20 7.00	2.00 7.00	2.50 7.75	1.60 5.50	1.60 6.00	1.40 5.00	1.10 4.00
DEMT	3.60 13.5	2.70 10.0	3.90 14.0	4.60 14.5	4.00 13.0	1.55 6.00	1.55 5.75	1.30 5.00	1.40 5.25	1.40 4.25	1.10 3.50	1.10 4.00
EAGH	2.40 7.00	1.90 6.50	3.70 11.5	3.40 10.5	1.50 5.50	1.00 3.50	0.70 2.25	0.90 3.00	0.90 3.00	1.00 3.00	0.95 3.00	- -
ELMO	3.40 -	2.60 10.0	4.80 13.5	3.90 13.0	4.10 13.0	4.20 12.5	3.90 13.5	3.90 13.5	5.25 16.0	4.60 16.0	4.00 15.0	4.00 12.0
GOLD	1.30 3.75	1.20 3.50	1.05 3.50	1.15 3.50	0.90 2.50	0.80 2.25	0.80 2.50	0.75 2.50	0.75 2.50	0.80 3.50	1.00 3.25	1.20 3.75
HYDE	1.20 4.00	1.10 3.25	1.00 3.75	1.00 3.50	1.90 7.50	0.65 2.00	0.60 2.00	0.50 1.75	0.50 1.50	0.60 2.25	0.55 1.75	0.45 1.50
JANE	2.70 10.5	3.20 -	4.50 13.0	4.70 16.0	4.90 18.0	2.05 8.00	1.40 4.50	1.30 5.00	1.30 4.50	1.00 4.00	1.00 4.00	1.25 4.50
MCCR	1.30 4.00	1.20 4.50	3.40 10.5	1.70 5.00	1.75 6.00	1.20 4.50	1.05 3.50	1.00 3.50	1.20 4.50	1.10 4.00	1.40 4.00	1.404. 50
MEDC	1.80 7.50	1.80 6.00	3.40 12.0	2.30 7.00	1.20 3.00	0.90 3.00	0.85 2.75	0.80 2.75	0.70 2.25	0.75 3.00	0.90 2.75	1.00 4.00
OLSN	4.10 14.0	2.90 10.5	3.60 12.5	3.45 11.5	3.60 13.0	2.60 9.50	2.00 7.25	2.20 7.50	1.90 6.50	1.70 6.00	1.20 4.50	1.25 4.00
PARL	1.20 3.75	1.50 5.00	1.55 5.50	3.00 9.00	0.75 2.00	0.85 3.50	0.70 2.10	0.50 1.50	0.50 1.75	0.60 2.00	0.50 1.50	0.65 2.00
RETZ	0.95 3.25	0.90 2.75	2.80 7.50	2.90 10.0	1.30 4.00	0.65 2.25	0.70 2.25	0.70 2.50	1.00 3.25	0.70 2.25	0.70 2.75	1.40 3.75
RILE	1.40 6.25	1.30 4.50	1.60 5.50	0.80 3.00	1.90 6.00	1.30 5.25	1.10 3.75	1.50 5.50	1.60 5.50	1.00 3.50	2.00 6.50	1.30 4.75
TWNL	0.80 2.50	0.90 2.75	1.10 4.00	1.00 3.25	0.60 2.00	0.50 2.00	0.70 2.25	0.60 2.00	0.60 2.25	0.75 2.75	0.70 2.50	0.80 2.50
TWNM	1.00 3.50	1.40 5.00	2.30 7.50	0.70 2.50	0.65 2.00	0.60 2.25	0.70 2.25	0.60 2.00	0.60 2.00	0.90 2.75	0.80 2.50	0.75 2.25
TWNU	0.80 2.50	0.70 2.50	1.00 3.25	0.65 2.00	0.50 1.70	0.40 1.25	0.45 1.75	0.40 1.00	0.55 2.00	0.60 2.00	0.40 1.25	0.55 1.75

\*Routine readings (m) are listed first, citizen readings (ft) are listed second.

**TOTAL PHOSPHORUS REPLICATES (µg/l), 1991**

Lake/Date		TREATMENT		
		*One:	**Two:	***Three:
BRYN	5/3	70/60	50/60	50/50
BRYN	5/31	40/50	40/40	30/30
BRYN	6/27	40/40	30/30	30/50
BRYN	7/24	30/30	30/40	30/30
BRYN	8/21	30/30	20/20	30/30
BRYN	9/20	60/50	60/50	--/--
ELMO	5/1	20/30	20/20	20/30
ELMO	5/29	20/10	10/10	10/10
ELMO	6/24	10/10	<10/10	10/20
ELMO	7/22	10/10	<10/<10	10/10
ELMO	8/19	10/10	10/10	20/10
ELMO	9/16	10/10	10/10	--/--
HYDE	5/7	100/100	110/110	130/110
HYDE	6/3	120/110	120/130	110/110
HYDE	6/28	300/290	310/350	250/250
HYDE	7/25	220/240	230/230	250/240
HYDE	8/22	160/160	150/160	160/170
HYDE	9/23	230/240	210/200	--/--
MCCR	5/1	80/80	70/80	90/90
MCCR	5/29	60/50	40/50	40/40
MCCR	6/24	50/60	50/50	60/60
MCCR	7/22	40/50	40/40	60/70
MCCR	8/19	40/40	30/30	30/30
MCCR	9/16	30/40	20/20	--/--
PARL	5/7	80/70	70/70	70/70

Lake/Date	TREATMENT		
	*One:	**Two:	***Three:
PARL 6/3	50/70	50/60	50/50
PARL 6/28	130/110	130/130	120/140
PARL 7/25	120/140	130/140	140/150
PARL 8/22	90/90	80/80	80/90
PARL 9/23	150/150	140/150	--/--
RILE 5/3	70/80	60/70	70/80
RILE 5/31	80/60	80/70	60/60
RILE 6/27	40/80	40/40	40/50
RILE 7/24	30/40	30/30	40/30
RILE 8/21	30/40	30/30	30/30
RILE 9/20	50/60	50/50	--/--

\* Treatment One - duplicate samples from routine samples

\*\* Treatment Two - duplicate samples from milk jug.

\*\*\* Treatment Three - duplicate samples from milk jug, freeze, submit in 60 days.

**TOTAL KJELDAHL NITROGEN REPLICATES (mg/l), 1991**

Lake/Date	TREATMENT		
	*One:	**Two:	***Three:
BRYN 5/3	1.15/1.39	1.30/1.30	1.25/1.20
BRYN 5/31	1.15/1.31	1.10/1.11	1.25/1.18
BRYN 6/27	1.14/1.07	1.15/1.24	1.15/1.12
BRYN 7/24	1.22/1.19	1.11/1.24	1.04/1.08
BRYN 8/21	1.10/1.10	1.08/1.06	1.18/1.19
BRYN 9/20	1.22/1.30	1.49/1.23	--/--
ELMO 5/1	0.65/0.72	0.60/0.52	0.47/0.66
ELMO 5/29	0.60/0.53	0.59/0.60	0.65/0.67
ELMO 6/24	0.62/0.56	0.54/0.55	0.55/0.48
ELMO 7/22	0.52/0.48	0.41/0.42	0.55/0.59
ELMO 8/19	0.61/0.33	0.30/0.54	0.90/0.96
ELMO 9/16	0.50/0.43	0.45/0.46	--/--
HYDE 5/7	2.08/2.08	2.00/2.10	2.12/1.99
HYDE 6/3	2.07/2.07	2.12/2.12	2.17/2.19
HYDE 6/28	2.69/5.75	2.13/2.85	3.01/2.66
HYDE 7/25	2.01/2.37	2.09/2.17	1.75/1.71
HYDE 8/22	1.81/1.91	1.64/1.63	2.26/2.43
HYDE 9/23	2.10/2.15	2.30/2.41	--/--
MCCR 5/1	1.62/1.62	1.30/1.40	1.43/1.40
MCCR 5/29	--/1.15	1.15/1.13	1.20/1.19
MCCR 6/24	1.17/1.28	1.22/1.25	1.21/1.12
MCCR 7/22	1.39/1.46	1.27/1.29	1.35/1.40
MCCR 8/19	1.14/1.31	1.28/1.26	1.34/1.41
MCCR 9/16	0.80/1.02	0.69/0.80	--/--
PARL 5/7	1.7/1.8	1.80/1.80	1.69/1.56
PARL 6/3	1.54/1.52	1.65/1.63	1.65/1.67

Lake/Date	TREATMENT		
	*One:	**Two:	***Three:
PARL 6/28	2.57/2.51	2.47/2.57	1.97/2.31
PARL 7/25	1.97/2.37	2.18/2.38	2.54/1.70
PARL 8/22	1.64/1.53	1.45/1.36	2.22/1.88
PARL 9/23	2.36/2.46	2.21/2.49	--/--
RILE 5/3	2.19/2.24	2.00/2.00	1.87/1.91
RILE 5/31	1.54/1.39	1.40/1.60	1.40/1.40
RILE 6/27	1.03/1.63	1.32/1.48	1.26/1.33
RILE 7/24	1.36/1.22	1.26/1.07	1.19/1.25
RILE 8/21	1.31/1.54	1.33/1.34	1.49/1.44
RILE 9/20	1.37/1.46	1.33/1.38	--/--

\* Treatment One - duplicate samples from the routine samples.

\*\* Treatment Two - duplicate samples from milk jug.

\*\*\* Treatment Three - duplicate samples from milk jug, freeze, submit in 60 days.

### CHLOROPHYLL REPLICATES (µg/l), 1991

Lake/Date	TREATMENT				
	*One:	**Two:	***Three:	****Four:	*****Five:
Bryn 5/3	28/17	19/19	22/15	19/22	25/23
Bryn 5/31	35/15	14/15	14/12	13/13	11/12
Bryn 6/27	13/13	13/12	13/12	11/11	--/--
Bryn 7/24	13/15	12/10	12/11	8.2/7.9	--/--
Bryn 8/21	16/15	17/18	13/15	--/--	--/--
Bryn 9/20	44/41	47/43	38/40	--/--	--/--
Elmo 5/1	8.6/7.6	9.6/8.8	9.6/6.3	11/11	8.4/9.3
Elmo 5/29	3.4/4.5	4.8/5.8	4.9/5.4	5.9/6	5.3/4.4
Elmo 6/24	3/3.6	2.8/3.6	3.1/2.8	3.2/1.7	--/--
Elmo 7/22	2.7/3.3	4.2/2.6	2.2/2.1	2.3/2	--/--
Elmo 8/19	2.8/3	3.2/3.1	2.4/3.1	--/--	--/--
Elmo 9/16	6.2/7	6.2/6.3	5.8/21	--/--	--/--
Hyde 5/7	43/36	30/32	--/28	28/30	31/32
Hyde 6/3	20/19	19/18	21/21	31/24	28/22
Hyde 6/28	146/134	139/139	192/180	228/134	--/--
Hyde 7/25	90/92	81/78	86/85	55/59	--/--
Hyde 8/22	39/43	43/44	48/42	--/--	--/--
Hyde 9/23	123/109	114/121	91/117	--/--	--/--
MCCR 5/1	66/40	54/49	52/40	64/64	59/58

Lake/Date	TREATMENT				
	*One:	**Two:	***Three:	****Four:	*****Five:
Bryn 5/3	28/17	19/19	22/15	19/22	25/23
MCCR 5/29	26/24	25/25	25/25	25/24	22/20
MCCR 6/24	25/26	28/29	28/28	19/19	--/--
MCCR 7/22	39/38	41/43	38/37	32/29	--/--
MCCR 8/19	24/25	23/27	25/23	--/--	--/--
MCCR 9/16	22/21	23/23	19/5.2	--/--	--/--
Parl 5/7	13/7.9	8.7/8.7	7.5/7.6	7.2/7.2	7.1/8.3
Parl 6/3	20/21	19/22	19/19	25/24	22/30
Parl 6/28	146/76	94/86	112/115	108/87	--/--
Parl 7/25	114/120	109/117	116/108	85/80	--/--
Parl 8/22	49/55	56/48	55/56	--/--	--/--
Parl 9/23	88/98	98/100	81/77	--/--	--/--
Rile 5/3	53/38	19/40	38/35	34/39	47/42
Rile 5/31	33/3.3	3.5/2.7	3.2/3.3	3.8/3.1	2.5/2.5
Rile 6/27	24/26	23/23	24/24	27/24	--/--
Rile 7/24	21/21	26/22	25/21	12/12	--/--
Rile 8/21	23/27	31/24	26/26	--/--	--/--
Rile 9/20	26/26	24/25	22/21	--/--	--/--

\* Treatment One - routine surface jug samples w/MGCO<sub>3</sub>. \*\*

\*\*\* Treatment Three - duplicates from milk jug w/o MGCO<sub>3</sub>, submit same day.

\*\*\*\*\* Treatment Five - duplicates from milk jug w/o MGCO<sub>3</sub>, freeze and submit in 60 days.

Treatment Two - duplicates from surface jug w/o MGCO<sub>3</sub>.

\*\*\*\* Treatment Four - duplicates from milk jug w/o MGCO<sub>3</sub>, freeze and submit in 30 days.

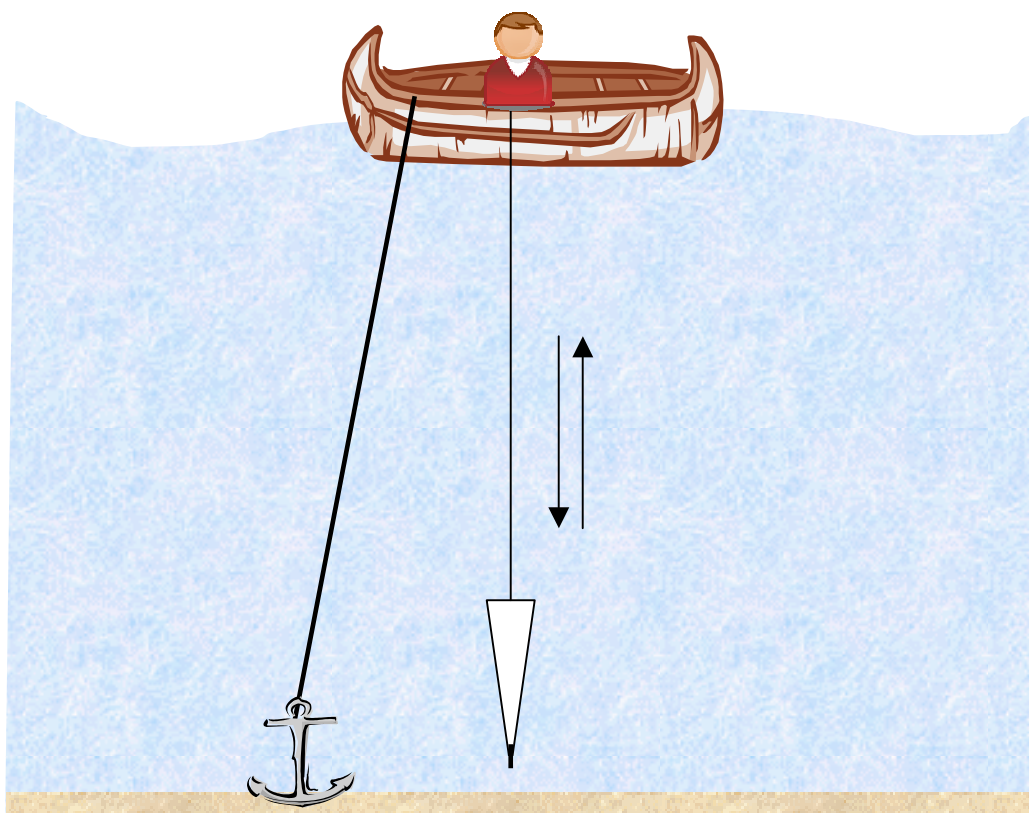
## 5.0 Procedure for Zooplankton Monitoring

### .1 Sampling Site Selection

Sampling sites will be determined using bathymetric maps of each lake. The deepest point within the lake will be selected as the sampling location. If more than one deep points exist, it may be necessary to perform sampling at both deep locations.

### .2 Sampling Equipment Preparation

Once you are at your selected sampling site, drop an anchor in order to keep yourself above the desired location. Record the date, time, organization, personnel, size of zooplankton net mesh, weather, and any other measurements deemed necessary. Take a measurement of depth using a depth finder or weighted measuring line. Record the depth on your sampling form. Although it is not necessary, a water quality sample and secchi transparency may be taken at the time of the zooplankton sample in order to correlate water quality chemical and physical parameters to what zooplankton were observed. Use a zooplankton net with a mesh size of 153  $\mu\text{m}$  and a ring size of 8 inches for sampling. Ensure that the clamp at the end of the plankton net is closed. Prepare a zooplankton sample bottle. Usually a 150 ml or 200 ml bottle is ideal. Label the bottle with the date, time, organization, and personnel.



### **.3 Zooplankton Sampling**

Begin by lowering the zooplankton net in such a fashion that no zooplankton are able to enter the net. The best way to perform this task is to lower the net slowly to a point just above the bottom such that the plankton entrance orifice is never advancing to the bottom previous to the exit orifice (See picture below).

Once the plankton net has been lowered to just above bottom, retrieve the zooplankton net by pulling it vertically at a rate of 1 meter/second. Once retrieved, use a bottle with a spray nozzle on it to wash all zooplankton collected to the bottom near the exit orifice. Take a sample bottle (150 or 200 ml bottle) and place the exit orifice tube into the bottle. Open the clamp to allow the zooplankton to flush into the bottle. Ensure that all zooplankton have been emptied into the bottle by using your wash bottle to spray more water near the exit orifice and visually inspecting the net. Once all zooplankton have been collected, the bottle may contain a bit of lake water. In order to remove this water and not remove any zooplankton, press the zooplankton net against the bottle orifice and tip the bottle to allow the water to drain. Once the bottle is empty, remove the net from the orifice, and fill the bottle with a 70% alcohol solution to preserve the sample. Record the meters that the net was towed on the sample bottle. Keep the sample in a dark location until the sample is analyzed.

### **.4 Zooplankton Sample Analysis Preparation and Shipping**

In order to have the zooplankton further analyzed (size, species, etc.), the sample(s) must be properly packed and a chain-of-custody must be established. First, ensure that all labels have the necessary information recorded (date, time, organization, personnel, and depth the net was towed. Record this information on a chain of custody form (see below) as well as any other pertinent information necessary to completely fill out the form. Once the chain of custody form has been completed; pack the samples in a watertight container (usually a water-tight plastic bag inside a box will suffice) with proper packing material and seal box with signed chain of custody form inside. Send the box via standard freight carrier and await a copy of the chain of custody form from the contractor performing the analysis. Refer to WCD S.O.P. Data Management for information on data management procedures related to data from outside contractors.



## 6.0 Macrophyte Survey

Macrophyte surveys will be performed utilizing an existing S.O.P. that has well-established precedence. The S.O.P. for Point Intercept Method for Aquatic Plant Management (Madsen, 1999) is a well-noted and highly utilized method for macrophyte surveys in this region. The webpage containing this S.O.P can be found at <http://el.erd.c.usace.army.mil/elpubs/pdf/apcmi-02.pdf>. All data recording procedures are also found in the S.O.P and refer to WCD S.O.P. Data Management for information on data management procedures related to storage of this data.

## References

Madsen, J. D. (1999). "Point intercept and line Intercept methods for aquatic plant management." APCRP Technical Notes Collection (TN APCRP-M1-02). U.S. Army Engineer Research and Development Center, Vicksburg, MS. [www.wes.army.mil/el/aqua](http://www.wes.army.mil/el/aqua).