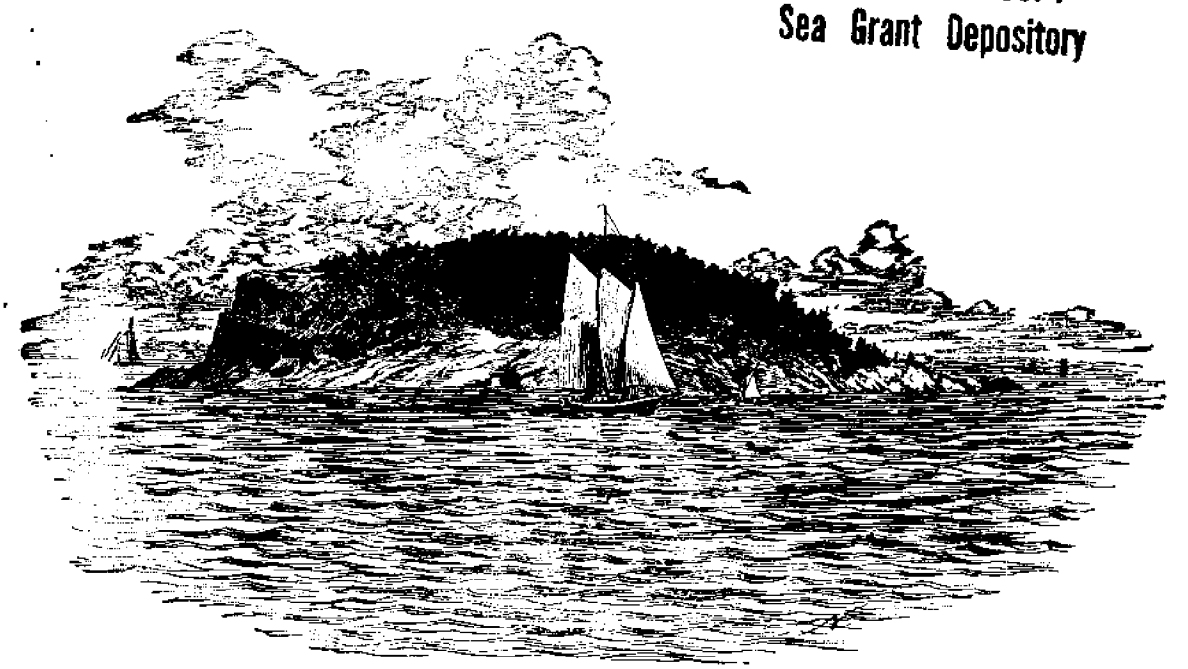
# Clean Water:

## A GUIDE TO WATER QUALITY MONITORING



*For Volunteer Monitors of Coastal Waters*





Esperanza Stancioff
University of Maine Cooperative Extension

Published by the Maine/New Hampshire Sea Grant Marine Advisory Program
and University of Maine Cooperative Extension
Orono, Maine / November, 1992

This publication was supported by University of Maine Cooperative Extension and by Grant # NA16RG0157-01 from the National Oceanic and Atmospheric Administration to the University of Maine/University of New Hampshire Sea Grant College Program. The views expressed herein are those of the author and do not necessarily reflect the views of NOAA or any of its sub-agencies.

Photographs: **Donald Blomquist**, pp. 6, 28, 53.
**Amanda Titus**, p. 53.

Gulf of Maine map: **Richard D. Kelly Jr.**, Maine State Planning Office, p. 12.

Illustrations of endangered species: **MaJo Keleshian**




Additional copies available at $7.50 each, without shipping costs; or at $10.50 each, including shipping and handling from:

Sea Grant Communications
University of Maine
30 Coburn Hall
Orono, ME 04469
(207) 581-1440

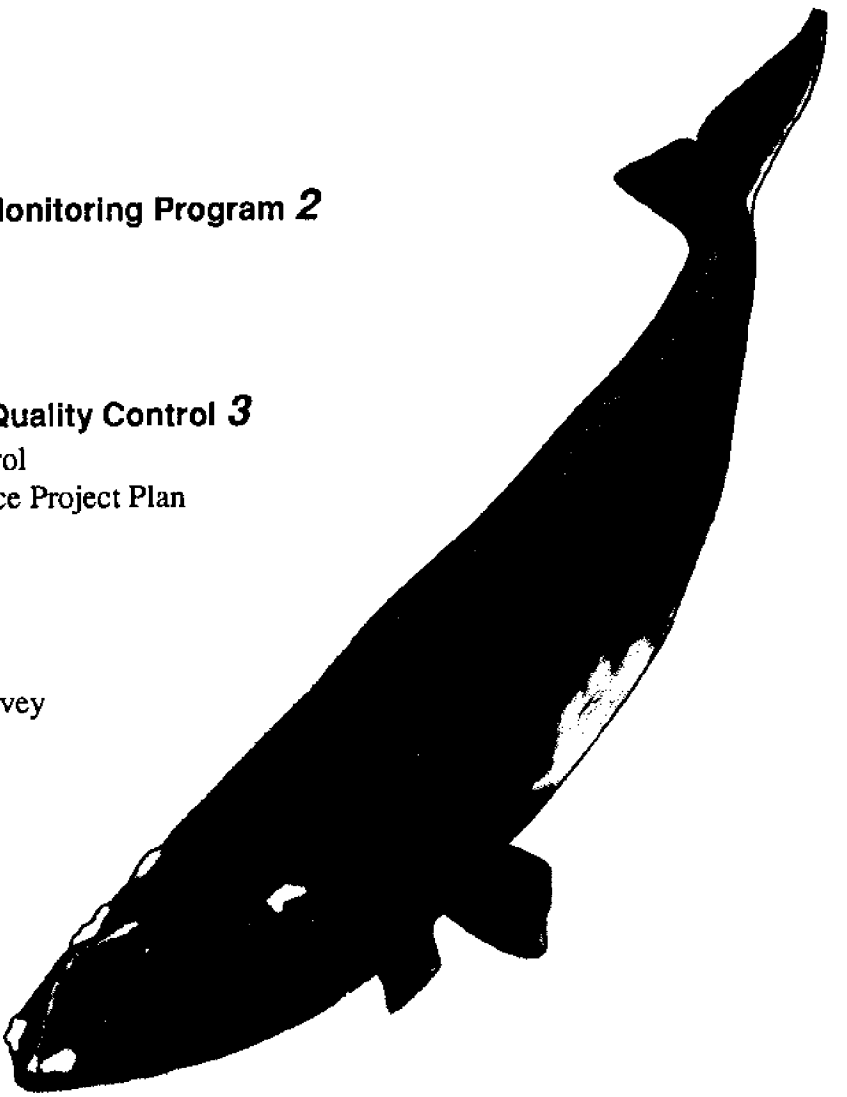
or

University of Maine
Cooperative Extension
Knox-Lincoln County Office
375 Main Street
Rockland, ME 04841
(207) 594-2104

E-MSG-92-6 500

# Table of Contents





# Acknowledgments

This manual was written as a joint effort of many people's ideas and contributions.

I would like to express special appreciation to Kathleen Leyden, Shore Stewards Program/Maine State Planning Office; Bernard J. McAlice, University of Maine Darling Marine Center; and John Sowles, Maine Department of Environmental Protection, for their assistance with meticulous reviews, rewriting of chapters, and many other contributions to the manual.

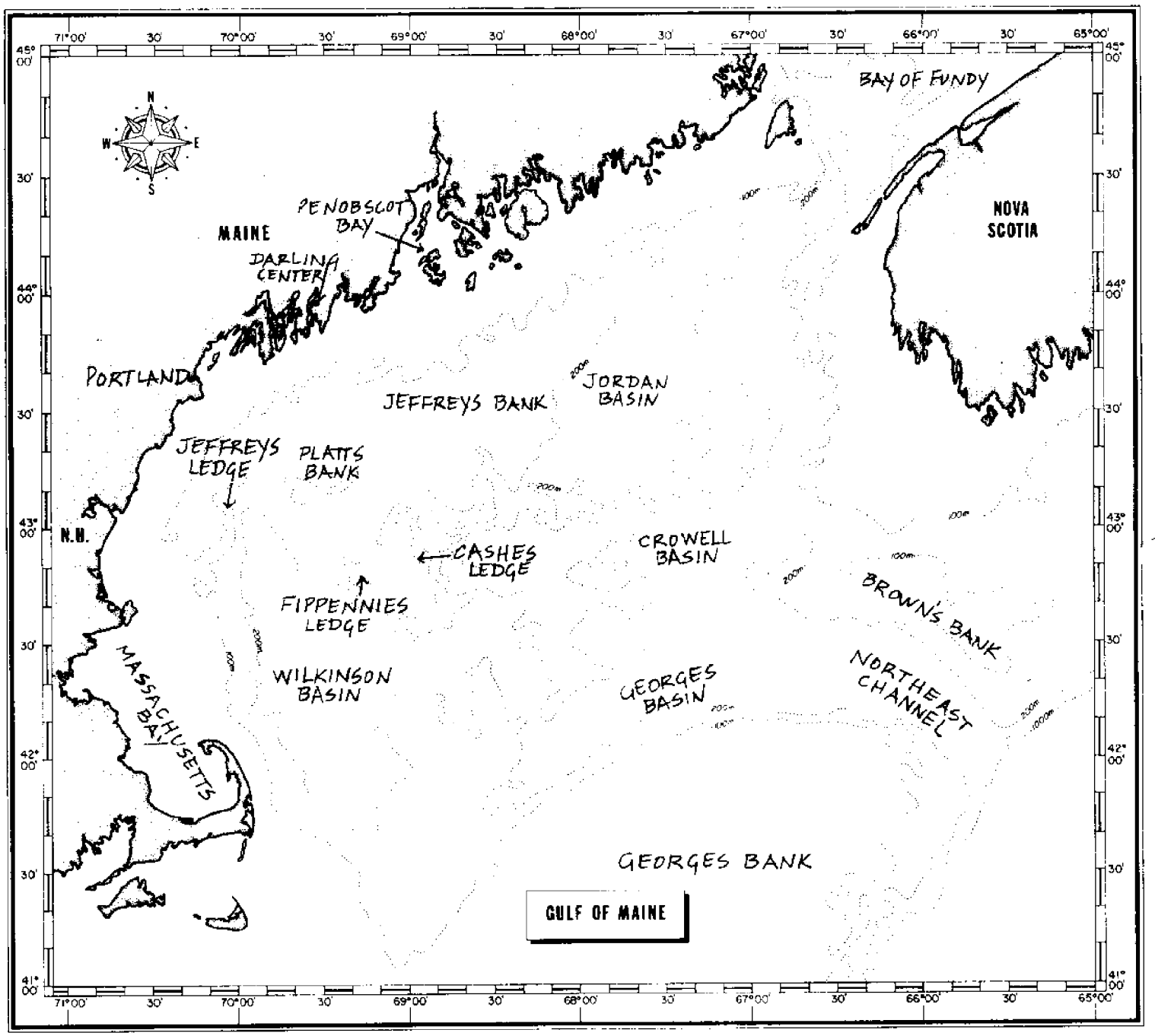
The draft of the manual was also reviewed by Lee Doggett, Casco Bay Estuary Project; Kathleen Ellett, Chesapeake Bay Estuary Project; Diane Switzer, U.S. Environmental Protection Agency; and Douglas Tremblay, Maine Department of Marine Resources. I would like to thank all of the reviewers for their time and helpful comments.

The volunteer monitors who inspired the writing of this manual and offered many useful suggestions include members of The Damariscotta River Tidewater Watch and The Georges River Tidewater Watch in Maine and Sharon Meeker of The Great Bay Watch. The Great Bay Watch is administered by the University of New Hampshire's Cooperative Extension and the Maine/New Hampshire Sea Grant Marine Advisory Program.

Finally, I would like to thank Kathleen Lignell and MaJo Keleshian of the University of Maine Sea Grant Communications Office for their expertise and assistance in editing and layout of this manual.

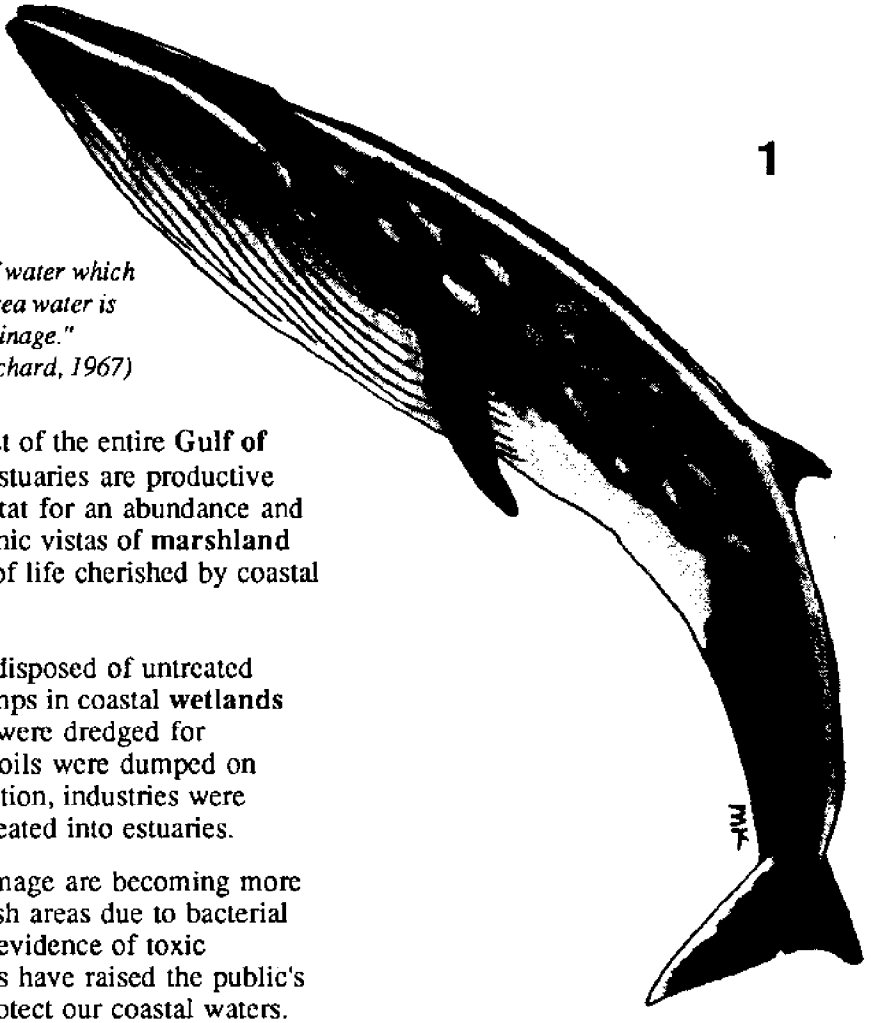
Esperanza Stancioff

Esperanza Stancioff


BAY OF FUNDY
NOVA SCOTIA
MAINE
PENOBSCOT BAY
DARLING CENTER
PORTLAND
JEFFREYS BANK
JORDAN BASIN
JEFFREYS LEDGE
PLATTS BANK
N.H.
CASHES LEDGE
CROWELL BASIN
FIPPENNIES LEDGE
BROWN'S BANK
WILKINSON BASIN
GEORGES BASIN
NORTHEAST CHANNEL
MASSACHUSETTS BAY
GEORGES BANK
GULF OF MAINE

# Introduction





*"An estuary is a semi-enclosed coastal body of water which has free access to the ocean and within which sea water is measurably diluted by freshwater from land drainage."*
*(Pritchard, 1967)*

By this classic definition, the coast of the entire **Gulf of Maine** may be considered an **estuary.** Estuaries are productive environments that provide valuable habitat for an abundance and diversity of both plants and animals. Scenic vistas of **marshland** and tidewaters visually define a quality of life cherished by coastal residents and visitors.

For generations, coastal residents disposed of untreated sewage in estuary waters and located dumps in coastal **wetlands** without concern. Channels and harbors were dredged for navigational purposes and the dredge spoils were dumped on marshes and other sensitive sites. In addition, industries were allowed to discharge harmful waste untreated into estuaries.

Recent signs of environmental damage are becoming more apparent. Widespread closures of shellfish areas due to bacterial pollution, declines in fish landings, and evidence of toxic compounds in estuary and bay sediments have raised the public's awareness of the need to manage and protect our coastal waters.

Our economy, our health, and our very existence depend on a healthy environment. Knowing the condition of our environment is therefore critical as we make decisions which affect it. Monitoring water quality informs us not only about coastal waters but also about the land from which the water flows—its **watershed.**

There are a growing number of citizens' groups and high schools working together in northern New England to monitor the health of our coastal waters, to provide baseline data, to pinpoint sources of contamination, and to educate the region's citizens. With the appropriate knowledge and training, citizen volunteers can participate in the environmental decision-making process and become directly involved in the stewardship of our commonly-held natural resources.

The purpose of this manual is to facilitate these volunteer efforts by providing citizens with the information they need to effectively monitor coastal waters. This is a working manual. As new material is developed or procedures change, new information can be added to supplement or replace outdated material.

**Note: The words highlighted in bold in the text are defined in the *Glossary* section in the back of this manual.**

*Section I* gives a brief introduction to the manual and *Section II* offers steps for organizing a monitoring program.

*Section III* on quality assurance and quality control provides guidelines for documenting a water quality monitoring program. It gives information on the importance of a **quality assurance project plan** and what to consider when developing a new monitoring program.

*Section IV* on watershed surveys gives a step-by-step procedure on how to conduct a survey, where to locate information about the watershed, and how to document the findings of the survey.

*Section V* on **variables** defines the tests a volunteer group may want to perform and the importance of each.

*Section VI* on monitoring and *Section VII* on bacteriological laboratory analysis cover safety precautions in the field and in the laboratory, things to consider in selecting **sample sites**, field procedures for sample collection and various methods of measurement, and laboratory analysis for fecal coliform bacteria.

*Section VIII* on storm event monitoring explains how to monitor waters running off the land during rainstorms or ice and snow thaws.

The *Appendices* give information on chemical reactions in the titration method for **dissolved oxygen** and dilutions in bacteria analysis, and a *Glossary* defines important terms. *References* used in writing this manual are also cited.

# Steps for Organizing a Monitoring Program

# 2

## TYPES OF MONITORING

Volunteer monitoring programs can include a variety of activities depending on their purpose and funding. For example, if the primary purpose of a monitoring program is public education, volunteers may focus on documenting pollution sources in a watershed, an activity which does not require very much equipment. Another group's purpose to collect scientific water quality data may necessitate a different level of funding and commitment.

The kinds of things a volunteer monitoring program can offer include the following:

- **Baseline data**—by consistent monitoring of the same sites over time.
- **Investigative sampling**—to locate sources of pollution by sampling areas found to be suspect and continuing sampling to pinpoint contamination.
- **Shoreline survey work or watershed surveys**—to document potential and actual, direct and indirect sources of pollution.
- **Resource inventory**—survey of flora and fauna of the area and surveys of benthic marine organisms.

## GETTING STARTED

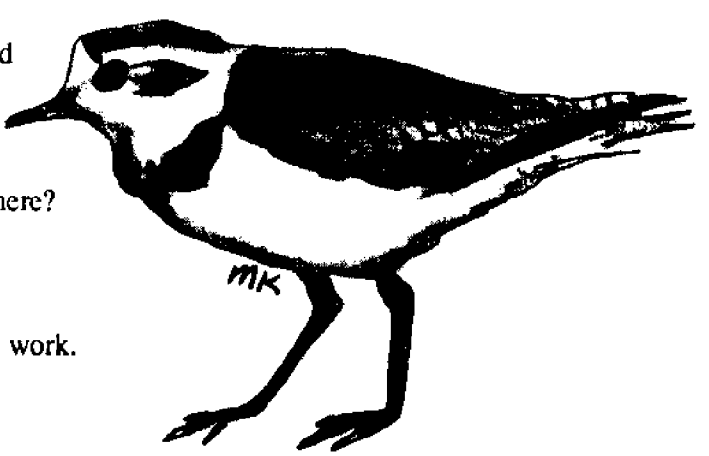
Organizing is a dynamic process for each group, and an integral part of the group's learning process. The following are some tips for getting started.

✓ Gather the troops.

- Have an early planning meeting with a few very interested people and define your purpose. Bring a map!
- Include youth in your early meeting and throughout the program.

✓ Gather information.

- Other groups. What's being done elsewhere?
- Local knowledge.
- Agencies.
- List of resources to be protected by this work.



✔ Gather more troops.

- Hold a public information meeting.
- Bring a map.
- Develop an agenda and stick to it!

✔ Structure and moderate the meeting. Include:

- Review basic steps and timeline to create a monitoring group.
- Ask what people want to know about the watershed.
- Review resource protection list.
- What areas should be studied?
- List known concerns and problems.
- Identify local people with skills to offer.
- Record or film that first public meeting for your archives.
- Gather names, addresses, and phone numbers. This is your starting core of volunteers.

## GETTING ORGANIZED

✔ Conduct an organizational meeting.

- Nominate a slate of officers and a board.
- Treasurers should be able to handle both finances and taxes.

✔ Deal with the tough organizational issues early.

- Should you incorporate?
- Seek tax exempt status?
- Set by-laws and charter to speed decisions?

## 1. Strategic Planning—Start with a Map!

✔ Decide what you want to know and for which of the following you want to test:

- Fecal coliform bacteria
- Dissolved oxygen
- Salinity

- Nutrients
- Temperature
- Transparency
- Faunal and floral surveys
- Algal counts
- Other?

✔ Select sample sites.

- Safe and easy access.
- Focus on known or suspected problems.

✔ Decide in advance how the group will act on findings of immediate importance.

- How will you handle the press?
- How will you treat the people or businesses at issue?
- How will you realistically accomplish your goals?
- What are your legal obligations?

## 2. Develop a Budget and Assess Equipment and Personnel Needs

✔ Equipment needs

- Get plenty of outside help to select, purchase or lend, transport, and maintain equipment.
- Remember film and camera.

✔ Personnel Needs

- Choose a volunteer coordinator.
- How many people will you need to collect samples? Conduct lab analyses? How often? At what cost?

✔ Fundraising and financial needs

- Develop a budget.
- Diversify funding sources.

## 3. Start Training

✔ Enlist volunteers for monitoring.

✔ Develop and conduct training sessions.

✔ Emphasize proper sampling techniques.

## 4. Get Laboratory Support

✔ High school labs, university labs, and private labs may all be needed depending on the group's goals.

## 5. Record and Publish Results

✔ Enter data into a database with reporting and graphing capabilities.

✔ Keep volunteers informed of findings at monthly meetings.

✔ Inform the community through news articles and reports.

## 6. Develop a Schedule and Make Presentations

✔ Schedule regular meetings.

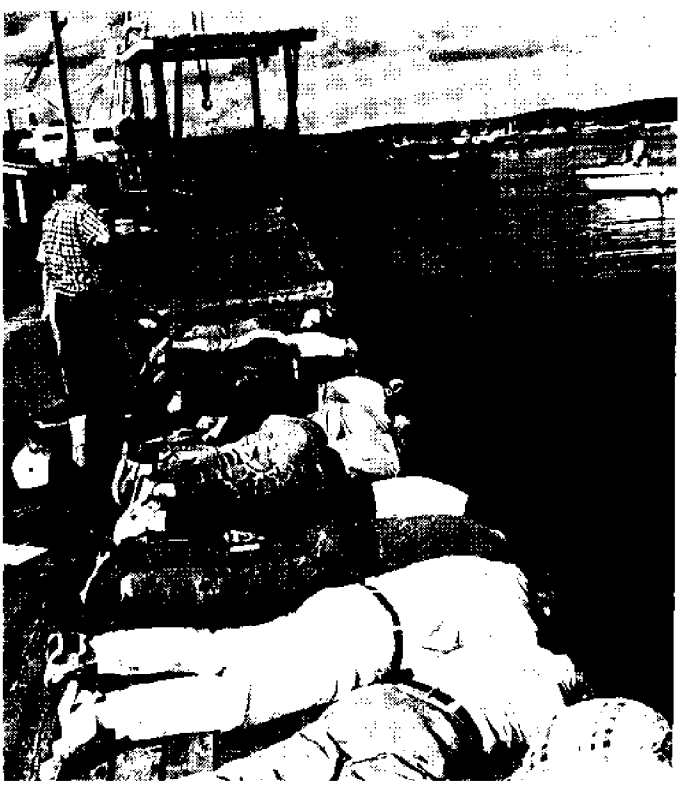
✔ Develop a sampling schedule.

✔ Develop a slide presentation for giving talks to other groups.

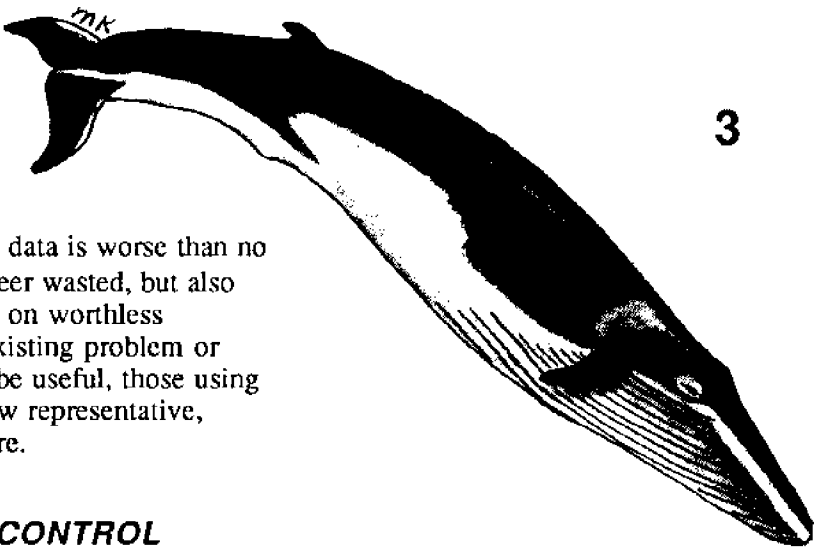
✔ Involve students in presentations.

## 7. Design Ongoing Educational Programs

✔ Sustain interest of volunteers and the community with public education forums.



# Quality Assurance and Quality Control



3

It is commonly recognized that "bad" data is worse than no data at all. Not only is your time as a volunteer wasted, but also environmental management decisions based on worthless information may be made that worsen an existing problem or create new problems. For volunteer data to be useful, those using the information must have confidence in how representative, consistent, and accurate the collected data are.

## QUALITY ASSURANCE AND CONTROL

**Quality assurance (qa)** refers to the whole system of activities carried out to provide users with data that meet defined standards of quality within a stated level of confidence.

**Quality control (qc)** refers to those specific activities performed during environmental data collection to produce data of desired quality.

## PREPARING A QUALITY ASSURANCE PROJECT PLAN

Early in their program, a monitoring group should develop their own quality assurance project plan. The plan should detail all procedures to enable anyone unfamiliar with the project to exactly repeat all the procedures to arrive at the data. The following sections should be included in a quality assurance project plan:

### 1. Objectives

Defining the purpose for monitoring may seem obvious, but it is often overlooked. The lack of a well-defined objective can lead to dissatisfied volunteers and data of questionable value.

### 2. Organization of the Group

The organization of the group could be arranged in several different ways: *geographically*, if the monitoring area is large enough; *politically*, if the organization has officers, etc.; or *functionally*, if varied skills and capabilities are needed to carry out the objectives.

### 3. Responsibilities of Individuals

The assignment of individual responsibilities defines the organization at a personal level, with names of individuals assigned to specific duties, offices, and roles. This documentation ultimately assures that the work is done. Developing detailed job descriptions would also be a useful way to document individual responsibilities.

## 4. Study Area

Include a detailed description of the study area, including sample sites, physical access, known pollution sources, valuable natural resources, and other information.

## 5. Sample Collection, Storage, and Handling

Describe collection containers (plastic bottles vs. sterile plastic bags), collection procedures (hand grabs vs. automatic pumping sampler), labeling, how the samples are stored (temperature, time, preservatives, light conditions, etc.), how samples are transported, and a chain of "custody" (i.e. who has responsibility for the sample at any point in the process), and other details specific to your program.

## 6. Field Procedures

Provide a detailed step-by-step description of how one is to proceed in the field— from packing the car with gear to filling out the data sheet for a monitoring station.

Any analyses done in the field will be described in this section and referenced (e.g., *Standard Methods for the Examination of Water and Wastewater*).

## 7. Laboratory Procedures

Describe exactly what is done to the sample, the analytical method used (reference), the dilutions anticipated, the filling out of the laboratory log book, etc.

## 8. Data Management

Include in your plan everything from how to round numbers (specifying significant digits for each variable) to how to store, edit, correct, and report data.

## 9. Precision and Accuracy (P and A) Checks

Precision and accuracy (P and A) checks are a "must" throughout the project. Precision refers to the reproducibility of a measurement. Accuracy refers to the agreement of the measurement with the known value. Each element of a measurement (person, instrument, analysis, time, place, and recording of data) is subject to errors of precision and accuracy. Knowing the amount of error helps define the value of the data.

For example, let's say you make up a solution of water containing 10 mg/l of salt (NaCl). Two volunteers each analyze it five times. Volunteer A's results are 8, 7, 8, 9, 8, and 8 mg/l, and Volunteer B's results are 10, 15, 5, 20, and 0 mg/l. Volunteer A's technique would be relatively precise (i.e., the values are very close together) but inaccurate (since the average is 8 mg/l and the known concentration is 10 mg/l).

On the other hand, although Volunteer B is accurate (the average value 10 mg/l agreeing with the known concentration), Volunteer B is not at all precise (the measurements being highly inconsistent). You would have less confidence in Volunteer B's results because of the imprecision, and you would probably discard the data. Volunteer A, however, is consistently and reliably low. As long as this is known, you can sometimes assign a correction factor to Volunteer A's data and use the data.

For each water quality test you perform, periodic precision and accuracy tests must be done to ensure that each step along the way to the final number is done reliably. Analyzing known samples and conducting split samples are all techniques to determine precision and accuracy.

## 10. Time Schedule

Set up a monitoring schedule to include starting date, trial run period, revision period, data collection, data entry, editing, final report, and the next year's work plan.

## 11. Trial Run

Even with the best-laid plans, things rarely go smoothly at first. Unanticipated problems, oversights, and mistakes will surface as the project proceeds. It is strongly recommended that a phase of the project be considered as the "shake down" phase where the *entire* plan is tested in the field. As problems arise and are resolved, the work plan should also be revised.

# POINTS TO REMEMBER

## 1. Budget

Developing a budget will help a group design a monitoring project that can realistically be achieved. The least expensive part of any program is collecting the sample. Later costs associated with analysis, data management, and project administration can easily be overlooked and will result in frustration, loss of motivation, and disenchantment. In the end, the ability to work within the program budget will affect the quality of the program and the information produced.

## 2. Training

Training is absolutely critical. Even the most well-explained plans and procedures will be interpreted differently by different individuals. A periodic step-by-step demonstration, with ample opportunity for questions and answers, must be built into any training program. Follow-up checks of how well volunteers are adhering to laboratory and field procedures must be conducted by qualified trainers.

## 3. Reporting

Reporting is very important in a monitoring program. Data stored in a file drawer have little value, but data synthesized into a report can then be used for many different things, which will help to meet the objectives of the monitoring project. Reports need not always be in written form. Consider making visual or oral presentations, or using a mixture of media like maps, tables, charts, etc. The important thing is to convert the data into useful information.

## 4. Peer Review

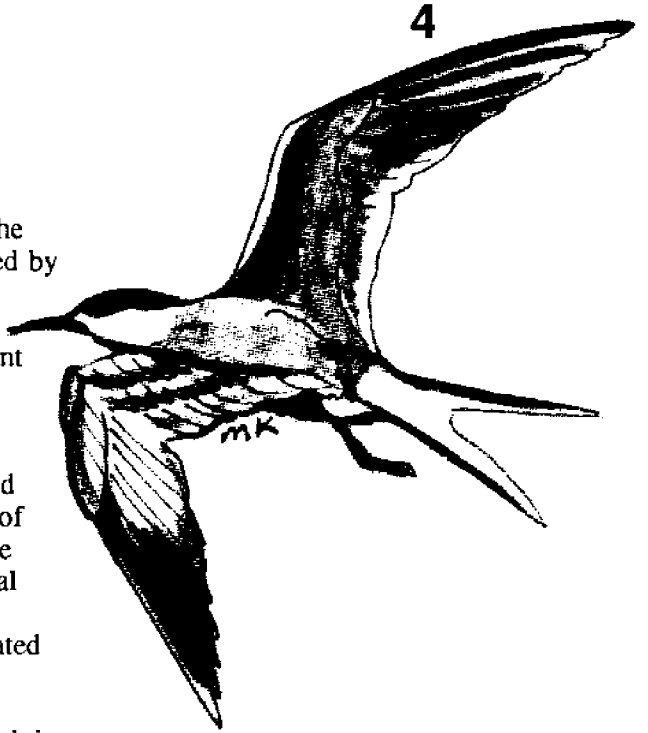
As the group decides how to present their information, and before the information is released to the public, it is recommended that the data be reviewed by a "peer" review team. This review team will objectively assess and assure the quality of the conclusions drawn from the data. The makeup of the team will depend on the project's objectives, but the team members should be identified early in the project to provide oversight and guidance as the project develops.

### *A Final Note:*

There are many books written on the subject of quality assurance, and there is not sufficient space in this manual to cover the topic thoroughly. Even more important than doing everything exactly correctly, detailed documentation will enable anyone later on to evaluate the quality of the data. In many cases, even "bad" data may be recovered if the procedures used can be precisely reproduced with the help of detailed written documentation. Word of mouth and memory are simply not sufficient.

# Watershed Survey

4



## THE WATERSHED SURVEY

Estuaries accumulate pollutants and sediments from discharges and land use practices upstream as well as along the estuary shores. Thus the water quality of an estuary is affected by all the uses of the land and water in the estuary watershed.

Human use of the land and waters influences the amount and type of soil, chemicals, and other pollutants carried into streams, rivers, and estuaries.

Pollutants discharged directly from pipes into rivers and estuaries are called **point sources of pollution.** Point sources of pollution include all licensed discharges with federal and state discharge permits from industries, small companies, municipal sewer systems, aquaculture pens, and **overboard discharges.** Some point sources, such as straight pipes discharging untreated residential sewage are often overlooked and unlicensed.

**Non-point source pollution** refers to any pollution which is not a licensed discharge or does not have a localized or clearly identified source.

Non-point source pollution is associated with land and water use and poses a serious threat to coastal water quality and estuarine ecology.

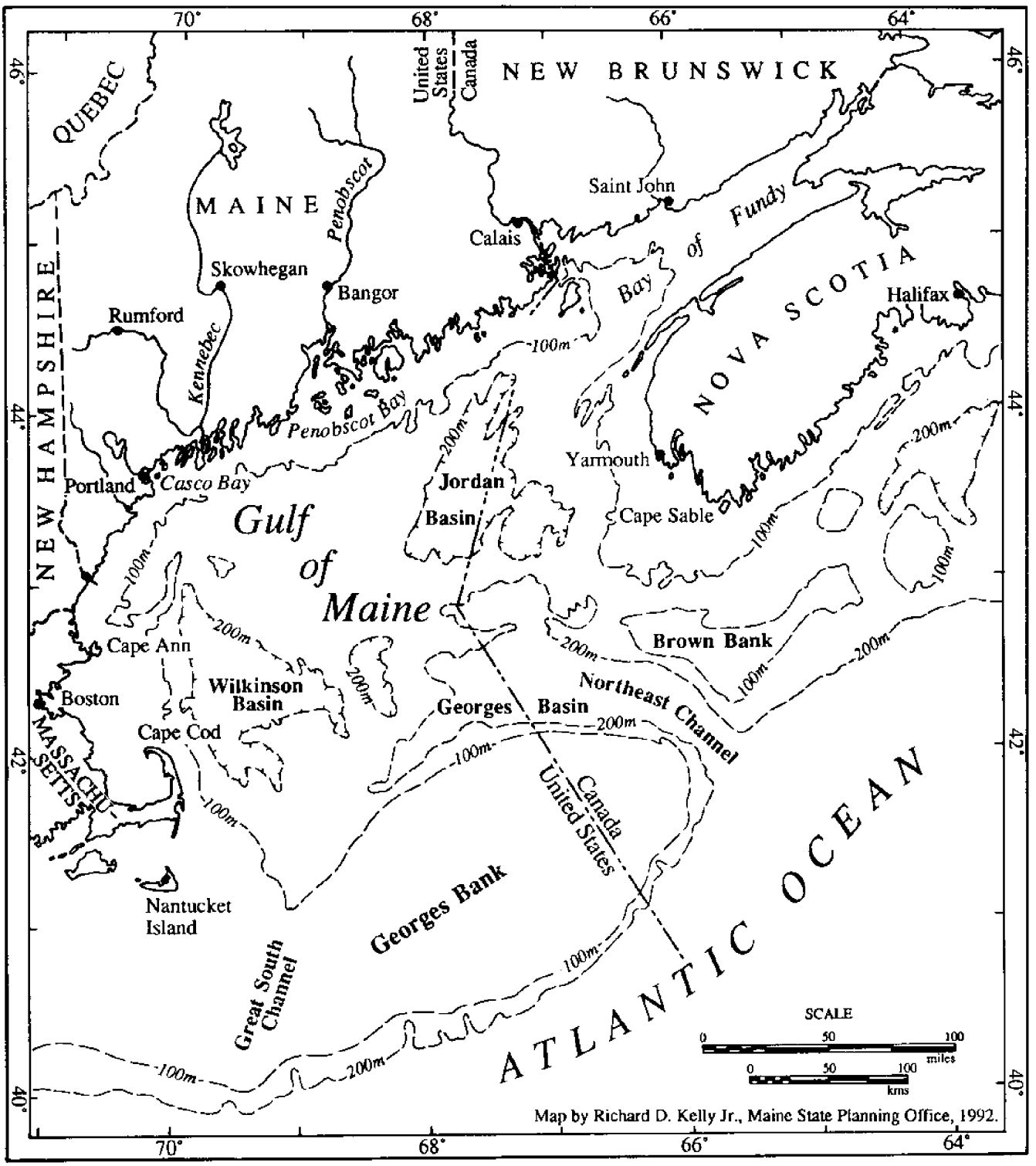
Malfunctioning septic systems, stormwater runoff, routine agricultural operations, waste from domestic animals and wildlife (particularly water birds), clearcutting, construction, and boat pollution all contribute to non-point source pollution along the northern New England coast.

A **watershed survey** consists of an evaluation of all sources of pollution that are likely to impact water quality. Simply put, the tasks of the volunteer survey team are to: find and field check all sources of pollution, locate them on a map, and document the extent of the problem on data field sheets for each area.

The watershed survey provides important documentation of the physical condition of the watershed, provides **baseline information** from which to monitor changes over time, and provides background information which can be used to support a community action plan for improving estuarine water quality.

The water quality testing methods described in the rest of the manual provide further documentation of problems uncovered during the watershed survey.

# The Gulf of Maine



# CONDUCTING A WATERSHED SURVEY

## 1. Defining Watershed Boundaries

The estuary watershed includes all lands that drain directly to the estuary and the smaller watershed of each river, stream, and brook flowing into the estuary. The boundaries of the watershed should be defined on 7.5 minute topographic maps of the area, which are available from sporting goods and office supply stores.

Start by studying the brown contour lines on the topo map that show elevation. Begin at one extreme of the estuary and work around to the other extreme. Draw a line perpendicular to the contour lines, following the highest points of elevation around the estuary. (See Appendix on "How to Read a Topo Map.")

Check the accuracy of the boundary by visualizing a drop of rain falling on the surface of the map and follow it downslope (perpendicular to the contours) to the nearest stream that flows to the estuary. It's helpful to use an enlarged topo map of the study area. This is a complicated task for the uninitiated, but with help from others who have experience, it becomes relatively easy.

## 2. Dividing Watershed into Sectors

Divide the land area of the watershed into sectors or sub-watersheds small enough for a few volunteers to cover in a few days.

## 3. Training Volunteers

Volunteers need to know what kind of field conditions to expect as well as what will be expected from them, including level of survey detail, time commitment, and paperwork. Volunteers need adequate training to complete the watershed survey.

The most important aspect of a training program is to inform volunteers of what to look for in the field. This is best done by looking at field examples or photographs of pollution problems. The Department of Environmental Protection (DEP), local Cooperative Extension offices, local Soil and Water Conservation Districts, and other groups can be of assistance in training volunteers to conduct watershed surveys.

## 4. Finding Available Information

Using existing information and personal knowledge of the watershed, determine the extent of actual and potential pollution sources that are likely to effect water quality in the estuary.

Sources of information include:

- Maine Department of Environmental Protection (DEP) discharge license maps
- Town Conservation Commission

- Maine Department of Marine Resources (DMR) shellfish growing area maps, files, and survey reports
- Municipal facility plans or sewage disposal system maps
- Aerial photographs
- Local land use inventories and comprehensive plan maps.
- Other studies conducted in the area

If you are monitoring in another state or province, check with your own authorities responsible for water quality monitoring and management. Since much of this information may be out of date, consult biologists, code enforcement officers, or local experts to help answer questions about the area.

## 5. Informing the Public

As part of the overall monitoring effort, conduct a public meeting to inform residents about the effort, the types of information you are collecting, and the uses to which it will be put. Discuss the watershed survey effort in similar detail.

Often, members of the public may become interested in the project and either provide valuable information or join the effort as a volunteer. On the other hand, residents may be concerned that the information will be used for enforcement purposes and they may not be supportive. The group must decide how to handle this.

Many successful groups agree up front not to use survey information for enforcement purposes. They may decide to work individually with landowners to provide technical assistance on how to correct problems or deficiencies.

If there is a need to cross private land when conducting a watershed survey, contact the landowners for permission, or send a letter to inform them of the project. Requests from landowners asking not to be included in the survey should be honored.

## 6. Refining the Scope of the Study

In order to use time and resources efficiently during the field portion of the survey, conduct a cursory tour of the area by vehicle and boat. More intensive survey work will be necessary in developed areas and in areas containing important resources to be protected (e.g., valuable shellfish areas).

## 7. Conducting Field Work

In the watershed, look for actual or potential pollution problems. Point sources include straight pipes, licensed discharges, sewage treatment outfalls, drains, drainage areas, and ditches.

## SAMPLE NOTICE TO WATERSHED PROPERTY OWNERS

Dear Watershed Property Owner:

[Name of Local Monitoring Group(s)] has/have embarked on a water quality monitoring project in conjunction with the High School. The attached sheet gives an overview of the project, its goals, and participants.

To initiate the project, the group will be updating Department of Marine Resources (DMR) data on watershed land use, methods of waste disposal and potential water quality problems. In particular, DMR records need to be kept current because this information directly affects the opening and closing of shellfish beds in the area. This information will be used to decide what areas should be studied further during the group's water testing project.

_____ has been selected by the group as one of their study areas. Land uses anywhere in the watershed (the area that drains to this waterbody) may be having an effect on water quality.

On _____, project volunteers will be surveying the shoreline and feeder streams in this area. On these days, you may see a group of people walking the shoreline areas, taking water samples, and making notes. If you are willing, you will be asked a few questions about your waste disposal system.

We wanted to take this opportunity to notify you about the project and to ask for your interest and support. If you would like to be a part of this project, volunteer applications are available.

Please contact us at the number below if you have any questions, or have information that may be helpful to us in this project.

Contact Person: JANE DOE (TELEPHONE #)

Non-point sources discharge into brooks, streams, rivers, and estuaries mostly in response to storm events. Look for dredging, mining, and logging operations; concentration of domestic and wild animals, including birds; agricultural fields; unstabilized construction; poorly constructed roads and ditches; and malfunctioning septic systems.

In tracking domestic pollution, check odors, lush vegetation, rock or brush piles concealing pipes, algal blooms, discoloration on rocks or bulkheads, erosion, and wet or spongy areas.

Don't forget to document the location of underground fuel tanks and abandoned or active dumps. Groundwater can be polluted by these sources, which may also seep into estuaries and pollute coastal waters.

You can also enlist the assistance of the town plumbing inspector to go over tax maps and records to identify newly installed septic systems and systems that may have been identified on older records and surveys but have since been placed in-ground or abated in some other way. Soil maps can assist in determining or diagnosing water quality problems.

## 8. Water Sampling

All streams, pipes, seepages or other suspect drainage should be sampled and evaluated using the pollution source and feeder stream survey form on page 18.

A source should be described in terms of type (i.e., straight pipe, drainage ditch area, stream, or culvert), amount of flow, and if it has a direct or indirect impact on the area's water quality.

Evaluate all flows by water sampling. In areas of little or no development and no likely sources of pollution, rely on other observations. When surveying by boat in remote areas, check all suspect pollution sources on foot.

If you are curious about a pipe that appears dry, check for flow immediately after heavy rainfall or spring runoff to determine if it is a stormwater drain. If you are concerned about failing septic systems, survey at a time when systems are most likely to malfunction. The best time for spotting evidence of overland flow of septage is late fall and early spring, or when the ground is saturated.

## 9. Evaluating Marinas

Marinas should be evaluated as sources of pollution. A **marina** is defined by the U.S. Food and Drug Administration as any structure (dock, ramps, floating docks, etc.) which is utilized for docking, storing, or otherwise mooring vessels and usually providing services to vessels such as repairing, fueling, security, or other related activities. Any waterway where boats are present at

some time in the year should be evaluated. You may find pollution problems associated with commercial and recreational boating.

An *Environmental Guide for New England Mariners* is available from the Coalition for Buzzards Bay, P.O. Box 268, Buzzards Bay, MA 02532. It is against the law to dump overboard within three miles of shore.

## 10. Evaluating Sewage Treatment Plants

Sewage Treatment Plants are direct sources of pollution. A sewage treatment plant should be located on a map, and its effect on the water quality should be evaluated, if possible. Sewage treatment plants process a variety of wastes from a variety of sources, including both industrial wastes and residential wastes. Some of the discharges from treatment plants may include bacteria, viruses, chemicals, and heavy metals.

The best way to evaluate a sewage treatment plant is to visit it. Arrangements should be made in advance with the plant operator who should be given an explanation of the type of information needed. This information may already be available from the agency responsible for coastal waters, however, an update may be necessary.

## 11. Evaluating Industries, Landfills, and Mines

Each of these activities should be visited within your survey area. Special care must be taken when investigating industries, and it is recommended that volunteers consult the plant engineer, town officials, and the Department of Environmental Protection. The pollution problems may be direct or indirect, potential, or actual. Depending on the nature of the industry, it may have its own sewage treatment facility.

**Industries** in your survey area should be evaluated to determine: 1) the type of industry involved; 2) the types of discharges, what they discharge, and the rate they discharge; 3) the types and amounts of deleterious substances manufactured, stored, buried, spilled, or mishandled and potentially allowed to run off on site; and 4) the distance, barriers, or buffers between industry and estuary.

**Landfills** in your survey area should be evaluated to determine: 1) the types of deleterious substances buried or stored on site, and 2) the presence of potential of pollution based on barriers, geography, topography, hydrology, and the distance of the landfill from the estuary.

**Mines** in your survey area also should be evaluated to determine the presence or potential of pollution from substances being mined or pollution associated with mining based on barriers, geography, topography, hydrology, and the distance of the mine to the estuary.

## WATER QUALITY MONITORING: Pollution Source Surveyand Feeder Stream Monitoring

Collected or surveyed by: _____ Area name: _____

Date surveyed: _____ Area letter: _____

Lab analysis by: _____ Fecal counts by: _____ Runoff conditions: _____

Date examined: _____

Time of Low/High Tide (**circle one**): _____

| Sample or Source | Time/ Temp C° | Sal. 0/00 | DO | pH | RESULTS Fecal Coliform Count | LOCATION (description/ address) | IMPACT Dir./ Ind. | Pot/ Act. | Description/ Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

Description of source should include: Type of source (pipe, culvert, failing septic, etc.); size of source; estimate of flow; other pertinent information

## 12. Reporting and Contacting Local Officials

After locating a failing septic system, straight pipe, or other pollution source affecting the water quality, contact the local plumbing inspector or code enforcement officer. Arrange to have him or her visit the site with you. At this time, re-sample the source sites and try to document the problem. If the situation indicates a problem associated with a house or business, it should be discussed within the volunteer monitoring committee to determine the most appropriate way to resolve the problem without unnecessarily embarrassing or threatening anyone.

A report documenting the results of the survey should be prepared including type of source, location, sampling dates and results, those notified, and a map showing where the source is located. The person to contact if the problem is a failing septic system or an outhouse is the local code enforcement officer or licensed plumbing inspector.

You can also enlist the assistance of the town plumbing inspector to go over tax maps and records to identify newly installed septic systems and systems that may have been identified on older records and surveys but have since been placed in-ground or abated in some other way. Soil maps, describing soils and their limitations for development and potential for movement of sediments and nutrients into surface waters, can assist in determining or diagnosing water quality problems.

## 13. Preparing the Report

A written report of a watershed survey should include the following information:

- A map locating the pollution sources.
- For each source, using the source survey/feeder stream monitoring form:
  - Describe the type of source, such as failing septic system, discharge, agriculture field, etc.
  - Detail specifically whether the pollution is direct or indirect and potential or actual.
  - Indicate the amount of pollution (gallons per minute) being discharged or potentially discharged, if you are able to get this information.
  - Describe the type of pollution, if known: pesticides, fertilizers, sewage, heavy metals, etc.

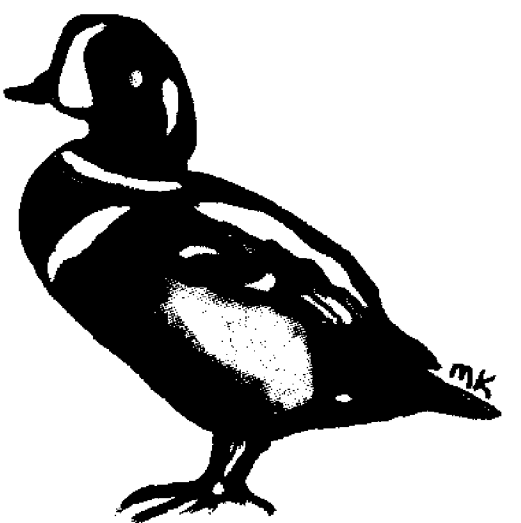
# Variables 5

Water quality variables which can be easily measured by volunteers participating in an estuarine citizen water quality monitoring project include: temperature, salinity, **dissolved oxygen**, pH, transparency, and **fecal coliform bacteria.** Samples to test for nutrients (ammonium, nitrate, nitrite, and phosphorus) and chlorophyll a can be collected and filtered by volunteers, but they should be analyzed by a professional laboratory.

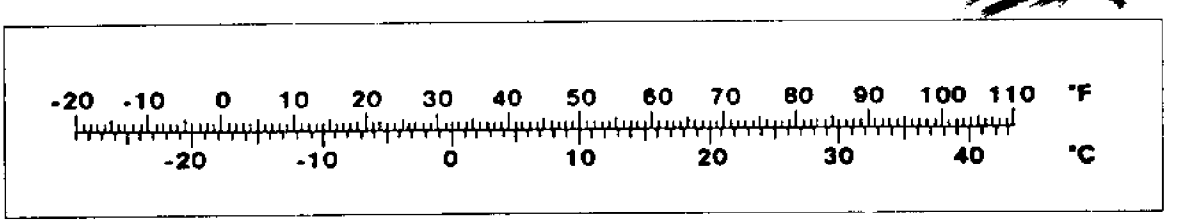
## TEMPERATURE

Water temperature exerts a major control over the distributions and activities of marine organisms. Temperature affects the rates of chemical and biochemical reactions. Many biological, physical, and chemical processes and activities are temperature-dependent. Among the most common of these are:

- The solubility of compounds in sea water. Gases are more soluble in cool water than in warm water. As water temperature increases, the rates of photosynthesis and plant growth also increase. An increase in plant growth and photosynthesis means that more oxygen is produced, but it also means that more plant respiration and decay will use oxygen;
- Distribution and abundance of organisms;
- The metabolic rates of organisms increase with increasing water temperature. Increased metabolism increases the oxygen demand of many organisms. Extreme high or low water temperatures may exceed the tolerance limits for marine organisms. Juveniles of some species may become stressed and thus more vulnerable to toxic chemicals, diseases, and parasites; and
- Density of water which affects inversions, mixing, and current movements.




Temperature and salinity are important variables to measure, because increase of either of them reduces the solubility of oxygen in water. Temperature can be measured in the field with an **armored thermometer** to the nearest 0.5 degrees C.




**Temperature Conversion Chart from Fahrenheit to Centigrade**

## SALINITY

Salinity is the concentration of dissolved salts in the water, usually expressed in parts of salts per thousand parts of water (ppt). Fresh water contains few salts (drinking water usually has a salinity of less than 0.5 ppt), while sea water averages 35 ppt.

In estuaries, salinity changes with the tides and is also subject to fluctuations due to changes in the rate of dilution by fresh water from the land. Salinity is the principal factor controlling the distribution of marine organisms, especially as the salinity begins to decrease well below oceanic levels.

Oceans supply 97% of the Earth's water. The next 2% is frozen, and the remaining 1% is found in rivers, streams, lakes, and groundwater.

The determination and definition of salinity is something which has been given much attention over the years by marine chemists and physicists.

The salinity of marine waters is a fundamental property which can be used to determine much about the mixing and chemical history of the waters. In the open ocean and even in coastal waters, variations in salinity are small and thus it is necessary to use very precise methods to determine the extent of real differences. In estuaries, differences in salinity are typically much greater and the use of high precision methods is often counter-productive. The use of such methods can introduce unwanted background noise which may obscure the information sought.

Salinity can be measured by using a hydrometer, a salinity hand-held refractometer, or a conductivity meter.

## DISSOLVED OXYGEN

Dissolved oxygen (DO) is essential for basic metabolic processes of most plants and animals inhabiting coastal waters. However, it is a particularly sensitive constituent because chemicals present in the water, biological processes, and temperature exert a major influence on its availability during the year.

A shortage of DO may not only be an indicator of pollution, but it can also be harmful to marine organisms. The ability of organisms to tolerate low dissolved oxygen conditions is extremely varied. However, if levels fall below 5 ppm (parts per million), certain species in the community may become stressed. Oxygen depletion is a significant event that can occur as a result of nutrient pollution and excessive phytoplankton production and can result in mass mortalities of fish and shellfish in coastal waters.

The oxygen in water comes from many sources. One of the largest sources is oxygen absorbed from the atmosphere. A second major source of oxygen is aquatic plants, including algae. During photosynthesis, plants remove carbon dioxide from the water and replace it with oxygen.

Once in the water, oxygen is used by marine organisms. Like land animals, fish and other marine animals need oxygen for respiration. Oxygen is also consumed by bacteria decomposing dead plants and animals.

The oxygen level of water is dependent not only on production and consumption. Many other factors work together to determine the oxygen level, including salinity, temperature, and atmospheric pressure.

Dissolved oxygen can be measured using a dissolved oxygen meter in the field or a Winkler titration method, which will give you dissolved oxygen in parts per million (ppm).

Oxygen is poorly soluble in water, roughly 100 ppm (parts per million) at 0-2$^{o}$C compared to almost 1700 ppm for carbon dioxide at the same temperature.

## CHLOROPHYLL *a*

Chlorophyll a is a green pigment contained in algae and other organisms and is necessary for photosynthesis. Its abundance is directly proportional to the abundance of algae in a body of water. Algal populations increase and decrease throughout the summer. As the population of algae increases, water clarity is reduced and a water body develops a greenish coloration, unless it is a brown or red bloom of **dinoflagellates.** As algal populations increase, chlorophyll a concentrations should increase. This increase leads to reduced water clarity.

Because chlorophyll a measurement requires special instrumentation, it probably will require the services of a well-equipped laboratory.

## FECAL COLIFORM BACTERIA

The fecal coliform group of bacteria is used by the U.S. Food and Drug Administration (FDA) as a microbiological indicator of sewage pollution to determine the potential for public health risks through dispersal of **pathogenic organisms** and for ecological damage through **nutrient loading.**

Fecal coliforms were chosen as the indicator because they originate in the digestive tract of warm-blooded animals and are discharged into the environment with fecal wastes. Presence of fecal coliforms therefore indicate the presence of sewage which could contain pathogenic bacteria, viruses, **protozoans,** or parasites. Detection of the pathogens would be an inefficient and sometimes impossible undertaking because of their limited numbers and diversity. Fecal coliforms were also chosen because of their relative ease of detection and their viability in the aquatic environment.

One member of this group is sometimes considered as a representative of the fecal coliform group. In fresh water, the bacteria *E. coli* is used as an indicator of water quality by the Environmental Protection Agency (EPA), and the enterococci group is used as an indicator in marine swimming areas.

Fecal coliforms can be detected and counted in the lab by use of media with specific **substrates** and specific incubation times and temperatures.

Fecal Coliform Bacteria numbers that indicate problems:

| Fecal Counts | Area Closed |
|---|---|
| 14 colonies/100 ml of sample | shellfish growing area |
| 200 colonies/100 ml of sample | swimming area |

# TRANSPARENCY

Transparency of water is a quick and easy measurement that integrates many important features of an aquatic system. Algae, microscopic animals, eroded soil, and resuspended bottom sediment contained in the water column interfere with light penetration and lessen the transparency of the water.

In late spring and early fall, there is usually less transparency because of plankton and algal **blooms**, and in the early spring the water may become more turbid with the silt being carried into the estuary with the spring run-off. Since sunlight is the basic energy source for most life forms, the degree of turbidity of the water has an important effect.

Transparency affects fish and other aquatic life by:

- limiting photosynthetic processes and increasing respiration, oxygen use and the amount of carbon dioxide produced;
- clogging of fish gills and feeding apparatus of bottom dwelling animals by suspended particles; and/or
- obscuring vision of fish as they hunt food and smothering bottom-dwelling animals.

A Secchi disk can be used to determine how deep into the water column the light penetrates. This technique may be less useful on mudflats and is impossible to use in shallow water areas.

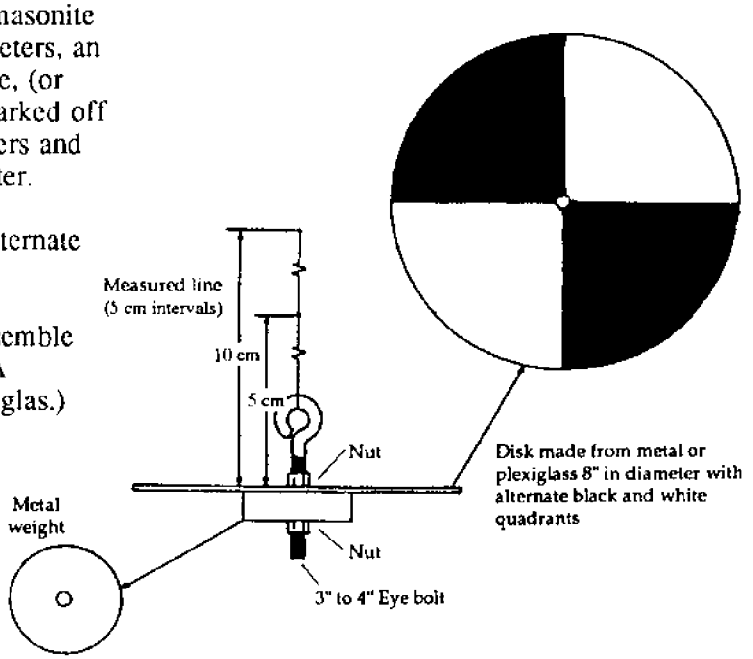
To build a Secchi Disk:

1. Use an aluminum sheet, plexiglas, or masonite that can be cut to a diameter of 20 centimeters, an eye bolt, washers, and braided dacron rope, (or some other rope that does not stretch), marked off every 10 centimeters for the first two meters and every 50 centimeters (half-meter) thereafter.

2. Divide the circle into quarters. Paint alternate quarters black and white.

3. Drill a hole through the center and assemble as shown in the diagram in the margin. (A metal weight will be needed if using plexiglas.)

**MAKING A SECCHI DISK**




Prepared by Michigan Department of Natural Resources
Self-Help Water Quality Monitoring Program

# pH

Most coastal groups monitoring in Maine do not regularly measure pH. It does becomes important, however, in certain situations such as during algal blooms or in freshwater streams flowing into an estuary.

pH is a measure of how acidic or basic (alkaline) a solution is. In any given solution some atoms of water dissociate to form hydrogen (H) and hydrogen (OH) ions (H O=H + OH). The pH scale shows which ion has the greater concentration.

At a pH of 7.0 the concentration of both hydrogen ions and hydroxyl ions is equal and the water is said to be neutral. Pure water has a pH of 7.0. When the pH is less than 7.0, there are more hydrogen ions than hydroxyl ions and the water is said to be acidic. When the pH is greater than 7.0, there are more hydroxyl ions than hydrogen ions and the water is said to be basic or alkaline.

pH is defined as the negative logarithm of the hydrogen ion concentration which means that the concentration of hydrogen ions does not increase or decrease in a linear fashion; that is, a pH of 3 is not just twice as acid as a pH of 6. Increases are in powers of 10. At pH of 5, there are 10 times more H than at a pH of 6. A change in pH of one whole number is, therefore, a large change.

Water dissolves mineral substances it contacts, picks up aerosols and dust from the air, receives human wastes, and supports photosynthetic organisms, all of which affect pH. The buffering capacity of water, or its ability to resist pH change, is critical to aquatic life, as it determines the range of pH.

Generally, the ability of aquatic organisms to complete a life cycle greatly diminishes as pH exceeds 9.0 or falls below 5.0. Coastal marine systems are well buffered. Consequently, pH is not an important indicator. The exception is during intense algal blooms. In an estuarine system where the salinity is highly variable, pH is a useful indicator. Also, it becomes important where an industrial discharge could effect the pH.

In fresh water, most fish can tolerate pH values between 5 and 9, but the ideal range falls between 6.5 and 8.2. When water with a low pH value comes in contact with certain chemicals and metals, the acid may cause these substances to become more soluble or more toxic than normal. Fish that can stand a pH as low as 4.8 may die at a pH of 5.5 if low concentrations of iron, aluminum, lead, or mercury are present.

Ocean water is a highly **buffered** solution with a pH of 8.1 to 8.3. Fresh water is, therefore, more affected by acid rain than the ocean or estuaries.

pH can be measured with a meter. It is not possible to get an accurate measurement with a prepared kit, especially in salt water.

# NUTRIENTS

## 1. Nitrogen

Nitrogen is one of the major constituents of plant and animal tissue. Its primary role is in the synthesis and maintenance of protein. Nitrogen enters the ecosystem in several chemical forms, including ammonia, nitrate, and nitrite. Nitrogen also occurs in other dissolved organic and particulate forms, such as living and dead organisms.

Some bacteria and blue-green algae can extract nitrogen gas from the atmosphere and transform it into organic nitrogen. This process, called **nitrogen fixation,** is an important pathway in the cycling of nitrogen between organic and inorganic components. Nitrogen is the **limiting nutrient** in Maine coastal waters.

## 2. Phosphorus

Phosphorus is another key nutrient and is found in the water as dissolved organic and inorganic phosphorus and also in particulate form. Phosphorous is essential to cellular growth and reproduction. Phytoplankton and bacteria assimilate and use phosphorus in their growth cycles.

When phosphate is highly concentrated in waters which contain oxygen, it combines with iron and suspended particles and eventually settles to the bottom, becoming unavailable to phytoplankton and temporarily excluded from the cycling process. Phosphate sometimes becomes a long-term constituent of the bottom sediments. When DO is absent, phosphorus is released and becomes available. Phosphorus is generally the limiting nutrient in freshwater lakes in Maine.

## 3. Uses of Nutrients

Just as fertilizer aids the growth of agricultural crops, nitrogen and phosphorus are vital to plant growth. These elements are supplied in significant quantities by sewage treatment plants, food processing industries, and urban and agricultural run-off. They are generally needed in a ratio of 16 parts nitrogen to one part phosphorus. If the availability of either drops below this ratio, it becomes the limiting nutrient in the growth of plant life.

Too many nutrients, on the other hand, can lead to over-abundances of phytoplankton, creating dense populations, or **blooms,** of plant cells. Blooms of green or blue-green phyto-plankton can become a nuisance in the upper tidal freshwaters. As the blooms decay, oxygen is used up in decomposition. This leads to **anoxic** (and odorous) conditions causing fish kills and nutrient releases.

Nutrient samples can be collected and filtered by volunteers, but they require a qualified lab for analysis.

# Monitoring



## SAFETY

Monitoring groups should have documented safety plans and volunteers need to be apprised of proper precautions.

### 1. General Safety Precautions

Always sample in teams of two or more as some areas may have hazardous conditions such as slippery rocks, soft mud, or strong currents.

Dress properly. Wool and polypropylene are the best fabrics to wear to retain body heat when wet. Plan on getting wet! Layered clothing, gloves, and boots are important in colder weather. Long pants and long sleeve shirts should be worn even in hot weather to protect you from sunburn, insects, and brambles.

Always use common sense in any situation. Getting samples is important *but not at the risk of injury*. You should always have a complete first-aid kit with you.

### 2. Boat Safety

Thorough pre-season inspections should be completed on all craft, including hulls, engines, equipment, and trailers. Repairs should be completed and defective parts or equipment replaced immediately. If thorough repair is not possible, the craft, engine, equipment or trailer should be taken out of service.

Before each trip, check the weather report for the monitoring area. Be sure that all required operational and safety equipment is on board. Personal flotation devices appropriate for the type of craft, water condition, and work activity must be on board. It is also strongly recommended that you wear a lifejacket.

Always adhere to safe boating rules and regulations. Keep a first-aid kit on board containing items appropriate to boating. The case should be maintained in good condition and be waterproof.

### 3. Lab Safety

Read all instructions to familiarize yourself with test procedures before you begin. Note any precautions in the instructions.

Keep all equipment and reagent chemicals out of the reach of small children and animals. **Some of the reagents are caustic.**

In the event of an accident or suspected poisoning, immediately call the Poison Control Center in your city or state. (See listings on this page.) If a reagent gets in your eye or on

**POISON CONTROL CENTERS:**

| | |
|---|---|
| Maine | 1-800-442-6305 |
| New Hampshire | 1-800-562-8236 |
| Massachusetts | 1-800-562-9211 |
| Toronto, Ontario | 416-598-5900 |
| Sainte Foy, Quebec | 418-656-8090 |

your skin, irrigate the area immediately with fresh water.

Protect yourself and your equipment by using the proper analytical technique. Follow these safety rules:

- ✔ Avoid contact with reagent chemicals.
- ✔ Wear safety goggles or glasses when handling the reagents.
- ✔ Use stoppers, not your fingers, to cover the bottles during shaking or mixing.
- ✔ Wipe up any reagent chemical spills (liquid or powder) as they occur. Rinse area with a wet sponge, then dry the area.
- ✔ Put newspapers down to protect surfaces.
- ✔ Rinse jars and bottles thoroughly before and after each use. Dry your hands and the outside of the bottles.
- ✔ Avoid prolonged exposure of equipment and reagents to direct sunlight. Keep reagents in a dark location, protected from extremes in temperatures.
- ✔ Wash everything that was in contact with chemicals or salt water after every test. Dry everything thoroughly.
- ✔ Wash your hands between samples and when finished conducting bacteria analyses.
- ✔ Do not come into contact with the bacterial colonies after they have been incubated.

## SELECTION OF SAMPLE SITES

After you have decided your purpose for monitoring and what variables you want to measure, you need to decide where to monitor. The following is a list of things to consider when selecting your sample sites.

- ✓ Use a **topographic map** or **navigational chart** that shows the part of the coast you want to monitor. Accurately mark your sites on this map when you are sure of the locations. A written description should also accompany the map using landmarks or latitude and longitude coordinates.

- ✓ Check with the Department of Marine Resources or any other group that monitors marine waters to note where their sample sites are. You may want to choose some or all of their sites in order to provide useful trend data.

- ✓ Choose sites in areas of known or suspected pollution.

- ✓ Check sites where there is fresh water entering the estuary such as a stream, river, pond, lake, or wetland.

- ✓ Check additional areas where there is little or no data, e.g., areas adjacent to land targeted for development to establish baseline data.

- ✓ Choose sample sites that are safely accessible by car, by foot, or by boat.

# SUMMARY OF MONITORING PROCEDURES

## 1. Procedure in the Field

**STEP 1**
Fill out the data sheet heading completely.

**STEP 2**
Place air thermometer out of the sun. Record temperature after 15 minutes. Do once at beginning of monitoring day.

**STEP 3**
Take the Secchi disk depth reading and record.

**STEP 4**
Immerse the armored thermometer in the water for 3-5 minutes, read, and record the water temperature.

**STEP 5**
Take dissolved oxygen reading with DO meter, or draw off water for DO test into a BOD bottle and fix sample if using a prepared kit.

**STEP 6**
Measure the salinity now if using a hydrometer.

**STEP 7**
Label **whirlpac bag** (sterile sample bag) and collect sample

**STEP 8**
Complete data sheet at each site. Record exact time, tidal stage, observations, and weather conditions.

## 2. Procedure in the Lab

**STEP 1**
Run samples for fecal coliform bacteria using the **membrane filtration technique.**

**STEP 2**
Check salinity now if using a conductivity meter or a refractometer.

**STEP 3**
If using titration wet kit method, complete required steps.

**STEP 4**
If measuring pH, use the meter to determine pH.

**STEP 5**
Rinse all the equipment in fresh water, dry, and store it.

# FIELD PROCEDURES

## 1. List of Equipment

- ~ Whirlpac bags (sterile sample bags)
- ~ Sample tongs
- ~ Thermometer
- ~ Permanent markers
- ~ Clipboard with data sheets, sample sites map, and field "tip sheet" ( should have a plastic cover for these to protect them in inclement weather)
- ~ Pencil (soft pencils will write on damp surfaces) and indelible pen
- ~ Cooler and ice (blue ice pack preferably)
- ~ Dissolved oxygen meter and probe or wet kit for testing DO
- ~ Secchi disk

## 2. Sample Collection and Transport

The frequency of sampling depends on program objectives, resources, accessibility, weather, number of monitors, and the variables to be monitored. For baseline monitoring, it would be ideal to sample every two weeks at high and low tides. In fact, there are many areas, such as mudflats, where there isn't any water at low tide or where areas are not navigable at any stage except high tide.

For investigative monitoring, sampling frequency will depend on how many samples are needed to adequately document a source of contamination.

The following procedures are for taking a water sample that will be analyzed for bacteria content.

**STEP 1**
Take the water temperature at each site by holding the thermometer in the water 3-5 minutes and reading the value to the nearest 0.5 degrees centigrade.

**STEP 2**
Record the temperature on data sheet. Tidal stage should be recorded, as well as present weather conditions and previous weather conditions (up to 48 hrs. before sampling). See *Tip Sheet* on page 36 for using in the field and figuring out tidal stage.

All sampling personnel should be aware of the concept of

"**aseptic technique**" and the integrity of sterile systems. It is imperative, especially under primitive field conditions, tha. precautions be taken against bacterial contamination or cross-contamination of containers or samples.

**STEP 3**
Collect water samples for bacteria examination in sterile plastic bags, such as whirlpac bags. Protection against contamination of the sample and container before, during, and after collection is extremely important.

Sterile bags must first be labeled on the bottom third of the bag starting with the area letter (if samples are to also be analyzed by the agency mandated or responsible for coastal waters), sample site number, time of sample (in military time), and date.

**STEP 4**
Samples should be collected with the aid of sampling tongs. Keep the sample container closed until immediately before filling. During sampling, protect the container closure from contamination.

**STEP 5**
To collect the sample, hold the bag with one hand and place the alligator clips of the sample tongs on the white tabs with the other hand. Tear off top of the bag at the perforation, taking care not to touch the opening. Squeeze tongs together and plunge bag *below the surface* 6 to 8 inches. Then tilt it with bag open and pointed toward current.

Before bringing the bag to the surface, close the opening by squeezing the tongs together. To facilitate shaking the sample in the laboratory, fill only two thirds full. Squeeze out any excess water so that an air space will remain in the two-thirds full bag of water.

**STEP 6**
Twirl the bag away from you, holding the ends, then twist the yellow paper-covered wire closures together over the top of the bag. Samples are then placed upright in the cooler, containing ice or ice pack(s), which should be kept between 4-10° C. (Plastic gallon milk jugs cut in half make good containers for keeping the samples in place and upright.)

**STEP 7**
Complete the data sheet as each sample is taken: sample number, temperature, time, Secchi reading, DO reading (if a meter is used), salinity (if a hydrometer is used), stage of tide, weather conditions and any observations that might relate to water quality (e.g. 10 seals on rocks, oil on surface of water, rotten egg odor, etc.)

(Name of Local Group)

# Citizen Monitoring Program
# Water Quality Data Sheet

**1 I.D.**

Site name/Number: _____ Collection date (mo/dy/yr):__/__/__

Monitor name(s): _____ Time (military):_____ hours

_____

**2 WEATHER CONDITION**

Air temperature: __.__ C

Weather (check one) ❒ clear ❒ snow ❒ overcast ❒ fog/haze ❒ drizzle ❒ downpour ❒ partly cloudy

Number of days with similar weather _____ days

Rainfall in previous 24 hours (check one): ❒ none ❒ light ❒ heavy ___inches

**3 SITE OBSERVATIONS**

Tidal stage (check one): ❒ high ebb ❒ high ❒ low ebb ❒ low ❒ low flood ❒ flood ❒ high flood

Water surface (check one): ❒ calm ❒ ripple ❒ waves ❒ white caps

Indicators (check all that apply):

| | | | |
|---|---|---|---|
| ❒ fishkills | ❒ dead crabs | ❒ oil on surface | ❒ debris |
| ❒ erosion | ❒ foam | ❒ bubbles | ❒ odors |
| ❒ abnormal color | ❒ birds | ❒ animals | ❒ other |

Please elaborate on the above: _____

_____

_____

_____

**4 FIELD/LAB MEASUREMENTS**

Secchi depth: __.__m. Water temperature: __.__C pH: __.__

Dissolved oxygen Test 1 - mg/l __.__ Test 2 - mg/l __.__

Salinity: __.__ 0/00 Fecal coliform colonies: _____ per 100 ml.

Lab analysis by: _____

Return to: _____

# FIELD TIP SHEET

When taking a sample, be sure to:

Mark the bag with black permanent marker **before** filling it with water.

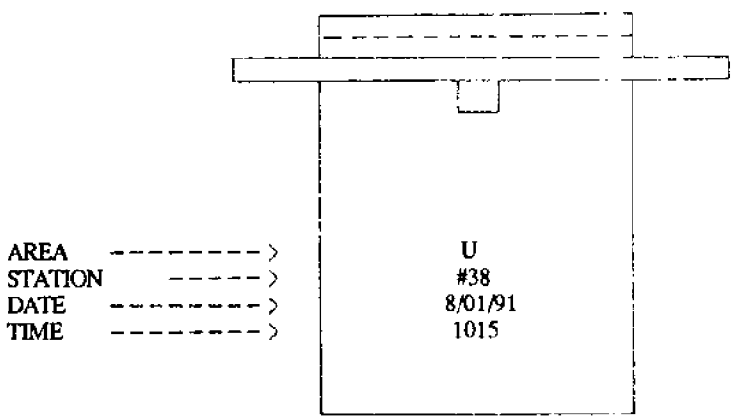
Mark the bag with AREA (U), STATION NUMBER, TIME (military), and DATE only. See example below. If you are working with the Maine Department of Marine Resources, use their letter designated for that area.

Look around at each station and record observations which could affect water quality. (For example: 25 gulls, 3 seals, seasonal cottage occupied, heavy runoff in stream in cove to north)

Be very careful not to contaminate the bag by opening it too early. Do not touch the bag near the perforated opening.

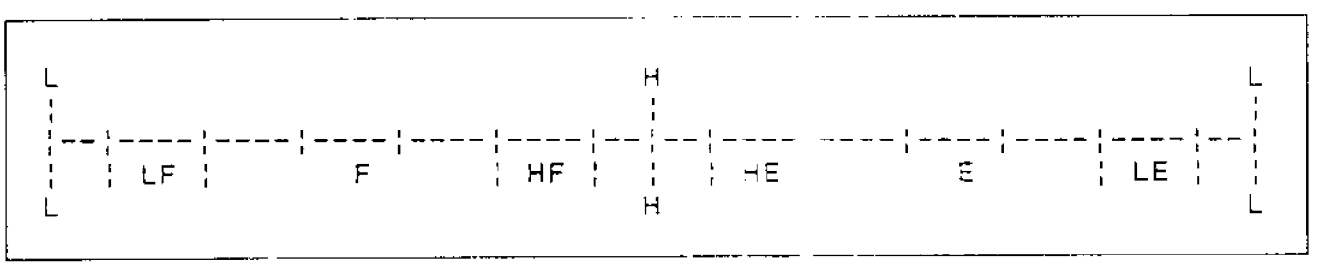
Sample water 6-8 inches below the surface. Fill the bag two-thirds full.

Keep samples on ice or cool packs and upright in the cooler.




For each sample taken, the stage of the tide should be noted on the log/data sheet. The abbreviations for tidal stages are as follows:

| | | | |
|---|---|---|---|
| H | = HIGH | L | = LOW |
| HE | = HIGH EBB | LF | = LOW FLOOD |
| E | = EBB | F | = FLOOD |
| LE | = LOW EBB | HF | = HIGH FLOOD |




**SCALE:** ⊢---⊣ **EQUALS ONE HOUR;** ⊢--⊣ **EQUALS ONE-HALF HOUR**

# FIELD MEASUREMENTS

## Dissolved Oxygen-YSI Meter and Winkler Titration Methods

There are advantages and disadvantages to each of these two methods. Good meters are a costly, up-front expenditure, but they are cheap to run on a volume basis. Groups might consider sharing equipment to spread out up-front costs. **Wet kits** are inexpensive up-front, but they need reagent refills with the more samples that are run. The wet kits use chemicals which cannot be reused and must be disposed of properly. Meters use batteries which last a long time but must be disposed of properly.

With either method, mistakes can occur. Meters can be misread or miscalibrated. Wet kits can be titrated incorrectly and values can be misread. Monitors need proper training and follow-up with either type of equipment.

If you are doing DO profiles (taking DO, salinity, and temperature readings at various depths), you will need long (50, 100, 150-foot) cables for the DO meter and conductivity meter marked off in meter increments. DO profiles can be taken with wet kits and hydrometers as well, provided you have a sampling device that can take samples at various depths. (See diagram of bottle train sampler in *Appendix C* at the back of this manual.)

### 1. Dissolved Oxygen Using a Meter

**(Operation and Care of YSI Model 57 Dissolved Oxygen Meter)**

#### A. Set-Up

Each of these procedures should be practiced and mastered before going out in the field.

**STEP 1**

Prepare and connect a YSI 5700 series dissolved oxygen probe. (Instructions for probe preparation are on page 39.)

**STEP 2**

With instrument off at the beginning of each sampling day, adjust meter to mechanical zero (if necessary). The set screw for adjustment is located on panel directly below the words "Oxygen Meter."

Tape may be placed over the set screw once the adjustment is made. Be consistent; keep meter in the same position while calibrating and sampling, either tilted or flat.

**STEP 3**

Switch to RED LINE. Leave for 15 minutes for circuitry to warm up before adjusting.

**STEP 4**
Switch to ZERO and adjust to zero on mg/L scale.

## B. Probe Calibration

Note: The meter and the probe must be at the same temperature.

**STEP 5**
Blow condensation off membrane before calibrating. Check to see that no bubbles are present. If bubbles are present, replace solution and membrane (see manufacturer's instructions and probe preparation section) .

Place probe in the small storage bottle with a moist sponge to provide 100 percent humidity. The probe may also be wrapped loosely in a damp cloth, provided that the cloth does not touch the membrane.

**STEP 6**
Set SALINITY (if equipped) control to FRESH. Switch to temperature and read. Refer to Table 1 (Solubility of Oxygen in Fresh Water) in the instruction manual or on the back of the meter and determine calibration value.

Example: If the temperature reads 23.5°C, read the calibration value for 23°C (8.58) and for 24°C (8.42). The average of the two values (8.50) will be the calibration value.

**STEP 7**
Switch to the appropriate mg/L range (for example above use 0-10) and adjust the CALIBRATE knob to the correct calibration value from step 3 (i.e., 8.50 for previous example). Wait two minutes to verify calibration stability. The probe should hold this calibration value for a series of measurements.

## C. Measurement

**STEP 8**
Adjust SALINITY knob to the salinity of the sample.

**STEP 9**
Place probe below water between one-half and one meter in depth. Gently move probe up and down 6 inches until readings for temperature and dissolved oxygen stabilize.

**STEP 10**
Read dissolved oxygen on appropriate scale (0-5, 0-10, or 0-20 mg/L), on which the calibration was initially done.

**STEP 11**
Switch to temperature and read on degrees Centigrade (C) scale.

## D. Care and Maintenance

✔ Keep meter covered in misty or wet weather. A large plastic bag can be used as a cover.

✔ Replace batteries when the RED LINE adjustment becomes difficult to read or sluggish.

✔ Carry extra batteries, probe solution, and membranes when sampling.

✔ Keep probe cover saturated. A very wet piece of kitchen sponge in a storage bottle works well.

✔ Rinse probe in fresh water (tap or stream water) after sampling in salt water.

✔ When sampling in a very shallow stream, lay probe on stream bottom (not in mud or near plants which will affect readings). The current of the stream will pass oxygen across the membrane.

✔ Keep gold cathode free from tarnish. Tarnish can be removed by gently rubbing with a pencil eraser. (See probe preparation.)

✔ Leave meter on during the sampling day to avoid having to repolarize the probe.

✔ For winter storage, remove all KCL from probe. Rinse probe with distilled water, and then fill probe with distilled water. Remove batteries from meter.

- A YSI Dissolved Oxygen meter costs approximately $1,400, with probe and cable.

## E. Probe Preparation

This procedure is not necessary unless there are bubbles or damage to the membrane, i.e., you do not need to do it every day.

STEP 1

Remove sensor guard from the probe. Rinse the sensor with probe solution. Instructions for making the KCL probe solution are on bottle.

STEP 2

Begin filling the probe with solution. Gently pump diaphragm (through hole on side of probe) with the eraser end of a pencil.

Continue filling and pumping until no more air bubbles appear, and a meniscus appears on the top.

STEP 3
Hold one end of membrane with thumb. Stretch membrane hard, up and over the top of probe. Secure other end of membrane with hand holding probe. Roll "O" ring over top of probe without touching the top of the membrane. There should be no wrinkles in membrane or trapped air bubbles.

STEP 4
Trim off excess membrane with scissors or a sharp knife. Make sure that the stainless steel temperature sensor is not covered by excess membrane.

STEP 5
Reinstall the sensor guard and place the probe in plastic storage bottle.

STEP 6
Replace membrane if bubbles form underneath membrane, if membrane becomes dirty or damaged, or if probe solution has evaporated.

## 2. Dissolved Oxygen Using Wet Kit

There are several types of prepared DO kits on the market. If you purchase one of them follow the manufacturer's specific instructions. Several groups in Maine use prepared kits purchased from La Motte because they are accurate and easy to use.

### A. La Motte Dissolved Oxygen Test Kit

| CONTENTS | LA MOTTE CODE |
|---|---|
| *Manganous Sulfate Solution | *4167WT-G |
| *Alkaline Potassium Iodide Azide | *7166WT-G |
| *Sulfuric Acid, 1:1 | *6141WT-G |
| Sodium Thiosulfate, 0.025N | 4169-11 |
| Starch Indicator Solution | 4170-G |
| Direct Reading Titrator, 0-10 ppm | 0377 |
| Titration Tube, 20 ml | 0299 |
| Pipette, plastic, with screw cap | 0392 |
| Bottle, Water Sampling, 60 ml, glass | 0688-DO |
| Cylinder, Graduated 25 ml, plastic | 2-2077 |

WARNING: Reagents marked with a * are considered hazardous substances. Material Safety Data Sheets (MSDS) are supplied for these reagents. For your safety, read label and accompanying MSDS before using.
Note: A Check Standard is needed to perform an "EPA Accepted" test.

## B. Collection and Treatment of the Water Sample

Steps 1 through 4 below describe proper sampling techniques in shallow water. At depths beyond arm's reach, special water sampling apparatus is required. (See diagram of bottle train sampler in *Appendix C.*)

**STEP 1**
To avoid contamination, thoroughly rinse the water sampling bottle (0688-DO) with sample water.

**STEP 2**
Tightly cap the bottle and submerge to the desired depth. Remove cap and allow the bottle to fill.

**STEP 3**
Tap the sides of the submerged bottle to dislodge any air bubbles clinging to the inside. Replace cap while the bottle is still submerged.

**STEP 4**
Retrieve bottle and examine it carefully to make sure that no air bubbles are trapped inside. Once a satisfactory sample has been collected, proceed immediately with Steps 5 and 6 to "fix" the sample.

Note: Be careful not to introduce air into the sample while adding the reagents in Steps 5 and 6. Simply drop the reagents into sample. Cap carefully, and mix gently.

**STEP 5**
Add 8 drops of *manganous sulfate solution (4167) and 8 drops of *alkaline potassium iodide azide solution (7166). Cap and mix by inverting several times. A precipitate will form. Allow the precipitate to settle below the shoulder of the bottle before proceeding.

**STEP 6**
Add 8 drops of *sulfuric acid, 1:1. Cap and gently shake until the reagent and the precipitate have dissolved. A clear-yellow to brown-orange color will develop, depending on the oxygen content of the sample.

Note: Following the completion of Step 6, contact between the water sample and the atmosphere will not affect the test result. Once the sample has been "fixed" in this manner, it is not necessary to perform the actual test procedure immediately. Several samples can be collected and "fixed" in the field, and then carried back to a testing station or laboratory where the test procedure is to be performed.

## C. Test Procedure

**STEP 1**
Fill the titration tube (0299) to the 20 ml line with the "fixed" sample and cap.

Note: If the color of the "fixed" sample is already a very faint yellow, skip to Step 3.

Note: For more precise oxygen measurements, fill graduated cylinder (2-2077) to 20 ml line with sample. Transfer to titration tube (0299). Cap.

**STEP 2**
Fill the direct reading titrator (0377) with sodium thiosulfate solution (4169). Insert the titrator into the center hole of the titration tube cap. While gently shaking the tube, slowly press the plunger to titrate until the yellow-brown color is reduced to a very faint yellow.

Note: For more precise measurements, the special DRT tip should be used. After filling titrator with sodium thiosulfate, 0:025N, push special DRT tip onto end of titrator until it clicks.

**STEP 3**
Remove the titrator and cap. Be careful not to disturb the titrator plunger, as the titration begun in Step 2 will be continued in Step 4. Use the pipette (0392) to add 8 drops of starch indicator solution (4170). Sample should turn blue.

**STEP 4**
Replace the cap and titrator. Continue titrating until the blue color just disappears. Read the test result where the plunger tip meets the scale. Record as ppm dissolved oxygen.

Note: Each minor division on the titrator scale equals 0.2 ppm.

**STEP 5**
If the plunger tip reaches the bottom line on the titrator scale (10 ppm) before the endpoint color change occurs, refill the titrator and continue the titration. When recording the test result, be sure to include the value of the original amount of reagent dispensed (10 ppm).

Note: These duplicate tests are run to guard against errors in analyses. If the DO results in the second test is 0.3 ml (0.6 mg/l) different than the first test, you should do a third test. Record the average of the two closest results.

Notes:
1. All reagents:
   Store at room temperature.
   Keep out of direct sunlight.
   After using, replace and tighten caps on the bottles.
   Avoid storing in humid conditions.
   Replace if a change occurs in the texture or appearance

2. The most common source of contamination in the DO testing procedure is improper treatment of the sodium thiosulfate. Do not return the thiosulfate from the titrating syringe into the chemical bottle—any thiosulfate left in the syringe when the titration is complete must be discarded.

3. It is important to achieve a pale yellow color with the sodium thiosulfate before adding the starch. If the starch is added too soon, the dark-yellow color of the treated DO sample can actually mask the color change needed from blue to clear.

- A prepared kit costs approximately $40 (for 50 tests). Reagent refills for the kit are approximately $20.

## Salinity Using Conductivity Meter, Hydrometer, and Hand-held Refractometer

A hydrometer is the least expensive instrument to measure salinity but must be used in the field and is awkward at best on a boat or uneven surface. A conductivity meter is the most expensive instrument, but it is also the easiest method to use.

A hand-held refractometer is also easy to use, but it is time consuming in the field because it is temperature-dependent and must be calibrated at each change in temperature. This difficulty is overcome when used in the laboratory by bringing all the samples to room temperature.

## 1. Salinity Using a Conductivity Meter

**(Operation/Care of YSI Model 33 Conductivity Meter)**

### A. Operation

**STEP 1**
Switch MODE control to OFF. Use meter screw to adjust meter needle to zero conductivity if necessary.

**STEP 2**
Plug probe into jack.

**STEP 3**
RED LINE the meter.

**STEP 4**
Switch MODE to TEMPERATURE, put probe in water, and read meter when needle is steady. (Temperature may also be read with the oxygen meter or hand-held thermometer.)

**STEP 5**
Set C control to indicated temperature.

**STEP 6**
Switch to SALINITY. Read S 0/00 scale.

### B. Care

**STEP 7**
Clean probe in 10 parts distilled water; 10 parts isopropyl alcohol; 1 part HCL. Soak for 5 minutes, and then rinse probe with distilled water.

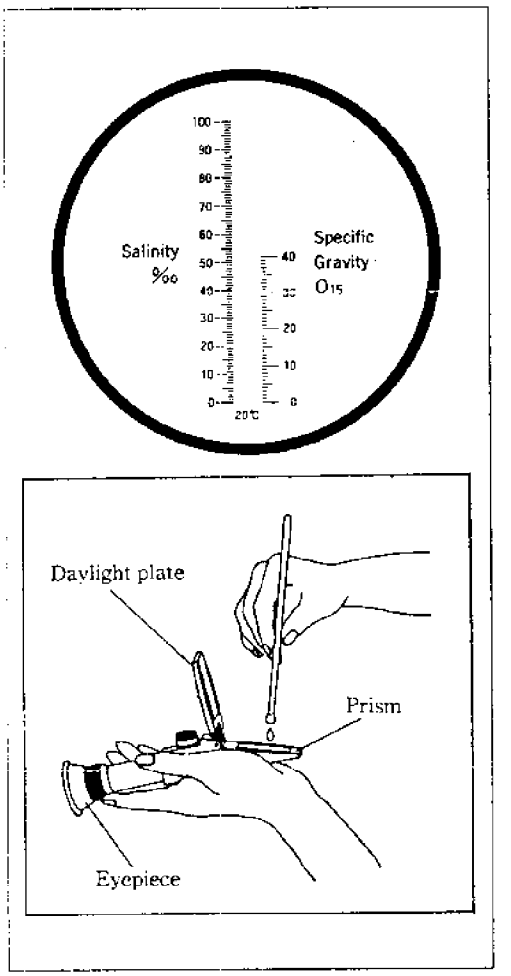
**STEP 8**
The probe should be stored in distilled water.

- Approximate cost of a YSI Model 33 Conductivity Meter and probe with 10 feet of cable is $750; with 50 feet of cable the cost is $850.

The more salts dissolved in water, the better the water conducts electricity. Salinity can be determined by measuring electrical conductivity and correcting for the effect of temperature.

## 2. Salinity Using a Hand-Held Refractometer

There are many types of refractometers. The less expensive ones are temperature dependent and need to be calibrated for each temperature change in a water sample. To avoid this time-consuming task, bring the samples back to the lab, allow them to come to room temperature (after conducting bacterial analysis), then measure the salinity for all the samples.




These instruments are fairly easy to use. Follow the manufacturers specific directions. The following directions are for a hand-held refractometer (S-100) made by Tanaka Sanjiro Co., Ltd. Cost is $270.

**STEP 1**
Open the daylight plate and apply one or two drops of a sample solution on the prism surface.

**STEP 2**
Close the daylight plate gently. The sample solution spreads like a thin film between the daylight plate and the prism. Make sure there are no bubbles in the sample solution.

**STEP 3**
Hold the refractometer with the daylight plate upward, direct it toward the light, and observe the field of view through the eyepiece. When the field of view is not clear, adjust it by turning the grooved plastic portion of the eyepiece either clockwise or counter clockwise.

**STEP 4**
The upper field of view appears in blue and the lower field of view appears in white. Read the scale where the boundary line of the blue and white fields cross the scale. The value read to the left is the salinity of the sample.

To calibrate: using distilled water, adjust the boundary line to read at the o o/oo of the scale by turning the scale adjusting knob.

**STEP 5**
Clean the refractometer after use with a soft cloth soaked in fresh water and wipe off the moisture with a dry cloth.

If the prism surface is smeared with oil or similar liquids, it will repel the sample and obstruct the measurement. Wipe off the contaminant with alcohol, then with fresh water.

## 3. Salinity Using a Hydrometer

Equipment: armored thermometer, hydrometer, 500 ml cylinder.

### A. Procedure

Objects float higher in salt water than in fresh water because salt water is more dense (heavier per unit of volume). Salinity may be calculated by measuring the specific gravity of a sample of water using a hydrometer, correcting for the effect of temperature and converting the readings to salinity by means of conversion tables.

**STEP 1**
Fill the 500 ml cylinder to the uppermost mark or 3/4 full with sample water.

**STEP 2**
Hang the armored thermometer in the jar by tying a string to the thermometer and attaching a large paper clip.

**STEP 3**
Insert the hydrometer with a twisting motion to remove bubbles. Be careful not to drop it, because it might break.

**STEP 4**
After 3-5 minutes, read the thermometer to the nearest 0.5° C. and record. Remove the thermometer.

**STEP 5**
Read the density, taking care to read at the bottom of the curve formed when the water adheres and rises slightly where it touches the sides of the hydrometer. This curve is called the **meniscus.** Record your reading on the data sheet.

**STEP 6**
To determine salinity, use Hydrometer Table 1 on page 47 which shows values for converting hydrometer readings to density 15° C.

Find the observed density reading along the vertical axis and the temperature reading along the horizontal. Record the number on your data sheet directly below the last two numbers of your observed density reading.

**Example:**
1.0110 density
.0021 correction
1.0131 corrected density

Remember that positive numbers are added; negative numbers are subtracted; when water temperature is 15° C no correction is needed.

**STEP 7**
Turn to Hydrometer Table 2: Corresponding Densities and Salinities. Locate corrected density in the appropriate column, read salinity, and record it on data sheet.

- The cost of a hydrometer is approximately $32.00.

Table 1. Values to convert hydrometer readings at any temperture to density at 15°C. From Zerbe and Taylor (1953).

| Observed Reading | Temperature of Water in Graduated Cyclinder (IC) | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -2.0 | -1.0 | 0.0 | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 | 10.0 | 11.0 | 12.0 | 13.0 | 14.0 | 15.0 | 16.0 | 17.0 | 18.0 | 18.5 | 19.0 | 19.5 | 20.0 |
| 0.9970 | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.9980 | | | | | | | | | | | | | | | | | | | | 3 | 4 | 5 | 6 | 7 | 8 |
| 0.9990 | -1 | -2 | -3 | -4 | -5 | -5 | -6 | -6 | -6 | -6 | -6 | -5 | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1.0000 | -2 | -3 | -4 | -5 | -5 | -6 | -6 | -6 | -6 | -6 | -6 | -5 | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1.0010 | -3 | -4 | -4 | -5 | -6 | -6 | -6 | -7 | -7 | -6 | -6 | -6 | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1.0020 | -3 | -4 | -5 | -6 | -6 | -7 | -7 | -7 | -7 | -7 | -6 | -6 | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1.0030 | -4 | -5 | -6 | -6 | -7 | -7 | -7 | -7 | -7 | -7 | -6 | -6 | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1.0040 | -4 | -5 | -6 | -7 | -7 | -7 | -8 | -8 | -7 | -7 | -7 | -6 | -6 | -5 | -4 | -3 | -1 | 0 | 2 | 3 | 5 | 6 | 6 | 7 | 8 |
| 1.0050 | -5 | -6 | -6 | -7 | -8 | -8 | -8 | -8 | -8 | -7 | -7 | -6 | -6 | -5 | -4 | -3 | -1 | 0 | 2 | 3 | 5 | 6 | 7 | 8 | 9 |
| 1.0060 | -6 | -6 | -7 | -8 | -8 | -8 | -8 | -8 | -8 | -8 | -7 | -6 | -6 | -5 | -4 | -3 | -1 | 0 | 2 | 3 | 5 | 6 | 7 | 8 | 9 |
| 1.0070 | -6 | -7 | -8 | -8 | -8 | -8 | -8 | -8 | -8 | -8 | -7 | -7 | -6 | -5 | -4 | -3 | -2 | 0 | 2 | 3 | 5 | 6 | 7 | 8 | 9 |
| 1.0080 | -7 | -8 | -8 | -9 | -9 | -9 | -9 | -9 | -8 | -8 | -7 | -7 | -6 | -5 | -4 | -3 | -2 | 0 | 2 | 3 | 5 | 6 | 7 | 8 | 9 |
| 1.0090 | -7 | -8 | -9 | -9 | -9 | -9 | -9 | -9 | -9 | -8 | -8 | -7 | -6 | -5 | -4 | -3 | -2 | 0 | 2 | 3 | 5 | 6 | 7 | 8 | 9 |
| 1.0100 | -8 | -9 | -9 | -10 | -10 | -10 | -10 | -9 | -9 | -8 | -8 | -7 | -6 | -5 | -4 | -3 | -2 | 0 | 2 | 3 | 5 | 6 | 7 | 8 | 9 |
| 1.0110 | -9 | -9 | -10 | -10 | -10 | -10 | -10 | -10 | -9 | -9 | -8 | -7 | -6 | -5 | -4 | -3 | -2 | 0 | 2 | 3 | 5 | 6 | 7 | 8 | 9 |
| 1.0120 | -9 | -10 | -10 | -10 | -10 | -10 | -10 | -10 | -10 | -9 | -8 | -7 | -7 | -6 | -4 | -3 | -2 | 0 | 2 | 3 | 5 | 6 | 7 | 8 | 9 |
| 1.0130 | -10 | -10 | -11 | -11 | -11 | -11 | -11 | -10 | -10 | -9 | -8 | -8 | -7 | -6 | -4 | -3 | -2 | 0 | 2 | 4 | 5 | 6 | 7 | 8 | 10 |
| 1.0140 | -10 | -11 | -11 | -11 | -11 | -11 | -11 | -11 | -10 | -10 | -9 | -8 | -7 | -6 | -4 | -3 | -2 | 0 | 2 | 4 | 5 | 6 | 8 | 9 | 10 |
| 1.0150 | -11 | -11 | -12 | -12 | -12 | -12 | -11 | -11 | -10 | -10 | -9 | -8 | -7 | -6 | -4 | -3 | -2 | 0 | 2 | 4 | 5 | 6 | 8 | 9 | 10 |
| 1.0160 | -12 | -12 | -12 | -12 | -12 | -12 | -12 | -11 | -11 | -10 | -9 | -8 | -7 | -6 | -5 | -3 | -2 | 0 | 2 | 4 | 6 | 7 | 8 | 9 | 10 |
| 1.0170 | -12 | -12 | -12 | -13 | -13 | -12 | -12 | -12 | -11 | -10 | -9 | -8 | -7 | -6 | -5 | -3 | -2 | 0 | 2 | 4 | 6 | 7 | 8 | 9 | 10 |
| 1.0180 | -13 | -13 | -13 | -13 | -13 | -13 | -12 | -12 | -11 | -10 | -9 | -8 | -7 | -6 | -5 | -3 | -2 | 0 | 2 | 4 | 6 | 7 | 8 | 9 | 10 |
| 1.0190 | -13 | -13 | -13 | -14 | -13 | -13 | -13 | -12 | -12 | -11 | -10 | -9 | -8 | -6 | -5 | -3 | -2 | 0 | 2 | 4 | 6 | 7 | 8 | 9 | 10 |
| 1.0200 | -14 | -14 | -14 | -14 | -14 | -13 | -13 | -12 | -12 | -11 | -10 | -9 | -8 | -6 | -5 | -3 | -2 | 0 | 2 | 4 | 6 | 7 | 8 | 9 | 10 |
| 1.0210 | -14 | -14 | -14 | -14 | -14 | -14 | -13 | -13 | -12 | -11 | -10 | -9 | -8 | -6 | -5 | -3 | -2 | 0 | 2 | 4 | 6 | 7 | 8 | 9 | 10 |
| 1.0220 | -15 | -15 | -15 | -15 | -15 | -14 | -14 | -13 | -12 | -11 | -10 | -9 | -8 | -7 | -5 | -3 | -2 | 0 | 2 | 4 | 6 | 7 | 8 | 9 | 11 |
| 1.0230 | -15 | -15 | -15 | -15 | -15 | -15 | -14 | -13 | -12 | -12 | -10 | -9 | -8 | -7 | -5 | -4 | -2 | 0 | 2 | 4 | 6 | 7 | 8 | 9 | 11 |
| 1.0240 | -16 | -16 | -16 | -16 | -15 | -15 | -14 | -14 | -13 | -12 | -11 | -10 | -8 | -7 | -5 | -4 | -2 | 0 | 2 | 4 | 6 | 7 | 8 | 10 | 11 |
| 1.0250 | -16 | -16 | -16 | -16 | -16 | -15 | -15 | -14 | -13 | -12 | -11 | -10 | -8 | -7 | -5 | -4 | -2 | 0 | 2 | 4 | 6 | 7 | 8 | 10 | 11 |
| 1.0260 | -17 | -17 | -17 | -16 | -16 | -16 | -15 | -14 | -13 | -12 | -11 | -10 | -8 | -7 | -5 | -4 | -2 | 0 | 2 | 4 | 6 | 7 | 9 | 10 | 11 |
| 1.0270 | -18 | -17 | -17 | -17 | -17 | -16 | -15 | -14 | -14 | -12 | -11 | -10 | -9 | -7 | -5 | -4 | -2 | 0 | 2 | 4 | 6 | 7 | 9 | 10 | 11 |
| 1.0280 | -18 | -18 | -18 | -17 | -17 | -16 | -16 | -15 | -14 | -13 | -11 | -10 | -9 | -7 | -6 | -4 | -2 | 0 | 2 | 4 | 6 | 8 | 9 | 10 | 11 |
| 1.0290 | -19 | -18 | -18 | -18 | -17 | -17 | -16 | -15 | -14 | -13 | -12 | -10 | -9 | -7 | -6 | -4 | -2 | 0 | 2 | 4 | 6 | 8 | 9 | 10 | 11 |
| 1.0300 | -19 | -19 | -19 | -18 | -18 | -17 | -16 | -15 | -14 | -13 | -12 | -10 | -9 | -7 | -6 | -4 | -2 | 0 | 2 | 4 | 6 | 8 | 9 | 10 | 12 |
| 1.0310 | -20 | -19 | -19 | -19 | -18 | -17 | -16 | -16 | -15 | -13 | -12 | -10 | -9 | -8 | -6 | -4 | -2 | 0 | 2 | 4 | | | | | |

Table 1. Values to convert hydrometer readings at any temperture to density at 15°C. From Zerbe and Taylor (1953).

| Observed | Temperature of Water in Graduated Cylinder (-C) | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reading | 20.5 | 21.0 | 21.5 | 22.0 | 22.5 | 23.0 | 23.5 | 24.0 | 24.5 | 25.0 | 25.5 | 26.0 | 26.5 | 27.0 | 27.5 | 28.0 | 28.5 | 29.0 | 29.5 | 30.0 | 30.5 | 31.0 | 31.5 | 32.0 | 32.5 | 33.0 |
| 0.9970 | | | 10 | 11 | 12 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 22 | 23 | 24 | 26 | 27 | 28 | 30 | 31 | 33 | 34 | 36 | 37 | 39 | 40 |
| 0.9980 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19- | 21 | 22 | 23 | 25 | 26 | 27 | 29 | 30 | 31 | 33 | 34 | 36 | 38 | 39 | 41 |
| 0.9990 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 20 | 21 | 22 | 24 | 25 | 26 | 28 | 29 | 30 | 32 | 33 | 35 | 36 | 38 | 39 | 41 |
| 1.0000 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 19 | 20 | 21 | 22 | 24 | 25 | 26 | 28 | 29 | 31 | 32 | 34 | 35 | 37 | 38 | 40 | 41 |
| 1.0010 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 17 | 18 | 19 | 20 | 21 | 23 | 24 | 25 | 27 | 28 | 30 | 31 | 32 | 34 | 35 | 37 | 39 | 40 | 42 |
| 1.0020 | 9 | 10 | 11 | 12 | 13 | 14 | 16 | 17 | 18 | 19 | 20 | 22 | 23 | 24 | 26 | 27 | 28 | 30 | 31 | 33 | 34 | 36 | 37 | 39 | 41 | 42 |
| 1.0030 | 9 | 10 | 11 | 12 | 13 | 15 | 16 | 17 | 18 | 19 | 21 | 22 | 23 | 25 | 26 | 27 | 29 | 30 | 32 | 33 | 35 | 36 | 38 | 39 | 41 | 42 |
| 1.0040 | 9 | 10 | 11 | 12 | 14 | 15 | 16 | 17 | 18 | 20 | 21 | 22 | 23 | 25 | 26 | 28 | 29 | 30 | 32 | 33 | 35 | 36 | 38 | 40 | 41 | 43 |
| 1.0050 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 19 | 20 | 21 | 22 | 24 | 25 | 26 | 28 | 29 | 31 | 32 | 34 | 35 | 37 | 38 | 40 | 42 | 43 |
| 1.0060 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 18 | 19 | 20 | 21 | 23 | 24 | 25 | 27 | 28 | 30 | 31 | 32 | 34 | 36 | 37 | 39 | 40 | 42 | 44 |
| 1.0070 | 10 | 11 | 12 | 13 | 14 | 15 | 17 | 18 | 19 | 20 | 21 | 23 | 24 | 26 | 27 | 28 | 30 | 31 | 33 | 34 | 36 | 38 | 39 | 41 | 42 | 44 |
| 1.0080 | 10 | 11 | 12 | 13 | 14 | 16 | 17 | 18 | 19 | 20 | 22 | 23 | 24 | 26 | 27 | 29 | 30 | 32 | 33 | 35 | 36 | 38 | 39 | 41 | 43 | 44 |
| 1.0090 | 10 | 11 | 12 | 13 | 15 | 16 | 17 | 18 | 19 | 21 | 22 | 23 | 25 | 26 | 28 | 29 | 30 | 32 | 33 | 35 | 36 | 38 | 40 | 41 | 43 | 45 |
| 1.0100 | 10 | 11 | 12 | 14 | 15 | 16 | 17 | 18 | 20 | 21 | 22 | 24 | 25 | 26 | 28 | 29 | 31 | 32 | 34 | 35 | 37 | 38 | 40 | 42 | 43 | 45 |
| 1.0110 | 10 | 12 | 13 | 14 | 15 | 16 | 17 | 19 | 20 | 21 | 22 | 24 | 25 | 27 | 28 | 30 | 31 | 32 | 34 | 36 | 37 | 39 | 40 | 42 | 44 | 45 |
| 1.0120 | 10 | 12 | 13 | 14 | 15 | 16 | 18 | 19 | 20 | 21 | 23 | 24 | 25 | 27 | 28 | 30 | 31 | 32 | 34 | 36 | 37 | 39 | 41 | 42 | 44 | 46 |
| 1.0130 | 11 | 12 | 13 | 14 | 15 | 16 | 18 | 19 | 20 | 22 | 23 | 24 | 26 | 27 | 29 | 30 | 32 | 33 | 35 | 36 | 38 | 39 | 41 | 43 | 44 | 46 |
| 1.0140 | 11 | 12 | 13 | 14 | 15 | 17 | 18 | 19 | 20 | 22 | 23 | 24 | 26 | 27 | 29 | 30 | 32 | 33 | 35 | 36 | 38 | 40 | 41 | 43 | 45 | 46 |
| 1.0150 | 11 | 12 | 13 | 14 | 16 | 17 | 18 | 20 | 21 | 22 | 23 | 25 | 26 | 28 | 29 | 31 | 32 | 34 | 35 | 37 | 38 | 40 | 42 | 43 | 45 | 47 |
| 1.0160 | 11 | 12 | 13 | 14 | 16 | 17 | 18 | 20 | 21 | 22 | 24 | 25 | 26 | 28 | 29 | 31 | 32 | 34 | 35 | 37 | 39 | 40 | 42 | 44 | 45 | 47 |
| 1.0170 | 11 | 12 | 13 | 15 | 16 | 17 | 18 | 20 | 21 | 22 | 24 | 25 | 27 | 28 | 30 | 31 | 33 | 34 | 36 | 37 | 39 | 40 | 42 | 44 | 46 | 47 |
| 1.0180 | 11 | 12 | 14 | 15 | 16 | 17 | 19 | 20 | 21 | 23 | 24 | 25 | 27 | 28 | 30 | 31 | 33 | 34 | 36 | 38 | 39 | 41 | 42 | 44 | 46 | 48 |
| 1.0190 | 11 | 12 | 14 | 15 | 16 | 18 | 19 | 20 | 21 | 23 | 24 | 26 | 27 | 29 | 30 | 32 | 33 | 35 | 36 | 38 | 39 | 41 | 43 | 44 | 46 | 48 |
| 1.0200 | 11 | 13 | 14 | 15 | 16 | 18 | 19 | 20 | 22 | 23 | 24 | 26 | 27 | 29 | 30 | 32 | 33 | 35 | 37 | 38 | 40 | 41 | 43 | 45 | 47 | 48 |
| 1.0210 | 12 | 13 | 14 | 15 | 17 | 18 | 19 | 21 | 22 | 23 | 25 | 26 | 27 | 29 | 31 | 32 | 34 | 35 | 37 | 38 | 40 | 42 | 43 | 45 | 47 | 49 |
| 1.0220 | 12 | 13 | 14 | 15 | 17 | 18 | 19 | 21 | 22 | 23 | 25 | 26 | 28 | 29 | 31 | 32 | 34 | 36 | 37 | 39 | 40 | 42 | 44 | 45 | 47 | 49 |
| 1.0230 | 12 | 13 | 14 | 16 | 17 | 18 | 20 | 21 | 22 | 24 | 25 | 26 | 28 | 30 | 31 | 33 | 34 | 36 | 37 | 39 | 41 | 42 | 44 | 46 | 47 | 49 |
| 1.0240 | 12 | 13 | 14 | 16 | 17 | 18 | 20 | 21 | 22 | 24 | 25 | 27 | 28 | 30 | 31 | 33 | 34 | 36 | 37 | 39 | 41 | 42 | 44 | 46 | 48 | 49 |
| 1.0250 | 12 | 13 | 15 | 16 | 17 | 18 | 20 | 21 | 23 | 24 | 25 | 27 | 28 | 30 | 31 | 33 | 35 | 36 | 38 | 39 | 41 | 43 | 44 | 46 | 48 | 50 |
| 1.0260 | 12 | 13 | 15 | 16 | 17 | 19 | 20 | 22 | 23 | 24 | 26 | 27 | 29 | 30 | 32 | 33 | 35 | 37 | 38 | 40 | 41 | 43 | 45 | 46 | 48 | 50 |
| 1.0270 | 12 | 14 | 15 | 16 | 17 | 19 | 20 | 22 | 23 | 24 | 26 | 27 | 29 | 30 | 32 | 34 | 35 | 37 | 38 | 40 | | | | | | |
| 1.0280 | 12 | 14 | 15 | 16 | 18 | 19 | 20 | 22 | 23 | 25 | 26 | 28 | 29 | 31 | 32 | | | | | | | | | | | |
| 1.0290 | 13 | 14 | 15 | 16 | 18 | 19 | 21 | 22 | 23 | | | | | | | | | | | | | | | | | |
| 1.0300 | 13 | 14 | 15 | 16 | 18 | | | | | | | | | | | | | | | | | | | | | |
| 1.0310 | | | | | | | | | | | | | | | | | | | | | | | | | | |

**Table 2. Corresponding Density (at 15°C) and Salinity (in parts per thousand). From Zerbe and Taylor, 1953.**

| Density | Salinity | Density | Salinity | Density | Salinity | Density | Salinity | Density | Salinity | Density | Salinity | Density | Salinity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.9991 | 0.0 | 1.0049 | 7.5 | 1.0097 | 13.7 | 1.0145 | 20.0 | 1.0193 | 26.3 | 1.0241 | 32.5 | 1.0289 | 38.8 |
| 0.9992 | 0.0 | 1.0050 | 7.6 | 1.0098 | 13.9 | 1.0146 | 20.1 | 1.0194 | 26.4 | 1.0242 | 32.7 | 1.0290 | 38.9 |
| 0.9993 | 0.2 | 1.0051 | 7.7 | 1.0099 | 14.0 | 1.0147 | 20.3 | 1.0195 | 26.5 | 1.0243 | 32.8 | 1.0291 | 39.0 |
| 0.9994 | 0.3 | 1.0052 | 7.9 | 1.0100 | 14.1 | 1.0148 | 20.4 | 1.0196 | 26.7 | 1.0244 | 32.9 | 1.0292 | 39.2 |
| 0.9995 | 0.4 | 1.0053 | 8.0 | 1.0101 | 14.2 | 1.0149 | 20.5 | 1.0197 | 26.8 | 1.0245 | 33.1 | 1.0293 | 39.3 |
| 0.9996 | 0.6 | 1.0054 | 8.1 | 1.0102 | 14.4 | 1.0150 | 20.6 | 1.0198 | 26.9 | 1.0246 | 33.2 | 1.0294 | 39.4 |
| 0.9997 | 0.7 | 1.0055 | 8.2 | 1.0103 | 14.5 | 1.0151 | 20.8 | 1.0199 | 27.1 | 1.0247 | 33.3 | 1.0295 | 39.6 |
| 0.9998 | 0.8 | 1.0056 | 8.4 | 1.0104 | 14.6 | 1.0152 | 20.9 | 1.0200 | 27.2 | 1.0248 | 33.5 | 1.0296 | 39.7 |
| 0.9999 | 0.9 | 1.0057 | 8.5 | 1.0105 | 14.8 | 1.0153 | 21.0 | 1.0201 | 27.3 | 1.0249 | 33.6 | 1.0297 | 39.8 |
| 1.0000 | 1.1 | 1.0058 | 8.6 | 1.0106 | 14.9 | 1.0154 | 21.2 | 1.0202 | 27.5 | 1.0250 | 33.7 | 1.0298 | 39.9 |
| 1.0001 | 1.2 | 1.0059 | 8.8 | 1.0107 | 15.0 | 1.0155 | 21.3 | 1.0203 | 27.6 | 1.0251 | 33.8 | 1.0299 | 40.1 |
| 1.0002 | 1.4 | 1.0060 | 8.9 | 1.0108 | 15.2 | 1.0156 | 21.4 | 1.0204 | 27.7 | 1.0252 | 34.0 | 1.0300 | 40.2 |
| 1.0003 | 1.5 | 1.0061 | 9.0 | 1.0109 | 15.3 | 1.0157 | 21.6 | 1.0205 | 27.8 | 1.0253 | 34.1 | 1.0301 | 40.3 |
| 1.0004 | 1.6 | 1.0062 | 9.2 | 1.0110 | 15.4 | 1.0158 | 21.7 | 1.0206 | 28.0 | 1.0254 | 34.2 | 1.0302 | 40.4 |
| 1.0005 | 1.7 | 1.0063 | 9.3 | 1.0111 | 15.6 | 1.0159 | 21.8 | 1.0207 | 28.1 | 1.0255 | 34.4 | 1.0303 | 40.6 |
| 1.0006 | 1.9 | 1.0064 | 9.4 | 1.0112 | 15.7 | 1.0160 | 22.0 | 1.0208 | 28.2 | 1.0256 | 34.5 | 1.0304 | 40.7 |
| 1.0007 | 2.0 | 1.0065 | 9.6 | 1.0113 | 15.8 | 1.0161 | 22.1 | 1.0209 | 28.4 | 1.0257 | 34.6 | 1.0305 | 40.8 |
| 1.0008 | 2.1 | 1.0066 | 9.7 | 1.0114 | 16.0 | 1.0162 | 22.2 | 1.0210 | 28.5 | 1.0258 | 34.8 | 1.0306 | 41.0 |
| 1.0009 | 2.3 | 1.0067 | 9.8 | 1.0115 | 16.1 | 1.0163 | 22.4 | 1.0211 | 28.6 | 1.0259 | 34.9 | 1.0307 | 41.1 |
| 1.0010 | 2.4 | 1.0068 | 9.9 | 1.0116 | 16.2 | 1.0164 | 22.5 | 1.0212 | 28.8 | 1.0260 | 35.0 | 1.0308 | 41.2 |
| 1.0011 | 2.5 | 1.0069 | 10.1 | 1.0117 | 16.3 | 1.0165 | 22.6 | 1.0213 | 28.9 | 1.0261 | 35.1 | 1.0309 | 41.4 |
| 1.0012 | 2.6 | 1.0070 | 10.2 | 1.0118 | 16.5 | 1.0166 | 22.7 | 1.0214 | 29.0 | 1.0262 | 35.3 | 1.0310 | 41.5 |
| 1.0013 | 2.8 | 1.0071 | 10.3 | 1.0119 | 16.6 | 1.0167 | 22.9 | 1.0215 | 29.1 | 1.0263 | 35.4 | 1.0311 | 41.6 |
| 1.0014 | 2.9 | 1.0072 | 10.5 | 1.0120 | 16.7 | 1.0168 | 23.0 | 1.0216 | 29.3 | 1.0264 | 35.5 | 1.0312 | 41.7 |
| 1.0015 | 3.0 | 1.0073 | 10.5 | 1.0121 | 16.9 | 1.0169 | 23.1 | 1.0217 | 29.4 | 1.0265 | 35.7 | 1.0313 | 41.9 |
| 1.0016 | 3.2 | 1.0074 | 10.7 | 1.0122 | 17.0 | 1.0170 | 23.3 | 1.0218 | 29.5 | 1.0266 | 35.8 | 1.0314 | 42.0 |
| 1.0017 | 3.3 | 1.0075 | 10.8 | 1.0123 | 17.1 | 1.0171 | 23.4 | 1.0219 | 29.7 | 1.0267 | 35.9 | 1.0315 | 42.1 |
| 1.0018 | 3.4 | 1.0076 | 11.0 | 1.0124 | 17.3 | 1.0172 | 23.5 | 1.0220 | 29.8 | 1.0268 | 36.0 | 1.0316 | 42.3 |
| 1.0019 | 3.5 | 1.0077 | 11.1 | 1.0125 | 17.4 | 1.0173 | 23.7 | 1.0221 | 29.9 | 1.0269 | 36.2 | 1.0317 | 42.4 |
| 1.0020 | 3.7 | 1.0078 | 11.2 | 1.0126 | 17.5 | 1.0174 | 23.8 | 1.0222 | 30.1 | 1.0270 | 36.3 | 1.0318 | 42.5 |
| 1.0021 | 3.8 | 1.0079 | 11.4 | 1.0127 | 17.7 | 1.0175 | 23.9 | 1.0223 | 30.2 | 1.0271 | 36.4 | 1.0319 | 42.7 |
| 1.0022 | 3.9 | 1.0080 | 11.5 | 1.0128 | 17.8 | 1.0176 | 24.0 | 1.0224 | 30.3 | 1.0272 | 36.6 | 1.0320 | 42.8 |
| 1.0023 | 4.1 | 1.0081 | 11.6 | 1.0129 | 17.9 | 1.0177 | 24.2 | 1.0225 | 30.4 | 1.0273 | 36.7 | 1.0321 | 42.9 |
| 1.0024 | 4.2 | 1.0082 | 11.8 | 1.0130 | 18.0 | 1.0178 | 24.3 | 1.0226 | 30.6 | 1.0274 | 36.8 | 1.0322 | 43.1 |
| 1.0025 | 4.3 | 1.0083 | 11.9 | 1.0131 | 18.2 | 1.0179 | 24.4 | 1.0227 | 30.7 | 1.0275 | 37.0 | 1.0323 | 43.2 |
| 1.0026 | 4.5 | 1.0084 | 12.0 | 1.0132 | 18.3 | 1.0180 | 24.6 | 1.0228 | 30.8 | 1.0276 | 37.1 | 1.0324 | 43.3 |
| 1.0027 | 4.6 | 1.0085 | 12.2 | 1.0133 | 18.4 | 1.0181 | 24.7 | 1.0229 | 31.0 | 1.0277 | 37.2 | 1.0325 | 43.4 |
| 1.0028 | 4.7 | 1.0086 | 12.3 | 1.0134 | 18.6 | 1.0182 | 24.8 | 1.0230 | 31.1 | 1.0278 | 37.3 | 1.0326 | 43.6 |
| 1.0029 | 4.8 | 1.0087 | 12.4 | 1.0135 | 18.7 | 1.0183 | 25.0 | 1.0231 | 31.2 | 1.0279 | 37.5 | | |
| 1.0030 | 5.0 | 1.0088 | 12.6 | 1.0136 | 18.8 | 1.0184 | 25.1 | 1.0232 | 31.4 | 1.0280 | 37.6 | | |
| 1.0031 | 5.1 | 1.0089 | 12.7 | 1.0137 | 19.0 | 1.0185 | 25.2 | 1.0233 | 31.5 | 1.0281 | 37.7 | | |
| 1.0032 | 5.2 | 1.0090 | 12.8 | 1.0138 | 19.1 | 1.0186 | 25.4 | 1.0234 | 31.6 | 1.0282 | 37.9 | | |
| 1.0033 | 5.4 | 1.0091 | 12.9 | 1.0139 | 19.2 | 1.0187 | 25.5 | 1.0235 | 31.8 | 1.0283 | 38.0 | | |
| 1.0034 | 5.5 | 1.0092 | 13.1 | 1.0140 | 19.3 | 1.0188 | 25.6 | 1.0236 | 31.9 | 1.0284 | 38.1 | | |
| 1.0035 | 5.6 | 1.0093 | 13.2 | 1.0141 | 19.5 | 1.0189 | 25.8 | 1.0237 | 32.0 | 1.0285 | 38.2 | | |
| 1.0036 | 5.8 | 1.0094 | 13.3 | 1.0142 | 19.6 | 1.0190 | 25.9 | 1.0238 | 32.1 | 1.0286 | 38.4 | | |
| 1.0037 | 5.9 | 1.0095 | 13.5 | 1.0143 | 19.7 | 1.0191 | 26.0 | 1.0239 | 32.3 | 1.0287 | 38.5 | | |
| 1.0038 | 6.0 | 1.0096 | 13.6 | 1.0144 | 19.9 | 1.0192 | 26.1 | 1.0240 | 32.4 | 1.0288 | 38.6 | | |

## Transparency

Equipment: Secchi disk, on line marked every five centimeters.

### 1. Procedure

(Take this reading at exactly the same spot each time).

**STEP 1**

Lower the Secchi disk into the water in the shade of your body as you stand with your back to the sun, until it just goes out of sight. Note depth. Then raise Secchi disk until it just reappears and note the depth. Record the average of the two depths. If the disk is resting on the bottom and is still visible, record Bottom SV (still visible).

Calibration for monitors' eyesight differences should also be made. Have someone with normal or corrected 20/20 vision and experienced in using a Secchi disk, take a reading alongside the volunteer monitor. This will give a good indication of how to compensate for eyesight differences.

## pH

pH is normally a variable that is tested for in fresh water. We include it mainly for testing the fresh water flowing into the estuary. There are many different models of pH meters you can use. Some volunteer groups in Maine and New Hampshire use the Corning pocket meter, because it is accurate and inexpensive. The following procedure is for the Corning pocket meter, which costs $45-$85.

Equipment: pH pocket meter, 7.0 buffer solution, small screwdriver.

### 1. Procedure

Be sure to immerse the probe in tap water to the red line for an hour at least once a week.

**STEP 1**

Obtain a sample of estuarine water and pour into bottles marked "rinse sample" and "test sample".

**STEP 2**

Calibration: (pH is temperature dependent. The calibration liquid must be near your sample temperature or visa-versa.) If you are unable to adjust the pH to 7.0, then change the batteries and attempt the calibration again.

If it still doesn't calibrate correctly, the solution could be weak, or something else could be wrong. Then don't take the reading, but have the meter checked out.

## 2. Calibration Procedure

**STEP 1**
Fill two small bottles with tap water.

**STEP 2**
Check two small bottles of pH 7 buffer—bottle marked "rinse buffer" should contain the older, used buffer and bottle marked "test" should contain the fresh, new buffer.

**STEP 3**
Remove protector cap from pH probe.

**STEP 4**
Turn on meter.

**STEP 5**
Rinse probe in bottles marked "rinse tap" and "test tap" by stirring gently. There is no need to take pH readings.

**STEP 6**
Rinse probe in small bottle of buffer solution marked "rinse pH7" and then immerse in "test pH7." If pH is between 6.9 and 7.1, the meter is calibrated. Record the calibration reading on your data sheet. If pH is not within range, adjust the reading to 7.0 using the small screwdriver in the hole located next to the pocket clip on the back of the meter.

If you are unable to calibrate the meter, change the three batteries by turning the meter off, carefully pulling on the top of the meter until the battery case is exposed, and then change the batteries. Record adjustments on the data sheet.

**STEP 7**
Rinse the probe in tap water, first the "rinse tap" then the "test tap." Don't record any numbers.

## 3. Measure pH of sample

**STEP 7**
Rinse probe in small bottle of "rinse sample", then immerse in "test sample" and allow reading to stabilize.

**STEP 8**
Read pH on meter and record on data sheet.

## 4. Cleanup

**STEP 9**
Rinse probe again in two tap bottles, and blot dry. Rinse sample bottles and tap water bottles in fresh water and dry. Change the buffer solutions. Old buffer can be disposed of

by pouring into waste jug and down any drain. Cap the pH meter and store in kit with clean bottles and buffer solution.

## Nutrient Sampling

The following is a list of some of the equipment we recommend for sampling:

Gelman inline filter holder, product, no. 4320 syringe filter holder 25 mm.

Millipore filter HAWP 025 00 HAO.45um, or equivalent cellulose acetate filter (from Gelman, etc. one that won't absorb phosphates).

50ml plastic disposal syringe. Found in VWR, cat. no. BD9663.

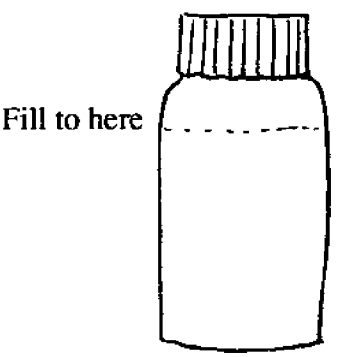
Scintillation Vials. Found in VWR, Wheaton cat. no. 66021-690.

### 1. Instructions for Nutrient Sample Collection

Samples for nutrient analyses may be stored in polyethylene scintillating vials which hold approximately 22 ml. The vials are washed prior to use with hot soapy water, rinsed with distilled water, soaked with approximately 10 percent HCl acid, and rinsed with low nutrient, deionized distilled water (DDW). Only DDW has low enough ammonium and silicate. Note that any substitute bottles must be treated in a similar manner to ensure that they are clean.

Freshly collected samples should be filtered in the field through 0.45mm filters (Millipore HA or equivalent), using cleaned and acid-washed plastic syringes (50-60 ml) and 25 mm inline filter holders from Millipore or Gelman. We like the Gelman ones the best.

After rinsing the syringe with the sample several times, the syringe is filled and approximately 20 ml of sample filtered and discarded to rinse the filter and holder. Then vials and caps should be rinsed with the filtered sample three (3) times prior to filling to below the shoulder as shown here:

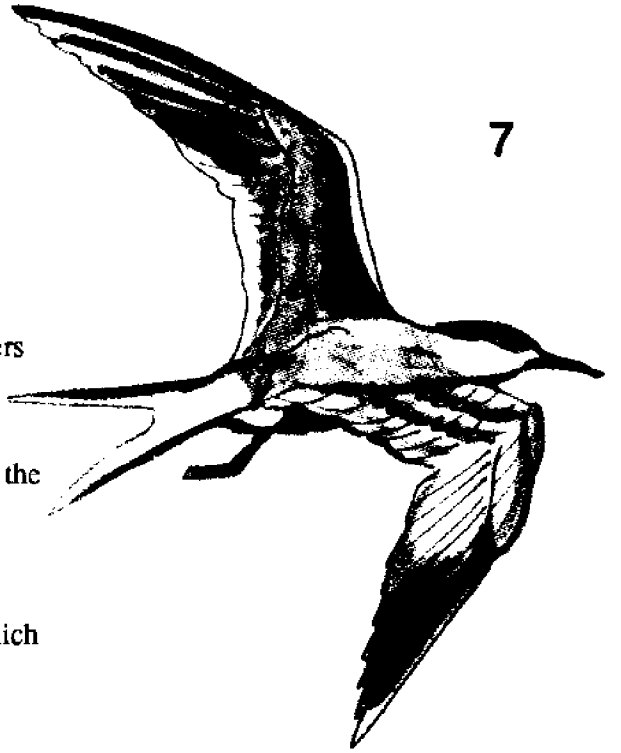



NUTRIENT VIAL

Do not fill the bottles any fuller than the shoulder because when the samples are frozen the caps are pushed out and some sample is lost, rendering the data useless. Once the bottle is filled as above and the cap tightened, the samples should be frozen in an upright position as soon as possible, we recommend dry ice. If freezing is not possible immediately, then samples should be kept on ice until they can be frozen. Keep the samples frozen until delivered for analysis.

# Bacteriological Lab Analysis





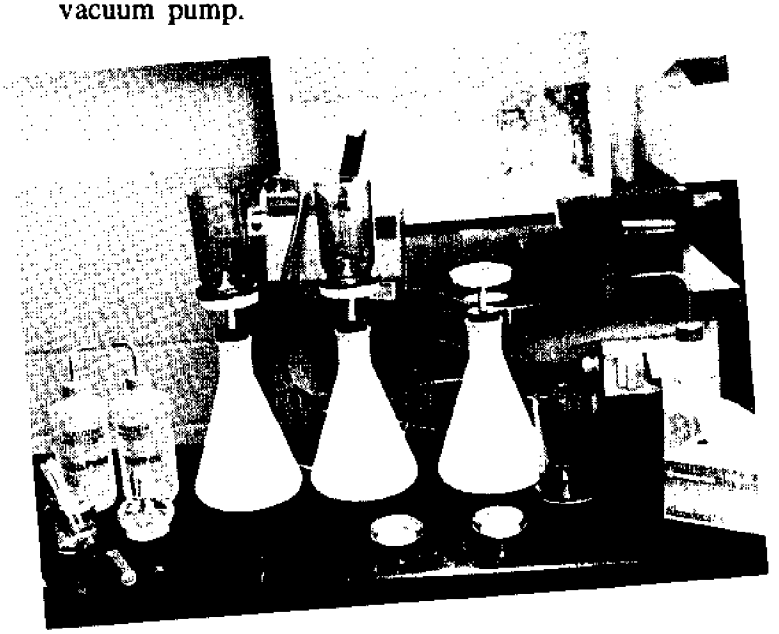
## MEMBRANE FILTRATION TECHNIQUE

### *with MFC Medium for Testing Fecal Coliform Bacteria*

Descriptions of other methods for marine and fresh waters can be obtained from the Environmental Protection Agency (USEPA).

The membrane filtration method was chosen because of the relative ease of the test procedure, low cost, and lower risk of contamination.

The filtering system consists of a glass or plastic micro-analysis filter assembly held by a rubber stopper in a flask, which is connected with plastic tubing to another flask and then to a vacuum pump.



## 1. Safety Measures

- Be very careful when handling the water samples. Wear gloves for protection and wash your hands after processing each sample.

- Do not come into contact with the bacterial colonies after they have been incubated.

- Do not use alcohol or any flammable material near an open flame. Always cap the alcohol burner when it is not in use.

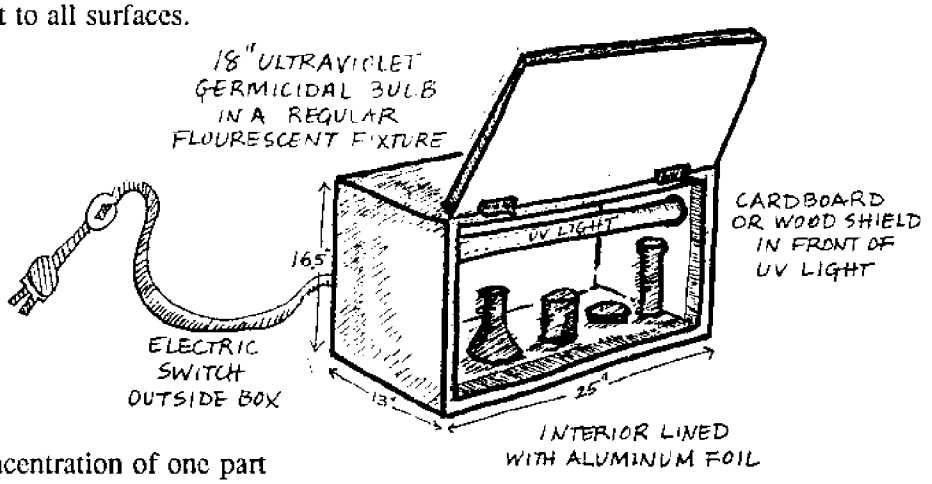
- Use proper disposal methods of the contents of the Petri dishes after the colonies have been counted and recorded. Either autoclave the Petri dishes and dispose of the contents in a plastic bag, or place the opened Petri dishes in a bucket containing a strong 15 percent solution of bleach for 10-15 minutes, drain the liquid into a sink and dispose of the paper that is left in a plastic bag. The chlorine water can be recovered, properly stored, and reused one time.

- To protect your eyes, do not open the UV box while the light is on . Protective eyewear should be worn when using UV light.

## 2. How to Process a Sample

**STEP 1**

Sterilize the filter apparatus, glass Petri dishes, and distilled water in an autoclave, or place under UV light (for glassware at least three minutes, distilled water for 20 minutes). Resterilize between samples. Make sure you separate the Petri dishes so the UV can get to all surfaces.




**STEP 2**

Mix the buffer water in a concentration of one part concentrated buffer solution (pH 7.0) with 24 parts of distilled water; or measure 42 mls of concentrated buffer solution and 1000 mls of distilled water, sterilize and put into a sterile nalgene squirt bottle.

**STEP 3**
Sterilize the working surface with alcohol.

**STEP 4**
Place a sterile absorbent pad from the dispenser in the Petri dish. Tap the medium in the ampoule into the larger part of the glass ampoule. Sterilize the narrow part of the ampoule by wiping it with alcohol. Using a plastic ampoule breaker, break open the 2 ml ampoule of MFC medium at the narrow part, and tap the medium onto the absorbent pad in the Petri dish. Replace the Petri dish cover.

**STEP 5**
Place the filter bottom half of the filter apparatus on the vacuum flasks.

**STEP 6**
Sterilize the forceps by dipping them in alcohol and flaming them. Using forceps, place a sterile membrane with the grid side up on each filter screen. Using aseptic or sterile technique in handling the nylon membrane is a little tricky at first.

Carefully open the plastic cover, and with the sterilized forceps separate the paper from the membrane filter, by holding onto the whole lot at the bottom. Then take the forceps and pull out the membrane filter and place it on the screen of the bottom of the filter apparatus. Do not touch the membrane filter with your hand, only with sterile forceps..

**STEP 7**
Place the filter funnel over the screen, clamping it with the metal clamp if using a glass filter apparatus, or simply putting it in place if using a plastic apparatus, which is magnetized.

**STEP 8**
The first and last sample run should be 100 ml of the sterile phosphate buffer water to check for sterilization. This is called a negative control.

You should also run a sample of known *E. coli* as a positive control to check your results. These samples are run as you would the other samples, as follows:

**STEP 9**
Check your sample number with the data sheet and mark top of Petri dish with indelible marker twice. Place that Petri dish in front of the filter apparatus you will be using for that sample. Shake the sample vigorously, approximately 100 times to facilitate even distribution of bacteria.

**To make up a positive control sample:** Using sterile sticks, inoculate 100 mls of sterile buffer water by dipping the stick into the tube of bacteria collecting about as much as the end of the head of a pin and swishing it into the sterile buffer water.

**To obtain a "slant" or tube of known E.coli or fecal coliform bacterial contact:** A local private lab or Maine Department of Marine Resources Lab in your region:

| | |
|---|---|
| Boothbay Harbor | Lamoine |
| 633-5572 | 667-5654 |

Or a local water company/local wastewater treatment facility.

Form a pouring spout and pour 100 ml of the sample into the graduated filter funnel. Get eye-level to the marks on the filter funnel to determine 100 ml. Make sure you do not touch the pouring surface of the bag or the funnel. More or less of the sample can be processed as long as the amount is noted.

**STEP 10**
Turn on the vacuum pump to 15 lbs of pressure. After the sample is completely through, rinse the sides of the filter funnel three times around with the buffer to make sure any bacteria clinging to the sides get rinsed.

**STEP 11**
Turn off the vacuum pump.

**STEP 12**
Remove the filter funnel. Remove the membrane filter with sterile forceps and place it in the Petri dish, being very careful not to trap air bubbles underneath. If air bubbles do get trapped, carefully pick up the membrane and try placing it in the Petri dish again. If the air is trapped again, run another 100 ml of the sample. The test will not work if air bubbles do get trapped. Make sure you check all your Petri dishes for air bubbles before putting them into the incubator!

**STEP 13**
Place two Petri dishes in a *new* whirlpak bag and expel as much air as possible. Roll up at least seven times and seal the bag to prevent leakage. Make sure you place the petri dishes in the incubator within 20 minutes of filtering them.

Place them in the incubator in a rack upside down (to prevent condensation from dripping on the membrane filter). Make sure the dishes are submerged completely

**STEP 14**
Incubate for 24 hours, plus or minus two hours at 44.5°C, plus or minus .2°C. Make sure the temperature is stable in the incubator. Record the temperature when placing samples in and also when you take them out. If possible, check the temperature periodically over the 24-hour period.

Proper temperature is very important. Lowering the temperature out of range allows nonindicator bacteria to grow, and temperature too high prohibits fecal coliform growth.

You should annually calibrate the incubator thermometer at 44.5° C with an NSB thermometer. This can be calculated at a state or private laboratory.

**STEP 15**
After 24 hours, remove the dishes and, using a binocular microscope (dissecting scope), count the number of colonies having a blue metallic sheen on the filter paper. This gives an approximation of the number of fecal coliform bacteria in 100 ml of water.

Samples should contain between 20 and 60 fecal coliform colonies per Petri dish for an accurate count. If the number of colonies is greater than 60 record as > 60, resample and dilute before filtering or use less of the sample. (See *Appendix E* for more detailed description of diluting samples.)

Note: When counting fecal coliform colonies, make sure they have a blue or blue-green metallic sheen and are shaped somewhat like a fried egg.

If you are getting tiny, pinprick colonies which can be easily dislodged by a dissecting needle, they are probably particles and not bacteria colonies. If you are getting yellowish colonies, seek assistance from a microbiologist or someone with experience in determining the problem(s).

To guard against problems:

1. Follow the procedures carefully.
2. Use the Filtration Log on page 58 as documentation.
3. Discard the first two absorbent pads from the dispenser.
4. Close windows to guard against airborne contamination.
5. *Always* keep samples, media, and buffer refrigerated.
6. Make up fresh buffer water each week.
7. When you receive the media from your supplier, check the data to be sure it does not expire for at least 10 months. Do not use it past the expiration date.

**STEP 16**
Record on the data sheet the number of colonies for each sample. These data should then be entered into a computer database.

A computer software program is available free of charge from the Shore Stewards Partnership, Maine State Planning Office, State House Station 38, Augusta, Maine 04333.

FILTRATION LOG PAGE # ____ FROM _____ TO _____

| SAMPLE # | DATE-TIME SAMPLED | DATE BUFFER MIXED | INCUBATOR TEMP. | DATE-TIME FILTERED | DATE-TIME READ | COMMENTS | RESULTS | INITIALS |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

## 3. List of Equipment and Approximate Cost

### Membrane Filtration Equipment and Supplies for Fecal Coliform Bacteria Analysis

Note: Equipment can be ordered through and scientific supplier. See *Appendix A* for this listing.

| Quantity | Catalog Item | Catalog Price |
|---|---|---|
| 1 | Stainless Petri dish rack for incubator—holds 96 (There are plastic ones available which are less expensive.) | $95 |
| 1 | Precision water bath incubator with cover & thermometer | $1295 |
| 1 | *Magnetic filter funnel | $85 |
| 1 | Gelman filters (47mm-GN6) | $80 |
| 1 | Gelman absorbent pad kit (1000 pads, with dispenser) | $90 |
| 1 pak | Fecal coliform ampulets (premeasured, 20 per/pk) | $20 per pak |
| 1 pak | Glass Petri dish 60x15mm (12 per/pk-$55) | $55 per pak |
| 1 | Filter forceps | $10 each |
| 1 | Kimwipes | $4 per box |
| 1 | Alcohol burner | $6 each |
| 1 | Whirlpac sample bags (500 bags per box) | $45 |
| 1 | Stainless sample tongs (Can be made by anyone who can solder.) | $6 each |
| 1 | Armored thermometer w/prot. plastic casing | $11 each |

| | | |
|---|---|---|
| 1 | pH buffer solution concentrate (pH 7.0, 500 ml) | $32 |
| 1 | Plastic Side-arm 1 L filtering flask, 6/pk | $81.30 per pak |
| 1 | #8 Stoppers, 12/pk | $16 per pak |
| 1 | 3/8" Clear Tubing Pak of 50' | $48 |
| 1 | Auto Clavable Wash bottles 500ml, 6/pk | $19 per pak |

---

Notes:
1. A vacuum pump is necessary. A new pump is $290. You will also need a cooler and ice packs to keep the samples cold; distilled water to make up the buffer solution; and 70 percent alcohol.

2. If you are setting up the lab in a high school, some equipment on this list may already be available such as: vacuum pump, tubing, flasks, stoppers. A bonus would be an autoclave for sterilizing equipment between sampling days. You also need a means of sterilizing between samples. You can make up a simple UV box with a germicidal bulb in a regular fluorescent fixture. (See diagram with dimensions on page 54.) You can purchase a germicidal bulb for $20 from an electrical supply company.

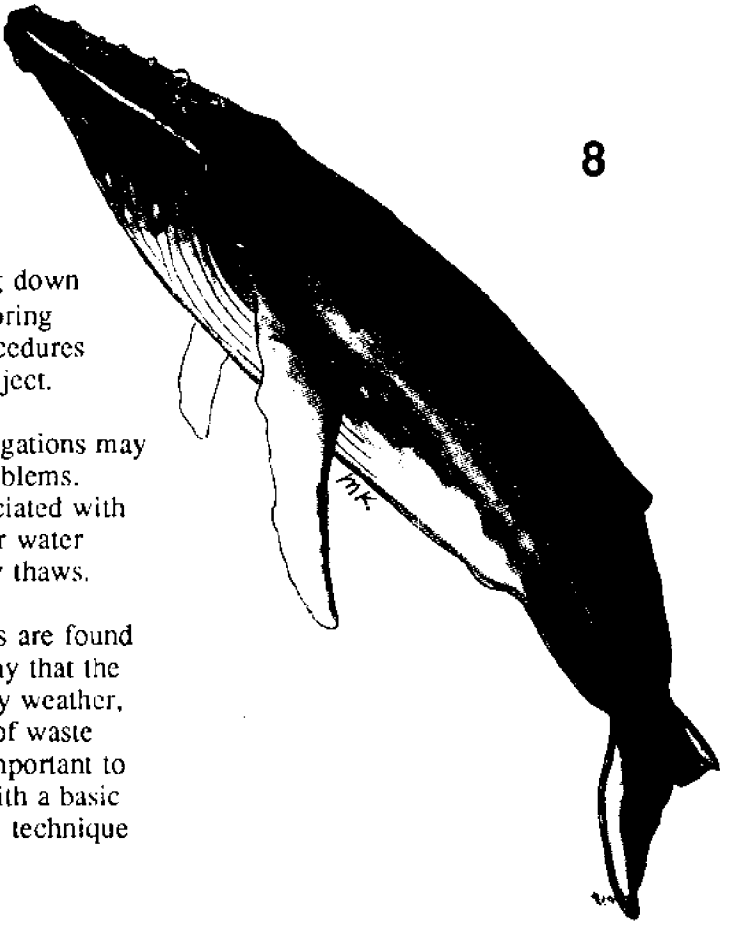
3. The last four items on the list can be split between two or three groups. It is less expensive to purchase these items in paks.

4. The number of thermometers, sample tongs, and filter funnels you purchase will depend on the number of sample stations.

* This is a plastic microanalysis filter apparatus which magnetically clamps to the base and is unbreakable. Another option would be a glass microanalysis filter apparatus, which includes a 300 ml glass funnel base, stainless steel mesh screen, a metal clamp, and a #8 stopper.

# Storm Event Monitoring

8



Storm event monitoring is important in tracking down problems. You may want to pursue this type of monitoring after you have adequate experience with basic test procedures and the resources for expanding the scope of your project.

As water quality problems are discovered, investigations may be initiated to determine the cause or causes of the problems. Since many of today's water quality problems are associated with non-point runoff, you may find it necessary to monitor water running off the land during rainstorms or ice and snow thaws.

Generally speaking, when water quality problems are found during and shortly after these runoff events, one can say that the source is non-point. If the problem persists through dry weather, however, it is likely caused by a continuous discharge of waste water. To narrow down the non-point source(s), it is important to understand a few principles of stormwater behavior. With a basic understanding, you can then adapt your own sampling technique to fit the situation in the field.

## TIMING OF SAMPLES

Pollutants enter the water primarily through erosion when pollutants adhering to soil particles are dissolved into solution and moved in suspension. The power of water to erode materials is related to the speed (energy) of the water. As **flow** (volume per unit of time) increases, so does energy.

One might look at a graph plotting water flow over time as an energy curve (see **hydrograph** on page 63). On the first part of the curve, the ascending **limb** rises as the flow increases. After the peak, as the flow begins to decline, the receding limb of the hydrograph, the power (or erosive force), also declines.

Most pollutants enter waterways near the beginning of the runoff event when the more easily dissolved and easily eroded material is first exposed to the rising force of the water. Once the exposed land surface has been washed free of easily dissolved and eroded material, there is little material left to erode during receding flows.

A graph for pollutant loading during and after storm events may be drawn which is similar in shape to the initial hydrograph. The results of sampling will depend very much on where (what time) on the hydrograph the samples are taken.

For example, if you took all your samples after the peak, the concentrations of pollutants would be underestimated. In fact,

they might even be less than during dry weather flows. At the end of the runoff period, the amount of dissolved and suspended material is very dilute. Results from these samples would lead you to conclude that no source exists in the watershed when, in fact, the sampling technique was simply too late to detect pollutants.

## LOCATION

The sampling location in the watershed also affects results. As the size of the watershed increases, the distance that water travels increases. Water leaving the upper reaches of the watershed may take hours and even days to reach the lower portions.

In the previous example in which the monitor took samples too late in the runoff event, the water sampled at that time and place was relatively free of the pollutant in question. The water that actually contained the pollutants is now farther downstream and has mixed with other waters of unknown quality. For these reasons, it is always a good idea to distribute samples over the entire hydrograph and at various locations in the stream system. Once the behavior of the watershed is understood in terms of the distribution of pollutants in time and space, a more refined and efficient sampling protocol may be developed.

## WEATHER

Weather conditions in the watershed prior to the storm may complicate the storm monitoring analysis. If the weather has been dry for weeks before the storm event, the watershed has had the opportunity to accumulate more and more of the contaminant in question. Runoff following such a period will contain more material than a similar runoff event following on the heels of runoff which has just cleansed the watershed.

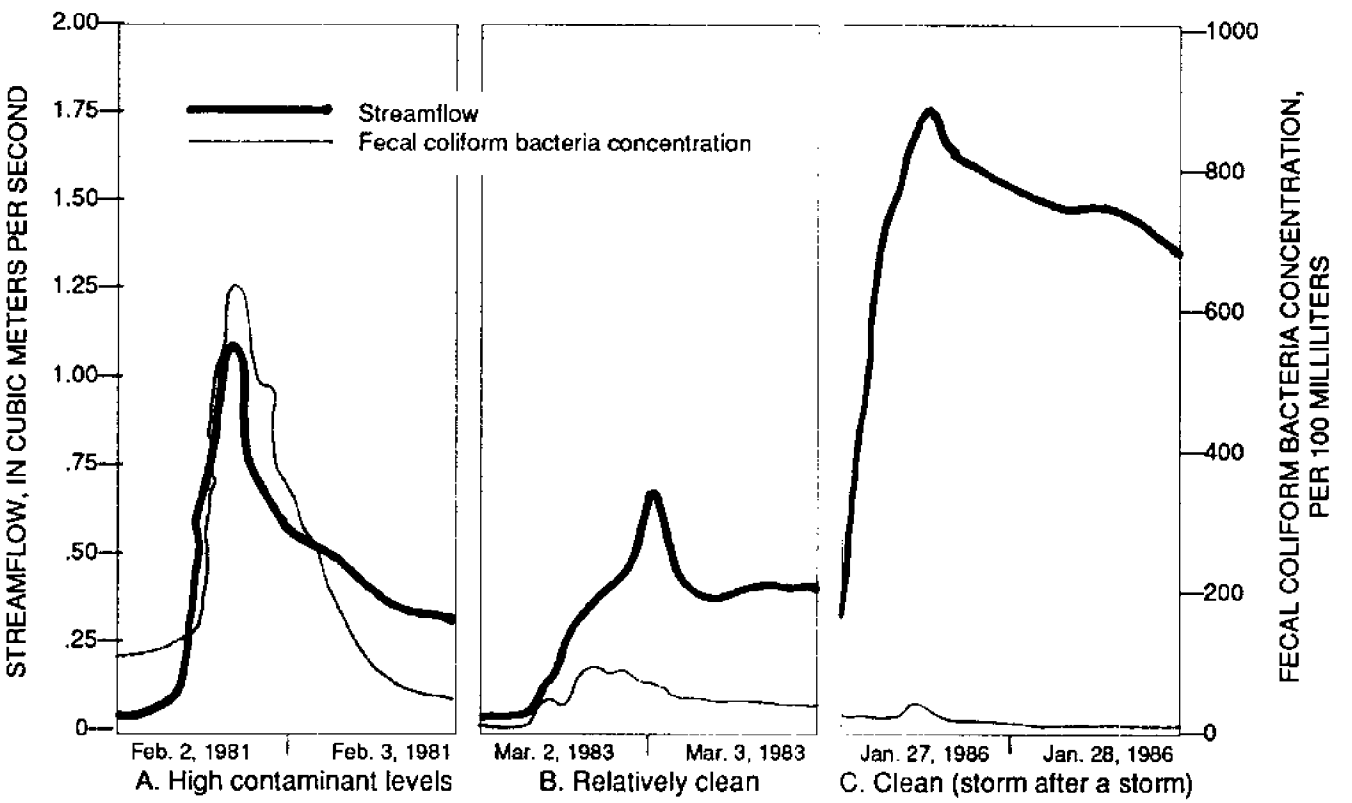
Also, the amount of rainfall or snowmelt necessary to produce runoff depends on the condition of the soils. Unfrozen, dry soils can have a tremendous capacity for absorbing a lot of water. Sometimes even half-inch rains produce no runoff in the summer if the storm event is a slow drizzle falling on dry ground.

On the other hand, frozen or waterlogged soils have little or no capacity to absorb water and produce runoff with very little rainfall or melt.

The type of storm also has much to do with the hydrograph. Intense storms like thunder showers produce short hydrographs with high peaks. These storms result in high flows and high energy and carry lots of material. While these storms are worth monitoring, they are especially elusive and difficult to monitor. There may be an intense cloudburst over a small fraction of the watershed and sunny weather over the rest.

Storm event monitoring is best conducted during heavy, sustained storms produced by cold fronts passing through a wide geographic area. These types of storms are also more or less predictable, and weather forecasts will enable sampling crews to prepare their sampling plans.

There are other important factors which can be considered such as season, land use, land form, and geology. In order to avoid complication, however, we have left these out of this discussion. For the purposes of monitoring, it is most important to recognize the variability of runoff events and some of the reasons for this variability. Armed with this information, you may then proceed with caution and consult appropriate expertise when necessary.




Hydrographs comparing runoff events of February 2, 1981, March 2, 1983, and January 27, 1986.

In hydrograph A, the peak of contaminants occurs near the peak of the stream flow; as streamflow declines contamination is still high indicating a severe source. This is in contrast to hydrograph B and C where the source is insignificant and the peak of contamination occurs before the peak of the streamflow.

# Glossary

***anoxia:*** The failure of oxygen to gain access to or be utilized by the body tissues of an organism. Absence of oxygen. (***anoxic*** adj.)

***armored thermometer:*** A thermometer reading to the nearest .5 degrees centigrade and encased in either metal or plastic to protect it from breakage.

***aseptic technique:*** The method of keeping away disease-producing or putrefying microorganisms; sterile procedure.

***baseline information:*** Data generated by consistent monitoring of the same sample sites over time.

***blooms:*** A dense concentration of phytoplankton which occurs in response to optimum growth conditions. ***Algal blooms:*** overgrowth of algae in a water body caused by excessive nutrient inputs; turns water a greenish color and reduces clarity; can cause fish kills.

***buffer:*** Substance dissolved in water which resists changes in pH. Used in bacterial analysis as rinse water to wash down the sides of the filter funnel.

***dinoflagellates:*** Microscopic unicellular organisms which have two flagella, or whip-like appendages.

***dissolved oxygen (DO):*** Oxygen dissolved in the water is essential for all plants and animals living in an estuary. The amount of DO is used as an indicator of water quality and the level of life that the water can support.

***estuary:*** A water body that forms a transition zone between fresh water and full-strength salt water.

***fecal coliform bacteria:*** A strain of bacteria (normally found in the intestines of warm-blooded animals) whose presence is an indicator of polluted water by human or animal wastes.

High fecal coliform counts lead to closure of shellfish beds. (The bacteria do not harm the shellfish, but they are an indicator of possible contamination by disease organisms causing a human health hazard.)

***flow:*** Water volume from runoff conditions per unit of time.

***Gulf of Maine:*** The water body which extends from Cape Sable, Nova Scotia to Cape Cod, Massachusetts and includes the Bay of Fundy and Georges Bank. A semi-enclosed sea, separated from the Atlantic Ocean by underwater banks; a marine ecosystem comprised of interrelated nutrient cycles, currents and tides, food chains, and energy flows.

***hydrograph:*** A graph or curve of the amount of rain or runoff beyond that which is absorbed by soil, vegetation, and ponding.

***limb:*** A part of the hydrograph curve which indicates whether the flow of water is increasing (ascending limb) or declining (receding limb).

***limiting nutrient:*** Anything other than the elements carbon, hydrogen, and oxygen that is needed in the synthesis of organic matter, and whose scarcity may limit biological productivity. The limiting nutrient in coastal waters is nitrogen.

***marshland*** or ***salt march:*** A protected intertidal wetland where fresh water and salt water meet, characterized by salt march cordgrass, salt hay, and black rush.

***membrane filtration technique:*** A method of analyzing fecal coliform bacteria which results in an approximate number of colonies of bacteria.

The bacteria are filtered onto a membrane using a specific nutrient broth, or medium, and then incubated at a specific temperature and time.

***meniscus:*** The free, upper surface of a liquid which is near the walls of a vessel and is curved because of surface tension.

***navigational chart:*** A map made by the U.S. National Oceanographic and Atmospheric Administration depicting depths and navigational details such as buoys. It also shows latitude and longitude and the outline of the coast.

***nitrogen fixation:*** A process in the nitrogen cycle which is the pathway for the cycling of nitrogen between organic and inorganic compounds.

***non-point runoff:*** Runoff water from rain or melted snow that drains or flows off the surface of the land.

***non-point source pollution:*** Contaminated runoff and seepage from many diffuse and/or small scale sources, mainly from human activity. It is generally initiated by stormwater runoff.

***nutrient loading:*** An excess of nutrients (nitrogen and phosphorous), which beyond normal levels leads to an overabundance of phytoplankton and creates dense populations, or blooms, of plant cells.

***overboard discharges:*** Individual residential sewage treatment systems treated with sand filtration and chlorination before disposal into marine waters.

***pathogenic organisms:*** A living thing (microorganism) capable of causing disease.

***point source pollution:*** Pollution discharged directly from a specific site such as a municipal sewage treatment plant or industrial outfall pipe.

***protozoans:*** Any of a group of one-celled, usually microscopic, animals.

***quality assurance:*** USEPA defined this as "the total integrated program for assuring reliability of monitoring and measurement data." This program includes quality control measures.

***quality assurance project plan:*** A written and observed plan detailing the following: Monitoring objectives, program scope, methods, field and lab procedures, and the quality assurance and control activities necessary to meet stated objectives of data quality.

***quality control:*** This is defined by USEPA as the "routine application and procedures for obtaining prescribed standards of performance and for controlling the measurement process."

***sample sites*** or ***stations:*** The location where a sample is taken and/or where measurements/tests are conducted. This location should be documented on a map and described in writing. The same location should be used each time a test is performed.

***substrate:*** The base on which an organism lives and grows.

***topographic map:*** A map graphically representing the exact physical configuration and detail of a place or region, including its water bodies, buildings, roads, railways, and elevations.

***variables:*** A test or measurement whose value varies or can vary. The term ***parameters*** is often used in place of variables.

***watershed:*** The region draining into a river, river system, or body of water.

***watershed survey:*** A qualitative and quantitative process of determining the extent of pollution in a watershed by identifying existing non-point sources of pollution and inspecting the point sources of pollution.

***wet kits:*** Prepared kits used to test water quality, such as dissolved oxygen test kits made by LaMotte or Hach.

***wetlands:*** Naturally vegetated lowlands, such as marshes or swamps, located between mean high water and the yearly normal maximum flood water level.

# References


1. American Public Health Association, Publications Office. *Standard Methods for the Examination of Water and Wastewater.* 17th ed. (Washington, D.C.: APHA, 1989).

2. Bearman, Gerry, ed. *Seawater: Its Composition, Properties, and Behavior.* (Oxford: Pergamon Press, 1989).

3. Boyd, Claude E. *Water Quality in Warmwater Fish Ponds.* (Opelika, Alabama: Auburn University, 1979).

4. Furfari, Santo A. *Training Course Manual, Nonpoint Pollution in Shellfish Sanitation.* (Washington, D.C.: U.S. Public Health Service, Food and Drug Administration, 1989).

5. Grasshoff, K., Erhardt, M. and K. Kremling, eds. *Methods of Seawater Analysis,* 2nd ed. (Weinheim: Verlag Chemie, 1983).

6. Hansen, N.R., Babcock, H.M., and Clark, E.H. *Controlling Nonpoint-Source Water Pollution: A Citizen's Handbook.* The Conservation Law Foundation and National Audubon Society. (Lancaster, PA: Wickersham Printing Company, 1988).

7. Head, P.C. *Practical Estuarine Chemistry, A Handbook.* (Cambridge: Cambridge University Press, 1985).

8. LaMotte Company. Fisher, Nina, ed. *The Monitor's Handbook.* (Chestertown, Maryland: LaMotte Company, 1992).

9. Maine State Planning Office, Maine Coastal Program. *The Estuary Book.* (Augusta, Maine: Maine Coastal Program, 1991).

10. Schauffler, Flis. *Watershed: An Action Guide to Improving Maine Waters.* (Augusta, Maine: Maine Dept. of Environmental Protection, Maine State Planning Office/Maine Coastal Program, and Univ. of Maine Cooperative Extension, 1990).

11. U.S. Environmental Protection Agency. Office of Marine and Estuarine Protection. *Guide for Preparation of Quality Assurance Project Plans for the National Estuarine Program.* Interim Final. 556/2-88-001. (Washington, D.C.: USEPA, 1988).

12. U.S. Department of the Interior Geological Survey. *Safety and Environmental Health Handbook.* (Reston, Virginia: U.S, Dept. of Interior Geological Survey, 1989).

13. U.S. Environmental Protection Agency. *Volunteer Water Monitoring: A Guide for State Managers.* Office of Water. (Washington, D.C.: USEPA, 1990).

14. U.S. Environmental Protection Agency. *The National Volunteer Monitor.* Periodic newsletter. (318 Masonic Ave., San Francisco, CA 94117).

15. U.S. Dept. of Health and Human Services, Public Health Service, Food and Drug Administration. ISSC, Part I, *Sanitation of Shellfish Growing Areas.* (Washington, D.C.: U.S. Dept. of Health and Human Services, rev. 1990).

16. U.S. Environmental Protection Agency. Office of Water Regulations and Standards. Assessment and Watershed Protection Division. Prepared by the Alliance for the Chesapeake Bay. *Volunteer Water Monitoring: A Guide for State Managers.* 440/4-90-010. (Washington, D.C.: USEPA, 1990).

17. Williams, Scott. Congress of Lakes Association. *A Citizen's Guide to Lake Watershed Surveys.* (Yarmouth, Maine: Congress of Lakes Association, 1992).

# Appendices

## Appendix A: Partial list of chemical and scientific equipment companies.

**Fisher Scientific**
711 Forbes Ave.
Pittsburgh, PA 15219-4785
(800) 766-7000

**Fritz Chemical**
P.O. Drawer 17040
Dallas, TX 75217
(800) 955-1323

**HACH Company**
P.O. Box 389
Loveland, CO 80539
(800) 525-5940

**Hydrolab Corporation**
P.O. Box 50116
Austin, TX 78763
(800) 949-3766

**LaMotte Chemical Products**
P.O. Box 329
Chestertown, MD 21620
(800) 344-3100

**Millipore Corporation**
397 Williams Street
Marlborough, MA 01752
(800) 225-1380

**Thomas Scientific**
P.O. Box 99
Swedesboro, NJ 08085
(800) 523-4414

**VWR Scientific**
P.O. Box 2643
Irving, TX 75061
(800) 527-1576

**Wildlife Supply Company**
301 Cass Street
Saginaw, MI 48602
(517) 799-8100

**YSI Incorporated**
1725 Brannum Lane
Yellow Springs, OH 45387
(800) 765-4974 ext 346

## Appendix B: A guide to reading topographic maps.

The following rules should assist surveyors in covering the watershed from the field. A USGS Topographic Map at a scale of no greater than 1:24,000 with a contour interval of 10 feet provides sufficient detail to conduct the survey. This information is located at the bottom center of the map.

1. Contour lines are brown; water features like lakes and wetlands, are blue; vegetation is green; cleared areas (fields, developed areas, and farmland) are white; and roads, buildings and other non-natural features are black. Urban areas are gray.

2. Contour lines connect points of equal elevation. These lines never cross each other.

3. Contour lines which are closely spaced represent steep slopes and those which are widely spaced represent shallow or flat areas. The percent slope of an area can be easily calculated by dividing the vertical distance of the area by the horizontal distance (see example).

4. Elevation is expressed in feet above sea level. Elevation is written on contour lines and on the summit of many hills and mountains.

5.a. Contour lines which represent a valley, or depression in terrain are usually V-shaped, and point towards higher elevations.

b. Lines which show a ridge are also V-shaped, but point towards lower elevations.

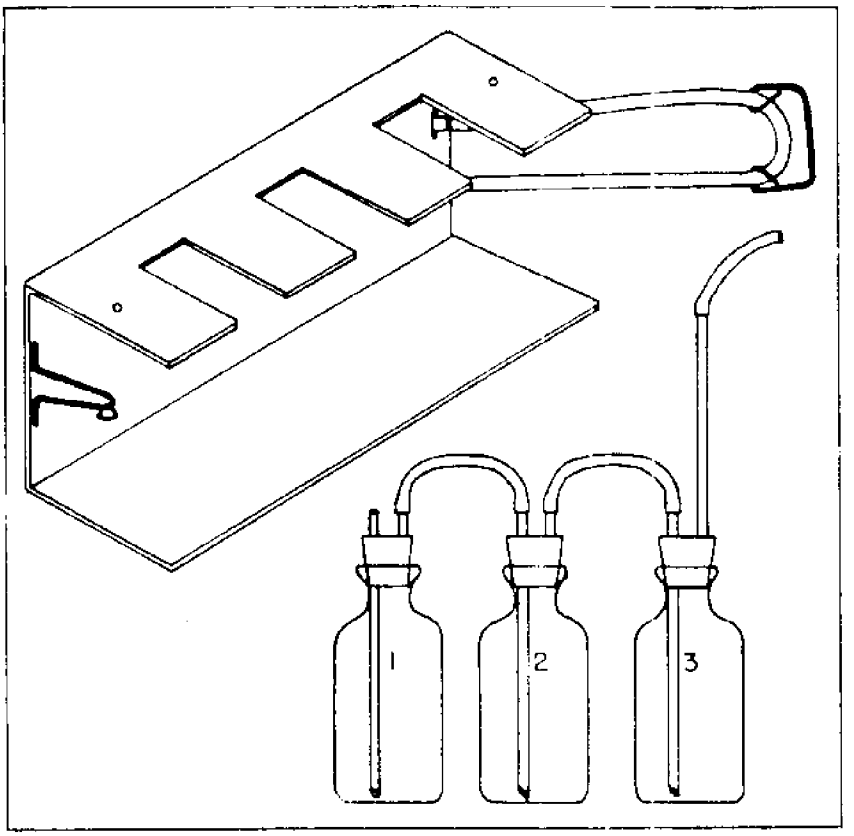
c. The "V" formed by contour lines which cross a stream always points upstream, or against the flow of the stream.

d. When two streams converge, the "V" formed by the point where the two came together points down stream with the flow of the new stream.

6. Hills and mountains appear as a series of successively smaller concentric circles. The circles are usually irregularly shaped and the smallest circle at the top represents the highest point of land.

7. Lines which connect the tops of hills and ridges form the boundaries of the watershed.

## Appendix C: Bottle train sampler.




A bottle train sampler. After Swingle and Johnson (1953).

The sampler is easily constructed from BOD bottles, glass or stiff plastic tubing, flexible rubber tubing, sheet aluminum, and metal weights (Swingle and Johnson, 1953). The bottles are connected by tubing so that bottle 1 is flushed twice and retains water from the third filling. The sample in bottle 1 may be used for dissolved oxygen analysis. Bottle 2 is flushed once and retains water from the second filling. The water in bottle 3 has been contaminated with air and cannot be analyzed for dissolved gases, but this water is suitable for other analyses.

To make a bottle train, take three two-hole No. 3 rubber stoppers. Into one hole of each insert a piece of glass tubing so that it is exactly flush with the small bent at right angles along the longer side 10.16 cm (4 inches) from each end. When the metal is bent in this manner, the device is 13.34 cm (5.25 inches) high - just high enough to allow BOD bottles to be slipped in and out easily. The top of the rack has three slots for the necks of the bottles at intervals that allow the sides of the bottles to touch when in place. Approximately 2 kg (4.4 lb) of sheet lead are bolted to the base. This weight of lead is adequate to sink the three stoppered BOD bottles rapidly. The bottles are held in place by a piece of rubber tubing. One end of the tubing is permanently attached to the sampler and the other end has a string or wire loop that slips on or off a small bolt-hook to facilitate removal and replacement of the bottles.

A hand line for the sampler may be made from a length of plastic clothesline with a wire core and is knotted to provide a good handhold. The first knot is tied 25 cm above the top of the bottles and the succeeding knots are at 25-cm intervals to calibrate the line.

To collect water, fasten the BOD bottles in place in the rack and insert the arrangement of stoppers and tubing to form the bottle train. Lower the sampler rapidly to the desired depth by counting the number of knots on the hand line.

## Appendix D: Chemical reactions when using the Azide modification of the Winkler method to test for dissolved oxygen.

The first step in a DO titration is the addition of Manganous Sulfate Solution (4167) and Alkaline Potassium Iodide Azide Solution 97166). These reagents react to form a precipitate, or floc, of manganous hydroxide, $Mn(OH)_2$. Chemically, this reaction can be written as:

$$MnSO_4 + 2KOH \longrightarrow Mn(OH)_2 + K_2SO_4$$

Manganous Sulfate + Potassium Hydroxide ⟶ Manganous Hydroxide + Potassium Sulfate

Immediately upon formation of the precipitate, the oxygen in the water oxidizes an equivalent amount of the manganous hydroxide to manganic hydroxide. In other words, for every molecule of oxygen in the water, one molecule of manganous hydroxide is converted to manganic hydroxide. Chemically, this reaction can be written as:

$$2Mn(OH)_2 + O_2 + 2H_2O \longrightarrow 2Mn(OH)_4$$

Manganous Hydroxide + Oxygen + Water ⟶ Manganic Hydroxide

After the precipitate is formed, a strong acid, such as Sulfamic Acid Powder (6286) or Sulfuric Acid, 1:1 (6141) is added to the sample. The acid converts the manganic hydroxide to manganic sulfate. At this point the sample is considered "fixed" and concern for additional oxygen being introduced into the sample is reduced. Chemically, this reaction can be written as:

$$2MN(OH)_4 + 4H_2SO_4 \longrightarrow 2Mn(SO_4)_2 + 8H_2O$$

Manganic Hydroxide + Sulfuric Acid ⟶ Manganic Sulfate + Water

Simultaneously, iodine from the potassium iodide in the Alkaline Potassium Iodide Azide Solution is replaced by sulfate, releasing free iodine into the water. Since the sulfate for this reaction comes from the manganic sulfate, which was formed from the reaction between the manganic hydroxide and oxygen, the amount of iodine released is directly proportional to the amount of oxygen present in the original sample. The release of free iodine is indicated by the sample turning a yellow-brown color. Chemically, this reaction can be written as:

$$2Mn(SO_4)2 + 4KI \longrightarrow 2MnSO_4 + 2K_2SO_4 + 2I_2$$

Manganic Sulfate + Potassium Iodide ⟶ Manganic Sulfate + Potassium Sulfate + Iodine

The final stage in the Winkler titration is the addition of sodium thiosulfate. The sodium thiosulfate reacts with the free iodine to produce sodium iodide. When all the iodine has been converted the sample changes from yellow-brown to colorless. Often a starch indicator is added to enhance the final endpoint. Chemically, this reaction can be written as:

$$4Na_2S_2O_3 + 2I_2 \longrightarrow Na_2S_4O_6 + 4NaI$$

Sodium Thiosulfate + Iodine ⟶ Sodium Tetrathionate + Sodium Iodide

## Appendix E: Calculation of bacteria colony counts.

Ideal range for number of positive colonies per plate:

| | |
|---|---|
| Total coliform | 20-80 colonies/plate |
| Fecal coliform | 20-60 colonies/plate |
| E. Coli | 20-80 colonies/plates |
| Enterococci: | 20-60 colonies/plates |

If the count of positive colonies on a plate is within the ideal range, the colonies are counted, the count calculated in terms of 100 mls, and recorded as "colonies/100 mls".

If the count is not within the ideal range, the following system is used in calculating and recording the results:

1. If the colony counts on all dilutions filtered of one particular sample are outside of the ideal range, the final result is calculated as follows:

   a. If all counts are too high, the highest ideal range number is divided by the smallest volume of sample filtered, multiplied by 100 ml, and recorded with an "L" (i.e. for E. coli, 1 ml = 80 X 100 - 1 = L8000, or for 10 ml, 80 X 100 - 10 = L800).
   b. If all counts are too low, the count closest to the lower limit of the ideal range is calculated, i.e. if a 1 ml plate of a sample has a count of 2, and the 10 ml plate has 14, the result is recorded as 140 (14 X 100 - 9).
   c. If the counts are both above and below the ideal range, the count closest to the lower limit of the ideal range is calculated, i.e. the 1 ml plate reads 14, the recorded result is 1400, (14 X 100 - 1).

2. Greater Than. If all counts are above the upper limit, or TNTC, the upper limit of the ideal range is divided by the smallest volume of sample filtered times 100, and the result is recorded with an "L" (i.e. L8000).

   Note: If the total of all of the colonies on the plate is over 200, the colonies are too numerous to count (TNTC), and the result is reported as above (i.e. L8000).

3. Less Than. If no colonies are present on any of the plates of a sample, divide the largest volume filtered into 100 and record the result with a "K", i.e. for 100 mls = K1; for 5 mls, K20.

   If the plate of the less volume filtered shows a colony count higher than the count of the higher volume filtered, the count of the smaller volume filtered is calculated (count X 100 - vol.) and recorded with a "K" (i.e. K100).

4. Confluence. If the count of a plate is with the acceptable limits and has a total colony count of under 200, but includes spreaders (colonies that have spread out over others), the sample is entered in the logbook as "C", and the count of a smaller volume is reported for the final result.

5. Indication of problems. If the results are obtained under less than ideal conditions, i.e. a lab accident causing the contamination of a sample, or a sample being held before analysis longer than is permitted by the holding-time limit, the final result is recorded with a "J".