Handbook for the Citizen-Assisted Lake Monitoring Program

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Metropolitan Council

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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

This edition of the Handbook for the Citizen-Assisted Lake Monitoring Program is a revision of the Metropolitan Council's 2003 handbook authored by Randall J. Anhorn.

Special appreciation is given 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 monitoring forms. A Metropolitan Council representative will pick up the samples.

Analytical Laboratory

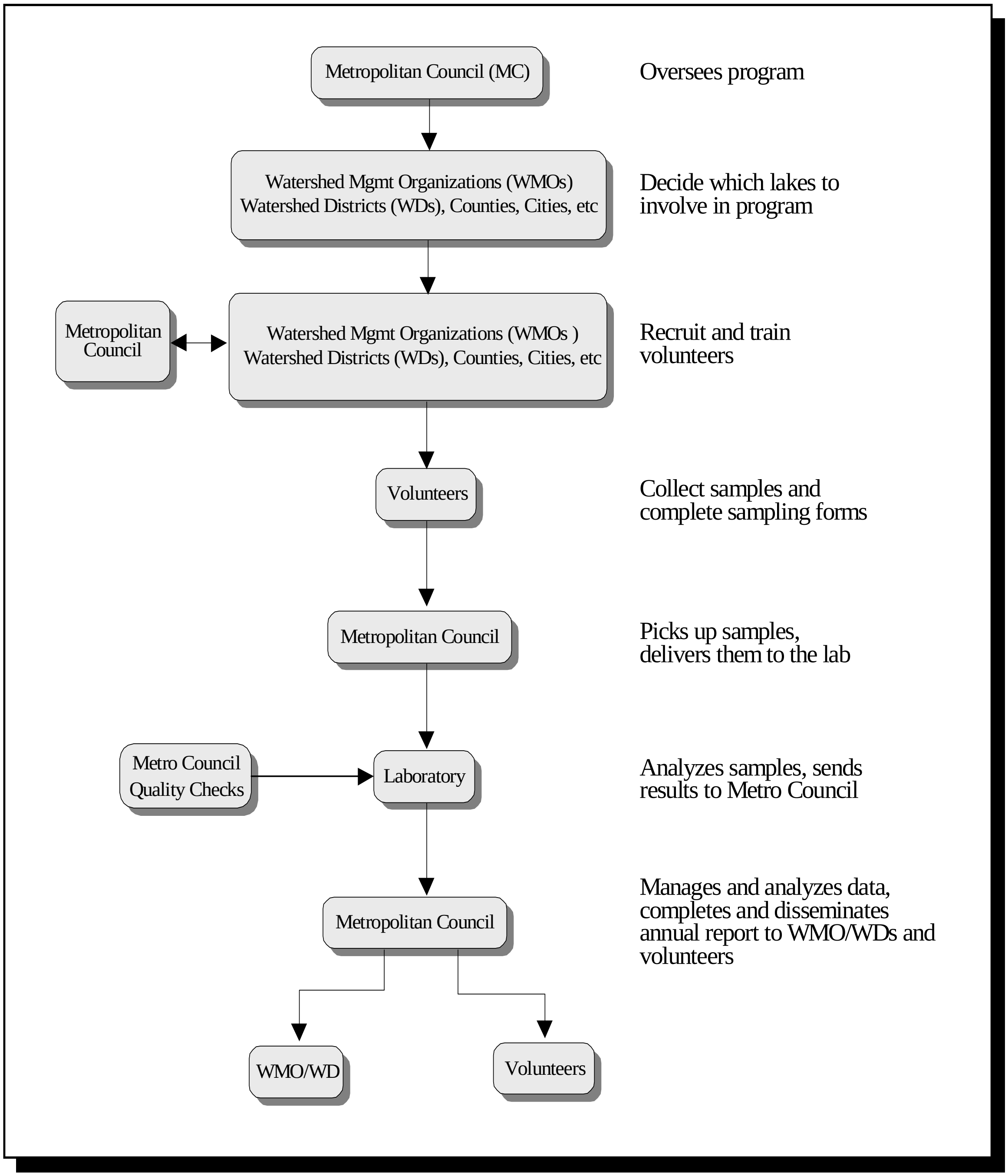
The analytical lab is responsible for the lake samples once they have been received from the Metropolitan Council representative. The lab, which has its own QA/QC program, will conduct the specified analyses (TP, TKN, and CLA) on the samples. Results from the analyses will then be sent to the Metropolitan 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)
∫ Monitoring 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.

Lake Name	**Date**
TP/TKN	

Lake Name	**Date**
TP/TKN	

Lake Name	**Date**
CLA	**______ ml**

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 monitoring form -** Observe lake and meteorological conditions and fill out form. An example of the monitoring 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 in 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, and let the jug completely fill.
d. Bring the jug into the boat.

Figure 3. CAMP Monitoring Form
(ver. 2012)
Metropolitan Council Environmental Services

Lake Name: ______________________ Site #: ________
DNR ID#: _______________

Sampling Date: _________________ Time: ___________ (military time)
(Use the same time on the sample labels.)

Name(s) of Volunteer(s):

____

____

Quantity of samples collected: Nutrient: _____ CLA: _____

SECCHI DISK DEPTH: ____________meters

Check the box if the disk is visible on the lake bottom: ☐

Check the circle if the visibility of the disk is blocked by vegetation: ○

SURFACE TEMPERATURE: __________°C

VOLUME OF FILTERED LAKE WATER (CLA): _______________ml

GENERAL OBSERVATIONS
(Circle the one best choice)

*** Water Color**

Clear Yellow
Green Gray
Brown Blue-Green
Comment:

*** Odor of Water**

None Rotten Egg-like
Fishy Septic-like
Musty Other: ________
Comment:

*** Wind Conditions**

Calm Breezy Strong

North South East West

(Choose one principal direction that the wind is mainly coming from.)

*** Water Surface**

Calm Moderate Waves
Ripple Whitecaps
Small Waves
Comment:

*** Cloud Cover**

0% 75%
25% 100%
50%

*** 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 Swimming / Boating OK (4)
No Aesthetics Possible (5)

Figure 4. Reading a Secchi Disk

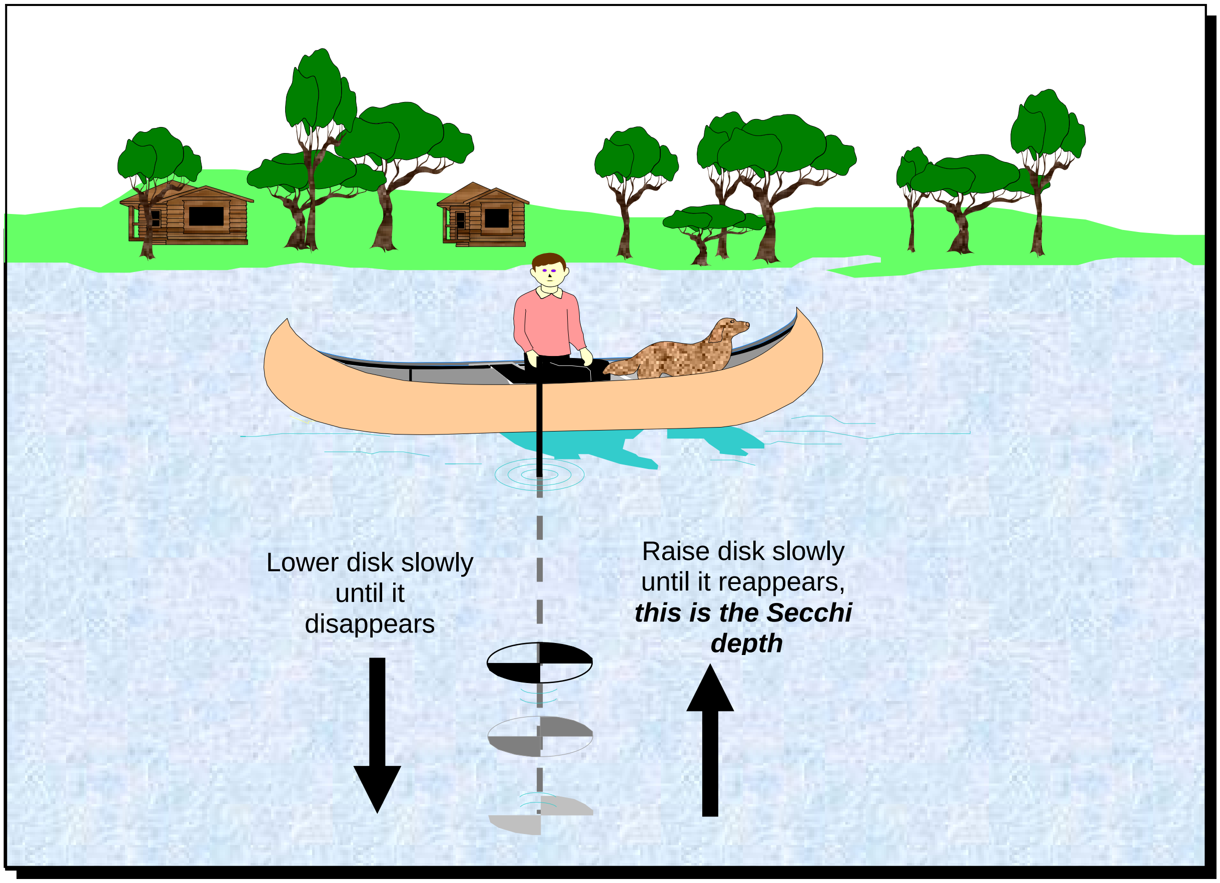
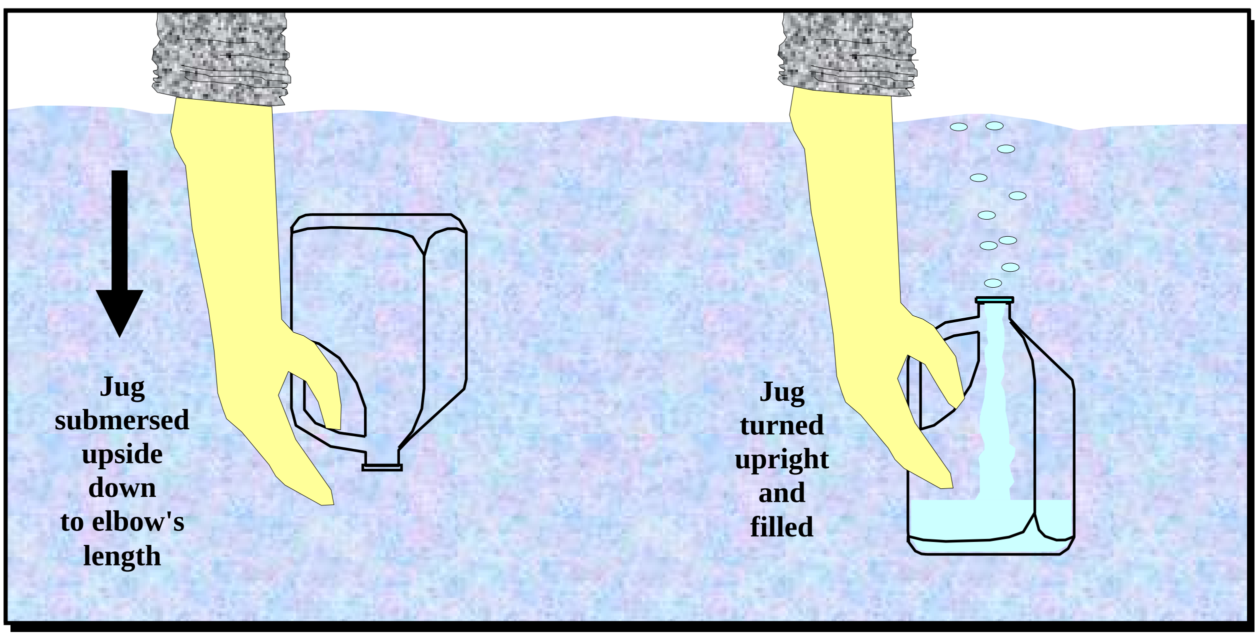


Figure 5. Taking a Surface Sample



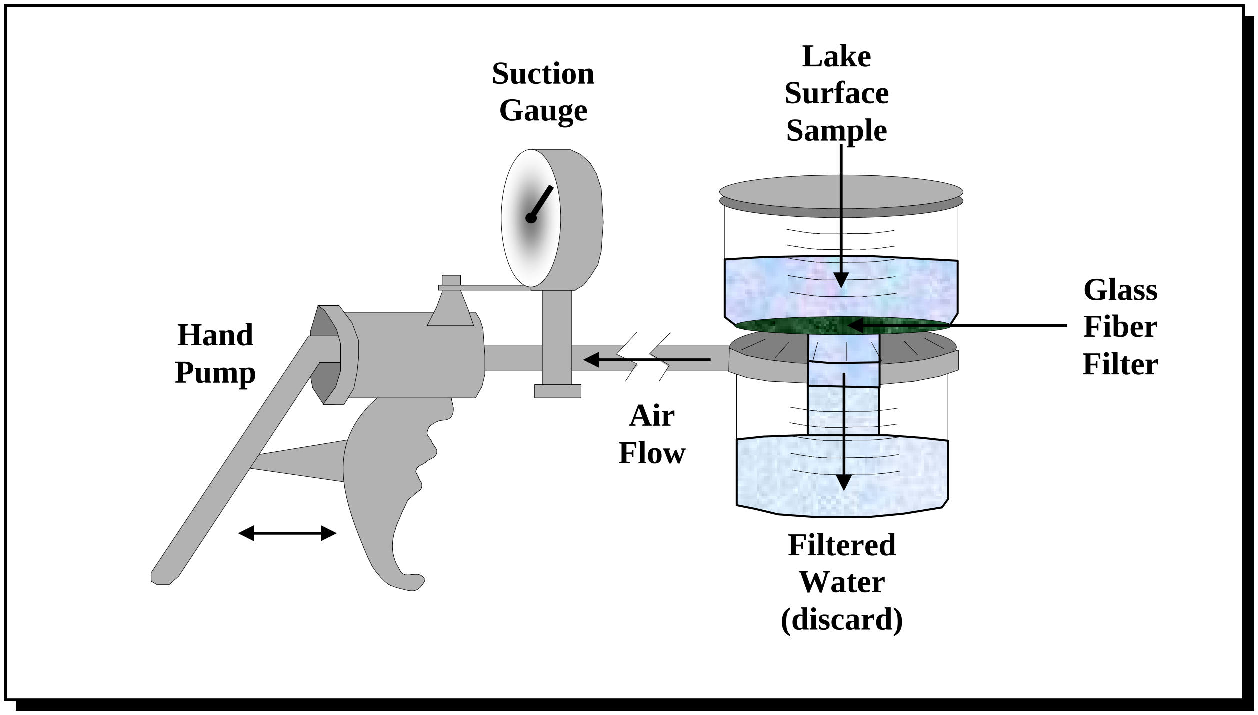
After collecting the water sample in the sampling jug, prepare and test for the following parameters:

∫ **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. The volunteer shall place the thermometer through the jug spout, making sure the metal probe of the thermometer is submerged in the water inside the jug. Special care should be taken to keep the sample out of direct sunlight in order to minimize temperature change.

∫ **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 1.0 micrometer (μm) 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.

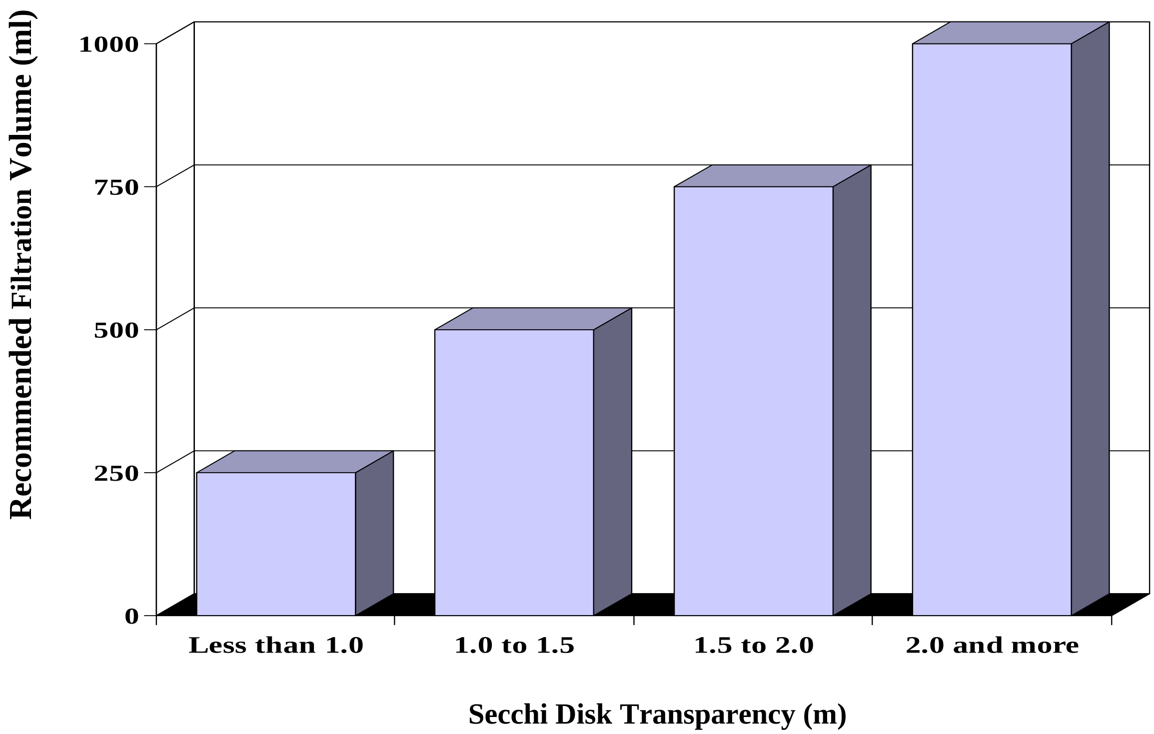
Figure 6. Chlorophyll Filtration Apparatus



If possible this process 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 monitoring 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).

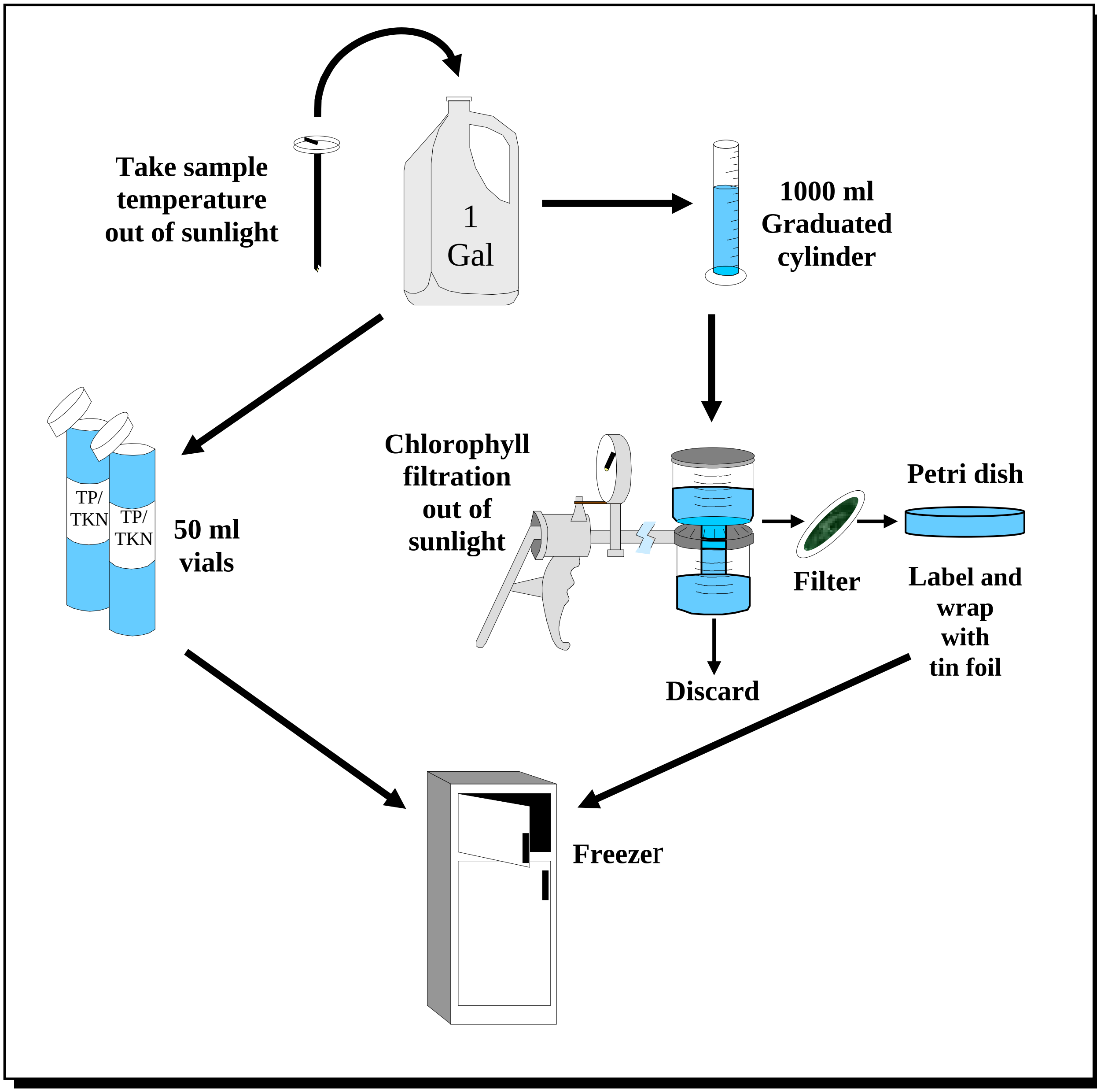
Figure 7. Suggested Filtration Volumes for Given Secchi Transparencies



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**.

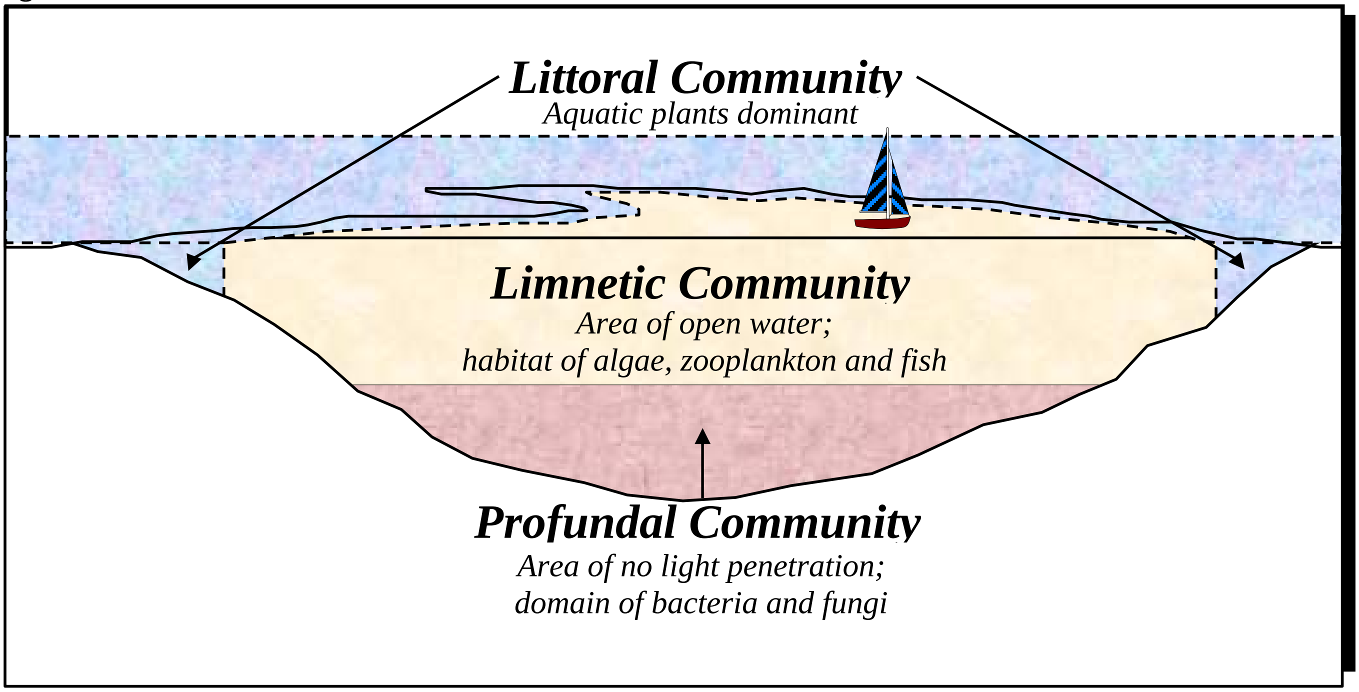
The lake turnovers are essential to the replenishing of the dissolved oxygen supply of bottom waters. Thus, turnovers help insure survival of fish that require cold water and high concentrations of dissolved oxygen. Furthermore, re-circulation brings nutrients (primarily nitrogen and phosphorus) from 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 macropyhtes produce oxygen, and provide a diverse habitat for many different animals including insects, fish, and crustaceans.

Figure 9. Lake Communities



The limnetic zone, or open-water zone, is home to fish and free-floating plankton. The major components of a lake's plankton community are **zooplankton** (microscopic animals) and **phytoplankton** (algae). The zooplankton include crustaceans and other microscopic animals without backbones (**invertebrates**), which feed on phytoplankton. Crustaceans are the freshwater relatives of shrimp and lobsters which, under the microscope, look quite similar to their larger marine cousins (NYDEC, 1990).

Phytoplankton make up the plant component of the plankton community. The phytoplankton 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

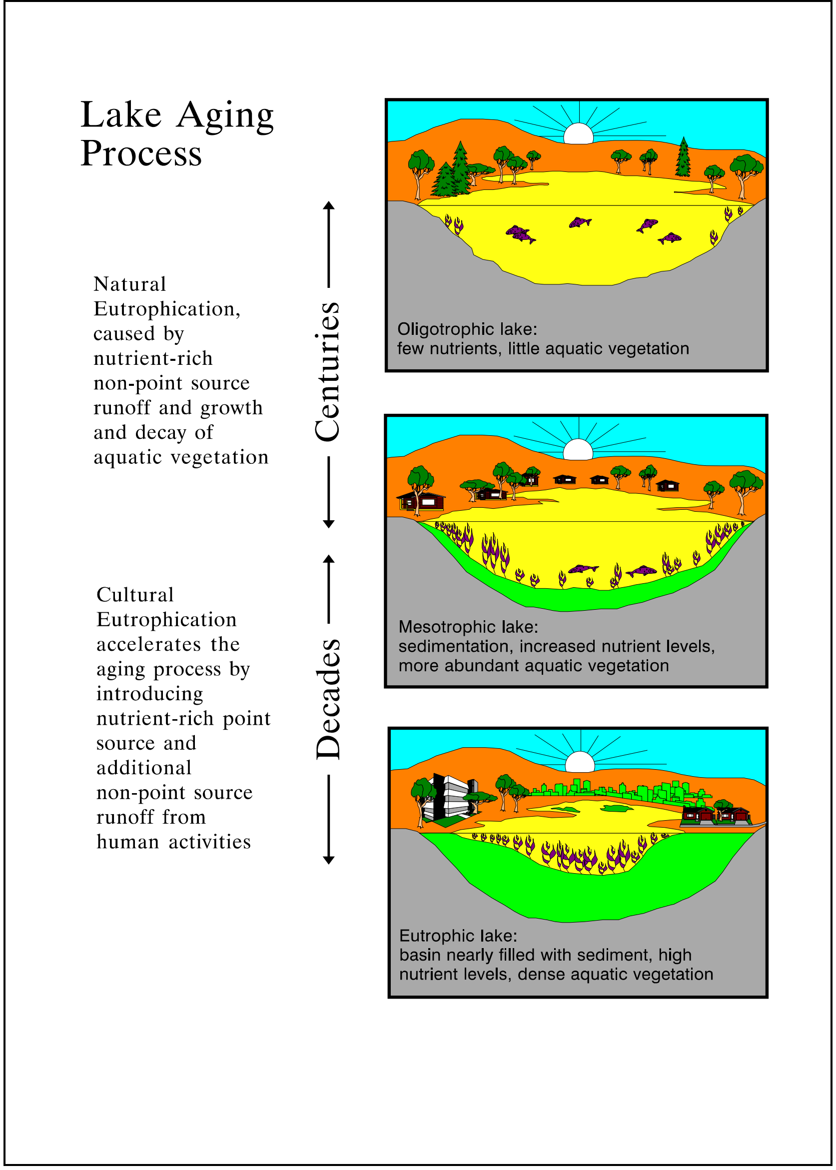
The idea of lake quality is tied to a concept of aging (NALMS, 1989). The natural process of lake aging is a progression from a young (**oligotrophic**) lake with few nutrients through a middle stage (**mesotrophic**) to advanced age (**eutrophic**). As the basin fills with sediment, nutrient levels 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.

Figure 10. Lake Aging Process



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 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 chloropyhll-a (CLA) values.

Table 1
General Trophic Classification of Lakes

Parameter	Oligotrophic	Mesotrophic	Eutrophic
Total phosphorus (μg/l)	≤ 12	13 - 25	> 26
Chlorophyll-a (μg/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 (μg/l)	CLA (μg/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

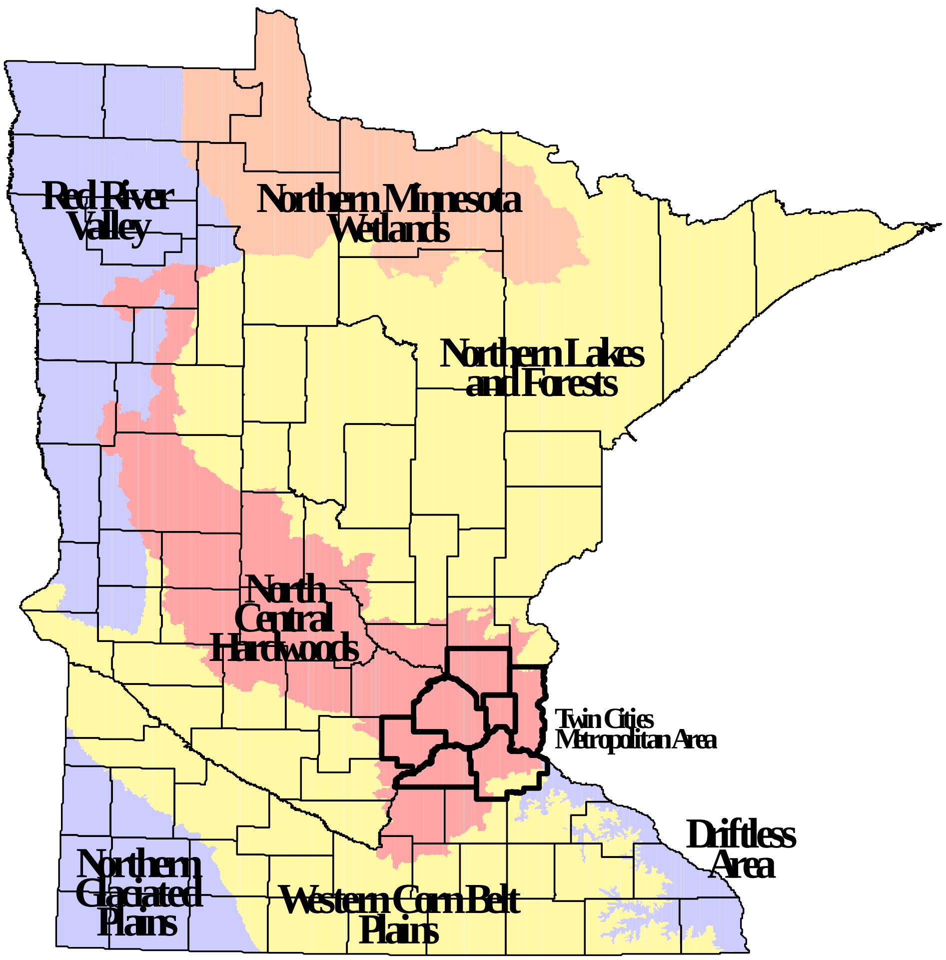
These water quality grades only characterize the open-water quality of lakes. Other nuisances, such as the abundance of aquatic macrophytes, are not indicated with these grades.

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 water 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 minimally impacted lakes (no point wastewater discharges or no large urban areas in the watershed) were sampled by the MPCA to represent reference lakes. The data was then used to illustrate representative lake quality for each ecoregion (Heiskary, 1991).

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 a 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 μm 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 ± 0.2 meters; 99% of the measurements were within ± 0.5 meters. Ninety percent of the measurements not within ± 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

TREATMENT			
Lake	**N=**	**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

Treatment						
Lake	**N=**	**One**	**Two**	**Three**	**Four**	**Five**
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	Lake Name
ABNW	Auburn
BRYN	Bryant
DEMT	Demontreville
EAGH	Eagle (Maple Grove)
ELMO	Elmo
GOLD	Golden
HYDE	Hydes
JANE	Jane
MCCR	McCarrons
MEDC	Medicine
OLSN	Olson
PARL	Parley
RETZ	Reitz
RILE	Riley
TWNL	Twin - Lower
TWNM	Twin - Middle
TWNU	Twin - Upper

ROUTINE AND PILOT TEMPERATURE READINGS (° C), 1991

Lake Name	WEEK OF: 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
PARL	6/3	50/70	50/60	50/50

Lake/Date		TREATMENT		
		*One:	**Two:	***Three:
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
PARL	6/28	2.57/2.51	2.47/2.57	1.97/2.31

Lake/Date		TREATMENT		
		*One:	**Two:	***Three:
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
Mccr	5/29	26/24	25/25	25/25	25/24	22/20

Lake/Date		TREATMENT				
		*One:	**Two:	***Three:	****Four:	*****Five:
Bryn	5/3	28/17	19/19	22/15	19/22	25/23
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/$MGCO_3$.
** Treatment Two - duplicates from surface jug w/o $MGCO_3$.
*** Treatment Three - duplicates from milk jug w/o $MGCO_3$, submit same day.
**** Treatment Four - duplicates from milk jug w/o $MGCO_3$, freeze and submit in 30 days.
***** Treatment Five - duplicates from milk jug w/o $MGCO_3$, freeze and submit in 60 days.