

Massachusetts Water Watch Partnership

Lake Volunteer Water Quality Monitoring Manual



June 2003

Principal Author: Marie-Françoise Walk, MassWWP

Acknowledgments:

This manual was adapted for lakes from the 1994 MassWWP Manual for Volunteer Water Quality Monitors (Rivers), compiled by Karen Pelto of MA. Division of Fisheries, Wildlife, and Environmental Law Enforcement's Riverways program. Principal authors: Geoff Dates, River Watch Network; Jerry Schoen, MassWWP, Paul Godfrey and Mark Mattson, UMASS Water Resources Research Center; Karen Pelto and Maria VanDusen, Massachusetts Department of Fisheries, Wildlife and Environmental Law Enforcement Riverways Programs.

*The Massachusetts Water Watch Partnership
Blaisdell House
University of Massachusetts
Amherst, MA
(413) 545-5531
www.masswwp.org*

The production of this manual was made possible by the support of the Massachusetts Environmental Trust.



CONTENTS

i. Why Monitor?.....	2
ii. Introduction.....	3
How To Use This Manual	4
Part One: Getting Ready	5
A. Limnology	5
I - Lake and watershed setting.....	5
II - How your lake functions	7
III - Human impacts on lakes	12
B. How To Design a Lake Monitoring Study.....	13
I - QAPPs.....	13
II. How To Run a Successful Volunteer Water Quality Monitoring Program.....	22
III. The Importance of Quality Data	26
Part Two: Getting Underway	30
I. Meet the Indicators	30
Fecal Bacteria	31
II. A Note About Safety.....	33
III. In the Field/In the Lab: An Overview.....	34
In the Field	34
In the Lab:	39
Quality Control with EAL: An Overview	41
Quality Control On Your Own: An Overview.....	42
IV. MassWWP Recommended Procedures	42
MassWWP Method for Locating a Lake Sampling Site.....	43
MassWWP Method for Lake Depth Determination.....	43
MassWWP Method for Lake Depth Determination.....	44
MassWWP Method for Lake Water Transparency	45
MassWWP Method for Lake Dissolved Oxygen	47
MassWWP Method for Lake Water Temperature.....	54
MassWWP Method for Lake pH and Alkalinity.....	56
MassWWP Method for Lake Total Phosphorus Sampling.....	65
5.6 Holding time for frozen sample is 12 months. MassWWP Method for Lake Chlorophyll a.....	67
MassWWP Method for Lake Chlorophyll a.....	68
MassWWP Method for Lake Bacteria Sampling.....	71
Part Three: The rest of the story.....	73
Data Management	73
Data Interpretation	73
Data Presentation.....	73
Action.....	73
Evaluation	74
Appendices.....	76
Appendix B: Massachusetts Water Quality Standards	79
Appendix C: Volunteer Monitoring Service Providers.....	82
Appendix D: Equipment List by parameter	87
Appendix E: Typical Lake Surveys	89

i. Why Monitor?

You are your local lake or pond's greatest resource and closest ally. Whether aimed at pinpointing trouble spots, restoring fish or wildlife, or evaluating overall lake health, water quality monitoring as a tool for lake or pond protection is well within your grasp.

Every lake is a reflection of its watershed. The natural chemistry of your lake is influenced by factors such as geology, climate, and vegetation, and, in part, determines what types of plants and animals will live and thrive there. Human activities can alter natural lake chemistry and biological communities. Water quality monitoring can provide you with an understanding of your lake's natural conditions and constraints as well as human-caused changes.

Our best hope for retaining wonder and a sense of place in the natural world is to protect and bring back to life those systems which we've impoverished and abused. Water quality data gathered by trained volunteer monitors can augment the assessments performed periodically by state agency monitoring programs and be useful locally for increasing public awareness and informing local decisions. Sound solutions to water quality problems depend upon a knowledgeable and concerned public. A great way to start the job is to train ourselves to listen to the lake, to learn its needs, and to heed its voice.

Many types of monitoring are available to help you evaluate your water body, including water quality and aquatic macrophyte surveys through the Massachusetts Water Watch Partnership, land use through Riverways' Lake Watershed Surveys, discharges through an NPDES inventory, or fisheries through a Physical Habitat Survey. A bit of research by you at the outset about your lake's character and your group's financial and people resources will help guide you toward the type of monitoring that will yield the most helpful information.

Whether you decide to do chemical, physical, biological, or land use monitoring, a well-designed study that is done systematically over time will begin to show trends in lake health. Persistence and consistency are the bywords.

This manual offers technical guidance on basic physical, chemical, and biological indicators, including temperature, water transparency, dissolved oxygen, pH, alkalinity, total phosphorus, chlorophyll, and aquatic plants.

ii. Introduction



Welcome to the Massachusetts Water Watch Partnership

The Massachusetts Water Watch Partnership (MassWWP) is a program of the Water Resources Research Center at the University of Massachusetts in Amherst, working in partnership with UMass Extension and with citizen volunteers, environmental organizations, state agencies, schools and universities, and industry to foster lay monitoring of river and lake water quality. Using a combination of public and private resources, MassWWP provides instruction to volunteer water quality monitoring programs on study design, training on sampling and analyses techniques, equipment advice and loan, quality control assistance and help on data interpretation and use.

You can obtain help from MassWWP by attending workshops, getting materials such as this manual, consulting our web site (www.masswwp.org), or by calling our office at (413) 545-2842. You will become part of a network of citizens mobilized to collect, evaluate, and act on scientifically credible water quality information for the benefit of Massachusetts watersheds.

Please use this manual to introduce yourself and your lake group to water quality monitoring. It contains information on key aspects of launching a successful monitoring program, including study design, building a successful program, field and lab techniques, and quality control. Detailed protocols are provided for measuring water temperature and transparency, sampling for dissolved oxygen, pH, alkalinity, total phosphorus, and chlorophyll, and how to analyze samples yourself for dissolved oxygen and pH/alkalinity. These protocols reflect MassWWP's suggested data quality requirements. They do not represent the only way to take and analyze water samples, nor are they the only parameters you may want to measure. MassWWP can offer advice and guidance on methods for other water quality indicators. Other providers of assistance are listed in Appendix C.



How Do You Start a Monitoring Program?

While the needs of each lake and lake group are different, starting a monitoring program is a straightforward process. The time commitment involved depends upon the resources and interest of your group and complexity of your lake's needs. Typically, the development of a monitoring program follows these steps:

First, you might hold an informal meeting in your community to share your concerns about the lake and dreams for its future. We can help you set goals and make plans to achieve them. To decide what type of monitoring is right for you and your lake, you will review existing water quality data and collect initial land use and landowner information, perhaps through a Lake Watershed Survey. This is a time for you to discuss options available to your group, including chemical and biological monitoring with MassWWP's assistance.

Following this, a subcommittee of your group will develop a series of questions about your lake's health that will form the basis of your study design. This is the time for evaluating available resources and setting priorities. You will then write a study design or a Quality Assurance Project Plan (QAPP), depending on the complexity of your

program and whether you will seek state or federal funding to underwrite it.

Focusing on the key lake issues and questions that require data to answer, you will choose water quality indicators and sampling sites that help you answer your questions. Finalizing the study design or QAPP involves developing a quality control program and a monitoring schedule, planning how to recruit volunteers, and choosing forms of public outreach.

The final step before you take to the lake is attendance at one or more training sessions, where you will learn the proper way to take samples in the field, analyze them in the lab, assure quality control, and monitor safely.

How To Use This Manual

This manual can be used in conjunction with training, advice, and assistance from MassWWP. However, you will also find it a useful tool to familiarize yourself with the process of developing a volunteer water quality monitoring program, as it provides many opportunities for research and "homework." The better prepared you are, the better able MassWWP will be to assist and advise you.

Part One: Getting Ready provides important background information on watershed ecology and on study design concepts. You will need this information in order to understand why you will be sampling your lake and what your investigations can tell you. A water quality monitoring program is only as good as your preparation. Attention paid at the start to study design, a healthy organization, and quality control will yield rewards for your lake and the people involved in your program. We urge you to read this carefully before you immerse yourself in the "nuts and bolts" of how to take and analyze a water sample.

Part Two: Getting Underway describes water quality indicators and MassWWP procedures for field sampling and lab analysis, including critical safety guidance. Equipment checklists, field and lab data sheets are provided. All sampling procedures found in this manual have been approved by the Massachusetts Department of Environmental Protection. This section can be used to learn about indicators and help you decide if you want to monitor them in your program. It is also useful to learn or to refresh your memory on how to monitor each indicator. It can be a useful training aid for anyone who intends to teach these methods to volunteers in your program.

The **Appendices** include references for further reading, a copy of the 2000 Massachusetts Surface Water Quality Standards, a list of agencies and organizations that can provide monitoring assistance, a list of recommended equipment and supplies, and examples of typical lake surveys.

To the Reader:

This manual is designed for easy reference and frequent use. Please feel free to photocopy procedures, worksheets and data sheets. If you have any questions or suggestions for future editions, please let us know!

Part One: Getting Ready

Lake vs. Pond

There is no universally accepted terminology for water bodies. In general, lakes are large bodies of water while ponds are small. Some limnologists use depth to distinguish between the two: a pond is shallow and has plants growing throughout the water body, while a lake is deeper and plants can only grow in its littoral (shoreline) zone. Still, nobody agrees on these definitions and in this manual we will usually write lake to mean both lakes and ponds.

A. Limnology

Limnology is the study of fresh waters and their ecology. *Lentic* limnology refers specifically to still waters. Limnology is obviously a considerable and complex field that we won't pretend to cover in this manual. Rather, we will cover a few concepts necessary for a basic understanding of how lakes work and respond to pollution. With a grasp of these concepts you should be in a position to design a better monitoring program. If you are interested in learning more about lake ecology, there are several sources of good information for lay people. Consult the bibliography or our website www.masswvp.org.

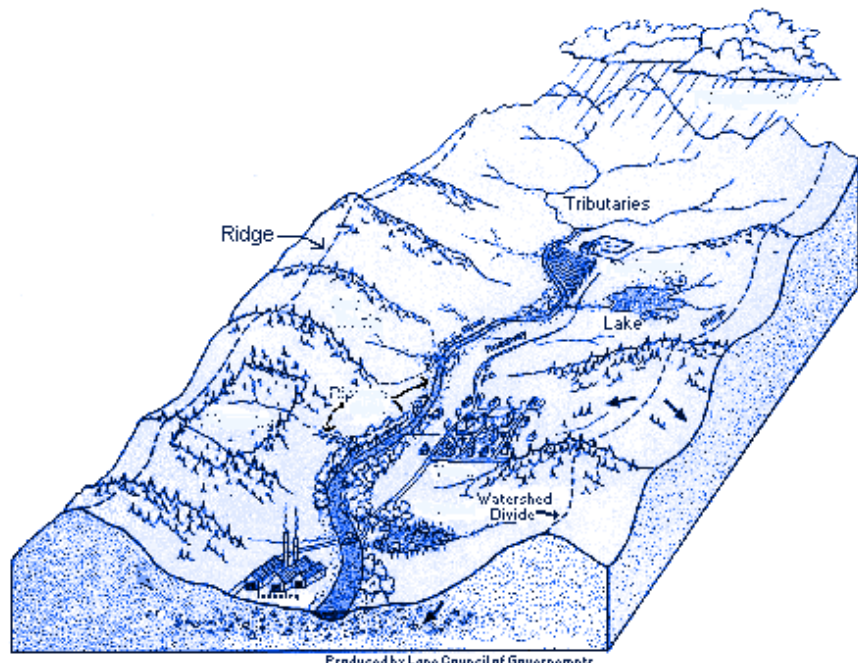
I - Lake and watershed setting

Geologic and landscape features are perhaps the most fundamental influences on the way a lake operates. They control, to a large degree, how and how much water, sediment, nutrients, and pollutants enter a lake, and how the lake responds. Most of these are slow to change. They can help you understand which phenomena are natural and which are caused by humans. This in turn helps you decide what management options are feasible (following the principle that 'you can't improve on nature').

Watershed

We use the term watershed extensively in this manual. A watershed is the area of land draining to a particular point. In the case of a lake, its watershed is the physical area that drains water to the lake. Picture a funnel: the inside walls of the funnel make up its watershed and the draining hole can be thought of the lake.

Figure 1: A watershed is the physical land area draining to a certain point. In this drawing, the area between the ridges drains the river to the point where it flows past the factory.



Slightly modified with permission from Lane Council of Governments

Produced by Lane Council of Governments

Important features of lake and watershed setting that affect water quality include:

- Watershed topography, area and land use
- Lake morphology – surface area, bathymetry, shape of lake
- Soil types in the contributing watershed
- Climate
- Hydrology (contributing water bodies such as rivers and upstream ponds)

Some specific things to consider with lake and watershed setting:

Topography

This will affect erosion rates with consequent water quality impacts. All other factors being equal, what you consider “normal” levels of sediment, nutrients, etc. in a steep-terrain watershed will be higher than in watersheds that are relatively flat.

Watershed size to lake area

The larger this ratio (that is, the larger the watershed relative to the size of the lake), the more likely water quality will suffer, as runoff will be greater and will pass over or through a larger amount of land – and all the potential nonpoint pollution sources located on that land. Nutrient loads will likely be higher. It also means that changes in land use that produce a relatively small increase per acre of nutrients can still have a significant overall increase in the receiving water. This can have a major impact on the trophic status¹ of a lake. Lakes with smaller watershed-to-lake size ratios are likely to be naturally oligotrophic (low nutrients, typically clear water); as the ratio grows, lakes tend towards eutrophic status (high nutrients, lots of biomass: algae, plants, animals). Knowing this can help you determine whether nutrient levels found in your lake are caused by natural processes or are a case of “cultural eutrophication” (i.e. human-caused).

Lake size, shape, and orientation

Large lakes are likely to experience windy conditions more often and with more severity than small lakes. The size, shape, and orientation of lakes also affect mixing of lake water (an important concept discussed in the section on stratification). A narrow lake that lies broadside to prevailing winds (see Lake A in Figure 2) might experience less mixing than one where winds commonly blow the length of the lake. If the lake shoreline is forested, further protection from wind will also minimize mixing.

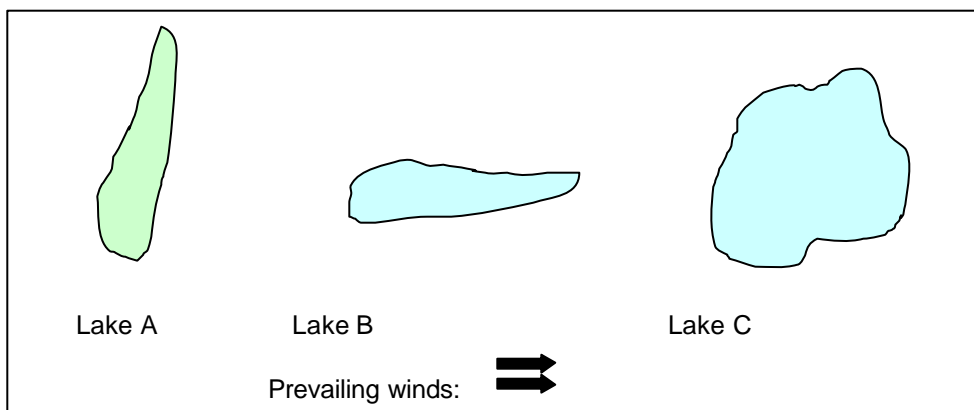


Figure 2: Lakes B and C are likely to experience more mixing than lake A

In general, the more uniform in shape a lake is (e.g. circular), the more valid it is to extrapolate a reading from one sample point (e.g. deep spot or center) to the entire lake. This is important when choosing a sampling location.

¹ Trophic status refers to how productive a lake is, how much biomass it supports. See section on Trophic status

Bathymetry

The depth of a lake is an important factor in how it functions. Shallow lakes tend to be more uniform than deep lakes, in terms of where plants and animals are found, temperature and oxygen levels, and the like. For instance, in those lakes that are shallow enough for light to penetrate to the bottom, rooted plants can cover large portions of the lake. This has obvious impacts on boating and swimming. It can also alter the dissolved oxygen dynamic considerably, as oxygen is usually available top to bottom. However, there are periods when oxygen can be depleted in shallow lakes:

- During warm cloudy periods in summer
- During cold winters, when thick ice covered by snow prevents oxygen exchange with the atmosphere and oxygen production by live aquatic plants. Fish and other organisms can use up the oxygen contained in the relatively small volume of lake water.

During those periods, oxygen deprivation is likely to occur throughout the lake.

Deeper lakes, on the other hand, can have highly segregated zones, at least during parts of the year and under certain conditions. These zones are a factor of seasonal changes, the amount of light reaching different depths, wind and mixing patterns and the relationship between water temperature and density, and how plant and animal life react to variations in these constituents. Typically, in the summer there will be a layer of warm water overlaying a zone of colder and denser water¹. You will often find different species of fish inhabiting separate coldwater and warm water zones; areas with high oxygen levels lying atop anoxic (without oxygen) layers; rooted plants on the (shallow) fringes of the lake, with floating algae throughout the upper layers of the entire lake, and virtually no plant life in deep waters. Deep lakes with a small surface area will generally exhibit better clarity and water quality than will broad, shallow lakes.

You can find bathymetric maps (maps that show the depth contours of the lake bottom) at: http://www.state.ma.us/dfwele/dfw/dfw_pond.htm



II - How your lake functions

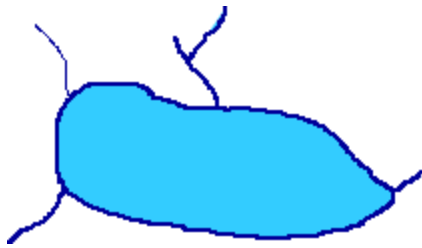
Landscape and lake morphology attributes determine how your lake functions in general. This in turn helps explain results you get when sampling specific parameters.

Hydrologic functions of your lake includes such phenomena as:

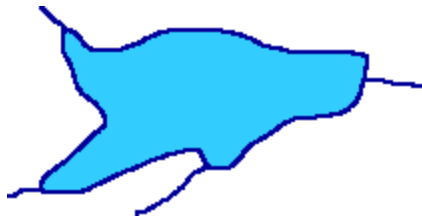
- Major inputs
- Residence time
- Stratification

¹ See section on stratification

Inputs



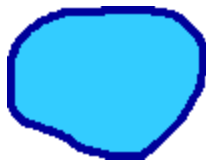
If the lake is fed primarily from its watershed and is also drained by a stream, it is called a drainage lake. Its source of water mostly comes from streams draining the land and emptying into the lake. Like for all lakes, some water will also come from direct precipitation onto the lake surface, and also from groundwater.



A special case of drainage lake is the impoundment: it is a dammed river so the source of water comes mostly from inlets. Usually there is an outlet, at the dam.



A groundwater drainage lake is one fed primarily by groundwater. It has no inlet streams, but has an outlet.



A seepage lake has no inlets nor outlets, and is fed mostly by groundwater, and some by runoff from the nearby land.

The source of water is important because it affects water quality in the lake and drives how you might manage the lake: if water comes mostly from the watershed via streams, land use and management will have an important effect on the lake water quality. Those lakes are more susceptible to non-point source pollution (sediments and pollutants carried from land surfaces along with stormwater). If groundwater is the principal source of water, the watershed geology will have an important effect on water quality: for example in watersheds rich in limestone, pH and alkalinity of lake water will be high. For this type of lake, you may want to concentrate your resources on groundwater protection.

The type of lake is also an indication of retention (see residence time section below).

Where to find above-mentioned information:

Existing studies such as Diagnostic Feasibility studies are always a good place to look.

Also consider water quality assessment –305(b)– reports produced by DEP as well as reports from other agencies such as the U.S. Geologic Survey. Hydrologic information may be found in some 604(b) studies

by Regional Planning Agencies. 305(b) reports can be found on the web at: <http://www.state.ma.us/dep/brp/wm/wgassess.htm>.

Residence time

Also called retention time, this is the amount of time a molecule of water resides in a lake before exiting through the outflow (or evaporation/groundwater loss in lakes with no stream outlets). Residence time is influenced by watershed size to lake size, lake morphology, land use, topography, and climate (which will affect evaporation rates). It is calculated by comparing the net input rate (i.e. inflow + precipitation – evaporation) with the lake volume.

A seepage lake will have a longer residence time than a drainage lake. The size of the watershed relative to the size of the lake is also important: a large lake draining a small watershed will have a longer retention than a small lake draining a large watershed.

Flushing rate, or the inverse of residence time, is often cited when discussing hydrologic budgets.

Residence time controls the significance of a chemical change in a water body. Residence times can range from a few days to hundreds of years. Lakes with long residence times will recycle nutrient inputs year after year while lakes with short residence times will flush nutrients faster than can be utilized.

Stratification

A very important concept is that of stratification. Water temperature is not constant in lakes from top to bottom, and in deeper lakes this temperature difference becomes very significant.

Wind action on the surface of a lake is constantly mixing water layers. How deep the mixing occurs depends on how strong and durable the wind is, but also its direction relative to the shape and size of the water body, as mentioned above. In shallow lakes exposed to strong winds, mixing occurs throughout the lake: the water is well mixed from top to bottom. In deeper lakes, however, mixing occurs only in the upper part of the lake, so that there is a well mixed layer of water sitting on top of another water layer. This occurrence of layers is called stratification. In this part of the country, lakes with depths greater than 10-20 feet usually stratify at least once per year. This means they develop segregated temperature zones.

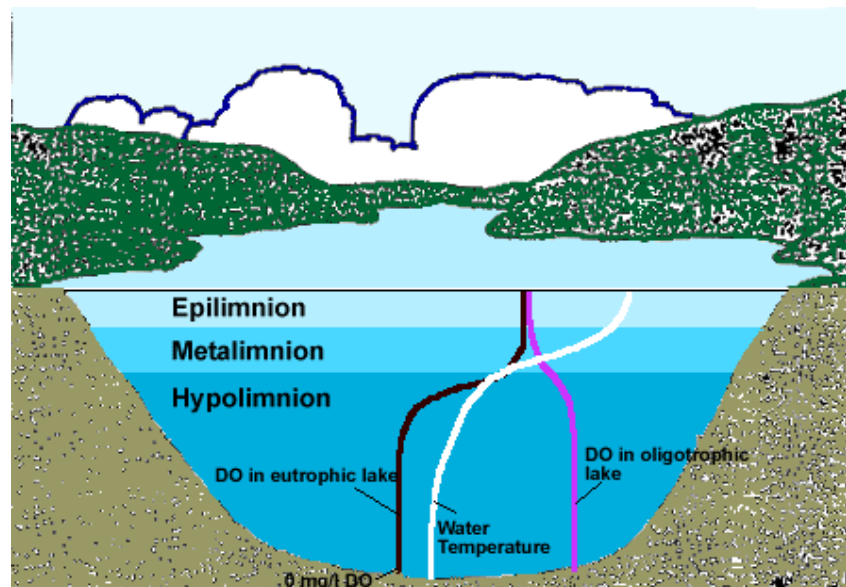


Figure 3: Lake Stratification

Adapted from The Lake and Reservoir Restoration Guidance Manual

What happens is that in the spring, when a lake is well mixed top to bottom, solar radiation heats up the surface water. Warm water is less dense than cold water, so it sits on top of colder water. The wind, as we explained above, tends to mix warm surface water with colder deeper water, but in a deep lake this mixing does not reach the lake bottom. As the summer progresses and more solar radiation is absorbed by surface water, the warm and light layer of water (called the epilimnion, meaning top-lake) gets deeper, while the layer of cold dense water (the hypolimnion, meaning bottom-lake) shrinks. At the boundary between those two layers is a zone of rapidly changing water temperature: the metalimnion, also referred to as thermocline. Because of their difference in density, the two layers do not mix and act almost independently. Here in New England, temperatures in the hypolimnion settle around 6 to 14°C after summer stratification and do not change all summer.

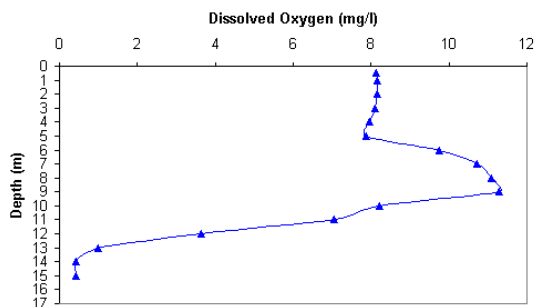
In the fall as solar radiation diminishes, the surface of the lake starts cooling. Mixing cooler surface water with warm lower layers causes the whole upper layer to cool. At a certain point there is no longer a temperature difference between the epilimnion and the hypolimnion (the thermocline has disappeared) and the two layers are free to mix again. This phenomenon is called turnover, in this case it is the fall turnover, when the lake is of uniform temperature top to bottom.

As temperatures continue to drop, a reverse stratification can occur where cold water sits atop warmer water. Water is densest at 4°C (water warmer or colder than 4°C will weigh less). When ice forms at the surface, the water temperature is 0°C at the surface, and progressively warmer below, up to 4°C at the bottom.

In the spring as air temperatures rise, the lake surface warms up to 4°C, making the lake “top heavy”. When this occurs the lake can again mix from top to bottom: this is spring turnover. As the season progresses and temperatures continue to rise, the lake stays mixed until the temperature difference becomes too large for the physical mixing action of the wind. Stratification begins again.

As mentioned above, the degree of stratification is influenced by climate, lake morphology and orientation. Stratification in turn influences distribution of nutrients, gases (i.e. dissolved oxygen), and plant and animal life. Dissolved oxygen is often low or absent in deep layers of stratified lakes that are rich in nutrients. This can cause a chemical reaction between sediments and the water column, releasing phosphorus that was bound to iron, calcium, or aluminum in the sediments into the water column.

Dissolved Oxygen



Stratification has a direct effect on dissolved oxygen, an element that is vital to many aquatic organisms. Oxygen comes from two sources in a lake: the atmosphere and photosynthesizing plants and algae. Oxygen sinks include respiring animals and plants, and organisms such as bacteria that decompose dead material in the lake.

The solubility of oxygen in water is dependent on temperature, pressure, and salinity. Water can hold more oxygen at low temperatures, high pressures, and low salinity. Because of its relationship with temperature, the concentration of dissolved oxygen in a lake varies with depth. It also varies due to the proximity of the surface (more oxygen available at the surface thanks to exchange with air) and due to production and use by plants and animals: sometimes you will see an increased level of oxygen at a certain depth colonized by algae, for example (see illustration above). This often occurs at the boundary between warmer (lighter) water and colder heavier water, where the buoyancy of the algae causes them to float at that depth.

You will normally see more dissolved oxygen (DO) near the surface than deeper in the lake, although if the wind is mixing the lake water efficiently, DO concentration will be fairly constant from top to bottom. When a lake

stratifies though, there are distinct layers of warm atop cold water. So you will usually measure decreasing DO levels with increasing depths: there is an unlimited supply of oxygen at the lake surface, so concentrations will stay near saturation there. Deeper, animals such as fish or zooplankton are using up oxygen for respiration. Deeper still, near the lake bottom, decomposers use up oxygen too. Meanwhile, there are fewer photosynthesizing plants and algae as solar radiation penetration decreases with depth. Below about 10 meters, there are practically no photosynthesizing organisms, so that oxygen is depleted and not restocked. Since there is no mixing with the upper layers in a stratified lake, oxygen levels decrease and can even disappear altogether: this is an anoxic situation, a potential problem for a couple of reasons:

- Some fish such as trout need cold water and oxygen both. If the lake's deeper colder waters become oxygen-poor, the fish will either migrate elsewhere or die if moving is not an option.
- Some sediment-bound elements such as the nutrient phosphorus get released back in the lake water under anoxic conditions. As we will discuss next, an overabundance of nutrients causes problems by increasing the growth of aquatic plants and algae.

Nutrients



source: Minnesota Sea Grant
[www.seagrant.umn.edu/seiche/
jun.02/art01.html](http://www.seagrant.umn.edu/seiche/jun.02/art01.html)

A common problem perceived

by lake groups is the very successful growth of aquatic plants and algae. While an increased plant community can mean a better wildlife habitat, human lake users often view abundant growth as an impairment to recreation such as boating and swimming. To appreciate what is the “right” amount of plant life for a lake, it is helpful to understand what causes plants to expand their coverage. To grow, plants need light, space and essential elements, for example oxygen, carbon, nitrogen, phosphorus, zinc, and potassium. What limits the growth of plants is the element that is present in the least amount. In other words, even if there is an unlimited amount of carbon, plants won't be able to grow unless they also have a sufficient supply of all other nutrients.

The nutrient or environmental factor that is least available is called the limiting factor. Often in lakes, that factor is the nutrient phosphorus.

Phosphorus is present in pollution such as sewage or detergents, but also occurs naturally bound to soil. When soil particles wash into a lake, they invariably bring along phosphorus, which becomes available in the water column. All living things also contain phosphorus, and when they die the phosphorus becomes available through decomposition. Chemical reactions at the lake bottom tie up the phosphorus in the sediment, but as we mentioned above, in anaerobic conditions the phosphorus is released back into the water. At next turnover, mixing brings the phosphorus back to the upper layer where plants and algae can use them.

Rooted aquatic plants (or macrophytes) get most of their nutrients from the sediment through their roots, though they also get some through their leaves from the water column. Algae, lacking true roots, get their phosphorus from the water column. This is important to remember when trying to investigate the cause of macrophyte overgrowth: while measuring the phosphorus in the water column can indicate that phosphorus is still being added to the lake, measuring the sediment phosphorus is a more direct assessment of the presence of excess nutrients.

Another nutrient of interest for macrophytes and algae is nitrogen. It is of lesser importance in lakes because it is rarely the limiting nutrient. Some groups measure it nonetheless as it is of great concern to estuaries and coastal waters where it is the limiting nutrient—and of course most water bodies eventually drain to the seashore.

Trophic Level

Trophic levels refer to the productivity of lakes. (Productivity is the rate of production and amount of organic

matter in a body of water). Limnologists talk about 3 or 4 trophic levels:

- Oligotrophic: poorly productive, few nutrients, clear water, little algae and few macrophytes. These are usually very clear lakes, often deep, well oxygenated, and with relatively few fish.
- Mesotrophic: moderately productive
- Eutrophic: nutrient-enriched; very productive, lots of macrophytes and algae
- Hypereutrophic: over-enriched.

As trophic levels increase, lakes are likely to carry more plant matter – rooted aquatic plants, algae, or both. Lakes will probably experience greater swings in oxygen levels, as the abundant plant life produces more oxygen during the day and consumes greater amounts during the night, when photosynthesis has shut down and replenishment does not occur. Lakes with higher trophic levels are also likely to support a higher population of fish and macroinvertebrates, which will also increase the oxygen demand. In addition to diurnal swings in oxygen, lakes that are both eutrophic and deep are likely to have more dramatic differences in oxygen levels from surface to bottom, for reasons discussed in the previous section. More plants up top produce higher (daytime) oxygen levels; more fish and decaying organic matter near the bottom produce greater oxygen demand. This can have a dramatic effect on the fish community, as the lower, colder levels become inhospitable to fish, due to lack of oxygen.

With the possible exception of hyper-eutrophia, all trophic categories are found in natural, undisturbed systems. Geology, soil type, and other watershed characteristics dictate whether a natural lake will be oligotrophic, eutrophic or in between. High mountain lakes are often oligotrophic. Lake Tahoe in the Sierras, with its 60+ feet of clarity is a classic example. Lowland lakes that receive more runoff from larger portions of the watershed are likely to tend towards the eutrophic state.

One consequence of high trophic levels is the increased amount of plant matter, rooted or floating. As these die, sink fall to the bottom and decay, they add to the sediment levels there, and the lake gradually becomes shallower.

All lakes have a finite life, as they eventually fill in due to gravity: soil from the watershed washes in the lake and slowly fills it, unless an event such as outlet undercutting occurs to reverse the pattern. In an undisturbed environment, this filling in would take thousands of years and the change would be unnoticeable during our lifetime. However, human activity can speed up the process of a lake filling in (see next section). We also have to remember that many Massachusetts lakes are impoundments that flooded sometimes-fertile farmland. It would be unreasonable to expect all Massachusetts lakes today to be oligotrophic, and in most cases the best you can hope for your lake is a mesotrophic level. Nevertheless, monitoring nutrient levels and their sources will give you an indication whether improvements to your lake are reasonably possible.

III - Human impacts on lakes



Source: [Washington State Department of Ecology](#)

Over thousands of years, gravity and natural erosion by streams result in the sedimentation of lakes. Sometimes natural disasters such as landslides will accelerate the input of sediments to a lake. In the long run, too much sediment will slowly fill in a lake and make it shallower. Sediments rich in nutrients encourage the growth of aquatic plants, especially if the lake is shallow and sunlight reaches the lake bed, and also favors algae growth.

Human activity often accelerates the transition from a deep, clear lake to a shallow, murky and “weedy” water body. The transition is called eutrophication, and when accelerated by human activity we call it cultural eutrophication.

What kind of activity accelerates eutrophication? Anything that will increase erosion and/or the addition of

nutrients to the lake. Land use changes, from forest to other uses such as farms, residential or urban, have consequences for eutrophication. In forested landscapes, soil permeability and low erosion rates means that fewer nutrients and sediment will reach the lake. Farming typically exposes the soil, adds nutrients to it, and can contribute to eutrophication, especially if vegetated buffers are not left around the lake and its tributaries: soil and fertilizers run off into the water. Landowners' habits and behavior can also dramatically affect the lake, especially when you add up all the effects: as the photographs suggest, fertilizing your lawn and washing your car can inadvertently fertilize the lake itself, if the nutrients and soap are not diverted away from the lake. Animal manure, and dirt washing off roads and driveways also contribute to eutrophication.

Other human activities adversely affecting lakes include the introduction of toxic substance to water: industrial chemicals (PCBs, metals, solvents), volatile organic carbons (petroleum by-products), pesticides, and even air-borne pollutants such as mercury or acids.

Finally, destruction of wetlands in the watershed and especially near shore eliminate wildlife habitat and natural filtration of sediments and pollutants. Shoreline development can also result in septic system leakage and removal of vegetated buffers.

A good source of information on this topic is THE WASHINGTON LAKE BOOK, written by Washington State Lake Protection Association (WALPA) volunteers. It can be found on the Washington State Department of Ecology's web site, at <http://www.ecy.wa.gov/programs/wq/plants/lakes/walpa.html>.

B. How To Design a Lake Monitoring Study

Building credibility begins before you collect your first lake sample. It begins with the study design process: deciding and documenting the why, what, where, how, and when of your monitoring effort. In many ways, study design is the most important step in your whole monitoring program. If you don't do this step, then

- You may spend a whole lot of time and money on equipment and procedures that are inappropriate
- You may look at the wrong things at the right places or the right things at the wrong places
- You may end up not answering the question you asked, or you may answer a question you didn't ask, or worst of all, you may not answer any questions at all
- You may find that decision-makers are reluctant to use your data, since they won't know how good it is.

Designing the study and preparing a written plan go hand in hand, since the process of writing the plan forces you to completely think through each aspect of the design.

I - QAPPs



In recent years, funders of volunteer monitoring programs have required groups to write a Quality Assurance Project Plan or QAPP. It is a document similar to the study design, but with a specific format and with detailed descriptions of quality assurance steps. If you need to write a QAPP, we refer you to our manual The Massachusetts Volunteer Monitor's Guidebook to Quality Assurance Project Plans, available at <http://www.state.ma.us/dep/brp/wm/files/qapp.pdf>, or check our calendar for workshops:

<http://www.umass.edu/tei/mwwp/workshop.html>.

Why Are You Monitoring?

The first step in designing your study is to define the reasons for it. What do you value most about your lake? What are the threats facing it? What are your organization's long and short-term goals for the lake and what information do you need to achieve those goals? What information is already known and where are the gaps that volunteer water quality monitoring can help fill in? Who will use the information you collect?

To help answer these questions, we recommend holding meetings at which representatives of the whole range of lake interests identify issues and work with topographic maps and aerial photos to locate pollution sources, lake uses, and problem areas. Then you can guide groups through a structured process of identifying and prioritizing issues and program goals. You can use *Worksheet # 1* found at the end of this section as a guide for this process.

Once you've identified issues, goals, and information needs, it's time to pose one or more specific questions that your monitoring effort will address. For example,

- Is the water safe to swim in?
- Does the lake meet state water quality standards for bacteria, dissolved oxygen, temperature, and aquatic life?
- What are the impacts of a stormwater discharge (or some other human alteration) on the physical, chemical, and biological integrity of the lake?
- What are the impacts of non-point source pollution on the lake?
- Does the lake support a healthy aquatic community?
- What is causing bladderwort encroachment in the coves?
- Can swimming be restored in the lake?

Designing Surveys



To answer each question you posed in the previous step, you will design a separate survey, which consists of monitoring one or more parameters. Your monitoring program may include just one survey, or several. For example if you want answers to the questions *Can the lake support a healthy aquatic community?* And also *Can swimming be restored in the lake?*, you will design two surveys: an aquatic community water quality standards survey, and a health assessment survey. For each survey you design, you will need to answer the following questions:

What Water Quality Indicators Will You Measure?

As we illustrated earlier, lakes are complex systems of interrelated physical, chemical, and biological characteristics. We can't measure all those characteristics, so we use water quality indicators – selected characteristics that tell us about the lake's basic health. Some examples of commonly used indicators are:

Physical: Temperature, depth, flow, bottom composition, water clarity, suspended solids

Chemical: Dissolved oxygen, pH, alkalinity, nutrients, conductivity, chlorophyll

Biological: Benthic macroinvertebrates (such as aquatic insect larvae), fish, bacteria, algae, rooted aquatic plants.

"Monitoring" covers a broad array of projects and the program you design should help you answer the questions you've asked about your lake. For example, if you want to know if the water is safe for swimming or boating, you would analyze for bacteria. If you want to know the trophic level of your lake, you would monitor dissolved oxygen and temperature, water transparency, total phosphorus and chlorophyll *a*. If you want to know more about fish habitat, document temperature and dissolved oxygen. Shoreline Surveys are a means of visually documenting lake shore land use, habitat, potential pollution problems and public access. Remember, you choose water quality indicators to round out your investigation, rather than build a program around indicators. Many water characteristics and problems are observable as well as measurable. A camera can be a very useful tool in documenting changes in water clarity before, during, and after a storm. Groups mapping macrophytes also observe and record surrounding land uses, shoreline erosion, and the presence of poor land management around the lake. Certain problems such as sediment may be better documented by frequent observations of sediment plumes entering a lake during storms than by infrequent (though more precise) measurements of sediment depth on the lake bottom. Ultimately, which indicators you will choose will also depend upon your available human and financial resources.

For a baseline survey, MassWWP recommends a minimum set of indicators for lakes: temperature, dissolved oxygen, and water transparency. It is also recommended, if your resources allow it, to monitor total phosphorus and perhaps also chlorophyll, and occasionally pH and alkalinity. An aquatic plant survey of some type is also useful. You may decide to monitor other indicators such as total suspended solids and bacteria; it will all depend upon your study goals. For other types of surveys, see Appendix E.

What Are Your Data Quality Objectives?

Data quality objectives are narrative statements that link the quality of data with the intended use of the data. Data quality requirements refer to how precise, accurate, and sensitive your methods and equipment need to be and how complete, representative, and comparable your data need to be in order to meet your data quality objectives. Key to determining your objectives is the audience you are trying to reach and the technical and financial abilities of your group.

For example, suppose your program goal is to obtain a state grant to manage an aquatic plant problem in your lake. A data quality objective would be to produce data that the Massachusetts Department of Environmental Management would accept as an indication of deteriorated conditions for recreation. The state actually now requires QAPPs as part of their grant deliverables, so you would need to write such a QAPP. As state agencies usually demand somewhat rigorous studies, you would choose state-approved methods for sampling and analysis, and include chain of custody for your samples. On the other hand, if your goal is to raise local landowners' consciousness of water quality versus their behavior toward land management, your data quality objectives may be more relaxed. For example you would probably skip chain of custody forms and adopt a less stringent set of quality control measures. For further discussion of data quality requirements, please see Section IV, "The Importance of Quality Data."

Where Will You Sample?

Where you sample is critical to the validity of your study. Locations are determined by what you want to know, what indicators you are measuring, the nature of the lake and watershed, and your program resources. You may want to monitor inputs to your lake and thus sample in tributary streams. In this case, use a USGS topographic map for a preliminary selection of sites that appear to meet your criteria.

1) If you are doing an in-lake baseline type study, logical sites are:

- Middle of lake and/or deepest spot in the lake. Middle is usually fairly representative of the lake as a whole. Deepest spot is usually where the most extreme conditions are found: lowest DO in stratified lakes, (which also leads to increased phosphorus levels), also greatest extremes of temperature and

DO, if you are doing a profile.

- Inlet(s), if you want to evaluate contributions from the upstream watershed
- Outlet, if you want to evaluate condition of water as it leaves the lake
- Any sites near human activity, such as a bathing beach, if you are trying to gauge possible threats to use of lake.

2) If you are doing an impact assessment of some activity or phenomenon (e.g. are near-shore septic systems, or storm drains contributing pollutants to lake) then you want to sample in proximity to those areas.

3) If you are concerned about upstream impacts, you might do stream sampling in tributaries. This might involve general sampling of different tributaries: i.e. sampling at one or more sites in each tributary; or it might involve an impact assessment of specific activities/phenomena on a tributary. In this case, you might want to sample just downstream, or above and below a suspected problem, such as a farm, golf course, or industrial site.

Following preliminary site selection, all sites should be verified in the field. (This may already have occurred as part of a [Shoreline Survey](#).) The monitoring coordinator should visit each site to ensure that they meet basic safety and accessibility criteria, using photographs and, optionally, a Sample Site Evaluation Sheet. Then, prepare detailed site maps and site location sheets for each volunteer team that show monitors how to get to the site and where at the site sampling should occur. The latter are important for three reasons: one, if the monitoring team needs a replacement, another volunteer can easily find the site; two, others may visit the site to collect additional samples for quality control purposes; and three, in case of an emergency, others will know where to send help. You may also want to permanently mark each stream location with colored tape.



For lake sites, you will want to choose a site that represents the whole lake, if possible. This could be in the center of the lake, or at the deepest spot. If your lake has an irregular shape with important coves, you will probably also choose sites to represent those coves. Depending on your study objectives, you may also choose to monitor at the mouth of inlets or near shore (for example at a private beach, or near a cluster of homes).

There is a triangulation protocol for finding and documenting site sampling locations, available in section IV of Part II. Archive all Site Location Sheets and photographs in a loose-leaf binder or electronically.

Safety and Courtesy

It is important to select sampling locations that are easy to reach safely. If prospective stream sites are on private property, or if you need to launch your boat from private property, permission from the landowner must be secured before monitoring can begin. Private property includes river bottoms and shorelines but not the water. So permission is needed to sample at a private site when wading, while no permission is required when sampling is done from a boat or canoe.

How Will You Collect Samples?

Once you've identified the in-lake site(s) you want to monitor, there are a number of decisions still to make. Will you monitor water at the surface or at specific depths? If you are going to collect samples for later analysis (as opposed to measuring the water directly with a meter), what type of container will you use? (Some chemicals in the water sample may bond to the inner surface of the containers and affect your results.) Do containers require special preparation such as sterilization? How large a sample must you collect to be representative and to give enough volume for analysis?

This manual contains sample collection procedures for the recommended indicators which answer these questions for you. Should you choose to measure others, MassWWP is available for advice or consult [The Massachusetts Volunteer Monitor's Guidebook to Quality Assurance Project Plans](#).

Quality assurance is important for sample collection, since this is the one link in the chain that can involve many people dispersed over a wide area. To minimize errors, keep sampling procedures simple and foolproof. Put yourself in the place of a volunteer collecting samples on a cold, wet spring morning. How much patience would you have with a complex procedure? Guidelines for sample collection quality control are presented in Part Two, Section III of this manual.

Where Will You Analyze Samples?

Samples may be analyzed either in the field or in a lab. Field analysis is preferred for indicators that will change during transport to the lab (for example, temperature) and often the only choice for monitoring groups without access to lab facilities. For certain indicators, such as dissolved oxygen, samples can be stabilized or "fixed" in the field and analyzed later in the lab. Field meters may be used for some indicators, such as dissolved oxygen, pH, and turbidity. Meters can speed up the work, for instance when you need readings at multiple depths to get a "depth profile" of the lake. However, meters may be expensive, difficult to operate and/or less sensitive than laboratory methods. Moreover, the number of sites you can sample simultaneously will be limited by the number of meters you have.



Many groups use field kits to analyze samples at the collection sites. The kits contain all the reagents and supplies needed to perform analysis in the field. MassWWP recommends that, wherever possible, volunteers perform analysis for the basic water quality indicators back in the lab. This makes QC easier, and using a volunteer or staff "lab analyst" to perform the protocols will help limit variability in your results due to error. Note that the "lab" can be your home kitchen for a relatively simple test like DO.

Field kits are often criticized for being crude, inaccurate, and imprecise and some of them are. However, field kits vary significantly in sophistication, precision and sensitivity. Be sure to match the sensitivity and precision of the kits you buy with your data quality objectives.

For laboratory analysis, you have two main options: you can send your sample to a (preferably certified) professional lab to be analyzed, usually for a fee; or you can set up your own project lab, hire a lab coordinator and recruit volunteer help for some or all of the analyses. The choice depends on a host of factors such as the difficulty of the analytical methods, equipment required, program resources, availability of labs and experienced personnel, and other program goals such as involving students and volunteers in the lab work. A list of certified labs can be found at <http://www.mass.gov/dep/bspt/wes/wespubs.htm#certification>.

Sending your samples to an outside lab is generally the easier of the two options, particularly for analyses that are complicated and require expensive equipment. A disadvantage is that the lab may not perform analyses on weekends. Some groups have found wastewater treatment plants willing to donate the analysis of a certain number of samples. If the lab is certified by the state or EPA, decision-makers will more easily accept your data. Keep in mind that some indicators, such as bacteria, require analysis within hours of sample collection, which may not be possible if no qualified lab is located nearby.

The expense of setting up your own project lab ranges from buying a few hundred dollars' worth or less of supplies to spending thousands of dollars on equipment and personnel. Many groups have had good luck with high school or university labs, where basic equipment is generally available and usually at least one teacher is interested and willing to help. Disadvantages include having to work around the academic schedule when classes are in session, the need to design and implement a quality assurance program, and the challenge of establishing the credibility of analyses performed in your project lab. Some lake groups have also cut equipment

costs by pooling their resources or teaming up with a watershed association that is monitoring the streams and rivers of the watershed.

If you decide to set up your own project lab, you will need to identify an independent lab to perform quality assurance-related activity such as making up known and unknown standard solutions, running duplicate analyses, and trouble-shooting problems. Many groups have worked successfully with state, private, and university labs for this purpose. Historically, the Environmental Analysis Lab at UMass-Amherst has provided this service for dissolved oxygen, pH, and alkalinity.

How Will You Analyze Samples?



This manual contains sample analysis procedures for the MassWWP recommended baseline indicators. For other indicators that you may choose to measure, here are some basic considerations:

The basic reference for methods is the American Public Health Association's Standard Methods for the Examination of Water and Wastewater (generally referred to as "Standard Methods," see Appendix A). In this four-inch thick book you will find various methods and procedures to analyze most any water quality indicator. Often you will find several methods for analyzing a given indicator. How do you choose among them? The methods you choose will be determined by your data quality requirements and by the limits of your human technical and financial resources.

Consider your requirements for how sensitive, precise, and accurate your data must be for each indicator. For example, a change in total phosphorous concentration of as little as 0.01 mg/l can affect the productivity of a lake. If you want to be able to detect such changes, you need to use persulfate digestion, followed by the ascorbic acid method using an infrared-sensitive spectrophotometer. Consult The Massachusetts Volunteer Monitor's Guidebook to Quality Assurance Project Plans for more information on this topic.

Once you have identified a method that satisfies your data quality requirements, consider how much time and how many people are needed to perform the method, as well as how much skill is required to complete it well. Will relatively small errors have a dramatic impact on your results? Consider also the equipment required by the method. Do you have it? Can you afford to buy it? Can you seek a donated lab space or equipment? Do you have people with the skills to train volunteers to operate it properly?

In some cases, you may decide that a particular indicator is not worth analyzing because achieving your data quality requirements is too expensive or complex.

When Will You Sample?

When you sample can greatly affect the outcome. Consider the time of day, holding time, frequency, and time of year.

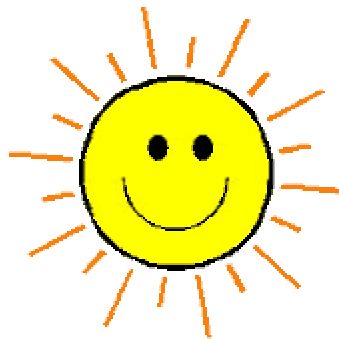
Time of Day: The time of day you collect your samples can affect the results. For example, in shallow lakes or coves with dense aquatic vegetation, dissolved oxygen levels fluctuate dramatically over a 24-hour period, with the lowest levels at sunrise and highest levels in mid-afternoon. So if you want the worst-case scenario, sample at sunrise. However, if you are sampling a deep, stratified lake, an early to mid afternoon sample might prove more useful: it will probably show a more pronounced DO curve as you sample from the upper, oxygenated layers (courtesy of daylight and photosynthesizing plants) to the layers near the bottom that, because it's always dark down there, will maintain a fairly constant DO level throughout the day.

Holding Time: For each test, take into account the maximum time a sample collected in the field can be held prior to analysis in the lab. For example, the maximum holding time for fecal coliform bacteria is **6 hours in a container with ice**. If the sample cannot be analyzed within this time frame, the results won't be valid.

Frequency: How often and how regularly you need to sample depends upon what you want to know. For example, if you are performing a characterization survey, you'll probably want to follow a set schedule. Many groups start with a one-day per month schedule and then build in more frequent sampling as more volunteers become involved, or if your results indicate a need for more frequent monitoring. On the other hand, if you want to investigate sources of bacteria to the lake, you will want to time your sampling to capture conditions when bacteria is likely to be high. In most cases, this calls for a "wet weather" survey; volunteers will be deployed to take samples during rain events, and may take several samples at regular intervals during the storm. In addition, dry weather sampling events will be scheduled for comparison purposes.

The indicator being sampled is often critical to determining how frequently to sample. For instance, chlorophyll sampling is often done to get a sense of how much algae is present in a lake. Because different species of algae bloom and die off at different times throughout the season, many groups like to schedule several chlorophyll samplings each summer – as often as every week or two. Determining a correlation between water transparency and lake use (e.g. boating, swimming) will likely require even more frequent sampling – at least a couple of times weekly. Conversely, aquatic macrophytes need only be sampled once per year.

Time of year: In deciding the time of year to conduct sampling, consider the uses of the water. If you want to know if the water is safe to swim in, sample in the summer. Also take into account the ease of field work: do you need to send volunteers out in freezing weather or during rainstorms? In some cases, the nature of the indicator determines the best sampling season. For example, aquatic macrophytes are best sampled in late summer (August) when they are at their peak abundance. But sampling a few plants in June while they are blooming will make identification easier.



What's Next?

Once you've been through the study design process, you need to document all the decisions – why and what you are monitoring, how sites were selected, where the sites are located, who the volunteer teams are, what equipment is being used, how the volunteers will be trained and how quality assurance will be carried out in a written study design or QAPP. Someone who is unfamiliar with your work should be able to read it and understand what your study is about. While written, the study design is a flexible document and can be refined as volunteers take to the field and learn more about the lake – sites and indicators may change over time.

The study design process may seem like a lot of work. But time spent on designing the study can ultimately save you and your volunteer teams many hours of wasted effort and frustration by assuring that your monitoring

matches your goals and resources.

Worksheet #1

ORGANIZING A LOCAL LAKE MONITORING PROGRAM

GOALS OF A LOCAL CITIZEN LAKE MONITORING PROGRAM

Clearly defined goals are essential for establishing a successful lake monitoring program. To define your goals, determine and document the answers to the following questions:

WHY? – Clearly specify and WRITE DOWN the reasons for starting a lake monitoring program. For example:

- Determine if the lake meets Massachusetts Surface Water Quality Standards for swimming, boating, or fishing
- Restore the lake water quality for specific recreational or natural purposes
- Determine the impact of new development along the lake shore
- Assess the effectiveness of management efforts
- Collect baseline data to promote better local and state planning for lake protection and management
- Determine the impact of non-point pollution sources
- Assess extent of aquatic macrophytes and whether they are native or exotic
- Assess extent of sedimentation and whether it is a major source of nutrients.

WHAT DO YOU PLAN TO ACHIEVE? – Clearly specify and WRITE DOWN the outcomes that the program is designed to achieve. For example:

- Educate public officials and local residents & businesses
- Stop further development/pollution
- Identify effective management strategies
- Protect the lake's fish and wildlife
- Build an informed constituency for lake protection
- Enhance or restore recreational use.

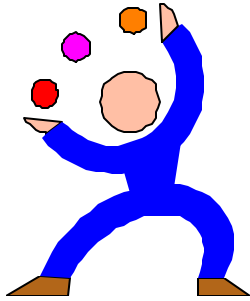
WHAT ARE YOU GOING TO DO WITH THE DATA YOU COLLECT? – Clearly specify the frequency and ways in which monitoring data are to be used. For example:

- Publish quarterly reports in the local newspaper
- Create education materials for the public
- Include the information in your association's newsletter and/or on your web site
- Submit yearly reports to local, state and federal environmental agencies
- Use data to alert environmental officials to potential pollution violations
- Submit data for inclusion in a grant proposal
- Use data in presentations to local decision-makers to stop pollution or pay for management.

HOW LONG WILL THE PROGRAM CONTINUE? – Clearly define the duration and frequency of monitoring activities. Consider what can be done to provide long-term baseline monitoring (5 to 10 years) while exploring phases limited to a relatively short time frame (e.g. 1 year). At the end of each phase of your program, review your accomplishments and difficulties and modify goals, activities and time frames if necessary.

II. How To Run a Successful Volunteer Water Quality Monitoring Program

Human and Financial Resources



Once you have shared a vision with people who want to monitor your lake and set your monitoring goals, you may want to take an inventory of the skills and resources you have available to your group. If you don't already belong to a lake or watershed association, you will need to build a strong organization in order to attract and manage the financial and human resources needed to implement a successful program. Although the human and financial requirements of each program will depend on its size and goals, most programs can use similar methods for recruiting volunteers and raising funds.

Some effective and inexpensive volunteer recruitment methods include: discussing your program with local watershed and environmental groups and landowner associations, advertising in local and environmental publications, and posting flyers at local high schools, colleges, institutions, and other organizations.

Chemical and bacteria monitoring programs will also need to obtain financing to purchase necessary equipment and supplies. Each organization will have to determine how much it will cost to accomplish its current monitoring goals and develop a plan for raising the necessary funds. Some effective fund-raising strategies include: charging membership dues, organizing fund-raising events (e.g. fishing derby or auction) and soliciting donations from local organizations and businesses.

Several effective ways for volunteer monitoring groups to obtain laboratory resources, either use of space and equipment or actual analysis include:

- Forming alliances with local wastewater treatment plant operators
- Getting commercial labs to donate services as a community service
- Working with interested local high school and college science teachers
- Working with local, state or federal officials responsible for maintaining water quality in your area.

Organizations that may provide volunteer, financial, or space/equipment assistance to a monitoring group include: conservation commissions, conservation districts, local or state governments, land trusts, businesses and corporations, civic clubs, fish & game clubs, watershed associations, public health departments, schools, colleges and conservation organizations.

Take A Team Approach

Each successful volunteer lake monitoring program also requires that the workload be distributed fairly. Monitors should feel satisfaction that their results have meaning. The following "job descriptions" are common to the needs of most groups and filling them will serve you well in the long run.

Steering Committee: MassWWP recommends that a volunteer water quality monitoring program involve all users of the lake in its design and implementation. Solicit input and help from town boards and departments, local businesses, civic groups, schools, trade associations, sportsmen's groups, and clubs. A point person should be selected to oversee the whole program.

Technical Advisory Committee: Every Volunteer Monitoring Group needs outside opinions to objectively design its study and help interpret its data. You should seek people with scientific expertise as well as people who represent different points of view. This is to give you a chance to subject your findings to as much scrutiny (maybe even criticism) as possible before you make them public. Here are some suggestions on what type of people you may ask to serve on your TAC, and where to find them:

What expertise do you need on your TAC?

River / Lake /Coastal Biology
Hydrology / Limnology
River / Lake / Coastal Chemistry
River / Lake / Coastal Ecology
Statistics (for trend analyses)

Local River / Lake / Coastal Uses and Problems
How State Agencies Work
Business Environmental Compliance
Laws and Regulations

Where to find TAC members:

Local State Agency staff
Scientists at universities and community colleges
Local Conservation Commission members
Town Water Department supervisor
Town Recreation director
Businesses who use the water body for discharge
or profit (industry, rafting business, boat rental
business, etc.)
Old Timer: someone who is very familiar with the
watershed today and in the past

Local Board of Health, or Health Dept.
Local or regional Planning Board or Planning
Dept.
Environmental consulting firm
Your county's Natural Resources Conservation
Service
Local non-profit organizations such as Audubon
Society
Any local branch of Fisheries and Wildlife, USGS,
DEM, etc.

Technical Coordinator: This person is responsible for coordinating the training of the volunteers (identifying needs and arranging training and QA/QC "checkups"); equipment maintenance and supplies, and serves as a point person for sampling and technique questions.

QA/QC Officer: This person works with the technical advisor to develop the QA/QC plan, runs lab analysis "checkups," spot checks sampling technique and arranges lab analysis of samples when necessary.

Volunteer Coordinator: This is the "people" person, who recruits and organizes the teams, makes the reminder phone calls, keeps monitors informed of results and interested in the project, through quarterly meetings, events, newsletter, etc.

Outreach Coordinator: This person writes regular summaries of results, press releases to local papers, landowner education, etc.

Lab Analyst: This person is in charge of performing laboratory procedures for the dissolved oxygen, pH, alkalinity, and bacteria tests.

In many programs one person will perform several of these tasks. At the beginning, the most important folks to recruit are the Technical Advisory Committee and Volunteer Coordinator. You may also want to include an equipment manager, legal/liability advisor, computer and graphics experts in your program.

It is important to evaluate your people resources well. There are many folks who are willing to go out once a month to take a sample; there may be other folks in the community who can make a greater time commitment. Be sure not to drain your group's time however, and try to identify a wide range of folks who may be able to fill the above "positions."

Keep the following in mind as you develop and implement your lake monitoring program:

- Limit your goals and work plans to make them manageable and measurable – don't take on too much for your group's size or experience
- Rotate tasks whenever you can in order to share and build skills among all group members
- Where certain tasks require continuity and accountability, assign the work to one, or at most two, people
- Watch carefully to see who in your group has special management, technical or outreach skills and draw on them!
- Respect people's limits – remember this is a volunteer effort and folks have other commitments as well at

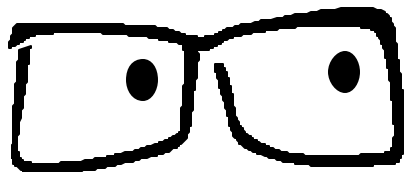
- home or at work
- Set clear expectations for leadership of the monitoring effort.

Table 1. The Monitoring Year: sample task year for a typical volunteer monitoring program

PERSON/GROUP	ACTIVITY	TIME
Program Planners	1. Convene Public or Association Meeting 2. Develop Study Design 3. Interpret results	Before program starts (can be the year before, or January of first year for a simple program) Oct/Nov
Program Coordinator	1. Recruit Volunteers (samplers, analysts, etc.) 2. Find a lab location 3. Oversee program, keep on top of volunteers 3. Order/maintain equipment and supplies	March ASAP April through October March-October
Trainers	Samplers and analysts go to training workshops OR send 1 volunteer there who will then train other volunteers back home	March/May (field sampling, chemistry) June (shoreline survey, weed survey)
Samplers	Collect (fix when necessary) samples on site	April through October, monthly, weekly or other
Analyst(s)	Analyze samples	Same as above
Computer Volunteer	Enter data Develop data summaries and graphs	April through October, ideally; after sampling season, alternatively October - November
Quality Control Volunteer	1. Contact EAL for QA/QC 2. Check on samplers and analysts 3. Check field and lab sheets 4. Check data entry and results	March through October on-going basis April-October " " " " " " " " " "
Technical Experts (TAC)	1. Review Study Design and advise on Techniques 2. Review results and help with data interpretation	Before program starts or January of first year October - December
Outreach / PR Volunteer	1. Advertise for volunteer recruitment 2. Disseminate recent data back to volunteers, on web, in local press 3. Disseminate data to media, book presentations and festival booths, etc	March April through October Throughout the year
Other Volunteers	Transportation of sampling equipment, samples to lab, write report, take photos and slides, prepare slide show and exhibits, staff booth at fair, go to conferences and workshops, keeper of the	Throughout the year

	paperwork, raise funds....	
--	----------------------------	--

III. The Importance of Quality Data



Let's face it – quality assurance is probably the least glamorous aspect of any environmental monitoring program. But the scientists, public officials, and members of the public who may use your data have a right to know how accurate and reproducible those data are, and a strong quality assurance program is the only way to convince these people that your data are worth looking at.

Quality Assurance Terminology

The literature on quality assurance is filled with technical jargon, and the definitions of terms vary from paper to paper. We've used the terms given by Keith et. al. (1983) (see Appendix A for citation).

Quality assurance is a broad plan for maintaining quality in all aspects of a program. The quality assurance plan guides:

- The selection of parameters and procedures
- Data management and analysis
- The steps taken to determine the validity of specific sampling or analysis procedures.

These steps are divided into two categories: *Quality control and quality assessment*

Quality control (QC) consists of the steps you take to make your analysis more accurate and precise while you are actually running the analysis or making the measurement. QC procedures let you know right away if you have a problem, so that you can take immediate actions to correct the problem. A standard solution of known concentration that you run along with your samples in a chemical analysis is an example of a quality control sample. As you will see in Part Two, UMass EAL provides quality control samples for pH and alkalinity and dissolved oxygen.

Quality assessment (QA), on the other hand, is your "after the fact" assessment of the overall precision and accuracy of your data. Quality assessment samples are often analyzed "blind" – that is, the analyst does not know the expected result. A duplicate sample taken in the field but not obviously labeled as a duplicate is one example of a quality assessment sample. Part Two of this manual offers general guidance for using "blind" samples.

Other terms commonly used in discussing quality assurance include the following:

Replicate samples, or duplicates: Two or more samples taken from the same place at the same time. MassWWP recommends taking one extra sample for every ten sites, or 10% of your sites.

Precision: The reproducibility of your method (how close the results of the replicate analyses of one sample are to each other). Precision is measured by the mean or standard deviation of replicate samples.

Accuracy: How close your results are to the true value. It is measured with audit samples.

Detection limit: The lowest concentration a method can detect as greater than zero.

How Much QC?

In order to decide how rigorous your QC program needs to be, you must first answer the question, "How good must the data be to serve your purposes?" You may already have answered this question through development of your study design, which called for determining your data quality objectives. If your primary purpose is to screen for potential problems so that you can alert agencies to follow up on your findings, you may need only basic quality control for your data. But if you want your data to be used for enforcement or to guide policy decisions, or even to stand up in court, then extensive quality control is essential.

Once you have set goals through your study design and decided how good you want your data to be, you need to weigh the ideal amount of quality control against your resources of time, money, equipment, and personnel. Since higher quality usually costs more, you may find at this point that you have to make some adjustments in your goals for the data.

Sample Collection In the Field



Quality assurance of data does not begin with the lab analysis – it begins with collecting the sample in the field. As we mentioned in the study design section, an important first step is to get volunteers to the correct site. Some volunteers may have difficulty reading maps, so it is best to have a program coordinator assist in locating sites the first time. In some cases it may be possible to affix a marker, such as a staff gage (at a stream site) or buoy (at a lake site), in the water at the sample site. The written directions to the site should refer to permanent landmarks.

All information concerning the sample collection (site, date, time, collector, etc.) should be recorded on preprinted data forms. You will find the standard MassWWP data forms for field collection and lab analysis in Part Two of this manual. Your study may also require a *chain of custody* document containing the signature of every person who sampled, transported, stored, or analyzed a sample. The chain of custody document certifies that no switch of samples has occurred.

Physical Data

Quality assurance procedures for physical measurements are generally fairly simple and straightforward. Instruments should be calibrated against a known standard and used according to instructions. For example, thermometers should be checked against a calibrated thermometer. Procedures for calibrating thermometers and pH meters are provided in the lab analysis sections contained in Part Two of this manual. MassWWP can offer training sessions where volunteers can learn the proper use of equipment in the field, and sells a video demonstrating lake sampling techniques.

Taking replicate samples in the field is important to assuring the quality of physical data. Another check on the quality of physical data is to field-check volunteer measurements by comparing them to side-by-side measurements made by professional staff.

Chemical Data

All those terms you hear for different types of quality assurance samples – like "split sample," "spike sample," "blank," "check sample" – apply mainly to chemical testing. See Table 2 below for descriptions of some of these samples and how each is used.

Table 2. Common Quality Assurance Samples

SAMPLE TYPE	DESCRIPTION	APPLICATION
<i>Quality Assessment</i>		
Field Blank	Deionized water treated as a sample	Use to estimate contamination from sample collection and processing
Field duplicate	Duplicate lake or stream sample	Use to estimate combined sampling and lab precision
Audit sample	Synthetic sample prepared by QC officer or obtained from outside source	Use to estimate accuracy and precision of lab
<i>Quality Control</i>		
Calibration Blank	Deionized water used to zero the instrument	Use to identify instrument signal drift; also, can be compared to field blank to detect contamination of sample
Quality control check sample (QCCS)	Standard solution (source other than calibration standard)	Use to determine accuracy and consistency of instrument calibration
Laboratory duplicate	Sample split in two at the lab	Use to test precision of lab measurements
Matrix Spike	Subsample spiked with known concentration of analyte (substance being measured)	Use to determine interference effects in the sample

The samples listed under "Quality Assessment" in Table 2 are usually *double blind* samples – that is, the person performing the analysis does not know the sample's identity or the expected result. These samples are delivered to the lab disguised as regular samples. The results of the quality assessment samples are later compared to the expected results and the comparison is used to assess the overall accuracy and/or precision of the data set.

The samples listed under "Quality Control," on the other hand, are samples whose *identity is known* to the analyst, but whose expected concentration is only known by the lab that manufactured them (such as the EAL). They should be run first, before the field samples are analyzed, and preferably the week before sampling, to check on the accuracy of the analytical procedures and instruments. After the QC samples are run, results are called or mailed in to the professional lab to compare the analyst's results to the expected values. EAL provides quality control samples for dissolved oxygen, pH and alkalinity to enable you to detect and correct any problems before the field samples are run.

The quality control check sample (QCCS) must originate from a different source than the one used in calibration. Standard solutions sold by scientific supply companies can be used as quality control check samples. EAL does not provide QCCS. It is a good idea to plot the QCCS results immediately on a graph called a quality control chart, so you can tell right away how the result compares to previous results with the same solution. If the QCCS result is outside the upper or lower control limit, you should stop and correct the problem before analyzing the samples.

A matrix spike is used occasionally to test for substances in the sample that may interfere with the analysis. Use of a matrix spike does not apply to the basic indicator protocols presented in Part Two of this manual. If you are testing other indicators, such as phosphorus, the lab doing your analyses should provide you with its quality control protocols.

Audit samples are used to test the accuracy and precision of your lab, either the volunteer-run lab or the one the work is sent out to. External audit samples are prepared by an outside agency, while internal audits are prepared from standard solutions by someone in your group. The correct concentrations are revealed after the results are turned in. One way to obtain blind audit samples is to participate in EPA's Water Pollution Performance Evaluation Sampling Program. Twice per year, participants in this program receive a set of audit samples for various chemical parameters from their regional EPA Quality Control Coordinator.

Not all QC procedures are appropriate for all analyses. For example, blanks and standards are not usually used for Winkler dissolved oxygen titrations, due to problems with contamination by oxygen from the air. However, a QC sample can be obtained from EAL, or you can use your own standard solution of potassium bi-iodate. A premixed iodate-iodide standard solution can be ordered from the Hach Chemical Company.

For small volunteer programs with limited resources, all the QA/QC procedures for chemical analyses may seem overwhelming. MassWWP recommends that the calibration blank, QCCS, and standards be run with each batch of samples. Other tests, like matrix spikes and field blanks, could be run monthly or yearly. For more information on chemical quality control procedures, see Standard Methods for the Examination of Water and Wastewater cited in Appendix A or our manual The Massachusetts Volunteer Monitor's Guidebook to Quality Assurance Project Plans.

Part Two: Getting Underway

I. Meet the Indicators

This section describes what the water quality indicators recommended by the Massachusetts Water Watch Partnership can tell you about the health of your lake. It provides the background needed to understand your lake's chemical and biological interactions.

pH is a measure of the hydrogen ion concentration of the water as ranked on a scale of 1.0 to 14.0. The lower the pH of water, the more acidic it is. The higher the pH of water, the more basic, or alkaline, it is. pH affects many chemical and biological processes in the water and different organisms have different ranges of pH within which they flourish. Most aquatic animals prefer a pH range of 6.5 - 8.0. pH outside of this range reduces the diversity in the lake because it stresses the physiological systems of most organisms and can reduce reproduction. Low pH can also allow toxic elements and compounds such as heavy metals to become mobile and "available" for uptake by aquatic plants and animals. Again, this can produce conditions that are toxic to aquatic life, particularly to sensitive species like trout.

Changes in acidity can be caused by atmospheric deposition (acid rain or acid shock from snowmelt), surrounding rock, and wastewater discharges. Technically, the pH scale measures the logarithmic concentration of hydrogen (H^+) and hydroxide (OH^-) ions, which make up water ($H^+ + OH^- = H_2O$). When both types of ions are in equal concentration, the pH is 7.0 or neutral. Below 7.0, the water is acidic (there are more hydrogen ions than hydroxide ions). When the pH is above 7.0, the water is alkaline, or basic (there are more hydroxide ions than hydrogen ions). Since the scale is logarithmic, a drop in the pH by 1.0 unit is a 10-fold increase in acidity. So, a water sample with a pH of 5.0 is ten times as acidic as one with a pH of 6.0. pH 4.0 is 100 times as acidic as pH 6.0.

Alkalinity (also called acid neutralizing capacity or ANC) is a measure of a water body's "buffering capacity," or its ability to neutralize acids. Alkaline compounds in the water – such as bicarbonates (baking soda is one type) – carbonates, and hydroxides remove H^+ ions and lower the acidity of the water (which means increased pH). They do this usually by combining with the H^+ ions to make new compounds. Without this acid neutralizing capacity, any acid added to a lake would cause an immediate change in the pH. Measuring alkalinity is important to determining a water body's ability to neutralize acidic pollution (as measured by pH) from rainfall or snowmelt. It's one of the best measures of the sensitivity of the lake to acid inputs. Alkalinity comes from rocks and soils, salts, certain plant activities, and certain industrial wastewater discharges. Alkalinity is measured by collecting a water sample, and measuring the amount of acid needed to bring the sample to a pH of 4.2. At this pH all the alkaline compounds in the sample are "used up." The result is reported as milligrams per liter (mg/l) of calcium carbonate.

The Massachusetts Acid Rain Monitoring Project ranks waters according to their alkalinity as follows:

<0* mg/l: Acidified	>5-10 mg/l: Highly Sensitive
>0-2 mg/l: Critical	>10-20 mg/l: Sensitive
>2-5 mg/l: Endangered	>20mg/l: Not Sensitive

*and pH less than 5.0.

Dissolved oxygen (DO) is the oxygen dissolved in the water. It is an important indicator since most aquatic plants and animals need it to survive. The lake system both produces and consumes oxygen. The lake

gains oxygen from the atmosphere through the aerating action of wind or turbulence and from plants through photosynthesis. Respiration by aquatic animals, decomposition, and various chemical reactions consume oxygen. Decomposition of organic matter discharged in wastewater or accumulating on the lake bottom consumes oxygen. If more oxygen is consumed than is produced, dissolved oxygen levels decline and some sensitive animals may disappear. DO levels fluctuate daily and seasonally. They also vary with water temperature – cold water holds more oxygen than warm water. The most critical time for many aquatic animals is early mornings on hot summer days, when lake water temperatures are high, and plants have not been producing oxygen since sunset. For a discussion of DO distribution in a lake, see section II in Part I.

We measure dissolved oxygen by collecting a water sample in a special bottle, "fixing" or stabilizing the amount of oxygen in the sample by adding certain chemicals, and then measuring the concentration in the lab. DO is measured in either milligrams per liter or "percent saturation." Milligrams per liter (mg/l) is the amount of oxygen in a liter of water and is the same as "parts per million" or ppm.

Many lake groups have purchased DO-meters to make field determinations. Organizations such as the Central Chapter of the Congress of Lakes and Ponds (COLAP) and Lakes and Ponds Association of Western Mass. (LAPA-WEST) have loan programs for their members to borrow such meters. The advantages of meters are that you can make a lot of measurements fast, get results while on the lake, and don't need to have a lab. The disadvantages are that they are expensive, can be fussy, and can't be used to measure QC samples. Quality assurance for DO-meters is therefore more complicated as you have to go through a two-step process involving someone taking a water sample simultaneously with your meter reading, and titrating the sample later. MassWWP occasionally will provide such quality control, on an individual case basis.

Percent saturation is the measured mg/l of oxygen in the water sample relative to the mg/l of oxygen that the water sample is capable of holding at a particular temperature. The amount of oxygen that water can hold varies with temperature. Cold water can hold more oxygen than warm water. At less than 100% saturation, the water will tend to take on oxygen from the air. At greater than 100% saturation, it will give off oxygen to the air. At 100% saturation, the oxygen of the water is at equilibrium with the oxygen in the air and no oxygen will be exchanged. Suppose the measured DO of your water sample is 5 mg/l. If you measured a lake water temperature of 20°C, your water sample is capable of holding about 9.0 mg/l (this fact is obtained in section IV.E). Dividing the measured DO by the expected DO gives the percent saturation, in this case 55%.

Fecal Bacteria

Members of two bacteria groups, coliform and Enterococci, are used as indicators of possible sewage contamination, because they are commonly found in human and animal feces. Though they are generally not harmful themselves, they indicate the possible presence of pathogenic (disease-causing) bacteria, viruses, and protozoans that also live in human and animal digestive systems. Therefore, their presence in water bodies suggests that pathogenic micro-organisms may also be present and that water contact recreation (such as swimming or boating) may be a health risk. In addition to the health risk, fecal material can cause a number of impacts on lakes: cloudy water, unpleasant odors, and an increased oxygen demand.

It's too difficult, time-consuming, and expensive to test directly for the presence of the large variety of pathogens, so water is routinely tested for fecal coliforms and Enterococci as indicator groups instead.

Sources of fecal contamination to surface waters include wastewater treatment plants, on-site septic systems, domestic and wild animal manure, and stormwater runoff.

Indicator Bacteria Types and What They Tell You:

In the past 50 years, the most commonly tested bacterial indicators have been total coliforms, fecal coliforms, *E. coli*, fecal streptococci and Enterococci. All but *E. coli* are comprised of a number of species of bacteria that all share common characteristics such as shape, habitat, or behavior. *E. coli* is a single species of fecal

coliform.

Total Coliforms are a group of bacteria that is widespread in nature. All members of the total coliform group may occur in human feces, but some may also be widespread in the environment, such as animal manure, soil, submerged wood and other places outside the human body. Thus, the usefulness of total coliforms as an indicator of fecal contamination depends upon the extent to which the bacteria species found are fecal in origin. For recreational waters, total coliforms are no longer recommended as an indicator. For drinking water, total coliforms are still the standard test since their presence indicates contamination of a water supply by an outside source.

Fecal Coliforms are a subset of total coliform bacteria, which is more fecal-specific in origin. However, even this group contains a genus, *Klebsiella*, with species that are not necessarily fecal in origin. *Klebsiella* are commonly associated with textile, pulp and paper mill wastes, in the absence of fecal contamination. For recreational waters, fecal coliform was the primary bacteria indicator until relatively recently when EPA began recommending *E. coli* and Enterococci as better indicators of health risk from water contact. Fecal coliforms are still being used in Massachusetts as the standard for recreation bacteria and this manual provides protocols for fecal coliform analysis.

Escherichia coli (E. coli) is a species of fecal coliform bacteria that is specific to fecal material from humans and other warm-blooded animals. EPA recommends *E. coli* as the best indicator of health risk from water contact in recreation waters and some states have changed their water quality standards and monitoring accordingly.

Fecal streptococci generally occur in the digestive systems of humans and other warm-blooded animals. In the past, fecal streptococci have been monitored together with fecal coliforms and a ratio of coliforms to streptococci calculated. This was used to determine whether the contamination was of human or non-human sources. However, this is no longer recommended as a reliable test in the 20th edition of Standard Methods.

Enterococci are a subgroup within the fecal streptococcus group. They are distinguished by their ability to survive in salt water, and in this respect more closely mimic many pathogens than the other indicators. They are generally more human-specific than the larger fecal streptococcus group. EPA recommends Enterococci as the best indicator of health risk in salt water used for recreation and as a useful indicator in fresh water as well. Massachusetts marine public beaches are now required by the Department of Public Health to be tested for Enterococci.

Massachusetts fresh water public beaches are now required by the Department of Public Health to be tested for *E. coli* or Enterococci.

Which Bacteria Should You Monitor?

Which bacteria you test for depends on what you want to know. Bacteria are commonly used to determine the health risk of water contact, or the presence of fecal contamination from humans or animals to help determine the impact of point or non-point pollution sources on a river or lake.

Studies conducted by the EPA to determine the correlation between different bacterial indicators and the occurrence of digestive system illness at swimming beaches suggest that the best indicators of health risk from recreational water contact in fresh water are *Escherichia Coli* and Enterococci. For salt water, Enterococci are the best. Interestingly, fecal coliforms as a group were determined to be a poor indicator of the risk of digestive system illness. However, Massachusetts continues to use fecal coliforms as their contact recreation standard.

If you want to know whether the water meets state water quality standards, use fecal coliforms. However, if you want to know the health risk from recreational water contact, the results of the EPA studies suggest that you should consider switching to the *E. coli* method for testing fresh water. In any case, it's best to consult with the people at the Massachusetts Department of Environmental Protection, especially if you expect them to use your data. Although the protocols for *E. coli* analysis are not included in this manual, MassWWP can offer training in

these methods upon request.

Temperature

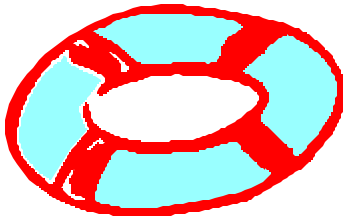
Temperature dramatically affects the rates of physical, chemical and biological processes in the water. Some of these are the solubility of compounds in water, the amount and distribution of organisms living in the water, the mixing of the water, the rates of bio-chemical reactions (including decomposition) and others. Cold water holds more oxygen than warm water.

Water temperature fluctuates considerably with the season and with lake depth. Colder, heavier lower layers may become low in dissolved oxygen if they do not mix with upper layers.

Macrophytes

These are rooted and free floating large aquatic plants (as opposed to algae). Lake groups would monitor aquatic plants to determine whether exotic invasives or even native invasives were present, and to what extent.

II. A Note About Safety



Always take time to be careful! Remember, lake sampling involves canoeing or boating in deep water and some of the analyses involve using chemicals – they are laboratory procedures and must be followed with care. Use caution or avoid harsh weather and/or dangerous windy conditions. Be attentive during sample collection to prevent loss of balance or injury from equipment. At no time should you place yourself in jeopardy for the sake of a sample.

- Use the buddy system – sample with a partner
- Plan ahead – Read and know all instructions in this manual and on your kits/equipment before going out into the field
- Prepare bottle labels before you go out into the field
- Wear rubber gloves when sampling polluted water and handling chemical reagents
- If sampling from a canoe or boat, wear your life preserver
- Note any precautions and first aid information for the reagents contained in the dissolved oxygen kits
- Take along a first aid kit
- Wear rubber gloves and safety goggles when performing lab analyses
- Avoid contact between reagent chemicals and skin, eyes, nose, and mouth
- Tightly close all reagent containers after use
- Keep all equipment and reagent chemicals out of the reach of children
- Keep this number close at hand in case of accidental exposure to chemical reagents – Poison Control

in Mass: 1-800-222-1222.

III. In the Field/In the Lab: An Overview

As we stated in the Introduction to this manual, these instructions are meant for groups who wish to sample using procedures and equipment in accordance with MassWWP recommendations. We don't mean to suggest these are the only ways to take and analyze lake samples. The advantages of using these methods are:

- We can offer training in the methods
- The UMass EAL provides quality control (QC) standards for some of the tests
- Standardization makes it easier for state agencies and others to read, evaluate, and compare your results.

In the Field

The field procedures for collecting samples consist of the following tasks:

- 1) Preparing sample containers
- 2) Preparing prior to leaving for the sampling site
- 3) Preparing at the sample site
- 4) Filling out field sheet and the label on the sample container
- 5) Collecting the sample
- 6) Returning samples and field sheets to the lab or drop-off point.

Volunteers should be provided with a sampling schedule, directions to each site, and sampling instructions. They should also have a number to call to verify that the sampling is taking place if conditions become unsafe, such as during electrical storms.

Preparing Sample Containers: Make arrangements with the coordinator to pick up sample containers and supplies before the sampling date. Otherwise, pick up your sample containers for the next sampling date each time you drop off your water samples. If some of the sample bottles are not numbered, ask the lab coordinator how to number them. Unless sample containers are to be marked with the site number, do not number them yourself.

Preparing Prior to Leaving for the Sampling Site:

Confirm the sampling date, time, and location. Volunteers should know in advance which sample sites they are covering and the dates they are sampling. They should receive a schedule of the sampling dates and times. If not, confirm with the program coordinator to avoid any misunderstanding about when and where sampling is to take place. Be sure you know which sites you will sample and that you have directions on how to get to each site.

Check Weather Conditions: If there is any question about the weather, if there is heavy rain or wind or other inclement conditions that might jeopardize the safety of samplers, it may be better not to sample. Plan for another day!

Some surveys, such as wet weather studies to determine pollution from stormwater runoff, may plan for sampling during inclement weather. In either case, it is a good idea to check with your program coordinator.

Check Equipment and Supplies:

- Sample Containers. Bring one sample container for each site to collect a water sample, one for each field blanks or duplicate, plus an extra container in case something happens to one of the container
- Small cooler with ice to keep samples cool

- Written procedures and field sheets. Be sure to understand the sampling procedures before leaving. Make sure to bring enough field sheets for the number of sites being sampled
- Rubber gloves if sampling below a wastewater treatment plant or in waters suspected to be polluted
- Towel and a dry, warm change of clothes
- Clip board and pencil (ink runs if the sheet gets wet)
- First Aid kit
- Personal flotation device
- Let someone know where you are going and when you expect to return.

Preparing At the Sample Site:

Park in a safe location! Do not block traffic!

Confirm the site location. Refer to your site directions to confirm that you have the right location.

Check lake conditions. Be aware of your own physical limitations and the difficulty collecting water under certain conditions. High winds can turn even the most placid lake into a turbulent place. Don't attempt to collect a sample if you feel the least bit of risk. Avoid dangerous situations.

Check traffic conditions. On summer weekends on large lakes, boat and jet ski numbers can be very high and make sampling dangerous. Some groups make noticeable signs they attach to their boats while sampling: Caution, water sampling underway!

Filling out field sheet and sample container labels

A copy of the MassWWP Lake Sampling field sheet is provided at the end of this section for your use. Record weather conditions and other observations on the field sheets first. Record any other observations or comments.

If taking samples, fill out the container labels with the requested information such as date, time, site #, and your name or initials.

Measuring water transparency and lake depth

Using a Secchi disk, measure the water transparency.
Then drop the disk until it is slack to record the lake depth.

Measuring water temperature

If using a probe or meter, measure the temperature at the surface and at pre-determined depths.

Collecting surface samples

There are two basic methods for collecting lake water samples: surface samples by hand, and depth samples with a Wisconsin sampler. Collect any surface samples before depth samples.

The Massachusetts Department of Environmental Protection's Standard Operating Procedures recommend that samples be collected in the following order:

1. Bacteria (coliform)
2. Dissolved Oxygen
3. pH and Temperature
4. Chemical
5. Nutrient
6. Metal

If you are sampling several or all of these, sample in this order.

Collecting depth samples

Using a Wisconsin sampler, collect samples at pre-determined depths, or at the bottom (40 cm above lake sediment) only. If using a hand-held thermometer, take water temperature measurements in the Wisconsin sampler for each depth. If collecting a total phosphorus sample at lake bottom, do that next.

Complete your field sheet AT THE SITE. If you don't complete the worksheet at the time of sampling, your observations and data will not be as accurate.

Returning Field Sheet and Sample to Lab for Analysis

After samples are collected, check to make sure they have been properly labeled, then store them for transport to the lab, in a cooler and on ice.

MassWWP Lake Sampling Form

Field Data Sheet Side 1

Date / Time: _____

Lake /Site: _____

Volunteers: _____

Weather Conditions :

The sky is:

- Clear
- Hazy
- Few Clouds
- Many Clouds
- Overcast

The air temperature is:

- Cold (below 5°C)
- Cool (6-15°C)
- Warm (16-26°C)
- Hot (27-32°C)
- Very Hot (over 32°C)

The wind conditions are:

- Calm
- Breezy
- Strong
- Gusty

The wind is generally from:

- No wind
- North
- East
- West
- South

The water surface is/has:

- Calm
- Ripple Waves
- Small Waves
- Moderate Waves
- White Caps

The lake level is:

- Above Normal
- Normal
- Below Normal

Water Conditions:

The water color seems:

- Clear
- Green
- Brown
- Yellow
- Gray
- Bluegreen

The amount of suspended sediment is:

- None
- Minimal
- Slight
- Moderate
- Substantial

The amount of aquatic weeds is:

- None
- Minimal
- Slight
- Moderate
- Substantial

The odor of the water is:

- None
- Fishy
- Musty
- Rotten egg-like
- Septic-like

Other Observed substances:

- None
- Dead Fish
- Garbage
- Oil film
- Waterfowl
- Algae Mats
- Algae Clumps
- Sediment Clumps
- Leaves/Debris

MassWWP Lake Sampling Form Field Data Sheet Side 2

Secchi Disk Depth: _____ meters 9 Viewscope was used

Lake Depth: _____ meters

CHLOROPHYLL

Secchi disk depth _____ m x 3 = _____m Number of samples taken: _____

Depth (m)	Temperature (°C)	DO*	pH/ANC*	TP*	Chl*	Bacteria*	Other:*

* Write sample ID in column at depth sample is taken, or write results for that depth if using field meter

Unusual conditions in the past week (storms, high winds, temperature extremes, etc.):

Comments to Lab Analyst:

In the Lab:

There are a couple of options once sampling is done. Either you bring or send your samples to an outside laboratory, or you analyze samples yourself.

Some analyses just can't be done in a makeshift volunteer lab with cheap kits. Examples are total phosphorus and chlorophyll, which necessitate costly spectrophotometers.

However, parameters such as pH, alkalinity, dissolved oxygen, and even bacteria can be analyzed by volunteers – whether in their kitchen, a custom-made lab in their basement, or at a school lab. The key is to pay meticulous attention to detail and quality control.

Clear counter space near the sink and sanitize it with a germ-killing product. There should be a ground-fault protected outlet if you need electricity. Make sure you have all the supplies you will need during analyses. This includes a gallon jug of distilled water, Kim wipes if you analyze pH, sponges and paper towels, scissors, data sheets, pencils, glassware, meters, chemicals and other equipment and supplies, depending which analysis you are performing. A refrigerator to store samples is advisable.

Another consideration is the safety of materials and chemicals you will use. A Material Safety Sheet accompanies purchased chemicals. You should read those carefully to learn of potential danger and how to respond to accidents. Be prepared for emergencies such as burns, spills and splashing. Do not allow children or pets in the work area during analyses until they are completed and the area is picked up and cleaned. You should also plan how to dispose of chemicals, especially if the lab is serviced by a septic system.

Organization and orderliness are key: devise a plan or method you will follow every time you are in the lab: for example, keep sample bottles in one spot before analysis, in another spot after analysis. Don't discard samples right after analysis. Wait until you are all done and confident that procedures were followed adequately. Keep your data sheet dry, be sure to report QC results on the lab sheet, and keep an eye on the clock to insure that holding times are respected.

We provide on the next page a sample lab sheet, which includes room for QC samples and field samples for dissolved oxygen, pH, and alkalinity.

Laboratory methods for analyzing dissolved oxygen, pH, and alkalinity are provided in the next section.



Massachusetts Water Watch Partnership Lab Data Sheet

Date: _____ Analyst:

Water Body:

Quality Control

QC Sample ID DO	Digits of Titrant	Measured D.O. (mg/l)

QC Sample ID pH + ANC	pH	Volume Titrated <small>(Should be 100 ml)</small>	Digits to pH 4.5 (A)	Digits to pH 4.2 (B)	Alkalinity (mg/l) <small>(2A-B)*0.1</small>

Field Samples

Sample ID & Replicate #	Secchi Depth (m)	Depth to Bottom (m)	Depth of Sample(m)	Temp. (EC)	Digits of Titrant	Measured DO (mg/l)

Sample ID & Replicate #	pH	Volume Titrated <small>(Should be 100 ml)</small>	Digits to pH 4.5 (A)	Digits to pH 4.2 (B)	Alkalinity (mg/l) <small>(2A-B)*0.1</small>

Quality Control with EAL: An Overview

At present, the Environmental Analysis Laboratory at UMass-Amherst operates a QC program for dissolved oxygen, pH, and alkalinity laboratory tests. You can order the number of samples you need by calling 413-545-2936 or emailing pkerr@chem.umass.edu or visiting http://www.umass.edu/tei/TEI_2003/envanalysis.html

Quality Control tests are conducted for 2 main reasons:

- To document the accuracy of your program's sampling results.
- To catch and correct errors **before** you analyze the field samples that volunteers have collected.

Errors can be due to mistakes in field technique, lab technique, improper or dirty equipment and supplies, or for other reasons. Most of the QC assistance provided by EAL targets laboratory procedures. However, your use of replicate samples is a form of QC, helping you to detect and minimize errors occurring in the field. See Part One, section IV, "The Importance of Quality Data" for tips on field QC, as well as Part Two, section IV, "Quality Control On Your Own: An Overview."

The DO, pH, and alkalinity QC program works as described below. **To assure the highest degree of quality control in your program, please follow this script carefully.**

Prior to each sampling date, EAL will mail each group's **lab analyst** a set of bottles containing standard solutions ("standards") of chemicals that can be analyzed (with minor procedural differences) as if they were actual field samples. The DO or pH and alkalinity values each standard represent are unknown to your lab analyst, in order to eliminate any bias in the procedure. Standards should arrive 2 - 5 days prior to your regular sampling date.

Refrigerate these standards upon receipt. However, before running the QC test, take them out and let them warm to room temperature (but do not open the bottles).

Perform a QC test on the standards, following procedures described in the appropriate QC sections of this manual. **Do this at least 2 days prior to the field sampling date.**

Call EAL with the results you obtain at 413-545-2936 Monday through Friday, to provide you with the true values. If any discrepancy exists between your results and EAL's, they'll discuss it with you and recommend taking corrective action as necessary. Such action might include a recommendation for a change in technique, mailing out replacement reagents, etc.

On the day your field samples are analyzed:

- 1) Perform a QC test on the standards before you analyze your field samples
- 2) Record the result on the lab data sheet
- 3) Analyze your field samples
- 4) If you are analyzing 10 or more field samples at a time, you must perform a second QC test on the standards after you've analyzed your field samples. If you are analyzing fewer than 10 field samples at a time, MassWWP recommends that you perform a second QC test afterwards
- 5) Record this second result on the lab data sheet

Quality Control On Your Own: An Overview

In addition to participating in the EAL QC program, each volunteer water quality monitoring group would be well served by a written QA/QC plan of its own. (If you have a QAPP, this plan will be already written.) This document spells out your sampling and analysis regimes in detail and serves as a reference for volunteers as well as a testament to the quality of your data for users. Please see Part One, section IV of this manual for a description of QA/QC procedures. However, the following general guidelines will help minimize variation among volunteers when collecting and analyzing samples:

QC During Field Sample Collection

It is important to collect samples properly. A sample is a small selection of the actual material it represents. For example, for fecal coliform analysis, the sample type, location, and timing must consider the entire population to accurately reflect the "real world." Therefore it is imperative that all samplers be familiar with, and adhere to, procedures, recommendations and safety guidelines for the collection and analysis of water quality samples. Improperly collected samples cannot be analyzed, and thus negate considerable effort and cost expended in their collection.

- Always sample at the same site and spot, marking the site with a buoy if necessary.
- Surface samples should be taken at elbow-depth, and be free from debris and surface scum.
- Keep fingers out of Wisconsin samplers and bottles and caps.
- When calibrating meters, pour some of the calibrating buffer or reagent into a clean beaker and calibrate. Do not immerse probe directly in buffer and/or reagent bottles as you may contaminate these solutions.
- Label all bottles with assigned site number, date, time.
- Once collected, samples should be kept cool and dark. This is to slow down biological activity that could alter results.
- When icing samples, put 5 inches or less of ice at bottom of cooler – don't fill cooler to top, as meltwater could enter the bottle and contaminate your sample.

QC During Sample Analysis if working with local lab or WWTP

The Massachusetts Department of Environmental Protection recommends analyzing replicate samples at 10% of the sites, for example, at one site in ten. If you sample fewer than ten sites, try to keep close to this average over the course of the season. For instance, if you sample eight sites, then one replicate per sample day is in order. If you sample five sites a month, take one replicate every two months. However, if you can and wish to, more frequent replicates will improve your QC documentation. Call MassWWP for more advice.

IV. MassWWP Recommended Procedures

For each indicator, we provide a DEP-approved method for field sampling, and lab analysis if applicable. We suggest that you photocopy and laminate these instructions so that they can be used by volunteer teams in the field or lab for reference purposes. Keep a master copy of all procedures and data sheets in a 3-ring binder. The method includes a checklist of field equipment you'll need and storage/transportation advice.

Total equipment lists and sources of equipment and supplies for each indicator appear at <http://www.umass.edu/tei/mwwp/equip.html> and in Appendix D.

MassWWP Method for Locating a Lake Sampling Site

Overview

This procedure describes how to locate lake sampling sites using the triangulation method.

1.0 Equipment List

___ Bathymetric or other map of the lake

___ Site location sheet and pencils

2.0 Protocol

2.1 Using a bathymetric map, go to your chosen site (often this is the deepest spot in the lake). You must permanently locate this spot so that you or other monitors can consistently find the site.

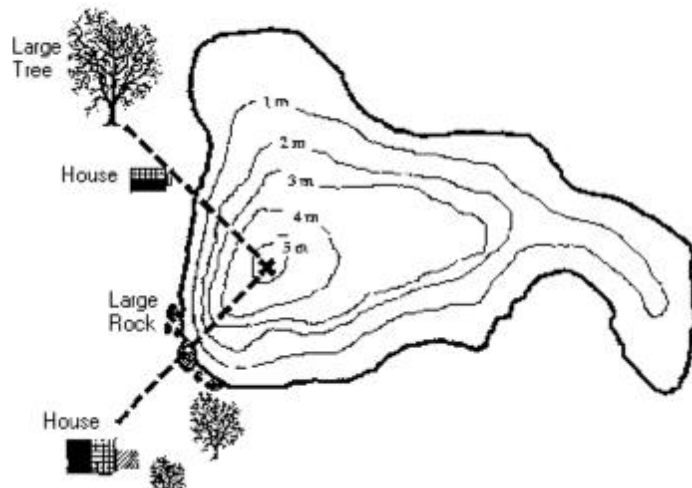
2.2 With the boat securely anchored at the site, select two permanent landmarks on shore that align one behind the other. This alignment forms an imaginary line through the objects to the site in a manner analogous to sighting a gun.

2.3 At about a 90 degree angle to this first bearing or line, select two more aligning landmarks.

2.4 All four landmarks and your sampling site should be carefully marked on your map of the lake.

Describe each landmark so that others can easily locate them. Remember that the “white house with green shutters” may be a brown house with black shutters next year, so try to find descriptive characteristics that are not likely to change, e.g. two-story brick house with wrap-around porch and two car garage on north side. Mark your sites on a field map. Include site code (e.g. #1,D)

Illustration from EPA's Volunteer
Lake Monitoring: A Methods



MassWWP Method for Lake Depth Determination

Overview

This procedure describes how to measure lake depth at any station, using a Secchi Disk with calibrated line.

1.0 Equipment List

- ___ Secchi Disk (8" black & white quadrant disk)
- ___ Calibrated line (either surveyor tape or cotton line)
- ___ Lake base map
- ___ Field data sheet and pencils

2.0 Measurement Protocol

- 2.1 Lower your Secchi Disk until the line goes slack (disk hits bottom).
- 2.2 Retrieve the line until all slack is removed.
- 2.3 Read depth on line at lake surface.
- 2.4 Record this bottom depth on your lake field sheet.

3.0 Maintenance

- 3.1 At the beginning of each sampling season, the calibrated line should be checked for shrinkage/stretching.
- 3.2 Attach a cloth tape measure to the bottom of the calibrated line. Lower the Secchi Disk as deep as you can without hitting lake bottom, feeding the tape measure so it is taut.

Compare the reading on the tape measure with the calibrated line reading. If they don't agree within 10%, you should adjust your Secchi Disk readings accordingly, or switch to a fiberglass tape.

MassWWP Method for Lake Water Transparency

Overview

This procedure describes how to measure lake water transparency using a Secchi disk.

1.0 Equipment List

- ___ Secchi disk (8" black & white quadrant disk)
- ___ Calibrated line (either surveyor tape or cotton line)
- ___ View Scope (3 feet-long, 5" wide PVC pipe, no fiberglass window)
- ___ Two spring clip clothespins
- ___ Field Data Sheet and pencils

2.0 Measurement Protocol

- 2.1 To minimize individual differences, use a viewscope.
- 2.2 Measurements should be taken between 10 a.m. and 2 p.m.
- 2.3 A team of two volunteers performs the Secchi disk measurement. Do not wear tinted or polarized sunglasses.
- 2.4 Volunteer 1 lowers the Secchi disk on the sunny side of the boat.
- 2.5 Volunteer 2 submerses the end of the viewscope and watches the lowering of the Secchi disk.
- 2.6 When the disk just disappears, volunteer 1 clips a clothespin on the calibrated line at the water's surface.
- 2.7 The disk is lowered another one or two feet and then slowly brought up toward the surface.
- 2.8 Volunteer 1 attaches another clothespin on the line at the water's surface when Volunteer 2 can see the disk again.
- 2.9 The Secchi disk depth is the average of these two measurements to the nearest tenth of a meter.
- 2.10 Repeat the measurement with the two volunteers reversing roles.
- 2.11 Record the Secchi disk reading of each viewscope operator. Average the two measurements and record on the lake field sheet. Note that if the Secchi disk hit bottom and did not disappear from view, report the result as : ">____" (insert bottom depth).

3.0 Maintenance

- 3.1** At the beginning of each sampling season, the calibrated line should be checked for shrinkage/stretching. Attach a cloth tape measure to the bottom of the calibrated line. Lower the Secchi disk as deep as you can without hitting lake bottom, feeding the tape measure so it is taut.
- 3.2** Compare the reading on the tape measure with the calibrated line reading. If they don't agree within 10%, you should adjust your Secchi disk readings accordingly, or switch to a fiberglass tape.

MassWWP Method for Lake Dissolved Oxygen

Overview

This procedure describes how to collect a lake grab sample for dissolved oxygen and how to fix the sample for transportation. Also included is the analytical determination of dissolved oxygen in the laboratory using a digital titrator.

1.0 Field Equipment List

- ___ Modified Wisconsin Sampler with 60 ml Dissolved Oxygen bottle inside
- ___ Calibrated line
- ___ Thermometer (depth-electronic or manual)
- ___ D.O. chemicals – Powder pillows #1, #2, and #3
- ___ Scissors
- ___ Field data sheet and pencils
- ___ Marble
- ___ Cooler
- ___ Ice
- ___ Frozen koolits
- ___ Zip-loc bags (1 gallon size)

2.0 Sampling Protocol

2.1 Check your data sheet for the depth of water at the sampling site. Subtract 0.4 meters (two marks on the calibrated line) from this depth. This will be the depth to collect the dissolved oxygen sample.

2.2 Lower Wisconsin sampling bottle to desired depth. Check that no bubbles are coming from the sampler.

2.3 Give a short, sharp yank on the lowering line to pull intake and outlet plugs. Wait until all bubbles disappear at the surface. (It takes about 90 seconds for the bottle to fill).

2.4 Retrieve bottle.

3.0 Fixing the Sample

3.1 The following is best done by two persons: Volunteer 1 carefully unscrews and removes sampler top to avoid spilling any water, then extracts D.O. bottle from sampler.

3.2 Volunteer 2 places the thermometer in the Wisconsin sampling bottle (not in the D.O. bottle).

Volunteer 1 holds D.O. bottle and cap.

3.3 Volunteer 2 pours D.O. reagent #1 (manganous sulfate) into D.O. bottle; then pours reagent #2 (alkaline iodide-azide) into the D.O. bottle. Do not be concerned if a small amount of water overflows the bottle, but do be careful not to introduce any bubbles.

3.4 Volunteer 1 carefully caps bottle to avoid trapping air bubbles inside (the cap is shaped like a cone to minimize this; holding the cap 1" above the lip, let go of the cap so it drops neatly inside the bottle).

3.5 Holding the D.O. bottle and with index finger on the cap to prevent its dislodging, Volunteer 1 inverts bottle 50 times (or until reagents dissolve) with a motion like turning a doorknob clockwise and counterclockwise in succession.

3.6 Allow bottle to sit for 5 minutes. A brownish flocculent material should accumulate on the bottom. [If the floc never settles, proceed with next step but make a note on field sheet that sample should be flagged.]

3.7 Meanwhile, Volunteer 2 removes thermometer from Wisconsin sampler, reads the temperature and notes it on the field data sheet.

3.8 Volunteer 1 carefully removes cap of D.O. bottle by twisting slightly and lifting.

3.9 Volunteer 2 pours reagent #3 (sulfamic acid) into bottle.

3.10 Carefully drop marble into bottle. (This step is optional and is meant to avoid air bubbles when you cap the bottle.)

3.11 Carefully drop the cap in the bottle again and repeat bottle inversion process. The liquid will turn a yellow color: the stronger the color, the more dissolved oxygen.

3.12 On lake field sheet, record sample ID, depth of sampling, and write 'DO' in Chemistry column.

4.0 Transporting the Sample

The process you have just completed has "fixed" the dissolved oxygen as a reasonably stable compound.

4.1 Store in the cooler for delivery to the lab.

4.2 If you cannot put ice directly in your cooler because you store other materials in there, use a gallon-size zip-loc bag filled with ice. Put your sample in that zip-loc bag, zip shut and place in cooler with koolit.

4.3 Deliver to lab within 8 hours of collection.

5.0 Lab Equipment List¹

- ___ Hach digital titrator
- ___ Hach sodium thiosulfate (0.2 N) titration cartridge with clean delivery tube
- ___ Starch indicator solution with drop dispenser
- ___ Clean 60 ml BOD bottle for QC sample
- ___ Fixed lake water samples
- ___ Graduated cylinders, 100 and 50 ml
- ___ Erlenmeyer flask or beaker, 100 ml
- ___ Distilled water
- ___ Magnetic stirrer and stirring bar (optional)
- ___ Lab sheet and pencils
- ___ Safety goggles and gloves

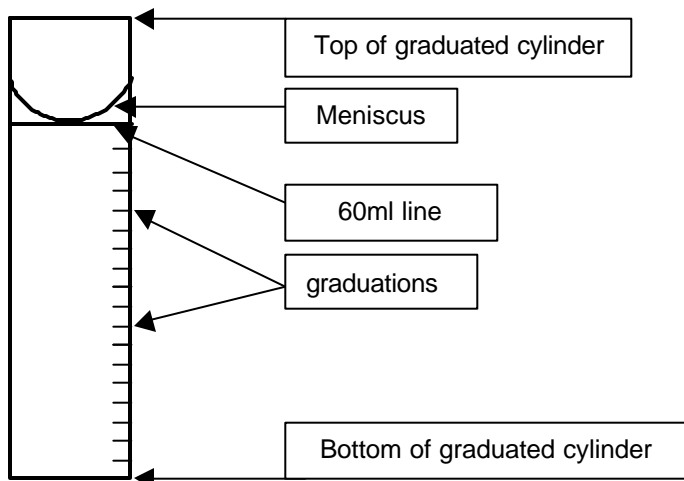
6.0 Quality Control Protocol using EAL2 QC sample

To obtain a QC sample from UMass-EAL, call the EAL Director at 413.545.2936

- 6.1 Remove QC sample from refrigerator, warm to room temperature before testing.
- 6.2 Rinse out a 100 milliliter graduated cylinder 3 times with distilled water.
- 6.3 Pour a few mls of the QC sample into it, swirling it around the cylinder, then pouring it down the drain.
- 6.4 Measure 60 ml of the QC sample in the 100 ml graduated cylinder. When you measure a liquid quantity in a cylindrical container, a "meniscus", (a shallow U shape) forms on the liquid's surface. The bottom of the U should rest on the 60 ml line.

¹ Inclusion of the trade names does not constitute endorsement by the MA Water Watch Partnership, the University of Massachusetts, or the Commonwealth of Massachusetts nor does it imply a comprehensive list of providers.

² EAL: University of Massachusetts Environmental Analysis Lab. QC samples may also be purchased from commercial laboratories



6.5 Pour the sample into a clean 60 ml BOD bottle.

6.6 Slowly empty the contents of an **alkaline iodide-azide** powder pillow (pillow # 2) into the bottle. (You don't use pillow # 1 in this QC test). Cap bottle so there is no air bubble, then invert several times. Let the solution settle, then invert several times again.

6.7 Empty the contents of a **sulfamic acid** powder pillow (pillow # 3) into the bottle. Swirl this around until the reagent is dissolved. The solution should turn yellow. This fixed sample is now ready to titrate.

7.0 Dissolved Oxygen Titration Protocol

Notes:

This method is valid for fixed QC samples and fixed lake samples.

Make sure you will use chemicals before their expiration date.

7.1 Always wear safety goggles. Rubber gloves are a good idea to avoid skin contact with chemicals.

7.2 Insert a **clean** delivery tube into a 0.2N sodium thiosulfate cartridge.

7.3 Attach the cartridge to the titrator body.

7.4 Over a sink, hold the titrator with the cartridge pointing straight up so any bubbles will drift to the top of the cartridge. Turn the delivery knob to eject air and a few drops of titrant – until there are no more bubbles present in the delivery tube or the cartridge.

7.5 Gently rinse the delivery tube off with distilled water. Do not try to flick the rinse water off the tube!

7.6 Reset the digit counter to 0.

7.7 Rinse a clean 50 ml graduated cylinder with some of your sample from the 60 ml BOD bottle.

7.8 Carefully measure exactly 50 ml of the sample in the graduated cylinder.

7.9 Rinse a 100 ml Erlenmeyer flask or beaker with distilled or deionized water.

7.10 Transfer sample from graduated cylinder to flask or beaker. Place the flask on a white surface because you will need to observe a color change.

7.11 Place the delivery tube tip into the solution and swirl gently the flask (or use a magnetic stirrer and stir bar) while turning the delivery knob. Carefully continue titrating until your sample turns a pale yellow color. If the sample abruptly turns clear, you've gone past the endpoint and selected the wrong sodium thiosulfate or sample size. Re-titrate using a larger sample volume or lower strength sodium thiosulfate.

7.12 Add a few drops of starch indicator solution and swirl to mix. This will turn your field sample dark blue.

7.13 Continue to titrate and swirl your sample, adding about 5 to 10 digits every few seconds. As the color turns to light blue, slow down, adding about 2 digits every few seconds until the blue just disappears.

7.14 Record the number of digits, but then continue titrating by adding one more digit as you look carefully for a blue swirl. Keep doing this every few seconds, one digit at a time until your last digit causes no visible change. Record the previous digit as the correct amount.

7.15 Calculate mg/l of DO: $DO = \text{Digits Required} \times 0.04$.
For example, if you saw a change at 194 digits, but none at 195, write down 194 as the units of titrant used and calculate as follows:
 $194 \times 0.04 = 7.76\text{mg/l DO}$ or 7.76 parts per million

7.16 Record your result on the lab data sheet immediately.

8.0 Troubleshooting

8.1 Some brown particles may remain when the sample is ready for titration. This can cause variable results because the chemicals in the sample are now unevenly concentrated.

TO AVOID THIS: Carefully observe the BOD bottle after adding all three reagents. If particles are visible, or if there is a deposit on the bottom of the bottle, try shaking the bottle to dissolve any remaining solid matter. If this doesn't work, use a plastic, teflon, stainless steel or glass stirring rod or spatula to stir up the bottom sediments. This should allow the acid in the solution to fully dissolve the particles.

NOTE: Make sure you rinse the stirring rod well after trying this, to avoid corrosion of your utensil.

In case you are still unable to fully dissolve the particles, proceed with the analysis but flag the results on the lab data sheet.

8.2 If your results seem wildly inaccurate, check to see you are using the sodium thiosulfate cartridge. Some folks have been known to use a sulfuric acid cartridge by mistake (that cartridge is used for pH and alkalinity analysis).

8.3 If you have titrated a quality control sample received from UMass and your value seems very high (remember, DO almost never goes above 14 mg/l in natural settings), it may be because you added powder pillow #1 to the sample before titrating. The QC test only uses pillows # 2 and # 3.

If your result is too high, you may have air bubbles in the cartridge: to avoid bubbles, advance the plunger manually or with the delivery knob until titrant is forced out of the delivery tip and the delivery tube is filled

with solution. Do this as you would a hypodermic syringe, with the delivery tip nearly straight up to remove all bubbles.

Sometimes an old cartridge can give an inaccurate reading, particularly if it has been left uncapped and allowed to evaporate somewhat. If you suspect the cartridge, try using a new one.

9.0 Figuring Percent Saturation of Dissolved Oxygen

9.1 Water can hold a limited amount of dissolved oxygen. When it holds the maximum amount it can, a water body is said to be at saturation, or 100% saturated. The dissolved oxygen (in mg/l) of water at saturation changes with temperature: the higher the temperature, the less oxygen water holds.

Massachusetts Surface Water Quality Standards express minimum criteria for dissolved oxygen in both mg/l and % saturation. To calculate % saturation of the sample, you divide the measured dissolved oxygen content of your sample by the maximum oxygen content at the temperature of your sample. The maximum oxygen content of water at various temperatures is given in Table 1 below.

$$9.2 \quad \frac{\text{Your DO Measurement}}{\text{Max. DO Concentration at Your Measured Temperature}} = \% \text{ DO Saturation}$$

For example, if you measured a DO concentration of 5 mg/l at 20°C (lake temperature) you would divide 5 mg/l by 9.1, the maximum concentration at 20° C. The percent saturation would be 55%.

Table 1. Saturation Dissolved Oxygen Concentration according to temperature

Temp °C	DO(mg/l)	Temp °C	DO(mg/l)	Temp °C	DO(mg/l)	Temp °C	DO(mg/l)
0	14.6	9.5	11.4	19	9.3	28.5	7.7
0.5	14.4	10	11.3	19.5	9.2	29	7.7
1	14.2	10.5	11.1	20	9.1	29.5	7.6
1.5	14.0	11	11.0	20.5	9.0	30	7.5
2	13.8	11.5	10.9	21	8.9	30.5	7.5
2.5	13.6	12	10.8	21.5	8.8	31	7.4
3	13.4	12.5	10.6	22	8.7	31.5	7.3
3.5	13.3	13	10.5	22.5	8.6	32	7.3
4	13.1	13.5	10.4	23	8.6	32.5	7.2
4.5	12.9	14	10.3	23.5	8.5	33	7.2
5	12.7	14.5	10.2	24	8.4	33.5	7.1
5.5	12.6	15	10.1	24.5	8.3	34	7.0
6	12.4	15.5	10.0	25	8.2	34.5	7.0
6.5	12.3	16	9.8	25.5	8.2	35	6.9
7	12.1	16.5	9.7	26	8.1	35.5	6.9
7.5	12.0	17	9.6	26.5	8.0	36	6.8
8	11.8	17.5	9.5	27	7.9	36.5	6.8
8.5	11.7	18	9.4	27.5	7.9	37	6.7
9	11.5	18.5	9.3	28	7.8	37.5	6.7

Note that this table assumes sample is taken at sea level. Oxygen levels will decrease about 4% for every 1000 feet of altitude gained. The saturation value can also vary slightly depending on barometric pressure. A stormy, low pressure day will depress levels a bit. Multiply the Dissolved Oxygen level (in ppm) by the correction factor.

Atmospheric Pressure (mmHg)	Equivalent Altitude (ft.)	Correction Factor
775	-540	1.02
760	0	1.00
745	542	.98
730	1094	.96
714	1688	.94
699	2274	.92
684	2864	.90
669	3466	.88

MassWWP Method for Lake Water Temperature

Overview

This procedure describes how to measure lake water temperature using either an alcohol thermometer or an electronic thermometer.

1.0 Equipment List

___ Depth electronic thermometer or Max-Min thermometer or:

___ Alcohol thermometer

___ Calibrated line

___ Field data sheet and pencils

2.0 Measurement Protocol

2.1 Alcohol thermometer:

2.11 Take a surface measurement on the shady side of the boat by holding the thermometer for two minutes at elbow's length below the surface.

2.12 If you collect a bottom dissolved oxygen sample, take another temperature reading as instructed in SOP L-4. **(DO NOT PUT YOUR HANDS IN THE WATER, ONLY THE TIP OF THE THERMOMETER!).**

2.13 Record both of these temperature readings on your lake field sheet.

2.2 Max-Min thermometer or electronic temperature probe:

2.2.1 Your calibrated line or cable should be weighted to ensure correct depth recording.

2.2.2 Measure the temperature at one meter intervals from top to bottom.

2.2.3 Always wait two minutes for the thermometer to reach water temperature before raising it to the surface.

2.2.4 Record temperature readings and depths on the lake field sheet.

3.0 Maintenance

3.1 All thermometers must be compared to an NIST-certified thermometer at the beginning and end of the sampling season.

3.2 Before leaving home, ensure that the alcohol column in your thermometer is not broken. If it is,

obtain a spare thermometer from coordinator.

MassWWP Method for Lake pH and Alkalinity

Overview

This procedure describes how to collect a lake grab sample for pH and alkalinity and how to measure pH and alkalinity in the laboratory using a pH-meter and a digital titrator.

1.0 Field Equipment List

___ High Density Polyethylene sample bottle, 500 ml

___ Field data sheet and pencils

___ Cooler

___ Ice

___ Frozen koolits

___ Zip-loc bag (1 gallon size)

2.0 Sampling Protocol

2.1 Rinse the sample bottle (including cap) three times with surface water at the sampling site. Be sure to empty your rinse water away from your sampling location.

2.2 Lower open sample bottle upside down to elbow length. Underwater, turn bottle upside right and let it fill up.

2.3 When no more bubbles come up, cap the bottle underwater and bring back up to the surface.

2.4 On your lake field sheet, record sample ID and write 'pH /ANC' in Chemistry column.

3.0 Transporting the Sample

3.1 Put sample in cooler with ice.

3.2 If you cannot put ice directly in your cooler because you store other materials in there, use a gallon-size zip-loc bag filled with ice. Put your sample in that zip-loc bag, zip shut and place in cooler with frozen koolit.

3.3 Deliver to lab within 8 hours of collection. Holding time for alkalinity is 14 days.

4.0 Lab Equipment List¹

- SAFETY GOGGLES
- Rubber gloves (optional)
- Wash bottle
- 100 ml graduated cylinder
- 150 ml or larger beaker
- pH meter in good working order
- Hach Digital Titrator, with clean delivery tube
- Sulfuric acid cartridge, 0.16N
- Distilled or deionized water to clean
- Lab data sheets

Optional, but preferred:

- Magnetic stirrer, with stir bar
- Ring stand and clamp to hold titrator
- Kim wipes

5.0 pH Meter Care and Maintenance

5.1 General electrode care and handling procedures are very important in your lab because pH measurements will only be as good as the condition of your electrode(s). For greater accuracy in your measurements and longer electrode life, there are a few areas of electrode care with which you should be familiar.

5.2 Storage:

5.2.1 Glass combination or separate pH and reference electrodes should be kept wet. The reference electrode requires a free-flowing junction, so be sure to maintain the reference filling solution at a level significantly above the storage or sample solution level at all times. This will provide a positive head pressure, which forces the filling solution out through the junction rather than the storage solution into the probe.

5.2.2 Whenever reference electrodes are placed in or stored in buffer solution, the vent hole MUST be open to allow the free flow of filler solution out the bottom of the electrode. Failure to keep the vent hole open and the reference solution height above the level of the buffer will allow the buffer to contaminate the filler solution and the electrode will be ruined.

¹ Inclusion of the trade names does not constitute endorsement by the MA Water Watch Partnership, the University of Massachusetts, or the Commonwealth of Massachusetts nor does it imply a comprehensive list of providers.

- 5.2.3** The filler solution should be topped up periodically if the electrode is stored in the buffer. Because the filler solution is continually bleeding out the end of the electrode, the filler solution height will decrease with time. When it falls below the level of the buffer, the electrode will be ruined. Maintaining the electrode properly will ensure a long life and proper functioning when needed. Electrodes can last ten years or more if they are well maintained.
- 5.2.4** For dry storage, the sleeve or plug should cover the filling hole to reduce the flow of filling solution. During the measurement or storage in pH 4 buffer, however, this sleeve or plug must be slid away or removed to allow flow of the reference solution into the sample.
- 5.2.5** To obtain a faster electrode response, the glass electrode should be stored in a slightly acidic solution. In the protective cap for the glass electrode, put a drop or two of pH 4 buffer and put the cap on the electrode, carefully. Distilled water extracts ions from the bulb causing a slower response; pH 7 buffer over a long time period ages the electrode slightly.
- 5.2.6** If using a separate reference electrode, the best solution would be to place the reference electrode in its own filling solution but this can be messy. Providing KCl to both sides of the junction keeps it flowing freer. To reduce the salt crust of saturated solution, an approximately 0.1 M KCl solution may be used, but for storage only. Experience indicates that simply covering the filling hole with the protective sleeve and storing dry suffices in most instances as long as the soaking procedure is followed.
- 5.2.7** For combination electrodes, store the electrode in a combined solution of approximately 0.1 M KCL and pH 4 buffer.

One day or more prior to analysis, soak both electrodes in pH 4 buffer and, during analysis, place the electrodes in the same buffer when not in use.

5.3 Reference Electrode Filling Solution

- 5.2.8** Read the instructions that came with your electrodes carefully. Saturated calomel reference electrodes such as those used by the Acid Rain Monitoring Project must not be filled with filling solutions containing silver chloride (AgCl). We use 4M KCl solutions only. However, the most common filling solution for combination electrodes is 4 M KCl saturated with AgCl. Be sure to ascertain which filling solution is correct for your electrode(s) and double check that your filling solution matches these requirements.
- 5.2.9** Permanently filled or Gel electrodes: Due to their unique micropore junction, it is recommended that they be stored hanging dry.

5.4 Preliminary Electrode Response Testing

- 5.4.1** If your electrode exhibits slow response, poor span between two buffer values or undue sensitivity to movement of the electrode, rejuvenation may be necessary to improve performance.
- 5.4.2** Response varies with the electrode and the solution it is in. Generally working electrodes reach 0.05 pH units of the final reading in buffer within 10 seconds. A stable reading (less than 0.01 pH units per minute change) should be reached in fresh water samples within a minute or two. If you have to wait too long (5 minutes or more) then the pH itself may change due to the contact of the water sample with air.
- 5.4.3** Electrodes may also require adjusting the slope to values significantly different from 100%

for two point calibration. Perform the following test if in doubt:

- Set your meter to 100% slope and room temperature
- Standardize as usual with pH 7 buffer
- Without moving the slope dial, read a pH 4 buffer. It should read between 3.85 and 4.15
- Set the slope to read pH 4, the slope should be 95% to 105%.

If your electrode exhibits either of the above problems or is sensitive to movement, rejuvenation is in order.

5.5 Glass Electrode Rejuvenation

5.5.1 To treat the bulb of the pH electrode:

EAL¹ can provide 2 bottles of acid and base (0.1N). BE CAREFUL WHEN HANDLING THESE SOLUTIONS. IF YOU GET ANY ON YOU RINSE IT OFF WITH LOTS OF WATER. To treat, simply dip the bulb into the acid and immediately into the base. Repeat this several times. Then rinse the electrode under tap water and let sit in pH 4 buffer for 2 hours. Rinse the electrodes and restandardize as you normally do with pH 7 and pH 4 buffers. You may need to do this several times a year.

5.5.2 To treat the reference electrode:

Replace the 4M KCl solution in the reference electrode and get rid of crystals that may have formed. If there are lots of crystals, then shake out the solution and put deionized pure water into the filling hole and soak the electrode tip in hot tap water for 15 minutes or so until the crystals have dissolved. Then shake all the liquid out of the filling hole in the reference electrode and refill with fresh 4 M KCl. Let the electrode sit at room temperature for 2 hours before use. Frequently add more 4M KCl solution to the reference electrode since it will continually leak out and evaporate. The solution in the electrode should be within 2 inches of the filling hole. The hole should be open when reading pH but close it when you are through for the day or else the solution will evaporate and new crystals will form. If you still have problems with slow response, try rubbing the tip on your blue jeans or on very fine (600 grit) sandpaper.

5.6 Final Test For Linearity

5.6.1 Standardize the meter as described below.

5.6.2 Rinse the electrodes and your sample cup with pure deionized water.

5.6.3 Then titrate 100.0 ml of deionized water with your 0.16N acid as follows:

5.6.4 Make sure your digital titrator is working and reset to zero.

5.6.5 Add 10 digits of acid, record digits and pH, increase acid to 20 digits, record pH.

5.6.6 Repeat in 10-digit increments until you have added 100 digits of acid and stop. Send the results to us and we will send you a report. If you want to see the results yourself, try plotting the hydrogen ion concentration ($H = 10^{(-pH)}$) vs. digits and see if the line is straight.

5.7 Movement Sensitivity

If your meter gives wild readings and is sensitive to your touch, it may not be properly grounded. Try using a three-prong power plug or attach a wire from the meter to a cold water pipe. Sometimes a problem of fluctuating readings or consistency wrong readings can be solved by disconnecting and reconnecting the electrode

¹ EAL: UMass Environmental Analysis Lab ,Blaisdell House, UMass, Amherst, MA 01003

connectors several times. Apparently an oxide layer can sometimes cause these symptoms.

6.0 Calibration¹

- 6.1 The pH meter should be standardized (calibrated) prior to sample analyses and after every 25 sample analyses. Buffers should be at room temperature (68°F).
- 6.2 Remove the electrodes from the pH 4 buffer solution where they have been soaking for at least one day.
- 6.3 Rinse with deionized water.
- 6.4 Insert the electrodes in pH 7.00 buffer and adjust the calibration dial until exactly pH 7.00 shows on the meter.
- 6.5 Remove the electrodes and rinse with deionized water.
- 6.6 Place the electrodes in pH 4.01 buffer and adjust the slope until the meter shows pH 4.01.
- 6.7 Rinse with deionized water.
- 6.8 A note on buffers. The accuracy of your pH measurement is in direct relation to the accuracy of the standard buffer solution used to calibrate your pH meter. In order to maintain a reasonable degree of accuracy when making a pH measurement, a number of precautions concerning the care and use of buffers should be observed. These include:
- 6.9 Do not use buffers after their expiration date. Mold growth, CO₂ absorption and contamination cause changes in the buffer pH.
- 6.10 Do not use buffers which have mold growth floating in the buffer.
- 6.11 Always cap the buffer container when storing to prevent contamination and reduce CO₂ pickup.
- 6.12 pH buffer values change with temperature. Be sure to measure the temperature of the buffer and look up its value at that temperature before standardizing the meter (see below).
- 6.13 Do not pour used buffer back into the bottle.
- 6.14 **Buffer Values at Various Temperatures**

Temperature		Buffers	
°C	°F	pH 4	pH 7
0	32	4.003	7.119
5	41	3.998	7.086
10	50	3.996	7.058
15	59	3.996	7.035
20	68	3.999	7.015
25	77	4.004	7.000
30	86	4.011	6.988

7.0 Quality Control Procedure using EAL²QC sample

1 Calibration steps may vary with pH-meters. Read and follow your meter's instructions.

2 QC samples may also be purchased from commercial laboratories

- 7.1 Review section 5 on pH meter care and maintenance. Check your pH meter out thoroughly each month before you proceed with analysis. Accurate use of a pH meter requires calibration with known pH buffers before each use. These buffers have a limited shelf life. It is a good idea to warm up both the analyst and the pH electrode with a trial titration before you begin QC or field sample analysis.
- 7.2 Quality control for pH and alkalinity consists of normal pH measurement and titration of a QC sample provided by UMass-EAL and sent to you prior to field collection. The procedures for analyzing QC and field samples are exactly the same.
- 7.3 **Remember, the general QC program requires that you:** Always standardize your pH meter using the pH 4 and 7 buffers prior to any analysis of QC samples or field samples.
- 7.4 Prior to measuring alkalinity, it is a good idea to check your titrator before inserting the sulfuric acid cartridge to see if the counter works properly. Some have been known to skip a digit at the ten or hundred place.
- 7.5 Run a QC sample (see section 8) 2 - 5 days prior to testing your field samples. Record your results.
- 7.6 Call UMass-EAL (contact person and phone number located on instructions that came with the QC sample) with the results of this test. Resolve any problems encountered.
- 7.7 Run a QC sample immediately before and immediately after you analyze your field samples. Record your results on the pH & alkalinity lab data sheet.
- 8.0 pH Measurement Protocol**
- 8.1 After calibrating your meter (see section 6), follow the same steps for analyzing both the field and QC samples:
- 8.2 Remove QC or field sample from refrigerator, bring to room temperature before testing (about an hour). **Keep bottle capped while it is warming up, to avoid sample coming into contact with air.**
- 8.3 Rinse a 100 ml graduated cylinder with sample water. Measure **100 ml** of the sample.
- 8.4 Rinse a 150 ml or larger beaker with distilled water and pour measured sample into it. Recap QC bottle.
- 8.5 Rinse your pH electrode in deionized or distilled water, then place the pH electrode in the beaker with sample. **pH should be analyzed within 5 minutes of uncapping the sample bottle.**
- 8.6 The sample should be stirred very gently, preferably with a magnetic stirrer. **Careful not to break the glass pH electrode!**
- 8.7 Watch for the meter reading to become stable. (This may take up to 3 minutes.)
- 8.8 When stable, but not in excess of 5 minutes, record the sample pH to the nearest 0.01 pH unit.
- 8.9 Record the pH value on the lab data sheet. Keep the pH electrode immersed in the sample as you

continue with the alkalinity procedure.

- 8.10** IF the pH of your sample is ABOVE 4.5, proceed directly to the lab procedure for alkalinity in section 9. IF the pH of your sample is at or BELOW 4.5, proceed to section 9.20 for additional steps required for the lab procedure for alkalinity.

9.0 Alkalinity Titration Protocol

- 9.1** Titrations go better if the delivery tip is positioned under the surface of the solution being titrated. For one or two samples, the titrator can be held in the hand. However, it is easier to mount the titrator on a ring stand using a clamp.
- 9.2** Try to keep the titrator in a vertical position (delivery tube down) throughout all titrations; putting the titrator horizontally on the bench between titrations may introduce bubbles in the tip.
- 9.3** **Put on your safety goggles!** Gloves are optional and at your discretion.
- 9.4** Attach a sulfuric acid cartridge to the Hach Digital Titrator. Attach a clean delivery tube to the cartridge.
- 9.5** Above a sink, advance the plunger manually or with the delivery knob until titrant is forced out of the delivery tip and the delivery tube is filled with solution. Do this as you would a hypodermic syringe, with the delivery tip nearly straight up to remove all bubbles.
- 9.6** Check for leaks where the tip connects to the cartridge.
- 9.7** Rinse the tip **gently** with distilled water; this is important because the titrant is concentrated and even a small amount left on the tube can affect your results. Do not flush titrant out of the tip.
- 9.8** Reset the digital titrator counter to zero and you are ready to titrate the 100ml sample.
- 9.9** Holding the titrator vertically, immerse the delivery tip into the sample, and begin adding titrant. Titrate until the pH is lowered to 4.5.
- 9.10** On the lab data sheet, record the number of digits of titrant it takes to get to pH 4.5.
- 9.11** Continue titrating, **without** resetting the counter, until you get to pH 4.2. Keep an eye on the digital counter to make sure it does not accidentally skip digits.
- 9.12** Record on the lab data sheet the number of digits shown on the counter.
- 9.13** After completing a titration and recording the digits of titrant used, rinse the delivery tip with distilled water. **This is easily forgotten when busy.**
- 9.14** RESET THE COUNTER before titrating the next sample.
- 9.15** Calculate alkalinity using the formulas provided in section 10.
- 9.16** **If you make a mistake and overshoot the initial 4.5 pH mark:**
- 9.17** Record the pH value you reached and the number of digits required to get there.
- 9.18** Continue titrating as above, until you reach a pH value 0.3 units below the value you reached above.

- 9.19** Record the second pH value and the number of digits. Calculate alkalinity using Method 1 in section 10.1.
- 9.20** **If the initial pH of your sample is at or BELOW 4.5:**
- 9.21** Make a note of the initial pH value on your lab data sheet.
- 9.22** Enter "0" in the 4.5 column of the lab data sheet.
- 9.23** Titrate as described in steps 1-12 above until the pH is 0.3 units below the initial pH value.
- 9.24** Enter the digits of titrant used in the 4.2 column of the data sheet.
- 9.25** Write down the pH reading where you stopped (as an accuracy check).
- 9.26** Calculate alkalinity using Method 2 in section 10.3.

10.0 pH and Alkalinity Calculation

Calculating alkalinity in mg/l CaCO₃:

- 10.1** If initial pH was above 4.5, use **Method 1**:

$$\text{Alkalinity} = (2A - B) \times 0.1.$$

where:

A = digits used to pH 4.5.

B = digits used to pH 4.2 (INCLUDING digits to get to 4.5).

Example: It took 100 digits to lower pH to 4.5, another 20 to lower to 4.2.

A = 100. B = 120.

Alkalinity = $(2 \times 100 - 120) \times 0.1 = 8.0$ mg/l CaCO₃.

- 10.2** The volume of sample you analyze affects this calculation. You should always titrate 100 ml of sample. Should the need arise to titrate 50 ml, use equation $(2A - B) \times .02$; if titrating 200 ml, use equation $(2A - B) \times 0.05$.

- 10.3** If initial pH was at or below 4.5, use **Method 2**:

$$\text{Alkalinity} = (2A - B) \times 0.1.$$

where:

A = 0

B = the endpoint # of digits.

Example:

Initial pH is 4.3. The sample required 22 digits to lower the pH to 4.0.

A = 0. B = 22.

Alkalinity = $(0 - 22) \times 0.1 = -2.2$ mg/l.

Although the negative alkalinity value may not seem to make much sense, it is an extremely important measurement for assessment of acidification. Negative alkalinity values indicate that not only has all the buffering capacity of the water been exhausted, but the water now has an excess of strong acids present

which further depress the pH.

MassWWP Method for Lake Total Phosphorus Sampling

Overview

This procedure describes how to collect a lake grab sample for later laboratory analysis of Total Phosphorus (TP).

0.0 References

This procedure was developed in concert with a site selection procedure (MassWWP Standard Operating Procedure Lakes-1 for Locating Sampling Site) and a lake depth finding procedure (MassWWP Standard Operating Procedure L-2 For Lake Depth Determination).

1.0 Surface Procedure Equipment List

- ___ One 250 ml or 125 ml Total Phosphorus sampling bottle
- ___ Field data sheet and pencils
- ___ Cooler
- ___ Ice
- ___ Frozen koolits
- ___ Zip-loc bag (1 gallon size)

2.0 Surface Sampling Protocol

- 2.1 Rinse the TP bottle and cap 3 times with lake water at the surface. Be sure not to put your fingers inside the bottle or the cap, and make sure you empty the rinse water on the other side of the boat. Try to avoid surface films or algae.
- 2.2 Uncap the sample bottle and dip it upside down in the water to elbow length.
- 2.3 Turn the bottle upside right and wait until there are no more air bubbles coming out of the bottle before removing it from the water.
- 2.4 Simultaneously squeeze the bottle and cap it.
- 2.5 On lake field sheet, write sample ID and depth taken and write 'TP' in Nutrients column.

3.0 Lake Bottom Procedure Equipment List

- ___ Wisconsin sampler
- ___ Calibrated line
- ___ One 125 ml Total Phosphorus pre-labeled bottle
- ___ Distilled water

- ___ Field data sheet and pencils
- ___ Cooler
- ___ Ice
- ___ Frozen koolits
- ___ Zip-loc bag (1 gallon size)

4.0 Lake Bottom Sampling Protocol

- 4.1** Just before sampling, use distilled water to rinse inside the Wisconsin sampler and outside the 125 ml bottle three times. Don't forget to rinse the sampler lid and the TP bottle cap with distilled water as well.
- 4.2** Place the TP bottle inside the Wisconsin sampler, with the long tube inserted in the TP bottle.
- 4.3** Lower the Wisconsin sampler to 0.3 m (1 ft) above lake bottom and pull ropes to fill TP bottle.
- 4.4** Retrieve sampler back into the boat.
- 4.5** Inspect water inside Wisconsin sampler for suspended sediment that may have been stirred by this or previous activity. If suspended sediment is present, the procedure needs to be repeated after conditions have returned to normal.
- 4.6** If water in sampler is clear, remove TP bottle from Wisconsin Sampler: use extreme care not to touch the inside of the TP bottle or its cap (if you do, rinse again and repeat procedure as described above).
- 4.7** Squeeze the TP bottle and cap it simultaneously.
- 4.8** Check 'TP sample taken' on lake field sheet and specify at what depth.

5.0 Transporting the Sample¹

- 5.1** Bottle should be pre-labeled with lake name, site, date, and analysis requested (TP).
- 5.2** Place sample in cooler with ice.
- 5.3** If you cannot put ice directly in your cooler because you store other materials in there, use a gallon-size zip-loc bag filled with ice. Put your sample in that zip-loc bag, zip shut and place in cooler with frozen koolit.
- 5.4** Back home, place sample in freezer.
- 5.5** Deliver frozen sample to lab. You can mail samples overnight in a small cooler, with insulation and frozen koolits, to: UMass EAL, Blaisdell House, UMass, Amherst, MA 01003

¹ Sample handling procedures are specific to the UMass EAL. If your samples will be analyzed by another lab, obtain that lab's handling procedures, as preservation methods vary with labs (e.g. acidifying rather than freezing samples).

5.6 Holding time for frozen sample is 12 months.

MassWWP Method for Lake Chlorophyll *a*

Overview

This procedure describes how to collect a lake grab sample for chlorophyll *a* and how to filter the sample onto a glass filter for later laboratory analysis.

1.0 Field Equipment List

- ___ 1 or 2 1-liter high density polyethylene sample bottles
- ___ Field data sheet and pencils
- ___ Cooler
- ___ Ice
- ___ Frozen koolits
- ___ Zip-loc bags, 1 gallon size

2.0 Sampling Protocol

- 2.1 Rinse a 1-liter sample bottle (including cap) three times with surface water at the sampling site. Be sure to empty your rinse water away from your sampling location.
- 2.2 Uncap the sample bottle and dip it upside down in the water to elbow length.
- 2.3 Turn the bottle upside right and wait until there are no more air bubbles coming out of the bottle before removing it from the water.
- 2.4 Cap and place in cooler with ice (or in an ice-filled zip-loc bag within the cooler).
- 2.5 If Secchi depth is greater than 3 meters, fill another sample bottle in the same manner.
- 2.6 On lake field sheet, write sample ID, how many bottles were filled, and check 'Chlorophyll *a*' column.

3.0 Filtering Equipment List¹

- ___ Distilled water
- ___ Graduated cylinder, 500 ml
- ___ Filter Apparatus, magnetic, 47 mm

¹ Filtering samples is required if analysis is done at UMass EAL. If you are using a different lab, obtain that lab's SOPs for sample handling

- ___ Filtering Flask, 1000 ml
- ___ Vacuum pump with gauge, hand operated
- ___ Glass Fiber filters, 47 mm
- ___ Forceps
- ___ Aluminum foil
- ___ Air-drying box

4.0 Filtering Protocol

- 4.1** Back on shore and in subdued light, set up the filter apparatus with vacuum flask, filter holder, glass fiber filter, and filling funnel.
- 4.2** Using a clean graduated cylinder, measure a precise volume and record the amount on your field data sheet.
- 4.3** Pour that measured sample in the clean filling funnel and operate the hand vacuum pump until the vacuum is 15" of vacuum units. It may require some patience to filter an adequate amount of water.
- 4.4** Review the field data sheets to learn the Secchi disk depth at the sample site. Use the following chart to determine the appropriate volume to filter (to provide sufficient chlorophyll for analysis and minimize your time in filtering):

<u>Secchi Depth</u>	<u>Volume to filter</u>
Less than .2 meters	100 ml
more than .2 meters; less than 1.0 meter	300 ml
more than 1.0 meter; less than 1.6 meters	500 ml
more than 1.6 meters; less than 3.0 meters	1000 ml
more than 3.0 meters	1500 ml

- 4.6** Despite the seeming certainty of the above table, you should be guided by common sense. The table above is a guide to a reasonable compromise. If you can filter more water without seriously increasing the filtering time, do so. If the filter is noticeably green and you haven't filtered the specified amount, you have still probably got enough for EAL to analyze. **It is most important that you record volume filtered to the nearest milliliter, in 'Notes' on the field data sheet.**
- 4.7** The above instructions describe a rule of thumb related to the Secchi disk transparency but an even better guide is a visible quantity of green or greenish brown on the filter. If you don't see more than a tinge, filter more sample. Be sure to keep track of the total amount filtered. Filtering may significantly slow in the later stages as the filter plugs up with material.
- 4.8** When all the measured sample has been filtered, remove the filling funnel, and carefully remove the filter from the filter holder using forceps.
- 4.9** Fold the filter in half (green side in), and place in the air drying box.
- 4.10** Rinse all equipment (cylinder, filtering apparatus, and forceps) with distilled water before processing additional samples.

- 4.11 Keep the lid on while you're filtering the next sample. Make sure to note which filters are placed where in the air drying box.
- 4.12 When all samples have been filtered, the drying box is plugged in.
- 4.13 Air dry the sample filters for at least 45 minutes or until they are dry.
- 4.14 Remove filters with forceps and place in aluminum foil.
- 4.15 Label the aluminum foil with sampler name, lake name, date, site and volume of water filtered.
- 4.16 These may be mailed, first class, to the Environmental Analysis Lab, Blaisdell House, UMass, Amherst, MA 01003 attn: Lab Director

MassWWP Method for Lake Bacteria Sampling

Overview

This procedure describes how to collect a lake grab sample for bacteria analysis either by wading near-shore or boating to an open water site. The field sheet mentioned in this SOP is MassWWP's Lake Field Data Sheet¹.

1.0 Equipment / Supply List

- ___ Sterile pre-labeled High Density Polyethylene (HDPE) bottle, 250 ml
- ___ Pair of latex gloves
- ___ Hip boots or chest waders (near-shore sampling only)
- ___ Rinse water and towel
- ___ Field data sheet and pencils
- ___ Cooler
- ___ Cubed ice
- ___ Frozen koolit
- ___ Zip-loc bag (1-gallon size)
- ___ 1 personal flotation device per person (boat sampling only)

2.0 Sampling Protocol

- 2.1 Wash hands with rinse water and dry with towel before starting sample run. If you sample in an area that may have high fecal levels, rinse hands before handling the next sample bottle.
- 2.2 Be careful not to touch your hands to yourself before you have cleaned them in order to avoid coming into contact with pathogens. If you are sampling from waters known to be contaminated with sewage, wear latex gloves to protect yourself.
- 2.3 Use pre-labeled sterile bottle (obtained from program coordinator or laboratory).
- 2.4 Sample should be taken from water representative of conditions you want to characterize (e.g. bathing beach, whole lake, tributary mixing area...). The water must be deeper than the sample bottle and free of surface scum and debris. Note that sampling from the lakeshore (as opposed to wading in) is discouraged, as it can result in non-representative samples.
- 2.5 Near shore sampling: Carefully wade into the lake to a depth of about 2 feet and avoid stirring up

¹ Available at <http://www.umass.edu/tei/mwwp/acrobat/mwwplakedatasheet.pdf>

bottom sediment. Stop and wait for pre-disturbance (from wading in) conditions to return before taking sample. If a dock is present, it is acceptable to sample from there, provided the water depth is at least two feet.

Boat sampling: Be sure to sample where the lake is more than 1 foot deep, and drop anchor on the side opposite to where you will collect sample. Wait for any disturbance of the bottom to settle and dissipate.

2.6 Place upright, capped sample bottle under the surface of the water about 6 inches. Do not rinse the bottle. Slowly uncap and let it fill to capacity under the water. With hands away from the bottle opening, bring the bottle up and out of the water, pour off a little water to leave some air space (approximately 1/2 inch) in the bottle. Cap the bottle and tighten.

2.7 Complete field data sheet immediately after collecting sample. On field sheet, record sample ID in the 'Bacteria' column for the appropriate depth. Include observations, such as presence of dogs in water, in the "other observations" section on side 1 of the field data sheet.

3.0 Transporting the Sample

3.1 Place the bottle in a clean zip-loc bag, place in a cooler filled with cubed ice. Frozen koolits are optional in addition to the ice.

3.2 Deliver to lab within 6 hours of collection.

Part Three: The rest of the story

Your volunteer monitoring program does not end with the production of data. Once analyses are done and raw numbers are available, the rest of the program begins: data management, interpretation, and presentation, followed by action if appropriate, and ending with program evaluation. Separate manuals have been written on those steps of volunteer monitoring, so we will only review those steps briefly here.

Data Management

Loose field and lab sheets scattered on a desk or packed in a box don't help your program in any way. To answer your study question, you must use your results. Data management begins in the field, making sure results are recorded properly on field data sheets. It also involves quality control as someone in the program reviews field and lab data sheets. Raw data gets entered in electronic form, whether in a spreadsheet or a database, gets checked again, and finally summarized into tables, graphs or charts. See the MassWWP [Data Management Manual](#) (1999) for more details.

Data Interpretation

Once you have the data summarized, it is much easier to make sense of it. For example, if your question was: "Does the lake meet state water quality standards for primary contact recreation?", a graph showing the results with a line representing the standard (200 colonies / 100ml, for example) will give you an immediate answer. Figuring out why the standard is not met takes more work, and we refer you to MassWWP's 2002 [Data Interpretation Manual](#) for step-by-step instruction.

Data Presentation

Most groups share their results once they have answered their study questions. Whether it's through a newsletter, a web site, a formal report to the Massachusetts Department of Environmental Protection, a presentation to the Conservation Commission or via an exhibit at the Pond Fair, data presentation is a very important step in a volunteer monitoring program: it not only shows the volunteers the fruits of their labor, it also positions you for the next and perhaps most important step: Action! For how-to instructions on data presentation, consult [Ready, Set, Present! A data presentation manual for volunteer water quality monitoring groups](#) (MassWWP, 1999).

Action

So far all the steps have not resulted in any real positive change for the lake. Data presentation is where a lot of groups stop, just when they have all the tools in hand to try and improve conditions. Action here refers to any number of concrete steps:

- Apply for a grant to manage the lake
- Manage the lake (harvest aquatic plants, do a drawdown...)
- Prepare a new town bylaw to protect the watershed
- Raise funds to buy and preserve a key parcel of land
- Close the beach
- Work with landowners to fix their septic systems, install best management practices on their farm, grow vegetated buffers on the lake's edge
- Develop a citizen's education campaign on invasive aquatic plants
- And so on...

MassWWP does not provide assistance on this type of work, but we suggest you contact the Congress of Lakes and Ponds (see Appendix C), the Massachusetts Department of Environmental Management (perhaps

soon to be incorporated into a Department of Environmental Conservation), the North American Lake Management Society (NALMS <http://www.nalms.org/>) and its New England Chapter, or even your regional planning agency. All those can explain what options you have to improve or protect your lake.

Evaluation

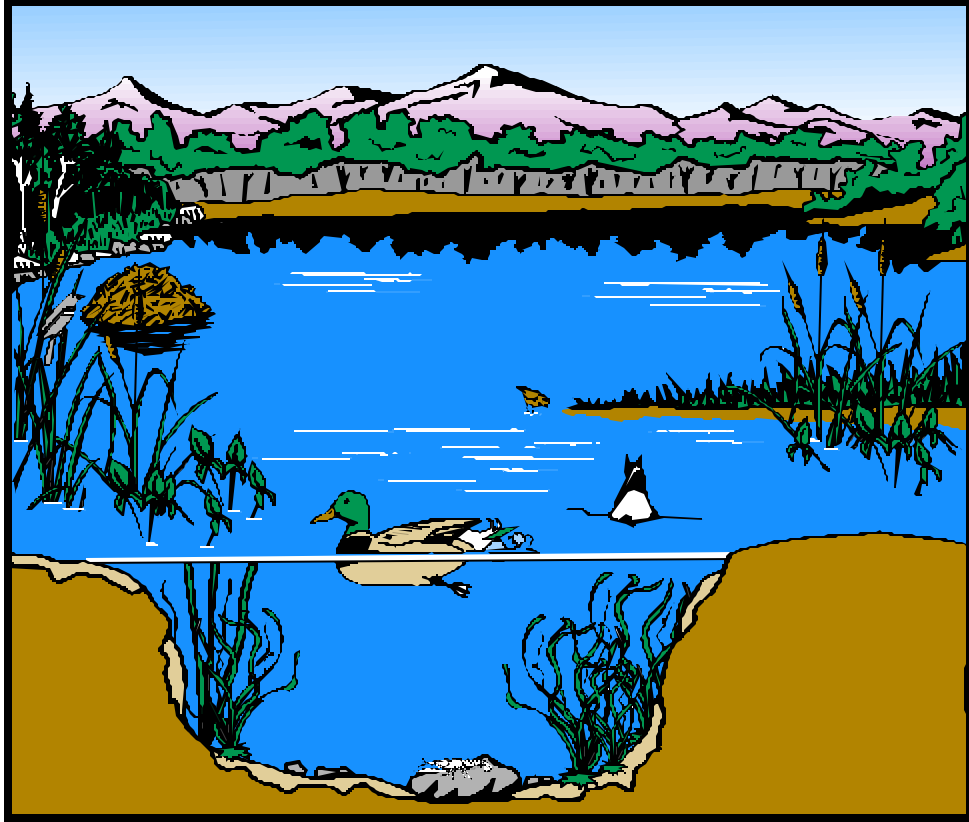
Ideally at the end of each monitoring season, the program coordinator pulls together the Technical Advisory Committee or another group to evaluate the program: what went well, what went wrong, should anything be modified to improve the program or redirect it in a more appropriate track?

We are not talking about data quality control here, but rather about the goals of the program and whether they are being met.

- Was the study realistic, should it be narrowed or expanded?
- Were enough resources allocated to the program?
- Was the timing or timeline appropriate?
- Is the study completed and can it be terminated?
- Was the focus adequate or should the program revised? In what ways?

You are trying here to ensure that your group is making good use of its resources and running a credible program that is meeting your goals. In most cases, you will need to tweak a few aspects of the program and continue the monitoring in the future. You will probably find that your volunteer monitoring program gives much more than data: a better educated constituency perhaps, a more professional image, an increased membership; the benefits are multiple and well worth your efforts.

Good luck and don't hesitate to contact MassWWP for assistance!



Appendices

Appendix A: Further Reading

American Public Health Association. 1998. Standard Methods for the Examination of Water and Wastewater. 20th ed. American Public Health Association, 1015 15th Street, NW, Washington, DC 20005.

Crow B., CB Hellquist, 2000 Aquatic and Wetland plants of northeastern North America

Davis, J., Storer, B., Zisette, R. THE WASHINGTON LAKE BOOK. Washington State Lake Protection Association (WALPA) June 1995. Reprinted Washington State Department of Ecology, 1997
<http://www.ecy.wa.gov/programs/wq/plants/lakes/walpa.html>.

Godfrey P., J. Schoen, G. Dates. Massachusetts Volunteer Monitor's Guidebook to Quality Assurance Project Plans, 2001. Mass DEP, 627 Main St 2nd floor Worcester, MA 01608

Hach Company, Water Analysis Handbook, 4th edition 2002.

Keith, L.H. 1990. Principles of Environmental Analysis. *Analytical Chemistry* 55:2210-2218

Kelly W., A Guide to Aquatic Plants in Massachusetts New England Aquarium, Central Wharf Boston MA 02110. Order copies from 617-973-0249.

Maine Dept of Environment Protection and Congress of Lake Associations, 1992 A Citizen's Guide to Lake Watershed Surveys. How to conduct a nonpoint source phosphorus survey State House Station 17 Augusta, ME 04333

Massachusetts Department of Environmental Protection, 2000 Massachusetts Surface Water Quality Standards. State Bookstore, State House, Room 116 Boston, MA 02133

Massachusetts Water Watch Partnership, 1999. Data Management Manual for Volunteer Monitors. Blaisdell House, University of Massachusetts Amherst, MA 01301
<http://www.umass.edu/tei/mwwp/acrobat/mgtmnl.pdf>

Massachusetts Water Watch Partnership, 1999. Ready, Set, Present! A data presentation manual for volunteer water quality monitoring groups
Blaisdell House, University of Massachusetts Amherst, MA 01301
<http://www.umass.edu/tei/mwwp/datapresmanual.html>

Massachusetts Water Watch Partnership, 2002. Data Interpretation Manual. Blaisdell House, University of Massachusetts Amherst, MA 01301
<http://www.umass.edu/tei/mwwp/acrobat/data%20interp%202002.pdf>

Minnesota Water Resources Research Center, A primer on Limnology
University of Minnesota Extension Service. Water Quality Program. 173 McNeal Hall. 1985 Buford Avenue. St Paul MN 55108 (612) 625-2282

Schoen, J, MF Walk 2002, Data Interpretation Manual MassWWP Blaisdell House, University of Massachusetts Amherst, MA 01301

Schoen, J., MF Walk, M. Tremblay 1999, Ready, Set, Present! a data presentation manual for volunteer water quality monitoring groups MassWWP Blaisdell House, University of Massachusetts Amherst, MA 01301

University of Wisconsin Cooperative Extension, 2002: Interpreting Lake Water Quality Data: A Citizen's Guide (G3582), Cooperative Extension Publications 45 North Charter Street Madison, WI 53715

U.S. Environmental Protection - 1996, The Volunteer Monitor's Guide To Quality Assurance Project Plans, Office of Wetlands Oceans and Watersheds - 4503F EPA 841-B-96-003

U.S. Environmental Protection Agency. 1998 Starting Out in Volunteer Water Monitoring United States Environmental Protection Agency Office of Water (4503F), Washington, DC 20460 EPA 841-B-98-002;

U.S. Environmental Protection Agency, Office of Water. 1991. Volunteer Lake Monitoring EPA440-4-91-002

The Volunteer Monitor. 1990+. River Network, 520 SW 6th Ave, Suite 1130, Portland, OR 97204-1535
Volunteer Environmental Monitoring Network, Characteristics of a Successful Volunteer Water Quality Program, 181 Canal Street, 3rd Floor P.O. Box 1377 Lawrence, MA 01842 Phone: 978-681-5777

Appendix B: Massachusetts Water Quality Standards

314 CMR 4.00:

4.05: Classes and Criteria

(1) Classes and Uses - The surface waters of the Commonwealth shall be segmented and each segment assigned to one of the Classes listed below. Each class is identified by the most sensitive, and therefore governing, water uses to be achieved and protected. Surface waters may be suitable for other beneficial uses, but shall be regulated by the Department to protect and enhance the designated uses. In accordance with 314 CMR 4.03(4), the Department may designate a partial use subcategory for these Classes. A partial use designation may be appropriate where waters are impacted by combined sewer overflows or stormwater discharges. Partial use is described in 314 CMR 4.06(1)(d)9.

(2) Criteria - Minimum criteria for each Class accompany each class description. Additional minimum criteria for all surface waters are listed in 314 CMR 4.05(5) and shall be applicable unless criteria specified for individual classes are more stringent.

Criteria for segments designated for partial use in 314 CMR 4.06(3) shall be site specific but, to the maximum extent feasible, shall be the same as the criteria assigned to the Class. For segments so designated because of the impacts of CSO or stormwater discharges, criteria may depart from the criteria assigned to the Class only to the extent necessary to accommodate the technology-based treatment limitations of the CSO or stormwater discharges.

(3) Inland Water Classes:

(a) Class A -

These waters are designated as a source of public water supply. To the extent compatible with this use they shall be an excellent habitat for fish, other aquatic life and wildlife, and suitable for primary and secondary contact recreation. These waters shall have excellent aesthetic value. These waters are designated for protection as Outstanding Resource Waters under 314 CMR 4.04(3).

1. Dissolved Oxygen -

- a. Shall not be less than six mg/l unless background conditions are lower;
- b. natural seasonal and daily variations above this level shall be maintained; levels shall not be lowered below 75% of saturation due to a discharge; and
- c. site-specific criteria may apply where back-ground levels are lower than specified levels or to the hypolimnion of stratified lakes where the Department determines that designated uses are not impaired.

2. Temperature -

- a. Shall not exceed 68°F (20°C) in cold water fisheries, nor 83°F (28.3°C) in warm water fisheries, and the rise in temperature due to a discharge shall not exceed 1.5°F (0.8°C); and
- b. natural seasonal and daily variations shall be maintained. There shall be no changes from background conditions that would impair any use assigned to this Class, including site-specific limits necessary to protect normal species diversity, successful migration, reproductive functions or growth of aquatic organisms.

3. pH -

Shall be in the range of 6.5 through 8.3 standard units but not more than 0.5 units outside of the background range. There shall be no change from background conditions that would impair designated uses.

4. Fecal Coliform Bacteria -

Shall not exceed an arithmetic mean of 20 organisms per 100 ml in any representative set of samples, nor shall 10% of the samples exceed 100 organisms per 100 ml. More stringent regulations may apply [see 314 CMR 4.06(2)(d)1.]

5. Solids -

These waters shall be free from floating, suspended and settleable solids in concentrations or combinations that would impair any use assigned to this class, that would cause aesthetically

objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom.

6. Color and Turbidity -

These waters shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this class.

7. Oil and Grease -

These waters shall be free from oil and grease, petrochemicals and other volatile or synthetic organic pollutants.

8. Taste and Odor -

None other than of natural origin.

(b) Class B -

These waters are designated as a habitat for fish, other aquatic life, and wildlife, and for primary and secondary contact recreation. Where designated they shall be suitable as a source of public water supply with appropriate treatment. They shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses. These waters shall have consistently good aesthetic value.

1. Dissolved Oxygen

- a. Shall not be less than 6.0 mg/l in cold water fisheries nor less than 5.0 mg/l in warm water fisheries unless background conditions are lower;
- b. natural seasonal and daily variations above these levels shall be maintained; levels shall not be lowered below 75% of saturation in cold water fisheries nor 60% of saturation in warm water fisheries due to a discharge; and
- c. site-specific criteria may apply where background levels are lower than specified levels, to the hypolimnion of stratified lakes or where the Department determines that designated uses are not impaired.

2. Temperature -

- a. Shall not exceed 68°F (20°C) in cold water fisheries nor 83°F (28.3°C) in warm water fisheries, and the rise in temperature due to a discharge shall not exceed 3°F (1.7°C) in rivers and streams designated as cold water fisheries nor 5°F (2.8°C) in rivers and streams designated as warm water fisheries (based on the minimum expected flow for the month); in lakes and ponds the rise shall not exceed 3°F (1.7°C) in the epilimnion (based on the monthly average of maximum daily temperature); and
- b. natural seasonal and daily variations shall be maintained. There shall be no changes from background conditions that would impair any use assigned to this Class, including site-specific limits necessary to protect normal species diversity, successful migration, reproductive functions or growth of aquatic organisms.

3. pH -

Shall be in the range of 6.5 through 8.3 standard units and not more than 0.5 units outside of the background range. There shall be no change from background conditions that would impair any use assigned to this Class.

4. Fecal Coliform Bacteria -

Shall not exceed a geometric mean of 200 organisms per 100 ml in any representative set of samples nor shall more than 10% of the samples exceed 400 organisms per 100 ml. This criterion may be applied on a seasonal basis at the discretion of the Department.

5. Solids -

These waters shall be free from floating, suspended and settleable solids in concentrations and combinations that would impair any use assigned to this Class, that would cause aesthetically objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom.

6. Color and Turbidity -

These waters shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this Class.

7. Oil and Grease -

These waters shall be free from oil, grease and petrochemicals that produce a visible film on the surface of the water, impart an oily taste to the water or an oily or other undesirable taste to the edible portions of aquatic life, coat the banks or bottom of the water course, or are deleterious or become toxic to aquatic life.

8. Taste and Odor -

None in such concentrations or combinations that are aesthetically objectionable, that would impair any use assigned to this Class, or that would cause tainting or undesirable flavors in the edible portions of aquatic life.

c) Class C -

These waters are designated as a habitat for fish, other aquatic life and wildlife, and for secondary contact recreation. These waters shall be suitable for the irrigation of crops used for consumption after cooking and for compatible industrial cooling and process uses. These waters shall have good aesthetic value.

1. Dissolved Oxygen -

- a. Shall not be less than 5.0 mg/l at least 16 hours of any 24-hour period and not less than 3.0 mg/l at any time unless background conditions are lower;
- b. natural seasonal and daily variations above these levels shall be maintained; levels shall not be lowered below 50% of saturation due to a discharge; and
- c. site-specific criteria may apply where background levels are lower than specified levels, or to the hypolimnion of stratified lakes where the Department determines that designated uses are not impaired.

2. Temperature -

- a. Shall not exceed 85°F (29.4°C) nor shall the rise due to a discharge exceed 5F (2.8°C); and
- b. Natural seasonal and daily variations shall be maintained. There shall be no changes from background conditions that would impair any use assigned to this Class, including the site-specific limits necessary to protect normal species diversity, successful migration, reproductive functions or growth of aquatic organisms.

3. pH -

Shall be in the range of 6.5 through 9.0 standard units and not more than 1.0 standard unit outside of the naturally occurring range. There shall be no change from background conditions that would impair any use assigned to this Class.

4. Fecal Coliform Bacteria -

Shall not exceed a geometric mean of 1000 organisms per 100 ml, nor shall 10% of the samples exceed 2000 per 100 ml.

5. Solids -

These waters shall be free from floating, suspended and settleable solids in concentrations and combinations that would impair any use assigned to this Class, that would cause aesthetically objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom.

6. Color and Turbidity -

These waters shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this Class.

7. Oil and Grease -

These waters shall be free from oil, grease and petrochemicals that produce a visible film on the surface of the water, impart an oily taste to the edible portions of aquatic life, coat the banks or bottom of the water course, or are deleterious or become toxic to aquatic life.

8. Taste and Odor -

None in such concentrations or combinations that are aesthetically objectionable, that would impair any use assigned to this Class, or that would cause tainting or undesirable flavors in the edible portions of aquatic life.

Appendix C: Volunteer Monitoring Service Providers

Bridgewater State College Watershed Access Lab

<http://www.bridgew.edu/wal/>

Dr. Kevin Curry kcurry@bridgew.edu (508)531-2082

Biology Dept., Bridgewater State College, Bridgewater, MA 02325

Kim McCoy (508)531-2630 oversees scheduling & use of WAL by teachers and Volunteer Monitoring Groups. She can be contacted at: kmccoy@bridgew.edu

Geographic Area Served: Southeastern Mass.

Located in the Moakley Center at the Bridgewater State College in Bridgewater, MA and headed by Dr. Kevin Curry, this newly formed lab mainly provides services for the Taunton River Watershed, but also assists teachers and volunteer groups in Southeastern Massachusetts.

Services provided:

- Laboratory Analyses for Dissolved Oxygen, pH, fecal coliform bacteria, nitrate, and reactive phosphorus. (Costs depend on grant support and program participation)
- Assistance on macroinvertebrate identification for biomonitoring
- Mass GIS site maps
- Access to the lab for trained teachers. You do analyses for the above parameters under supervision of the lab director

Charles River Watershed Association

<http://www.crwa.org/>

Peg Savage savage@crwa.org (617)965-5975

2391 Commonwealth Ave., Auburndale, MA 02166-1773

Geographic Area Served: Boston Harbor (Mystic), Charles, Ipswich, and North Coastal watershed

The Charles River Watershed association seeks to protect and enhance the health, beauty and enjoyment of the Charles River and its tributaries.

Services provided:

- Water testing laboratory (some analyses provided free or at a reduced cost to volunteer groups)
- GIS Mapping
- Quarterly newsletter called The Streamer
- Assistance to volunteer monitoring groups with QAPPs, sampling design, start-up, data analysis, etc.

Environmental Analyses Laboratory

<http://www.umass.edu/tei/wrrc/EAL.shtml>

Dr. Peter Kerr pkerr@chem.umass.edu (413)545-2936

Blaisdell House University of Massachusetts Amherst, MA 01003-0820

Geographic Area Served: Statewide for quality control, western Mass for analyses

EAL conducts a wide variety of inorganic analyses. The samples might include water, sediment or tissue samples.

Services provided:

- Quality control program for pH, ANC, and DO
- Water sample analysis for Total Phosphorus and Chlorophyll

- Metal analysis
- Chemical analyses advice

Coastal Zone Management

<http://www.state.ma.us/czm/czm.htm>" Massachusetts
Christian Krahforst Christian. Krahforst@state.ma.us (617)626-1216
251 Causeway St. Suite 900 Boston, MA 02114-2119

Geographic Area Served: Massachusetts Coastal Areas

The goal of the Massachusetts Coastal Zone Management Office (MCZM) is to balance competing interests by protecting the natural resources of the coast while promoting responsible economic development.

Services provided:

- Volunteer Coastal Monitoring Grants Program
- Technical services for recipients of the citizens grant program
- Answer questions relating to coastal monitoring

Lakes and Ponds Association - West (LAPA-West)

<http://www.lapa-west.org/>
Kathy I. Regan timesave@bcn.net (413)528-6133.

Geographic Area Served: Western Massachusetts (Connecticut River and west)

Services provided (to LAPA_West members):

- Loan of pH, conductance, temperature and dissolved oxygen meters
- Lake Steward Gene Chague will come to your lake to help with monitoring
- Symposium on lake and watershed issues
- Workshops on specific issues
- Training in lake monitoring techniques
- DEP-approved lake monitoring methods

Massachusetts Congress of Lakes and Ponds, Inc. (COLAP)

<http://www.colap.com/>
Carol Hildreth, Secretary of the Board hildrethcr@aol.com (800)845-2769
135 Washington St. Holliston, MA 01746

Geographic Area Served: Statewide

COLAP is a non-profit organization dedicated to preserving the aesthetic, recreational and commercial values of our lakes and ponds through maintenance and improvement of such environmental factors as: water quality, lake water levels, watershed ecology, water and boating safety, agricultural soils practices, shoreline woodland development, residential building standards, and promotion and development of environmental quality standards essential for satisfactory life styles and conditions in the natural community.

Services provided:

- Annual Lake and Pond Restoration and Management Workshop, held the third or fourth Saturday in January in Leicester, MA
- Annual Meeting in the Spring
- Occasional workshops on timely topics
- Publication of a quarterly newsletter, Lake Wisdom
- Assistance to lake and pond associations in getting established and keeping healthy

- Loan of Monitoring Equipment (<http://www.lapa-west.org> LAPA-West)

Massachusetts Water Watch Partnership

mwwp@tei.umass.edu

Marie-Françoise Walk

mfwalk@tei.umass.edu

(413)545-5531

Blaisdell House, UMass Box 30820, Amherst, MA 01003

Jerry Schoen

jschoen@tei.umass.edu

(413)545-5532 FAX: (413)545-2304

Geographic Area Served: Statewide

The Massachusetts Water Watch Partnership (MassWWP) provides training and other technical assistance to citizen organizations who conduct water quality monitoring programs on the lakes, rivers, and estuaries of Massachusetts

Services provided:

- Development of standardized protocols for volunteers measurement of a variety of physical, chemical, and biological water quality parameters
- Production of manuals and videos on monitoring methods
- Consultations on study designs and quality assurance project plans for individual watershed monitoring surveys
- A quality control program for field sampling and laboratory methods
- Workshops to train citizen groups to sample, analyze, interpret data and present findings to diverse audiences
- Conferences for monitors to meet, learn, and share experiences
- Monitoring equipment on loan
- Distribution of publications and loan of video tapes

New England Aquarium

mwc@neaq.org

Mark Chandler (617)973-5274

Central Wharf, Boston, MA 02110-3399

Geographic Area Served: Greater Boston Area, some New England-wide

The New England Aquarium is a not-for-profit institution whose mission is to promote, protect and preserve the world of water. The New England Aquarium worked with a few volunteer monitoring groups in 1997 to help them develop biological monitoring in their ponds and lakes. In 1998 they planned to lead a training session on sampling and identification of macroinvertebrates, plants and fish in the Parker River and Ipswich River watersheds.

Services provided:

- Biological monitoring training (limited opportunities)
- Help with identification of aquatic plants, macroinvertebrates, and fish (you come to the aquarium with your specimens)
- Help with biological monitoring data collection strategies
- Help with biological monitoring data interpretation

River Network Vermont

<http://www.riverwatch.org/>

Geoff Dates gdates@rivernetwork.org (802)223-3840

153 State Street Montpelier, VT 05602

Geographic Area Served: Nationwide

Harnessing the power of people and communities to monitor, restore, and protect the world's rivers

Services provided:

- Workshops
- Organizational and technical support and consultation
- Publications
- Other tools that help groups and individuals monitor and protect rivers

Riverways

http://www.state.ma.us/dfwele/river/riv_toc.htm

Cindy Del Papa Cindy.DelPapa@state.ma.us (617)626-1540

Dept. of Fisheries, Wildlife & Environmental Law Enforcement's Riverways Program.

251 Causeway St., Suite 400 Boston, MA 02114

Geographic Area Served: Statewide

The mission of the Riverways Program is to promote the restoration and protection of the ecological integrity of the Commonwealth's watersheds: rivers, streams and adjacent lands. They provide technical assistance and outreach to communities, citizens groups and others on various aspects of river, stream and watershed protection, restoration and stewardship.

Services provided:

- Assist the formation/strengthening of watershed associations, Adopt-a-Stream; groups, Stream Teams, and other citizen initiatives for the protection of specific rivers/streams
- Prepare and distributing a periodic newsletter, workbooks, brochures, and other "how to"; publications for river and watershed protection and maintaining a resource library of similar publications gleaned from across the U.S. and Canada
- Conduct training sessions for citizens on specific river conservation tools and formulating action plans
- Disseminate notices of permit reviews and other pending government actions affecting rivers to citizens groups and providing guidance on how to evaluate environmental impact and participate in government decisionmaking
- Assist communities in drafting and adopting river protection bylaws, ordinances and other local regulatory techniques
- Provide direct support to watershed associations in each of the state's 28 major river basins as well as sub-basins and about 140 Adopt-a-Stream groups in the preparation of educational curricula, riparian land mapping, shoreline surveys, water quality monitoring programs and other resource protection tools
- Negotiate the donation of land and conservation restrictions protecting several miles of river frontage in conjunction with watershed associations and land trusts, enhancing their ability to attract additional land gifts
- Provide planning and organizational support for Federal Wild and Scenic River studies and designations on the Farmington, Westfield and Sudbury/Assabet/Concord rivers
- Serve as a repository for all documents relating to the Merrimack River Initiative
- Secure funding and staff support for anadromous fish restoration in the Ipswich, Concord, Neponset and Danvers Rivers
- Coordinating the application of GIS computer mapping systems in the Ipswich, Chicopee and Merrimack River watersheds, which is greatly facilitating the formulation of resource protection strategies
- Supporting local decisions on preventing nonpoint source pollution and protecting aquatic habitats through federally- funded special projects in the Taunton, Ipswich, Assabet and Merrimack River watersheds
- Provide grants to municipalities, Regional Planning agencies and watershed associations through the Riverways Small Grants Program to improve public access to and along rivers.

Waquoit Bay National Estuarine Research Reserve

<http://www.waquoitbayreserve.org/>

(508)457-0495

P.O. Box 3092 Waquoit, MA 02635

Geographic Area Served: Cape Cod, Nantucket Island, Martha's Vineyard, and Buzzard Bay watersheds
Waquoit Bay Reserve's citizen water quality monitoring coordination program was established in 1995 to strengthen individual monitoring programs by providing technical assistance and increased access to information, while drawing the groups into larger regional programs and goals. In addition, the Reserve has been working with governmental and non-governmental agencies to develop a regional approach to citizen monitoring, with the long-term goal of improving data quality so governmental and scientific organizations can use citizen data. The Reserve's program focuses on Cape Cod, and the islands of Martha's Vineyard and Nantucket, but also collaborates with other monitoring groups, especially in southeastern Massachusetts.

Services provided:

- Training workshops
- Library of training materials, reports, newsletters, and videos, including manuals for starting a monitoring program, sampling methods, quality assurance, and more
- Technical assistance on study design, sampling methods, quality assurance, etc.
- Assistance in locating funding sources
- Hosting regional gatherings for information sharing among local groups
- Regional coordination of special monitoring projects, such as the Great American Secchi Dip-In
- Clearinghouse for information on state and federal water quality initiatives, research efforts, programs provided by other citizen monitoring service providers, and access to equipment and laboratory analysis
- Publication of the Directory of Cape Cod and Islands Citizen Water Quality Monitoring Groups
- Publication of The CAPER, an occasional newsletter about citizen monitoring on the Cape and Islands.

Appendix D: Equipment List by parameter

MassWWP Equipment List 2002				
<i>Prices may be outdated</i>				1/18/02
EQUIPMENT LIST BY TEST PERFORMED		* = A local lab may have these		
# = May be able to share these with other groups in your area				
	per pkg	price	Supplier	
SECCHI/TEMP				
Secchi disk	1	\$ 27.50	Aquacenter	
Eyebolt & weights	1	\$ 2.00	Hardware store	
Viewscope	1	\$ 3.00	"	
Handle, bolts	1	\$ 4.30	"	
Thermometer	1	\$ 17.50	Hach	
Max/Min thermometer	1	\$ 17.95	Forestry Suppliers	optional
Rope		\$ 15.00	Hardware store	
DISSOLVED OXYGEN LAKES				
Wisc. Sampler	1	\$ 10.00	MassWWP	
Polyprene rope		\$ 15.00	Hardware	
DO bottle, 60ml	1	\$ 11.50	Hach	
# Sod. Thios. Cart. ~	1	\$ 11.45	Hach	
# Digital titrator ~	1	\$ 105.00	Hach	
# DO reagent 1, Mang Sulfate 60ml	100	\$ 10.86	Hach	For lakes
# DO reagent 2, Alk Iod-Azide, 60ml	100	\$ 10.86	Hach	"
# DO reagent 3, Sulfamic Acid, 60ml	100	\$ 16.16	Hach	"
* Grad Cyl 50 ml	1	\$ 4.00	Hach	
* Beaker 150ml	1	\$ 11.75	Hach	
# Starch sol 100ml ~	1	\$ 6.37	Hach	
# Magnetic Stirrer ~	1	\$ 135.00	Cole-Parmer	
# Stir Bar 12x8mm ~	1	\$ 2.50	Hach	
Delivery tube ~ (if need extras)	5	\$ 4.85	Hach	
		\$ 355.30	cost for 100 Lake DO samples	
CHLOROPHYLL				
Vacuum Pump	1	\$ 73.00	ColeParmer	
Filter forceps	1	\$ 11.50	ColeParmer	
Glass fiber filter	100	\$ 97.50	ColeParmer	
2 liter jar	6	\$ 10.00	Hach	
Mag. Filter Holder	1	\$ 71.42	VWR Scientific	
Filter flask	1	\$ 13.19	ColeParmer	
Grad Cyl 500ml	1	\$ 26.50	Hach	
Grad Cyl 50ml	1	\$ 11.75	Hach	
Chlorophyll a Analysis	1	\$ 20.00	UMass EAL	
Air dryer	1	\$ 60.00	MassWWP	
		\$ 334.86	cost for first chlorophyll sample	
		\$ 20.98	cost for each subsequent chloro. sample	
pH, ALKALINITY	per pkg	price	Supplier	

Beaker 150 ml	1	\$ 4.00	Hach		
Grad cyl 100ml	1	\$ 14.00	Hach		
# Digital titrator	1	\$ 105.00	Hach		
Sample bottle	12	\$ 32.50	Hach		
Sulf. Acid Cart.	1	\$ 10.70	Hach		
Beckman pHi 250 pH meter	1	\$ 465.00	VWR		
Electrode, refill	1	\$ 147.00	VWR	If/when original wears out	
Elect. Cable	1	\$ 36.50	VWR	" "	
# Magnetic Stirrer	1	\$ 135.00	Cole-Parmer		
# Stir Bar12x8mm	1	\$ 3.00	Hach		
Kim Wipes	1	\$ 3.97	VWR		
MISCELLANEOUS					
Wash Bottle, 500ml	1	\$ 4.25	Hach		
Depth finder	1	\$ 169.00	Forestry Suppliers		
Fiberglass Tape (50m)	1	\$ 38.95	Forestry Suppliers		
Min/Max Thermometer	1	\$ 17.95	Forestry Suppliers		*Do not purchase mercury-filled thermometers

Appendix E: Typical Lake Surveys

1. Shoreline Survey

To answer the questions: What is the lay of the watershed/shoreline?
Are there special areas in need of protection?
Are there obvious/potential sources of pollution?

Monitor:

- visual survey of the lake's shoreline
- "windshield survey" of watershed
- intensive survey of tributaries

Commitment: Depending on size of lake and watershed, half-day or more for the shoreline survey. Windshield survey takes about a day depending on how many volunteers you have. Intensive surveys of tributaries are more time-consuming.

Expertise: Training required to learn what to look for and how to report findings consistently.

2. Baseline Conditions

To answer the questions: What is the current water quality in the lake?
Is water quality in the lake changing over time?

Monitor: *some or all of the following. *highly recommended*

- water transparency*
- water temperature profile*
- pH
- alkalinity
- dissolved oxygen*
- total phosphorus
- map aquatic vegetation

Commitment: No more than once a month at one site or a few sites, maybe less. About 2 - 3 hours, depending on # of parameters measured. Mapping aquatic vegetation is more time consuming. Depending on lake size, may involve 10 - 20 hours of labor annually.

Expertise: some training needed for water chemistry; lab expertise needed for pH, alkalinity and DO; aquatic vegetation requires some training.

3. Monitoring an Algae Problem

To answer these questions: Is there an excessive amount of algae in the lake?
Is the lake nutrient-enriched?
What are the sources of nutrients to the lake?

Monitor:

- water transparency and/or chlorophyll a
- water temperature profile
- total phosphorus in the water column
- optional: sediment nutrients

Commitment: Sample monthly or more from ice-out to fall turnover (March-October)

Expertise: Some training for sample collection, but analyses usually done at a professional lab. Cost is higher because nutrient and chlorophyll analyses are costly

4. Monitoring an Aquatic Vegetation Problem

To answer these questions: Is there an excessive amount of aquatic vegetation in the lake?
Is the aquatic vegetation extent increasing?

Why is aquatic vegetation becoming overabundant?

Monitor:

- aquatic vegetation mapping
- identifying aquatic vegetation
- total phosphorus in the water column?
- optional: sediment nutrients

Commitment: Substantial. Mapping plants is time consuming, and this survey should be done once between mid July and mid September, ideally in August. There are various levels of complexity. Some surveys can take a couple of hours on the lake, others up to a couple of days on the lake. Mapping should be done once in the summer, but other trips on the lake (as often as once a week, or as infrequently as once a month in the growing season) are recommended to check on the presence of plants, which may be gone in August, or that bloom in June and are easier to identify then.

Expertise: Training required for plant identification, unless samples are sent to experts. For sediment nutrients, MassWWP loans out a sampler, analyses can be done at EAL for a fee.

5. Monitoring an Exotic Species Problem

To answer the questions: Are there invasive exotic plants or animals in the lake? What is the current extent of invasive exotic species in the lake?

Monitor:

- aquatic vegetation and/or animals (e.g. zebra mussels), extent and identification

Commitment: Depends on whether an actual map is done, which is time consuming (see above) or just a visual check with a resulting sketch of the presence of exotics.

Expertise: Identification of species requires training.

6. Monitoring a Health Risk

To answer the questions: Is it safe to swim at private beaches in the lake? (Public beaches should already be monitored by local authorities.) Does the lake meet Massachusetts health standards for swimming, fishing or boating?

Monitor:

- fecal coliform bacteria (to compare with MA standards)
- E. coli (EPA preferred bacteria test for fresh waters)
- water transparency

Commitment: If the beach is used regularly, sampling should be done on a weekly basis. Analysis must be performed within 6 hours and requires two days for completion.

Expertise: Samples can be brought to a professional lab, or can be run by a volunteer, but equipment is expensive and analyst must be very meticulous.

7. Monitoring the effects of a Lake Management Technique

To answer the question: What is the effect of drawdown on the lake?
(for example)

Monitor:

- aquatic vegetation
- benthic macroinvertebrates
- amphibians, reptiles, and fish

Commitment: Considerable. Mapping vegetation and surveying animals before and after drawdown will take several weeks each year

Expertise: Training required for macrophyte mapping and identification, as well as for animal identification and survey methods. Benthic macroinvertebrates are especially tricky to identify.

