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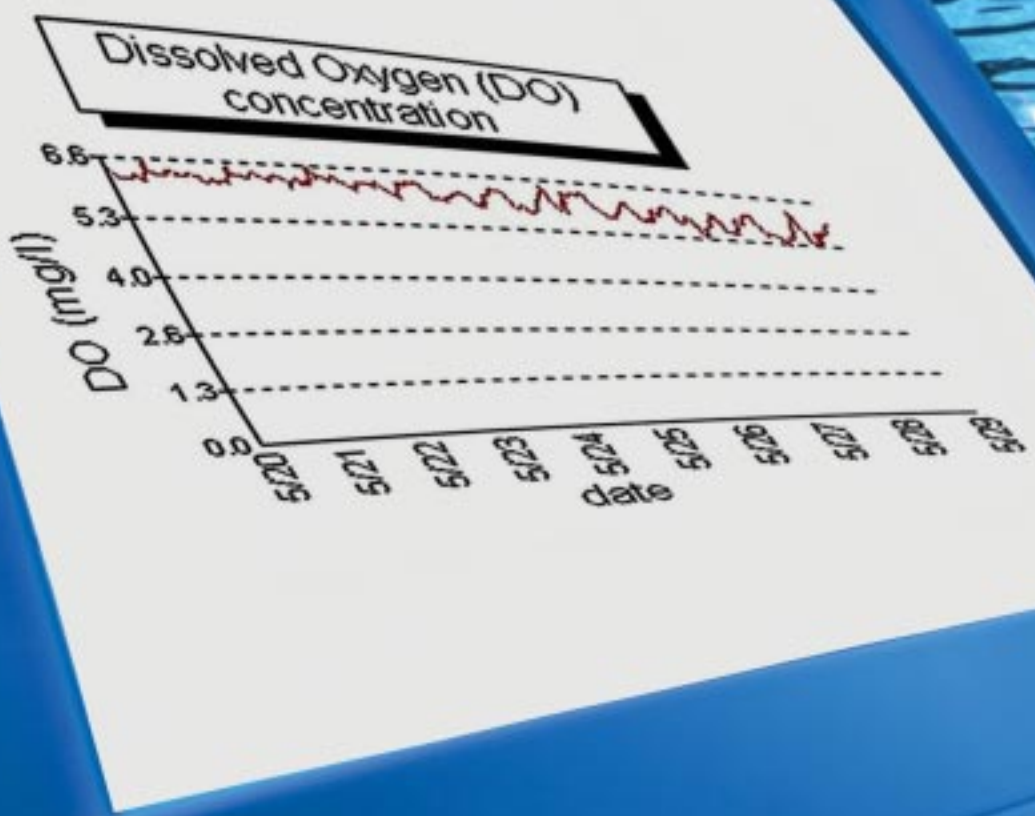
Delivering Timely Water Quality Information to Your Community - The Chesapeake ...

United States
Environmental Protection
Agency

Delivering Timely Water Quality Information to Your Community

The Chesapeake Bay and National Aquarium in Baltimore EMPACT Projects



E M P A C T

Environmental Monitoring for Public Access & Community Tracking

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September 2002

Delivering Timely Water Quality Information to Your Community

The Chesapeake Bay and National Aquarium in Baltimore EMPACT Projects

United States Environmental Protection Agency
Office of Research and Development
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1. INTRODUCTION

1.1 EMPACT Overview

This handbook offers step-by-step instructions about how to provide timely water quality data to your community. It was developed by the U.S. Environmental Protection Agency's (EPA's) **E**nvironmental **M**onitoring for **P**ublic **A**ccess and **C**ommunity **T**racking (EMPACT) program. The EMPACT program was created by EPA's Office of Research and Development (ORD) to introduce new technologies that make it possible to provide timely environmental information to the public. EMPACT has worked with several of the largest metropolitan areas and Native American Tribes in the country to help these communities:

- Collect, manage, and distribute timely environmental information.
- Provide residents with easy-to-understand information they can use in making informed, day-to-day decisions.

To make this and some other EMPACT projects more effective, partnerships with the National Oceanic and Atmospheric Administration (NOAA) and the United States Geological Survey (USGS) were developed. EPA works closely with these federal agencies to help achieve nationwide consistency in measuring environmental data, managing the information, and delivering it to the public.

Environmental information projects were initiated in more than 86 of 156 EMPACT-designated metropolitan areas and Native American Tribes. These projects cover a wide range of environmental issues, including water quality, groundwater contamination, smog, ultraviolet radiation, and overall ecosystem quality. Some of these projects were initiated directly by EPA. Others were launched by communities themselves. Local governments from any of the 156 EMPACT metropolitan areas and Native American Tribes were eligible to apply for EPA-funded Metro Grants to develop their own EMPACT projects. The 156 EMPACT metropolitan areas and Native American Tribes are listed in the table at the end of this chapter.

One such Metro Grant recipient is the Chesapeake Bay EMPACT Project. The project provides the public with timely water quality monitoring data and impacts of water quality management activities in the Baltimore - Washington Area. The EMPACT project also supplements Maryland DNR efforts to characterize water quality conditions in estuarine systems that have experienced or have the potential to experience harmful algal blooms.

1.2 Background

The Chesapeake Bay is the largest estuary in the United States and one of the most productive in the world. It is approximately 200 miles long and varies in width from 4 to 30 miles across. The Bay watershed drains 64,000 square miles of land in six states - Maryland, Virginia, Delaware, Pennsylvania, West Virginia and New York and Washington D.C. The Bay area is home to approximately 16 million people and supports nearly 2,700 different plant and animal species.

Scientific and estuarine research conducted on the Bay between 1976 and 1983 pinpointed four problems requiring immediate attention: nutrient enrichment, sediment loading, dwindling underwater Bay grasses, and toxic pollution. These findings led to the development of the Chesapeake Bay Program in 1983 and the Chesapeake Bay Monitoring Program in 1984, which monitors the overall health of the Bay through the collection of comprehensive data on physical, chemical and biological characteristics throughout the year in the main-stem of the Bay and tributaries. Information obtained through these programs is vital to evaluate the progress of management actions aimed at restoring the Bay and its tributaries, to address emerging issues such as *Pfiesteria*, and to provide guidance for future actions.

In 1997, toxic *Pfiesteria piscicida* (fee-STEER-ee-uh pis-kuh-SEED-uh) killed thousands of fish in several of Maryland's Lower Eastern Shore tributaries to the Chesapeake Bay, including the lower Pocomoke River in Maryland and Virginia, the Chicamicomico River , and King's Creek in Maryland. *Pfiesteria piscicida* is a toxic dinoflagellate that has been associated with fish lesions and fish kills in coastal waters from Delaware to North Carolina. A natural part of the marine environment, dinoflagellates are microscopic, free-swimming, single-celled organisms, usually classified as a type of alga. The vast majority of dinoflagellates are not toxic. Although many dinoflagellates are plant-like and obtain energy by photosynthesis, others, including *Pfiesteria*, are more animal-like and acquire some or all of their energy by eating other organisms.

[Source: http://www.epa.gov/owow/estuaries/pfiesteria/fact.html#11]

A statewide *Pfiesteria*, water, and habitat quality monitoring program was initiated by the Maryland Department of Natural Resources (MD DNR) to measure key components of the ecosystem, including pollutant inputs, water quality, habitat and living resources. In conjunction with this program, the Chesapeake Bay EMPACT Project was established to provide timely information regarding water quality information and the relationship to possible toxic *Pfiesteria piscicida* outbreaks on the Pocomoke River. This project was meant to supplement data collected as part of the comprehensive *Pfiesteria* monitoring program that is integrated with water and living resource quality assessments through the broader Chesapeake Bay Monitoring Program. The EMPACT project enables people to learn more about Maryland's waterways and keep up to date with water quality and *Pfiesteria* issues.

In 1998, the first year of EMPACT continuous monitoring, two stations were established in the Pocomoke River to monitor various water quality parameters: one at Cedar Hall Wharf and the other in Shelltown. In 1999, another surface meter (sonde) was deployed on the Pocomoke at Rehobeth and a bottom meter was added at Cedar Hall Wharf. Data from the bottom meter provides information about possible differences between bottom and surface conditions.

For 2000, the project was expanded to provide a more bay-wide representation of water and habitat quality and potential impacts to living resources. Two sondes were depolyed in the Magothy River: one at Cattail Creek and one at Stonington. These stations provide data from a waterway in a more urban setting. The Stonington site is located adjacent to a large submerged aquatic vegetation (SAV) bed. SAV provides critical habitat for living resources and the restoration of SAV is critical to bay recovery. Two additional monitors were placed in lower eastern shore tributaries: one in the Chicamacomico River at Drawbridge and one in the Transquaking River at Decoursey Bridge. These two waterways have repeatedly shown evidence of *Pfiesteria*. Through a cooperative program with the National Aquarium in Baltimore (NAIB), data is also being collected from a station established in 2001 in the Baltimore Harbor adjacent to the Fort McHenry field station.

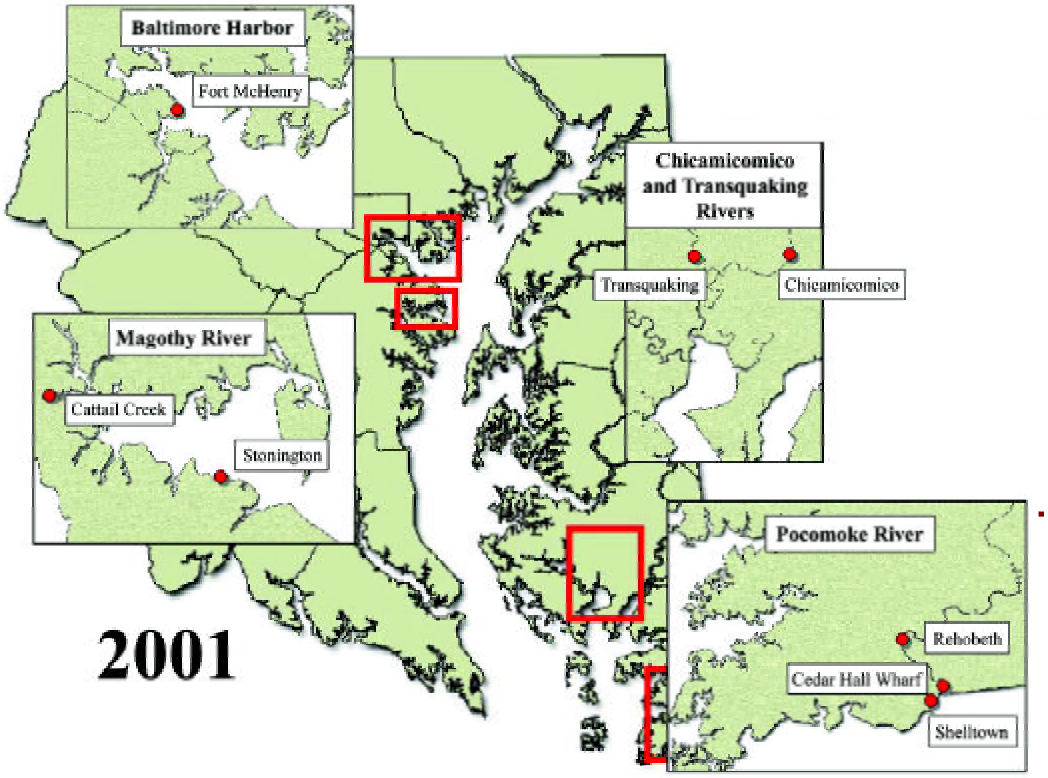
[Source: http://mddnr.chesapeakebay.net/empact/faq.html]

Initially, the monitoring stations were not equipped with telemetry to collect real-time data; however in 2000, most of the stations were outfitted with this equipment so that timely data could be collected. "Timely data" refers to data that is collected and communicated to the public in a time frame that is useful to their day-to-day decision-making about their health and the environment, and relevant to the temporal variability of the parameters measured. Figure 1.1 shows the geographical location of the monitoring stations.

In addition to supplementing the *Pfiesteria* program, this project provided a means to gain a greater understanding of how tributaries of the Chesapeake Bay function. For example, the relationship between storm events and fresh water flows to the Pocomoke is poorly understood because of its altered watershed hydrology resulting from human activities over the past several years. This is an important process to understand because of the likely linkage between runoff, nutrient loading, and conditions that influence *Pfiesteria* populations.

Other objectives of the EMPACT project were to measure and evaluate low dissolved oxygen conditions that affect certain Maryland waterways during the summer months and to evaluate SAV habitat conditions. Low oxygen conditions can stress fish and other aquatic organisms, and can lead to fish kills under severe conditions. SAV is a key living resource in Chesapeake Bay and provides valuable habitat for fish, crabs and other species.

Figure 1.1 Chesapeake Bay EMPACT Monitoring Stations



1.3 Chesapeake Bay EMPACT Project

Note: The National Aquarium in Baltimore (NAIB) project is discussed in Chapter 7.

1.3.1 Overview

The Chesapeake Bay EMPACT project was initiated in 1998 and ended in 2001. During that time, the Chesapeake Bay EMPACT project maintained as many as eight continuous water quality monitoring sites. Most sites were equipped with sampling and telemetry equipment. Timely data was available from the Rehobeth and Cedar Hall Wharf Stations on the Pocomoke River, the Stonington Station on the Magothy River, the Drawbridge Station on the Chicamacomico River, the Decoursey Bridge Station on the Transquaking River, and from the Fort McHenry Field Station in Patpsco River. The data for the Shelltown site on the Pocomoke River and the Cattail site on the Magothy was downloaded manually by MD DNR scientists. [Source: http://mddnr.chesapeakebay.net/newmontech/contmon/index.cfm]

Note: Although the Chesapeake Bay EMPACT Project has ended, MD DNR continues to collect timely water quality data at many of the monitoring sites listed above. In some cases, the equipment has been moved to other sites to collect similar data.

The field monitors (or sondes) were located at a constant depth of one meter below the surface of the water, with the exception of Cedar Hall Wharf on the Pocomoke, which also has a surface and bottom meter. The sondes were programmed to record seven environmental parameters: water temperature, salinity, dissolved oxygen saturation, dissolved oxygen concentration, pH, turbidity, and fluorescence. Each parameter was recorded every 15 minutes. Once a week (May through October), the monitors were replaced with clean, recalibrated units. The data collected by the sondes were downloaded and reviewed using the software, EcoWatch® for Windows™, that was provided with the sonde. Scientists reviewed the data to identify and delete obvious erroneous data. After reviewing the data, the scientist sends the data to the Web site manager where graphs are prepared for placement on the EMPACT Web site for the public to view. The Web site manager also archives the data for long-term storage. A telemetry system, which includes cellular phones located in the sampling stations, transferred the near real-time monitoring results to the MD DNR and NAIB twice each day. These data were processed and stored in a database within minutes so that Web users could query and generate graphs of the data.

In addition to the data collected by the sondes, water samples were collected at each location weekly for analysis in the laboratory. The analyses were used to calibrate the sondes and to check the data for accuracy. Water samples were collected for nutrient analysis, Chlorophyll A levels, and water column respiration rates.

1.3.2 Chesapeake Bay EMPACT Project Objectives

Overall project objectives included the following:

- Record chemical and physical data that will provide an understanding of the environmental factors that contribute to the occurrence of harmful algal blooms and low dissolved oxygen occurrences in the Chesapeake and Coastal Bays.
- Provide *in-situ* timely data to the Maryland DNR that supplements state efforts for *Pfiesteria* surveillance monitoring and SAV restoration.
- Utilize high-frequency timely data along with weekly measurements to characterize physical conditions and time frames over which physical processes occur. Identification of recurring events and their associated physical conditions are used as a basis for the development of future monitoring schemes to optimize recognition of any signals, impacts or events in the tributaries.
- Provide comprehensive assessments of technical environmental data in an easy to understand format that will increase the public's understanding of factors contributing to the frequency of toxic outbreaks of *Pfiesteria* and *Pfiesteria*-like organisms, fish kills, low dissolved oxygen and the loss of SAV habitat.

1.3.3 EMPACT Project Team

The Chesapeake Bay Project team consisted of the following members and key partners:

I. Key Personnel

- Tony Allred, MD DNR - Data management oversite.
- Bruce Michael, MD DNR - EMPACT project coordination and management.
- Drew Koslow, Chris Aadland, Maryland DNR - Data management and analysis, Web site design and maintenance.
- Ned Burger, University of Maryland Chesapeake Biological Laboratory, Chris Trumbauer, MD DNR, and John Ungarelli, MD DNR - Responsibilities included field work and in-house downloading and archiving raw data from instruments following each weekly deployment, making and documenting any data deletions or conversions, and transferring the corrected data to DNR.
- Glenn Page, National Aquarium in Baltimore, Director of Conservation - oversees all conservation efforts for NAIB.
- Angie Lawrence, National Aquarium in Baltimore, Chesapeake Bay Program Manager - responsible for all tidal wetland restoration efforts, manages volunteers.
- Dan O'Connell, Maryland DNR - database manager/programmer, maintains the Chesapeake Bay EMPACT Web site.

II. Key Partners

- Maryland DNR, Resource Assessment Service, Tidewater Ecosystem Assessment Division.
- NAIB (National Aquarium in Baltimore).
- NOAA (National Oceanic and Atmospheric Administration).
- University of Maryland Center of Environmental Services, Chesapeake Biological Laboratory (CBL)/Horn Point Laboratory (HPL).
- Morgan State University.
- The Chesapeake Bay Program.
- Other local partners.

1.3.4 Project Costs

The costs to conduct a water quality monitoring project similar to the Chesapeake Bay Project can vary significantly. Factors affecting the cost include, but are not limited to, the size and location of your study area, the number and types of parameters you want to measure, the number of monitoring stations that you want to deploy, whether you want a telemetry system to receive timely data, the personnel needed to collect and analyze the data, the number of samples to collect, and the amount of new equipment which will need to be purchased.

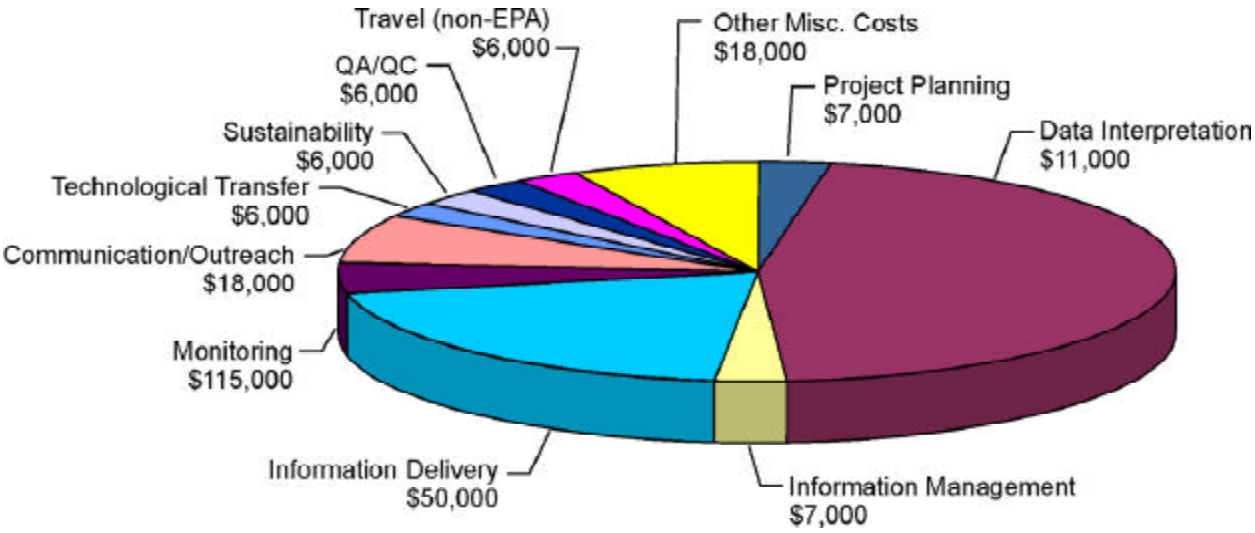
Each year from 1998 through 2000, Maryland's DNR applied for and received incremental EMPACT funding for their water quality monitoring program, totaling $475K. In 1998, the Chesapeake Bay EMPACT project received $100K to set up and maintain continuous monitoring at two sites on the Pocomoke River. Four sondes (two per monitoring site) were purchased for weekly collection of monitoring data. With an EMPACT Grant of $125K in 1999, four more sondes were purchased and set up to provide continuous monitoring at two additional sites on the Pocomoke. No telemetry was installed during these two years. A grant of $250K in 2000 enabled the Chesapeake Bay project to expand its continuous monitoring program Bay-wide. Two sites on the Magothy River and one site each on the Transquaking and Chicamacomico Rivers were set up, requiring the purchase and maintenance of eight additional sondes. With the additional funds, the purchase and use of telemetry was also initiated.

Figure 1.2 provides an example of the expenditure breakdown for the major project phases/tasks which occurred in 2000. In addition to EMPACT Grant funding, Maryland DNR provided funding for nutrient analysis, and staff time for project oversight, data management, data analysis and interpretation, and information dissemination. The University of Maryland also provided staff time for project oversight. [Source: EMPACT EPA Project Plan 2000, Revised January.]

One should keep in mind that significant initial capital costs may be incurred when implementing such a monitoring effort. For example, if you need to purchase equipment to measure parameters (i.e., sondes) or if you want to have access to timely data which would require telemetry hardware and software, then you should account for such expenditures. A monitoring station equipped with sondes and electronic hardware for a telemetry system can cost $17,000 to $22,000, excluding the manpower necessary for maintaining the equipment.

Added to this are annual costs for staff time necessary for sample collection and maintaining the sondes, data management, data analysis, and Web page maintenance. Utilizing a telemetry system also has additional costs such as cell phone charges.

Figure 1.2 Chesapeake Bay EMPACT Grant (FY2000)



1.3.5 Technology Transfer Handbook

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

Free copies of both print and CD-ROM versions of the handbook are available for direct on-line ordering from EPA's Office of Research and Development Technology Transfer Web site at http://www.epa.gov/ttbnrmrl. A PDF version of the Handbook can be downloaded directly from the same Web site. You can also order a copy of the handbook (print or CD-ROM version) by contacting ORD Publications by telephone or mail at:

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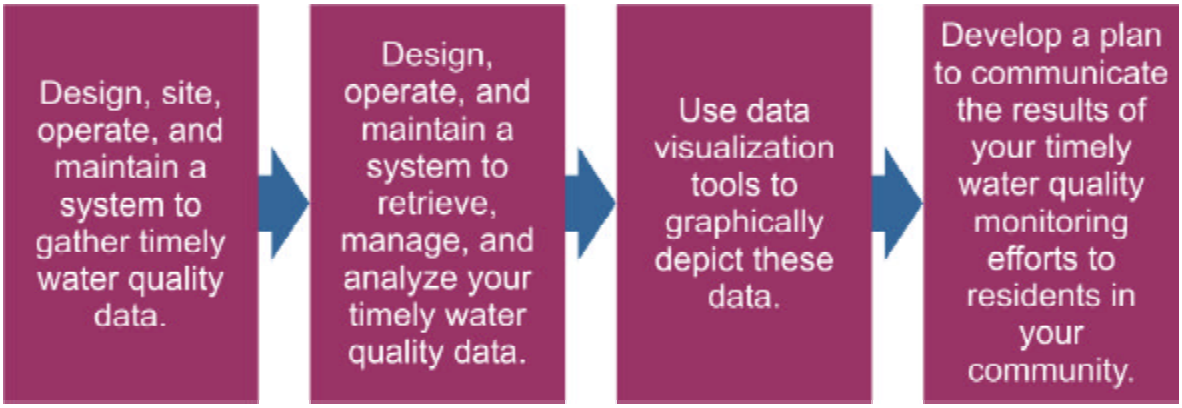
Note: Please make sure you include the title of the handbook and the EPA document number in your request.

We hope you find the handbook worthwhile, informative, and easy to use.

2. HOW TO USE THIS HANDBOOK

This handbook provides you with step-by-step information on how to develop a program to provide timely water quality data to your community, using the Chesapeake Bay Project in Maryland as a model. It contains detailed guidance on how to:



This Handbook also provides information on how to conduct a wetland restoration effort in your community. Specifically:

- Chapter 3 provides information about water quality monitoring - the first step in the process of generating timely information about water quality and making it available to residents in your area. The chapter begins with an overview of water quality monitoring in estuarine systems and then focuses on the monitoring components that are part of the Chesapeake Bay Project.

- Chapter 4 provides step-by-step instructions on how to collect, transfer, and manage timely water quality data. This chapter discusses time-series sampling equipment calibration, transferring sampling data, managing sampling data, and checking sampling data for quality. In addition, this chapter presents details on water quality field sampling including details on sampling, water quality parameter analyses, and data transfer and management.

- Chapter 5 provides information about using data visualization tools to graphically depict the timely water quality data you have gathered. The chapter begins with a brief overview of data visualization. It then provides a more detailed introduction to selected data visualization tools utilized by the Chesapeake Bay team. You might want to use these software tools to help analyze your data and in your efforts to provide timely water quality information to your community.

- Chapter 6 outlines the steps involved in developing an outreach plan to communicate information about water quality in your community. It also

provides information about the Chesapeake Bay Project's outreach efforts. The chapter includes a list of resources to help you develop easily understandable materials to communicate information about your timely water quality monitoring program to a variety of audiences.

- Chapter 7 discusses related projects that were conducted by the National Aquarium in Baltimore. Such projects include a similar water quality monitoring project at the Fort McHenry National Monument in Baltimore, MD; wetlands restoration efforts at Fort McHenry; and the development of a GIS product to provide online access to water quality information.

This handbook is designed for decision-makers considering whether to implement a timely water quality monitoring program in their communities and for technicians responsible for implementing these programs. Managers and decision-makers likely will find the initial sections of Chapters 3, 4, and 5 most helpful. The latter sections of these chapters are targeted primarily at scientists and technicians and provide detailed "how to" information. Chapter 6 is designed for managers and communication specialists. Chapter 7 is designed to inform individuals or groups about other projects which resulted or benefitted from the Chesapeake Bay EMPACT project.

The handbook also refers you to supplementary sources of information, such as Web sites and guidance documents, where you can find additional guidance with a greater level of technical detail. The handbook also describes some of the lessons learned by the Chesapeake Bay team in developing and implementing its timely water quality monitoring, data management, and outreach program.

3. WATER QUALITY MONITORING/SAMPLING

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

The chapter begins with a broad overview of water quality monitoring and then focuses on the monitoring components that were part of the Chesapeake Bay EMPACT Project. The chapter also provides instructions on how to install, operate, and maintain continuous monitoring equipment. Readers primarily interested in an overview of water quality monitoring might want to focus on information presented in this introductory section and the introductory parts of Sections 3.1, 3.2, and 3.3. If you are responsible for the design and implementation of a water quality monitoring project whose goal is to provide timely water quality sample results to the public, you should review Subsections 3.2.1 through 3.2.8. They provide an introduction to the specific steps involved in developing and operating a water quality monitoring project and information on where to find additional guidance. If you are responsible for the design and implementation of a water quality field sampling project, you should review Subsections 3.3.1 through 3.3.2. They provide information on setting up a field sampling program. Subsections 3.3.3 and 3.3.4 provide instructions on how to collect and analyze water samples for various parameters.

3.1 Water Quality Monitoring: An Overview

Water quality monitoring provides information about the condition of streams, lakes, ponds, estuaries, and coastal waters. It can also tell us if these waters are meeting their standards for designed uses, such as for swimming, fishing, or drinking. Water quality monitoring can consist of the following types of measurements:

- *Chemical* measurements of constituents such as nutrients, metals, and oils in water.
- *Physical* measurements of general conditions such as temperature, dissolved oxygen, conductivity/salinity, current speed/direction, water level, water clarity.
- *Biological* measurements of the abundance, variety, and growth rates of aquatic plant and animal life in a water body or the ability of aquatic organisms to survive in a water sample.

You can conduct a variety of water quality monitoring projects, including:

- At fixed locations on a continuous basis.
- At selected locations on an as-needed basis or to answer specific questions.

- On a temporary or seasonal basis (such as during the summer at swimming beaches).
- On an emergency basis (such as after a spill).

Note: As you will read later, the majority of Chesapeake Bay's Water Quality Monitoring Project was conducted on a seasonal basis from April/May through October which corresponds to the times of highest biological activity and it is representative of the SAV growing season in Maryland.

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

Water quality monitoring is conducted for many reasons, including:

- Characterizing waters and identifying trends or changes in water quality over time.
- Identifying existing or emerging water quality problems.
- Gathering information for the design of pollution prevention or restoration programs.
- Determining if the goals of specific programs are being met.
- Complying with local, state, and federal regulations.
- Responding to emergencies such as spills or floods.

EPA helps administer grants for water quality monitoring projects and provides technical guidance on how to monitor and report monitoring results. You can find a number of EPA's water quality monitoring technical guidance documents on the Web at: http://www.epa.gov/owow/monitoring/techmon.html. The EPA's Office of Water has developed a Watershed Distance Learning Program called the "Watershed Academy Web." This program, which offers a certificate upon completion, is a series of self-paced training modules that covers topics such as watershed ecology, management practices, analysis and planning. More information about the Watershed Academy Web can be found on the Web at: http://www.epa.gov/watertrain/. The EPA also has a Web site entitled "Surf Your Watershed" which can be used to locate,

use, and share environmental information on watersheds. For more information about the resources available on Surf Your Watershed, please see the following Web site: http://www.epa.gov/surf3. The EPA also has a collection of watershed tools available on the Web at http://www.epa.gov/OWOW/watershed/tools/. The watershed tools deal with topics such as data collection, management and assessment, outreach and education, and modeling.

In addition to the federal EPA resources listed above, you can obtain information about lake and reservoir water quality monitoring from the North American Lake Management Society (NALMS). NALMS has published many technical documents, including a guidance manual entitled *Monitoring Lake and Reservoir Restoration*. For more information, visit the NALMS Web site at http://www.nalms.org. State and local agencies also publish and recommend documents to help organizations and communities conduct and understand water quality monitoring. For example, the State of Maryland maintains a Web site (http://www.dnr.state.md.us/bay/monitoring/) that lists its monitoring strategy for the Chesapeake Bay. State and local organizations in your community might maintain similar listings.

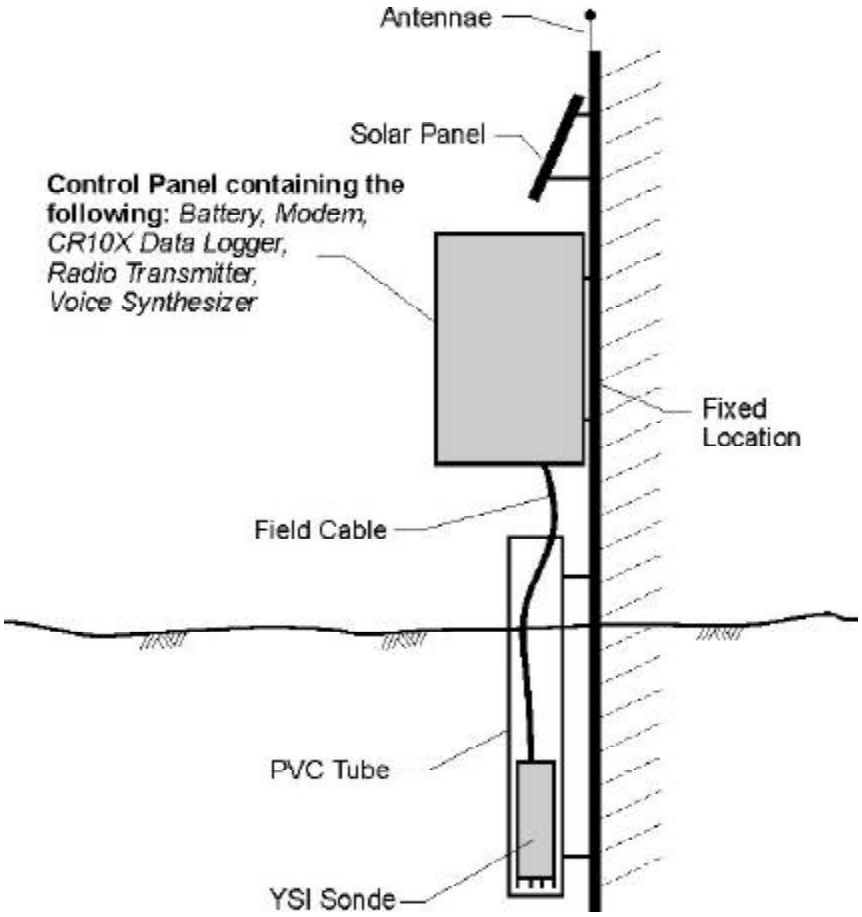
In some cases, special water quality monitoring methods, such as remote monitoring, or special types of water quality data, such as timely data, are needed to meet a water quality monitoring program's objectives. *Timely* environmental data are collected and communicated to the public in a time frame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

3.2 Timely Water Quality Monitoring

The Chesapeake Bay Project monitored a range of water quality parameters including chloropyhll A, dissolved oxygen, nutrients, salinity (conductivity), temperature, and total suspended solids. This information was used to help the State of Maryland, EMPACT project stakeholders and partners, as well as the public, better understand the environmental conditions that can lead to harmful algal blooms, fish kills or the emergence or decline of SAV.

The Chesapeake Bay Project monitored various water quality parameters at eight locations along five rivers feeding into the Chesapeake Bay: Cedar Hall Wharf, Shelltown, Rehobeth (located along the Pocomoke River); Fort McHenry (located along the Baltimore Harbor in the Patapsco River); Cattail Creek and Stonington (located along the Magothy River); Drawbridge (located along the Chicamacomico River); and Decoursey Bridge (located along the Transquaking River). At these locations, the team operated monitoring equipment which monitor water quality using commercially available sondes. A sonde is a group of sensors which transmits timely water quality data to a data acquisition/telemetry system mounted above the water level. Provided below is a schematic showing the general equipment associated with the monitoring station.

Figure 3.1 Monitoring Station



Every 15 minutes, the water quality monitoring station unit equipped with a YSI© 6600 multiprobe water quality sensor measured the following parameters:

- Dissolved oxygen
- DO% Saturation
- Fluorescense/Chlorophyll A
- pH
- Specific conductance/Salinity
- Turbidity
- Water temperature

The remainder of this chapter provides guidelines for designing a water quality monitoring project. It also provides information on the sample collection and analysis procedures used for the field sampling effort.

3.2.1 Designing a Timely Water Quality Monitoring Project

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

In order to clearly define the objectives of your particular water quality monitoring project, you need to understand the system you are planning to monitor. This means that you need to collect background information about the aquatic system, such as naturally occurring processes, system interactions, system ecology, and human impacts on the system.

Since the Chesapeake Bay monitoring project involves estuarine ecology, the following paragraphs provide some basic background information about this topic.

Estuarine Ecology

Estuaries are bodies of water that are balanced by freshwater and sediment influx from rivers and the tidal actions of the oceans, thus providing transition zones between the freshwater of a river and the saline environment of the sea. The result of this interaction is an ecologically rich environment where estuaries, with large expanses of adjacent marshes and seagrasses, provide a highly productive ecosystem that supports wildlife and fisheries and contributes substantially to the economy of coastal areas. As spawning, nursery, and feeding grounds, estuaries are invaluable to fish and shellfish.

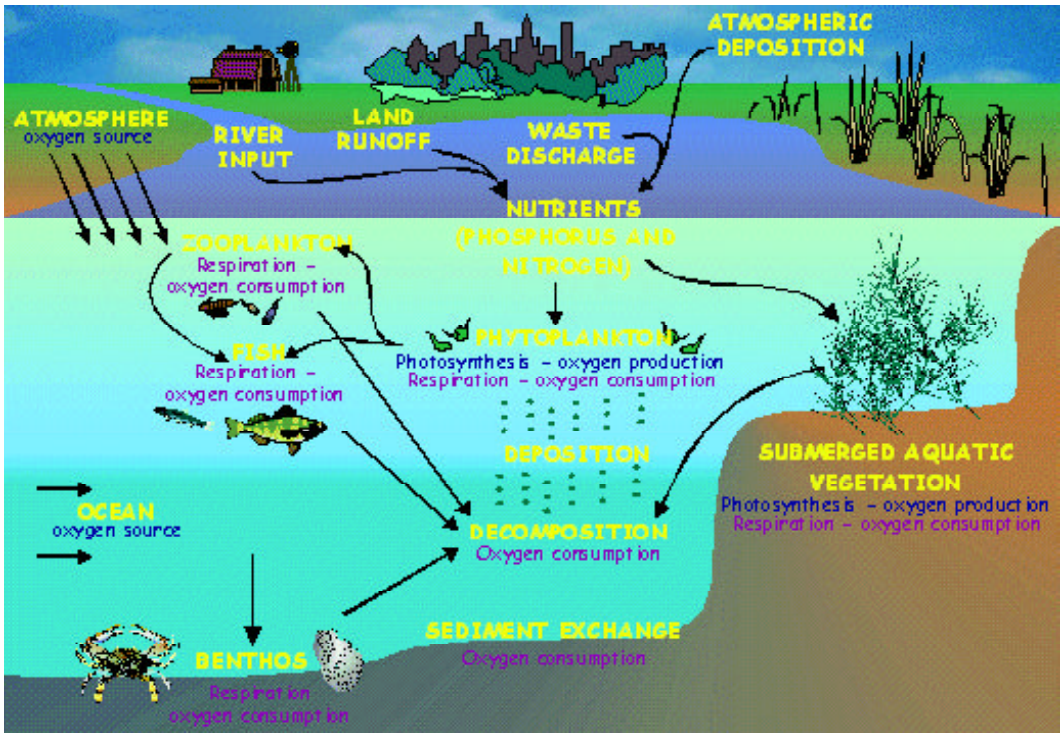
Estuaries and wetland environments are intertwined. Coastal emergent wetlands border estuaries and the coast and include tidal saltwater and freshwater marshes. Coastal wetlands serve as an essential habitat for a diverse range of species. These wetlands are used as a nursery, nesting area, shelter or feeding area by shorebirds, migratory waterfowl, fish, crabs, invertebrates, reptiles, and mammals. Mudflats, salt marshes, mangrove swamps, and barrier island habitats also provide year-round nesting and feeding grounds for abundant populations of gulls, terns, and other shorebirds. Estuaries, marshes and associated watersheds provide habitat for many threatened and endangered species.

Effect of Nutrients on the Chesapeake Bay

Nutrients and organic matter enter the Bay from a variety of sources, including sewage treatment plant effluents, stream inputs, local non-point drainage and direct rainfall on bay waters. A portion of organic matter sinks to the bottom, decomposes and contributes to the development of hypoxic (low oxygen) and anoxic (no oxygen) conditions. Estuarine sediments have the ability to store nutrients that can later allow a "flux" of nutrients from sediments to the water. These fluxes can fuel high rates of

phytoplankton growth and biomass accumulation. Once phytoplankton die, they fall to the bottom where they are decomposed by bacteria. The process of decomposition requires the use of oxygen (see Figure 3.2). Therefore, large amounts of organic matter created by dead phytoplankton blooms can deplete oxygen in bottom sediments which can lead to hypoxia or anoxia. Hypoxia and anoxia are common in eutrophic estuarine systems and threaten our living resources, including SAV, shellfish, fish and other fauna.

Figure 3.2. Components in the Chesapeake Bay That Produce and Consume Oxygen



[Source: http://www.dnr.state.md.us/bay/monitoring/eco/affect.html].

There are usually three overlapping zones in an estuary: an open connection with the sea where marine water dominates, a middle area where salt water and fresh water mix, and a tidal river zone where fresh water dominates. Tidal forces cause the estuarine characteristics to vary. Also variation in the seasonal discharge of rivers causes the limits of the zones to shift, thus increasing the overall ecological complexity of the estuaries.
[Source: http://encarta.msn.com/find/Concise.asp?z=1&pg=2&ti=761570978#s1]

Most of the world's freshwater runoff eventually encounters the oceans in estuaries. Tides or winds help mix the lighter, less dense fresh water from the rivers with the salt water from the ocean to form brackish water. The salinity of brackish water is typically 2 to 10 parts per thousand (ppt), while the salinity of sea water is about 35 ppt. Due mostly to changes in the river flow, the three main estuarine zones - sea water, brackish,

and freshwater - can shift seasonally and vary significantly from one area to another. [Source: http://encarta.msn.com/find/Concise.asp?z=1&pg=2&ti=761570978#s1]

Note: The salinity in the Chesapeake Bay varies from fresh water levels in the upper bay to 20-30 ppt in the low bay.

Harmful Algal Blooms

How An Algal Bloom Can Occur

Ideal conditions for algal growth occurs when you have a combination of algae, high levels of nutrients (e.g., nitrogen and phosphorus), and water temperature and salinity levels conducive to phytoplankton growth in the water body.

In such conditions, the algae consumes the excess nutrient causing a decrease in dissolved nitrogen and phosphorus in the water body.

During the day, overall dissolved oxygen (DO) increases as phytoplankton produces oxygen as photosynthesis occurs.

At night, the DO levels decrease sharply as the algae consumes oxygen.

As the amount of nutrients are depleted, the algae population decreases sharply in what is called a "crash."

As this crash occurs, the dead phytoplankton sinks to the bottom of the water column where they are consumed by decomposers.

Since decomposers require oxygen to break down the algae, DO levels decrease.

Low oxygen levels can be detrimental to fish health. If DO levels drop to below 3 mg/L, fish kills will result!

Microscopic, single-celled plants (phytoplankton) serve as the primary producers of energy at the base of the estuarine food web. Some species of phytoplankton grow very fast, or "bloom," and accumulate into dense, visible patches near the surface of the water. Although the causes of algal blooms are not entirely known, scientists suspect that blooms occur as a result of a combination of high temperatures, a lack of wind, and, frequently, nutrient enrichment. Some algal blooms are called brown tides. While not harmful to humans, they cause serious ecosystem impacts due to decreases in light penetration and dissolved oxygen. Brown tides can cause seagrass die-offs and fish kills. Some algae, such as *Pfiesteria* may produce potent toxins that can cause fish kills and human health problems. Due to the significant health and economic concerns surrounding the outbreaks of toxic *Pfiesteria* that Maryland experienced in 1997, a primary goal of the Chesapeake Bay EMPACT project is to supplement Maryland's larger *Pfiesteria* monitoring efforts.

Pfiesteria

Pfiesteria piscicida is a toxic dinoflagellate that has been associated with fish lesions and fish kills in coastal waters from Delaware to North Carolina. A natural part of the marine environment, dinoflagellates are microscopic, free-swimming, single-celled organisms, usually classified as a type of algae. The vast majority of dinoflagellates are not toxic. Although many dinoflagellates are plant-like and obtain energy by photosynthesis, others, including *Pfiesteria*, are more animal-like and acquire some or all of their energy by eating other organisms.

Pfiesteria normally exists in non-toxic forms, but becomes toxic when it detects an ephemeral substance that live fish excrete or secrete into the water. In its toxic form, *Pfiesteria* secretes toxins into the water which make the fish lethargic. These toxins also injure the fish skin causing bleeding sores and hemorrhaging. North Carolina State University has conducted much research on *Pfiesteria*. For more information, refer to http://www.pfiesteria.org/pfiesteria.

Designing the Chesapeake Bay Project

The Chesapeake Bay Project team's decision to collect timely water quality data was made so that the data would serve as a communications link with the public, providing frequent updates of "real-time" data and emphasizing that the state and EPA are watching 24 hours a day specific areas which could experience harmful algal blooms or other environmental problems. Citizens can access the frequently updated data on the Chesapeake Bay EMPACT Web site (http://mddnr.chesapeakebay.net/newmontech/contmon/index.cfm) which depicts actual conditions being measured in the Pocomoke, Chicamacomico, Transquaking, and Magothy Rivers as well as at Fort McHenry in the Baltimore Harbor.

The project team decided to conduct timely monitoring of water quality to be able to detect algal blooms early and to provide timely environmental information to natural resource and human health protection agencies. Having timely data allows entities to respond quickly to adverse environmental conditions, make appropriate decisions to ensure economic and environmental sustainability of the affected environment, and protect the health of commercial and recreational users.

3.2.2 Selecting Your Monitoring Duration and Frequency

The duration of your monitoring will depend on your project objectives. For example, like the Chesapeake Bay project, if you want to measure the environmental conditions that contribute to *Pfiesteria* outbreaks or other harmful algal blooms, you will want to monitor when those conditions generally occur in your region.

The goal of the Chesapeake Bay EMPACT monitoring program is to have most of the sites collecting data from April through October. These dates correspond to the SAV growing season and are when *Pfiesteria* outbreaks are most likely to occur. However, if your goal is to monitor the effects of freshwater river diversions on a coastal wetland, you may want to monitor water quality year-round.

- If you want to identify existing or emerging water quality problems such as algal blooms, you could tailor your monitoring frequency to collect data often enough to identify problems early in order to take measures to alleviate the problem and warn the public.
- If you want to study seasonal water quality problems, you may want to increase your monitoring frequency during seasons when water quality problems are

more predominant (i.e., low dissolved oxygen levels and associated fish kills during summer months).

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

Chesapeake Bay Monitoring Season

- Most of the stations collect data from April through October
- The Fort McHenry station operates year-round and occasionally other sites are maintained year-round to test equipment

The Chesapeake Bay project team programmed its monitoring station to collect water quality data every 15 minutes. This monitoring frequency provides timely environmental data to supplement Maryland's rapid response and comprehensive water and habitat quality assessments of Maryland tributaries that have a potential risk for harmful algal blooms. It also provides the temporal resolution they need to see naturally occurring cyclical changes in various parameters (e.g., Chlorophyll A fluctuations occurring during the daytime and nighttime).

3.2.3 Selecting Water Quality Parameters for Monitoring

The monitoring parameters that you select depend on your project's objectives and the technologies available to you. The Chesapeake Bay/NAIB project teams chose to monitor the following water quality parameters every 15 minutes using the YSI 6600 probe:

- Dissolved oxygen (mg/l)
- DO % saturation (%)
- Fluorescence (%)
- pH
- Salinity (ppt)
- Turbidity (NTU)
- Water temperature (degrees Celsius)

The importance of each parameter is discussed below.

Dissolved Oxygen. Dissolved oxygen (DO) is an indicator of the habitability of estuarine waters for marine life and it is routinely measured by monitoring programs interested in characterizing the eutrophic state of estuaries. DO is recognized as an indicator of the extent of eutrophication because wide fluctuations in DO often result

from increased primary productivity of phytoplankton and may reflect prior nutrient loading. DO concentrations may also vary because of natural processes, such as stratification, depth, wind-induced mixing, and tidal fluxes. DO levels below 5 mg/L can stress organisms while sustained DO levels of less than 3 mg/L can result in fish kills. [Source: http://mddnr.chesapeakebay.net/empact/Current_results_display.cfm.] Sufficient evidence exists that DO < 2 mg/L is extremely stressful to most aquatic organisms. Hypoxia (condition where DO is less than 2 mg/L) increases stress from other factors (e.g., contaminants) on marine organisms, whereas anoxic conditions (DO < 0.1 mg/L) produce toxic hydrogen sulfide which can be lethal to marine biota. Many states require DO concentrations of 4-5 mg/L for estuaries to meet their designated use criteria. Low DO is usually observed from May through September in Chesapeake Bay and is primarily driven by nutrient loading. [Source: http://www.epa.gov/ged/gulf.htm]. Additional information about hypoxia can also be found on the following USGS Web site: http://www.rcolka.cr.usgs.gov/midconherb/hypoxia.html.

DO% Saturation. DO saturation percent shows the level of dissolved oxygen as a percentage of the possible DO the water could contain. Generally, colder water can hold more DO than warmer water. Supersaturation (over 100% DO saturation) can occur when there is a large algal bloom. During the daylight, when the algae are photosynthesizing, they can produce oxygen so rapidly that it is not able to escape into the atmosphere, thus leading to short-term saturation levels of greater than 100%.

Fluorescence. Fluorescence is an indirect measure of the amount of Chlorophyll A in the water column. Since the primary source of the photosynthetic pigment Chlorophyll A is phytoplankton, we can use the fluorescence reading (percent full scale or %FS) as an indicator of phytoplankton populations in the water column. [Source: http://mddnr.chesapeakebay.net/empact/Current_results_display.cfm]

pH. pH is a measure of the hydrogen ion concentration (or acidity) in the water. A pH of 7 is considered neutral. Values lower than 7 are considered acidic and higher than 7 are basic. Many important chemical and biological reactions are strongly affected by pH. In turn, chemical reactions and biological processes (e.g., photosynthesis and respiration) can affect pH. If water becomes either too alkaline or acidic, it can become inhospitable to many species of aquatic life. Lower pH values can also increase the amount of dissolved metals in the water. High pH values can be an indication of an algae bloom.

Salinity. Salinity (or electrical conductivity) is an estimator of the amount of total dissolved salts or total dissolved ions in water. Many factors influence the electrical conductivity/salinity of estuarine water, including the watershed's geology, the watershed's size, wastewater from point sources, runoff from nonpoint sources, atmospheric inputs, evaporation rates, precipitation, fresh water diversion from rivers, tidal surges, and some types of bacterial metabolism. Electrical conductivity/salinity

affects the distribution and health of benthic animals, fish, and vegetation. Both excessively high or low salinities can negatively impact the estuarine ecosystem. Salinity levels are important to aquatic organisms, as some organisms are adapted to live only in brackish or saltwater, while others require fresh water. If the salinity levels get too high, the health of freshwater fish and grasses in the system can be affected.

Turbidity. Turbidity (or backscatter) describes the clarity of the water. Turbidity is a measurement of the amounts of total suspended solids in the water. The particles that make up the turbidity can range from sediment to phytoplankton. In combination with the Chlorophyll A measurements, it can be determined if mineral matter or organics dominate. Predominant organics can be an indication of an algal bloom, which could mean that algae below the zone of light penetration are decaying and consuming oxygen, which in turn, can result in hypoxia that affects bottom dwelling organisms. Measurements of turbidity and backscatter are interrelated in that water with high turbidity measurements also yields high reflectance measurements. Simply put, the more particles that are present in the water, the more light can be scattered back to the sensor. Increased turbidity has several adverse effects on water quality, including the following:

- Turbidity reduces light penetration, which deceases the growth of aquatic plants and organisms. The reduced plant growth reduces photosynthesis, which results in decreased daytime releases of oxygen in the water.
- Suspended particles eventually settle to the bottom, suffocating eggs and/or newly hatched larva, and occupy potential areas of habitat for aquatic organisms.
- Turbidity can also negatively impact fish populations by reducing the ability of predators to locate prey, shifting fish populations to species that feed at the estuary bottom.
- Fine particulate material can affect aquatic organisms by clogging or damaging their sensitive gill structures, decreasing their resistance to disease, preventing proper egg and larval development, and potentially interfering with particle feeding activities.
- Increased inputs of organic particles deplete oxygen as the organic particles decompose.
- Increased turbidity raises the cost of treating surface water for the drinking water supply.

Water Temperature. Water temperature is a product of warming from the sun and air and is another variable affecting suitability of the waterway for aquatic organisms. Water temperature affects metabolic rates and thus has a direct effect on biological activity and the growth of aquatic animal life and aquatic vegetation. Generally, high temperatures (up to a certain limit) increase biological activity and growth, while low temperatures decrease biological activity and growth. For example, high temperatures

in nutrient rich environments promote algal growth and may lead to algal blooms. If water temperatures are consistently higher or lower than average, organisms can be stressed and may have to relocate to areas with a more suitable water temperature. Temperature also affects biological activity by influencing lake water chemistry, such as the oxygen content of the water. Warm water contains less dissolved oxygen than cold water. Low dissolved oxygen levels in the water might not be sufficient to support some types of aquatic life.

3.2.4 Selecting Monitoring Equipment

The type of monitoring method selected depends on your data quality objectives and the purpose of the monitoring. A group of sensors configured together to measure specific physical properties are available as single instruments and are commonly referred to as a sonde, which typically has a single recording unit or electronic datalogger to record the output from the group of sensors. When you select your monitoring equipment, you should carefully consider ease of use, equipment lifetime, reliability, and maintenance requirements. You also might consider using equipment that has been used successfully for similar types of projects.

Note: For descriptions of other EPA EMPACT projects see http://www.epa.gov/ttbnrmrl/Handbks.htm.

The Chesapeake Bay Project team selected the YSI 6600 sensor package to collect timely water quality data. This capability provides opportunities for multi parameter data collection and helped the project team to meet its objectives as described below:

- Archive and display timely water and habitat quality parameters on the Internet for presentation of the data to the general public.
- Provide timely interpretation, as appropriate, relevant to water and habitat quality monitoring data.
- Provide timely environmental data to supplement Maryland's rapid response and comprehensive water and habitat quality assessments of Maryland tributaries that have a potential risk for harmful algal blooms.
- Demonstrate the local government's response to emerging water and habitat quality issues of concern to the public.

Even though the teams use YSI equipment, other manufactures provide similar or alternative equipment. For example, Hydrolab (http://www.hydrolab.com) is another multi-parameter sensor manufacturer. The Maryland DNR uses Hydrolab sensors for some of its other monitoring projects. However, the Chesapeake Bay project team chose the YSI sensor because of its patented Rapid Pulse Dissolved Oxygen Sensor, which provides accurate results without the need for a mechanical stirrer.

Description of a Typical Monitoring Station

The typical monitoring site utilized for the Chesapeake Bay project consists of two types of equipment: monitoring equipment and telemetry equipment. The monitoring equipment consists of a sensor package and a field cable. The telemetry equipment, which is necessary for providing near real-time data to an end user, consists of a datalogger, a battery, a solar panel, modem, and voice synthesizer. The telemetry equipment is discussed in Chapter 4. Information about the monitoring equipment utilized by the Chesapeake Bay team was obtained from the Yellow Springs Instruments, Inc. (YSI) Web site (http://www.ysi.com) and is discussed below.

Sensor Package. The Chesapeake Bay team selected the YSI 6600 sensor package which has a multi-sensor probe, called a sonde, to measure the various water quality parameters. A picture of the YSI 6600 sensor package is shown in Figure 3.3.

The 6600 sonde is YSI's premier unit and can be deployed to measure water quality in fresh, sea, or polluted water at depths up to 200 meters. It is 3.5" in diameter, 20.4" long, and weighs approximately 6 pounds. It has an internal power supply consisting of 8 C-size alkaline batteries. The battery life is approximately 75 days assuming that you buy quality batteries and sample at 15-minute intervals at 25°C. A fully loaded YSI 6600 sonde can measure 11 different parameters and calculate up to 7 additional parameters. The YSI 6600 has 384 kilobytes of logging memory and can store up to 150,000 readings.

Figure 3.3 YSI 6600 Multi-probe sensor

[Photo Courtesy of YSI]

The YSI sondes are warranted for two years; all cables are warranted for one year; and dissolved oxygen, temperature/conductivity, pH, turbidity, and Chlorophyll A probes are warranted for one year.

Also when selecting your equipment, you will want to ensure that it meets generally accepted accuracy and sensitivity requirements. The USGS Web site (http://water.usgs.gov/pubs/wri/wri004252/#pdf) is a good source for background information on calibration and data QA/QC of "real-time" water quality monitoring systems. Table 3.1 shows the YSI sensor calibration requirements and how it compares to the USGS sensor calibration/accuracy requirements.

The information in this Section is summarized from the USGS document titled "Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting" available from the USGS Web site listed above. The USGS guidelines referred to in this document have evolved based on decades of experience with water-quality monitoring. For more information on the YSI 6600's performance specifications, see http://www.ysi.com.

Initially, the Chesapeake Bay team deployed YSI 6920 sondes. The 6920 sonde lacked the capability to measure both turbidity and fluorescence simultaneously because it had only one optical port. As a result, the team could only monitor turbidity. The YSI 6600 is equipped with two optical ports, so when it became available, the team replaced its 6920 sondes with the 6600 so they could also monitor Chlorophyll A which required the additional optical port.

Field Cable. The field cable is a communication link between the YSI 6600 and either a computer or data collection device. The field cable attaches directly to a connector built into the sonde. The other end of the field cable is a military-style 8 pin connector (MS-8). The MS-8 connector plugs directly into YSI 610-D or 610DM display/loggers. Using a YSI 6095B MS-8 to DB-9 adapter, the sonde can be connected directly to a computer for setup, calibration, and uploading files.

PVC Tube. Although not part of the standard YSI-issued sonde equipment, the Chesapeake Bay Team mounts the YSI sonde inside a specially prepared PVC tube. The tube adds further protection for the sonde against the local wildlife, debris, and human tampering. When deploying the sonde inside a PVC tube, the tube should be painted with an anti-fouling coating to prevent algae and barnacles from attaching to the pipe and fouling the DO and fluorescence sensors.

Care should be taken when choosing an antifouling coating, because some will not work in certain conditions. Because Chesapeake Bay's sondes are located in tidal waters, they use an ablative antifouling paint which will remain active as the sonde is continuously re-exposed to water due to tidal forces. If you want to monitor water quality in a fresh water lake where the salinity levels are lower and there are no tidal influences, you should choose a different type of antifouling paint. Antifouling paints can be purchased from boat and marine suppliers.

Other Peripheral Equipment and Software. For the initial setup of the sonde, you will also need a computer with a communications port (DB-9). YSI recommends that the initial setup procedure take place in a laboratory environment rather than in the field. YSI provides a copy of its EcoWatch® for Windows™ (EcoWatch®) which is necessary for programming the sonde. The software is a Windows 3.1 program that works well with Windows 95, 98 and Windows NT. EcoWatch® must be used with an IBM-compatible PC equipped with at least a 386 processor and a 3.5" floppy disk drive. EcoWatch® is discussed further in Chapter 4.

Table 3.1 Performance Specifications for the YSI 6600.

Parameter		YSI Performance Specification	Recommended USGS Performance Specification*
Dissolved Oxygen	Range Resolution Accuracy	0 to 50 mg/l 0.01 mg/l 0 to 20 mg/l: ±2% of reading or 0.2mg/l, whichever is greater; 20 to 50 mg/l:±6% of reading	±0.3 mg/l
% Dissolved Oxygen Saturation	Range Resolution Accuracy	0 to 500% 0.1% 0 to 200%: ± 2% of reading or 2% air saturation, whichever is greater; 200 to 500%: ±6% of reading	Not Addressed
Fluorescence/ Chlorophyll A	Range Resolution	0 to 100% FS 0.1% FS	Not Addressed
pH	Range Resolution Accuracy	0 to 14 units 0.01 unit ±0.2 unit	±0.2 pH units
Conductivity/Salinity	Range Resolution Accuracy	0 to 70 ppt 0.01 ppt ± 1% of reading or 0.1 ppt, whichever is greater	±3%
Turbidity	Range Resolution Accuracy	0 to 1000 NTU 0.1 NTU ±5% of reading or 2 NTU, whichever is greater	±5%
Water Temperature	Range Resolution Accuracy	-5 to 45 °C 0.01 °C ±0.15 °C	±0.2 °C

* See http://water.usgs.gov/pubs/wri/wri004252/#pdf, Table 9.

3.2.5 Siting Monitors

The water quality monitoring location(s) that you select depends on your project's objectives. When you select your monitoring location(s), you should carefully consider the following factors:

- Will the data collected at this ocation(s) fulfill your project's objectives? For example, if you would like a means for early detection of harmful algal blooms,

you need to make sure that you are monitoring parameters that will indicate such.

- Is your community supportive of equipment installation for monitoring in the location(s) you selected?
- Does the monitoring equipment at the selected location(s) present a danger to your community? For example, is the location(s) in an area with heavy boating, swimming, or personal water craft traffic?
- Is your monitoring equipment safe at the selected location(s)? For example, is the equipment protected from vandalism, tampering, or weather-related damage?
- Are there any local, state, or federal regulations that you need to consider in siting the monitor(s)?
- Is access to the monitoring location(s) adequate?

Siting the Chesapeake Bay Locations

You should attempt to place the sonde in an inconspicuous location in a remote area. Human tampering is a risk associated with unattended stations. The Chesapeake Bay team had two options when deciding how to prevent human tampering. One option was to make the station as visible as possible (e.g., place signs stating that monitoring is being conducted, who to report incidents of vandalism to, and visibly securing the sonde). The other option was to hide the station as much as possible. The Chesapeake Bay team chose to hide their monitors or put them in areas where known individuals could easily check the station. To date, the team has not had any problems with human tampering.

The Chesapeake Bay team decided to locate the monitoring system at eight locations (see Table 3.2). Locations were selected because of past fish kills or fish health problems attributable to low DO, or they were adjacent to SAV beds.

Baltimore Harbor - The Maryland Department of Natural Resources is working with the NAIB and Morgan State University to operate a continuous monitoring station in Baltimore Harbor. This station yields water quality and habitat information from a very urban setting adjacent to the Fort McHenry wetland restoration site. The sonde is located inside a PVC pipe attached to a corrugated bulkhead adjacent to the Ft. McHenry wetland restoration site (see Chapter 7).

Pocomoke River - Cedar Hall Wharf - In 1998, the YSI 6600 monitor was anchored to a dock at the Beverly Farm in Cedar Hall Wharf. One surface meter was used at this location. The shallow water location of this meter contrasts with the mid-channel meter placement at Shelltown. The location of this site is such that water quality is still somewhat affected by bay conditions, but not as strongly

as the Shelltown site. Due to the upstream, near-shore placement, water conditions are generally smoother at this site as well.

Table 3.2 Location and Placement of the Chesapeake Bay Monitoring Stations.

Location - Station	Placement	Meter Depth
Baltimore Harbor- Fort McHenry Field Station	Near Shore	One monitor suspended 1 meter below surface
Pocomoke-Cedar Hall Wharf	Near Shore	One monitor suspended 1 meter below surface; Second monitor anchored 1 meter above river bed
Pocomoke-Shelltown	Center Channel	Suspended 1 meter below surface
Pocomoke-Rehobeth	Near Shore	Suspended 1 meter below surface
Magothy-Cattail Creek	Near Shore	Suspended 1 meter below surface
Magothy-Stonington	At the End of a Long Pier	Suspended 1 meter below surface
Chicamacomico-Drawbridge	Center Channel (narrow channel area)	Suspended 1 meter below surface
Transquaking-Decoursey Bridge	Center Channel	Suspended 1 meter below surface

Pocomoke-Shelltown - The original location (1998) of the Shelltown station was in the Pocomoke River on a dock near Shelltown. In 1999, the station was moved to a piling driven into the sediment slightly downstream at Williams Point (near the Pocomoke Sound). Williams Point is one of the Pocomoke River sites of the 1997 *Pfiesteria* outbreaks resulting in fish kill estimated at 10,000 to 15,000 fish. This station is more affected by bay conditions than further upstream conditions. Due to its proximity to the bay, salinity levels at this station are generally higher than at other stations.

Pocomoke-Rehobeth -The site was installed in 1999. The YSI 6600 monitor is anchored to a piling near a retaining wall at Rehobeth. This area is close to shore and somewhat protected from wave action and high rates of water flow. Being the furthest away from the bay, this site is the least affected by bay water quality fluctuations. Due to its distance from the Bay, this site experiences lower salinity levels than the other continuous monitoring sites.

Magothy-Stonington - This site was installed in 2000. The YSI 6600 monitor is anchored at the end of a long pier located in a residential area. The pier is maintained by a home owners association so MD DNR had to obtain permission to place the station there.

Magothy-Cattail - This site was installed in 2000. The YSI 6600 monitor is anchored on the side of a residential pier. MD DNR obtained permission from the home owner to place the station at this site. This station is located in an inlet area where the water does not circulate well and typically shows very low DO levels. A non-toxic *Pfiesteria* piscicida outbreak was confirmed in 1999 near this site. Once the EMPACT project ended, this monitor was moved to the Whitehurst location on the Magothy River.

Chicamacomico-Drawbridge - This site was installed in 2000. The YSI 6600 monitor is located on the side of a small fishing pier. The location is fairly remote but there is a small boat manufacturing company located next to the pier. In 1997, a portion of the Chicamacomico River near Drawbridge Road in Dorchester County was closed after a significant number of menhaden were found in distress and dying with *Pfiesteria*-like lesions. Results of water samples from the Chicamacomico indicated the presence of toxic levels of *Pfiesteria piscicida.*

Transquaking–Decoursey Bridge - The YSI 6600 monitor is anchored on the side of a small bridge in a remote area. To prevent tampering, the team made an effort to position the station so that it could not easily be seen from the road or bridge. This station was located near the site of a non-toxic *Pfiesteria* outbreak in 1999. Once the EMPACT project ended, this monitor was moved to the Severn river to collect similar data.

3.2.6 Installing the Monitoring System

This section discusses some of the basic preparation and installation procedures for the monitoring system. Detailed step-by-step installation procedures for the monitoring equipment are available from the YSI's Environmental Monitoring Systems Operations Manual for 6-Series sondes. The user's manual for the YSI 6-Series sondes can be downloaded from the Yellow Springs Instruments, Inc. Web site at http://www.ysi.com. If you purchase a YSI sonde, you will receive a manual.

Unpack and Inspect the Monitoring Equipment

The first step to installing the monitoring system is to unpack and inspect the equipment. As soon as you receive the equipment, you should do the following:

- Remove the equipment from the shipping boxes or containers.
- Using the enclosed packing slip, perform an inventory of all items. If you are missing any items, contact the manufacturer immediately.
- Conduct a thorough visual inspection of all items. If you observe any damage, contact the manufacturer and the carrier.

Prepare the Sonde for Use

The second step to installing the monitoring system is to prepare the sonde for calibration and operation. You should perform the following basic procedures:

- Install the DO membrane on the DO probe.
- Install the other probes (e.g., turbidity, conductivity, temperature, pH etc.).
- Provide power for the sonde (e.g., install batteries or external power supply).
- Connect the field cable to the sonde.

Install Software

The third step to installing the monitoring system is to install the necessary computer software. As stated earlier, YSI recommends that the software be installed on a computer in a laboratory setting for the initial setup of the sondes.

Two different types of computer software can be used with YSI's environmental monitoring systems. EcoWatch® for Windows™ or PC6000, which is a DOS-based software. The Chesapeake Bay team uses EcoWatch® for Windows™.

To get started with EcoWatch® for Windows™, perform the following steps:

- Install EcoWatch® for Windows™ on your computer. Place Disk 1 of EcoWatch® in your 3.5" drive, select "Run" and type "a:\setup.exe" at the prompt. Click on "OK" and the display will indicate that EcoWatch® is being installed. Follow the instructions on the screen after the installation is complete.
- Connect your field cable (and sonde) to a communication port on the computer where EcoWatch® is installed.
- Click on the EcoWatch® icon on your computer to begin running the software.
- Select the **Sonde** icon on the Ecowatch tool bar and then select the proper communication port to which your sonde is connected (e.g., 1 or 2).
- Ensure that the baud rate is 9600 on the **Comm** menu.
- Specify a parallel port to select a printer.
- Select **Sonde** from the EcoWatch® menu to communicate between your computer and the sonde. Once the proper communication port is selected, a window showing a # sign will appear. Type "menu" after the # sign and press **Enter** to get the Sonde **Main Menu**. From the Sonde **Main Menu**, you can set up the date and time, choose communication baud rates, select page lengths, identify your instruments (sondes), enable the sondes' sensors, and develop a report to show the parameters you want to see when you collect your

data. For detailed instructions on these procedures refer to the YSI Environmental Monitoring Systems Operations Manual for 6-Series sondes.

You may encounter some problems with the communication between the sonde and the computer. Possible causes and recommended actions to correct the problem are provided in the Table 3.3.

Table 3.3 Troubleshooting Communication Problems Between the Sonde and Computer.

Possible Cause	Recommended Actions
Sonde has no power	Check the batteries or the power source
Field Cable connection is loose	Check both ends of the field cable
Damaged Connectors	Check the pins at both ends; they should be straight, dry and clean
Com port not selected	Change to other port or try another computer or display/logger

Calibrate the Probes on the Sonde

The next step to installing the monitoring system is to calibrate and check the sonde according to the manufacturer's instructions. Various reagents and calibration standard solutions are required to calibrate the various probes. YSI makes a calibration cup for their sondes which serves as a chamber for all calibrations and minimizes the amount of reagents required to calibrate the sonde. You may use laboratory glassware instead to perform the calibrations; however, you should take special precautions to avoid damaging the probes.

Program the Sonde for Monitoring

After the sensors have been enabled and calibrated and a report is developed to display your monitoring results, you are ready to program the sonde for your unique monitoring conditions. Selecting **1-Run** from the main menu will allow you to set up your parameters for your study. You have two monitoring options: "discrete sample" and "unattended sample." The monitoring frequency for discrete sampling is likely to be for only seconds in order to obtain short term or "snapshot" results as you move from site to site during the day. The monitoring frequency for unattended sampling is usually longer (e.g., minutes) because the sonde will be deployed for days or weeks at a time. This is where you specify your sampling interval (e.g., seconds or minutes), the sampling start date, the sampling start time, the duration for sampling, and which parameters to log.

Once you program your monitoring parameters, the internal software of the sonde will automatically calculate the expected battery life and the amount of time to fill the internal memory of the sonde. You can use this information to determine if your monitoring program should be adjusted or if you need new batteries, etc.

Once you finish programming the sonde you can begin collecting monitoring data. The data collected by the sonde is saved in a .dat file in the sonde's memory (386 kilobytes max.).

Note: The Chesapeake Bay project programs their sondes for unattended sampling.

3.2.7 Using EcoWatch® to Capture, Upload and Analyze Data

This section discusses the basic steps for using EcoWatch® to capture, upload, and analyze data collected by the sonde. The procedures listed below were summarized from the YSI's Environmental Monitoring Systems Operations Manual for 6-Series sondes. You will need to refer to this manual for detailed step-by-step operation guidance.

Capturing Data

EcoWatch® can be used to capture real-time data to your computer's hard drive or to a disk. To use this function, you will need to do the following:

- Connect the sonde's field cable to your computer's communications port.
- Run the EcoWatch® software.
- Click on the **Sonde** icon and choose the correct communications port.
- From the sonde's **Main** menu, press **1-Run** and then **1-Discrete Sample**.
- Verify that the sample interval is set to the correct value.
- Open the **Real-Time** menu, click on **New** and select the directory where you want the data transferred. Name the file giving it the extension **.RT**.
- Click **OK** and wait for data transfer to begin. EcoWatch® will automatically save the data as a .DAT file in your designated directory.
- When finished, open the **Real-Time** menu, choose **Close**, and click on **OK**.

Uploading Data

EcoWatch® can also be used to retrieve data already stored in the sonde's memory (i.e., sondes which have been running unattended). To use this function, you will need to perform the following procedures:

- Connect the sonde's field cable to your computer's communications port.
- Run the EcoWatch® software.
- Click on the **Sonde** icon and choose the correct communications port.
- Enter the **File** menu, and select **1-Directory** to view the files currently stored in the sonde's memory.
- Select **2-Upload** to upload the data to your computer.
- Select **1-Proceed** and choose a file transfer protocol (PC6000 is recommended because it is faster). A status box will appear on the screen indicating the status of the file transfer.
- Select **4-View File** to see the data in any file currently stored in the sonde's memory.
- If you want to *permanently* delete the data from the sonde's memory select **6-Delete**.

Analyzing Data

Once you have uploaded the sonde's data to your computer, you can use EcoWatch® to view, plot, manipulate and report the data. For example, when you select **File** and **Open** to open a data file, you can see a one-page plot showing line graphs of all the data logged on your sonde. Based on your selection, you can view as many (or as few) graphs as you prefer. You can also set time limits to view data within a specified time frame (e.g., a day as opposed to a week). Viewing data using EcoWatch® is useful because you can see daily variations in parameters such as temperature and dissolved oxygen. You may see obvious erroneous data such as flat-line data where the sonde was out of the water just prior to deployment. While in the graph mode, you can put your cursor on the graph and hold down the right mouse button causing a vertical dotted line to appear. The instantaneous value will appear where the vertical line crosses the graph. You can move the mouse to scan the graph and read the corresponding instantaneous values. EcoWatch® allows you to view data in a tabular mode as well. The software also has a **Statistics** function which will calculate minimum, maximum, mean, and standard deviation information for each activated parameter.

Saving, Importing, Exporting, and Printing Data

EcoWatch® has various options under its **File** menu to save, import, export, and print data. You can modify and save or rename a file. Once saved, you can export a file in a Comma & ' ' Delimited format (.CSV) or print it to a compatible printer. EcoWatch® has a **Help** function which will explain these features.

3.2.8 Maintaining the Monitoring System

The scheduled maintenance activities for your monitoring system will likely involve cleaning and calibration of your water quality monitoring sensors and replacement of desiccant for the water level sensor. Maintenance frequency is generally governed by the fouling rate of the sensors and this rate varies by sensor type, hydrologic environment, and season. The performance of temperature and specific conductance sensors tends to be less affected by fouling, whereas the dissolved oxygen, pH, and turbidity sensors are more prone to fouling. The use of wiper or shutter mechanisms on modern turbidity instruments has decreased the fouling problem significantly. For stations with critical data quality objectives, service intervals may be weekly or more often. Monitoring sites with nutrient-enriched waters and moderate to high temperatures may require service intervals as frequently as every third day. In cases of severe environmental fouling, the use of an observer for servicing the water quality monitor should be considered. In addition to fouling problems, physical disruptions (such as recording equipment malfunction, sedimentation, electrical disruption, debris, or vandalism) also may require additional site visits. The service needs of water quality monitoring stations equipped with telemetry can be recognized quickly, and the use of satellite telemetry to verify proper equipment operation is recommended. The USGS Web site (http://water.usgs.gov/pubs/wri/wri004252/#pdf) is a good source for background information on operation and maintenance of near-real time water quality monitoring systems. The information in this Section is summarized from the USGS document titled "Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting." This document is available from the USGS Web site listed above.

Chesapeake Bay Project Maintenance Activities

Because of the potential fouling of the dissolved oxygen sensor, the Chesapeake Bay team decided that all stations should be maintained weekly May through October. Personnel from the Chesapeake Biological Laboratory (CBL) maintained the three stations located on the Pocomoke River once each week. MD DNR personnel maintained the four stations located on the Magothy, Chicamacomico, and Transquaking Rivers each week, and similarly the Baltimore Aquarium personnel maintained the station located at Fort McHenry once each week. In the event of physical disruptions (such as recording equipment malfunction, sedimentation, electrical disruption, debris, or vandalism), the Chesapeake Bay/NAIB teams would conduct additional site visits. Also during weekly visits (May through October), the teams collect water samples to be analyzed later for nutrient analysis (see Section 3.3). Although some of the stations are not close to each other, the teams can typically service up to four monitoring stations in a single day.

Each team had two YSI 6600 sondes for each monitoring station. During the weekly field visit, the team removed the deployed sonde from the station and replaced it with

a freshly calibrated sonde. Both the field monitor being retrieved and the replacement field monitor were recording simultaneous data for beginning and endpoint comparison. Prior to deploying the fresh sonde, the team used a long brush to scrub the inside of the PVC tube where the sonde is placed. The team was careful to switch the sondes prior to a monitoring event that occurs in 15 minute intervals to avoid interruptions in the data collection.

The sondes were retrieved from each monitoring station and wrapped in wet towels to keep the DO membrane in a 100% saturated-air environment. The sondes continued to log data while out of the water so they could achieve equilibrium for the post calibration test. The sondes were taken back to the laboratory where they continued to log data overnight in order to equilibrate. Usually the next day, the team performed post calibration tests for each of the sensors to determine if they operated correctly while in the field. The pH, turbidity, conductivity and Chlorophyll A sensors were calibrated against known standard solutions. The calibration of the dissolved oxygen sensor was conducted in the controlled environment of the team's laboratory. Calibration of the temperature sensor was not required.

In addition to the post calibration test, the team used EcoWatch® to upload and visually inspect the data collected by the sonde (see Chapter 4 for further discussions). The team checked the sonde's batteries and inspected and cleaned the various sensors according to the manufacturer's instructions. The sensors were carefully cleaned to remove algae and any other organisms that could foul the sensors. The team typically spent one half to a full day calibrating, inspecting, and cleaning the sonde's sensors.

The detailed maintenance requirements and procedures for the monitoring equipment are available from the user's manuals of the individual pieces of equipment. The user's manual for the YSI 6600 sensor package can be downloaded from the Yellow Springs Instruments, Inc. Web site at http://www.ysi.com.

Table 3.4 Common Troubleshooting Issues and Actions

Symptoms	Possible Cause	Action
Dissolved Oxygen reading unstable or inaccurate	Probe not properly calibrated	Follow DO calibration procedures
	Membrane not properly installed or punctured	Follow setup procedure
	DO probe electrodes require cleaning	Follow DO cleaning procedure
	Water in probe connector	Dry connector; reinstall probe
	Algae or other contaminant clinging to probe	Rinse DO probe with clean water
	Barometric pressure is incorrect	Repeat DO calibration procedure
	Calibrated at extreme temperature	Recalibrate at/near sample temperature
	DO charge too high (>100): (1) Anode polarized (tarnished) (2) Probe left on continuously	Enable DO charge parameter in sonde report menu. Run sonde, if charge is over 100, recondition probe. Follow DO cleaning procedure.
	DO charge too low (<25); insufficient electrolyte.	Replace electrolyte and membrane
	DO probe has been damaged	Replace probe
	Internal failure	Return sonde for service
pH, chloride, ammonium, or nitrate readings are unstable or inaccurate. Error messages appear during calibration	Probe requires cleaning	Follow probe cleaning procedure
	Probe requires calibration	Follow calibration procedures
	pH probe reference junction has dried out from improper storage	Soak probe in tap water or buffer until readings become stable
	Water in probe connector	Dry connector; reinstall probe
	Probe has been damaged	Replace probe
	Calibration solutions out of spec or contaminated	Use new calibration solutions
	Internal failure	Return sonde for service
Level Sensor unstable or inaccurate	Desiccant is spent	Replace desiccant
	Level sensor hole is obstructed	Follow level sensor cleaning procedure
	Level sensor has been damaged	Return sonde for service
	Internal failure	Return sonde for service
Conductivity unstable or inaccurate. Error messages appear during calibration	Conductivity improperly calibrated	Follow recalibration procedure
	Conductivity probe requires cleaning	Follow cleaning procedure
	Conductivity probe damaged	Replace probe
	Calibration solution out of spec or contaminated	Use new calibration solution
	Internal failure	Return sonde for service
	Calibration solution or sample does not cover entire sensor	Immerse sensor fully
Installed probe has no reading	Sensor has been disabled	Enable sensor
	Water in probe connector	Dry connector; reinstall probe
	Probe has been damaged	Replace probe
	Report output improperly set	Set up report output
	Internal failure	Return sonde for service
Temperature unstable or inaccurate	Water in connector	Dry connector; reinstall probe
	Probe has been damaged	Replace probe
Turbidity probe unstable or inaccurate. Error messages appear during calibration	Probe requires cleaning	Follow probe cleaning procedure
	Probe requires calibration	Follow calibration procedure
	Probe has been damaged	Replace probe
	Water in probe connector	Dry connector; reinstall probe
	Calibration solutions out of spec	Use new calibration solutions
	Wiper is not turning or is not synchronized	Activate wiper. Assure rotation. Make sure set screw is tight
	Wiper is fouled or damaged	Clean or replace wiper
	Internal failure	Return probe for service

3.3 Water Quality Field Sampling

3.3.1 Purpose of Field Sampling

The team also collected water samples during their weekly visits. The samples were collected to analyze for chemical properties that cannot be measured by the automated field monitors, to calibrate the field monitors, and to verify the accuracy of transmitted and downloaded data.

3.3.2 Parameters Measured from Field Samples

The following parameters were measured from the samples collected during weekly maintenance visit:

- Chlorophyll A
- Nutrients
  - Particulate carbon
  - Particulate nitrogen
  - Dissolved organic carbon
  - Dissolved organic nitrogen
  - Dissolved organic phosphorus
  - Dissolved inorganic phosphorus
  - Particulate phosphorus
  - Nitrate-Nitrite
  - Nitrite
  - Ammonium
- Total suspended solids

The importance of each of these parameters is discussed below.

Chlorophyll A

Chlorophyll A can be an indicator of the first level response to nutrient enrichment. Measurements of chlorophyll A (via fluorescence) in the water column represent the standing stock or biomass of phytoplankton. Blooms of phytoplankton often indicate that an estuary is undergoing eutrophication. In some estuaries, there is a good correlation between nitrogen loadings from various sources and concentrations of Chlorophyll A. In other estuaries, however, the relationship does not hold and it is possible, in fact, for an estuary to receive heavy loads of nitrogen and yet not exhibit increases in phytoplankton biomass. Other factors such as light limitation, depth of the mixing zone, flushing rates, and contaminants may affect the growth of phytoplankton.

Nutrients

Particulate Carbon and Dissolved Organic Carbon. Organic matter plays a major role in aquatic systems. It affects biogeochemical processes, nutrient recycling, biological availability, chemical transport and interactions. It also has direct implications in the planning of wastewater treatment and drinking water treatment. Organic matter is typically measured as total organic carbon (TOC) and dissolved organic carbon (DOC), which are essential components of the carbon cycle. [Source: BASIN Water Quality Terminology, http://bcn.boulder.co.us/basin/natural/wqterms.html]

Particulate Nitrogen, Dissolved Organic Nitrogen, Nitrate-Nitrite, Nitrite, and Ammonia. Nitrogen is required by all organisms for the basic processes of life to make proteins, to grow, and to reproduce. Nitrogen is very common and found in many forms in the environment. Inorganic forms include nitrate (NO_3) and nitrite (NO_2). Organic nitrogen is found in the cells of all living things and is a component of proteins, peptides, and amino acids. Excessive concentrations of nitrate, nitrite, or ammonia can be harmful to humans and wildlife. Nitrate, nitrite, and ammonia enter waterways from lawn fertilizer run-off, leaking septic tanks, animal wastes, industrial waste waters, sanitary landfills and discharges from car exhausts. [Source: BASIN Water Quality Terms, http://bcn.boulder.co.us/basin/natural/wqterms.html]

Particulate Phosphorus, Dissolved Organic Phosphorus, Dissolved Inorganic Phosphorus. Phosphorus is a nutrient required by all organisms for the basic processes of life. Phosphorus is a natural element found in rocks, soils, and organic material. Its concentration in clean water is generally very low; however, phosphorus is used extensively in fertilizer and other chemicals, so it can be found in higher concentrations in areas of human activity. Phosphorus is generally found as phosphate (PO_4^{-3}). High levels of phosphate, along with nitrate, can overstimulate the growth of aquatic plants and algae, resulting in high dissolved oxygen consumption, causing death of fish and other organisms. The primary sources of phosphates in surface water are detergents, fertilizers, and natural mineral deposits. [Source: BASIN Water Quality Terms, http://bcn.boulder.co.us/basin/natural/wqterms.html]

Total Suspended Solids (TSS). TSS refers to matter (e.g., silt, decaying plant and animal matter, industrial wastes, and sewage) suspended in water, and is related to both specific conductance and turbidity. High levels of TSS in water can have detrimental effects because it reduces sunlight passing through the water, which reduces the rate of photosynthesis, which lowers the amount of dissolved oxygen in the water. [Source: BASIN General Information on Solids, http://bcn.boulder.co.us/basin/data/FECAL/info/TSS.html]

3.3.3 Sample Collection Procedures

The team used an Alpha™ water bottle to collect the field samples. To collect the sample, the 2 liter Alpha™ bottle is opened and horizontally-mounted on a line. The Alpha™ bottle is lowered into the water and positioned at probe depth (i.e., 1 meter below the surface). Once in position, a small stainless steel weight (called a messenger) which is attached to the line), is released and slides down the line to the Alpha™ bottle. The impact of the messenger causes the Alpha™ bottle to close thereby collecting a raw water sample. The Alpha™ bottle is removed from the water. The results from the analysis of the water sample are related to readings from the field monitor that correspond to both the beginning and end-point readings for respective data records.

Note: An additional Hydrolab sonde and data display are also taken to the field to obtain instantaneous temperature, salinity, and DO readings.

Raw sample water is drawn immediately from the Alpha™ bottle to a 500-ml Nalgene bottle for further processing (see Figure 3.4). A standard thermometer is placed in the Nalgene bottle to equilibrate while additional raw sample water is drawn from the Alpha™ bottle for Winkler dissolved oxygen determinations. From the Alpha™ bottle, one clear glass 300-ml BOD bottle is filled and preserved immediately.

Figure 3.4 Water Sampling Alpha™ Bottle

Note: For more information on the use and costs of Alpha™ bottles and other peripheral equipment see http://www.wildco.com/liquid.html.

Next, raw water in the 500 ml Nalgene bottle is shaken gently. Using a vacuum pump, flask and filter apparatus, a measured quantity is filtered through a pre-combusted filter

pad (Whatman 25 mm diameter 0.7 μm particle retention) for particulate carbon and particulate nitrogen analysis (1 pad for each). Pads are folded and placed in aluminum foil pouches on ice.

Figure 3.5 GF/F Filter Being Placed in a Foil Pouch

The filter apparatus is then exchanged to accommodate larger filter pads. Raw water in the 500 ml Nalgene bottle is shaken gently, a measured quantity is filtered through a 47 mm filter pad for Chlorophyll A analyses and the pad is folded and placed in an aluminum foil pouch on ice.

At this point, the resulting filtrate is decanted and a portion used to rinse respective containers for the following samples. A measured quantity of filtrate is retained in a capped test tube for dissolved organic nitrogen and phosphorus analyses. Three auto-analyzer (AA) vials are filled for nitrite-nitrate, nitrite, and ammonium analyses. A capped Teflon® tube is filled for dissolved organic carbon analysis.

The remaining raw water in the 500-ml Nalgene bottle is shaken and a measured quantity is filtered through a pre-weighed filter pad (Whatman 47 mm diameter GF/F filter pad) for particulate phosphorus and total suspended sediment analysis (1 pad for each). Pads are rinsed twice with deionized water, folded and placed in aluminum foil pouches on ice (see Figure 3.5).

Remaining water in the Alpha™ bottle is shaken and a portion is used to fill a 500-ml Nalgene bottle for phytoplankton species composition analysis. The sample is preserved using 5 ml Lugol's solution (a strong iodine solution).

All on-site sample processing is completed within 30 to 45 minutes of water collection. The three aluminum pouches, three AA vials, one Teflon® tube and one test tube from

each site remain on ice during the transport back to the laboratory, where they are frozen until later laboratory analysis. The samples processed by the MD DNR and Baltimore personnel are sent by courier to the CBL for analysis.

3.3.4 Sample Analysis Procedures

When CBL receives the processed samples, they perform a variety of analyses. Winkler titration procedures are performed and water samples for nutrient and Chlorophyll A determination are processed and sent out for laboratory analysis. Beginning and end-point Winkler dissolved oxygen determinations are completed and used for calibration of instrument measurements. Since laboratory analyses results of Chlorophyll A and turbidity measurements require a longer time for completion, calibration of those parameters is completed at a later time. All time-series data are edited to reflect any calibration corrections or deletions as needed and documented.

Standard oceanographic and estuarine methods of chemical analysis are used for all determinations of dissolved and particulate materials. The water quality techniques used by CBL to conduct the water quality analyses are described below. Further discussion on these techniques are discussed in the Nutrient Analytical Services Laboratory's Standard Operating Procedures found at http://www.cbl.cees.edu/nasl/documents/SOP.pdf.

Determination of *ammonia* is by the Berthelot Reaction in which a blue-colored compound similar to indophenol forms when a solution of ammonium salt is added to sodium phenoxide, followed by the addition of sodium hypochlorite. The addition of potassium sodium tartrate and sodium citrate solution prevents precipitation of hydroxides of calcium and magnesium. This is an automated colorimetric technique. The reaction forms a blue color measured at 630 nm using the Technicon TrAAcs-800 Nutrient Analyzer. [Methodology: Technicon Industrial Method No. 804-86T. August 1986. Technicon Industrial Systems. Tarrytown, New York, 10591]

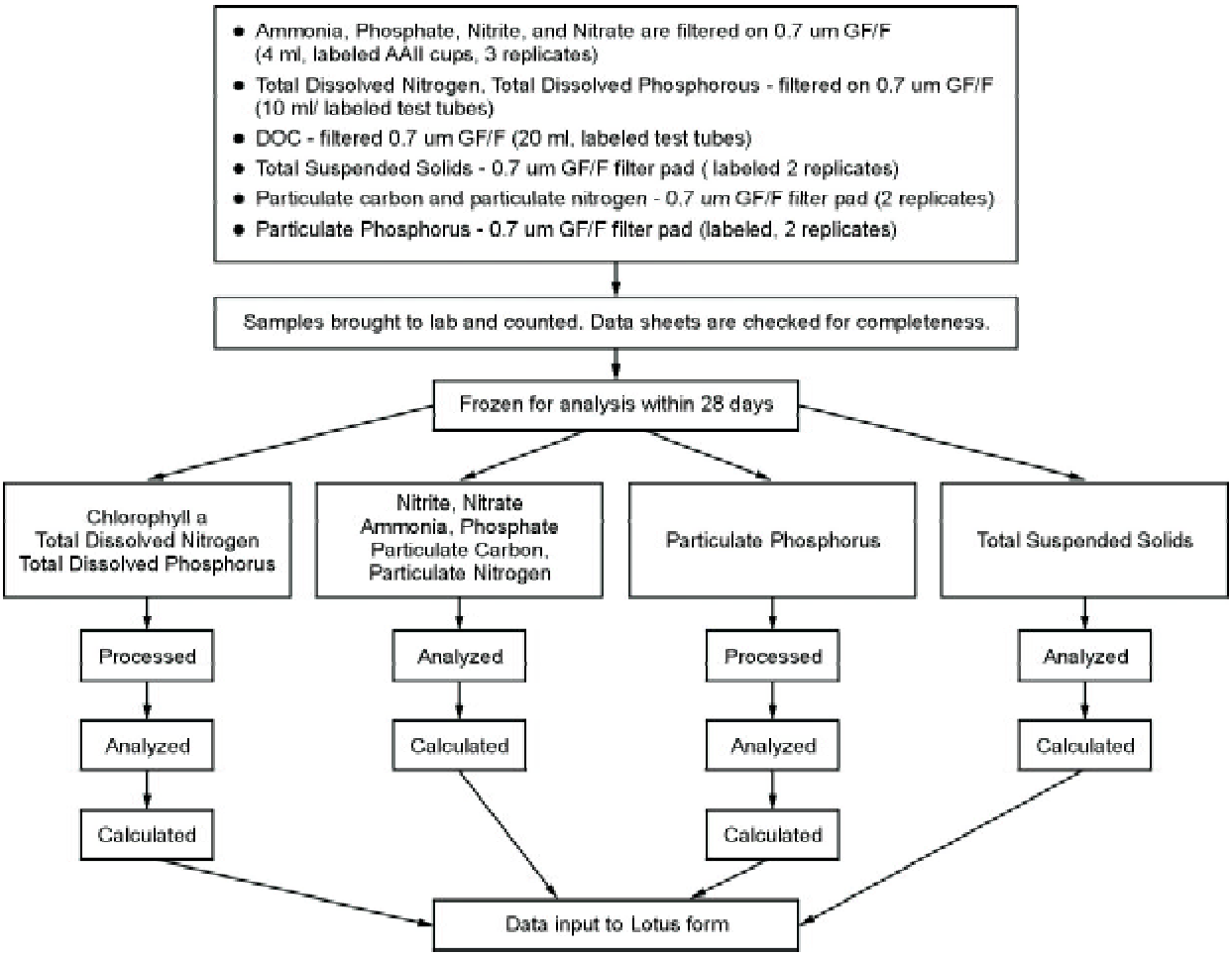
Nitrate reacts under acidic conditions with sulfanilamide to form a diazo compound that couples with N-1-naphthylethylenediamine dihydrochloride to form a reddish-purple azo dye measured at 520 nm using the Technicon TrAAcs-800 Nutrient Analyzer. [Methodology: Technicon Industrial Method No. 818-87T. February 1987. Technicon Industrial Systems. Tarrytown, New York, 10591]

For *Nitrite* + *Nitrate* measurement, filtered samples are passed through a granulated copper-cadmium column to reduce nitrate to nitrite. The nitrite (originally present plus reduced nitrate) then is determined by diazotizing with sulfanilamide and coupling with N-1-naphthylethylenediamine dihydrochloride to form a colored azo dye that is measured at 550 nm using a Technicon AutoAnalyzer II. Nitrate concentration is obtained by subtracting the corresponding nitrite value from the nitrite + nitrate concentration. [Technicon Industrial Method No. 158-71 W/A † Tentative. 1977.

Technicon Industrial Systems. Tarrytown, New York, 10591 and USEPA. 1979. Method No. 353.2 *in* Methods for Chemical Analysis of Water and Wastes. United States Environmental Protection Agency, Office of Research and Development. Cincinnati, Ohio. Report No. EPA-600/4-79-020, March 1979.]

Methods for measuring dissolved organic carbon, nitrogen and phosphorus are described below. All procedures require the addition of potassium persulfate to a sample, which when under heat and pressure, breaks down the organic constituents to inorganic forms. Inorganic fractions then are subtracted from the total dissolved sample to yield the dissolved organic concentration. See Figures 3.6, 3.7 and 3.8.

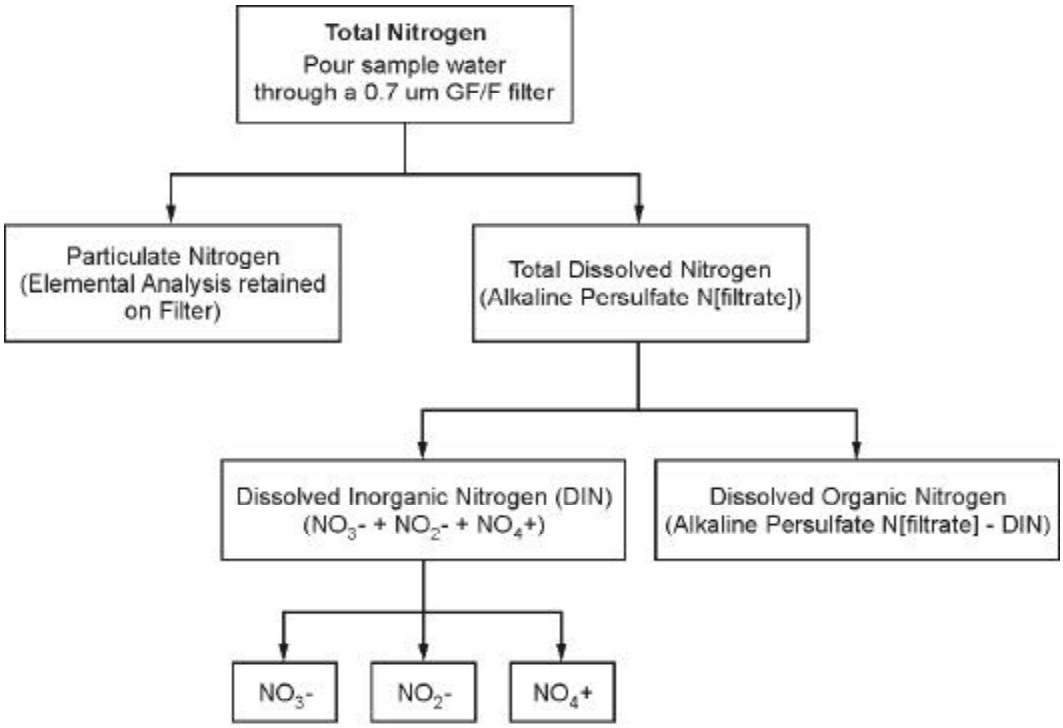
Figure 3.6 General Laboratory Procedures for Nutrient Analyses.



The method for determining *Total Dissolved Nitrogen* and *Phosphorus* is a persulfate oxidation technique for nitrogen and phosphorus where, under alkaline conditions, nitrate is the sole nitrogen product and phosphate is the sole phosphorus product. Ammonium molybdate and antimony potassium tartrate react in an acid medium with dilute solutions of phosphorus to form an antimony-phospho-molybdate complex which is reduced to an intensely blue-colored complex by ascorbic acid. Color is

proportional to phosphorus concentration. Digested samples are passed through a granulated copper-cadmium column to reduce nitrate to nitrite. The nitrite then is determined by diazotizing with sulfanilamide and coupling with N-1-naphthylethylenediamine dihydrochloride to form a colored azo dye. Color is proportional to nitrogen concentration. Color is measured by a Techni-con AutoAnalyzer II. [D'Elia, C.F., P.A. Steudler and N. Corwin. 1977. Determination of Total Nitrogen in Aqueous Samples using Persulfate Digestion. Limnol. Oceanogr. 22:760-764. and Valderrama, J.C. 1981. The Simultaneous Analysis of Total Nitrogen and Total Phosphorus in Natural Waters. Mar. Chem. 10:109-122]

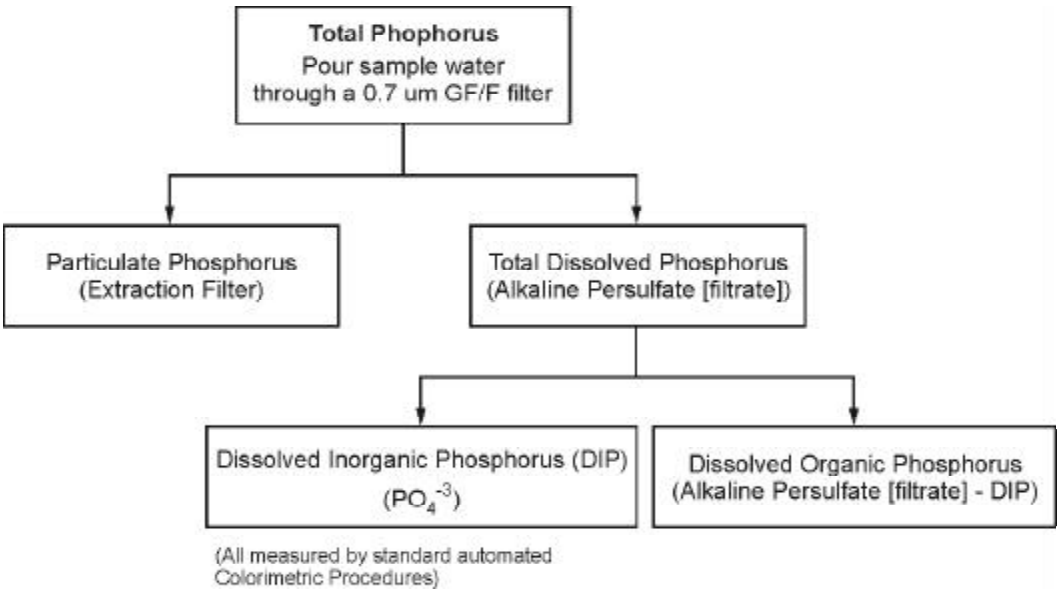
Figure 3.7 General Laboratory Procedures for Nitrogen Analyses.



Total Phosphorus is determined using an automated colorimetric analysis. Ammonium molybdate and antimony potassium tartrate react in an acid medium with dilute solutions of phosphorus to form an antimony-phospho-molybdate complex which is reduced to an intensely blue-colored complex by ascorbic acid. Color is measure at 880 nm using a Technicon Auto-Analyzer II. The color is proportional to phosphorus concentration. [Menzel, D.W. and N. Corwin, 1965. The Measurement of Total Phosphorus in Seawater Based on the Liberation of Organically Bound Fractions by Persulfate Oxidation. Limno. Oceanogr. 10:280-282 and USEPA. 1979. Method No. 365.3 *in* Methods for Chemical Analysis of Water and Wastes. United States Environmental Protection Agency, Office of Research and Development. Cincinnati, Ohio. Report No. EPA-600/4-79-020. March 1979.]

Total Inorganic Carbon (TIC) is determined by the measurement of carbon dioxide released by acidification of a sample. As pH decreases, carbonate and bicarbonate ions are converted to dissolved CO_2. The CO_2 is purged from solution, concentrated by trapping on a molecular sieve column, then desorbed and carried into a non-dispersive infrared analyzer (IR). The IR (OI Corp. Model 700 TOC Analyzer) is calibrated to display the mass of TIC in the sample divided by the sample volume. [Menzel, D.W. and R.F. Vaccaro. 1964. The Measurement of Dissolved Organic and Particulate Carbon in Seawater. Limnol. Oceanogr. 9:138-142]

Figure 3.8 General Laboratory Procedures for Phosphorus Analysis.



Total Organic Carbon (TOC) is determined by the measurement of CO_2 released by chemical oxidation of organic carbon in a sample. The sample is acidified and purged of TIC and sodium persulfate, a strong oxidizer, is added. The oxidant quickly reacts with organic carbon in the sample at 100˚C to form CO_2. When the oxidation reaction is complete, CO_2 is purged from solution, concentrated by trapping on a molecular sieve column and detected as described for TIC. [Methodology: Menzel and Vaccaro, 1964.]

Direct measurement of particulate carbon, nitrogen and phosphorus is the preferred method used by the Nutrient Analytical Services Laboratory (NASL). It is believed that a greater volume filtered onto the pad yields a more representative sample. Direct measurement is also rapid, sensitive and more precise.

For *Particulate Carbon and Nitrogen*, samples are combusted in pure oxygen under static conditions. Products of combustion are passed over suitable reagents in the combustion tube where complete oxidation occurs. In the reduction tube, oxides of nitrogen are converted to molecular nitrogen. The carbon dioxide, water vapor and

nitrogen are mixed and released into the thermal conductivity detector where the concentrations of the sample gases are measured. Instrumentation: CE-440 Elemental Analyzer.

Particulate Phosphorus is determined using a high temperature/HCl extraction technique where organic phosphorus is broken down to the inorganic form at 550˚C, extracted in 1N HCl for 24 hours and analyzed for phosphate using a Technicon AutoAnalyzer II. This is a total analysis where both inorganic and organic components are included. It has been determined that for Chesapeake Bay waters there is a varied and sometimes substantial inorganic particulate phosphorus component both temporally and spatially. [Aspila, I., H. Agemian and A.S.Y. Chau. 1976. A Semi-Automated Method for the Determination of Inorganic, Organic and Total Phosphate in Sediments. Analyst 101:187-197]

Total Suspended Solids (TSS) is the retained material on a standard glass filter pad after filtration of a well-mixed sample of water. The filtrate is measured and the filter is weighed. Results are expressed in mg/l. [APHA. 1975. Method 208D. Total Nonfilterable Residue Dried at 103-105 C (Total Suspended Matter) *in* Standard Methods for the Examination of Water and Wastewater, 14th Edition. American Public Health Association. Washington, D.C. 1193pp. and USEPA. 1979. Method No. 160.2 (with slight modification) *in* Methods for Chemical Analysis of Water and Wastes. United States Environmental Protection Agency, Office of Research and Development. Cincinnati, Ohio. Report No. EPA-600/4-79-020, March 1979. 460pp.]

Chlorophyll A is measured using a fluorometric method where a filter pad containing particulate material is extracted in 90% acetone in the cold and dark for 12 hours prior to analysis. Fluorescence of the extract is measured before and after acidification using a Turner Fluorometer Model 112. Fluorescence is proportional to Chlorophyll A concentration. [Strickland, J.D.H. and T.R. Parsons. 1972. A Practical Handbook of Seawater Analysis. Bulletin 167 (2nd Ed.). Fisheries Research Board of Canada, Ottawa, Canada. and Parsons, T.R., Y. Maita and C.M. Lalli. 1984. Determination of Chloropyhlls and Total Carotenoids: Spectrophotometric method. pp. 101-112 *in* Parsons, T.R., Y. Maita and C.M. Lalli. A Manual of Chemical and Biological Methods for Seawater Analysis. Pergamon Press, Oxford.]

4. MANAGING AND TRANSFERRING WATER QUALITY DATA

In the previous chapter, we discussed how to collect water quality data using automated monitors (or sondes) and by manual sampling. Using either method, you can accumulate vast amounts of data for your project. This Chapter discusses how to manage and transfer the water quality data once it is either collected and stored in the sonde's memory or manually collected in the field.

A data collection, transfer, and management system has potential benefits for your community. The system may allow you to automate the collection of water samples and control the resulting data flexibly and easily. By using the system's software (e.g., EcoWatch®), you can program your water quality monitors to collect data at specified intervals. Then you can call the monitoring station as needed for data transmission, or program your system to call for transmissions of data at specified times. Once the data arrives, the information can be formatted and stored or otherwise prepared for export to another database, or it can be analyzed using geographical information system (GIS) or data visualization software and placed on a Web site.

The system's flexibility enables you to establish sampling and data transfer protocols based on your specific monitoring needs. For example, you might program your monitoring station unit to monitor every hour, 7 days a week, in order to characterize general conditions. You might also want to conduct sampling specific to certain events, such as conditions conducive to algal blooms, during which you might monitor water quality on a 15-minute basis. Sampling on this scale helps analysts learn more about smaller scale conditions that may only last for a few hours or days. This information would be lost if sampling was only conducted on a weekly or monthly basis.

Readers interested in an overview of the management and transfer equipment and procedures utilized by the Chesapeake Bay project should focus primarily on the introductory information in Section 4.1 below. If you are responsible for or interested in managing and transferring *remotely* collected water quality data, you should carefully read the technical information presented in Section 4.2. Details on managing and transferring water quality data collected manually are discussed in Section 4.3.

4.1 System Overview

Each sonde used in the Chesapeake Bay project records 96 readings for seven parameters every 24 hours, 4,704 data points per week are generated at each site. If you are only interested in obtaining and analyzing the data, you can periodically visit your monitoring station (e.g., once per week), retrieve the sonde, download the data, and run your analysis as described in Section 3.2.7. One limitation with this approach is that you would not have access to timely data. If you downloaded data from the

sonde only once per week, chances are that any notable events would have already transpired. Another downside is that you would not be aware of a sonde malfunction until your next visit and could miss several days of monitoring.

When the Chesapeake Bay project first started, the team did not utilize a telemetry system and simply visited the monitoring station each week to upload the data as described in Section 3.2.7. As funds became available in 2000, the team decided to equip most of its monitoring stations with a telemetry system so they could receive timely data. This new telemetry equipment enabled users to view important water quality data the day it was collected. Table 4.1 identifies the monitoring stations equipped with telemetry. The telemetry system automatically sends a 12-hour block of data (i.e., physical parameters discussed in Section 3.2.3) directly to MD DNR twice each day (at 7:30 A.M. and 7:30 P.M). The frequency of data access can be determined by the project needs and objectives. Once received at MD DNR, this data is automatically processed, graphed and placed on the EMPACT Web site. Utilizing the telemetry system allowed the team to deposit raw data automatically on the EMPACT Web site for the public to view. Receiving timely data also allows the team to evaluate the performance of the sonde or specific sensors and to determine if more frequent maintenance or service is required for the sonde.

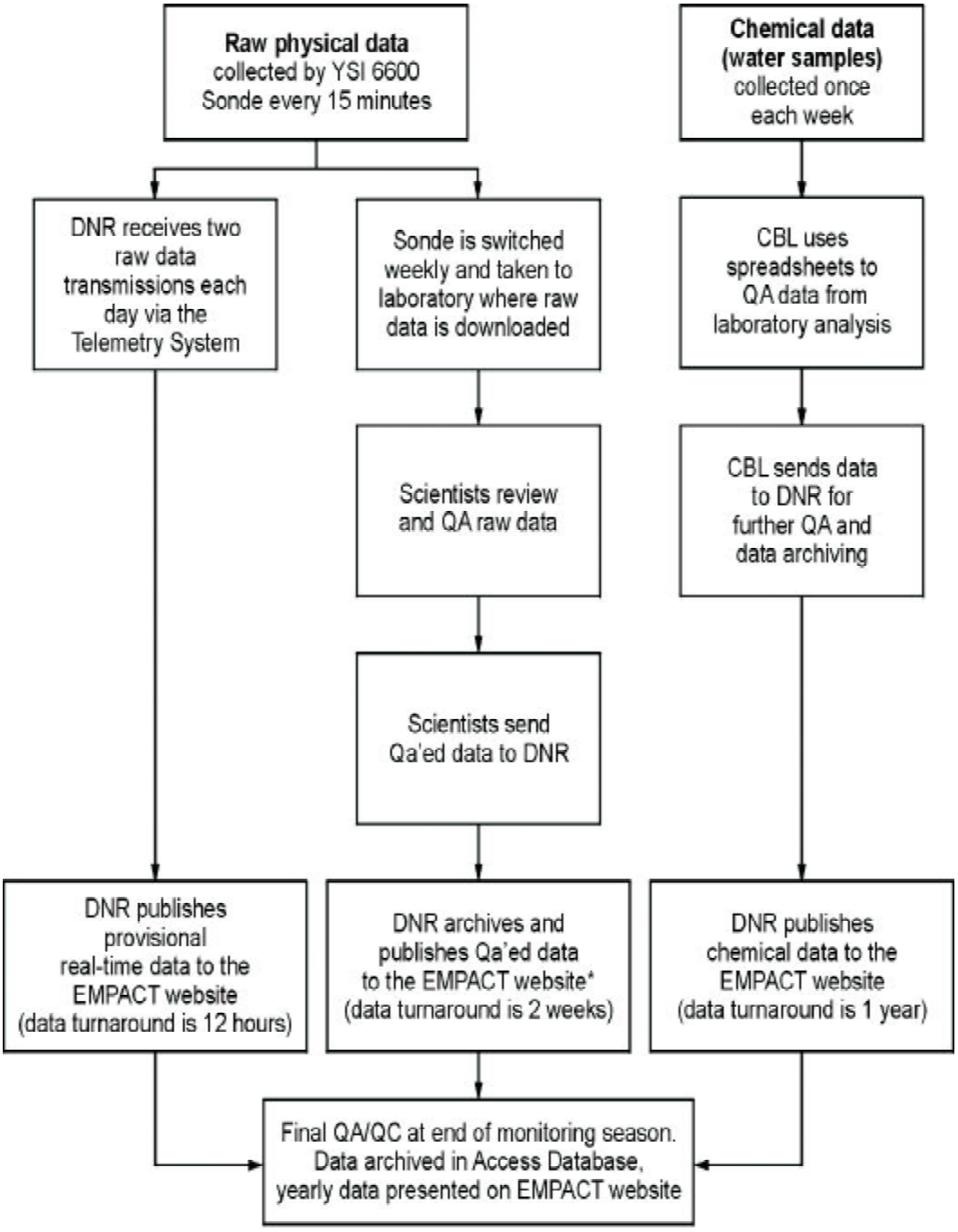
Table 4.1 EMPACT Monitoring Stations Equipped With Telemetry.

Location-Station	Telemetry	Physical Data Transfer Frequency	Chemical Data Transfer Frequency
Baltimore Harbor- Fort McHenry	Yes	Two transfers per day	Manually collected each week
Pocomoke- Cedar Hall Wharf	Yes	Two transfers per day	Manually collected each week
Pocomoke-Shelltown	No	Downloaded from sonde once each week [1]	Manually collected each week
Pocomoke-Rehobeth	Yes	Two transfers per day	Manually collected each week
Magothy-Cattail Creek	Yes	Downloaded from sonde once each week	Manually collected each week
Magothy-Stonington	Yes	Two transfers per day	Manually collected each week
Chicamacomica- Drawbridge	Yes	Two transfers per day	Manually collected each week
Transquaking- Decoursey Bridge	Yes	Two transfers per day	Manually collected each week

[1] The Shelltown site will be equipped with telemetry soon.

The water samples collected manually each week for nutrient analysis are sent to CBL for analysis. Figure 4.1 shows the overall management and transfer of the data collected by the Chesapeake Bay team.

Figure 4.1 Data Flow for the Physical and Chemical Measurements



* When the weekly QA'ed data is published to the EMPACT website it overwrites the corresponding provisional data

4.2 Transferring and Managing Remote Water Quality Sampling Information

4.2.1 Designing a Data Transfer System

As a first step in designing a data transfer system, you will need to determine what data communication (or telemetry) equipment to install at your sampling site. In general, the type of equipment you choose, especially the telemetry equipment, will depend on where your monitoring stations will be located and the communication options available to you. For example, if the station is not located near your computer network lines then your local or wide area network is probably not a viable communication option. Telemetry equipment enables data collected at a sampling station to be transferred to a receiving station located elsewhere. A complete telemetry system includes equipment components for data storage, retrieval/transfer, and archiving. Each of these components are discussed below.

Data Storage Equipment. Although a sonde may have internal memory for storing data, if telemetry is utilized the sonde's data must be scanned, interpreted (e.g., converted to other units), and stored in a datalogger. The information stored in the datalogger can be transferred to various storage media, such as a computer hard drive or diskette. The data can then be retrieved from the computer or diskette and analyzed or manipulated using a spreadsheet or data analysis package. There are various manufacturers of dataloggers. Such manufacturers include Campbell Scientific, Inc. (CSI) (http://www.campbellsci.com), Sutron Corporation (http://www.sutron.com), Yellow Springs Instruments, Inc (YSI) (www.ysi.com), and Geo Scientific Ltd. (www.geoscientific.com).

Data Retrieval/Transfer Equipment. Once the data is stored in a datalogger, it must be transferred from the datalogger to a computer for analysis or manipulation. This transfer process can be done using telecommunication equipment, a portable computer, or a storage module.

Telecommunication Equipment. Using telecommunication equipment, a computer can call the datalogger (or vice-versa) to transfer the data. Telecommunication options include cellular telephone (analog or digital), a computer equipped with a modem, two-way radio, direct connect (e.g., local or wide area networks), or satellites. Manufacturers of such equipment include CSI (http://www.campbellsci.com), Sutron Corporation (http://www.sutron.com), and YSI (www.ysi.com).

Portable Computers. A portable computer can be carried to the site and used to download data from the datalogger. The computer would need to be equipped with a software which can communicate with the datalogger. For example, the software EcoWatch® for Windows™ can be used to download data from YSI sondes.

Storage Module. A portable hand held storage medium can be carried to the site. Such hand held units are typically more rugged and compact than portable computers and more convenient to use in adverse conditions. Manufacturers of such equipment include CSI (http://www.campbellsci.com), YSI (www.ysi.com), and Hydrolab Corporation (www.hydrolab.com).

Data Archiving. You should develop a database to store the data that you collect. You may want to consider having different databases for raw unreviewed data and reviewed data. For the Chesapeake Bay EMPACT project, the data collected by the sampling monitor is transmitted via cell phone at set time intervals and stored on MD DNR's computer network in an MS Access database.

Other. In addition to hardware, such as dataloggers and communication equipment, you will also need software to program the datalogger and telemetry equipment. Such software can create a datalogger program, send the program to the datalogger, monitor and collect data from the datalogger, and analyze the collected data. The Chesapeake Bay team uses EcoWatch® for Windows™ to program how often the datalogger queries its sonde and which parameters to query and store. The team also uses the software PC208 to program the telemetry equipment. The PC208 software enables MD DNR to program when each monitoring station is contacted to retrieve data from the datalogger.

4.2.2 Selecting Your Transfer Frequency

How frequently you transfer data from your monitoring station to a receiving station will depend on your goals and objectives. For example, if your intent is to provide timely data to the public, then you must decide how timely (e.g., hourly or daily) is appropriate. If you use cellular telephone telemetry, you will have to balance factors such as providing timely data and costs because the more frequently you transfer data, the higher your monthly telephone bill.

Due to the cost of using cellular telephone telemetry, the MD DNR and NAIB decided to transfer data twice each day so that the data published on the Web site collected at the monitoring stations on the Pocomoke, Magothy, Chicamacomica, and Transquaking Rivers and NAIB is no more than 12 hours old. Each data transfer takes approximately 2 to 4 minutes. MD DNR and Baltimore plan to switch to digital telemetry in order to reduce costs while providing unlimited access data.

4.2.3 Selecting Data Storage/Telemetry Equipment

Ned Burger of the CBL was responsible for procuring and installing the data storage and telemetry equipment for the Chesapeake Bay EMPACT project. Due to the complexities and the numbers of various technical solutions for installing telemetry at the various monitoring sites, Mr. Burger decided to hire a contractor to recommend and

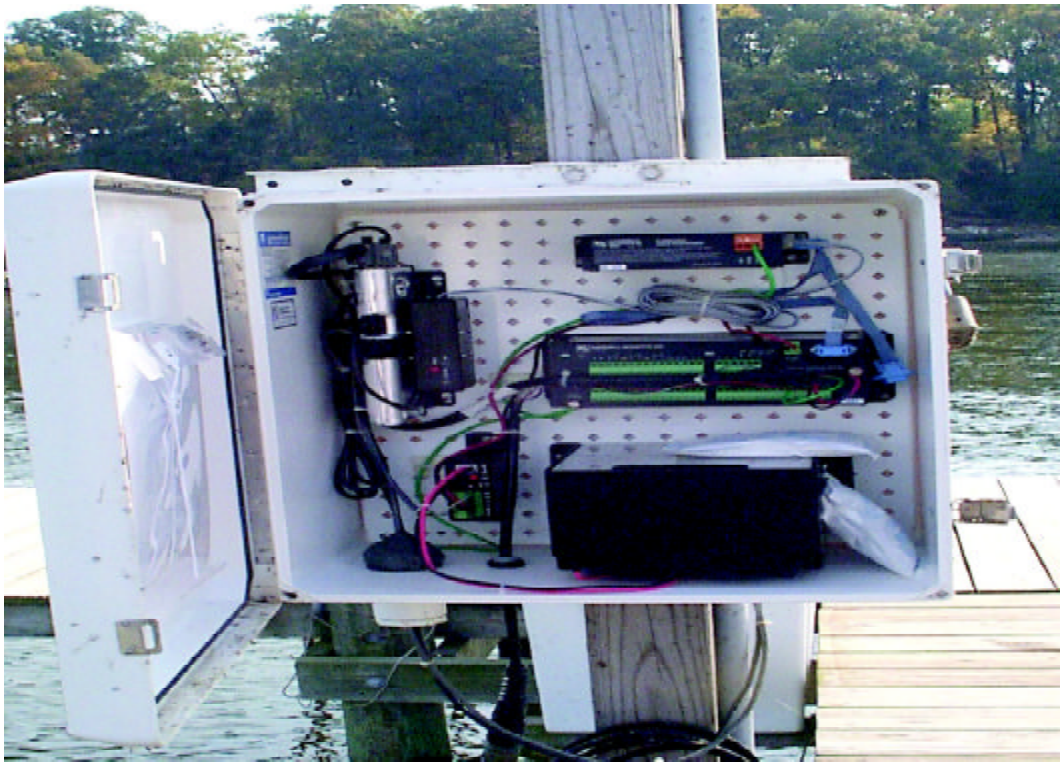
implement the best alternative for the Chesapeake Bay sites. He requested quotes from five vendors and selected one. Mr. Burger provided the contractor with details about the Stonington site so they could recommend a telemetry solution. Once a solution was developed, the contractor procured and installed the following equipment at the Stonington site in September 2000:

- CR10X Datalogger
- Modem
- Battery and Solar Panel
- Voice Synthesizer (optional)

Figure 4.2 shows the telemetry equipment at the Stonington site. In Figure 4.2, the battery is the large black object located in the bottom of the control panel. The CR10X datalogger is located just above the battery. The voice synthesizer is located above the CR10X datalogger. The modem is located just to the left of the datalogger. Each of these pieces of equipment are discussed below.

Note: The white pouches contain desiccant which absorbs moisture that may condense inside the control panel.

Figure 4.2 Telemetry Equipment at the Stonington Site (excluding the solar panel).



CR10X Datalogger. The project utilizes the Campbell Scientific, Inc. (CSI) CR10X datalogger for data storage (http://www.campbellsci.com). It is a programmable datalogger/controller that scans the sonde's sensors, measures and interprets the signals sent by the sensor, and saves the result in its memory (128 K Static Random Access Memory).

Telemetry Equipment (e.g., modem). The monitoring station and the MD DNR-based computer are equipped with communications hardware featuring a cellular transmitter. This equipment allows the monitoring station and computer at MD DNR to "talk" to each other over long distances. At the MD DNR, the software automatically contacts the monitoring station for data collection and transfer. The project team uses analog cellular phone telemetry. However, they plan to switch to a digital phone telemetry in the near future to reduce the costs of phone charges.

Figure 4.3 Solar Panel (Stonington Site).

Battery and Solar Panel. Each monitoring station is equipped with a large sealed rechargeable battery and solar power assembly. Typically, the monitoring station can run on battery power for about three days. However, due to the monitoring frequency and the number of parameters being monitored, solar panels are necessary to charge the battery. To determine your power needs see http://www.campbellsci.com/power.html.

Voice Synthesizer (optional). The voicesynthesizer is a device that allows the team to call the monitoring station to obtain a verbal readout (via a computer-generated voice) of the last set of data that was logged by the datalogger. For example, MD DNR can call the station and find out the last pH and DO measurements at the site. This optional piece of equipment can be used as a diagnostic tool to troubleshoot potential problems with the data collection or telemetry equipment. By utilizing the voice synthesizer, the team can use any wireless phone to call the monitoring station from any location and obtain the most recent readings.

4.2.4 Siting the Equipment

The telemetry equipment should be co-located with the sampling equipment since it will be attached to the monitoring equipment via a field cable (see Figure 3.1). As

with the monitoring equipment, you will want the telemetry equipment to be inconspicuous to decrease the chance of vandalism. If your system requires a solar panel, you will want to ensure that your panel is situated to receive as much direct sunlight as possible.

One important consideration is that the telemetry equipment must be above water (see Figure 3.1). You will need to account for rises in water level due to tidal variances, wave action, and storm surges. For example, if your monitoring station and telemetry equipment is located on a coastline, you will want to ensure that your telemetry equipment is mounted far enough above sea level to be clear of wave action and storm surges due to hurricanes.

The Chesapeake Bay team placed their telemetry equipment near their monitoring stations. The telemetry equipment is mounted inside a weather resistant control box several feet above the monitoring station.

4.2.5 Installing the Transfer/Telemetry Equipment

The Chesapeake Bay team hired a contractor to select and install the telemetry equipment at the Stonington site. They performed the following:.

- Installed telemetry antennas and correctly pointed directional antennas.
- Assembled the electrical system.
- Connected the sensor package (sonde) to the telemetry equipment sensor.
- Positioned and connected the solar panel.
- Connected the power supply (battery).
- Performed testing to ensure proper operation.
- Tested the sensors.

After the telemetry equipment was installed at the Stonington monitoring site, the contractor installed the PC208 software on a computer at the CBL. The contractor programmed the PC208 software to communicate and obtain results from the Stonington monitoring site twice each day.

After the telemetry equipment was installed at the Stonington site, Mr. Burger evaluated its operation over the winter. In the following spring, he directed the contractor to assemble similar equipment for the other sites. The contractor assembled and shipped the equipment to Mr. Burger which he installed at the other sites listed in Table 4.1.

4.2.6 Programming the Transfer/Telemetry Equipment

The Chesapeake Bay team uses a software called PC208 to program the telemetry equipment to automatically contact each monitoring station every 12 hours. The software resides at the MD DNR and CBL. The program calls the datalogger and instructs it to transmit all raw data that was recorded during the previous 12 hours. The data transfer takes about 2-4 minutes. Once transmitted, the raw data is stored in a dedicated data folder on the MD DNR server. Once the folder receives the data, the data is then automatically processed through various program modules (developed in Visual Basic) which converts the data to the appropriate format. For example, one of the modules converts the date tags from Julian to Gregorian format.

4.2.7 Maintaining the Transfer/Telemetry Equipment

Since the system is equipped with cellular telemetry, proper equipment operation can be verified at all times allowing quick identification of any service needs of the water quality monitoring station.

4.2.8 Data Storage

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

4.2.9 Quality Assurance/Quality Control (QA/QC)

Depending on the type of data (real-time versus non-real-time data) you are providing to the public, you can spend different amounts of time and effort on quality control checks. If your goal is to provide real-time data, there is no time for extensive manual QA/QC checks. For real-time data, you may choose not to QA/QC the data and simply place it on your Web site noting that it is provisional data which has not been reviewed for accuracy. You may choose to program your system to perform QA/QC checks to identify obvious erroneous data (e.g., a pH of 12 in a stream). On the other hand, if you are providing non-real-time data, you have time to perform extensive manual QA/QC reviews.

To ensure timely access to the data and to avoid data management problems, the water quality monitoring data should be processed soon after data collection and retrieval. The Chesapeake Bay team uses macros in the Access database to discard any data that is considered an outlier. Once received the data is stored, processed, graphed, and placed on the Chesapeake Bay EMPACT Web site. A statement that the data is provisional is also placed on the Web site. In the future, the team plans to program some automatic QA/QC checks to remove obvious data errors from the timely data prior to placing it on their Web site.

The QA/QC of the timely data occurs after the weekly visit to the monitoring site when the sonde is replaced. The sonde removed from the field is taken back to the lab where the data is downloaded to a computer using EcoWatch®. Scientists use features in EcoWatch® to graph the data. The graphs are visually inspected to identify obvious erroneous data (e.g., extremely high values) or data that was collected prior to the sonde being placed in the water.

After the data is quality assured using Access, it is imported back into EcoWatch® and graphed again for a final visual QA/QC. This data is exported from EcoWatch® into a .CSV file and placed in a designated directory on the MD DNR network. When the data is placed in the designated directory, it is automatically processed, graphed and sent to the Chesapeake Bay EMPACT Web site. This data, which is approximately 2 weeks old, replaces provisional timely data already displayed on the Web site.

4.3 Transferring and Managing Field Water Quality Sampling Data (Nutrients)

4.3.1 Data Transfer

After the nutrient water samples are collected, processed, and transported to CBL as described in Section 3.3.3, they are analyzed as described in Section 3.3.4. Analytical results are then entered into a spreadsheet and exported to .CSV files. These files are e-mailed to MD DNR for storage, processing, and posting on the Chesapeake Bay EMPACT Web site.

4.3.2 Data Management

Because analysis time varies for each nutrient parameter, the analytical data is stored in a spreadsheet (Quattro Pro) as it is received. Mr. Ned Burger of the CBL is responsible for assembling and organizing the raw nutrient analytical data. Once assembled and reviewed (see Section 4.3.3), he sends the data to the Maryland DNR. Data delivery to Maryland DNR is approximately six weeks for the nutrient samples analyzed by CBL. Mr. Drew Koslow and Chris Aadland are responsible for maintenance, organization, and management of the data received at MD DNR. The nutrient data for the entire monitoring year is placed on the MD DNR Web site a few months after the end of the monitoring season.

4.3.3 Quality Control

The analysis of the water samples collected each week are keyed into QuattroPro. Print-outs of the data are manually checked for errors by laboratory personnel. As necessary, the data files are reviewed and a second printout is re-verified by a different staff member, then the data is transferred (via e-mail) to MD DNR. Final QA/QC checks occur at the end of the monitoring season when the data are stored in an Access database.

5. DEVELOPING IMAGES TO PRESENT WATER QUALITY MONITORING DATA

Once your water quality monitoring network is in place and you have collected and received the resulting data, you can provide your community with water quality information using data visualization tools to depict such information in graphical form. Using visualization tools, you can create graphical representations of water quality data that can be downloaded on Web sites and/or included in reports and educational/outreach materials for the community.

Section 5.1 provides a basic introduction and overview to data visualization and is useful if you are interested in gaining a general understanding about data visualization. Section 5.2 discusses the various types of data visualization software. You should consult Section 5.2 if you are responsible for choosing and using data visualization software to model and analyze your data. Section 5.3 discusses the charting software, CFXGraphics Server, which was used by the Chesapeake Bay EMPACT project to produce graphs of their water quality data which are placed on the project Continuous Monitoring Web site. Section 5.4 discusses guidelines for interpreting and conveying the significance of water quality data.

5.1 What is Data Visualization?

Data visualization is the process of converting raw data to images or graphs so that the data are easier to comprehend and understand. A common example of data visualization can be seen when you watch the weather report on television. The electronic pictures of cloud cover over an area or the location and path of an impending hurricane are examples of satellite data that have been visualized with computer software. Graphs and charts, such as those found on the Chesapeake Bay EMPACT Web site, are another example of data visualization.

Displaying data visually enables you to communicate results to a broader audience, such as residents in your community. A variety of software tools can be used to convert data to images. Such tools range from standard spreadsheets and statistical software to more advanced analytical tools such as:

- Web-based application servers
- Geographic Information Systems (GIS)
- Satellite imaging software products

By applying the appropriate visualization tools to water quality data, you can help residents in your community gain a better understanding of factors affecting the water quality in area rivers or nearby estuaries (e.g., chlorophyll A or turbidity). You can use the visualized data for a variety of purposes such as:

- Characterizing water quality conditions.
- Exploring trends in pH, dissolved oxygen concentration, salinity, specific conductance, turbidity, and water temperature.
- Making resource management decisions.
- Supporting public outreach and education programs (e.g., providing graphs on a public Web site or in brochures).

5.2 Various Data Visualization Software

There are a number of commercially available computer software programs that allow you to graphically represent water quality data. Examples of these software tools are listed in Table 5.1 below.

Table 5.1. Various Software Tools to Visualize Water Quality Data

Tool Group	Tools	Primary Uses
Spreadsheet Software	Microsoft Excel, Corel Quattro Pro, and Lotus 123	Displays raw data Creates graphs of individual parameters Allows for the investigation of correlations or trends in water quality variables
Geographic Information Systems (GIS)	Examples include ArcInfo, ArcView, GeoMedia, and MapInfo Professional	Integrate and model spatial data (e.g., water quality and land use) Develop Internet mapping applications
Web-based application servers/graphics engines	CFXGraphicsServer/ Cold Fusion, PopChart, ChartWorks, and KavaChart	Develops and sends user-defined graphs of real-time data to the user's Web browser.

5.2.1 Spreadsheet Programs

Spreadsheet programs such as Microsoft Excel, Quattro Pro, and Lotus 123 can be used to develop images of water quality data. These programs are handy for organizing large amounts of data and can be used to create various types of graphs and tabular

summaries of water quality parameters plotted over time. These software can be purchased at most stores which sell computer equipment and software. They are easy to install and run on a variety of operating systems (e.g., Windows 95/98/NT).

Graphs or charts developed using spreadsheets can be placed on a Web site or pasted into a brochure, report, or presentation. If your goal is to produce a static graph or chart of non-real time water quality data and place it on a Web site, then spreadsheet software would accomplish your goal. However, if you want the users to define their own parameters to graph real-time data, then you will need to use more sophisticated software such as Web-based applications (see Section 5.2.3)

5.2.2 GIS

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

GIS includes a varied range of technologies. Using GIS technology allows you to produce a wide range of graphical outputs, including maps, drawings, animations, etc. To choose, obtain, and use them, you will need to understand the various technologies available which might be appropriate for your needs and situation. For more information on specific GIS software packages, you can consult manufacturer's Web sites including:

- ESRI (http://www.esri.com), whose suite of tools includes ArcInfo, ArcView, and ArcIMS internet mapping software.
- Intergraph (http://www.intergraph.com/gis/), whose software includes GeoMedia and GeoMedia Web Map.
- MapInfo (http://www.map.info.com/), whose products include MapInfo and MapInfo Xtreme (an Internet mapping software).

Although the Chesapeake Bay EMPACT team did not utilize GIS for its project, the NAIB has an EMPACT project that uses the GIS application ArcIMS to link data from various GIS/information servers, including the Maryland's DNR EMPACT project, as well as information from EPA's Watershed Information Network and the Chesapeake Bay Program. This application will eventually be available on the NAIB Web site, www.aqua.org. The user will be able to access information about land use/ land cover, percent impervious, projected growth centers, and watershed association headquarter and meeting locations for five major tributaries feeding into the Chesapeake Bay. ArcIMS, produced by ESRI, is a product designed to display

geographic information from multiple GIS data sources through the internet (see Chapter 7).

You can read about how GIS was used in another EMPACT project in the handbook entitled *Delivering Timely Water Quality Information to Your Community: The Lake Access - Minneapolis Project* (EPA/625/R-00/013). You can request a copy of this Handbook by writing or calling EPA ORD Publications (see Section 1.3.5 of this handbook).

5.2.3 Web-based Application Servers and Graphics Engines.

Web-based application servers and graphics engines can be programmed to take user-defined queries from Web browsers, submit them to a database, format the query (e.g., make a graph of the queried data), and send the information back to the user's Web browser. There are various charting software packages that allow you to graph data for display on a Web browser. Such charting software packages include, but are not limited to, CFXGraphicsServer, (http://www.cfxgraphicsserver.com), PopChart (http://www.corda.com), ChartWorks (http://www.corda.com), and KavaChart (http://www.ve.com). The capability (as well as the price) of these and other similar software varies significantly so before purchasing any software you should consult a Web developer to discuss your graphing needs.

Depending on the charting software package, some feature Java servlets or applets. Java servlets are said to be "server-side" meaning they run or process on the server. Java applets are "client-side" meaning they download and run on the user's computer. This distinction is important because server-side charting software can usually generate the graph in file formats (e.g., jpg or gif) that are browser-friendly, can be downloaded and saved on a computer, and are easier to print. Applets do not generate the graphs in a separate file but embeds them in an HTML page so that graphics may not print as shown on the computer screen. Also the charting software listed does not run alone. Instead they must be run with Web-based application servers such as Cold Fusion, Apache, BEA Web Logic, or IBM WebSphere. Such Web-based servers supply the interface between the user and the charting software.

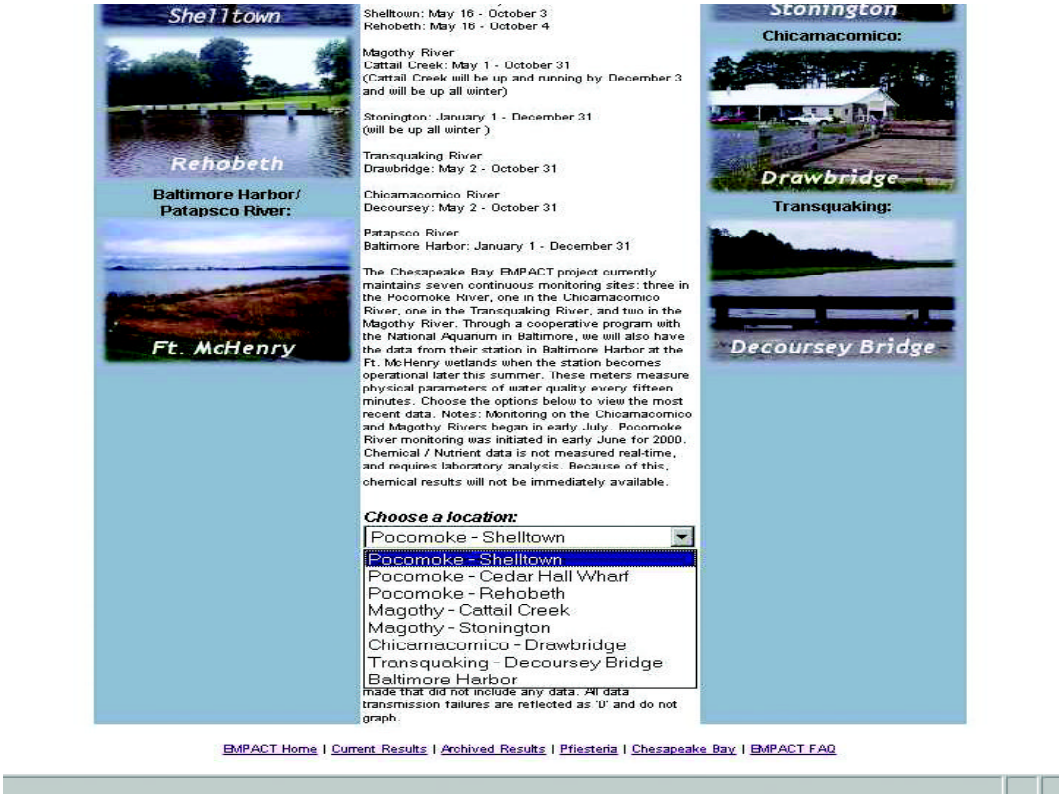
Before attempting to use such software you should have some experience in Web development and database management. Web development experience is important in order to develop user-friendly query forms that allow users to easily specify the data they want to see. Database management experience is important because charts will be generated from data in either yours or someone else's database. Also, depending on the Web-based product you select, you may also need programming experience with at least one scripting language such as JavaScript, VBScript, PERL, or Dynamic HTML.

5.3 Visualization Software Used on the Chesapeake Bay EMPACT Project

Once the timely data arrives at MD DNR, it is processed with various Visual Basic modules to convert the data appropriately and store it in a database. Maryland's DNR decided to allow the public to specify their own data parameters when viewing the current (e.g., real-time) or archived data. As a result, MD DNR needed an application that could develop user-defined graphs quickly. They used a Web application development tool developed by Macromedia (http://www.allaire.com) called *Cold Fusion* and an add-on graphics server engine called *CFXGraphicsServer* which is owned by TeraTech, Inc. (http://www/teratech.com). *CFXGraphicsServer* is a high-performance graphing and charting engine that is compatible only with *Cold Fusion*.

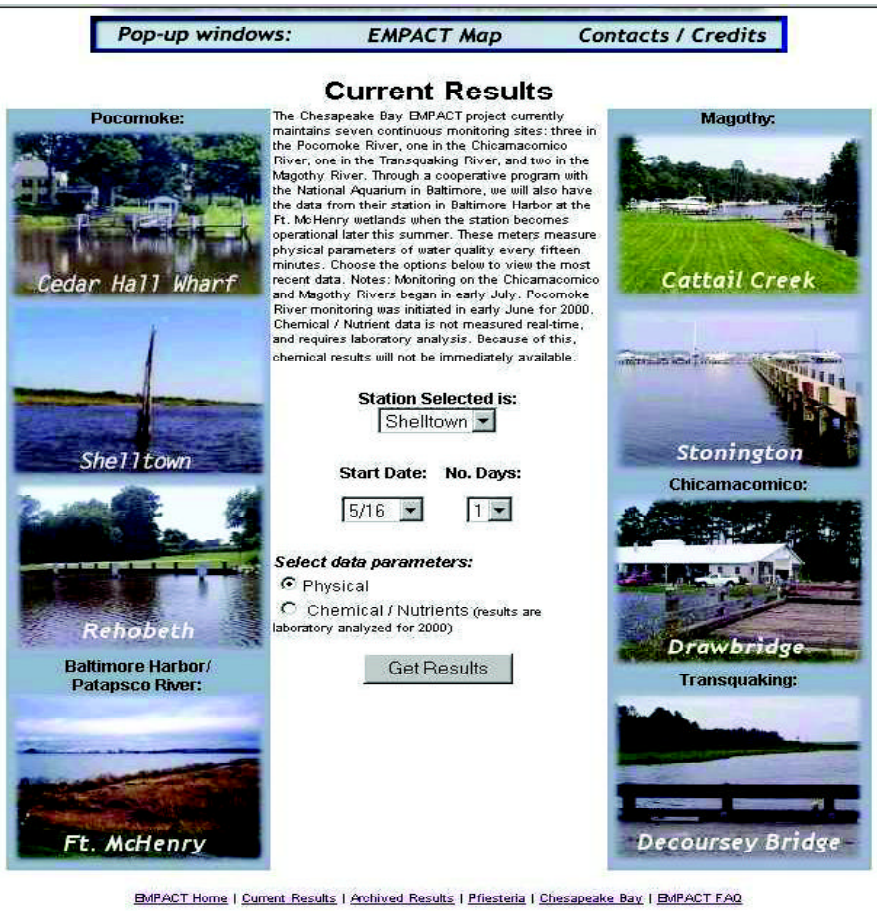
As shown in Figure 5.1, the user, via their Web browser, can select one of the eight monitoring stations from which to view data. In this case the Shelltown station on the Pokomoke River has been selected. Once a station has been selected, the user clicks on the **Get Date Range** button and is sent to another form which allows them to select a date or date range, and either physical or chemical parameters (see Figure 5.2). After the user makes their selection, the data is returned to the user in graphical form. An example of this is shown in Figure 5.3.

Figure 5.1 MD DNR's First Web-Based Interactive Form.



CFXGraphicsServer has a "Point & Click" drill-down capability to graphically present complex data at various levels of detail. *CFXGraphicsServer* allows your Web developer to generate over 30 graph types and styles with over 100 various graph attributes. It also includes a full VTML "Visual Interface" that requires virtually no coding to generate the graphs. The graphics engine server generates the graphic images in jpg or gif formats.

Figure 5.2 MD DNR's Second Web-Based Interactive Form.



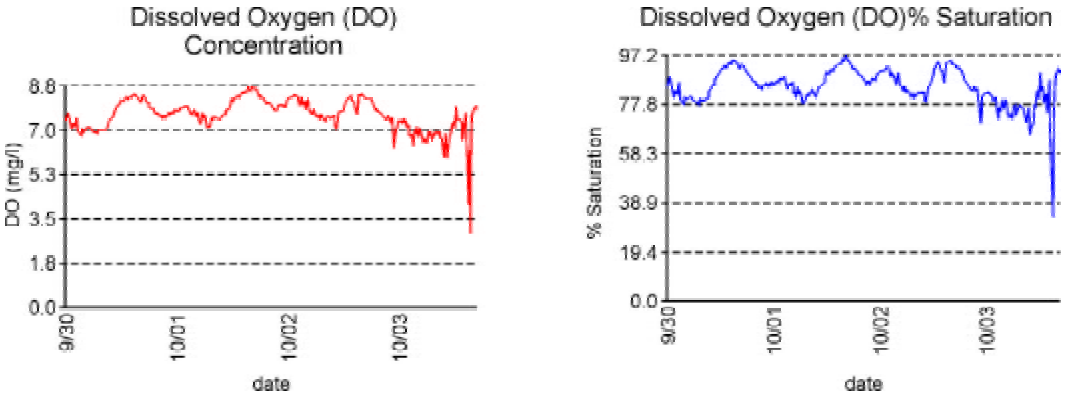
Currently, *CFXGraphicsServer* will only run under the Windows operating system - a UNIX version is not available. There are three versions of the graphics engine. They are as follows:

CFXGraphicsServer - Developer is the least expensive version and provides a developer with a local host restricted version which can be used to build and test an application. Because this version only supports local host access, it can not produce graphs that can be viewed on external machines.

CFXGraphicsServer - Professional is the mid-priced version and can produce graphs for a single Web site on a server using one Internet protocol (IP) address. The number of clients which can browse the graphs are unlimited.

CFXGraphicsServer - Enterprise is the most expensive version and can produce graphs for an unlimited number of IP addresses that are hosted on any one server. [Source: http://www.cfxgraphicsserver.com]

Figure 5.3 Ouput Results



The graphs above show the concentration and saturation of dissolved oxygen (DO) in the water. Since most aquatic organisms such as shellfish and other living resources require oxygen to survive, this is a very important measure of water quality. DO levels below 5 mg/l can stress organisms. Sustained DO levels of less than 3 mg/l can result in fish kills. DO saturation percent shows the level of dissolved oxygen as a percentage of the possible DO the water could contain. Generally, colder water can hold more DO than warmer water. Super-saturation (over 100% DO saturation) can occur when there is a large algal bloom. During the daylight, when the algae are photosynthesizing, they can produce oxygen so rapidly that it is not able to escape into the atmosphere, thus leading to short-term saturation levels of greater than 100%. The cycles evident in these data, however, appear to be driven primarily by tidal influences.

5.4 Guidelines for Interpreting and Conveying the Significance of the Water Quality Data

Data visualization also includes providing supporting interpretative text to make the data meaningful to the general population. Displaying data visually enables you to communicate results to a broader audience, such as residents in your community, while providing data interpretation can help the community to understand how it impacts the health of the surrounding environment.

Visual representation of the data is extremely useful to a knowledgeable professional and helpful to the general public but must be supported by additional explanatory material. For instance, a line graph of DO is only slightly more meaningful to the general public than a table of DO values; a crucial element is to supplement the line graphs with interpretive text by a qualified analyst. Consequently, the Chesapeake Bay project provides the public with line graphs accompanied by interpretive text explaining the overall importance of the parameters. An example of this are line graphs of DO and DO% Saturation as well as interpretive text for the Pocomoke-Shelltown station on September 5, 2001 shown in Figure 5.3.

6. COMMUNICATING WATER QUALITY INFORMATION

In addition to designing and implementing a timely water quality monitoring system, you will also want to consider how and what types of data to communicate to the community. This chapter is designed to help you develop an approach for communicating pertinent water quality information to people in your community, or more specifically, your target audience. This chapter provides the following:

- The steps involved in developing an outreach plan.
- Guidelines for effectively communicating information.
- Resources to assist in promoting community awareness.
- The outreach initiatives implemented by the Chesapeake Bay teams.

6.1 Developing an Outreach Plan for Timely Water Quality Reporting

Your outreach program will be most effective if you ask yourself the following questions:

- Who do you want to reach? (i.e., Who is your target audience?)
- What information do you want to distribute or communicate?
- What are the most effective mechanisms to reach your target audience?

Developing an outreach plan ensures that you have considered all important elements of an outreach project before you begin. The plan itself provides a blueprint for action. An outreach plan does not have to be lengthy or complicated. You can develop a plan simply by documenting your answers to each of the questions discussed below. This will provide you with a solid foundation for launching an outreach effort.

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

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

As you develop your outreach plan, consider whether you would like to invite any organizations to partner with you in planning or implementing the outreach effort. Potential partners might include shoreline property owner associations, local businesses, environmental organizations, schools, boating associations, local health departments, local planning and zoning authorities, and other local or state agencies. Partners can participate in planning, product development and review, and distribution. Partnerships can be valuable mechanisms for leveraging resources while enhancing the quality, credibility, and success of outreach efforts. Developing an outreach plan is a creative and iterative process involving a number of interrelated steps, as described below. As you move through each of these steps, you might want to revisit and refine the decisions you made in earlier steps until you have an integrated, comprehensive, and achievable plan.

6.1.1 What Are Your Outreach Goals?

Defining your outreach goals is the initial step in developing an outreach plan. Outreach goals should be clear, simple, action-oriented statements about what you hope to accomplish through outreach. Once you have established your goals, every other element of the plan should relate to those goals. Here were some project goals for the Chesapeake Bay EMPACT project:

- To display and archive timely water and habitat parameters on the Internet for presentation and interpretation of the data to the general public.
- To provide timely interpretation, as appropriate, relevant to water and habitat quality monitoring data.
- To demonstrate government response to emerging water and habitat quality issues of concern to the public.
- To supplement Maryland DNR efforts to characterize water quality conditions in estuarine systems that have experienced or have the potential to experience harmful algal blooms, loss of submerged aquatic vegetation or experienced low dissolved oxygen events.
- To provide timely environmental data to supplement Maryland's rapid response and comprehensive water and habitat quality assessments of Maryland tributaries that have a potential risk for harmful algal blooms.

6.1.2 Whom Are You Trying To Reach?

Identifying Your Audience(s)

The next step in developing an outreach plan is to clearly identify the target audience or audiences for your outreach effort. As illustrated in the Chesapeake Bay project goals above, outreach goals often define their target audiences (e.g., the public, coastal

scientists, and fisheries). You might want to refine and add to your goals after you have defined your target audience(s).

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

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

Defining Your Audience(s)

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

- What is their current level of knowledge about water quality?
- What do you want them to know about water quality? What actions would you like them to take regarding water quality?
- What information is likely to be of greatest interest to the audience? What information will they likely want to know once they develop some awareness of water quality issues?
- How much time are they likely to give to receiving and assimilating the information?
- How does this group generally receive information?
- What professional, recreational, and domestic activities does this group typically engage in that might provide avenues for distributing outreach products? Are there any organizations or centers that represent or serve the audience and might be avenues for disseminating your outreach products?

Ways to identify your audience and their needs include consulting with individuals or organizations who represent or are members of the audience, consulting with colleagues who have successfully developed other outreach products for the audience, and using your imagination.

Chesapeake Bay's Target Audience

Chesapeake Bay's target audience consisted of the following:

General Public. The general public, including students, can monitor the conditions in the various rivers and learn about the link between physical conditions, nutrient concentrations, *Pfiesteria* outbreaks, and water quality problems.

Tributary Strategy Teams. In 1995, ten Tributary Teams were initiated in Maryland. The Governor appointed 350 members to the Tributary Teams. The Tributary Strategy Teams are one of the State's major programs to reduce nutrient input into the Chesapeake Bay. The purpose and mission of the Tributary Teams are to:

- support and promote actions and policies to ensure healthy watersheds with abundant and diverse living resources;
- through education, heighten awareness of each individual's impact on water quality;
- promote implementation of projects to restore and protect living resources and water quality; and
- facilitate communication and coordination among governments, landowners, businesses, and all other citizens toward this common goal.

[Source: http://www.dnr.state.md.us/bay/tribstrat/index.html]

The Tributary Teams will use the data collected by the EMPACT program to evaluate water quality conditions, monitor nutrient levels and gauge the effectiveness of their nutrient reduction strategies.

Researchers and Scientists. Researchers and scientists can use the EMPACT data to better understand the linkages between water quality and toxic *Pfiesteria* outbreaks, low DO occurrences, and SAV habitat restoration.

Environmental Managers. Environmental managers use the EMPACT data to make decisions on how to manage the Bay's watersheds to help prevent future *Pfiesteria* outbreaks. [Source: Time-Relevant Data Collection of Physical, Chemical and Biological Parameters to Monitor and Characterize a Tributary Targeted for Maryland's *Pfiesteria* Monitoring Program in Chesapeake Bay, January 2000]

6.1.3 What Do You Want To Communicate?

The next step in planning an outreach program is to think about what you want to communicate. In particular at this stage, think about the key points, or "messages," you

want to communicate. Messages are the "bottom line" information you want your audience to walk away with, even if they forget the details.

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

- National Aquarium in Baltimore joins Chesapeake Bay EMPACT.
- EMPACT expands!

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

6.1.4 What Outreach Products Will You Develop?

The next step in developing an outreach plan is to consider what types of outreach products will be most effective for reaching each target audience. There are many different types of outreach: print, audiovisual, electronic, events, and novelty items. Table 6.1 provides some examples of each type of outreach product.

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

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

Table 6.1 Various Distribution and Outreach Products to Communicate Data

Distribution Avenues	Outreach Products
Mailing lists	$ Brochures $ Newsletters $ Fact sheets $ Utility bill inserts or stuffers
Phone/fax	$ Promotional hotline
E-mail/Internet	$ Newsletters $ E-mail messages $ Web pages $ Subscriber list servers
Radio/TV	$ Cable TV programs $ Public service announcements $ Videos $ Media interviews $ Press conferences/releases
Journals or newsletters	$ Newsletters $ Editorials $ Newspaper and magazine articles
Meetings, community events, or locations (e.g., libraries, schools, marinas, public beaches, tackle shops) where products are made available	$ Exhibits $ Kiosks $ Posters $ Question-and-answer sheets $ Novelty items (e.g., mouse pads, golf tees, buttons, key chains, magnets, bumper stickers, coloring books, frisbees) $ Banners $ Briefings $ Fairs and festivals $ Meetings (one-on-one and public) $ Community days $ Speeches $ Educational curricula

- Would it be effective to have distinct phases of products over time? For example, an initial phase of products designed to raise awareness, followed by later phases of products to increase understanding.
- How newsworthy is the information? Information with inherent news value is more likely to be rapidly and widely disseminated by the media.

You also need to consider how each product will be distributed and determine who will be responsible for distribution. For some products, your organization might manage

distribution. For others, you might rely on intermediaries (such as the media or educators) or organizational partners who are willing to participate in the outreach effort. Consult with an experienced communications professional to obtain information about the resources and time required for the various distribution options. Some points to consider in selecting distribution channels include:

- How does the audience typically receive information?
- What distribution mechanisms has your organization used in the past for this audience? Were these mechanisms effective?
- Can you identify any partner organizations that might be willing to assist in the distribution?
- Can the media play a role in distribution?
- Will the mechanism you are considering really reach the intended audience? For example, the Internet can be an effective distribution mechanism, but certain groups might have limited access to it.
- How many people is the product likely to reach through the distribution mechanism you are considering?
- Are sufficient resources available to fund and implement distribution via the mechanisms of interest?

6.1.5 What Follow-up Mechanisms Will You Establish?

Successful outreach may cause people to contact you with requests for more information or expressing concern about issues you have addressed. Consider whether and how you will handle this interest. The following questions can help you develop this part of your strategy:

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

6.1.6 What Is the Schedule for Implementation?

Once you have decided on your goals, audiences, messages, products, and distribution channels, you will need to develop an implementation schedule. For each product, consider how much time will be needed for development and distribution. Be sure to factor in sufficient time for product review. Wherever possible, build in time for testing and evaluation by members or representatives of the target audience in focus groups

or individual sessions so that you can get feedback on whether you have effectively targeted your material for your audience. Section 6.3 contains suggestions for presenting technical information to the public. It also provides information about online resources that can provide easy to understand background information that you can use in developing your own outreach projects.

6.2 Elements of the Chesapeake Bay Outreach Programs

The Chesapeake Bay team use a variety of mechanisms to communicate timely water quality information - as well as information about the project itself - to the general public. The team developed a Web site (part of the MD DNR Web site) as the primary vehicle for communicating timely information to the public. They also give presentations at conferences or Tributary Team meetings to inform the public about the Chesapeake Bay EMPACT program. These elements of the project's communication program are discussed below.

Note: NAIB is developing a variety of outreach tools (e.g., a restoration development manual, CD-ROM's, and an interactive Web site. See Chapter 7 for more information.

6.2.1 Bringing Together Experts.

The EMPACT project stakeholders are made up of a variety of organizations that provide input on the information generated from the project and how it is communicated. These stakeholders are identified below.

- EPA Office of Water's Office of Wetlands, Oceans, and Watersheds (OWOW)
- Maryland Department of Natural Resources (MD DNR)
- University of Maryland
- Maryland's Tributary Strategy Teams (comprised of farmers, watermen, industry representatives, interested citizens, local and state government officials)
- National Aquarium in Baltimore

6.2.2 Web Site.

The Chesapeake Bay EMPACT Web site is part of the Maryland DNR Web site and can be accessed at http://mddnr.chesapeakebay.net/newmontech/contmon/index.cfm. The Web site is the main avenue used by the team for disseminating the water quality information. The site has links that provide current and archived monitoring results. The site also has links that provide information about Chesapeake Bay, algal bloom, *Pfiesteria*, and the effects of hurricanes on the water quality.

MD DNR is continuously modifying the Web site so that it is more user friendly. In the near future, the Web site will be modified so that users can access the data more easily.

Note: NAIB's Web site is http://www.aqua.org.

Experience Gained and Lessons Learned

The Chesapeake Bay Team has learned that it is best to keep the Web site simple. For example, keep the Web page lengths to a minimum so that users will not have to scroll through pages and pages of data.

Also when developing a Web site, design the site so it can be easily changed or modified. Some off-the-shelf Web development packages allow you to quickly design a site, but may not let you make changes easily without redesigning large portions of the Web site.

The team also learned that it takes a significant amount of time to maintain a site that provides timely data. As a result, they recommend that anyone interested in developing a Web site to provide data to the public be prepared to commit the resources of a Web programmer to maintain the site.

6.2.3 Piggybacking on Existing Events.

The Chesapeake Bay team found opportunities to promote the EMPACT project at other events. In August, 2001 MD DNR manned a booth at the Maryland State Fair where they displayed posters and answered questions about the EMPACT monitoring project. Representatives from the Chesapeake Bay EMPACT Team also periodically present papers about the Chesapeake Bay EMPACT project at Tributary Team meetings.

6.3 Resources for Presenting Water Quality Information to the Public

As you develop your various forms of communication materials and begin to implement your outreach plan, you will want to make sure that these materials present your information as clearly and accurately as possible. There are resources on the Internet to help you develop your outreach materials. Some of these are discussed below.

6.3.1 How Do You Present Technical Information to the Public?

Environmental topics are often technical in nature and full of jargon, and water quality information is no exception. Nonetheless, technical information can be conveyed in

simple, clear terms to those in the general public not familiar with water quality. The following principles should be used when conveying technical information to the public:

- Avoid using jargon.
- Translate technical terms (e.g., reflectance) into everyday language the public can easily understand.
- Use active voice.
- Write short sentences.
- Use headings and other formatting techniques to provide a clear and organized structure.

The following Web sites provide guidance regarding how to write clearly and effectively for a general audience:

- The National Partnership for Reinventing Government has a guidance document, *Writing User-Friendly Documents*, that can be found on the Web at http://www.plainlanguage.gov.
- The American Bar Association has a Web site that provides links to on-line writing labs (http://www.abanet.org/lpm/bparticle11463_front. shtml). The Web site discusses topics such as handouts and grammar.

As you develop communication materials for your audience, remember to tailor your information to consider what they are already likely to know, what you want them to know, and what they are likely to understand. The most effective approach is to provide information that is valuable and interesting to the target audience. For example, the fishermen in the Chesapeake Bay are concerned about *Pfiesteria* outbreaks, so it would be of interest to them to convey information about *Pfiesteria* and related conditions. Also, when developing outreach products, be sure to consider special needs of the target audience. For example, ask yourself if your target audience has a large number of people who speak little or no English. If so, you should prepare communication materials in their native language.

The rest of this section contains information about resources available on the Internet that can assist you as you develop your own outreach projects. Some of the Web sites discussed below contain products, such as downloadable documents or fact sheets, which you can use to develop and tailor your education and outreach efforts.

6.3.2 Federal Resources

EPA's Surf Your Watershed
http://www.epa.gov/surf3

This Web site can be used to locate, use, and share environmental information on watersheds. One section of this site, "Locate Your Watershed," allows the user to enter the names of rivers, schools, or zip codes to learn more about watersheds in their local area or in other parts of the country. The EPA's Index of Watershed Indicators (IWI) can also be accessed from this site. The IWI is a numerical grade (1 to 6), which is compiled and calculated based on a variety of indicators that point to whether rivers, lakes, streams, wetlands, and coastal areas are "well" or "ailing."

EPA's Office of Water Volunteer Lake Monitoring: A Methods Manual
http://www.epa.gov/owow/monitoring/volunteer/lake

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

EPA's NonPoint Source Pointers (Fact sheets)
http://www.epa.gov/owow/nps/facts

This Web site features a series of fact sheets (referred to as "pointers") on nonpoint source pollution (e.g., pollution occurring from storm water runoff). The pointers cover topics including: programs and opportunities for public involvement in nonpoint source control, managing wetlands to control nonpoint source pollution, and managing urban runoff.

EPA's Great Lakes National Program Office
http://www.epa.gov/glnpo/about.html

EPA's Great Lakes National Program Office Web site includes information about topics such as human health, visualizing the lakes, monitoring, and pollution prevention. One section of this site (http://www.epa.gov/glnpo/gl2000/lamps/index.html) has links to Lakewide Management Plans (LaMP) documents for each of the Great Lakes. A LaMP is a plan of action developed by the United States and Canada to assess, restore, protect and monitor the ecosystem health of a Great Lake. The LaMP has a section dedicated to public involvement or outreach and education. The program utilizes a public review process to ensure that the LaMP is addressing their concerns.

You could use the LaMP as a model in developing similar plans for your water monitoring program.

U. S. Department of Agriculture Natural Resource Conservation Service
http://www.wcc.nrcs.usda.gov/water/quality/frame/wqam

Under "Guidance Documents," there are several documents pertaining to water quality that can be downloaded or ordered. These documents are listed below.

- A Procedure to Estimate the Response of Aquatic Systems to Changes in Phosphorus and Nitrogen Inputs
- Stream Visual Assessment Protocol
- National Handbook of Water Quality Monitoring
- Water Quality Indicators Guide
- Water Quality Field Guide

6.3.3 Education Resources

Project WET (Water Education for Teachers)
http://www.montana.edu/wwwwet

One goal of Project WET is to promote awareness, appreciation, knowledge, and good stewardship of water resources by developing and making available classroom-ready teaching aids. Another goal of WET is to establish state- and internationally-sponsored Project WET programs. The WET site has a list of all the State Project WET Program Coordinators.

Water Science for Schools
http://wwwga.usgs.gov/edu/index.html

The USGS's Water Science for Schools Web site offers information on many aspects of water and water quality. The Web site has pictures, data, maps, and an interactive forum where you can provide opinions and test your water knowledge. Water quality is discussed under "Special Topics."

Global Rivers Environmental Education Network (GREEN)
http://www.earthforce.org/green

The GREEN provides opportunities for middle and high school-aged youth to understand, improve and sustain watersheds in their community. This site (http://www.igc.apc.org/green/resources.html) also includes a list of water quality projects being conducted across the country and around the world.

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

Adopt-A-Watershed is a school-community learning experience for students from kindergarten through high school. Their goal is to make science applicable and relevant to the students. Adopt-A-Watershed has many products and services available to teachers wishing to start an Adopt-A-Watershed project. Although not active in every state, the Web site has a list of contacts in 25 States if you are interested in beginning a project in your area.

National Institutes for Water Resources
http://wrri.nmsu.edu/niwr/niwr.html

The National Institutes for Water Resources (NIWR) is a network of 54 research institutes throughout each of the 50 States, District of Columbia, the Virgin Islands, Puerto Rico, and Guam/Federated States of Micronesia. Each institute conducts research to solve water problems unique to their area and establish cooperative programs with local governments, state agencies, and industry.

6.3.4 Other Organizations

The Chesapeake Bay Program - America's Premier Watershed Restoration Program
http://www.chesapeakebay.net/

This Web site provides information about the current condition of the Chesapeake Bay. It also provides information about the habitats, animals, plants, Bay stressors, water quality monitoring, and Bay restoration efforts. The site also provides information about how to get involved in restoration efforts for the Bay.

North American Lake Management Society (NALMS) Guide to Local Resources
http://www.nalms.org/

This Web site provides resources for those dealing with local lake-related issues. NALMS's mission is to forge partnerships among citizens, scientists, and professionals to promote the management and protection of lakes and reservoirs. NALMS's Guide to Local Resources (http://www.nalms.org/resource/lnkagenc/links.htm) contains various links to regulatory agencies, extension programs, research centers, NALMS chapters, regional directors, and a membership directory.

The Watershed Management Council
http://watershed.org/wmc/aboutwmc.html

The Watershed Management Council (WMC) is a nonprofit organization whose members represent a variety of watershed management interests and disciplines. WMC membership includes professionals, students, teachers, and individuals whose interest is in promoting proper watershed management.

Gulf of Mexico Program
http://gmpo.gov

The EPA established the Gulf of Mexico Program (GMP). Their mission is to provide information and resources to facilitate the protection and restoration of the coastal marine waters of the Gulf of Mexico and its coastal natural habitats. The GMP's Web site has links to existing coastal projects, has links to educator and student resources, and provides near-real time oceanic data.

The Barataria - Terrobonne National Estuary Program (BTNEP)
http://www.btnep.org

BTNEP is the result of a cooperative agreement between the EPA and the State of Louisiana under the National Estuary Program. The program's charter was to develop a coalition of government, private, and commercial interests to identify problems, assess trends, design pollution control, develop resource management strategies, recommend corrective actions, and seek implementation commitments for the preservation of Louisiana's Barataria and Terrebonne basins.

6.4 Success Stories

In the summer of 1998, there was a massive fish kill of approximately 500,000 menhaden in the Bullbegger Creek, a tributary of the Pocomoke River. This kill occurred approximately one year after the toxic *Pfiesteria* outbreaks in the Pocomoke. The severity of the fish kill received a lot of publicity and the public was extremely concerned that the kill was caused by a reoccurrence of toxic *Pfiesteria*.

MD DNR believed that the fish kill was caused by low DO levels and not *Pfiesteria*; however, due to the remote location of the Pocomoke, scientist could not take water samples until after the kill occurred. Analysis of the discrete samples taken after the kill showed DO readings of 4.0 mg/l and higher which did not confirm low DO as the cause of the kill.

Fortunately, MD DNR had deployed the YSI sonde at Shelltown which is directly across from Bullbegger Creek. MD DNR reviewed the data logged by the sonde and discovered that the morning of the kill, at around 5:00 am, the sonde recorded DO values of less than 1.0 mg/l with consistent readings during the morning hours at levels lethal to fish.

This evidence was sufficient for MD DNR to document that low DO levels, not toxic *Pfiesteria*, was the probable cause of the fish kill. The fishermen and citizens in the area were relieved to learn that they were not experiencing another toxic outbreak of *Pfiesteria*.

6.5 Most Frequently Asked Questions and Answers

This section contains questions frequently asked about the Chesapeake Bay EMPACT project as well as about the Bay in general.

Q: What are the goals of the Chesapeake Bay EMPACT Project?

A: The primary objective of the Chesapeake Bay EMPACT Project originally was to provide time-relevant information regarding *Pfiesteria piscicida* and water quality on the Pocomoke River, a tributary of Chesapeake Bay. The Pocomoke was the location of toxic *Pfiesteria* outbreaks in 1997. This project is meant to supplement data collected as part of the larger statewide *Pfiesteria*, water, and habitat quality monitoring program coordinated by the Maryland Department of Natural Resources. Due to human health concerns, possible living resource impacts, business concerns for the local seafood industry, and extensive media coverage, many people throughout the state have a renewed interest in water and habitat quality. This EMPACT project will allow people to learn more about Maryland's waterways and keep up to date with water quality and *Pfiesteria* issues.

For 2000, the EMPACT project was expanded to provide a more bay-wide representation of water and habitat quality. Four new stations were initiated by MD DNR in the summer of 2000. Two monitors were placed in the Magothy River. Not only will this provide data from a waterway in a more urban setting, but this river also provides critical SAV habitat and has experienced fish kills in previous years. Two more continuous monitors were also placed in lower eastern shore tributaries. Stations on the Chicamacomico and Transquaking Rivers will provide data from two more systems that have repeatedly shown evidence of *Pfiesteria*.

Additionally, this project will enable us to gain a greater understanding of how tributaries of the Chesapeake Bay function. For example, the relationship between storm events and freshwater flows to the Pocomoke is poorly understood because of its altered watershed hydrology. This is an important process to understand because of the likely linkage between runoff, nutrient loading, and conditions that influence *Pfiesteria* populations.

A secondary objective of this project is to measure and evaluate low dissolved oxygen conditions (hypoxia and anoxia) that affect certain Maryland waterways during the summer months. These low oxygen conditions put stress on fish and

other aquatic organisms; if the conditions are severe enough or persist long enough, they can force fish out of an area or even lead to fish kills. Several fish kills believed to have been caused by low dissolved oxygen have occurred in various tributaries the past several years. EMPACT monitoring may provide further insight into these events.

Q: What types of meters are used?

A: The sondes (or meters) used for the EMPACT project are all manufactured by Yellow Springs Instruments (YSI). YSI 6600 sondes are being used at all the monitoring sites. With the exception of the bottom meter at Cedar Hall Wharf on the Pocomoke, meters are located at a constant depth of one meter below the surface of the water. This is achieved by mounting them inside PVC pipes to prevent drifting, and attaching them to structures to maintain a constant depth. In 1998, the first year of EMPACT program monitoring, two stations were used: one at the Beverly Farm in Cedar Hall Wharf, the other near Williams Point in Shelltown. For 1999, two more locations were added: one surface meter further upstream near Rehobeth and a bottom meter at the Cedar Hall Wharf location. The addition of the bottom meter provides us with information to determine possible differences between surface and bottom conditions. For 2000, four more meters were added to three different waterways, giving MD DNR a more bay-wide continuous monitoring presence. In 2001, a monitoring station was established near Fort McHenry in the Baltimore Harbor as part of NAIB's Technology Transfer Project.

Q: How is the monitoring done?

A: Each sonde originally was programmed to record four environmental parameters: water temperature, salinity, dissolved oxygen (DO) saturation, and DO concentration. For 2000, all sondes were upgraded to record three additional parameters: pH, turbidity, and fluorescence (a measure of Chlorophyll A present in the water column). Each parameter is recorded every 15 minutes. Once every week, each station is accessed by field staff. The sondes are retrieved, and the stored data is transferred electronically into a computer spreadsheet. To prevent biofouling during warm months, the sondes are replaced weekly with clean, recalibrated units. The deployed sondes are brought back to the lab for cleaning and maintenance. Additionally, May through October water samples are taken at each location weekly, brought back to the lab, and analyzed with established methods. These results are used to calibrate the sondes and to check the data for accuracy. The samples are also tested for chemical parameters that cannot be measured by the sondes, such as dissolved inorganic nutrients, Chlorophyll A levels, and water column respiration rates. These three tests help provide an understanding of environmental factors that contribute to the occurrence of harmful algal blooms and low oxygen conditions. The field monitors are active

from April through late October, except for Fort McHenry and Stonington which are active year-round.

Q: What is biofouling?

A: Biofouling occurs when aquatic organisms such as algae begin to grow on the sondes. If buildup gets too thick, the sondes will not be able to obtain accurate results. This is especially a problem with the dissolved oxygen sensors on the sondes, as they contain soft membranes that are ideal for algal growth. If the sondes stay out in the field for longer than one week during the summer months, the risk of losing data due to biofouling increases greatly. For this reason, the sondes are rotated weekly with clean, calibrated sondes. The deployed sondes are brought back to the lab for cleaning and maintenance. In addition to biofouling, errors can also be caused by crabs poking holes in the soft DO sensor membrane. Once that membrane has been penetrated, DO measurements are no longer viable. The addition of a screen around the sensors has prevented most crabs from getting to the membrane. [Source: http://mddnr.chesapeakebay.net/empact/faq.html]

Q: How big is the Bay?

A: The Chesapeake Bay is the largest estuary in the United States. It is about 200 miles long. At the Bay Bridge near Annapolis, it is only 4 miles across, but it is 30 miles across at the widest point near the mouth of the Potomac River. The Bay watershed drains 64,000 square miles of land in six states - Maryland, Virginia, Delaware, Pennsylvania, West Virginia and New York and Washington, D.C. To give some idea of the size, the Bay watershed is about 5 times bigger than the state of Maryland and 30 times larger than Delaware, yet it is only one-fourth the size of Texas!

Q: How many kinds (species) of plants and animals live in the Bay?

A: About 2,700 different plants and animals live in the Bay.

Q: How many people live in the Bay watershed?

A: In 1960 there were 11 million people. Currently, approximately 16 million people live in the watershed.

Q: Won't all those people living in the watershed have a large impact on the Bay?

A: Yes, they certainly will. The biggest problem is the change in land use. All of those people (that's you and me by the way) have to live somewhere. We go to work, to school, to church, to shopping malls, and to the grocery store. And we want to have fun! We cut down trees, pave roads and parking lots and build houses, malls, schools, etc. By changing the landscape we change the way the natural system

works. Consequently, there is more soil erosion, more polluted run-off from paved surfaces, higher volumes of water rushing through streams during storms, and our natural systems have less capability of buffering these impacts - not to mention all of the water we use and the wastewater we produce.

Q: Isn't trash the largest pollution problem in the Bay today?

A: No, trash is not the biggest problem although it really is ugly. Trash is one form of pollution that we can control by putting litter where it belongs. The biggest threat to the Bay is excess amounts of nutrients, specifically nitrogen and phosphorus. These nutrients come primarily from animal waste (including human waste), from fertilizers on crops and on lawns, and from the air.

Q: Don't aquatic plants need nutrients to grow?

A: Yes, they do. The problem occurs when there are too many nutrients. This causes microscopic plants called algae to reproduce rapidly. These algae "blooms" form large mats which block sunlight from reaching the submerged aquatic vegetation (SAV), or grasses growing on the Bay's bottom. SAV is an ideal habitat for small fish and crabs. Without sunlight, the SAV dies robbing the fish and crabs of food and shelter.

Q: Do the algae blooms cause other problems?

A: Yes. When the algae begin to die, most sink to the bottom of the Bay, where the process of decomposition takes oxygen from the water. All animals need oxygen to live, so when oxygen levels get low, fish swim away if they can. Aquatic animals that cannot move such as oysters may die if oxygen levels get too low. In fact, during the summer, most of the water deeper than 30 feet has no oxygen and cannot support any aquatic life.

Q: Why are aquatic plants so important to the health of the Bay?

A: There are many reasons submerged aquatic vegetation, often called SAV, are vital. SAV is a producer in the Bay's food web. This means SAV uses the sun's light to make food through a process called photosynthesis. SAV also produce oxygen as a by-product of photosynthesis. Waterfowl eat the seeds and roots of SAV while microscopic animals called zooplankton live on decaying SAV.

SAV also filter and trap sediment which could make the water cloudy. SAV beds slow down the motion of waves which helps to protect the shoreline. Finally, these grass beds are hiding places for small fish trying to escape larger predators and for soft crabs waiting for their shells to harden.

Q: Why did the Governor pledge to plant trees on 600 miles of streams in Maryland by the year 2010. What is that all about?

A: Scientists have known for years that trees play a vital role in our natural systems. Recent evidence indicates that trees are extremely important in maintaining healthy streams and a healthy Chesapeake Bay. Trees planted on streambanks, so called forest buffers, perform many functions. Forest buffers capture rainfall and regulate streamflow, even out temperature changes in the water and the air, stabilize streambanks, and provide habitat for fish and wildlife - all of which are beneficial to Maryland's streams, creeks and rivers. They also improve water quality downstream in the Bay by filtering nutrients like nitrogen and phosphorus and by removing sediments. So, the more trees we plant along the banks of our streams and rivers, the cleaner and healthier our environment and the Bay will be. [Source: http://www.dnr.state.md.us/bay/education/faq/bayfacts.html]

7. RELATED PROJECTS

Maryland's DNR has been able to pass along their knowledge and experience so that the National Aquarium in Baltimore (NAIB), through a technology transfer project, could implement a similar water quality monitoring project near the Fort McHenry National Monument and Historic Shrine in Baltimore. In addition to the water quality monitoring project near Fort McHenry, the NAIB is also conducting a wetland restoration effort at Fort McHenry. Finally, through a data integration project, NAIB is developing a GIS application to integrate various data sources to provide even more information to the communities in and around the Chesapeake Bay. Section 7.1 discusses the NAIB's Technology Transfer Project. Section 7.2 discusses the NAIB's wetland restoration effort at Fort McHenry. Section 7.3 discusses the NAIB's data integration project.

7.1 Technology Transfer Project

Through a technology transfer project, Maryland's DNR assisted the NAIB in installing a similar water quality monitoring station at the Fort McHenry National Monument and Historic Shrine in Baltimore, MD. The NAIB is a non-profit institution dedicated to promoting good stewardship of aquatic environments through exhibits, education, and ecological restoration programs.

The water quality monitoring station is equipped with the same basic hardware (i.e., YSI sonde, datalogger, and telemetry equipment) as the stations maintained by the Maryland DNR for their EMPACT water quality monitoring program. The Fort McHenry station collects the same water quality parameters (i.e., temperature, specific conductivity, salinity, dissolved oxygen, pH, Chlorophyll A, and turbidity) every 15 minutes. The data collected by the Aquarium is used to help further an understanding of the causes and effects of human activity on a watershed, interpret watershed health, and promote watershed stewardship.

Similar to MD DNR's project, the Aquarium queries the monitoring station twice each day and stores the near real-time data on their server and a Web site being designed to display the data at a 6th grade reading level. The data is also displayed on the MD DNR Web site.

Note: The Aquarium Web site (http://www.aqua.org) allows users to retrieve data directly from the Aquarium Web site.

The Aquarium also installed a weather monitoring station near the Fort McHenry wetland. The weather station monitors total rainfall, photosynthetically active radiation, wind speed, wind direction, air temperature, relative humidity, and barometric pressure. The data, which is collected and stored as 15 minute averages,

is downloaded twice a day from the weather station. The weather is also available on the Aquarium Web site.

Through a similar technology transfer effort, the NAIB transferred the experience they gained with the water quality monitoring equipment to students at Morgan State University (MSU). Through a job training program, NAIB has worked with eight MSU students teaching them how to service and maintain the water quality monitoring and telemetry equipment.

7.2 Wetlands Restoration at Fort McHenry

The Fort McHenry wetland is not a natural wetland, but was constructed in 1982 to mitigate the impact stemming from the construction of the Fort McHenry tunnel. The 10-acre wetland site, adjacent to the Fort McHenry National Monument and Historic Shrine in Baltimore, Maryland, was chosen as a field station by NAIB because of its location at the head of a tidal tributary and its significance as a cultural landmark. The constructed wetland served as a refuge for many species of wildlife, including sea ducks, heron, muskrats, and red-winged blackbirds. However, after the wetland was established, there was no plan to maintain it. Over time the wetland degraded due to the growth of non-native grasses and accumulation of trash and debris. In 1997, the National Parks Service, in partnership with the NAIB's Conservation Department, began efforts to restore and maintain the wetland.

To restore the Fort McHenry Wetland, the Aquarium partnered with various agencies and groups including, but not limited to:

- National Park Service
- Maryland DNR
- US Department of Commerce (NOAA)
- US EPA
- Chesapeake Bay Program
- Morgan State University
- Baltimore Bird Club
- Boy Scouts of America

The components of the Fort McHenry restoration project includes the following:

- Site activities (e.g., clean-up and planting of beneficial marsh grasses)
- An avian monitoring program
- Development of a manual for community involvement in tidal marsh restoration that can be used in other areas of the country.

Each of these components are discussed below.

7.2.1 Site Clean-up Activities

During the last few years, the NAIB's Aquarium Conservation Team (ACT), has led 13 public field days at the site. The field days allows participants to learn how to restore tidal wetlands. More than 1,100 volunteers have logged a total of 8,500 hours in tidal marsh restoration activities. Such activities include planting beneficial vegetation and catalogging and removing more than 155,000 pieces of debris, most which were plastic or foamed plastic items.

7.2.2 Avian Monitoring

NAIB and the Baltimore Bird Club formed a partnership to implement an Avian Monitoring Program at Fort McHenry. The program began on August 17, 1999. In the program's first year of monitoring, Baltimore Bird Club members spent 114 hours counting and observing over 6,180 birds, representing 120 species in and around the wetland. It is interesting to note that the number of bird species observed at the 10-acre site represents approximately 30% of all the birds recorded in the state of Maryland. Members also installed a variety of nesting boxes and platforms in and around the wetland which have been inhabited by tree swallows, purple martins, wrens, and a pair of osprey.

7.2.3 Restoration Development Manual

The tidal wetlands at Fort McHenry National Monument provides a model for community-based involvement in restoration activities. The NAIB is developing a manual for community involvement in tidal marsh restoration that can be used in other areas of the country. The manual is designed for use by volunteer programs and covers such topics as restoration, maintenance, and monitoring for restored or created tidal wetlands. Specifically, the manual will enable volunteers to determine the following parameters for a tidal marsh:

- Initial logistics and basic site information, including site history and geography
- Hydrology and topography
- Sediment trapping capabilities
- Sediment properties (organic carbon and grain size)
- Groundwater level, salinity, and redox potential
- Vegetation community structure
- Faunal utilization

By applying the methodologies outlined in the manual, volunteers can generate detailed tidal wetland structural information which will be disseminated to evaluate the capacity of the wetland to perform various functions and collect all necessary field data within a maximum labor effort of 100 hours per site per year.

7.2.4 Principles of Wetland Restoration

The EPA Office of Wetlands, Oceans, and Watersheds (OWOW) has assembled a list of wetland restoration principles that are critical to the success of any restoration project. These principles focus on scientific and technical issues, but as in all environmental management activities, the importance of community perspectives and values should not be overlooked. The restoration principles are as follows:

- Preserve and Protect Aquatic Resources
- Restore Ecological Integrity
- Restore Natural Structure
- Restore Natural Function
- Work Within the Watershed and Broader Landscape Context
- Understand the Natural Potential of the Watershed
- Address Ongoing Causes of Degradation
- Develop Clear, Achievable, and Measurable Goals
- Focus on Feasibility
- Use Reference Sites
- Anticipate Future Changes
- Involve a Multi-disciplinary Team
- Design for Self-sustainability
- Use Passive Restoration when Appropriate
- Restore Native Species, Avoid Non-native Species
- Use Natural Fixes and Bioengineering Techniques
- Monitor and Adapt Where Changes are Necessary

For a detailed explanation of these restoration principles, see http://www.epa.gov/owow/wetlands/restore/principles.html.

7.3 Data Integration Project

Currently, the Aquarium is leading a project with the Maryland DNR, the Chesapeake Bay Program, EPA Region III, and several other regional partners to integrate and interpret real-time water quality information as well as other data sources to raise public awareness and stimulate action. The Aquarium, with the help of its partners, is developing an interactive GIS product accessible through the Internet which will provide a comprehensive and clear view of Chesapeake Bay's real-time water quality results to the general public. Such products will include GIS-based maps for five major sub-watersheds in the Chesapeake Bay. These maps which will present concrete and germane information for the non-technical user. For example, for each of the sub-watersheds, GIS-based maps will be developed to include population, percent developed/protected land, land use, and public involvement opportunities. Also a GIS application could be developed to allow the user to input their address, locate their watershed, and follow the path of water from their home, through the network of storm drains, to the Bay.

To facilitate broader use of the information, the Aquarium will develop and distribute 20,000 copies of a CD-ROM product for its stakeholders. The CD-ROM will serve as a communication/outreach tool which will allow users without access to the Internet (e.g., schools) to have access to water quality and other relevant environmental information for areas of the Chesapeake Bay. For more information on this project, contact Glenn Page (gpage@aqua.org) at the NAIB at (410) 576-3808.

[Source: Improving Public Access to Water Quality and Watershed Information in the Chesapeake Bay, Quality Assurance Project Plan, National Aquarium in Baltimore, May 18, 2001.]

APPENDIX A
GLOSSARY OF TERMS & ACRONYM LIST

A

AA: Auto-analyzer

Algae: Simple single-celled, colonial, or multi-celled aquatic plants. Aquatic algae are (mostly) microscopic plants that contain chlorophyll and grow by photosynthesis. They absorb nutrients from the water or sediments, add oxygen to the water, and are usually the major source of organic matter at the base of the food web.

Algal bloom: Referring to excessive growths of algae caused by excessive nutrient loading.

Anoxia: Absence of oxygen in water.

B

C

CBL: Chesapeake Biological Laboratory

Chlorophyll: Green pigment in plants that transforms light energy into chemical energy by photosynthesis.

Chlorophyll A: A type of chlorophyll found in plants and algae which makes photosynthesis possible.

CO_2: Carbon dioxide

CSI: Campbell Scientific, Inc.

CWSRF: Clean Water State Revolving Fund

D

Dissolved oxygen (DO): The concentration of oxygen (O_2) dissolved in water, usually expressed in milligrams per liter, parts per million, or percent of saturation (at the field temperature). Adequate concentrations of dissolved oxygen are necessary

to sustain the life of fish and other aquatic organisms and prevent offensive odors. DO levels are considered a very important and commonly employed measurement of water quality and indicator of a water body's ability to support desirable aquatic life. Levels above 5 milligrams per liter (mg O_2/L) are considered optimal and fish cannot survive for prolonged periods at levels below 3 mg O_2/L. Levels below 2 mg O_2/L are often referred to as hypoxic and when O_2 is less than 0.1 mg/L, conditions are considered to be anoxic.

DNR: Department of Natural Resources

DO: Dissolved oxygen

DOC: Dissolved organic carbon

DVT(s): Data visualization tools

E

Ecosystem: The interacting plants, animals, and physical components (sunlight, soil, air, water) of an area.

EDF: Environmental Defense Fund

EMPACT: Environmental Monitoring for Public Access and Community Tracking

EPA: Environmental Protection Agency

Estuary: Body of water that provides a transition zone between the freshwater of a river and the saline environment of the sea.

Eutrophication: The process by which surface water is enriched by nutrients (usually phosphorus and nitrogen) which leads to excessive plant growth.

F

% full scale: Unit of measurement for fluorescence

ft: feet

FTP: File transfer protocol

G

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

GREEN: Global Rivers Environmental Education Network

µg/l: micrograms (10^{-6} grams)/liter

µS/cm: micro siemens per centimeter

H

HCl: Hydrochloric acid

HNO_3: Nitric acid

H_2SO_4: Sulfuric acid

HPL: Horn Point Laboratory

Hypoxia: Physical condition caused by low amounts of dissolved oxygen in water (i.e., less than 2 mg/L).

I

IC: Inorganic carbon

IMS: Information Management System

J

K

L

L: liter

LaMP: Lakewide Management Plans

M

m: meters

mg: milligrams

mg/L: milligrams/liter

Monitor: To track a characteristic, such as dissolved oxygen, nitrate level, or fish population, over a period of time using uniform methods to evaluate change.

MS: Military style

N

NAIB: National Aquarium in Baltimore

NALMS: North American Lake Management Society

NaOH: Sodium hydroxide

Near-real-time: Refers to data current enough to be used in day-to-day decision-making. These data are collected and distributed as close to real time as possible. Reasons for some small time delays in distributing the collected data include the following: (1) the time it takes to physically transmit and process the data, (2) delays due to the data transmission schedule (i.e., some collected data are only transmitted in set time intervals as opposed to transmitting the data continuously), and (3) the time it takes for automated and preliminary manual QA/QC.

NH_3: Ammonia

NH_4: Ammonium ion

NOAA: National Oceanic and Atmospheric Administration

nm: Nanometer, 10^{-9} meter

Non-point Source: Diffuse, overland runoff containing pollutants. Includes runoff collected in storm drains.

NRCS: Natural Resources Conservation Service

NTU: Nephelometric turbidity unit

Nutrient loading: The discharge of nutrients from the watershed into a receiving water body (e.g., wetland). Expressed usually as mass per unit area per unit time (kg/hectare/yr or lbs/acre/year).

O

ORD: Office of Research and Development

Organic: Refers to substances that contain carbon atoms and carbon-carbon bonds.

OWOW: Office of Wetlands, Oceans, and Watersheds

P

pH scale: A scale used to determine the alkaline or acidic nature of a substance. The scale ranges from 0 to 14 with 0 being the most acidic and 14 the most basic. Pure water is neutral with a pH of 7.

Parameter: Whatever it is you measure - a particular physical, chemical, or biological property that is being measured.

Pfiesteria Piscicida: A toxic dinoflagellate that has been associated with fish lesions and fish kills in coastal waters from Delaware to North Carolina.

Photosynthesis: The process by which green plants convert carbon dioxide to sugars and oxygen using sunlight for energy.

ppt: parts per thousand

Point Source: A pipe that discharges effluent into a stream or other body of water.

Primary Productivity: The productivity of the photosynthesizers at the base of the food chain in ecosystems. (Adapted from the USGS Water Science Glossary at http://wwwga.usgs.gov/edu/dictionary.html.)

PVC: Polyvinyl chloride

Q

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

R

Remote Monitoring: Monitoring is called *remote* when the operator can collect and analyze data from a site other than the monitoring location itself.

Runoff: Precipitation, snow melt, or irrigation water that appears in uncontrolled surface streams, rivers, drains or sewers. Runoff may be classified according to speed of appearance after rainfall or melting snow as direct runoff or base runoff, and according to source as surface runoff, storm interflow, or ground-water runoff. (Adapted from the USGS Water Science Glossary at http://wwwga.usgs.gov/edu/dictionary.html.)

S

Salinity: Measurement of the mass of dissolved salts in water. Salinity is usually expressed in ppt.

SAV: Submerged aquatic vegetation

SC: Specific conductance

Sediment: Fine soil or mineral particles

SMSA: Standard metropolitan statistical area

Sonde: A group of sensors configured together to measure specific physical properties of water. A sonde may be attached to a single recording unit or electronic data logger to record the output from the group of sensors.

Specific Conductance (SC): The measure of how well water can conduct an electrical current. Specific conductance indirectly measures the presence of compounds such as sulfates, nitrates, and phosphates. As a result, specific conductance can be used as an indicator of water pollution. Specific conductivity is usually expressed in μS/cm.

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

STP: Sewage treatment plant

Suspended solids (SS or Total SS [TSS]): Very small particles that remain distributed throughout the water column due to turbulent mixing exceeding gravitational sinking.

T

TDS: Total dissolved solids

Timely data: Data that are collected and communicated to the public in a time frame that is useful to their day-to-day decision-making about their health and the environment, and relevant to the temporal variability of the parameter measured.

TOC: Total organic carbon

TSS: Total suspended solids

Turbidity: The degree to which light is scattered in water because of suspended organic and inorganic particles. Turbidity is commonly measured in NTU's.

U

USGS: United States Geological Survey

V

W

Watershed: The entire drainage area or basin feeding a stream or river. Includes surface water, groundwater, vegetation, and human structures.

WET: Water Education for Teachers

WMC: Watershed Management Council

X

Y

YSI: Yellow Springs Instruments, Inc.

Z