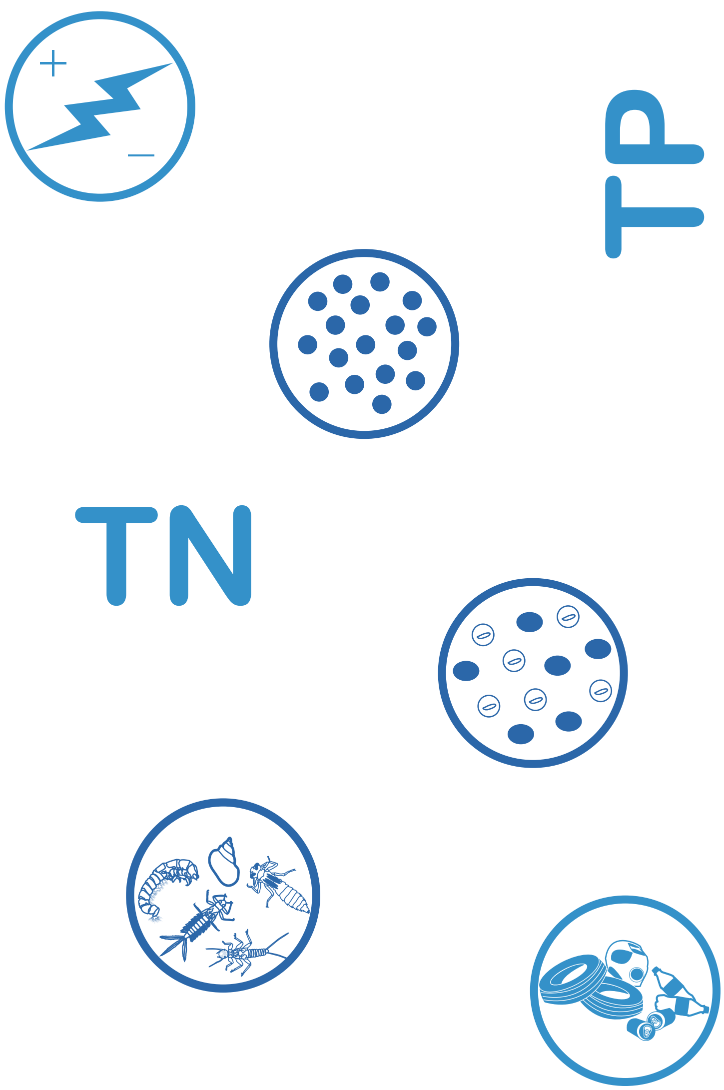
Sampling and data analysis protocols for Mid-Atlantic non-tidal stream indicators



MTAC
Mid-Atlantic
Tributary
Assessment
Coalition

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Contributors

The protocols discussed in this document represent the collective efforts of many individuals and organizations working within the Mid-Atlantic Tributary Assessment Coalition (MTAC). The following individuals contributed significantly to the development of these protocols: Peter Bergstrom, Dan Boward, Jamie Brunkow, Carol Cain, Jana Davis, David Flores, Katie Foreman, Adam Griggs, Liza Hernandez, Jonathan Kellogg, Tom Leigh, Carol McCollough, Ron Melcer, Joe Ports, Rupert Rossetti, Chris Trumbauer, Beth Wasden.

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The Integration and Application Network (IAN) is a collection of scientists interested in solving, not just studying environmental problems. IAN seeks to inspire, manage, and produce timely syntheses and assessments on key environmental issues, with a special emphasis on Chesapeake Bay and its watershed. IAN is an initiative of the University of Maryland Center for Environmental Science, but links with other academic institutions, resource management agencies, and non-governmental organizations.

Beginning as a small college laboratory and a state research and education agency, UMCES has developed into a multi-campus institution of Maryland's university system. UMCES continues its rich tradition of discovery, integration, application, and teaching at its three laboratories: Chesapeake Biological Laboratory (1925), Appalachian Laboratory (1962), and Horn Point Laboratory (1973), as well as Maryland Sea Grant in College Park and the Annapolis Synthesis Center in downtown Annapolis. The Integration and Application Network was established in 2002 to allow UMCES to apply the scientific knowledge of its faculty and staff to the environmental challenges we face today.

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Chapter 1: Standardizing watershed monitoring results

Environmental health report cards (Figure 1.1) are detailed ecosystem health assessments that have proven to be important outreach tools for generating community interest and increasing citizen understanding of ecosystem health, water quality, and watershed issues. Report cards provide useful and timely information on environmental issues to local decision-makers and can highlight actions that residents can take to become involved in the improvement and conservation of their communities.

Although report cards are proven tools, their effectiveness can be enhanced by increasing the consistency of water quality monitoring, data analysis, and communication efforts among report card-producing organizations. This protocol document, developed by EcoCheck through consensus of Mid-Atlantic Tributary Assessment Coalition (MTAC) members, will substantially improve the utility of report cards across watersheds (e.g., rivers and streams).

The overall objective of this protocol document is to encourage and enable comparisons of monitoring results from report card-producing organizations and to increase the scientific validity of report cards as outreach tools. This document is intended for use in non-tidal rivers and streams only, as the ecosystem health indicators (see text box) and thresholds discussed are pertinent only to non-tidal watersheds. A companion document, which presents tidal protocols, was completed in summer 2011. Visit the MTAC website (http://ian.umces.edu/ecocheck/citizen-science/) for updates and more information.

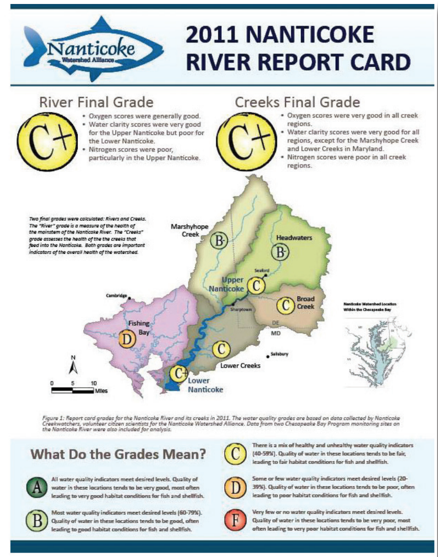


Figure 1.1. An example of a report card. This one is produced by the Nanticoke Watershed Alliance.

Local-scale monitoring provides a detailed picture of health

Report cards have been very successful as local outreach tools for individual water systems. However, report cards that are based on different indicators and methods for monitoring and analysis can't be compared to one another. This makes it difficult to compare results and health among various watersheds.

Report card indicators

Report cards provide scores for individual ecosystem health indicators, such as total nitrogen and conductivity, that are averaged into an overall report card grade. An indicator is a measure, an index of measures, or a model that characterizes an ecosystem or one of its critical components (Longstaff et al. 2010). Indicators relay complex messages, potentially from numerous sources, in a simplified and useful manner.

The primary uses of indicators are to characterize current condition status, to track or predict significant changes, and to identify trends.

Historically, state and federal government agencies have monitored the health of watersheds for management and regulatory purposes. For example, Maryland's Department of Natural Resources and Virginia's Department of Environmental Quality perform most monitoring activities that support the management and regulation of the Chesapeake Bay watershed. Additionally, the Chesapeake Bay Program—a regional partnership mandated with management and regulation of the Chesapeake Bay—works closely with state and federal agencies, such as the U.S. Geological Survey (USGS) and the U.S. Environmental Protection Agency (US EPA), to evaluate environmental impacts on the Bay.

Unfortunately, it is not economically or logistically feasible to place monitoring stations in all focus areas of a watershed, most often because the area is large and crosses multi-jurisdictional boundaries. In the Chesapeake Bay watershed, the U.S. Geological Survey has carefully chosen sampling site locations to maximize coverage, so as to adequately assess watershed-wide nutrient conditions (Figure 1.2a). However, this may mean that there are only one or two monitoring stations within each sub-watershed (e.g., the Potomac and Choptank watersheds).

Despite more than two decades of intense monitoring and assessment at a watershed-wide scale, more information is needed at finer scales (i.e., targeted regions within the Bay watershed, such as the Nanticoke River watershed) to evaluate the effectiveness of management actions taken at the local level (Figure 1.2b). This is particularly important in light of the new Chesapeake Bay Total Maximum Daily Load (TMDL) and state Watershed Implementation Plans (WIPS)(US EPA 2010; MDE 2010).

Data collection at the scale needed for these types of assessments is currently being carried out by many watershed associations and citizen monitoring programs. These data are very useful for providing detailed assessments of local environments (Figure 1.2c).

However, these watershed associations and citizen monitoring programs may choose to monitor different indicators based on unique local issues. Varied indicators and methods for monitoring and analysis make it difficult to compare data and results across water systems. This diminishes the overall power of report cards.

This protocol document addresses the need for a common framework of monitoring, analysis, and communication efforts among watershed associations and citizen monitoring programs. It will add substantial value to the data collected and reported by individual groups by allowing direct comparisons of results from one watershed to another. Establishing this common framework protocol will also improve data quality and consistency. In doing so, this protocol will also greatly enhance the value of information synthesized from existing and planned report card projects. Monitoring data may then also be integrated into additional, Chesapeake Bay-wide assessments.

Standardization of sampling and data analysis methods

The Mid-Atlantic Tributary Assessment Coalition (MTAC) was formed to better organize and coordinate Mid-Atlantic citizen monitoring programs that are interested in producing watershed or regional report cards. MTAC conducts monthly group meetings to share information and work toward reaching consensus on ecosystem health indicators for tidal and non-tidal watersheds; sampling methodology for measuring these parameters; and data analysis procedures for calculating report card scores. Current participating groups represent the Chester, Magothy, South, West/Rhode, Nanticoke, Sassafras, Gunpowder, Octoraro, Severn, and Anacostia Rivers, Maryland's Coastal Bays, and Baltimore's Inner Harbor. Other agencies and organizations involved in this effort include the Chesapeake Bay Program, National Oceanic and Atmospheric Administration (NOAA), University of Maryland Center for Environmental Science (UMCES), Maryland Department of Natural Resources (MD DNR), and the Chesapeake Bay Trust.

This protocol document was developed by MTAC (Figure 1.3), with technical guidance provided by scientists from UMCES, CBP, & MD DNR, who have extensive experience identifying indicators, analyzing data, and developing integrated assessments of ecosystem health. UMCES regularly partners with watershed organizations and citizen monitoring programs to assist in the production of tributary report cards.

This document provides guidelines for the successful production of non-tidal (watershed) ecosystem health report cards. Specifically, this document develops clear and consistent protocols for the identification, collection, and analysis of indicators to be used by report card-producing organizations in the Mid-Atlantic region.

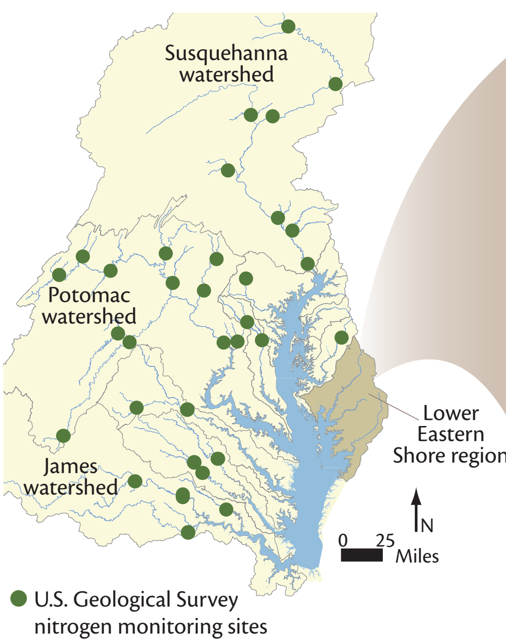


Figure 1.2a: The U.S. Geological Survey sampling site locations are located throughout the watershed. Information at this scale is used for Bay-wide health assessments.

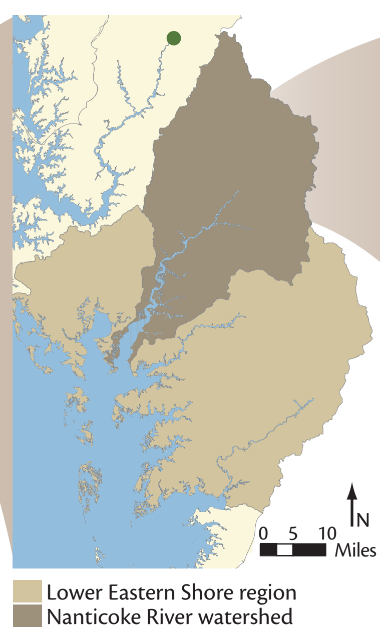


Figure 1.2b: The Lower Eastern Shore region, used in Bay-wide assessments, groups several smaller watersheds together because there are few or no sampling locations within the region.

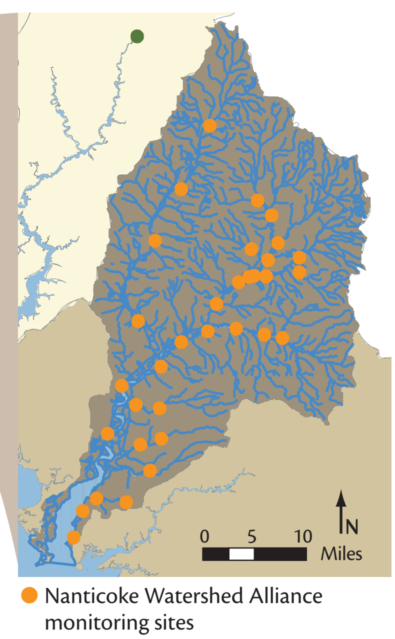


Figure 1.2c: The Nanticoke Watershed Alliance focuses on monitoring just the Nanticoke River and its streams, and therefore has a higher data density in that watershed than is provided by Bay-wide monitoring efforts.

Amy Pelsinsky

Figure 1.3. Members of the Mid-Atlantic Tributary Assessment Coalition (MTAC) meet once each month to discuss sampling methodology, data analysis, and report cards.

These watersheds have similar physical, chemical, and biological characteristics that allow for the application of standardized protocols. However, different ecoregions (e.g., Piedmont, Coastal Plain) often need different thresholds for the same indicator. The specific thresholds are provided in each indicator chapter. See the References and Further Reading section for more information. Protocols for tidal indicators have already been presented in a companion document (http://ian.umces.edu/press/publications/313/).

The methods in this document are recommendations for watershed organizations and are not intended to be prescriptive. While these protocols are not mandatory, they were established by consensus among the many groups currently producing report cards. It is hoped that groups both currently producing report cards, and those considering them can begin using this common framework. Sampling and data analysis for all indicators were discussed and agreed upon at the MTAC monthly meetings from 2011 to 2013.

General conclusions and recommendations for indicator sampling and analysis include:

- A sampling regime based on a random sampling design and targeted sampling sites.
- Minimum once monthly sampling for a minimum total of 12 samples per year. Non-tidal indicators should be measured year-round.
- Four core water quality indicators: total nitrogen, total phosphorus, conductivity, and turbidity.
- Three diagnostic, or vital signs indicators: dissolved oxygen, pH, and temperature.
- Two core pollution indicators: bacteria and trash. Bacteria and trash are measured for an annual assessment.
- One core habitat indicator: benthic macroinvertebrates. This indicator integrates a variety of physico-chemical and habitat parameters that makes it an ideal habitat indicator for non-tidal streams. It is also commonly measured by state and federal agencies and therefore a rich dataset may already exist. This indicator is measured for a two-year comprehensive assessment.

These indicators are relatively easy to measure, have reasonable lab costs, and are pertinent to most non-tidal watersheds. Core water quality indicators are measured for an annual assessment. See following chapters for details on each indicator. Elective indicators may be chosen by each reporting organization, and include those that may be difficult to measure, costly, or of particular importance to regional groups.

Organization of document

This document begins with a brief introduction to successful monitoring programs, followed by a discussion of quality assurance and quality control (QA/QC) procedures. It then details each of the core indicators, including field sampling methods and techniques, laboratory analyses, and data analyses. Finally, synthesis of data into indices and communication of results (i.e., report cards) are discussed.

Chapter 2: Organizing a successful monitoring program

This chapter addresses monitoring programs that seek to assess the ecosystem health of a local water system. Monitoring the health of these ecosystems is important because it informs management, local decision-makers, and residents and also provides direction to research. Integrating monitoring results via a report card or other communication product builds community knowledge, which is usually a cornerstone objective of watershed associations and citizen monitoring groups.

Additional information on the importance of standardizing sampling, analysis, and communication efforts is discussed in Chapter 1.

Establishing goals & objectives

The most critical step in the planning process for a monitoring group is to establish the goals and objectives of the program; every decision and action that follows will stem from this initial framework. For the purposes of this document, the overall goal of an effective monitoring program is to accurately assess the ecosystem health of a non-tidal (watershed) water system. In developing this kind of program, the following considerations must first be taken into account:

- Capacity (e.g., number of volunteers, availability of volunteers, accessibility of sampling site locations and sampling equipment, financial support) and
- Specific program objectives (e.g., to produce a river or stream report card, to contribute to larger assessments or mandated regulatory programs, to establish a baseline condition assessment).

Understanding an organization's capacity is critical to the program's success. The total number of employees in the program may be small or large, but the number of people that help with the actual monitoring, both paid and volunteer, is key. The number of people required to perform the monitoring must be determined. Staff and volunteers need to be properly trained and provided with appropriate equipment. Sampling locations must be determined (Figure 2.1). This process also includes assessing the financial support needed for continued monitoring. To keep costs reasonably low, many of the indicators discussed in this document only require basic equipment and can be easily measured by volunteers from docks and piers rather than from boats.

Objectives of a monitoring program may include providing a general picture of the ecosystem, establishing a baseline assessment against which to evaluate the impact of future changes, providing an early warning system (forecast) for threats or future changes, and/or evaluating if management actions (e.g., restoration, nutrient controls) result in a measurable difference (Longstaff et al. 2010).

Properly trained staff and volunteers, appropriate oversight and management, reliable and well-maintained instrumentation, and a valued and usable end product are all features of a successful monitoring program that matches its capacity to its objectives (Longstaff et al. 2010).

Recruiting, training, & retaining volunteers

In order to successfully recruit and retain volunteers, it is important to understand what motivates people to volunteer in the first place. Some people volunteer because they believe in the cause (in this case, ecosystem health, water quality, and watershed issues) and think it is important to be involved. Others volunteer because they enjoy social interaction with like-minded people, or because they enjoy learning new skills and knowledge that might help them grow in their career and/or personal lives.

Few aspects of a monitoring program are more important than the training of volunteers because proper training provides the background needed for a scientifically-sound and well-designed data collection effort.

Nanticoke Watershed Alliance

Figure 2.1. Volunteers monitor water quality off of a bridge in Laurel, Delaware, in a creek that drains into the Nanticoke River. Volunteers are a critical part of a monitoring program.

There are three broad types of volunteer training:

- introductory,
- quality assurance and quality control (QA/QC), and
- motivational sessions.

Introductory training should describe the monitoring program and teach standard methods for collecting and analyzing samples. Training on how to collect field samples should take place in the field to prepare volunteers for conditions that may be less predictable than those to which they are accustomed.

QA/QC training will help ensure consistency and reliability of data collected by volunteers. Such sessions should focus on proper techniques and ideally be offered two times per year.

Volunteer monitoring program "Do"s and "Don't"s

DO:

- *Have a team leader (and give him or her adequate time).* It takes time to build the proper framework for a successful program, but remember: don't re-invent the wheel! Call upon experts and draw from programs already in place.
- *Understand your volunteers' motivations.* Volunteers want what they're doing to be meaningful. Collecting and managing consistent, reliable data will ensure that.
- *Explain what you are asking your volunteers to do.* Prepare them by explaining that monitoring programs are highly involved and scientifically rigorous. They don't need to be scientists, but they do need to be willing to learn and follow the protocols in place.
- *Put it in writing.* Studies have shown that volunteers often want to be treated like paid staff. Provide them with formal descriptions and clear expectations.
- *Provide regular communications and support.* It is the program's responsibility to train, and provide ongoing support to, volunteers. Express appreciation for relevant contributions, address any widespread issues, and generally applaud what the volunteers are doing.
- *Get—and use—feedback from your volunteers.* Volunteers are a program's on-the-ground eyes and ears. They will know what's working and what's not.
- *Let volunteers grow or diversify.* Use their broad range of skills!
- *Keep in touch with "retired" volunteers.* Keep former volunteers on your mailing lists. Allow them the opportunity to return.

DON'T:

- *Let a recruitment opportunity pass you by.* Concerned citizens that call your program with questions are potential volunteers. Let them know what you're doing and ask if they'd like to help.
- *Take your volunteers for granted.* Provide enrichment activities or other gatherings on a regular basis to show your appreciation.

Motivational sessions may be held as needed to encourage the exchange of information between volunteers, identify any problems, and, of course, to motivate! Supplemental continuing education and re-training sessions are often helpful.

If sampling is conducted on a seasonal basis, training sessions for new volunteers and re-training for returning volunteers can be held before the sampling period begins, with a QA/QC session scheduled for the middle of the season, and motivational sessions as needed.

Retaining volunteers is also important to the success of a monitoring program. Finding and training volunteers takes time and effort, so losing volunteers can be a drain on the program's resources. In order for volunteers to feel compelled to continue with a monitoring program, volunteers must feel that their efforts are recognized, respected, and appreciated, and that their work is producing tangible, useful results. Producing a report card is a great way to use volunteer-collected data to achieve all of these things. Additionally, a retention plan can include incentives for longer-term volunteers, volunteer appreciation days, and other related activities.

Types of sampling

Once the goals and objectives of a monitoring program are established and volunteers have signed up to help monitor, a program needs to determine what indicators to measure and where to monitor. Water quality monitoring can be used to assess a wide variety of indicators, depending on the goals of the program and the type of water system. Regardless of the type of water system, a monitoring program should sample a set of core indicators that can be used to assess the health of that system.

Types of sampling include:

- basic water quality monitoring,
- nutrient monitoring,
- biological monitoring,
- sediment monitoring, and
- bacteria monitoring.

Basic water quality monitoring refers to indicators—such as temperature, dissolved oxygen, pH, and turbidity—that can typically be measured instantaneously with a multi-parameter instrument. Nutrient—chiefly nitrogen and phosphorus—and conductivity monitoring usually involves collecting water samples to be processed later by a laboratory. Biological monitoring involves sampling living resources, such as fish and benthic macroinvertebrates. Sediment monitoring requires taking samples from the bottom to analyze the content and make-up of the sediment. Bacteria monitoring usually requires water samples to be collected and analyzed at a laboratory.

Sampling considerations

Determining what to monitor and where to collect data is often decided upon in meetings and workshops, and by summarizing existing literature or surveying existing monitoring programs. Drawing on experts not only in the field of environmental science but also in the community will help monitoring programs to be well-rounded. Many sampling considerations focus on what pressures are occurring in the ecosystem and on what management actions are being taken to correct them. Measuring the health of an ecosystem is important for tracking changes resulting from these pressures and actions. Before beginning a sampling program it is important to consider the goals of the monitoring program and what questions or problems are trying to be solved.

Some programs have changed their sampling scheme after establishing their monitoring program, usually due to a higher capacity (e.g., more volunteers, more funding) to sample more areas. This is fine to do, as long as the new sampling scheme is communicated to the public and is well documented.

In general, a greater number of sites will result in a more accurate assessment. The goal is to maximize available resources, so do not go overboard with sampling. If volunteers commit to two hours a week, do not design a sampling run that will take four hours.

Many volunteer organizations do not have access to the shoreline directly, so data can collected from piers, docks, bridges, as well as the shoreline, if access is available. Always be mindful of safety and respectful of private property. One consideration when choosing sample sites is to look for areas where public roads cross streams. Remain in the public right of way to avoid trespassing on private property and be careful of traffic.

Spatial sampling scheme

In order to monitor the overall condition of an entire watershed, a random sampling design should be used. When a random sampling design is used, the information compiled can be easily compared between larger groups of rivers and watersheds, provided those use a random sampling design as well. Random site selection allows for the determination of ecosystem condition to be as unbiased as possible.

Although random sampling is preferable to obtain a representative assessment, targeted sampling may be used to evaluate specific issues. For example, monitoring downstream of a sewage treatment plant can give information on how that plant is operating. Several targeted sampling sites can be determined according to the needs of your specific waterway, however, these should not be included in the overall assessment. It may be tempting to target only problem areas; however, a random sampling regime will more accurately represent the true health of the ecosystem.

The recommended number of sampling sites in one watershed is 40 sites. With this many sites randomly distributed, you should see a clear picture of overall ecosystem condition. A minimum of 10 sampling sites is recommended for a reliable assessment. Depending on funding, staffing, and geographic constraints, the watershed can be broken up into smaller areas or sub-watersheds.

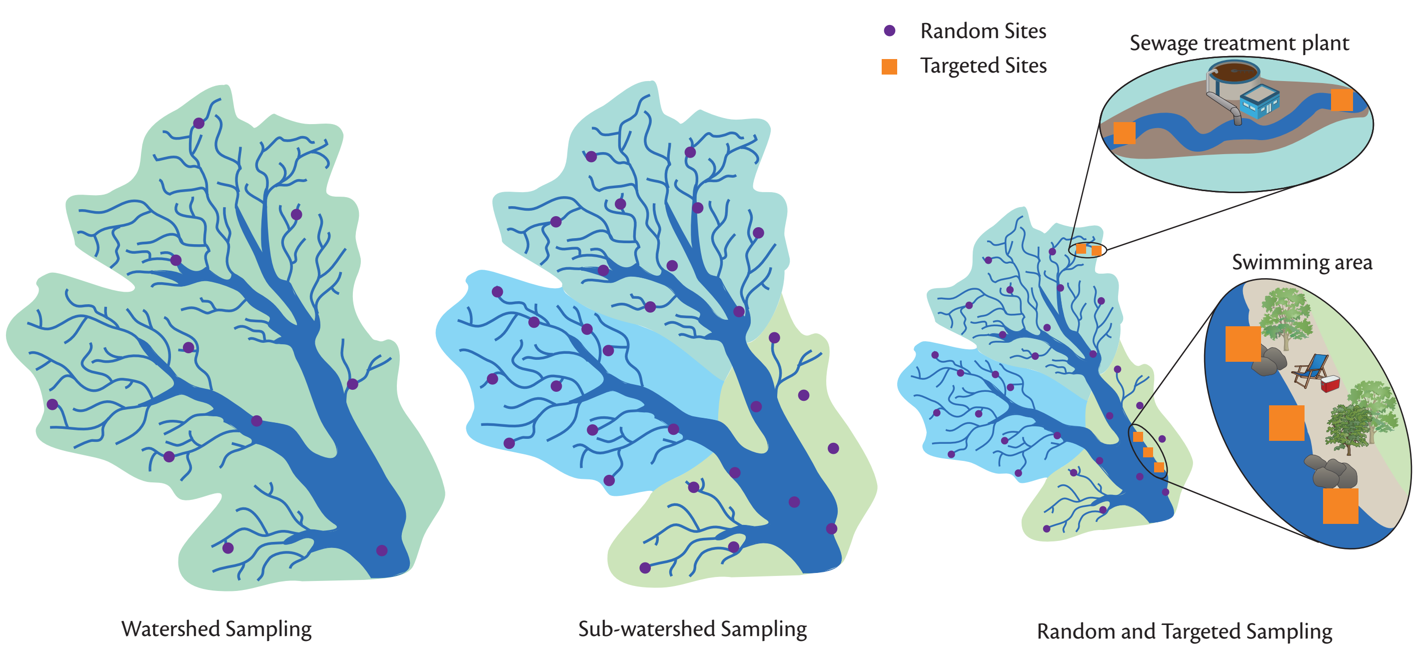


Figure 2.2. Site locations should be randomly selected for an unbiased condition assessment. A minimum of 10 sites should be chosen at either the watershed scale, or for each sub-watershed. Targeted sampling sites can also be selected to study specific issues, such as the safety of swimming areas or the effectiveness of a sewage treatment plant.

Within sub-watersheds, the same recommendations would apply to provide an overall view of each smaller area independently. For example, if a watershed is broken into 3 sub-watersheds, there should be 10 sampling sites in each sub-watershed (30 total). To express data at the sub-watershed level, there should be at least 10 sampling sites in each sub-watershed (Figure 2.2).

There are several ways to randomly select sites in a watershed. Statistical and mapping software can be used, although many times it is too expensive or unavailable. The easiest way to select sites randomly is to break watershed segments into sections of uniform length (e.g. 75 meters). Each section should be numbered, and then a random number generator (often free online, and included in spreadsheet software) can be used to pick sections where sites will be placed. Another consideration is the scale of the map that is used to identify streams in your watershed. The recommended scale is 1:100,000, which is used by the National Hydrography Dataset (http://nhd.usgs.gov/data.html).

Remember, once you have randomly selected your sites, you can adjust the location to public access points, if you don't have a boat to sample from, or stream side access.

Temporal sampling regime

To determine an appropriate sampling frequency, consider the variability of the indicators being assessed. Some indicators, such as dissolved oxygen and temperature, have daily cycles. Other indicators (i.e., turbidity, bacteria) tend to be episodic—they follow a pattern in that they are generally affected by precipitation events (i.e., precipitation often flushes increased sediment and bacteria loads into water systems).

Modern technology allows near-continuous monitoring of many indicators (e.g., multi-parameter data sondes can be deployed unattended and, with proper maintenance, can provide very accurate data). However, data are most valuable when they are properly captured, analyzed and interpreted, so be sure to reference your program's capacity for data collection and analysis.

For this protocol document, the recommended sampling frequency is twice per month year-round for all seven water quality indicators: nutrients, conductivity, turbidity, dissolved oxygen, pH, and water temperature. Additionally, it is recommended to include sampling during storm events once a quarter. Therefore, there will be at least four storm event samples for the entire year. However, recognizing funding and staffing constraints, the minimum sampling recommendation is once monthly in as many months as possible (Refer to Table 4.1). See Chapter 4 for more information and chapters 5–11 for specific indicator recommendations.

It is best to evenly distribute sampling within the specified time period. For example, it is not desirable to have four samples in one month and zero in the following month. Furthermore, monitoring should occur on the same day of the week at the same time each week. This increases the likelihood that data are consistent and reliable, and are not biased due to weather events or other influences on the measurement. Varied spatial and temporal scales among programs are resolved when comparisons are made at the region or sub-region level for individual indicators and index scores.

Once the monitoring program, including goals and objectives, volunteer recruiting, and the sampling regime, are planned, monitoring can begin! The first parameter that must be measured is streamflow.

Measuring streamflow


Maryland DNR


Doug Boyer

Figure 2.3. Examples of measuring streamflow throughout the Chesapeake watershed.

Streamflow is a key characteristic that must be accounted for when sampling in non-tidal streams (Figure 2.3). Chemical and physical processing varies with water flow. Flow also determines the total amount of a pollutant that is delivered downstream. Generally, streamflow tends to be higher in spring and fall. Precipitation events, such as snow melt, spring rainfall, and summer thunderstorms, and severe events like drought, tropical storms, and hurricanes all affect streamflow. Key pollutants delivered by rainfall and streamflow include nutrients, sediments, chemical contaminants, bacteria, and trash. Accounting for flow in stream sampling is essential. For pollutants, measuring concentration and streamflow together is the only way to provide the information necessary to determine the total amount of the pollutant delivered. For instance, low concentrations at high flow can deliver more of a pollutant than high concentrations and low flow.

Flow is defined as the total volume of water that flows past a specified point within a specified amount of time. A common unit of flow is cubic feet per second (cfs). Stream stage is defined as the height of the stream at any given time, and is commonly referred to as gage height. Discharge is another term for streamflow.

Field sampling procedures

There are many ways to measure flow, with large variation in accuracy of the measurement. In this protocol, we provide three options, based on complexity, cost, and personnel time.

NOTE: An important consideration for all field sampling in streams is the possibility of flash floods or dangerous conditions. Use extreme caution when conducting fieldwork in streams.

Option 1. Determine flow from nearest permanent stream gage station. Low cost, low time required

This option is available if there is a permanent stream gage station near your watershed (Figure 2.4). Because rainfall, and therefore streamflow, is often similar over a region, relative streamflow in one stream may be estimated from flow in a nearby stream. This option may be limited in several important ways: 1) Although relative streamflow (below average, average, above average) information may be determined, actual streamflow (cubic feet per second) cannot. Stream characteristics are far too variable to equate actual flow measurements among streams; 2) There may be no nearby stream gage station. A stream gage 10 miles away will provide much more relevant information than a stream gage 50–100 miles away; 3) Rainfall, and therefore streamflow, is highly variable regionally, particularly with summer storms. Rainfall in one region may have little similarity to rainfall in another region, even one nearby.

This option should be used to estimate relative stream conditions (low, medium, or high flow) and only if there is a stream gage station relatively nearby (<10 miles; Figure 2.5). The USGS maintains permanent gage stations which can be accessed at: http://waterdata.usgs.gov/nwis/rt. Organizations in Pennsylvania can access a streamflow estimator tool at http://pa.water.usgs.gov/projects/surfacewater/flow_estimation/.


USGS

Figure 2.4. A USGS gage station.

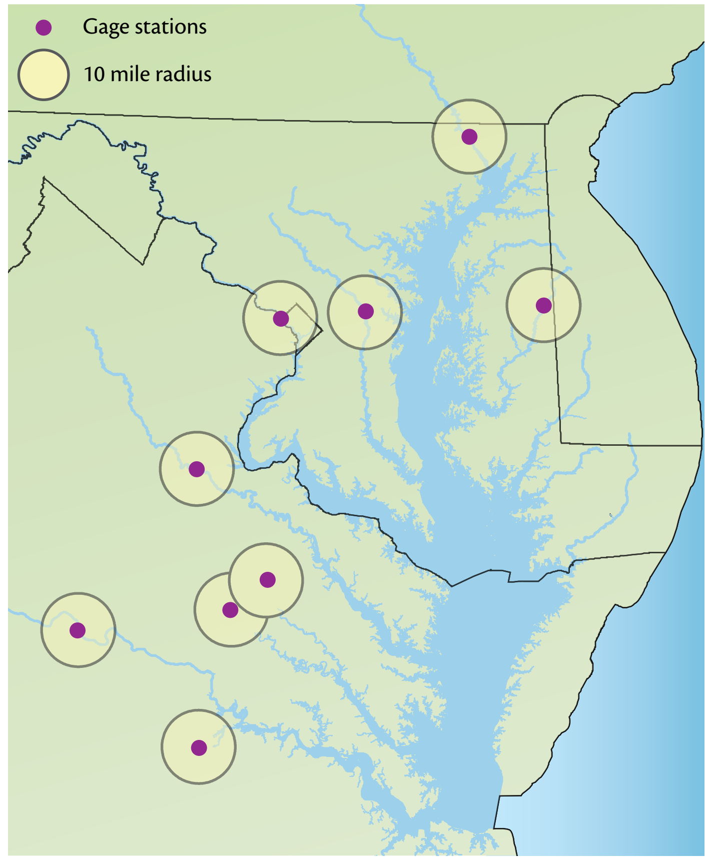


Figure 2.5. This map shows example gage stations around the Chesapeake Bay and a 10-mile radius around each station.

Option 2. Establish general flow range at low, medium, and high flow. Low cost, some time required

Recording general information as below average, average, or above average flow condition, can provide context for water quality measurements in a stream. This may require repeated observations of a stream under different conditions, and examining the stream banks for evidence of the range of stream heights that can be expected in a given stream. This provides important qualitative information such as the general streamflow condition when samples were taken.

To develop estimates of actual flow, relative stream flow can be taken one step farther. Flow can be determined by estimating both the cross-sectional area of the stream and the water velocity. Cross-sectional area can be estimated by assuming a triangular shape (with one vertex at the stream bed and two vertices on the stream banks), to estimate the stream width and depth (Figure 2.6). Velocity can be estimated by measuring the time required for a tennis ball

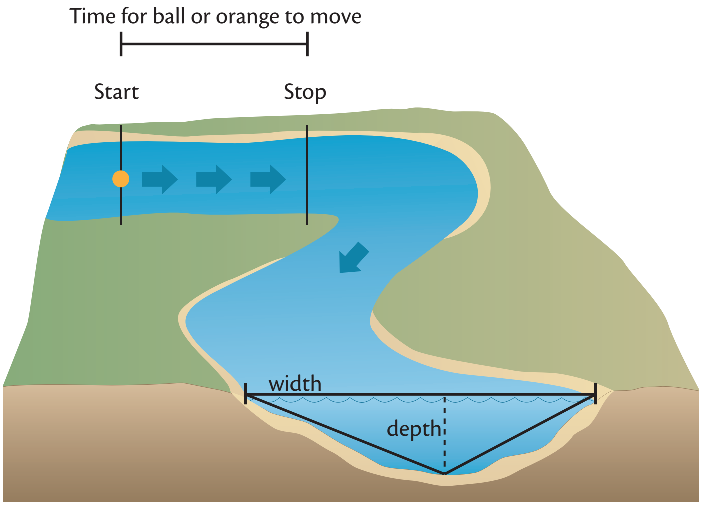


Figure 2.6. This conceptual diagram shows how to determine the relative streamflow, by measuring the velocity and the cross-sectional area of a stream.

or orange to float a given distance. Determine a starting point, start a stop watch, and stop the clock when the tennis ball reaches a designated stopping point. Divide the distance by the total seconds to get a velocity in feet per second. Multiply the velocity (in feet per second) by the cross-section area (in square feet) to estimate flow (in cubic feet per second). This should be repeated at relatively low, medium, and high flow periods to develop a range of estimated flows. These estimates have limited accuracy, however. Most streams do not have exactly triangular cross-sectional shapes, and water velocity varies with position in the water column and proximity to the stream edge and bottom (US EPA).

Option 3. Measure streamflow using a streamflow meter. Moderate cost, high time commitment

This option is similar to the extended version of Option 2, but is much more robust. For this method you need a stream flow meter. A streamflow meter is used to measure both the velocity and cross-sectional area of the stream at defined intervals. These are integrated into an overall flow measurement at the stream at a given time.

A streamflow meter has a probe on one end and a digital readout of measured flow (Figure 2.7). Although more expensive, a streamflow meter can be a shared instrument between watershed groups because they are only used periodically.

wildco.com

Figure 2.7. This photograph shows a streamflow meter that can be used to more accurately measure flow.

Flow should be measured using the manufacturers instructions at all sampling sites, repeatedly, and under different conditions (low, medium, and higher flows).

Establish a stream height to flow relationship

For each of the three measurement options, it is useful to develop a relationship between water height measured at a stream gage and flow measurements. By measuring streamflow and height at the same time under different conditions, a relationship can be developed that equates stream height with accurate calculations of flow. Subsequently, recording the water height at the stream gage provides an associated flow estimate (Figure 2.8). Re-calibrating the relationship between stream height and flow is necessary periodically (every two years or so), or when a stream undergoes obvious changes, such as modification/restoration or alteration from flood events.

USGS

Figure 2.8. A stream gage can be installed by securing it to bedrock to record the height of the water.

Chapter 3: Ensuring high quality data

> "A Quality Management Plan is a management tool that documents an organization's quality system for planning, implementing, documenting, and assessing the effectiveness of activities supporting environmental data operations and other environmental programs." —US EPA

Collecting data according to a scientifically credible method is necessary for the success of any water quality monitoring program. Good sampling practices ensure data validity and that data collected can be used to meet the program's goals and objectives.

If followed consistently, the methods described here can help ensure high data quality and enhance the value of data collected and information synthesized by monitoring programs.

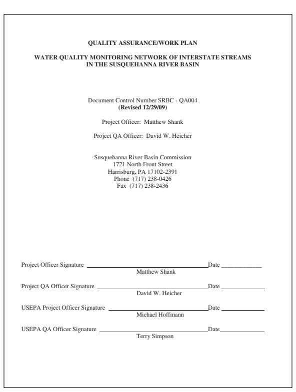
A quality assurance project plan is a key element of monitoring programs

A Quality Assurance Project Plan (QAPP) is an essential component of monitoring programs' sampling and reporting efforts (Figure 3.1). Every monitoring program should prepare a QAPP and revise it periodically to ensure that procedural changes are documented and that quality assurance is considered when these changes are made.

QAPPs should provide details for the following elements:

- project management,
- data generation and acquisition (i.e., sampling and sample analysis),
- assessment and oversight, and
- data validation.

Guidelines presented in this chapter were developed by experts and practitioners that use quality assurance and quality control (QA/QC) procedures on a regular basis. QA/QC procedures, which are common for monitoring programs, are intended to ensure that data are not lost or corrupted during transcription or analysis.


QUALITY ASSURANCE/WORK PLAN

WATER QUALITY MONITORING NETWORK OF INTERSTATE STREAMS
IN THE SUSQUEHANNA RIVER BASIN

Document Control Number SRBC - QA004
(Revised 12/29/09)

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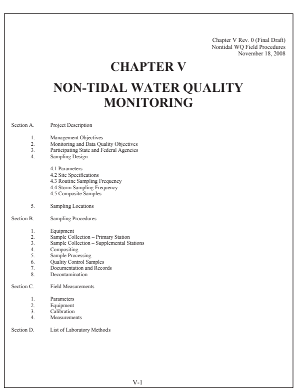
Chapter V Rev. 0 (Final Draft)
Nontidal WQ Field Procedures
November 18, 2008

CHAPTER V

NON-TIDAL WATER QUALITY MONITORING

Section A. Project Description

1. Management Objectives
2. Monitoring and Data Quality Objectives
3. Participating State and Federal Agencies
4. Sampling Design

4.1 Parameters
4.2 Site Specifications
4.3 Routine Sampling Frequency
4.4 Storm Sampling Frequency
4.5 Composite Samples

5. Sampling Locations

Section B. Sampling Procedures

1. Equipment
2. Sample Collection – Primary Station
3. Sample Collection – Supplemental Stations
4. Compositing
5. Sample Processing
6. Quality Control Samples
7. Documentation and Records
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Section C. Field Measurements

1. Parameters
2. Equipment
3. Calibration
4. Measurements

Section D. List of Laboratory Methods

V-1

Figure 3.1. Left: Example of a QAPP from the Susquehanna River Basin Commission. Right: Chesapeake Bay Program protocols help monitoring programs ensure that their data can be incorporated into the EPA's regulatory process.

Many of the recommendations presented in this chapter are intended to help create QAPP's for acceptance for EPA-funded projects. Please visit the Chesapeake Bay Program website (www.chesapeakebay.net) and state-specific websites for more information on requirements for data acceptance into program databases. Additional links to helpful documents are included in the References section.

High quality data are necessary to achieve objectives

One objective of many ecosystem health assessments is to inform citizens, local decision-makers, and other resource managers of scientific discovery in light of management objectives. If ecosystem health assessments are to influence public policy or citizen behavior, they must first be grounded in reliable, high quality data.

Many monitoring programs that provide data to constituents and resource managers may also make it available to wider scientific audiences. Only data with clear and rigorous quality management procedures will be acceptable if it is to be useful in these larger contexts. Samples should be collected using consistent, accepted methods and analyzed using scientifically accepted methods. It is essential to write a QAPP before implementing a monitoring program for these reasons.

Sampling Methods

Strategies for standardizing sampling schemes and methodologies are discussed in subsequent chapters of this document. Pre- and post-sampling calibration of monitoring instruments are necessary for consistent, reliable data. Data cannot be considered valid or acceptable without a rigorous instrument calibration protocol, and these calibration results should be recorded. Calibration procedures can normally be found within the instrument documentation. Documentation of sampling methods and calibration are important elements of a QA/QC program.

Good data management is important for quality assurance

After data are collected, they must be recorded and analyzed appropriately. This may involve:

- transferring data from data sheets or data loggers to spreadsheets or databases,
- grouping data for analysis to extract information, and
- integrating data to calculate scores and synthesize information.

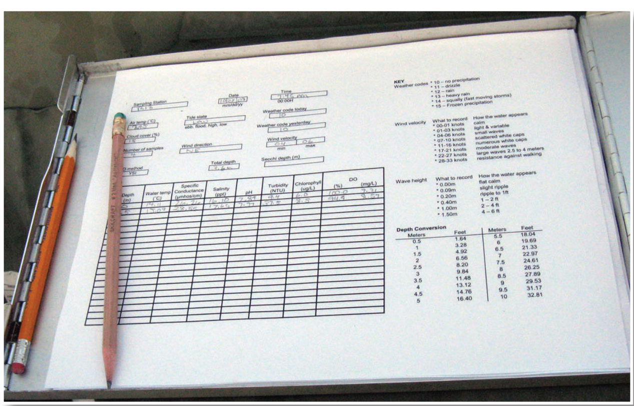
Each of these steps provides an opportunity for mechanical, human, or computational errors and requires attention to quality assurance measures to maintain good quality data (Figures 3.2 and 3.3).

To maintain reliable data, monitoring programs should:

- manually review data sheets and transferred data,
- keep unaltered, original data sheets in a secure location,
- flag unusual, blank, or out-of-range data values, and
- document analytical and integration objectives and methods.

Avoiding errors is critical when transferring data

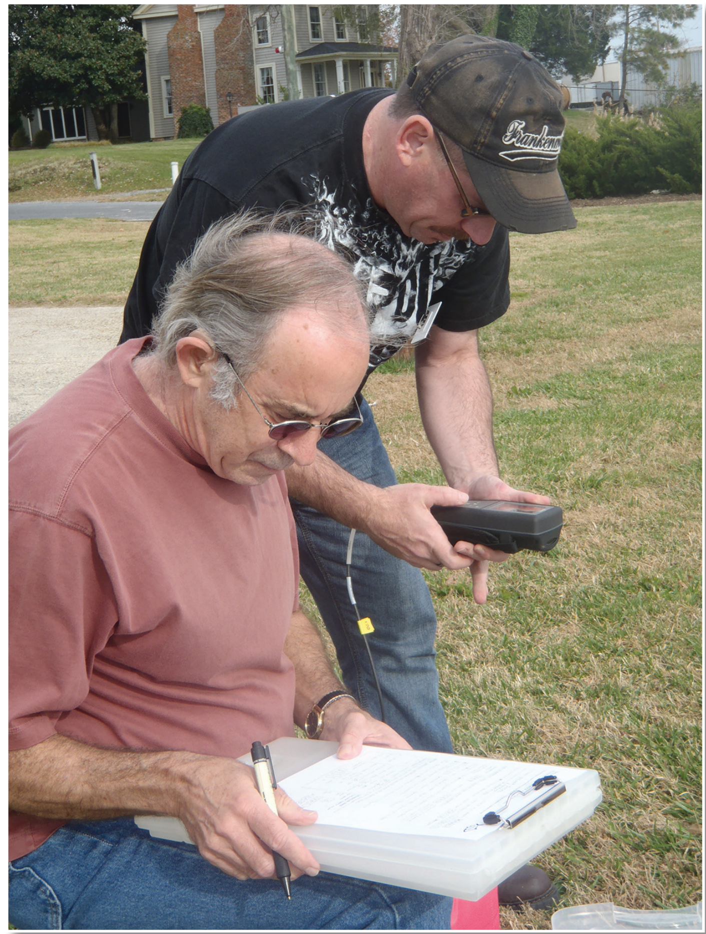
Transferring data from data sheets to spreadsheets or databases can be a tedious process—and one of the most common sources of errors. Poor handwriting, smudges and smears from field conditions, and tired samplers can all contribute to errors in data transcription. Care should be taken to ensure that the data are transcribed accurately. Make notes of handwriting questions or obscured values and ensure that they are addressed as soon as possible, while information is fresh in the field crews' minds. It is important to note that original data sheets are considered records and must not be altered in any way (Table 3.1). Original data should be stored on a CD or external hard drive and write-protected for security.



Caroline Wicks

Figure 3.2. Data sheets are filled out in the field and data need to be entered into a computer spreadsheet or database program (e.g., Microsoft Excel or Access). Avoiding numerical errors when transferring data is critical.

Transferring data from data loggers to spreadsheets or databases (Table 3.2) also can cause problems; errors are often invisible to the field or office personnel performing the transfer. Always confirm that the data are recorded in the spreadsheet or database correctly. One quick step is to double-check that the correct number of records is present. Twelve sampling stations should be accompanied by 12 data records—if these numbers do not match, there should be an explanation why. It is also a good practice to have another person with "fresh eyes" check the data for inconsistencies and/or incompleteness.



Nanticoke Watershed Alliance

Figure 3.3. Data are recorded on a field data sheet before being taken back to the office and put into a spreadsheet.

Most monitoring programs store and work with their data in a basic spreadsheet application (e.g., Microsoft Excel). Although spreadsheets are relatively easy to use, errors can nevertheless be quickly created and compounded. If unnoticed, even small errors lead to lost time and, in the worst cases, incorrect or misleading interpretations of data. To prevent misinterpretations or permanent data loss from spreadsheet errors, always save the original spreadsheet in multiple locations before working with the data, and "lock" the original spreadsheet so that it is protected and cannot be changed. Copy the spreadsheet to a new location for analysis and calculation of report card scores, and periodically refer back to the original, secured data to ensure that errors are detected and corrected if necessary.

Table 3.1. It is important to note the difference between documents and records. Original data sheets are considered records.

Document	Record
A document is a living thing.	A record, on the other hand, is history.
The information contained within a document is subject to change; it can be revised.	The information contained within a record cannot be changed, because it simply states what's already happened.

Table 3.2. Spreadsheets and databases are computer software programs that help manage and process data.

Spreadsheet	Database
A spreadsheet is a computer software program that simulates a piece of paper with rows and columns, with each cell containing either alphanumeric text or numeric values.	A database is a computer software program that stores, retrieves, and manipulates a collection of organized information in a regular structure.
e.g., Microsoft Excel ®	e.g., Microsoft Access ®

Alternatively, databases may also be used to store original data. Databases are generally more stable than spreadsheets (i.e., they are less likely to be affected by small errors in aligning data, or wholesale changes to columns or rows), and data can be extracted from databases to work within spreadsheet applications.

Once data are organized and ready for analysis, a good practice is to "flag" data values that are suspicious (e.g., extremely high or low values, or values completely out of the range of possibility). Expressions, or mathematical functions that use equations to determine certain outcomes, are useful tools to help identify unusually high or low values. In a spreadsheet, it is relatively easy to write an expression that searches a column for values exceeding a user-specified range. These values can be checked against data sheets or data loggers and investigated for accuracy.

Decisions to include or remove data are made on an individual basis, but in general, data should be excluded only if values are clearly outside the range of possible values, or if there are clear reasons to suspect that the data are incorrect (e.g., inconsistent or abnormal calibration information from data sheets). Because of data quality issues, only the most senior data analysts or program staff should decide if individual observations should be included in analyses. Decisions to include or exclude data should be clearly documented.

Chapter 4: Using core indicators

The previous chapters have provided a general overview of monitoring programs, spatial and temporal sampling considerations, and quality assurance/quality control procedures. These are critical steps that support the production of a report card. This chapter, and those following, discuss in detail how to sample and analyze the indicators that should be incorporated into a non-tidal (watershed) report card.

For non-tidal systems, there are several types of indicators that are needed to assess health. These include water quality (e.g., nutrients and conductivity), habitat (e.g., stream bank erosion, benthic macroinvertebrates), and biological (e.g., fish) indicators. In this document, we divide them into annually and periodically assessed indicators. Annual indicators include water quality and pollution indicators. Periodical (multi-year, decadal) indicators include habitat and biological indicators.

All the indicators in this protocol document (see Figure 4.1 and Table 4.1) were chosen by the Mid-Atlantic Tributary Assessment Coalition (MTAC) to be used by report card-producing organizations in the Mid-Atlantic region for watershed assessments. The indicators and the methods for evaluation are specifically chosen for non-tidal rivers and streams. They were chosen due to their ease of collection and communication, low cost, and, most importantly, the amount of information they convey about the ecosystem. They answer the question: "How is the system doing; is it healthy or unhealthy?"

The indicators are:

- total nitrogen and phosphorus
- conductivity
- turbidity
- dissolved oxygen, pH, and water temperature
- bacteria
- trash
- benthic macroinvertebrates

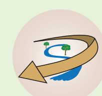
These indicators should be measured and analyzed by all monitoring programs that wish to compare the health of their watersheds with adjacent watersheds.

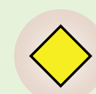
Sampling and data analysis

An overview and methods for sampling and data analysis are provided for each indicator in the following chapters. A summary table of preferred and minimum recommendations is provided here (Table 4.1).

Elective indicators

The indicators discussed in this document provide a consistent base for data comparisons among water systems. However, elective indicators, such as stream bank erosion, bottom habitat, and toxic contaminants, may also be measured if organizations have a particular interest in them.





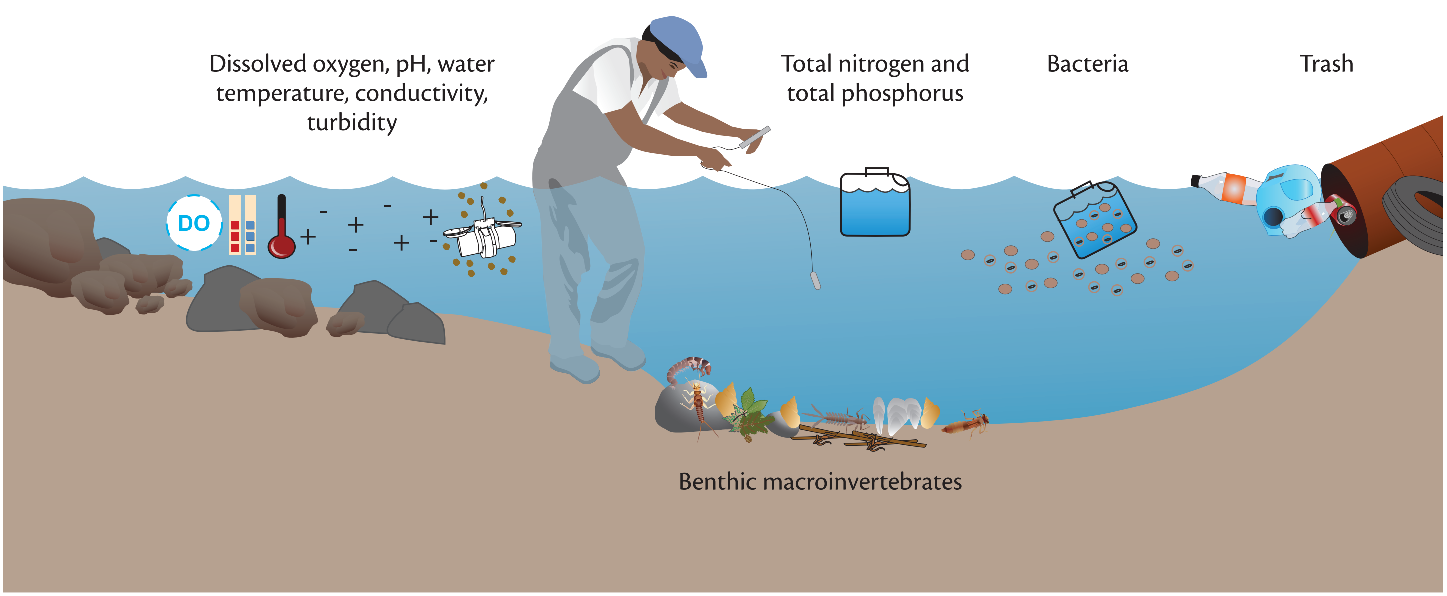


Figure 4.1. This conceptual diagram illustrates the indicators discussed in this document. They include water quality (e.g., dissolved oxygen, pH, temperature, conductivity, turbidity, and nutrients), pollution (e.g., bacteria, trash), and habitat (e.g., macroinvertebrates).

Table 4.1. Summary of preferred and minimum sampling recommendations for all indicators.

Indicator	Preferred sampling period	Preferred sampling resolution	Minimum sampling period (needed for data analysis)	Minimum sampling resolution	Storm event sampling
Total nitrogen, total phosphorus, conductivity, DO, pH, water temperature	Year round	Twice monthly	April–November	Once monthly	Once quarterly
Turbidity	Year round	Twice monthly	April–November	Once monthly	Once quarterly, twice in winter and spring preferred
Benthic macroinvertebrates	Year round	Once quarterly	N/A	N/A	Not necessary
Bacteria	Year round	Twice monthly	April–November	Once monthly	Once quarterly
Trash	Year round	Twice monthly	April–November	Once monthly	Once quarterly

The recommended amount of samples taken is twice monthly, or higher. The more samples taken, the more accurate the assessment of the watershed. However, if groups do not have enough resources to measure twice or more a month, once monthly sampling may be conducted so that there are enough samples from which to calculate an average. Additionally, some samples should be taken during or right after storm events, since rainfall and run off affect these indicators. Sampling should occur for at least one storm event (1 inch of rainfall in 24 hours) per quarter.

Due to funding and time constraints of watershed organizations, it is understood that a group may only have enough capacity to sample just once per month (the minimum recommended amount). Therefore, this protocol also provides a minimum sampling effort that is required to adequately assess and score the indicators.

When sampling in rivers and streams, it is important to sample in the middle of the stream. Do not take your sample from the sides of the stream or in areas of ponding.

Figure 4.2. Sampling should be conducted from the middle of the stream, whether that is from a bridge or through wading.

Sampling from bridges or by wading are the two most common ways to sample (Figure 4.2). Do not enter fast moving water or sample in inclement weather if conditions are unsafe.

Since sampling for most indicators should occur year round, there may be some cases in which the water has frozen over in the winter. If the water has frozen solid, do not attempt to break through the ice to sample unless you have special training. Never walk on a frozen river or stream even if you think it will hold your weight.

In this protocol, we recommend one sample or holding the probe directly below the surface for each indicator. Samples should be taken facing upstream, and on the upstream side of the bridge, to prevent contamination from the bridge structure. While it is better to have depth-integrated measurements of each indicator for the best representative sample, funding and time constraints may prevent this. During low flow conditions, one sub-surface sample matches well with depth-integrated sampling. At high flow conditions, however, a single sample is not as representative of stream conditions as depth-integrated sampling. Depth-integrated sampling is when a sample is taken at various depths (for example every 6 inches or every foot) at one site. These measurements are averaged together to have an integrated sample over the entire depth at the site.

Thresholds

Assessment thresholds are determined using information from previous studies

The reporting framework used in this protocol is similar to other assessments done by the University of Maryland Center for Environmental Science, and requires that data values be assessed in relation to specific ecological thresholds of significance (Table 4.2). The thresholds are significant because they represent the point where prolonged exposure to unhealthy conditions leads to

Table 4.2. The core indicators used in this protocol and examples of threshold values used to compare observed data to the reference community.

Health indicator	Example threshold value	Comparison of data to threshold
TN Total nitrogen	<0.64 mg·l⁻¹	= Proportion of data that meets threshold values for each indicator
TP Total phosphorus	<0.01 mg·l⁻¹	
Conductivity	≤42 µsiemens ·cm⁻¹	
Turbidity	<3 NTUs	
DO Dissolved oxygen	>5.0 mg·l⁻¹	
pH	>6.5 & <8.5	
Water temperature	<68˚F (20˚C)	
Bacteria	≤235 organisms ·100 ml⁻¹	
Trash	N/A	
Benthic community	IBI = 3.0	

a negative ecosystem response (Longstaff et al. 2010). Thresholds described in this document were derived from peer-reviewed scientific articles and consultation with Chesapeake Bay non-tidal analysts (ICPRB 2011; US EPA 2000 a; US EPA 2000 b; US EPA 2000 c).

These recommendations provide one way of measuring the indicators and analyzing data so that each system's results are comparable. Exceptions and other unforeseen reasons that an indicator could be measured or analyzed in a way different than recommended are explained in breakout boxes throughout the document, or in an addendum.

Scoring of data

The recommended time period for non-tidal data is year round. All samples collected within a calendar year should be included in data analyses. Once thresholds have been identified, data are scored using either a pass/fail or multiple threshold method. Ideally, multiple thresholds are used to provide some gradation of results from poor to excellent, rather than just pass or fail, but this may not be appropriate for all indicators.

Pass/Fail scoring method

A pass/fail scoring method is a simple method used to calculate indicator scores based on the percent of measurements that met an ecologically relevant threshold. The process is outlined in Figure 4.3, using dissolved oxygen as an example, and results in a score on a scale of 0 to 100%, where the higher percentage values represent more healthy conditions (Williams et al. 2008).

One disadvantage of using a pass/fail method is that it doesn't describe how close a failing value is to passing. For example, if a dissolved oxygen measurement is 4.9 mg·l⁻¹, it fails because the threshold is 5.0 mg·l⁻¹. However, it is much closer to passing than a value of 1.0 mg·l⁻¹.

Multiple thresholds

Multiple thresholds are used to score indicators based on a gradient of healthy to unhealthy conditions (Table 4.3). For example, total phosphorus is an indicator of the water system. However, the amount of phosphorus, from acceptable levels, to

1. Sort data by station

Station	Date	Time	DO value
Strecker Rd (PC-70)	4/22/12	15:00	16.0
Strecker Rd (PC-70)	5/21/12	10:00	7.0
Strecker Rd (PC-70)	6/18/12	9:45	7.0
Strecker Rd (PC-70)	11/18/12	9:40	8.0
Harris Rd (PC-60)	4/22/12	16:50	14.0
Harris Rd (PC-60)	5/21/12	19:50	8.0
Harris Rd (PC-60)	6/19/12	7:00	7.0
Harris Rd (PC-60)	8/20/12	15:00	10.0
Harris Rd (PC-60)	11/18/12	17:25	7.0

2. Calculate the score for each data point
Ex: If DO>5.0 mg l⁻¹, then Score = Pass (or 100)

Station	Date	Time	DO value	Threshold (mg/L)	Score
Strecker Rd (PC-70)	4/22/12	15:00	16.0	5.0	100
Strecker Rd (PC-70)	5/21/12	10:00	7.0	5.0	100
Strecker Rd (PC-70)	6/18/12	9:45	7.0	5.0	100
Strecker Rd (PC-70)	11/18/12	9:40	8.0	5.0	100
Harris Rd (PC-60)	4/22/12	16:50	14.0	5.0	100
Harris Rd (PC-60)	5/21/12	19:50	8.0	5.0	100
Harris Rd (PC-60)	6/19/12	7:00	7.0	5.0	100
Harris Rd (PC-60)	8/20/12	15:00	10.0	5.0	100
Harris Rd (PC-60)	11/18/12	17:25	7.0	5.0	100

3. Calculate the score for each station
Ex. ((Total # of scores = Pass)/(Total # of scores for that station))*100 = % total

Station	Date	Time	DO value	Threshold (mg/L)	Score	Station Score
Strecker Rd (PC-70)	4/22/12	15:00	16.0	5.0	100	100
Strecker Rd (PC-70)	5/21/12	10:00	7.0	5.0	100	
Strecker Rd (PC-70)	6/18/12	9:45	7.0	5.0	100	
Strecker Rd (PC-70)	11/18/12	9:40	8.0	5.0	100	
Harris Rd (PC-60)	4/22/12	16:50	14.0	5.0	100	100
Harris Rd (PC-60)	5/21/12	19:50	8.0	5.0	100	
Harris Rd (PC-60)	6/19/12	7:00	7.0	5.0	100	
Harris Rd (PC-60)	8/20/12	15:00	10.0	5.0	100	
Harris Rd (PC-60)	11/18/12	17:25	7.0	5.0	100	

4. Calculate sub–watershed scores by averaging all station scores per sub–watershed.

Station	Station Score	Sub-Watershed	Sub-Watershed Score
Strecker Rd (PC-70)	100	Main Stem	96.2
Harris Rd (PC-60)	100	Main Stem	
Patten Tract Rd (PC-50)	100	Main Stem	
Bogart Rd (PC-40)	90	Main Stem	
Columbus Ave (PC-30)	100	Main Stem	
Oakland Cemetery (PC-25)	83.5	Main Stem	
Perkins Ave (PC-20)	100	Main Stem	

5. To calculate overall watershed score, sum the sub–watershed values weighted by % of total area.

Region	Score	Area (sq ft)	Percent	Weighted Score
Main Stem	96.21	16.16	33.32	32.05677526
East Creeks	99.39	9.1	18.76	18.64843299
West Creeks	93.72	23.24	47.92	44.90830515
Pipe Watershed	95.61	48.5	100.00	95.6135134

Figure 4.3. A pass/fail scoring method is a simple way to score some indicators.

Table 4.3. Core indicators discussed in this document that are measured against multiple thresholds include total nitrogen, total phosphorus, conductivity, and turbidity. Measurements are compared against multiple thresholds, then scored from zero to five. The score is then converted into a grade scale.

	Multiple Thresholds		Grade	% Score
	5	Pristine condition		
			A	80 – 100
	4			
			B	60 – <80
Measured indicator value	3			
			C	40 – <60
	2			
			D	20 – <40
	1			
			F	<20
	0	Impaired condition		

just a little bit too much, to a truly excessive amount, can have different effects on the ecosystem. Therefore, when the measured value of total phosphorus is compared to multiple thresholds, it can score high, medium, or low. This is similar to a grading scale, in which an A is excellent, a B is good, and a C is average. In this way, indicators can be assessed with greater precision than using a pass/fail method.

Multiple thresholds can be determined analytically in a number of ways, which are described for each indicator in detail in Addendum I.

Scores are standardized to 0–100% scale

In order to integrate individual indicator scores into a more encompassing index (e.g., a water quality index), scores are standardized to a 0–100% scale. This allows indicators with different score classes to be easily combined. For instance, one indicator may have three appropriate thresholds that are useful, while others may have five. By converting each to 0–100%, the results can be combined into an overall index.

A score for a reporting region is calculated by averaging all station scores within the region. An overall (i.e., system-wide) score can be calculated as the area weighted average of regional scores.

Grading scale

Once each indicator is compared against the multiple threshold table, assigned a score, then averaged into the sub-region score (see individual indicator chapters), a grade can be assigned. For the *ecological indicators* in this protocol, the grading scale follows the Chesapeake Bay report card scale of 0–100%, with equal interval breaks (Table 4.4). This was determined through consensus meetings with the Chesapeake Bay Program. Grades are equally divided to provide a clearer picture of health. Following the typical school grading scale (<60% = F, 60-70% = D, etc.) would result in consistently failing grades, which does not provide information about small improvements or declines in ecosystem health. The equally divided grading scale and multiple thresholds both allow evaluation of small changes in ecosystem health, even in the very poor, poor, and moderately poor ranges. A narrative description of the major categories are provided, which relate the grade to ecological health (Figure 4.6).

Table 4.4. A grade and description are assigned based on the score that the indicator or sub-watershed achieves.

Score (%)	Grade	Description
=100	A+	Very Good
≥95 – <100	A+	Good
≥85 – <95	A	Good
≥80 – <85	A–	Good
≥75 – <80	B+	Moderately Good
≥65 – <75	B	Moderately Good
≥60 – <65	B–	Moderately Good
≥55 – <60	C+	Moderate
≥45 – <55	C	Moderate
≥40 – <45	C–	Moderately Poor
≥35 – <40	D+	Poor
≥25 – <35	D	Poor
≥20 – <25	D–	Poor
≥0 – <20	F	Very Poor

A — All water quality and biological health indicators meet desired levels. Water quality in these locations tends to be very good, most often leading to very good habitat conditions for fish and shellfish.

B — Most water quality and biological health indicators meet desired levels. Water quality in these locations tends to be good, often leading to good habitat conditions for fish and shellfish.

C — There is a mix of good and poor levels of water quality and biological health indicators. Water quality in these locations tends to be fair, often leading to fair habitat conditions for fish and shellfish.

D — Some or few water quality and biological health indicators meet desired levels. Water quality in these locations tends to be poor, often leading to poor habitat conditions for fish and shellfish.

F — Very few or no water quality and biological health indicators meet desired levels. Water quality in these locations tends to be very poor, most often leading to very poor habitat conditions for fish and shellfish.

Figure 4.6. Descriptions of ecological health that correspond with each grade.

For the bacteria indicator in this protocol, the grading scale does not follow the overall watershed report card scale, but rather follows the traditional 10-point intervals (Table 4.5). Since bacteria is a human health indicator, a stricter grading scale was needed to ensure that bacteria scores were communicated properly to the public. See the Chapter 9 for more information on bacteria.

Table 4.5. Scoring and description for bacteria indicator.

Score	Narrative
100	Excellent
90 – <100	Good
80 – <90	Moderate
70 – <80	Moderately Poor
60 – <70	Poor
<60	Very Poor

Summary

This overview of the core indicators, sampling specifications, and thresholds should provide a general understanding of this protocol. The following chapters provide more detail and step-by-step instructions for the collection, analysis, and assessment of each indicator.

TN TP Chapter 5: Measuring Nutrients

Nutrients such as nitrogen and phosphorus occur naturally in both freshwater and saltwater. Plants and animals need nutrients to grow and survive. Nutrients are important for the growth of organisms in the environment, but as nutrient levels increase in rivers and streams, they can negatively impact the environment. Elevated levels of phosphorus and nitrogen in streams can result from fertilizer use, animal waste, septic systems, wastewater treatment plants, and air pollution (Figure 5.1).

Organisms living in rivers and streams can also be affected by nitrogen in the form of ammonia and ammonium. Ammonia is harmful to aquatic life and can accumulate in fish and other organisms. Excess nutrients entering streams and rivers can also cause impacts downstream in tidal areas (Figure 5.2)

When nutrients are in excess, turbidity increases and sunlight cannot get into the stream or river. Algal blooms occur in areas of pooled water and these blooms can lead to toxic conditions for other organisms. For example, some strains of an algae called *Microcystis* produce toxins that result in health problems to animals that drink the water, and minor skin irritation and gastrointestinal discomfort in humans that come in contact with toxic blooms. Additionally excess nutrients in rivers and streams can travel into the groundwater and drinking water supply.

Using total nitrogen and phosphorus as nutrient indicators allow a direct measurement of nutrient enrichment since these are the main nutrient contaminants in the non-tidal areas of Chesapeake Bay watersheds.

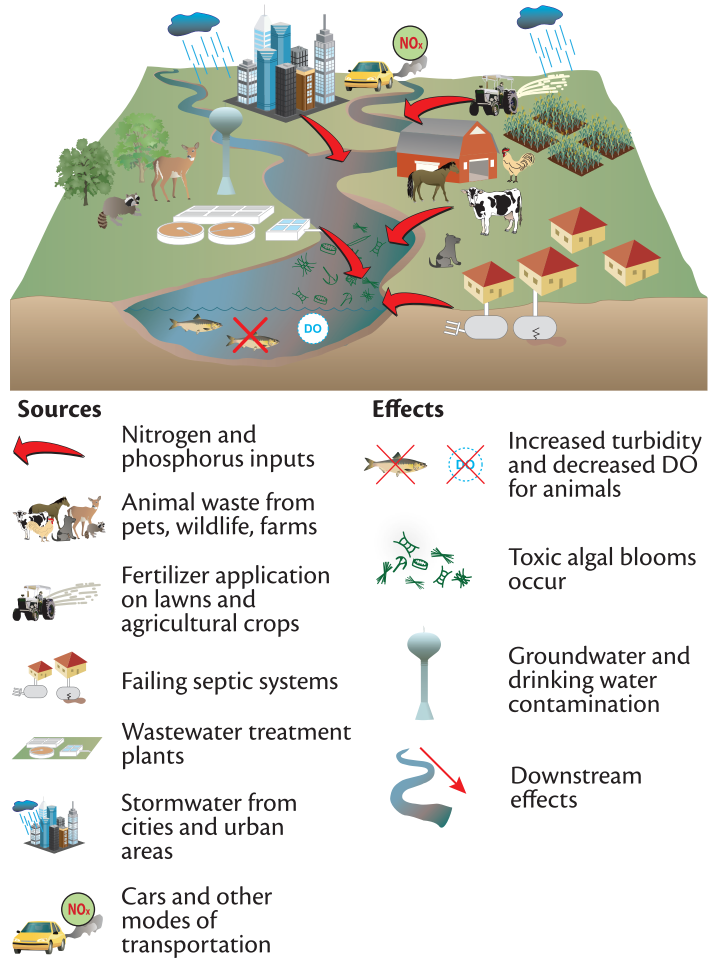


Figure 5.2. This conceptual diagram expresses sources of nutrients in streams and effects caused by excess nitrogen and phosphorus.

Joanna Woerner

Figure 5.1. Fertilizer from residential lawns and farms is a large source of extra nutrients entering rivers and streams.

Field sampling procedures

While there are many forms of nitrogen and phosphorus in the water column, for this protocol, it is recommended that total nitrogen and total phosphorus be measured and analyzed as indicators of water quality. This provides a picture of nutrients as a whole, and therefore the processes that they affect. Nitrogen and phosphorus interact with one another and then impact organisms in the environment, so evaluating them together is recommended.

In the Mid-Atlantic region, total nitrogen and total phosphorus should be assessed year-round. Sampling should be conducted at least once a month at all sites (Figure 5.3). Samples should be taken in both clear and inclement weather. During storms with rainfall greater than one inch in twenty four hours, sampling should be conducted at as many sites as possible. Try to sample at least one storm per quarter (four per year) if possible.

Conduct sampling on a regular schedule. On the same week of every month, there should be a small window of days when sampling occurs regardless of

Peggy Greb

Figure 5.3. A researcher collects a water sample in the Choptank River Watershed.

weather conditions. Sampling should occur twelve times per year, independent of weather, unless there are unsafe conditions. Including data from both dry and wet weather in the analysis provides for an overall health assessment of the river or stream. This will be reported as a frequency of attainment. Evaluating data separately for only dry weather dates is also useful for identifying hot spots and for trend analysis such as comparison between rivers and between years.

Sampling equipment

Adherence to sample collection protocols is crucial to obtain accurate sample results and to ensure the integrity of the nutrient monitoring process. Each group should follow the procedures set by the analytical laboratory where their samples will be analyzed. Select the appropriate sampling scheme based on stream flow conditions and safety. Here are some general guidelines:

- 1-liter sampler bottles with caps: Different bottles are needed for wading versus sampling from a bridge.
- Pre-cleaned polyethylene bottles, as specified by the laboratory. Make sure bottles are clean and do not use bottles for low concentrations after they have been used for high concentration samples.
- Bucket for grab sample
- Extendable pole or rope
- Cooler with ice
- Hand filters or vacuum pump, if needed
- Chest waders, if needed

Sample collection from bridge or overpass

1) Water samples should be taken in the middle of the river or stream on the upstream side of the bridge. Samples should be taken 0.5 meters (1.5 feet) below the surface, avoiding getting near the bottom.
2) At sites with depths less than 0.5 meters (1.5 feet), water samples should be taken at approximately 60% depth below the surface.
3) Facing upstream, lower the rope and bucket, rinse the bucket three times, then collect the sample the fourth time.
4) Divide the grab sample into bottles for nutrient analysis. Measure other water quality parameters within the bucket water.
5) After nutrient samples are taken, immediately place the sample on ice up to the shoulders of the bottle. The lid should not be immersed under the ice, in case ice water leaks into the sample bottle, diluting the concentration of the sample. It is good procedure to put the samples in clean plastic bags that can be sealed while they are in the cooler, which prevents contamination from the ice/water/slush in the cooler and/or other samples. It is important to note that when freezing samples the water contained in the container will expand. If too much water is placed in the sample container, the lid may pop off or the sample may leak out, and contamination may occur (Figure 5.4).
6) If possible, one set of duplicate samples should be taken for quality assurance/quality control purposes. An example of how this is labeled would be: Station 1, depth below surface, duplicate.
7) On the field data sheet, record the time, date, and any other information about the water sampling event.

Beth Wasden

Figure 5.4. Labeled water samples are placed in a cooler with ice to preserve the integrity of the sample.

Sample collection in a stream or river (through wading)

1) Water samples should be taken in the middle of the river or stream on the upstream side of the bridge. Samples should be taken 0.5 meters (1.5 feet) below the surface, avoiding getting near the bottom.
2) At sites with depths less than 0.5 meters (1.5 feet), water samples should be taken at approximately 60% depth below the surface.
3) Wade into the middle of the river or stream. Always use waders and do not enter the water if there is inclement weather or unsafe conditions.
4) Attach the sample bottle to the sampling pole, making sure that the clamp is tight.
5) The sampling point in the stream or river should have a low to medium flow and not be in eddies or stagnant water.
6) Facing upstream, extend the pole and bottle, rinse the bottle out three times, and take the sample the fourth time.
7) Fill the bottle up to the shoulders and immediately cap and place on ice. The lid should not be immersed under the ice, in case ice water leaks into the sample bottle, diluting the concentration of the sample. It is good procedure to put the samples in clean plastic bags that can be sealed while they are in the cooler. This prevents contamination from the ice/water/slush in the cooler and/or other samples. It is important to note that when freezing samples the water contained in the container will expand. If too much water is placed in the sample container, the lid may pop off or the sample may leak out and contamination may occur.
8) If possible, one set of duplicate samples should be taken for QA/QC purposes. An example of how this is labeled would be: Station 1, depth below surface, duplicate.
9) On the field data sheet, record the time, date, and any other information about the water sampling event.

Laboratory analysis

Samples should be mailed overnight to arrive at the analytical laboratory as soon as possible. If properly packaged and frozen, nutrient samples can be stored for up to 28 days. The package should also be marked to indicate "nutrient samples" as contents. Field analysis of total nitrogen and total phosphorus is not recommended.

Data analysis

Once samples have been analyzed in the lab, a spreadsheet of data will be provided. *The thresholds for total nitrogen and total phosphorus are different, so make sure the appropriate thresholds are being used.* A set of multiple thresholds has been determined for nitrogen and phosphorus (Table 5.1 and Table 5.2). These threshold levels are based upon how benthic organisms are affected by increasing nutrient levels. For total nitrogen and total phosphorus, each measurement is separated into ecoregion and compared to a corresponding set of thresholds. The five most relevant ecoregions are Mid-Atlantic Coastal Plain, Southeastern Plain, Piedmont, Ridges, and Valleys. To determine in which ecoregion(s) your river or stream sites are located see Addendum II. For nitrogen and phosphorus analysis, these five ecoregions are combined into two groups. The two major groups are 1. Piedmont, Valleys, and Ridges; and 2. Coastal Plain (Mid-Atlantic Coastal Plain, Southeastern Plain; ICPRB, 2011).

Applying thresholds to individual sites allows determination of total nutrient condition. Each data point is compared to the thresholds in the appropriate table and scored from 0–5. Each measurement score (0–5) is averaged into a station score for the entire year. Then, station scores are averaged into a sub-watershed score. Once the sub-watershed score is calculated, calculate the total overall score by area-weighting each sub-watershed score and averaging them for an overall watershed score. For example, we can consider an example Site x, located in the Piedmont ecoregion. The total nitrogen measured at Site x was 1.70 $mg{\cdot}l^{-1}$. So when looking at Table 5.1, we can compare to the threshold levels to see which range the measurement falls into. For total nitrogen, Site x is greater than 1.65 but less than 2.15, so it scores a 3.

Table 5.1. Ecologically relevant multiple thresholds for TOTAL NITROGEN by ecoregion.

Score	Piedmont, Valleys, & Ridges ($mg{\cdot}l^{-1}$)	Coastal Plain ($mg{\cdot}l^{-1}$)
5	<0.64	<0.82
4	≥0.64 – <1.65	≥0.82 – <1.52
3	≥1.65 – <2.15	≥1.52 – <2.22
2	≥2.15 – <2.65	≥2.22 – <2.66
1	≥2.65 – <3.66	≥2.66 – <3.61
0	≥3.66	≥3.61

Table 5.2. Ecologically relevant multiple thresholds for **TOTAL PHOSPHORUS** by ecoregion.

Score	Piedmont, Valleys, & Ridges ($mg \cdot l^{-1}$)	Coastal Plain ($mg \cdot l^{-1}$)
5	<0.01	<0.02
4	≥0.01 – <0.03	≥0.02 – <0.06
3	≥0.03 – <0.05	≥0.06 – <0.09
2	≥0.05 – <0.06	≥0.09 – <0.12
1	≥0.06 – <0.09	≥0.12 – <0.17
0	≥0.09	≥0.17

A summary of steps for calculating total nitrogen and total phosphorus scores is:

1) For nitrogen and phosphorus, the sampling period is year-round with once-a-month sampling.
2) Make sure the appropriate thresholds for total nitrogen and total phosphorus are used.
3) Assign scores of 0–5 to each sampling value.
4) Average the 0–5 scores for a station score.
5) Calculate sub-watershed scores by averaging the scores of the stations in each sub-watershed. Remember that 10 sampling sites are needed for each sub-watershed, so average to the sub-watershed level if possible, but otherwise average to the watershed level if not.
6) Assign a grade to each sub-watershed or watershed score (see Chapter 4 for grade scale).

If you have a score for each sub-watershed, you can determine the average % score and grade for the overall watershed by area-weighting the sub-watershed scores.

1) Determine the percent-area for each sub-watershed. For example: sub-watershed 1 area = 5 km^2 , divide by the total watershed area of 20 km^2 = 0.25.
2) Multiply the sub-watershed proportion (0.25) by the sub-region score (76%) to equal 19%.
3) Sum the resulting sub-watershed scores into an overall watershed score.
4) Based on the overall score, assign a grade for the entire watershed.

For health assessments, it is recommended that measurements for each station are scored and the % passing for each station is calculated. This method is followed so that a station that has many more measurements than others is not weighted more heavily than others. For example, if one site has 12 measurements all year and another site has 5, the site with 12 measurements would have more influence on the final average nitrogen or phosphorus score than the site with 5 measurements if the values were averaged over the whole region. However, if the percent passing is calculated for each station, the % passing scores are equally weighted.

Chapter 6: Measuring Conductivity

Conductivity is a measurement of ion concentration in water. When conductivity levels are high, the ecosystem cannot physiologically maintain a salt balance. This affects organisms living in a river or stream. Plants and animals are not adapted to high concentrations of ions in the water. Conductivity levels directly stress organisms since they cannot regulate the water and salt content within their cells. This stress can change the diversity of species in the ecosystem. Conductivity also influences other abiotic factors in the environment such as pH. As conductivity increases, the pH of the water decreases, becoming more acidic.

The amount of dissolved ions is measured by how much they interact with each other in the water, which is called electrical conductivity (Figure 6.1). The constituents involved are solid materials that wash into a stream and dissolve. Even though you cannot physically see the ions, when they increase in number, they are contaminating the water with a suite of different chemicals. The main components that increase conductivity are positive ions (calcium, magnesium, sodium, and potassium) and negative ions (bicarbonate, carbonate, chloride, and sulfate). Conductivity is a sensitive indicator that demonstrates a direct source of pollution (Figure 6.2). The main sources of high conductivity are mining, hydraulic fracturing, road salts, wastewater treatment plants, stormwater runoff, and human waste pollution (Figure 6.3).

In Karst regions, such as the mountains of Virginia, there can be high levels of conductivity naturally. This is due to the ions from the geologic features in the area eroding and flowing into the water. In highland streams, pH can be lower due to acid rain and other issues in the ecosystem.

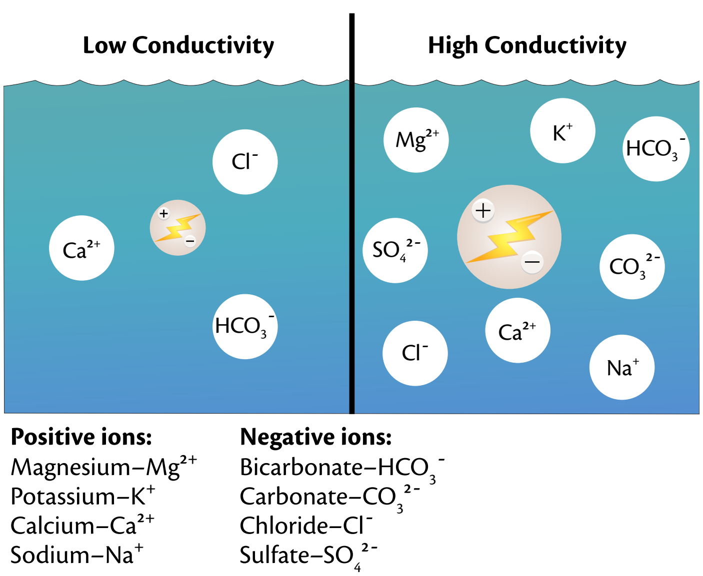


Figure 6.1. When different chemicals dissolve into the water of rivers and streams, their ions increase the conductivity of the water.

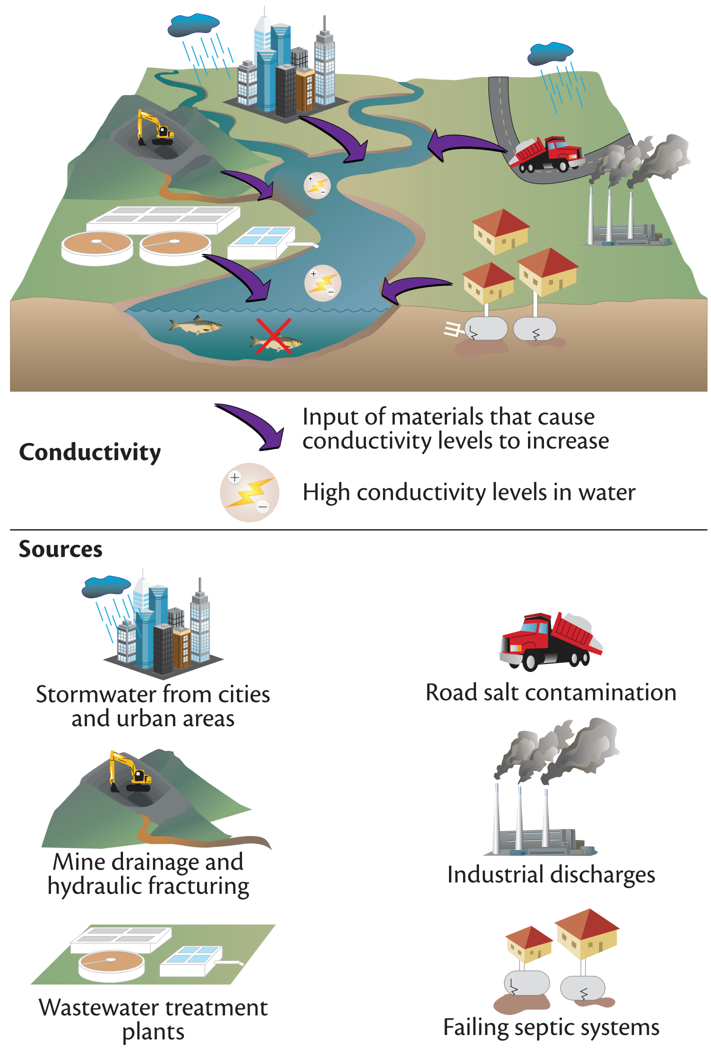


Figure 6.2. This conceptual diagram illustrates sources of ions that increase conductivity levels in water.

Organisms in these areas can be adapted to low pH and high conductivity, but this is due to adaptation over time. It is doubtful that unadapted organisms would be able to survive in these conditions.

Field sampling procedures

Sampling should be conducted at least once a month at all sites. Samples should be taken in both clear and inclement weather. During storms with rainfall greater than one inch in twenty four hours, sampling should be conducted at as many sites as possible. Try to sample at least one storm per quarter (four per year) if possible, but especially storms during winter and spring.

Conduct sampling on a regular schedule. On the same week of every month, there should be a small window of days when sampling occurs regardless of weather conditions. Sampling should occur 12 times per year,

Brent Walls

Figure 6.3. Discharge from the Upper Potomac River Commission wastewater treatment plant is expelled from a submerged pipe into the North Branch of the Potomac River. Wastewater treatment plant discharge can be a source of conductivity problems.

independent of weather, unless there are unsafe conditions. Including data from both dry and wet weather in the analysis provides for an overall health assessment of the river or stream. This will be reported as a frequency of attainment. Evaluating data separately for only dry weather dates is also useful for identifying hot spots and for trend analysis such as comparison between rivers and between years. In the Mid-Atlantic region, conductivity should be assessed year-round.

Sample equipment

- 1-liter sampler bottles with caps, if needed: different bottles are needed for wading versus sampling from a bridge
- Pre-cleaned polyethylene bottles, if needed, as specified by the laboratory: make sure bottles are clean and do not use bottles for low concentrations after they have been used for high concentration samples
- Bucket for grab sample
- Extendable pole, or rope
- Chest waders, if needed
- Conductivity meter

Sampling procedure

Adherence to sample collection protocols is crucial to obtain accurate sample results and to ensure the integrity of the conductivity monitoring process. Conductivity is measured using a meter. If there are not enough meters for *in situ* monitoring, water samples can be collected and brought back to the office for analysis. Before going in the field, the meter should be calibrated.

1) Prepare the conductivity meter for use according to the manufacturer's directions.
2) Use a conductivity standard solution (potassium chloride or sodium chloride) to calibrate the meter. Use the manufacturer's directions to correctly prepare the calibration solution.
3) Rinse the conductivity probe with deionized or distilled water.
4) Select the appropriate range beginning with the highest range and working down. Read the conductivity of the water sample. If the reading is in the lower 10 percent of the range, switch to the next lower range.

If measuring conductivity directly in stream:

1) Water samples should be taken in the middle of the river or stream on the upstream side of the bridge. Samples should be taken 0.5 meters (1.5 feet) below the surface, avoiding getting near the bottom.
2) At sites with depths less than 0.5 meters, water samples should be taken at approximately 60% depth below the surface.
3) Facing upstream, lower the probe end of the meter into the water, making sure to disturb the water as little as possible.
4) Lower the sensor into the water and gently move it up and down to dislodge bubbles. Continue moving until the value on display stabilizes.
5) If sampling from a bridge, be sure to sample in the middle of the stream in areas of low to medium flow. If the water is shallow, sampling should be done through wading.
6) Record the date and time of sampling on data sheet.

Laboratory analysis

Samples that are taken back to a lab need to be tested within 28 days of collection. If bringing samples back to the office for analysis, follow these steps:

1) Once back in the office, mix the sample bottles gently.
2) Uncap the bottle, insert the conductivity probe, and record the data on the datasheet.
3) If the conductivity of the sample exceeds the range of the probe, dilute the sample. The manufacturer's instructions should have steps on how to properly perform the dilution. The dilution might not have a simple linear relationship, so be sure to check the instructions.
4) Rinse the probe with deionized or distilled water.

Data analysis

First, temperature affects conductivity. If the conductivity meter automatically compensates for temperature, use the data directly. However, if it does not or if the samples were brought back to the office, the conductivity data needs to be adjusted using the water temperature data collected at the same time as the conductivity data.

Data from the laboratory results are analyzed to calculate a percent of samples below the appropriate threshold. A set of multiple thresholds has been determined for conductivity. These threshold levels are based upon how conductivity levels impact organisms in the environment. For conductivity, each measurement is separated by ecoregion and compared to a corresponding set of thresholds (Tables 6.1–6.4). The four most relevant ecoregions are Piedmont, Valleys, Ridges, and Coastal Plain (which includes Mid-Atlantic Coastal Plain, and Southeastern Plain; ICPRB 2011).

Applying these thresholds to individual sites allows determination of total conductivity condition. Each data point is compared to the thresholds in the appropriate table and scored from 0–5. Each measurement score (0–5) is averaged into a station score for the entire year. Then, station scores are averaged into a sub-watershed score. Once the sub-region score is calculated, calculate the total overall score by area-weighting each sub-watershed score and averaging them for an overall score. A summary of steps for calculating conductivity scores is:

1) For conductivity, the sampling period is year-round with once-a-month sampling.
2) Make sure the appropriate threshold for conductivity is used.
3) Assign scores of 0–5 to each sampling value.
4) Average the 0–5 scores for a station score.
5) Calculate sub-watershed scores by averaging the scores of the stations in each sub-watershed. Remember that 10 sampling sites are needed for each sub-watershed, so average to the sub-watershed level if possible, but otherwise average to the watershed level if not.
6) Assign a grade to each sub-watershed or watershed score (see Chapter 4 for grade scale).

If you have a score for each sub-watershed, you can determine the average % score and grade for the overall watershed by area-weighting the sub-watershed scores.

1) Determine the percent-area for each sub-watershed. For example: sub-watershed 1 area = 5 km^2 , divide by the total watershed area of 20 km^2 = 0.25.
2) Multiply the sub-watershed proportion (0.25) by the sub-region score (76%) to equal 19%.
3) Sum the resulting sub-watershed scores into an overall watershed score.
4) Based on the overall score, assign a grade for the entire watershed.

For health assessments, it is recommended that measurements for each station are scored and the % passing for each station is calculated. This method is followed so that a station that has many more measurements than others is not weighted more heavily than others. For example, if one site has 12 measurements all year and another site has 5, the site with 12 measurements would have more influence on the final average conductivity score than the site with 5 measurements if the values were averaged over the whole region. However, if the percent passing is calculated for each station, the % passing scores are equally weighted.

Table 6.1. Ecologically relevant multiple thresholds for conductivity for the Piedmont ecoregion.

Conductivity (µsiemens cm^{-1})	Score
≤42	5
>42 – ≤100	4
>100 – ≤158	3
>158 – ≤249	2
>249 – <544	1
≥544	0

Table 6.2. Ecologically relevant multiple thresholds for conductivity for the Valleys ecoregion.

Conductivity (µsiemens cm^{-1})	Score
≤49	5
>49 – ≤137	4
>137 – ≤267	3
>267 – ≤430	2
>430 – <626	1
≥626	0

Table 6.3. Ecologically relevant multiple thresholds for conductivity for the Ridges ecoregion.

Conductivity (µsiemens cm^{-1})	Score
≤21	5
>21 – ≤66	4
>66 – ≤130	3
>130 – ≤214	2
>214 – <521	1
≥521	0

Table 6.4. Ecologically relevant multiple thresholds for conductivity for the Coastal Plain (Mid-Atlantic and Southeastern) ecoregion.

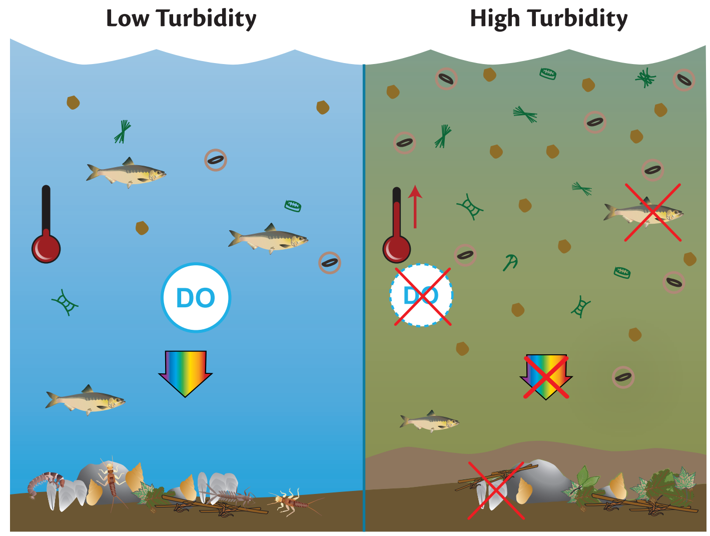
Conductivity (µsiemens cm^{-1})	Score
≤56	5
>56 – ≤108	4
>108 – ≤182	3
>182 – ≤257	2
>257 – <526	1
≥526	0

Chapter 7: Measuring Turbidity

Turbidity is a measure of water clarity which expresses how much light passes through the water column. It is dependent upon the amount of suspended particles (e.g., sediment, algae, bacteria) and colored organic matter present. Clear water is critical for the growth and survival of fish, crabs, and other aquatic organisms.

However, clear water should not be confused with the color of the water. Black water systems, for example, have highly colored water, but that is a natural phenomenon and is not an indication of eutrophication or sedimentation.

High turbidity levels are caused by a combination of different sources such as stream bank erosion, in-stream erosion, agricultural runoff, construction site runoff, urban runoff, stormwater, and excess algal growth (Figure 7.1). Turbidity indicates sedimentation, which decreases light and covers habitat for organisms in the river or stream. Physiological effects can also occur, such as decreased dissolved oxygen in the water and increased water temperatures. Water temperatures increase because the suspended particles absorb more heat. Dissolved oxygen levels are affected since warm water can hold less dissolved oxygen than cold water (Figure 7.2). Some of the particles that make up the turbidity in the water are directly detrimental to the environment, like bacteria, toxics, pollutants, and sediment. All of these things stress organisms and can cause habitat loss (Figure 7.3).



Turbidity is caused by particles suspended in the water. Some of these particles are sediments, plankton, and bacteria. High turbidity causes temperature to increase since particles in the water absorb more heat than water molecules. This reduces the dissolved oxygen (DO) in the water because cold water holds more DO than warm water. Light availability decreases, and fish and benthic organisms become smothered.

Figure 7.2. This conceptual diagram illustrates problems caused by high turbidity.

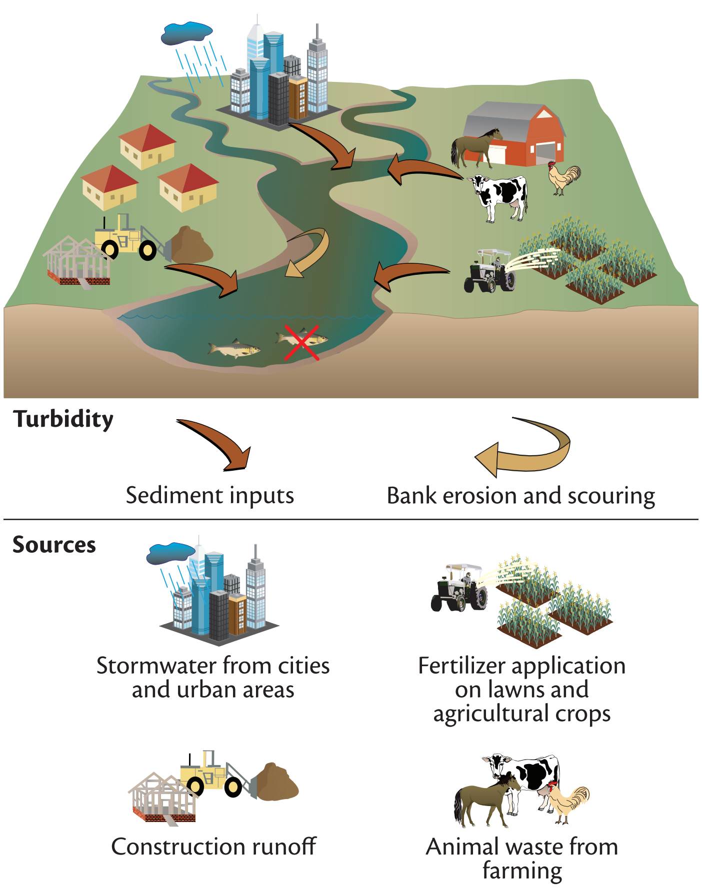


Figure 7.1. Turbidity can be caused by a variety of sources.

Field sampling procedures

Sampling turbidity should be conducted at least once a month at all sites. Samples should be taken in both clear and inclement weather. During storms with rainfall greater than one inch in twenty four hours, sampling should be conducted at as many sites as possible. Try to sample at least one storm per quarter (four per year) if possible but especially storms during winter and spring.

Conduct sampling on a regular schedule. On the same week of every month, there should be a small window of days when sampling occurs regardless of weather conditions. Sampling should occur 12 times per year, independent of weather, unless there are unsafe conditions. Including data from both dry weather and after rainfall in the analysis provides for an overall health assessment of the river or stream. This will be reported as a frequency of attainment. Reporting data for only dry weather dates is also useful for identifying hot spots and for trend analysis such as comparison between rivers and between years.

Ron Melcer

Figure 7.3. High turbidity levels in the Chesterville Branch of the Chester River.

In the Mid-Atlantic region, turbidity should be assessed year-round. Turbidity is measured using a turbidity meter. Specific steps are provided in the next section.

Sample equipment

- Turbidity meter
- Chest waders, if needed
- 1-liter sampler bottles with caps: Different bottles are needed for wading versus sampling from a bridge
- Bucket for grab sample, if needed
- Extendable pole or rope, if needed

Sampling procedure

Adherence to sample collection protocols is crucial to obtain accurate sample results and to ensure the integrity of the turbidity monitoring process. Turbidity is measured using a meter in the river or stream. Units should be measured in Nephelometer Turbidity Units (NTU). Before going in the field, the meter should be calibrated.

1) Prepare the turbidity meter for use according to the manufacturer's directions.
2) Use a turbidity standard solution to calibrate the meter. Use the manufacturer's directions to correctly prepare the calibration solution.
3) Rinse the turbidity probe with deionized or distilled water.
4) Water samples should be taken in the middle of the river or stream on the upstream side of the bridge. Samples should be taken 0.5 meters (1.5 feet) below the surface, avoiding getting near the bottom.
5) At sites with depths less than 0.5 meters, water samples should be taken at approximately 60% depth below the surface.
6) Facing upstream, lower the probe end of the meter into the water, making sure to disturb the water as little as possible.
7) If sampling from a bridge, be sure to sample in the middle of the stream in areas of low to medium flow. If the water is shallow, sampling should be done through wading.
8) If sampling via wading, carefully wade out to the middle of the stream, making sure to minimize disturbance of the bottom sediments and the water column. Avoid taking measurements near the stream banks or in high velocities.
9) Record the date and time of sampling on data sheet.

Some turbidity meters can not be used by placing the probe directly in the water. For these meters, a water sample must be taken from a bridge or overpass, or through wading.

1) Take a water sample, with either a bucket or a sample bottle.
2) Then shake the sample vigorously.
3) After the bubbles have disappeared, pour the sample into the tube.
4) Wipe the tube with a lint free cloth and place it into the turbidity meter, which reads the turbidity measurement.
5) Record the measurement along with the date and time of sampling on the data sheet.

Data analysis

Data from field sampling are analyzed to calculate a percent of samples below the appropriate threshold. A set of multiple thresholds has been determined for turbidity. These threshold levels are based upon how turbidity levels impact organisms in the environment. For turbidity, each measurement is compared to a corresponding set of thresholds.

Applying these thresholds to individual sites allow determination of total turbidity condition. Each data point is compared to the thresholds in Table 7.1 and scored from

Table 7.1. Ecologically relevant multiple thresholds for turbidity.

Turbidity (NTUs)	Score
<3	5
≥3 – <4.75	4
≥4.75 – <6.5	3
≥6.5 – <8.25	2
≥8.25 – <10	1
≥10	0

0–5. Each measurement score (0–5) is averaged into a station score for the entire year. Then, station scores are averaged into a sub-watershed score. Once the sub-region score is calculated, calculate the total overall score by area-weighting each sub-watershed score and averaging them for an overall score. A summary of steps for calculating turbidity scores is:

1) For turbidity, the sampling period is year-round with once a month sampling.
2) Make sure the appropriate threshold for turbidity is used.
3) Assign scores of 0–5 to each sampling value.
4) Average the 0–5 scores for a station score.
5) Calculate sub-watershed scores by averaging the scores of the stations in each sub-watershed. Remember that 10 sampling sites are needed for each sub-watershed, so average to the sub-watershed level if possible, but otherwise average to the watershed level if not.
6) Assign a grade to each sub-watershed or watershed score (see Chapter 4 for grade scale).

If you have a score for each sub-watershed, you can determine the average % score and grade for the overall watershed by area-weighting the sub-watershed scores.

1) Determine the percent-area for each sub-watershed. For example: sub-watershed 1 area = 5 km^2 , divide by the total watershed area of 20 km^2 = 0.25.
2) Multiply the sub-watershed proportion (0.25) by the sub-region score (76%) to equal 19%.
3) Sum the resulting sub-watershed scores into an overall watershed score.
4) Based on the overall score, assign a grade for the entire watershed.

For health assessments, it is recommended that measurements for each station are scored and the % passing for each station is calculated. This method is followed so that a station that has many more measurements than others is not weighted more heavily than others. For example, if one site has 12 measurements all year and another site has 5, the site with 12 measurements would have more influence on the final average turbidity score than the site with 5 measurements if the values were averaged over the whole region. However, if the percent passing is calculated for each station, the % passing scores are equally weighted.

Vital signs indicators: DO, pH, & water temperature

Dissolved oxygen

Dissolved oxygen (DO) is a key indicator of ecosystem health. Nearly all aquatic animals need adequate DO in the water to survive (Figure 8.1). DO is biologically essential for benthic and fish community health. Even aquatic plants can be harmed if the water around their roots is low in DO. Low dissolved oxygen levels can also cause changes in water chemistry that may trigger the release of nutrients from sediments into the water column.

In non-tidal rivers and streams, DO is not a sensitive indicator, but it is something that is important to measure and track. The DO of a stream can be considered a basic vital sign, or the pulse describing the health of that waterbody. Measuring DO can show that there is a serious problem with the stream if the DO scores are low. Low DO is often a result of eutrophication—excess nutrients in the water fuel algal blooms, and when the algae die and decompose, the decomposition process uses up DO. Problems with low DO can occur due to increased temperatures (warm water holds less oxygen). Low DO can occur in areas that are ponded, or slow moving; flowing water always has more DO than stagnant water (Figure 8.2).

pH

Dissolved oxygen can be combined with pH and temperature as a suite of vital sign indicators that give a picture of the basic health of a river or stream. The pH of a stream expresses the acidity or alkalinity of the water. It provides a measure of the aquatic life and habitat suitability of a stream. A pH level that is out of normal range for the stream will be harmful to plants and animals living there.

The pH can be an indicator of point source pollution, such as discharge from mining. There is generally lower pH levels in highland areas, and pH can have some seasonal variability that is important to record. The water's pH level can interact with nutrients such as nitrogen and phosphorus. Phosphorus can be more readily released from sediments if pH levels are low, and higher pH can increase nitrification rates.

Roman Jesien

Figure 8.1. A fish kill due to near-zero dissolved oxygen levels in Worcester County, Maryland.

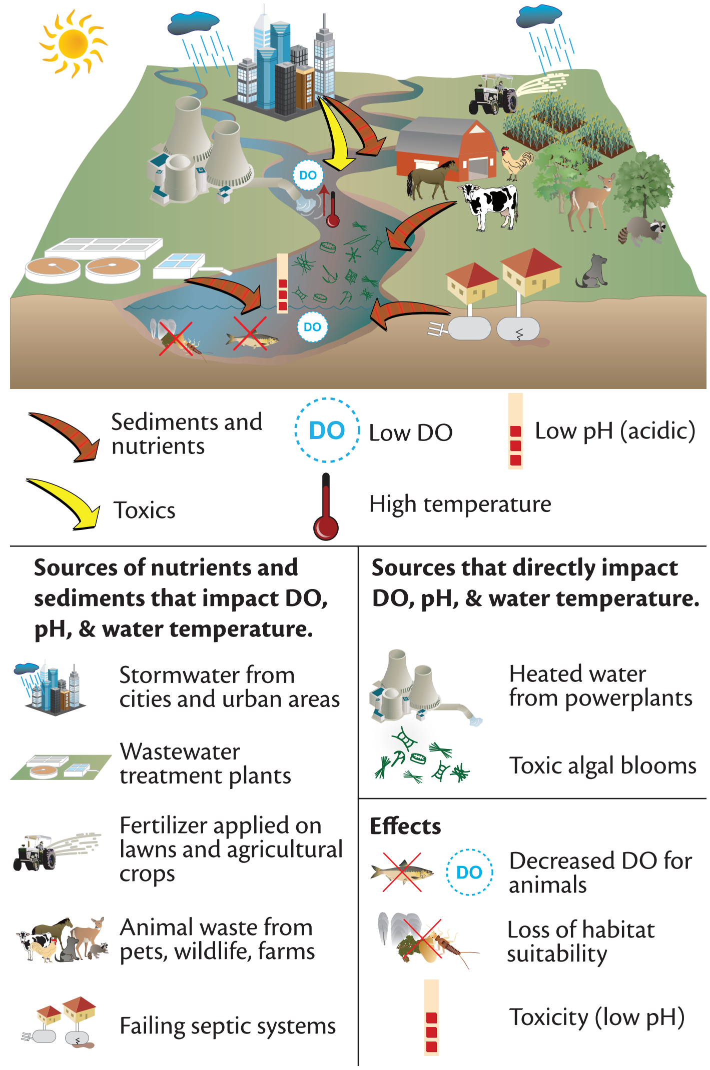


Figure 8.2. This conceptual diagram illustrates sources and effects of poor dissolved oxygen, pH, and water temperature levels.

Water temperature

Temperature is another indicator that is a vital sign of rivers and streams. Water temperature influences habitat suitability, fish communities, and dissolved oxygen levels. Spikes of high and low temperature negatively impact organisms living in the stream, but they do not necessarily have a cumulative effect. Variations in temperature can occur on a rapid scale, especially in areas that are not shaded. If a factory is expelling hot water into a stream, for example, this can affect the habitat suitability. Because of normal temperature variability, sampling needs to be consistent and occur at the same time during the day.

Field sampling procedures

Dissolved oxygen, pH, and temperature sampling should be conducted at least once a month at all sites (Figure 8.3). Samples should be taken in both clear and inclement weather. Conduct sampling on a regular schedule. On the same week of every month, there should be a small window of days when sampling occurs regardless of weather conditions. Sampling should occur 12 times a year, independent of weather unless there are unsafe conditions. Including data from both dry and wet weather in the analysis provides for an overall health assessment of the river or stream. This will be reported as a frequency of attainment. Reporting data for only dry weather dates is also useful for identifying hot spots and for trend analysis such as comparison between rivers and between years.

In the Mid-Atlantic region, vital signs indicators should be assessed year-round, using a meter. Using litmus paper is not recommended. Specific steps are provided in the next section.

Sample equipment

- DO, pH, water temperature meter
- Chest waders, if needed.

Sample procedure

Multi-parameter meters, such as YSI sondes, are typically used to measure DO, pH, and water temperature. The general procedure for measuring these parameters in the field using a meter is as follows:

1) The probe must be calibrated prior to use. Turn on the meter and toggle to calibration mode. Refer to the manufacturer's instructions for the proper calibration procedure.
2) Water samples should be taken in the middle of the river or stream on the upstream side of the bridge. Samples should be taken 0.5 meters (1.5 feet) below the surface, avoiding getting near the bottom.
3) At sites with depths less than 0.5 meters (1.5 feet), water samples should be taken at approximately 60% depth below the surface.
4) If sampling from a bridge, be sure to sample in the middle of the stream in areas of low to medium flow. If the water is shallow, sampling should be done through wading.
5) If sampling via wading, carefully wade out to the middle of the stream, making sure to minimize disturbance of the bottom sediments and the water column. Avoid taking measurements near the stream banks or in high velocities.
6) Facing upstream, remove the protective cover and replace it with the probe guard, if needed.
7) Holding the probe in the water, wait for the reading to stabilize (at least 1 minute).
8) Record the reading on the field datasheet and/or in the YSI computer for DO, pH, and water temperature, making sure to name the station and date correctly.
9) Replace the protective cover to prevent damage to the probes during transition, and proceed to the next sampling location.

If, at any point, the probe touches the bottom, raise the probe to the desired depth above the bottom and wait several minutes for the disturbed sediment to settle or to flow away from probe. If the probe is equipped with a turbidity probe, wait until the turbidity reading returns to appropriate range before recording DO. This is an indication that any disturbance caused by the probe hitting the bottom has passed.

Troubleshooting

If the recorded DO value is impossible (e.g., less than zero) or highly improbable (e.g., thousands of milligrams per liter), or the reading takes a very long time to stabilize, the probe likely needs to be re-calibrated or the DO membrane needs to be replaced. If pH and water temperature readings are also impossible or improbable, recalibrate the probe before recording the measurement.

Nanticoke Watershed Alliance

Figure 8.3. A scientist collects a water sample to measure dissolved oxygen in the Nanticoke River, Maryland.

Data analysis

Field sampling measurements should be marked on a field data sheet, then entered in a spreadsheet or database. Data are compared against ecologically relevant criteria and assigned as passing or failing. For analysis, each data observation is compared to a corresponding threshold (Table 8.1).

Comparison to criteria

For non-tidal streams, do, pH, and water temperature thresholds are defined based on a designated use set by state agencies. Designated uses include water contact recreation, support of marine life, support of shellfish harvesting and public water supply. To determine if your stream has a designated use of warmwater or coldwater, see Addendum II.

Dissolved oxygen

For coldwater non-tidal streams, the dissolved oxygen concentration may not be less than 5.0 mg·l^{-1} at any time, with a minimum daily average of not less than 6.0 mg·l^{-1}. For warmwater non-tidal streams, the dissolved oxygen concentration may not be less than 5.0 mg·l^{-1} at any time. Each individual data point is compared to this criterion and scored as pass or fail.

pH

Both coldwater non-tidal streams and warmwater non-tidal streams must have a pH measurement between 6.5 and 8.5. Each individual data point is compared to this criterion and scored as pass or fail.

Water temperature

For coldwater non-tidal streams, the temperature must not exceed 68°F (20°C). For warmwater non-tidal streams the temperature must not exceed 90°F (32°C). Each individual data point is compared to this criterion and scored as pass or fail.

Scoring

Each individual measurement is assigned a 100 (pass) or a zero (fail) and a station score is calculated by averaging all measurements taken at that station during the relevant time period. Then, station scores are averaged into a sub-watershed score. An overall watershed score is calculated as an area-weighted average of the sub-watershed scores. A summary of the data analysis steps for vital sign indicators is listed below:

1) For vital sign indicators, the sampling period is year-round with once a month sampling.
2) Make sure the appropriate threshold for DO, pH, and water temperature is used.
3) Compare measured value to the threshold and assign it pass/fail.
4) For each pass value, assign it a 100 (one hundred), and for a fail, a 0 (zero).
5) Average the 100s and 0s (zeroes) for each station. This is the average % passing, and therefore the station score.
6) Calculate sub-watershed scores by averaging the scores of the stations in each sub-watershed. Remember that 10 sampling sites are needed for each sub-watershed, so average to the sub-watershed level if possible, but otherwise average to the watershed level if not.
7) Assign a grade to each sub-watershed or watershed score (see Chapter 4 for grade scale).

If you have a score for each sub-watershed, you can determine the average % score and grade for the overall watershed by area-weighting the sub-watershed scores.

1) Determine the percent-area for each sub-watershed. For example: sub-watershed 1 area = 5 km^2 , divide by the total watershed area of 20 km^2 = 0.25.
2) Multiply the sub-watershed proportion (0.25) by the sub-region score (76%) to equal 19%.
3) Sum the resulting sub-watershed scores into an overall watershed score.
4) Based on the overall score, assign a grade for the entire watershed.

For health assessments, it is recommended that measurements for each station are scored and the % passing for each station is calculated. This method is followed so that a station that has many more measurements than others is not weighted more heavily than others. For example, if one site has 12 measurements all year and another site has 5, the site with 12 measurements would have more influence on the final average DO, pH, or water temperature score than the site with 5 measurements if the values were averaged over the whole region. However, if the percent passing is calculated for each station, the % passing scores are equally weighted.

Table 8.1. Passing scores for DO, pH and temperature fall into the following thresholds from warm and cold water regions.

Stream type	DO	pH	Temperature
warmwater	>5.0 mg·l^{-1}	6.5–8.5	<90°F (32°C)
coldwater - instantaneous concentration	>5.0 mg·l^{-1}	6.5–8.5	<68°F (20°C)
coldwater - minimum daily average	>6.0 mg·l^{-1}	6.5–8.5	<68°F (20°C)

Chapter 9: Measuring bacteria

Bacteria and viruses occur naturally in both fresh and salt water. Bacteria are also commonly found in the intestines of humans and other warm-blooded animals. Most are harmless to humans and animals, but some are pathogenic and can cause illness for swimmers (Figure 9.1). Pathogens can come from the feces of many animals, including wildlife and pets. They can also come from humans through leaking septic systems and broken sewage lines.

Testing for all pathogens is difficult, so a test for the presence of indicator bacteria is used instead. Indicator bacteria, such as enterococci and *E. coli*, are present in large numbers, which means they are easy to find and relatively inexpensive to monitor. These indicators are not usually harmful themselves, but can come from similar sources as pathogens. The presence of these indicators suggests that harmful pathogens may also be present. During significant rainfalls, there is an increased risk for elevated or unsafe bacteria in natural waters (Figure 9.2). *E. coli* is generally used as an indicator in fresh waters (US EPA 1986).

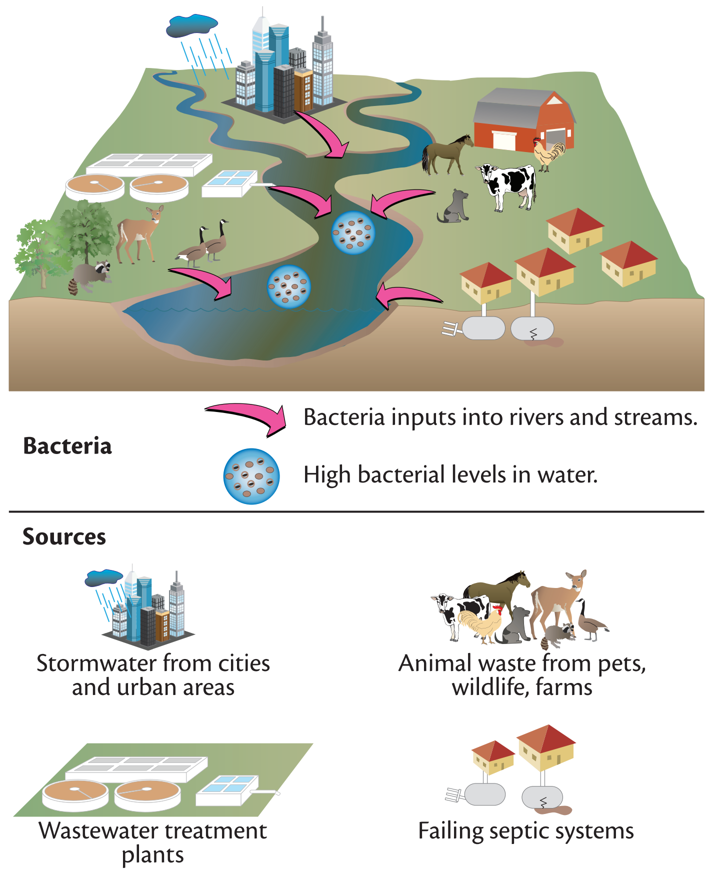


Figure 9.2. This conceptual diagram illustrates the sources of bacteria in an ecosystem.

Heath Kelsey

Figure 9.1. Local health departments monitor bacteria levels at public swimming areas throughout the state.

Field sampling procedures

Sampling locations should be in areas of high recreational use, such as public swimming and boating areas. There should be a minimum of 5 sites sampled, but the appropriate number will probably vary among tributaries—the number of samples should be representative of recreational use and potential exposure in the water. Additionally, reference sites, in mid-channel locations, should also be sampled. These sites will provide a comparison to bacteria "hot spots" and provide a more random sampling design. A randomly sampled, non-targeted bacteria program is rare in the Mid-Atlantic region. If the objective of your bacteria sampling program is to determine human health risks while swimming or boating, a random sampling design is not necessary.

In the Mid-Atlantic region, bacteria should be assessed from Memorial Day to Labor Day. These months cover the period of time when most people come into contact with the water via swimming, wading, boating, and fishing, among other uses. A minimum of twice monthly sampling is recommended for assessment. However, weekly sampling is preferred.

Sampling should always occur on the same day of the week, independent of weather. Including data from both dry weather and after rainfall in the analysis provides for an overall health assessment of the river or stream. This will be reported as a frequency of attainment. Reporting data for only dry weather dates is also useful for identifying hot spots and for trend analysis such as comparison between rivers and between years.

Sample equipment

- Cooler with ice
- Labeled sterile sample bottles and caps
- Extendable pole

- Chest waders
- Disinfectant gel or sanitizer
- Latex gloves

Sample procedure

Adherence to sample collection protocols is crucial to obtain accurate sample results and to ensure the integrity of the bacteria monitoring process. The following recommended steps for sample collection are taken from the EPA's 2002 National Beach Guidance and Required Performance Criteria, 1992, Standard Methods for Water and Wastewater Examination.

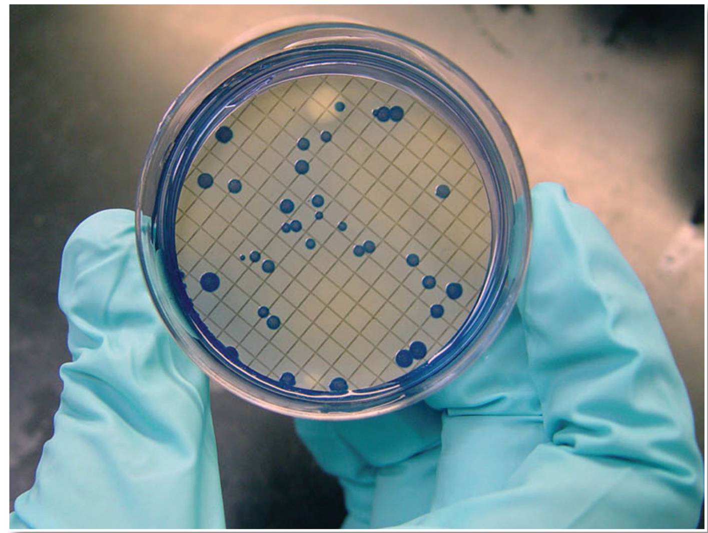
1) Prior to monitoring, fill bacteria sampling cooler halfway with ice. All samples must be placed at 1–4°C at all times until filtration.
2) Only autoclaved sterile containers must be used and all bottles must be pre-labeled before going out into the field.
3) Identify the sampling site on the data sheet and compare to the sterile bottle.

At station:

4) Record all information while at the station on the data sheet—number of waterfowl, people/swimmers, pets, etc.
5) Attach the bottle to the sampling pole (Figure 9.3), securing it tightly, open the cap without touching the inside of the lid.
6) If sampling from a bridge, be sure to sample in the middle of the stream in areas of low to medium flow. If the water is shallow, sampling should be done through wading.

Sally Hornor

Figure 9.3. A researcher collects a water sample, which will be used to analyze bacteria levels.



Susan Boyer (USDA)

Figure 9.4. After a sample is taken, the water is filtered to collect bacteria cells and placed on a growing medium.

7) If sampling through wading, wear chest waders in areas where high bacterial counts are expected or are unknown. Carefully wade out to the middle of the stream, making sure to minimize disturbance of the bottom sediments and the water column.
8) Facing upstream, extend the pole outward and dip at approximately 0.5 meter (1.5 feet) depth.
9) Fill the bottle to shoulders, tightly cap the bottle.
10) Record the date and time of sampling on data sheet.
11) Place sample on ice.
12) After samples have been collected from a station, wipe arms/hands with disinfection gel to reduce exposure to potentially harmful bacteria or other microorganisms (EPA 2002).

Taking duplicate samples or re-sampling areas is recommended in case of unexpected results or noteworthy data, but is not necessary.

Laboratory analysis

The recommended method is membrane filtration technique with selective media (http://water.epa.gov/scitech/methods/cwa/bioindicators/upload/method_1103_1.pdf). This method is recommended by the US EPA and is a common method used at government and academic laboratories in the Mid-Atlantic (Figure 9.4). Field analysis of bacteria is not recommended. Check with the laboratory for their Standard Operating Procedure to make sure the field collection method you use is appropriate for their lab methods.

Data analysis

The EPA threshold for *E. coli* is 235 organisms·100 ml^{-1} for any single water sample. The laboratory cultures the water sample and then counts how many bacteria organism colonies are on the plate which is called the colony forming units (CFU). Some labs use a slightly different method where that reports the number of organisms as the most probable number (MPN) in the dish. Data provided from the laboratory are analyzed to calculate a percent of samples below the *E. coli* threshold. The percent of samples in a sampling season (Memorial Day to Labor Day) that were below the threshold is the percent passing (score) for each station. A summary of steps for calculating bacteria scores is:

1) Make sure the data used for analysis are from the relevant months. For bacteria, the minimum sampling period is Memorial Day to Labor Day with twice monthly sampling.
2) Make sure the appropriate threshold for *E. coli* is used.
3) Calculate the percent of samples that were below the threshold for a station score. Do not average the individual station values before calculating the percent. Compare each station value directly to the threshold to see if it meets the threshold value. (For example: a data value of 300 organisms·100 ml^{-1} is above the 235 threshold, therefore it scores a zero. A data value of 100 organisms·100 ml^{-1} is below the threshold and therefore it scores a one. Take the average of the ones and zeros to find the percent of samples that are below the threshold for each station.
4) For this protocol, we do not recommend calculating an overall grade for the sub-watersheds or overall watershed because bacteria data are so variable.

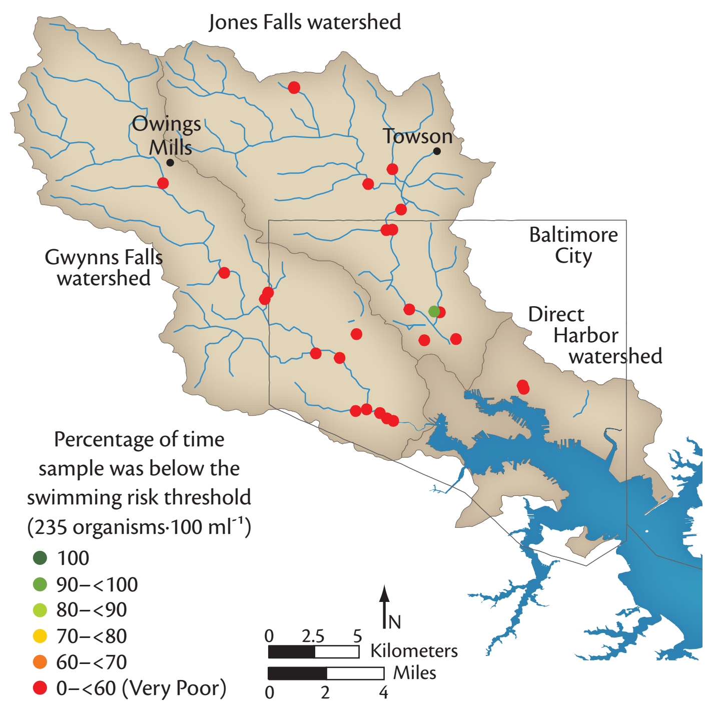


Figure 9.5. Baltimore Harbor watershed map for *E. coli* scores. Note the 10-point ranges for this indicator compared to the 20-point ranges for ecological indicators.

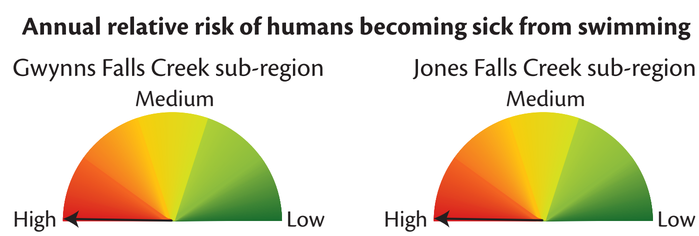


Figure 9.6. A dial or "fire danger" symbol can be used to illustrate the relative risk of becoming sick from swimming.

Communicating bacteria score results

Since bacteria is a human health indicator, it is communicated differently than ecological indicators. For bacteria, station average scores are calculated, then presented on a 10-point scale (not the 20-point scale used by ecological indicators; Table 9.1). Furthermore, due to the variability of bacteria scores within small areas, a map of station average scores should be presented along with the overall sub-region or region information (Figure 9.5). To interpret scores correctly, scores on the map and the associated text should be described as the "Percentage of time samples were below the swimming risk threshold." For an overall sub-region average, "fire danger" symbols or dials can be used to illustrate relative risk of becoming sick from swimming (Figure 9.6). This is provided by calculating an overall sub-region score, with Low risk = 100% passing and High risk= 60% passing. To calculate the sub-region score, station scores are averaged into a sub-region score.

Table 9.1. Scoring and description for bacteria indicator.

Score	Narrative
100	Excellent
90 – <100	Good
80 – <90	Moderate
70 – <80	Moderately Poor
60 – <70	Poor
<60	Very Poor

When creating the "fire danger" symbol, use the following steps to calculate the angle of the arrow. This angle is the proportion the score takes up out of 180º.

1) Take the sub-region score and subtract it from 100. For example: sub-region score = 75%. 100-75 = 15%.
2) Next determine what percent the resulting number (15 in our example) is out of 40. 40 covers the range between 60 and 100. So, the angle will be equal to 15/40 multiplied by 180. Using this example, the angle is 67.5º.

Suggested narrative

Bacteria indicators differ from other ecosystem health indicators in that they include both targeted (samples are taken at fixed locations designed to evaluate swimming illness risk) and random (samples are taken at randomly assigned locations to represent all potential locations) sampling. Indicator bacteria are useful to evaluate how safe water is for swimming, but are not easily used to describe ecosystem health. There is no clear link between more traditional measures of ecosystem health (e.g. TN, TP, etc.) and bacteria concentration. For that reason, it is not recommended that bacteria scores be integrated with other ecosystem health indicators.

There are also many factors that can affect bacteria concentration and the interpretation of results. The suggested list below describes some of these important topics, which could be described in a narrative statement within the bacteria section of the report card. This discussion can also be in a separate document that is referenced in the report card.

- *Rainfall and dry weather data.* The most important transport mechanism for fecal bacteria to streams is often rainfall runoff. Bacteria are transported from animal feces by stormwater, and measurements of fecal indicator bacteria may often be high following rain events. To help interpret the score, report the number of sampling days on which rainfall was a factor. However, when comparing among regions or time series, it is useful to remove the rainfall data from analysis so that comparisons are performed using similar conditions. With any comparison that has different *numbers* of rain dates, drop the data from rain dates, to reduce bias toward values in the dataset with more rain dates. Analysis of dry weather data only allows direct comparison of results from other tributaries and at individual swimming areas in different years.
- *Potential sources.* Fecal bacteria (and pathogens) can come from a variety of animal sources including humans, wildlife, pets, and even soils. It is mostly assumed that fecal pollution from human sources presents higher risk to humans, but this is difficult to prove; US EPA recommends that fecal indicator bacteria thresholds be applied regardless of the likely bacteria source. It is very difficult to determine the source of bacteria found in the water. Even so, in reporting bacteria scores, it is useful to discuss the potential sources of the bacteria to provide context and interpret results. For example, interpolation of high bacteria concentrations might be different if there are large numbers of geese in an area or if there are many residences with failing septic systems.
- *Scoring.* Currently, there are single thresholds for *E. coli* bacteria for full contact recreational use. The use of a single threshold indicator, while helpful, does not show the resolution that a multiple threshold indicator does.
- *Limitations of indicator bacteria.* When fecal indicator bacteria are present, pathogens are more likely to be present, but they may not always be there. The likelihood of getting sick from swimming is therefore not perfectly correlated with indicator bacteria concentration. Still, these indicators are the current, best information to predict illness risk, and EPA guidelines say that the risk of illness from swimming is too high when bacteria concentrations exceed the guidelines. Due to the difficulty in assigning risk from different sources, and because rainfall is a major contributor of fecal pollution, Maryland Department of the Environment recommends that people do not swim in the 48-hour period immediately following rainfall greater than one inch.
- *Health implications.* To improve the linkages between illness and swimming, we recommend that gastrointestinal illnesses following swimming are reported to the health department and other public health databases.
- *Homework/tips.* Including information in the report card about what citizens can do to decrease bacteria is always helpful (e.g. pick up pet waste, maintain septic systems, etc.)
- *Site specific details.* Site specific details help citizens identify locations of high bacteria concentrations and raise awareness of where bacteria concentrations are a problem in the ecosystem (See potential sources also).

Chapter 10: Measuring trash

Trash is often overlooked as a pollutant in local streams and rivers. Trash is any man-made item that is found on the ground, and which should be thrown away. Plastic items (plastic bags, food wrappers, and water bottles) are the most common type of trash found in trash clean-ups. Trash can come from a variety of activities and locations, including picnics, sporting events, fast food restaurants, and landfills. Fishing and other water-based activities can also produce trash (Figure 10.1).

Trash is a common problem in urban environments, but is rarely thought of as a water pollutant. For example, uncovered trash cans put out for garbage pick-up are a source of trash in the environment. Once trash is on the ground in neighborhoods, along roads, and in parking lots, it washes into the storm drain system and into local waterways. Every time it rains, trash is washed from streets, roadside ditches, and streambanks into streams.

Trash is harmful to the environment because it leaches harmful chemicals into the ecosystem, is a breeding ground for harmful bacteria and other pathogens, and can entangle aquatic organisms. Fish and other animals can become entangled in trash, and can also ingest parts of trash, thinking that it is a food source. This can lead to dead and malnourished animals. Trash is also unpleasant to look at and can be a safety hazard when boating or swimming.

Field sampling procedures

There are at least two methods that can be used to sample for and assess trash. Trash can be assessed directly by picking up trash and removing it from the stream (Figure 10.2). In this case, weight, volume, type, and number of items can be evaluated in detail. It also allows trend analysis, to see if overall trash amounts are decreasing or increasing over time (Moore et al. 2007). The second method for evaluating trash is to perform a visual survey of a specified area and count the amount and types of trash. This method does not include collecting the trash, but is simple, cost-effective, and can provide valuable information.

Option 1: Trash collection method

Some watershed organizations have access to sites on the banks of their rivers and streams. For areas with direct access, this is the preferred trash assessment method. Trash can be measured directly, while cleaning up the environment at the same time.

Sample equipment

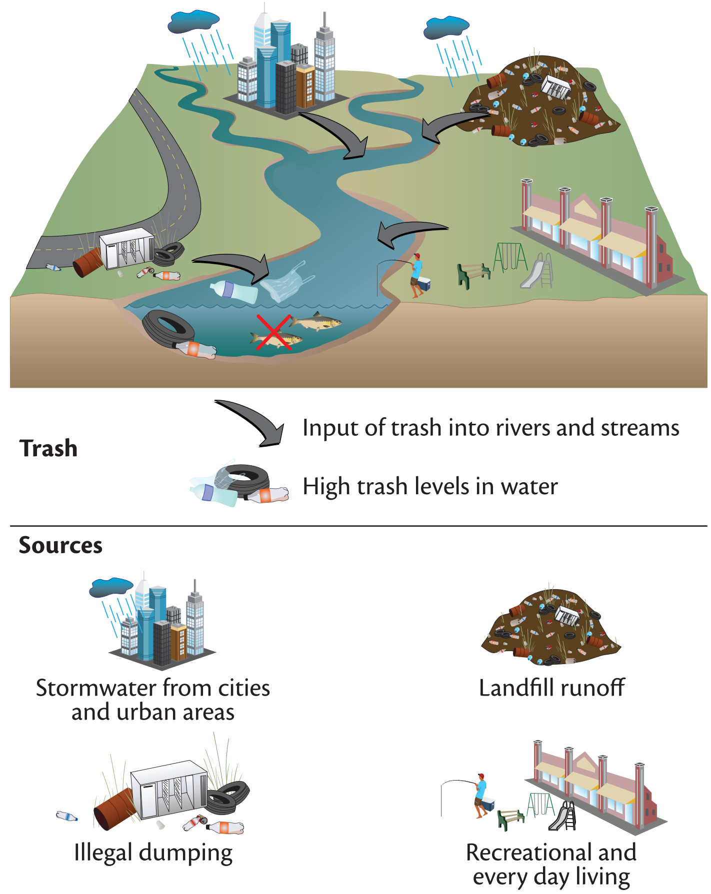


Figure 10.1. This conceptual diagram illustrates sources of trash that can flow into rivers and streams.

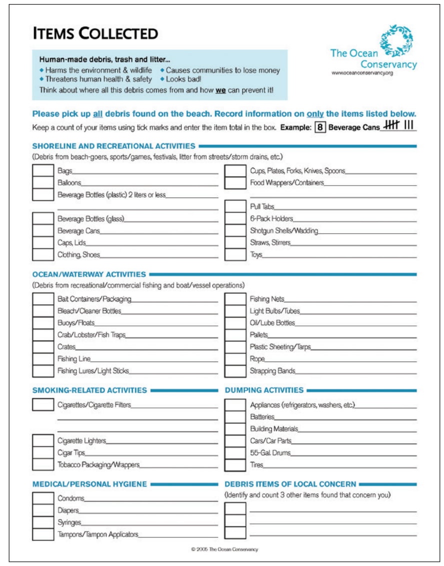
- Trash bags
- Trash grabber/pole
- Gloves
- Measuring tape
- GPS unit
- Camera
- Waders (optional)

Sample procedure

The first step in evaluating trash using the collection method is to measure the stream length and bank area where trash can be collected. The length of stream that is chosen should represent a uniform set of physical, chemical, and biological conditions within a reporting region. This protocol recommends a length of 100 meters along the stream and 10 meters into the stream bank area, if possible. When measuring the stream length, make sure to follow the stream pattern rather than measure in a straight line. This will allow for comparison across different streams. Many protocols recommend that the stream length assessed be 12 times the width of the current channel. However, that may not be possible when walking along the stream length, due to private property areas, impenetrable vegetation, and amount of time and effort of volunteers (Figure 10.3).

Anacostia Watershed Society

Figure 10.2. Make sure to be properly attired to pick up trash—wear gloves, waders, and pick up trash with a grab pole.



ITEMS COLLECTED

The Ocean Conservancy
www.oceanconservancy.org

Human-made debris, trash and litter...
- Harms the environment & wildlife
- Causes communities to lose money
- Threatens human health & safety
- Looks bad!

Think about where all this debris comes from and how **we** can prevent it!

Please pick up all debris found on the beach. Record information on only the items listed below.
Keep a count of your items using tick marks and enter the item total in the box. **Example:** 8 **Beverage Cans** ||||| |||

SHORELINE AND RECREATIONAL ACTIVITIES
(Debris from beach-goers, sports/games, festivals, litter from streets/storm drains, etc.)

- Bags
- Balloons
- Beverage Bottles (plastic) 2 liters or less
- Beverage Bottles (glass)
- Beverage Cans
- Caps, Lids
- Clothing, Shoes
- Cups, Plates, Forks, Knives, Spoons
- Food Wrappers/Containers
- Pull Tabs
- 6-Pack Holders
- Shotgun Shells/Wadding
- Straws, Stirrers
- Toys

OCEAN/WATERWAY ACTIVITIES
(Debris from recreational/commercial fishing and boat/vessel operations)

- Bait Containers/Packaging
- Bleach/Cleaner Bottles
- Buoys/Floats
- Crab/Lobster/Fish Traps
- Crates
- Fishing Line
- Fishing Lures/Light Sticks
- Fishing Nets
- Light Bulbs/Tubes
- Oil/Lube Bottles
- Pallets
- Plastic Sheeting/Tarps
- Rope
- Strapping Bands

SMOKING-RELATED ACTIVITIES

- Cigarettes/Cigarette Filters
- Cigarette Lighters
- Cigar Tips
- Tobacco Packaging/Wrappers

DUMPING ACTIVITIES

- Appliances (refrigerators, washers, etc.)
- Batteries
- Building Materials
- Cars/Car Parts
- 55-Gal. Drums
- Tires

MEDICAL/PERSONAL HYGIENE

- Condoms
- Diapers
- Syringes
- Tampons/Tampon Applicators

DEBRIS ITEMS OF LOCAL CONCERN
(Identify and count 3 other items found that concern you)

© 2005 The Ocean Conservancy

Figure 10.4. Example of a trash field sheet.

A good practice to follow is to have easily identified starting and ending points. These can be marked by an unusual or notable object in the landscape or a flag or pole can be set up. Additionally, a handheld GPS unit can be used to mark the starting and ending points. Latitude and longitude coordinates should be recorded on the field sheet (Figure 10.4). These coordinates should be used every time you perform the survey.

This protocol recommends quarterly surveys as the minimum and monthly as the preferred. Keep in mind that different seasons bring different challenges. If collecting trash in spring and summer, tick and mosquito repellent may need to be used. Long sleeves and long pants help with insects but also with thorny vegetation.

The start and end time of the trash survey should be marked on the fieldsheet. Before starting the survey, determine if you will collect trash within the stream as well as the stream banks. Perhaps the stream is flowing very fast from recent rains. If it is unsafe to wade in the stream, do not do so! Note on the field paper that trash was not collected within the stream that day. Walk along the stream length and collect any trash present. This includes small pieces and cigarette butts. Note the type (plastic, glass, etc.) and location (below water line, below high water mark, along streambank) of trash on the field paper.

BlueWater Baltimore

Figure 10.3. Volunteers pick up trash along a stream outside of Baltimore, Maryland.

Continue along the total length of stream until reaching the ending point. All trash that was collected should be written on the field paper. However, the trash needs to be taken to the office or lab where the total weight can be determined as well.

Option 2: Visual survey of trash

Many watershed organizations do not have direct access to streams because they are on private property or they are inaccessible from the road because of thick vegetation, steep embankments, etc. These watershed organizations sample from bridges, overpasses, and docks. However, these groups still want to assess trash in their system and therefore, a visual survey of trash can be used. A visual survey does not include collecting trash and therefore trends (i.e., is trash increasing or decreasing over time?) cannot be determined.

Sample equipment

- Measuring tape or GPS unit
- Field sheet
- Camera (optional)

Sample procedures

This visual survey is straight forward and quick. It is preferred that a visual survey of trash be performed on a monthly basis, but a minimum of quarterly surveys is needed. If the level of trash does not change on a monthly basis, surveys can be adjusted.

Using a measuring tape or GPS unit, determine where the person who will do the survey should stand. This can be standing at the edge of a bridge, looking down at the site, or at the top of the streambank looking down onto the stream. Mark down the exact position and view the person has from that spot. The same visual area should be used each time the survey is performed. A camera can be used to take a picture of the exact area that the person will be surveying. This picture can be used as a reference each time the survey is performed. Additionally, a picture can be taken each time a person does the survey as documentation of the amount of trash.

Keeping the entire area surveyed in mind, sweep from the top left to top right of the area, marking down the types and amount of trash seen. Continue from left to right and from top to bottom to visually count the trash and mark down the type of trash found. The start and end time of the trash survey should be marked on the fieldsheet.

Data analysis

Data analysis includes total number of trash articles, types of trash, and most importantly level of trash. Data analysis starts in the field with determining types of trash collected. Individual plastic bottles and wrappers can be counted as stand-alone pieces. However, pieces of glass and bits of paper can be counted separately. Keeping in mind how those pieces would impact a swimmer or fisherman can help determine whether each piece is counted separately or together. Dumping sites should be noted on the fieldsheet and within the analysis.

Trash can be divided into different categories for comparison purposes. Categories can include plastics, glass, aluminum, and other metals. Additionally, biohazards or bulk items can be included. Dumping sites should be noted, but may be left out of any calculations because they skew the data. Trash can also be divided into source categories such as household trash, fast food restaurants, drugstores, etc. This provides several different ways to evaluate the trash and determine its source.

If possible, level of effort should be calculated (e.g. person hours). This provides an idea of how long it takes to evaluate and collect trash for a specific stream length. Using the start and end time of the survey marked on the fieldsheet, calculate the per person amount of time it takes to conduct the survey.

Comparison to criteria

While trash is recognized as an important indicator, at this time there are no quantitative thresholds that have been determined for trash. Although two methods of trash field sampling procedures have been described, for the first method of trash collection there is no recommendation on how to give a score for this data. Only scoring procedures for option 2 have been determined thus far. This is similar to a scoring system but is more qualitative (Table 10.1). Trash is divided into 5 qualitative categories, to correspond to the 5 bins used for the grading scale (See page 16). While there are currently no quantitative thresholds for trash assessments, this qualitative method can provide information and context on trash problems in the region.

Table 10.1. Qualitative descriptions of trash levels that correspond to grades. Adapted from Maryland Biological Stream Survey (Stranko et al. 2010) and San Francisco Rapid Trash Assessment Protocol (Moore et al. 2007).

Trash grade		Narrative description
A		No trash visible from stream or streambank
B		Trash present in minor amounts; have to look for it
C		Trash present in moderate amounts
D		Trash present in moderate amounts; affecting and/or blocking stream flow and natural corridors along stream banks
F		Trash abundant and unsightly; an obvious dumping site

Scoring

Since trash is qualitatively scored, each data point has to be given a numerical value simply to average all of the scores together. This numerical value is for averaging purposes only and is not the grade or score of trash health. Each data point is compared to the qualitative bins in Table 10.1 and scored from A to F. Each score is then given a numerical value from 100 to 0 (Table 10.2). All of these values for a single station are averaged into a station score for the entire year, and station scores are averaged into a sub-region score. Once the sub-region score is calculated, calculate the total overall score by area-weighting each sub-region score and averaging them for an overall score. A summary of steps for calculating trash scores is:

1) For trash, the sampling period is year round with quarterly sampling.
2) Make sure the appropriate bin for trash is used (Table 10.1).
3) Assign scores of A to F to each sampling value.
4) Assign values of 100 to 0 for each score.
5) Average the 100 to 0 values for a station score.
6) Calculate sub-region scores by averaging the scores of the stations in each sub-region.
7) Assign a grade to each sub-region score (Table 10.2).
8) Now you have a grade for each sub-region. Next, you want to determine the average % score and grade for the overall waterbody.

If you have a score for each sub-watershed, you can determine the average % score and grade for the overall watershed by area-weighting the sub-watershed scores.

1) Determine the percent-area for each sub-watershed. For example: sub-watershed 1 area = 5 km^2 , divide by the total watershed area of 20 km^2 = 0.25.
2) Multiply the sub-watershed proportion (0.25) by the sub-region score (76%) to equal 19%.
3) Sum the resulting sub-watershed scores into an overall watershed score.
4) Based on the overall score, assign a grade for the entire watershed.

For health assessments, it is recommended that measurements for each station are scored and the % passing for each station is calculated. This method is followed so that a station that has many more measurements than others is not weighted more heavily than others. For example, if one site has 12 measurements all year and another site has 5, the site with 12 measurements would have more influence on the final average trash score than the site with 5 measurements if the values were averaged over the whole region. However, if the percent passing is calculated for each station, the % passing scores are equally weighted.

Qualitative grade	Quantitative value
A	100
B	75
C	50
D	25
F	0

Site X

Sampling Time	Grade	Numerical value
Spring	B	75
Summer	D	25
Fall	B	75
Winter	A	100
Yearly average for Site X	B	68.75

Table 10.2. Qualitative descriptions of trash levels correspond to grades. Each grade corresponds with a quantitative value that can be used to average all of the grades for each site and then for each sub-region. First the qualitative grade is determined, then from that grade the numerical value is applied. An example, Site X, is qualitatively graded and then averaged together using the corresponding numerical values and rounded up for a B grade.

Chapter 11: Measuring benthic community

Benthic macroinvertebrates are freshwater organisms including snails, mussels, and insects that live in and on the stream and river bottom (Figure 11.1). The abundance and diversity of these organisms are good indicators of local stream health because they have more limited movement than fish and they respond quickly to pollutants such as nutrients and sediment and other environmental stressors. The health of bottom-dwellers is threatened by pollutants introduced into streams and rivers by sources such as mining, agriculture, stormwater, fossil fuel combustion, and household and industrial wastewater treatment facilities. These human activities can add nitrogen and phosphorus to the water, which lead to algal blooms and low dissolved oxygen in slow-moving streams. Mining, agriculture, and development can also add fine sediment to streams, which smothers benthic organisms and contributes to low dissolved oxygen. Mining also can add toxic chemicals to the water that directly kill these bottom-dwellers (Figure 11.2).

West Virginia Department of Environmental Protection

Figure 11.1. Healthy benthic macroinvertebrate communities need streams with ample shade, rocks, and woody debris.

Field sampling procedures

Most monitoring programs in the Mid-Atlantic region collect samples of benthic macroinvertebrates with somewhat similar field methods and calculate a common suite of indicators from the data. However, these programs use state-specific protocols to score and evaluate these indicators in order to identify "impaired" waters for regulatory requirements. Watershed organizations in Maryland, for example, can participate in the Maryland Department of Natural Resources' Stream Waders

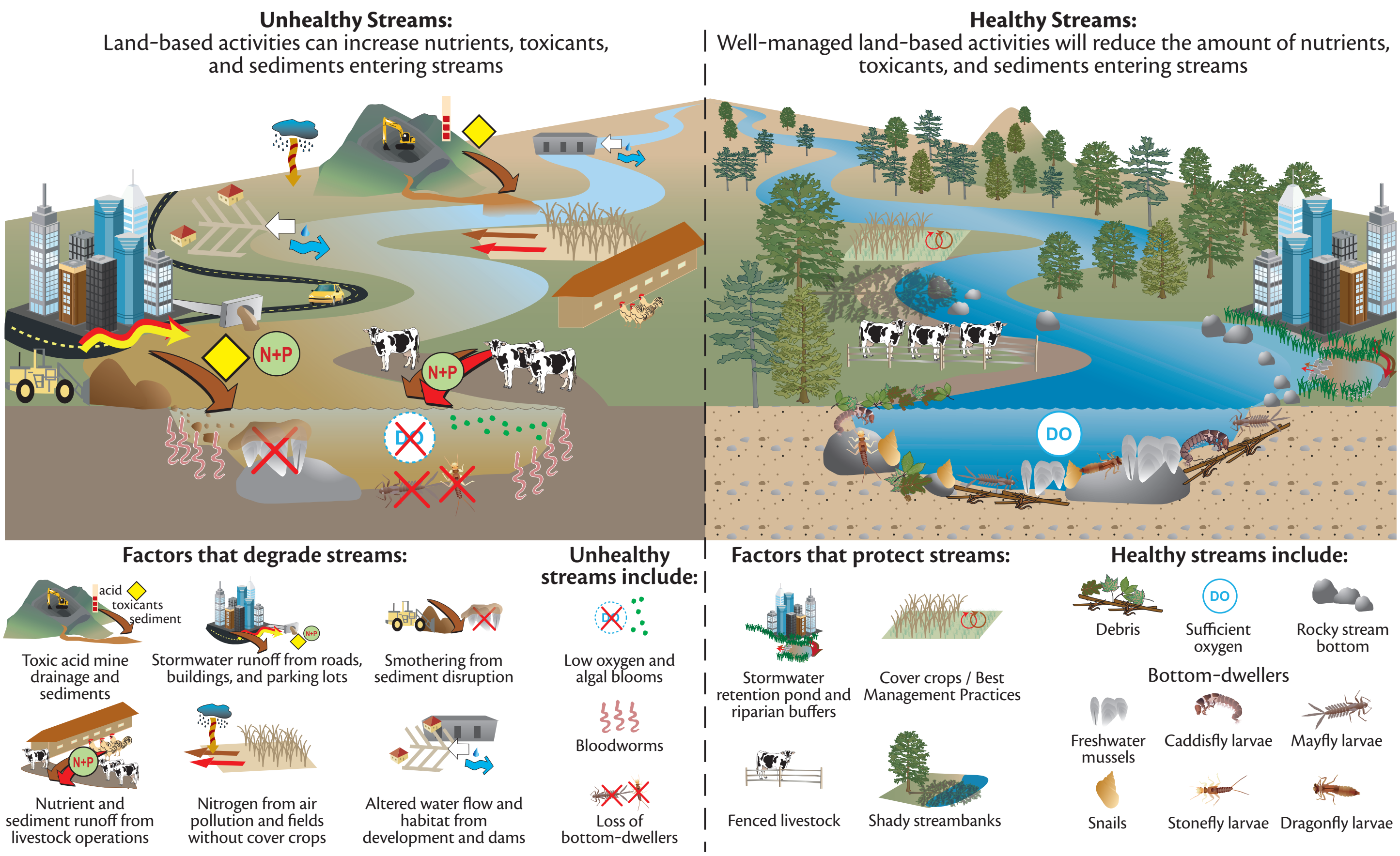


Figure 11.2. Conceptual diagram illustrating the land-based activities that affect bottom-dwellers and the habitat that they need to survive.

Program. This program trains volunteers to collect benthic macroinvertebrates for submission into the overall Maryland Biological Stream Survey. Other states, such as Pennsylvania and Virginia, have established state collection and analysis programs for benthic macroinvertebrates that they are using for regulatory purposes (Figure 11.3).

This non-tidal benthic macroinvertebrate indicator provides an ecological health assessment for biological components of streams using statewide data, but assessed on a scale that is comparable across all geographic locations. Field collections are carried out by state and local jurisdictions, so there are no field sampling procedures for watershed organizations recommended in this manual. If your organization chooses to conduct its own benthic macroinvertebrate sampling, you can follow procedures established by the Audubon Naturalist Society or Izaak Walton League of America (see References and Further Reading). Oftentimes, it is not financially feasible to conduct benthic community sampling for watershed organizations. In Maryland, watershed organizations are encouraged to participate in the MD DNR Streamwaders Program, which includes annual field training in sampling procedures. To learn more about this program, or to access Stream Waders data for use in completing a report card, visit their website at: http://www.dnr.state.md.us/streams/streamWaders.asp.

Lab sampling procedures

No lab sampling procedures are needed for this indicator, as it will be performed by state and local jurisdictions (Figure 11.4).

Chesapeake Bay Program

Figure 11.3. State and local jurisdictions collect benthic macroinvertebrate samples in the field.

Chesapeake Bay Program

Figure 11.4. The variety of bugs and larvae evaluated in the Benthic Index of Biotic Integrity. Lab analyses is performed by state and local jurisdictions, not by watershed organizations.

Data analysis

Data analysis of the benthic macroinvertebrate indicator consists of averaging individual station scores over the watershed for an average watershed score. Unlike water quality indicators, this indicator uses the six most recent years worth of data to determine current condition. Data from the six most recent years provides a good assessment of current health conditions. Data from 6 to 10 years old should be used with caution or flagged. Data that is older than 10 years should not be used to evaluate current conditions.

Benthic macroinvertebrate sampling includes both targeted and random sites. Targeted sites are used to focus on potential issues within a stream reach. Using both targeted and random sites in your assessment provides more data within the specified timeframe. However, if you want to roll up the data into an overall score, only use random sites. Using only random sites is necessary for averaging because it ensures unbiased sampling results to be included in the assessment.

To roll up the individual sampling site scores into an overall watershed score, a minimum of 5 sampling sites are needed for small (HUC-12) watersheds and a minimum of 10 sampling sites are needed for larger (HUC-8) watersheds. HUCs, or hydrologic unit codes, are the subdivisions of watersheds in the US. For more information about HUCs, please visit the USGS website: http://water.usgs.gov/GIS/huc.html.

Table 11.1. Benthic IBI scores and ratings are provided in the downloadable Excel spreadsheet. This table helps to determine the overall watershed average score, rating, and therefore the grade.

IBI Score (%)	Rating	Grade
≥ 67	Excellent	A
50 – <67	Good	B
30 – <50	Fair	C
17 – <30	Poor	D
<17	Very Poor	F

HUC-12 and HUC-8 watersheds show very detailed information, which is important for benthic macroinvertebrate sampling. Unfortunately, there are few state programs that cover these small areas enough to average into a watershed score. Pennsylvania, for example, only has sporadic random sampling sites throughout the state. Some small watersheds can be evaluated, but not all. In these cases, it is best to provide just the targeted and sampling site scores on a map, rather than provide an overall average score.

The following bullet points provide a step-by-step process for data analysis.

- Become familiar with the CBP Interactive Mapping website: http://www.chesapeakebay.net/indicators/indicator/health_of_freshwater_streams_in_the_chesapeake_bay_watershed. This will help determine how many sampling sites are within your watershed, which helps to determine if you can average the scores or just provide a map of individual sampling sites.
- Benthic Index of Biotic Integrity scores are available for download from the Chesapeake Bay Program's database: http://www.chesapeakebay.net/data/downloads/watershed_wide_benthic_invertebrate_database. Benthic IBI scores and ratings are provided in a downloadable Excel spreadsheet (Table 11.1).
  - Determine which HUCs are within your watershed boundary before downloading benthic data from the CBP website.
  - Download the data from the website.
    - Download the most recent six years worth of data from the database. The most recent six years of data provides a good assessment of current condition.
    - See Database information below for more detailed instructions.
- Using the spreadsheet, determine the average score for each of the HUCs within your watershed. Otherwise, you can use the individual sampling site scores from the Random and Targeted tab to display the individual sampling site scores, as discussed above.
- The last step is to average each HUC average score into an overall watershed score. Do not area-weight because you are already using randomly sampled sites.

Database information

Benthic Index of Biotic Integrity scores are available for download from the Chesapeake Bay Program's database: http://www.chesapeakebay.net/data/downloads/watershed_wide_benthic_invertebrate_database.

- Download the most recent six years worth of data from the database. The most recent six years of data provides a good assessment of current condition.
- Click download the data.
- The Data Source should be non-tidal benthic data.
- Select indicators and calculated metrics below Data Source dropdown menu.
- Select indicators and calculated metrics again under Data Type.
- Click continue.
- Choose state as the attribute.
- Enter the date range, which the website allows a maximum of five years. You can download three years at a time, since the last six years of data is needed.
- Type in your email address.
- Download data.

Chapter 12: Synthesizing and communicating data

The previous chapters discussed in detail how to measure and analyze the core indicators that will be synthesized into a report card. To synthesize data is to combine and integrate large amounts of data into a single entity that generates meaningful information. Specifically, in the case of this protocol, it means to score a river or stream and to give it a grade that is incorporated into a report card. Synthesizing data into one score for each indicator is an important step in answering the question, "How healthy is the river or stream?" The audience does not necessarily want to see each measurement that goes into a year-long monitoring program's database. Rather, they want to know the ultimate outcome of those measurements, or what the data collected mean. Synthesizing data also allows for better communications products that the audience, many times the general public, is able to understand. After synthesizing data and determining the grade of the river or stream, then this information is disseminated through a newsletter or report card.

One way to synthesize data is to "roll up" individual indicators into an overarching index. An index can combine similar types of indicators (e.g., chemical, physical, biological) into one index (Figure 12.1), or it can be an average of all measured indicators. Overarching indices give a better integrated assessment (and therefore representative score) of an ecosystem's health than can be achieved using a single indicator. Additionally, comparing indices between different tributaries negates the need to resolve varying temporal and spatial sampling scales.

How to synthesize

Selecting reporting sub-watersheds

Sub-watersheds of your system may have already been determined to help clarify where to assign sampling sites (see Chapter 2). However, if they have not already been defined, it is one of the first tasks in developing a report card. There must be a sufficient number of sampling sites (at least 10 are recommended) in a sub-watershed to provide a representative and accurate score for each indicator. The boundaries of the sub-watersheds are defined by topography, but when delineating sub-watersheds, consider the land use, population, and contribution of the sub-watershed to the entire watershed.

To weight or not to weight

There are advantages and disadvantages of weighting indicators that depend upon whether you have chosen to use targets or relative ranking as your approach for measuring success or failure. For this protocol document, indicators will be weighted evenly. This means that each indicator is as important as all others when averaged into a health index score.

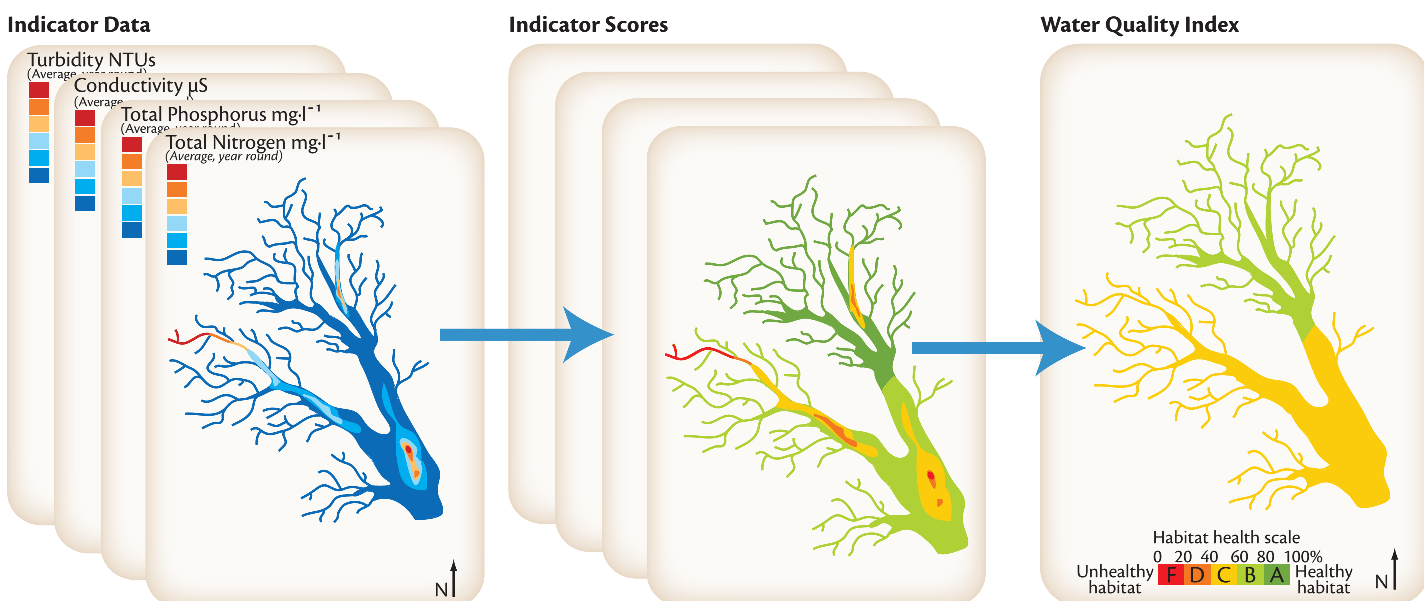


Figure 12.1. In non-tidal report cards, four water quality indicators are evaluated against threshold values. The water quality indicators are then averaged into a Water Quality Index, which gives information on the health of the river or stream.

Water Quality Index

The four core indicators used in this protocol, total nitrogen, total phosphorus, conductivity, and turbidity, can be averaged together for a water quality score for a sub-watershed. Then, scores for each sub-watershed are area-weighted (i.e., the area of the sub-watershed divided by the total area of the watershed) and averaged for one watershed score. Each monitoring program will need to decide if it wants to provide sub-watershed scores, or if it wants to average the indicators into one Water Quality Index (WQI) for the entire river or stream. It is recommended that quantitative grades are given for each indicator and the Water Quality Index (Figure 12.1). When giving an overall grade for the watershed, all of the indicators will be wrapped together into a single overarching score.

Indicator	Score	Visual
Dissolved oxygen	95%	
pH	100%	
Water temperature	70%	

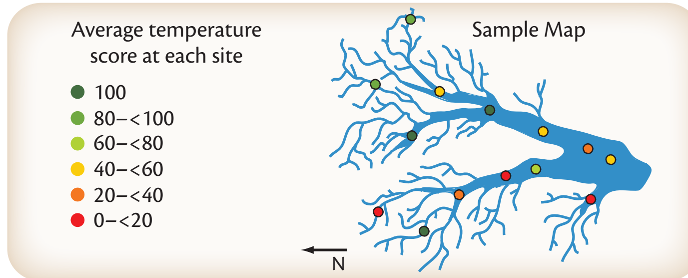


Figure 12.2. When any of these indicators scores lower than 80%, a thumbs down symbol and a map of the sampling sites with the specific scores should be provided.

Vital signs indicators

Dissolved oxygen, pH, and water temperature are considered to be vital signs of the watershed, and give the pulse of the system. Vital signs are generally not directly reported on in communication products such as report cards. These indicators are usually "Very good" unless there is a site-specific reason for them to be poor, such as an area of the stream where chemicals have been dumped, causing poor pH levels. Vital signs should be measured and monitored for sudden changes, and can be reported if they are strongly influencing the health of the waterway, such as consistent low dissolved oxygen levels.

When one or more vital sign indicator is showing low scores, then the vital signs indicators should be further examined and evaluated for what may be going on in the river or stream. If one vital signs indicator scores lower than 80%, this low grade should be expressed with a red thumbs down symbol  . Accompanying the symbol should be a map of the watershed displaying each sampling site and showing where the indicator is doing poorly (Figure 12.2). If all of the indicators are doing well, a green thumbs up symbol  can be used, and a map of the sampling sites is not necessary (Figure 12.3).

Since vital signs indicators should not have much variability and should score well, wrapping them up with the other indicators would skew the grades. For this reason, these vital signs indicators are not wrapped up with the four core indicators or with each other.

Indicator	Score	Visual
Dissolved oxygen	99%	
pH	100%	
Water temperature	95%	

Figure 12.3. If all vital signs indicators score 80% or higher, then a thumbs up symbol can be used to express the health of the ecosystem.

Bacteria

Bacteria is a human health indicator, which is communicated differently than ecological indicators. If desired, however, bacteria scores can be incorporated into an overall grade calculation. Bacteria, calculated on a 10-point scale (not the 20-point scale used by ecological indicators; Table 12.1), are presented as station averages.

Table 12.1. Scoring and description for bacteria indicator.

Score	Narrative
100	Excellent
90 – <100	Good
80 – <90	Moderate
70 – <80	Moderately Poor
60 – <70	Poor
<60	Very Poor

Furthermore, due to the variability of bacteria scores between sampling sites, a map of station average scores (Figure 12.4) should be presented with the specific grade per sampling station. When expressing bacteria data alone, an overall bacteria grade for the watershed should not be expressed. For bacteria, specific sites can have high variability, and averaging all of the sites into a single score loses the resolution of the data. For instance, one site could be consistently poor, but would be averaged out if not expressed individually.

To communicate the data, annually averaged results for each bacteria sampling site should be displayed spatially and accompanied by a "fire danger" diagram indicating the "annual relative risk of humans becoming sick from swimming" in those locations (Figure 12.5).

Bacteria station scores can be averaged together for an overall bacteria watershed score. In order to integrate bacteria with the other indicators, it has to be standardized to a 20-point scale (Figure 12.6).

The final bacteria score can be averaged with other human health indicators into an index. If other human health indicators are available, the bacteria score or Human Health Index can be evenly averaged with the Water Quality Index, benthic community, and trash. Additional human health indicators (such as toxins, like heavy metals, or carcinogens) are not directly addressed in this protocol.

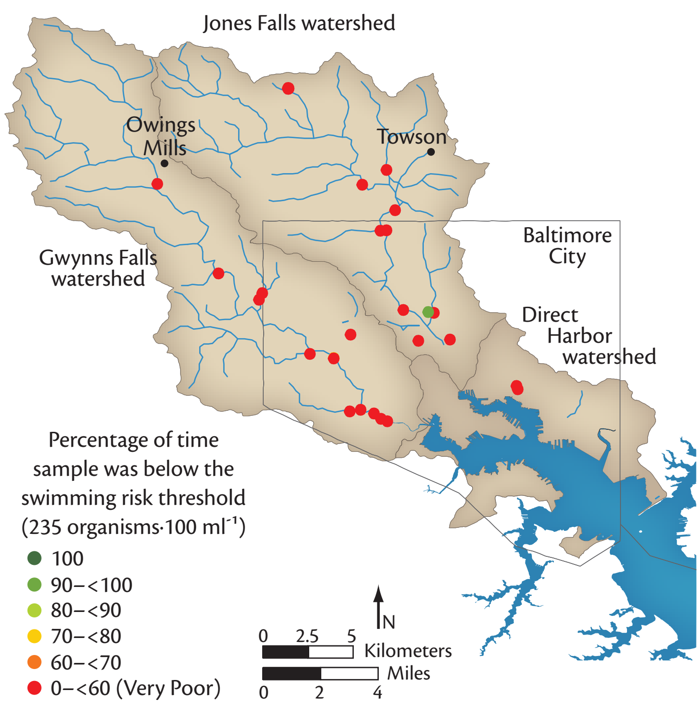


Figure 12.4. Baltimore Harbor watershed map for *E. coli* scores. Note the 10-point ranges for this indicator compared to the 20-point ranges for ecological indicators.

Remember, although we recommend averaging the data to wrap up bacteria with the other indicators, we do not recommend expressing the overall bacteria score in communication materials.

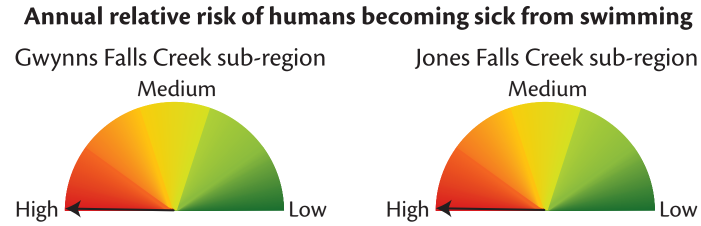
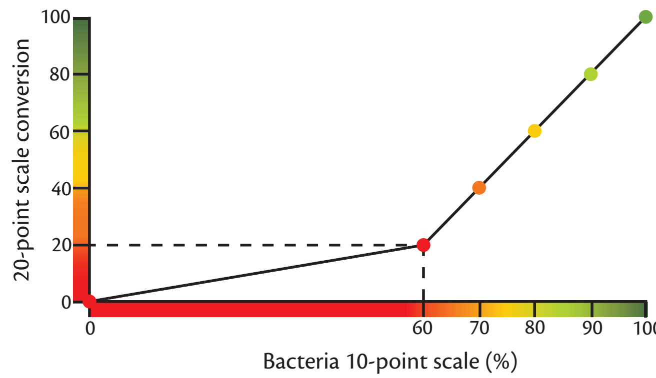


Figure 12.5. A dial or "fire danger" symbol can be used to illustrate the relative risk of becoming sick from swimming.



If the bacteria is <60%, then divide it by 3.
If the bacteria is ≥60%, then multiply it by 2, and subtract 100.

Conversion equations

$$y = \begin{cases} 1/3x & \text{for } <60\% \\ 2x-100 & \text{for } \geq 60\% \end{cases}$$

x = Percent of meeting the swimming risk threshold

y = Converted score for integration

Figure 12.6. This graph shows the conversion of the 10-point scale used by bacteria to the 20-point scale used by all other indicators.

Trash

Trash is an optional indicator which can be wrapped up with the Water Quality Index, bacteria, and benthic community to help express the health of the river or stream. Since trash is qualitatively scored, each data point has to be given a numerical value simply to average all of the scores together. This numerical value is for averaging purposes only and is not the grade or score of the trash health. Each data point is compared to the qualitative bins in Table 10.1 and scored from A to F. See Chapter 10 for more details.

All of these values for a single station are averaged into a station score for the entire year. Then, station scores are averaged into a sub-region score. Once the sub-watershed score is calculated, calculate the total overall score by area-weighting each sub-watershed score and averaging them for an overall score. This overall score can then be averaged together with the Water Quality Index, bacteria score, and benthic score.

To communicate trash by itself for the entire watershed, a fire danger symbol should be used along with the overall letter grade, since these data are qualitative (Figure 12.7).

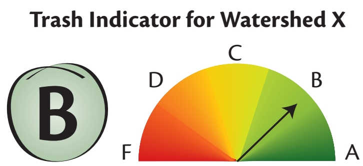


Figure 12.7. A dial or "fire danger" symbol can be used to illustrate the qualitative trash grade for the entire waterway.

Benthic community

Benthic community can be communicated separately, as well as wrapped up with the Water Quality Index, bacteria, and trash indicators into an overall watershed health grade.

To roll up the individual sampling site scores into an overall watershed score, a minimum of 5 sampling sites are needed for small (HUC-12) watersheds and a minimum of 10 sampling sites are needed for larger (HUC-8) watersheds. While these data are quantitative and may be spatially integrated, state data reporting is only completed every other year. The average benthic community score for the watershed will be reported for two years in a row in your report card. This letter grade is the score that will be wrapped in with the rest of the indicators.

Streamflow

Streamflow should be an element that is used to help tell the story of why some indicators scored high or low. Flow data should be compared to past years' flows to determine whether the flow was above normal, below normal, or average. Use the narrative within a report card or newsletter to describe how results are linked to the streamflow. If your program was unable to measure streamflow (as discussed in Chapter 2), precipitation data could be used instead to describe the year as dry, normal, or wet. Present the flow data as a simple graph showing flow over the year (Figure 12.8). Discussion of large storm events that happened during the year can also be helpful.

Overall grade

The overall grade of the river or stream integrates the Water Quality Index (total nitrogen, total phosphorus, conductivity, and turbidity), bacteria, trash, and benthic community results. These four items can be considered indexes that are integrated into an overall score. In addition to showing the overall score, another method for communicating the results that shows more detail is to generate a grid of the indicators that may be spatially averaged (i.e. all but bacteria) along one axis and the list of sub-watersheds on the other axis (Figure 12.9). The color in each grid cell would then indicate the grade for that indicator in that location.

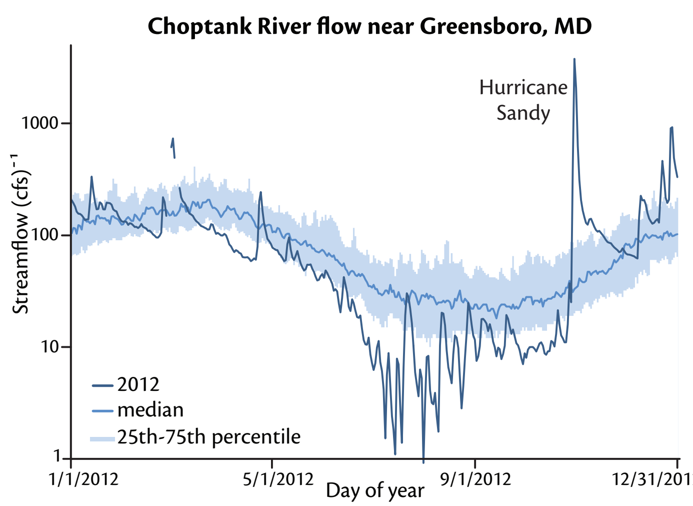


Figure 12.8. A streamflow graph can be used to show whether the flow was high, average, or low compared to past years. Streamflow data is for the Choptank River from USGS.

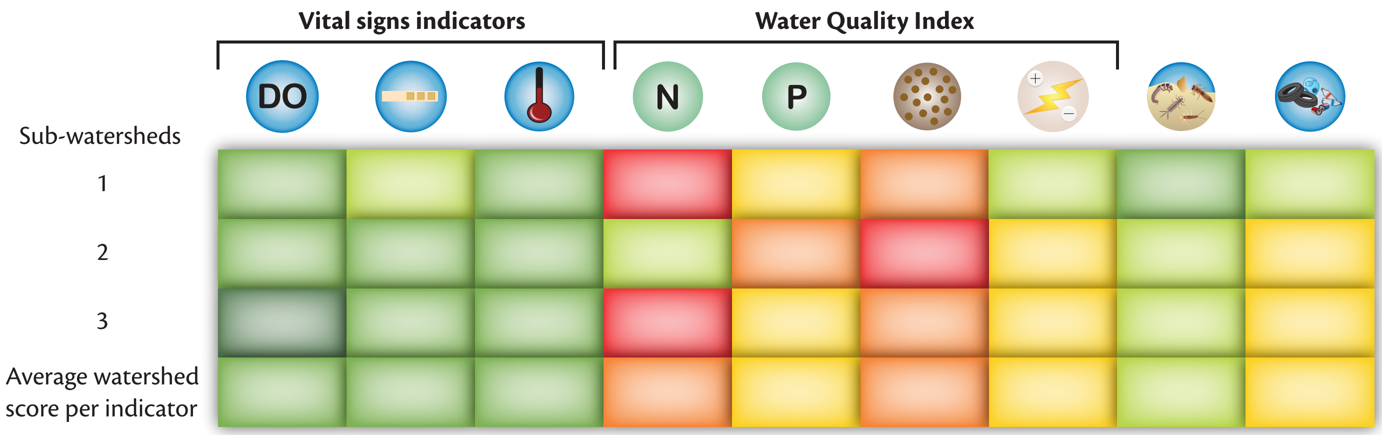


Figure 12.9. Using a grid of scores is another method for communicating the results that shows more detail about what is happening with each indicator in each sub-watershed and the overall watershed.

Report cards

The final health grade for the whole river or stream can be communicated via a printed report card and a press release. Additionally, all supporting indicator and sub-watershed scores and indicator and sub-watershed maps can be provided on a website if enough resources are available to do so. Laying out all of this information on a report card may seem like a daunting task, but there are many resources available (See References and Further Reading). Figure 12.10 shows an example layout of a report card with information about the grades and indicators.

Communication strategy

A well-rounded communications strategy outlines key messages (i.e., what one wants to convey), identifies target audiences (i.e., with whom one wants to communicate), helps choose a spokesperson, and determines communication vehicles (i.e., the documents or techniques through which one communicates). At the same time communication products are being determined, the content of those products should also be decided.

The report card itself can be a printed product, such as a 4-page newsletter or double-sided trifold, or it can be produced on your organization's website (Figure 12.10). Often, the suite of communication products are determined at the beginning of a monitoring project during the proposal stage, so make sure that sufficient time and resources are allotted to complete the products that are committed to in the proposal. Each communication product engages a different audience and requires different time commitments. Figure 12.11 shows an example layout of a report card with information about the grades and indicators.

A website is now considered an essential science communication tool. It allows the widest possible audience to be reached in the most timely manner, without the normal delays of print media. The constant ability to edit

Figure 12.10. Examples of different report card products. Top to bottom: 2011 Chester River report card (4-page newsletter), 2011 State of the Anacostia River (8-page brochure), 2012 West & Rhode River Report Card (12-page brochure), and 2012 South River Report Card (17-page pamphlet).

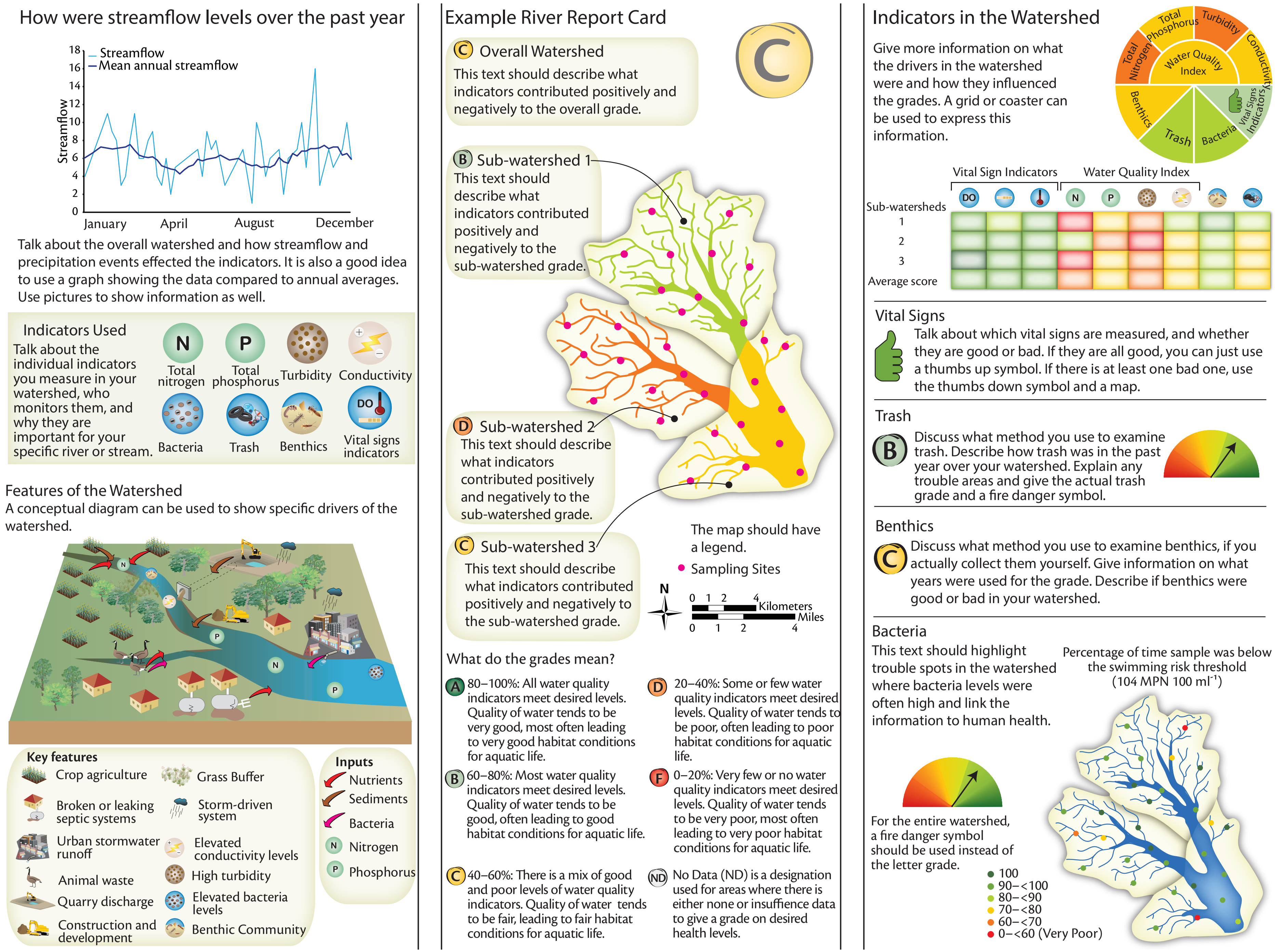


Figure 12.11. This sample spread of a report card shows how to integrate all of the elements to create a visually appealing and informative communication product.

and refine a website is one of the key features that makes them effective for science communication. However, this can also be a trap because it is often too easy to publish something that is not well-designed, thinking that it can always be fixed later. The reality is often quite different, and as a result, the website can become a jumble of disjointed pages with a poorly designed structure and navigation system. Like other media, websites should follow the principles of effective science communication—they should be visually appealing and cleanly laid out with the right balance of meaningful graphics and informative text. They should also have a consistent look and feel. Some key features of an effective website are a clear and consistent navigation system and obvious hyperlinks. Above all, do not get too fancy—bells and whistles are not as important as good, clear content.

The high profile and sometimes controversial nature of report cards necessitates special attention to the communication strategy. A communication strategy needs to consider the main messages that the report card will deliver, how to best deliver the message, and how to reach a broad audience. In terms of messaging, a report card provides an opportunity to communicate the overall health of a region, how one region compares to another, and how health may have changed from one year to another. The report card also provides a vehicle to communicate other related messages such as restoration efforts being undertaken in the area or how the audience can become involved and help in restoration activities. Before releasing a report card, it is advisable to brief appropriate people and agencies about what the report card scores will be (with an embargo on their release until the chosen release date) so that they have the opportunity to prepare appropriate responses.

All of these products—a printed report card, website, and a general communication strategy—have varying amounts of time and effort associated with them. Discussion of these time constraints are beyond the scope of this protocol, but a thorough explanation of different communication products, time commitments, and audiences is provided in Longstaff et al. (2010).

Conclusions

Need for standardization

Ecosystem health report cards are proven outreach tools for engaging and educating citizens, stakeholders, managers, and elected officials about the health of their ecosystem. Many organizations in the Mid-Atlantic region have recognized the power of such report cards and have begun to produce them on an annual basis. Currently, most organizations that have been producing report cards use indicators, data collection procedures, and analysis methods that are unique to their own monitoring program. This presents several potential issues and problems:

- Results from different report cards cannot be assessed in relation to each other. If each organization is using different indicators and methods, the results are not comparable. This limits the utility of report cards to present a larger picture of ecosystem health in a region.
- Data collected by individual organizations and/or citizen volunteers may not always adhere to rigorous scientific standards for quality control. Products derived from these data may be then viewed as less reliable and therefore not taken seriously.
- Data may also fail to be integrated into larger analyses or used in criteria assessments or management programs if the quality of the data are suspect.

Using this protocol to build scientific and public knowledge via report cards

The project that supported the development of this protocol was intended to alleviate some of the aforementioned concerns by developing standards for quality control, data collection, and data analysis that would enhance the overall quality and utility of data collected and the resulting products produced (e.g., report cards). This document is intended to provide guidance for organizations as they develop monitoring programs and consider producing report cards for their watersheds. This protocol aims to achieve two main objectives:

- Enhance the ability of organizations to produce effective ecosystem health report cards for watersheds in the Mid-Atlantic region, and
- Increase the utility of data collected by these organizations through standardization of data collection and analysis methods.

The availability of consistent, high quality data is the cornerstone of any assessment project, and one that cannot be achieved without rigorous and consistent guidelines for program design, quality control, sampling, and data analysis methods. For report cards, which are produced annually, it is especially important to have long-term consistency in the way data are collected and analyzed, and results presented.

This document represents the first attempt to develop consistent methods for these indicators relevant to watershed health in non-tidal rivers and streams. It addresses total nitrogen, total phosphorus, conductivity, turbidity, bacteria, trash, benthic community, dissolved oxygen, pH, and water temperature. By standardizing indicators and monitoring protocols, the scientific validity of the data collected will also be strengthened, thereby increasing the ability of groups to successfully reach and influence their audiences. Additionally, the overall utility of the data collected by individual groups will be enhanced by allowing direct comparison of results among regions.

Many organizations have contributed to this protocol document that already had sampling and data analysis procedures in place before this protocol was developed. Therefore, all current groups in MTAC do not necessarily follow every single guideline recommended here. The hope is that, in time, all organizations will be able to adjust their monitoring and analysis procedures to be in keeping with the guidelines.

There are many critical elements to developing a report card as a successful communication tool, such as synthesis of indicators into an overall grade, effective communication of results, and supporting stories. This protocol addresses many of these critical elements, but obviously cannot address all eventualities and scenarios. The editors and contributors sincerely hope that the guidelines presented in this document will help new organizations as they design their sampling programs and reporting frameworks.

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Chesapeake Bay Program: chesapeakebay.net
Chesapeake Bay Trust: cbtrust.org
NOAA: noaa.gov
US EPA, Rivers & Streams: water.epa.gov/type/rsl/
USGS, Water Resources: usgs.gov/water/
UMCES: umces.edu

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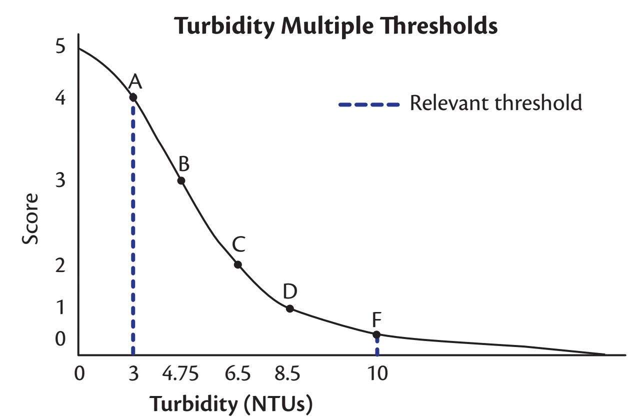
Addendum I: Multiple thresholds analysis

Turbidity

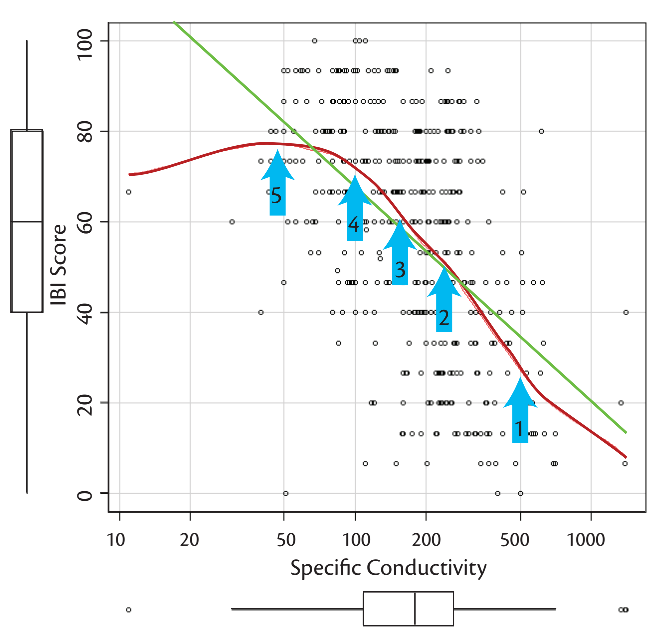
Applications of multiple thresholds work well if associated with either an ecologically relevant value, or a value recommended by federal or state governments. To develop a set of thresholds from one or two values, equal intervals are used. For example, multiple thresholds for turbidity were determined by using government standard values; 3.0 nephelometric turbidity units (NTUs) is a value EPA recommends as a pass/fail level, and 10.0 NTUs was a level determined by MD DNR (US EPA 2000; Kilian et al. 2006). By anchoring 3.0 as the 4 value and 10.0 as the 1 value, equal intervals were used to determine the remaining threshold levels.



Thresholds for turbidity were determined by anchoring scores using two EPA recommended values, then dividing the scores using equal intervals.

Conductivity

Multiple thresholds were also determined for conductivity using ecologically relevant data. For conductivity thresholds, scatter plots were generated for each ecoregion (Mid-Atlantic Coastal Plain, Southeastern Plain, Piedmont, Ridges, and Valleys) comparing conductivity levels to different benthic macroinvertebrate metrics and the Chesapeake Non-tidal Benthic Database. These scatter plots were fit with linear regression best fit lines and locally weighted scatterplot smoothing (LOESS) curves. The LOESS curves indicate where conductivity levels begin to be associated with decreasing Benthic Index of Biotic Integrity (Benthic IBI). The start of the curve, where Benthic IBI began to decrease, was selected as the threshold for the 5 score, or "A" grade. Lower scores were reconciled with observations of the Benthic IBI on the scatterplot and percentiles in the frequency distribution of the data.



Conductivity is compared to Benthic IBI scores to determine at which increasing conductivity levels does Benthic IBI decrease. The green line expresses the best fit linear regression and the red line is the LOESS curve. The blue arrows indicate conductivity thresholds determined by drops in the Benthic IBI score.

Nitrogen and phosphorus

For total nitrogen and total phosphorus, multiple thresholds were determined from analysis of the Chesapeake Non-tidal Benthic Database dataset. Breakpoints for threshold levels were identified for each ecoregion (Mid-Atlantic Coastal Plain, Southeastern Plain, Piedmont, Ridges, and Valleys) using recursive partitioning. The analysis found that benthic macroinvertebrate health, as measured by an Index of Biotic Integrity, decreased with increasing nutrient levels. The nutrient–biotic response tended to identify lower breakpoints, which were used for the 5–3 scores (A–C grades).

Addendum II: Ecoregion and use determination

United States ecoregions

The US EPA has assigned each location in the country into 1 of 14 distinct ecoregions. These ecoregions allow agencies to determine regionally specific and locally appropriate water quality criteria for lakes, reservoirs, rivers, streams, and wetlands. These 14 ecoregions are further divided into more specific subcategories.

To determine which ecoregions your sampling sites are in, use the US EPA website at: http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/ecoregions/ecoregions_rivers_index.cfm.

Maryland ecoregions

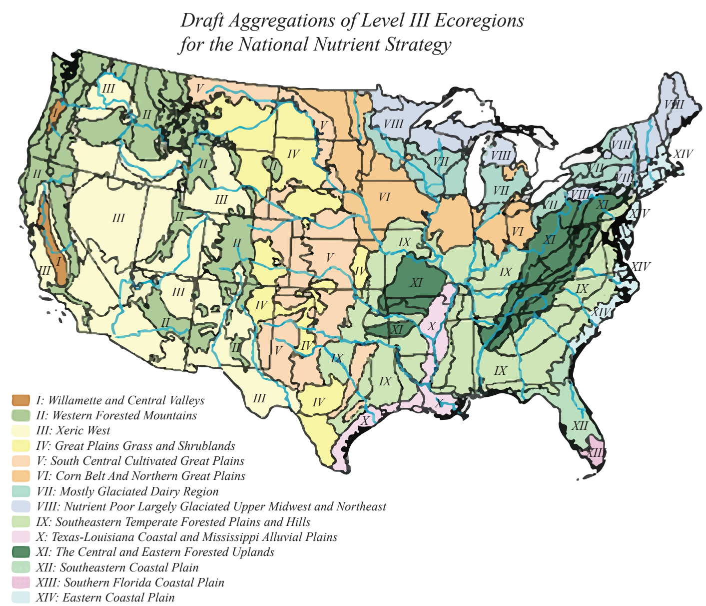
In the Mid-Atlantic, the ecoregions are part of EPA region 3, levels III and IV. These more specific ecoregions are what were used to determine the thresholds for total nitrogen, total phosphorus, and conductivity. The ecoregions that were used for this protocol are Mid-Atlantic Coastal Plain, Southeastern Plain, Piedmont, Ridges, and Valleys.

Warmwater and coldwater designated uses

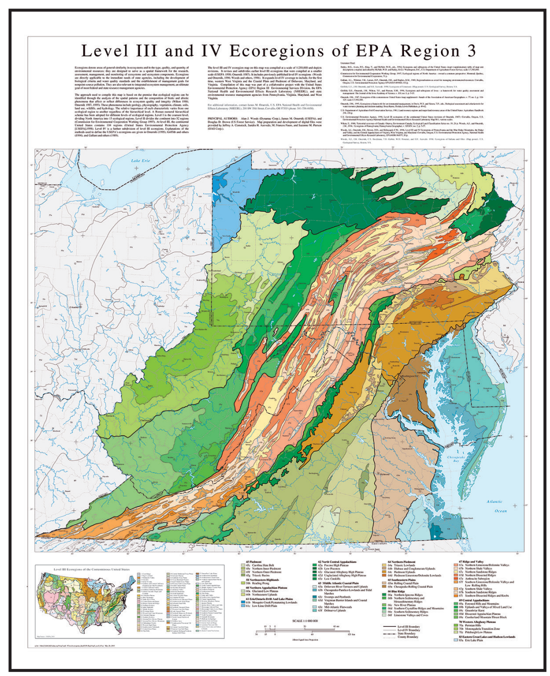
The designated use for each waterway in the US is determined by either the EPA or the state environmental agency. For example, Maryland Department of the Environment has assigned each waterbody in Maryland a designated use, which has corresponding goals for water quality. Maryland has the following eight general uses:

- Use I: Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life
- Use I-P: Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply
- Use II: Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting
- Use II-P: Tidal Fresh Water Estuary – includes applicable Use II and Public Water Supply
- Use III: Nontidal Cold Water
- Use III-P: Nontidal Cold Water and Public Water Supply
- Use IV: Recreational Trout Waters
- Use IV-P: Recreational Trout Waters and Public Water Supply

These designated uses apply to both tidal and non-tidal areas of Maryland. If your river or stream is located in Maryland, you can determine whether your stream is warmwater or coldwater by going to the following website: http://www.mde.state.md.us/programs/Water/TMDL/Water%20Quality%20Standards/Pages/programs/waterprograms/tmdl/wqstandards/wqs_designated_uses.aspx.



This map shows the 14 EPA ecoregions in the contiguous United States.



This map shows more detailed ecoregions over the Mid-Atlantic states.

In other states of the Mid-Atlantic, and throughout the entire country, the designated use can be determined by going to each state's environmental agency website. These websites are listed in the References and Further Reading section of this document.