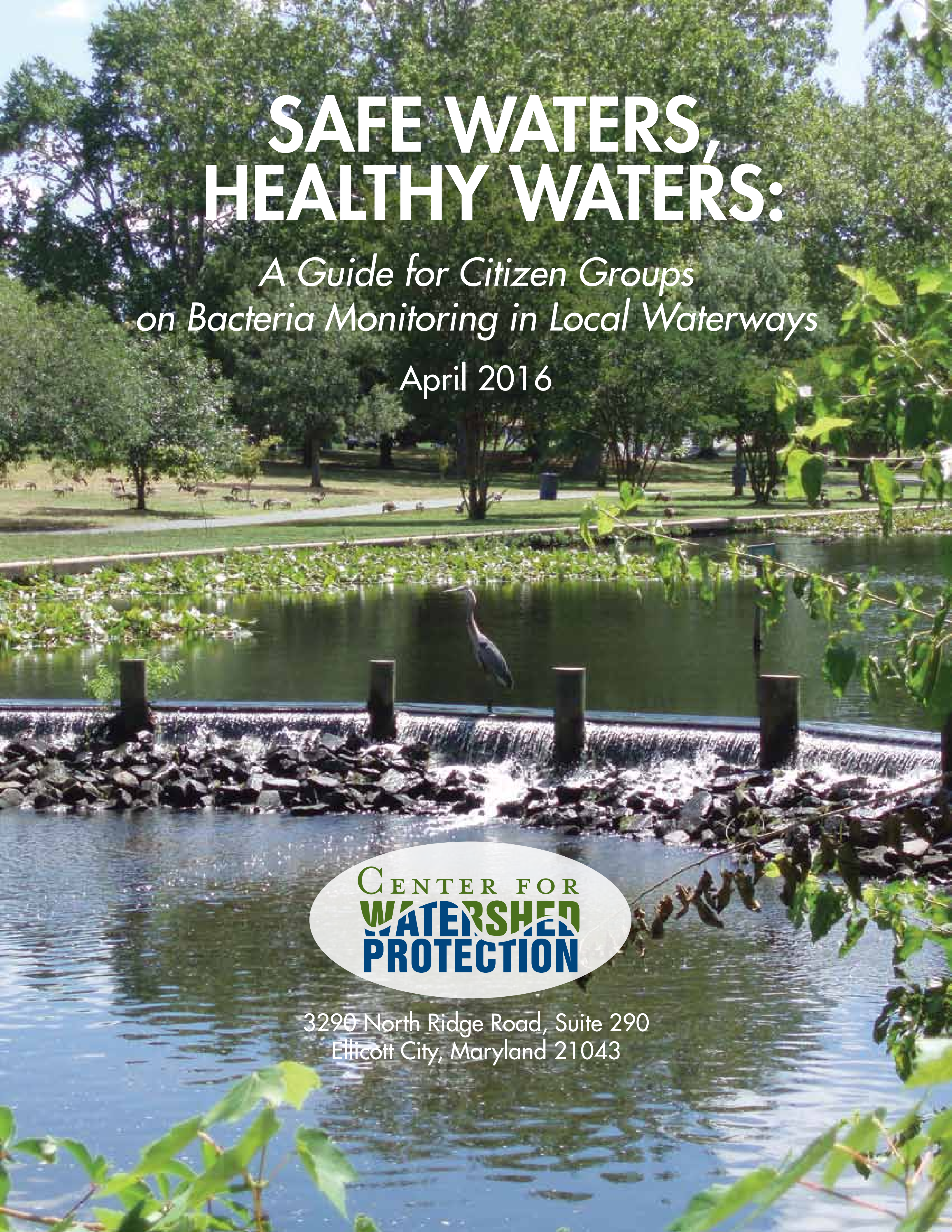


SAFE WATERS, HEALTHY WATERS:

A Guide for Citizen Groups on Bacteria Monitoring in Local Waterways

April 2016

Center for Watershed Protection

3290 North Ridge Road, Suite 290
Ellicott City, Maryland 21043

Table of Contents

About This Guide

In urban waters across the U.S., reports of discharges of untreated or partially treated sewage are regrettably not uncommon. Sources of sewage discharges can include sanitary sewer overflows (SSOs) and leaks from old and deteriorating systems, dumping, illegal sewer connections and failing septic systems. Water that is contaminated with sewage presents a serious health risk to the public, particularly in areas where people recreate, such as beaches and swimming holes.

The Center for Watershed Protection has been working at both the local and federal levels to address the important issue of sewage discharges, including authoring a national guidance on illicit discharge detection and elimination (IDDE) in 2004 and working with more than 20 communities to apply the monitoring protocols for identifying and tracking the sources of illicit discharges, such as sewage. The Center's work has shown some surprising results about the prevalence and contribution of sewage discharges in urban areas. Even in cities such as Baltimore, Maryland, where MS4 permit requirements and consent decrees for SSOs are being enforced, initial sampling showed that 53% of outfalls tested had bacteria levels above the recommended threshold for contact recreation. In the same Baltimore watershed, the bacteria load from outfalls with suspected illicit discharges was estimated to be 51% of the bacteria reductions required under a local TMDL. Other communities have missed detecting a portion of their illicit discharges simply because they don't sample small outfalls or do not use ammonia as an indicator. Our work also showed that eliminating illicit discharges can be significantly more cost-effective than most other practices, including green infrastructure, to reduce nutrients and other pollutants.

It is clear from these findings that many local governments need help to effectively address sewage discharges, and the success of Blue Water Baltimore in supporting the Baltimore City government with outfall monitoring has highlighted the important role of citizen volunteers. Citizen monitoring programs can help to sample where other agencies aren't testing or provide data to convince local agencies to establish monitoring programs. Citizen monitoring is also an effective way to improve the public's knowledge of the safety of their water and to act as a "watchdog" to ensure that local agencies are addressing the problem. The Center's 2004 IDDE manual was intended for regulated MS4 communities tasked with setting up a program, but did not address the role of volunteers. To fill this gap, the *Safe Waters, Healthy Waters* document provides guidance for citizen groups on how to identify, narrow down sources and communicate about bacterial contamination, with a specific focus on human sewage sources and monitoring techniques that are simple, reliable and low-cost.

This guide was written by Karen Cappiella, Carol Wong, Lori Lilly and Laurel Williamson and designed by Kim Roberts. The authors would like to acknowledge the Ittleson Foundation for generously providing funding to develop this guide and to the Cornell Douglas Foundation for funding local case studies in Vermont. Thank you to the following people who provided a review of the guide: Sarah Bounty, Neponset River Watershed Association; Jennifer Epstein and Dan Shapley, Hudson Riverkeeper; James Beckley, Virginia Department of Environmental Quality; Sarah Devries, Arkansas Highway & Transportation Department; and Jim Pease, Vermont Department of Environmental Conservation. Thanks also to the following individuals who contributed case studies and other content to the guide: Mara Dias, Surfrider Foundation; Jason Ulseth, Chattahoochee Riverkeeper; David Hannah, Rivanna River StreamWatch; Anna Mathis and Bill Shanabruch, Alliance for the Chesapeake Bay/Reedy Creek Coalition; Hilary Solomon, Poultney Mettowee Natural Resources Conservation District; Karen Reynolds, Environmental Canine Services; and Dana Allen, Watershed Consulting Associates. For more information about this guide, contact Laurel Williamson, Stormwater and Watershed Planner, Center for Watershed Protection, at lw@cwp.org.

1 Background on Bacteria in Local Waterways

Contaminated water presents a serious health risk at beaches and in rivers and streams throughout the United States. This is particularly the case in urban areas where numerous pollution sources (and water users) are concentrated within a relatively small area. The most recent estimate from the US Environmental Protection Agency (EPA) shows that 39% of assessed rivers and streams, 13% of assessed lakes, reservoirs and ponds, and 30% of assessed bays and estuaries in the US are not clean enough to support recreational uses such as fishing or swimming (US EPA, 2015).

Figure 1. Beach closing due to fecal contamination
(Source: South Carolina Department of Natural Resources)

One of the most commonly identified pollutants in our Nation's waters is bacteria. Bacteria exist naturally in all surface water and are not typically harmful to humans, but certain types of bacteria present in fecal contamination can cause infections in humans. Detecting fecal bacteria is an effective way to determine the likelihood of presence of pathogenic organisms in water.

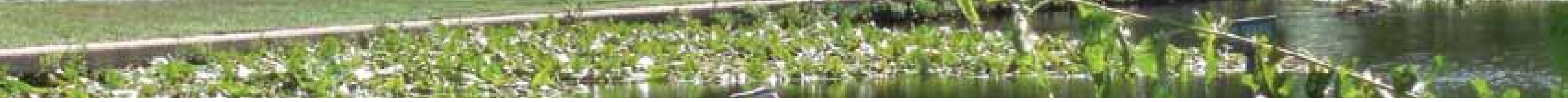
Fecal bacteria are microorganisms that inhabit the gastrointestinal tract of humans and most other warm-blooded animals. Fecal waste can contain pathogens such as harmful bacteria, viruses and protozoa. Pathogens can cause disease in humans, including minor illnesses such as gastroenteritis or upper respiratory infections, and, occasionally, more serious diseases (Figure 1). Pathogens are difficult and expensive to detect, therefore fecal indicator bacteria such as E. coli and Enterococci, are used to determine the presence of fecal waste in surface water. Most fecal indicator bacteria are non-pathogenic, but are good indicators of fecal contamination. The actual risk of contracting a disease from a pathogen depends on a host of factors, such as the method of exposure or transmission, pathogen concentration, incubation period and the age and health status of the infected party.

Researchers and regulatory agencies have determined that conducting indicator bacteria monitoring can help to identify human health risks associated with drinking, shellfish consumption and recreational water contact. The Clean Water Act structure for conducting this monitoring is described below.

1.1 Basics of Water Quality Standards

The Clean Water Act (CWA) sets forth the goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters so that they can support—among other uses—"the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water." Water Quality Standards are the foundation of the Clean Water Act and regulate how clean a water body should be. Water Quality Standards include three parts: 1) designation of uses for all water bodies, 2) establishment of Water Quality Criteria to protect those uses, and 3) development of provisions to protect water quality from pollutants. Each state and tribe is responsible for designating uses–for instance public water supply, recreation, or navigation–for all waters under its jurisdiction. For each designated use, Water Quality Criteria are defined to protect these intended uses. Water Quality Criteria are limits on particular chemicals or conditions in a water body and can be expressed numerically or as narrative statements.

In 2012, the EPA released the Recreational Water Quality Criteria designed to protect waters designated for primary contact recreation, including swimming, bathing, surfing, water skiing, tubing, water play by children, and similar water contact activities where a high degree of bodily contact with the water, immersion and ingestion are likely. Water



Quality Criteria for recreation are based on the use of bacterial indicators of fecal contamination as a result of studies that show a link between illness and fecal contamination in recreational waters. The detection and enumeration of fecal indicator bacteria provides a practical method to determine the potential health risk from water exposure.

EPA's 2012 Water Quality Criteria for recreational waters are based on the use of two bacterial indicators of fecal contamination, enterococci (recommended for marine and fresh water) and *E. coli* (fresh water only). Previously, fecal coliform was used as the basis for recreational water quality criteria, but recent studies have shown that *E. coli* and enterococci are better indicators for predicting health risks. The EPA criteria include two sets of concentration thresholds for fecal bacteria, measured as the geometric mean of colony-forming units, or cfu, in water quality samples. Both concentration thresholds will protect primary contact recreational use; but Option 2, which is based on an illness rate of approximately 1 in 31 people, encourages some incremental improvement over Option 1, which is based on an illness rate of approximately 1 in 28 people. For both options, the waterbody geometric mean should not be greater than the selected geometric mean magnitude (Table 1) in any 30-day interval. The statistical threshold value serves as a backstop or secondary level of concentration to protect public health. No more than 10% of samples taken should exceed the statistical threshold value in the same 30-day period. It should be noted that these thresholds are calculated differently than in the past, and are based on a revised definition of gastrointestinal illness.

Table 1. EPA Recreational Water Quality Criteria Recommendations

Criteria Elements	Option 1		Option 2	
Indicator	Geometric Mean (cfu/100 mL)	Statistical Threshold Value (cfu/100 mL)	Geometric Mean (cfu/100 mL)	Statistical Threshold Value (cfu/100 mL)
Enterococci (marine and fresh)	35	130	30	110
E. coli (fresh)	126	410	100	320

In addition to these criteria, the EPA Recreational Water Quality Criteria provides Beach Action Values (BAVs), which are single sample maximum values that can be used to issue health advisories at beaches. The BAVs for enterococcus are 70 cfu/100mL for a risk of infection of 1 in 28, and 60 cfu/100mL for a risk of infection of 1 in 31. The BAVs for *E. coli* are 235 cfu/100mL for a risk of infection of 1 in 28, and 190 cfu/100mL for a risk of infection of 1 in 31. These values, while not recommended for determining use attainment, can be used as a precautionary tool for making beach notification decisions. EPA's Water Quality Criteria recommendations are intended as guidance in establishing new or revised water quality standards, and states and authorized tribes have the discretion to adopt, where appropriate, other scientifically defensible water quality criteria. Check with your state agency to determine the applicable fecal indicator bacteria criteria for your local jurisdiction or watershed.

After setting Water Quality Standards, states assess their waters to determine the degree to which these standards are being met. To do so, states may take biological, chemical, and physical measures of their waters; sample fish tissue and sediments; and evaluate land use data, predictive models, and surveys. Waters that do not meet one or more of their designated uses are placed on the impaired waters list also known as the 303(d) list, named for the section of the Clean Water Act that requires it. States must submit a biennial report on the status of all its assessed waters (as required under section 305(b) of the Clean Water Act), a listing of its impaired waters and the causes of impairment, and the status of actions being taken to restore impaired waters. For impaired waters, a total maximum daily load (TMDL) must be developed that quantifies how much of the pollutant of concern can be discharged into the waterbody while still meetings its designated uses. Usually, a TMDL implementation plan is also developed that outlines how the TMDL will be met.

Nationally, pathogens are the cause of impairment for more river and stream miles than any other pollutant, and more TMDLs (over 12,000) have been developed to address pathogens than any other pollutant. The majority of these TMDLs have been for fecal coliform (6,447) and *E. coli* (4,014). Table 2 summarizes the status of pathogen impairments in the U.S.

Table 2. National Summary of Pathogen Impairments

Water Body Type	Length/Area Impaired by Pathogens
Rivers and streams	159,451 miles
Lakes, reservoirs and ponds	248,878 acres
Bays and estuaries	6,157 square miles
Coastal shoreline	1,085 miles
Ocean and near coastal waters	81 square miles
Wetlands	72,349 acres
Great Lakes shoreline	492 miles

Source: EPA Watershed Assessment, Tracking and Environmental Results System (WATERS) database: http://water.epa.gov/scitech/datait/tools/waters/index.cfm

1.2 Sources of Bacteria in Local Waterways

So how did all these rivers, streams and lakes become impaired in the first place? Bacteria make their way into urban surface waters indirectly through stormwater runoff (a "nonpoint source") or are discharged directly into streams, rivers and lakes at a single point of entry (a "point source"). The most common point and nonpoint sources of bacteria in urban waters are described below, along with applicable federal regulations to control them. The bacteria monitoring and source identification methods presented in this guide focus primarily on ***human sewage sources*** because it is thought that human fecal material is more likely to contain organisms that are the most pathogenic to humans than is fecal material from other animals. Additionally, human fecal matter is typically more controllable than non-human sources, such as wildlife.

Stormwater runoff

Numerous studies have consistently documented high concentrations of bacteria in urban stormwater runoff (Pitt, 1998; Schueler, 2000). Stormwater picks up bacteria and other pollutants as it flows across hard surfaces, such as rooftops, roads and parking lots, and transports them through the storm sewer system and ultimately into a surface water body. The bacteria found on impervious surfaces may come from pet waste, wildlife or other sources. The Clean Water Act Section 402 regulates stormwater discharges through the National Pollutant Discharge Elimination Program (NPDES). Dischargers who must obtain a permit include certain municipal separate storm sewer system (MS4) communities and operators of construction sites disturbing one acre or more and industrial stormwater discharges. Reductions from MS4s and other point sources identified in TMDL plans are enforced through the NPDES permit program.

Combined sewer overflows (CSOs)

Many older cities have a sewer system that carries both wastewater and stormwater. These systems were often constructed before the risks of combined sewers were fully understood. During some storms, the capacity of the treatment system and pipe network is exceeded, and a combination of stormwater and wastewater is discharged directly into surface water without treatment (Figure 2). This discharge is known as a combined sewer overflow, or CSO. CSOs have extremely high bacteria levels due to the presence of untreated sewage and deserve immediate attention as a bacteria source when they are present in any watershed. EPA's Combined Sewer Overflow Control Policy is a national framework for control of CSOs through the NPDES permitting program. CSO communities must implement nine minimum controls, which are measures that can reduce the prevalence and impacts of CSOs and that are not expected to require significant engineering studies or major construction. They are also expected to develop long-term CSO control plans that will ultimately provide for full compliance with the Clean Water Act, including attainment of water quality standards. Visit this web-site to determine if your community has a combined sewer system: http://www.epa.gov/npdes/pubs/csossoRTC2004_AppendixD.pdf

Figure 2. Combined sewer overflow *(Photo courtesy of EPA)*

Sanitary sewer overflows (SSOs)

Human sewage can be introduced into surface waters even when storm and sanitary sewers are separated. Leaks and overflows are common in many older sanitary sewers where capacity is exceeded, high rates of infiltration and inflow occur (i.e., outside waters gets into pipes, reducing capacity), frequent blockages occur, or aging pipes fail due to the pipe material or joints. Power failures at pumping stations are also a common cause of SSOs. Sanitary sewage discharged into a street during an SSO will enter the stormwater system through the nearest catch basin and can then find its way into the receiving water without treatment. The greatest risk of a SSO occurs during storm events; however, little comprehensive data is available to quantify SSO frequency and bacteria loads in most watersheds. MS4 communities regulated under the NPDES stormwater program are required to establish a program to detect and eliminate illicit discharges to the stormwater system, which include SSOs. SSO may also be identified as sources of impairments in TMDLs, or threats to drinking water supply or endangered species. For these latter situations, the Safe Drinking Water Act and Endangered Species Act come into play to help ensure these problems are corrected promptly. Some states track and publish SSO discharges and some states do not; check with your state department of environmental protection to determine if this information is available to the public.

Illicit connections to storm sewers

Sewage can be introduced into storm sewers and surface waters by accident or design (Figure 3). The hundreds of miles of storm and sanitary sewer pipes in a community create a confusing underground network of utilities, so it should not be surprising that improper connections are made to the wrong sewer. For example, Johnson (1998) reported that almost 10% of all businesses in Wayne County, Michigan had illicit connections, with an average of 2.6 illicit connections found at each detected business. While most illicit connections did not contain raw sewage (e.g., floor drains, sinks), 11% of the Wayne County illicit connections included toilet discharges. Illicit connections are one type of illicit discharge, which are regulated under the MS4 Permits.

Illegal dumping

There is quite a bit of anecdotal evidence of illegal transient dumping of raw sewage into storm drain from septage vacuum trucks (i.e., honey wagons), recreational vehicles, and portable toilets (Johnson, 1998) or improperly disposed diapers. In addition, there may be inadvertent dumping from moving vehicles, such as livestock carriers and recreational vehicles. The overall significance of illegal or inadvertent dumping as a watershed bacteria source, however, is hard to quantify. Most types of illegal dumping qualify as an illicit discharge and are regulated but are difficult to catch or enforce.

Figure 3. Illegal discharge of septic system effluent to a local waterway *(Photo courtesy of EPA)*

Failing septic systems

About one-fifth of all American households rely on on-site septic systems to dispose of their wastewater, which translates to about 26 million individual systems (U.S. Census Bureau, 2007). After solids are trapped in a septic tank, wastewater is distributed through a subsurface drain field and allowed to percolate through the soil. Bacteria are effectively removed by filtering and straining water through the soil profile, if the septic system is properly located, installed and maintained. A large number of septic systems fail, however, when wastewater breaks out or passes through the soil profile without adequate treatment. According to the U.S. EPA, about 10 percent of all septic systems in the U.S. are estimated to be malfunctioning at any given time (US EPA, 2003), with rates as high as 70% being reported in some areas. The causes of septic system failure are numerous: inadequate soils, poor design, siting, testing or inspection, hydraulic overloading, tree growth in the drain field, old age, and failure to clean out. In rarer cases, septic systems are illegally diverted directly to surface waters as shown in Figure 3. States, tribes and local governments are responsible for regulating individual onsite systems and property owners are responsible for the maintenance.

Wildlife and domestic animals

Documented non-human sources of fecal coliform bacteria in urban watersheds are dogs, cats, raccoons, rats, beaver, gulls, geese, pigeons and even insects. Dogs in particular appear to be a major source of coliform bacteria and other microbes, which is not surprising given their population density, daily defecation rate, and pathogen infection rates. According to van der Wel (1995), a single gram of dog feces contains 23 million fecal coliform bacteria. Dog feces can be a significant issue in a watershed where dog handlers dispose waste in catch basins or directly into water bodies. In highly urban areas, rats and pigeons can be a major source of bacteria (Lim and Oliveri, 1982). Geese, gulls and ducks are speculated to be a major bacterial source in urban areas, particularly at lakes and stormwater ponds where large resident populations become established. Livestock can even be a major source of fecal coliform in unsewered urban watersheds, particularly those areas of the urban fringe that have horse pastures, "hobby" farms and ranchettes. Bacteria from wild and domestic animals may indicate the presence of the parasites Giardia or Cryptosporidium.

Marinas / marine sanitation devices (MSDs)

MSDs are used to collect and, in some applications, treat the wastewater that is generated on marine vessels. Although certain MSDs are designed to be pumped out, they are too frequently discharged overboard, resulting in a direct discharge of untreated sewage to the water. Discharge of sewage directly overboard is actually a legal practice outside the US territorial waters (3 or more miles from shore), which unfortunately may discourage MSD operators from properly disposing of their stored waste. An exception is "no discharge zones," established by EPA or the states in sensitive areas and where discharge of treated or untreated sewage is prohibited. Marinas may also be a source of bacteria from spills during pumpout of MSDs. The EPA and the U.S. Coast Guard jointly regulate MSDs under CWA section 312; however, detection and enforcement of discharges that do not meet the effluent standards is very difficult because the source of the discharge (watercraft) is mobile. Efforts to encourage pumpouts and best practices to reduce spills have been most effective.

1.3 The Role of Citizen Monitoring

You might wonder, with the current Clean Water Act regulatory structure to protect water quality, why should citizen groups conduct bacteria monitoring? Citizen monitoring programs can help to support and inform state and local agency programs by testing where other agencies aren't testing, providing data to convince local agencies to establish monitoring programs, or providing essential data for TMDL development and implementation. Citizen monitoring is also an effective way to improve the public's knowledge of the safety of their water and to act as a "watchdog" to ensure the local agencies are addressing the problem.

Bacteria can be difficult to sample and analyze, for many reasons. Natural bacteria levels in streams can vary significantly. For example, they can rise sporadically in response to passing waterfowl or other wildlife. One Massachusetts beach study found that sampling at ankle depth yielded consistently higher E. coli readings than sampling at waist level, which gave higher readings than samples collected at chest level (Doolittle, 2002). Bacteria conditions are strongly correlated with rainfall, and thus comparing wet and dry weather bacteria data can be a problem. Many analytical methods have a low level of precision yet can be quite complex, and absolutely sterile conditions are required to collect and handle samples. Given these challenges, regular monitoring is important for any waterbody that is used for recreation to better quantify the potential health risks. Volunteer bacteria monitoring has the ability to provide tremendous insight on local waters, helping local and state agencies improve water quality.

There are also some limitations to the Water Quality Standards development process that make collection of additional and/or different types of data important for answering the question "is the water safe?" Existing monitoring data may not be adequate for the reasons described below.

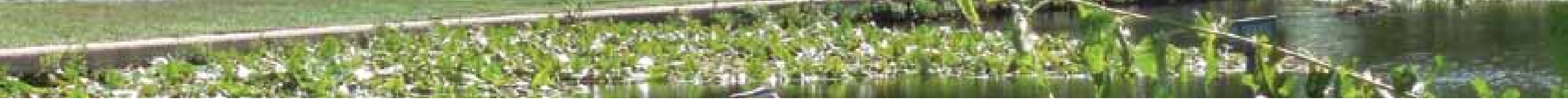
Use of outdated bacterial indicators

Studies conducted by EPA to determine the correlation between different bacterial indicators and the occurrence of digestive system illness at swimming beaches suggest that the best indicators of health risk from recreational water contact in fresh water are *E. coli* and enterococci (EPA, 2012). For salt water, enterococci are the best (EPA, 2012). Although these indicators have been shown to correlate better with the risk of digestive system illness, many states still use fecal coliform as their primary fecal indicator bacteria.

If your state is still using total or fecal coliforms as the indicator bacteria and you want to know whether the water meets state water quality standards, you should monitor fecal coliforms. However, if you want to know the health risk from recreational water contact, the results of EPA studies suggest that you should consider switching to the *E. coli* or enterococci method for testing fresh water. In any case, it is best to consult with the water quality division of your state's environmental agency, especially if you expect them to use your data.

Limited spatial extent of sampling

Ambient (background) monitoring networks are typically designed to characterize water quality conditions at a broad scale and may not be as useful for assessing the health of a specific stream reach. EPA's guidance on monitoring design for the 305(b) assessment program encourages states and tribes to include a probability-based network for making statistically valid inferences about the condition of all state water types over time as part of the monitoring design. As an example, Maryland Department of the Environment uses the approach that if greater than 10 percent of the streams monitored do not meet biological indicator standards, the entire 8-digit Hydrologic Unit Code watershed is considered impaired. Therefore, simply being located in a watershed designated as impaired does not necessarily mean that your specific stream is unsafe and additional monitoring may be warranted.



Infrequent sampling

Due to the notoriously variable nature of bacteria data, regular sampling is important for recreational waters such as swimming beaches. A one-time sampling effort is not sufficient to determine the safety of these waters today, especially if there have been changes to land use/land cover since the monitoring was conducted. However, the EPA does not specify a minimum number of samples needed, as it depends on concentration of bathers, historical records, accessibility, potential pollution sources, and other factors (EPA, 2002). For recreational beach waters, the EPA recommends water quality samples to be taken at least once a week, and more frequently at locations with a more dense population of swimmers (EPA, 2012). It is important to consider that these recommendations are for states to design their recreational water quality criteria and monitoring programs. For a volunteer monitoring program, the number of volunteers and available resources may limit the ability to sample as frequently.

The remainder of this guide lays out protocols for a bacteria sampling program for citizen groups that addresses the above limitations. It is important to note that there is no one-size-fits-all approach for citizen monitoring programs. The needs of each organization may vary greatly, and this guide attempts to summarize the pieces needed for a successful program. Depending on the status of your citizen group, you may want to begin at the section that best fits your needs.

- *Section 2. Designing Your Baseline Bacteria Monitoring Program*. This section covers the basic information needed to design a bacteria monitoring program. Depending on the goals of the program, different levels of effort will be needed to ensure success.
- *Section 3. Investigating Potential Pollutant Sources*. If you already suspect a potential pollutant source OR you found a suspicious hotspot through monitoring, this section will help you to understand the steps needed to investigate a pollutant source as a citizen group. It is important to note that there is limited action a citizen group can take to investigate the pollutant source—local officials will be needed in most situations.
- *Section 4. Sharing Your Findings and Taking Action.* After developing your monitoring program, it is important to share the data with your community. If the pollution is suspected to come from a controllable source, education and outreach is important to help address the problem. A strong relationship with local authorities is also vital to help reduce or eliminate the pollutant source.

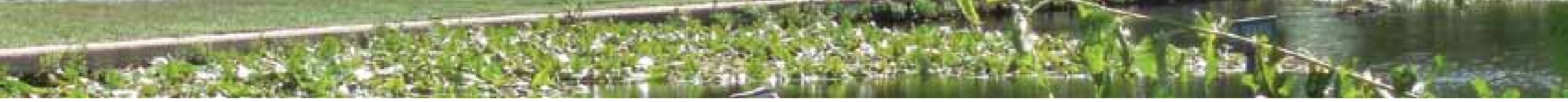
1.4 Resources

If your stream is a recognized public recreation area, there may be other groups already conducting bacteria sampling to determine if the water is safe and allow for notification about public health risks if bacteria concentrations exceed the recommended levels. The best place to start may be your local health department, environmental agency or citizen groups such as Waterkeeper organizations. If no local monitoring data is available, state data collected as part of water quality assessment may be the next best source.

- State and tribal Water Quality Standards as well as federally promulgated standards can be accessed on EPA's Water Quality Standards Repository: http://water.epa.gov/scitech/swguidance/standards/wqslibrary/index.cfm

- Many of the state Water Quality Standards are organized by major river basin. To determine what river basin you are located in, go to EPA's Surf Your Watershed: http://cfpub.epa.gov/surf/locate/index.cfm

- Many larger, developed volunteer monitoring programs can provide tremendous amounts of resources for newer programs. The Chattahoochee Riverkeeper has a guide to develop a Neighborhood Water Watch, which is a very successful volunteer monitoring program in Atlanta. http://chattahoochee.org/wp-content/uploads/2013/05/NWW-guide_FINALFINAL.pdf



- The best source to determine if your stream has been designated as impaired for bacteria is EPA's Watershed Assessment, Tracking and Environmental ResultS (WATERS) database, which can be searched by state: http://iaspub.epa.gov/waters10/attains_nation_cy.control?p_report_type=T.%20Accessed%2015%20June%202010

- EPA also provides a GIS shapefile of impaired waters that can be downloaded to see the designated reach in greater detail: http://water.epa.gov/scitech/datait/tools/waters/data/downloads.cfm

- EPA's Water Quality Standards website has state-by-state links to information on Water Quality Standards: http://water.epa.gov/scitech/swguidance/standards/regions.cfm. The state agency responsible for Water Quality Standards should be able to provide data collected for 305(b) monitoring requirements.

Other national sources of monitoring data for your stream include:

- EPA's STOrage and RETreival (STORET) Data Warehouse: http://www.epa.gov/storet/

- USGS, EPA and the National Water Quality Monitoring Council's Water Quality Portal: http://www.water-qualitydata.us/

- USGS water quality data: http://water.usgs.gov/owq/data.html

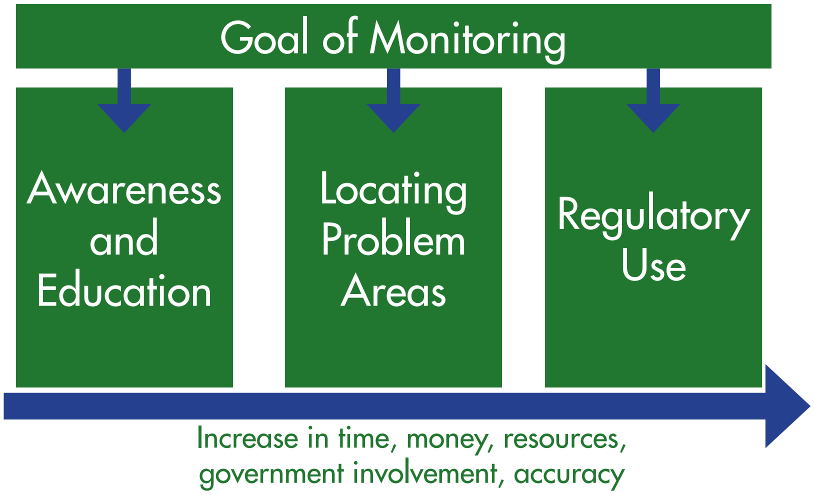
2 Designing Your Baseline Bacteria Monitoring Program

This section provides general guidance on the design of a bacteria monitoring program for citizen groups and volunteers to perform baseline assessments of their surface waters in order to help answer the question "is my water safe?" A baseline assessment is useful when there is limited data on the waterway and can be used to evaluate long-term trends. Bacteria monitoring programs can vary tremendously from location to location based on factors such as weather, resource availability, recreational water usage, available data, site accessibility and community involvement. Before any monitoring begins, it is important to develop a plan that addresses these factors and that will produce meaningful results if some factors change. Because consistency is particularly important in long-term monitoring programs, the plan should identify standardized procedures that will be adhered to by volunteers, which helps to ensure replicability of results since volunteers may change from year to year. The basic elements of a bacteria monitoring program and plan are described below.

2.1 Determine Goal of Monitoring Program

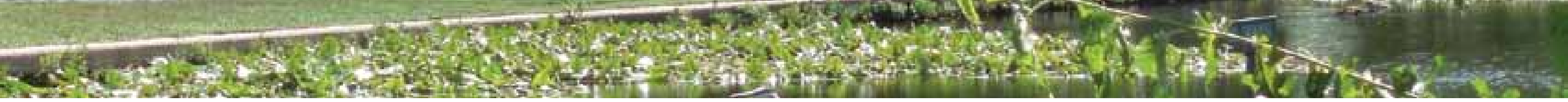
The first decision is to determine the goal of the bacteria monitoring program and how the data will be used. Depending on the goal, different methods of sampling and analysis will be needed. If your goal is to educate citizens or promote clean water practices, you can use more cost-effective methods that have a low degree of resolution. If your goal is to help local agencies by providing supplemental data, you may need better resolution and a higher level of quality assurance and quality control (QA/QC), and you should also meet with these agencies to determine how any new data can support their water quality goals. In general, the funding and time requirements of monitoring methods increase with the accuracy of the resulting data. It is imperative that you work with potential users of your data to ensure that your efforts are in line with their needs.

Below is a diagram of an example range of monitoring and the resources needed. As the goals approach regulatory use, the resources and government involvement increase.



Review Existing Data

Prior to developing a bacteria monitoring program, available TMDLs, watershed plans, monitoring data and other relevant information should be reviewed to determine the scope of previous monitoring efforts and whether any potential bacteria sources have already been identified. These plans may simply parse out the estimated bacteria load from urban versus agricultural versus wildlife sources, or they may be more specific such as estimating the number of failing septic systems in the watershed. The point is to get a general sense of the types of sources you are dealing with in the watershed and find out if any specific sources have been pinpointed as a problem to help guide your monitoring effort. Plans that include the locations of state or regional monitoring sites can also be used as a guide for locating additional monitoring sites to supplement the data. Local officials, such as health officers or beach managers, can also help to identify areas where high bacteria is suspected. Community members that know their local streams well are also a good way to learn more about water quality issues.



If the data collected from sampling and analysis need to have a high level of credibility, state-certified contract lab or in-house testing using approved EPA methods and proper sampling training will be necessary. The approved EPA methods for recreational waters are listed in Table 3. To increase your credibility, you can also have an EPA approved Quality Assurance Program Plan (QAPP). See Section 2.3 for more information. If credibility is not a priority, an in-house, less robust method can be used. While it is certainly acceptable to use EPA methods for less stringent uses, but it may not be cost- or time-effective. If you need high quality data, it is advised to send the samples to certified labs if you are a new organization or do not have laboratory facilities to perform the analysis.

You will want to use more stringent, EPA-approved methods if:

- You plan to provide your data to the State or another regulatory body;
- You want to provide scientific evidence of a problem that needs to be addressed; or
- Providing defensible data is a priority for some other reason.

You may want to start with a simpler method if:

- You are just starting a bacteria monitoring program and are not ready for or do not have funds for big investments;
- You may later want to use more stringent and expensive method for a particular sampling location;
- You will be using the data gathered for internal management decisions only;
- You are looking to get a sense of baseline or magnitude of bacteria in your area of concern; or
- Ease of collection and analysis is a priority.

2.2 Baseline Sampling and Analysis Plan

A monitoring plan should be developed that includes the location of sampling sites, frequency of sampling, timing and duration of sampling, and sampling parameters and analysis methods. The plan should also include other pertinent information, such as a field supply list; transport instructions, if applicable; references for analytic methods; instructions for collection of duplicates or other quality control procedures, and data reporting requirements. This latter information could alternatively be included in a QAPP, which is useful (and sometimes required) for a sampling program, and is discussed in Section 2.3.

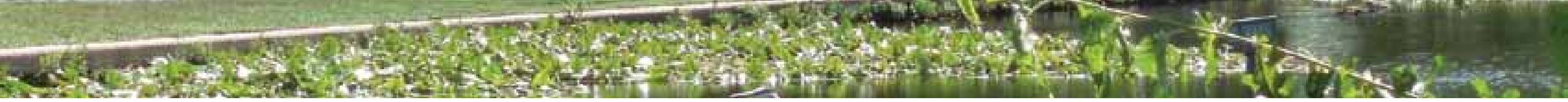
Lake and Coastal Monitoring
Monitoring in lakes, coastal waters or other deepwater environments may require sampling from a boat and other unique planning and equipment considerations.

Location of Sampling Sites

Sampling should be targeted to waterbodies that are frequently used for recreation. Specific sampling locations within these areas should be selected on the basis of the ability of a small number of samples to adequately describe water quality at the site (EPA, 2010). However, these is no standard formula for determining the number of sites needed. Locations where water quality can be best characterized are those with relatively low variability in bacteria concentrations (based on historical data where available) and those near known or likely human sewage pollution sources, such as stormwater outfalls, and away from non-human sources (e.g., bird nesting areas) or areas where resuspension/mixing may occur (EPA, 2010). Another option is to sample at a location where contamination is unlikely, providing a reference location.

Frequency of Sampling

For recreational beach waters, the EPA recommends water quality samples be taken at least once a week, and more frequently at locations with a more dense population of swimmers (EPA, 2012). There is no minimum recommendation for other waters, and the number of volunteers and available resources may limit the ability of a volunteer monitoring program to sample this frequently. Therefore, decisions about sampling frequency will need to balance the available capacity of volunteers with the need for information, and will also be influenced by the number of sampling locations. In general, the more samples, the better information you'll have when interpreting your data.



When samples exceed established Water Quality Criteria, more frequent or daily sampling may be appropriate, to determine whether the area should be closed to recreational use. Subsequent sampling is also needed to determine when to reopen the recreational area.

Timing of Sampling

Sampling should occur at each location at generally the same time of day, preferably in the morning before the sun degrades the bacteria. For crowded beaches, sampling when recreational use is highest may be appropriate (e.g., mid-afternoon). Using a contract lab for analysis may affect the timing of sampling since samples can only be kept on ice for a short period before they are brought to the lab. Labs are also not typically open 24/7 and staff may not be available 24-48 hours later to read the results. Also keep in mind that bacteria levels change frequently and analysis results often take 24 hours. Therefore the data provided is less effective (in terms of beach closures, for instance) the older it gets or if weather conditions change.

If possible, samples should be collected immediately following a large storm event as well. Both baseline and storm-event sampling can be useful to help identify general sources of the bacteria. Storm event sampling can be useful to identify sources that are associated with stormwater runoff. If you are sampling during a storm, you will need to determine if your organization has the manpower to collect samples and ensure that it is safe for volunteers to sample. See the Resources section and the rainfall sidebar in Section 3 for more information on sampling during and after storms. Dry weather sampling is important for identifying sources such as continuous illicit discharges or leaking septic systems and is also important because recreational use of water typically occurs during dry weather. Dry weather discharges can also contain very high counts of bacteria, since there isn't the stormwater to dilute the discharge.

Duration of Sampling Period

If you are monitoring recreational water, sampling only during those months of recreational use should be sufficient (e.g., April through October).

Number of Samples

It is best to have field duplicate samples for 10% of the sample sites to ensure proper monitoring technique, but this will increase the cost of monitoring. See Quality Control for more details.

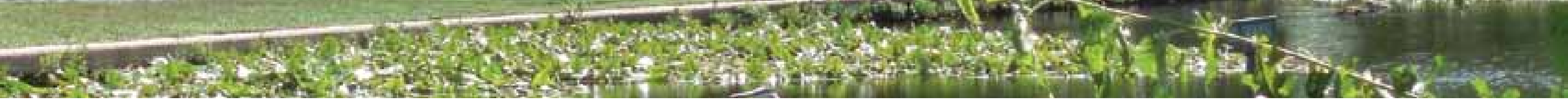
Monitoring Parameters and Analysis Methods

The plan should include instructions on which bacteria to monitor and what type of bacterial analysis method will be used to assess the water quality. The best indicators of health risk from recreational water contact are E. coli (fresh water) and Enterococci (fresh and salt water). If the waterbodies you plan to sample vary in salinity levels, or if you plan to compare results between freshwater and salt water areas, use Enterococci as the indicator. However, some states still use total coliform and fecal coliform as indicator bacteria. You will want to research what the regulations are for your state (see the Resources in Section 1). If you want to know whether your water meets state water quality standards then you will need to use those same criteria. If you are monitoring to determine the health risk from recreational water contact, enterococci and E. coli are best. Section 2.4 summarizes the different bacterial analysis methods for each parameter.

As stated in the previous section, how your data will be used will determine if your sampling and analysis methods need to be EPA approved. If you are new at bacteria monitoring, it is advised to either send out the sample for analysis to an experienced laboratory or start with simpler in-house methods, as being compliant with regulations can be costly and time intensive.

2.3 Quality Control

The monitoring project should ensure that data collected is good-quality data that is consistent over time and across projects and group members. You can develop a Quality Assurance Project Plan (QAPP) to have uniform monitoring procedures for all volunteers. Although a QAPP is not always necessary, it provides a cohesive document that can be referred to by volunteers. Due to the transient nature of volunteer work, it is helpful to have this document to aid



new volunteers. QAPPs are also sometimes required by funders. The QAPP will include information from the sampling and analysis plan, as well as other details that ensure quality control. Check with your local or state government to see if there is a QAPP already written for volunteer monitoring. The EPA also has a guideline for how to write QAPPs. See the resources section for more information.

Quality Assurance Project Plan
A QAPP is an important tool to help defend the data that volunteers collect. A QAPP contains information such as:

- Project Description
- Training Requirement/Certification
- Sampling Methods
- Sampling Handling and Custody Requirements
- Analytical Methods
- Quality Control
- Instrument/Equipment Testing, Inspection, and Maintenance
- Data Management

QAPP development resources can be found in the resources section.

Samples should be collected and analyzed using standardized, accepted techniques so that results are comparable to data collected through other assessments using the same methods. Few water quality agencies will use volunteer data unless methods of data collection, storage, and analysis are documented. Clear and concise documentation of procedures also allows newcomers to the project to continue monitoring using the same methods as those who came before them. This is particularly important to a volunteer project that may see volunteers come and go and that intends to establish a baseline of water quality information that can be compared over time.

It is also important to remember that repetition is the best way to have a meaningful analysis. A single bacteria sample result only represents that waterway at that specific point in time–it doesn't tell us information about the environment and the factors affecting the water quality of that stream. Below are some typical quality control procedures. Not all organizations can have this level of testing, but that does not mean the data is wrong–you will just need to interpret the data differently. There are protocols to determine how to interpret data depending on your level of quality control. The manufacturer of the test setup you select will often provide information to help you understand how to interpret the results. The EPA standards may also include guidance for interpretation, as well as local or state guidance.

Field Quality Control

- Make sure all volunteers are regularly trained in sample collection methods
- Collect *field blanks* using distilled water at 10% of sample sites
- Collect *field duplicates* at 10% of sample sites

Lab Quality Control

Although laboratory instructions are not provided in this guidance, the following EPA website describes some quality control measures that should be taken https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/nonpoint-source-volunteer-monitoring:

- Conduct *lab replicates* on 10% of bacteria plates for counting
- Test *positive and negative controls*
- *Split one of the samples* equally and analyze one sample in your lab, and send the other to a different lab

Definitions:
Field Blanks: These are filled with sterile water at the sample collection site to make sure that there is no contamination with the sampling method. Results should detect no bacteria.

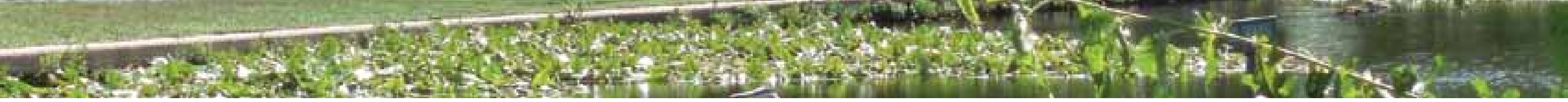
Field Duplicates: At 10% of the sites (random), there should be two samples taken at the same site. This is used to determine the sampling and analysis precision.

Lab Replicates: Samples are split into subsamples at the lab and tested. The results are compared for precision in laboratory analysis.

Positive Control: Known target bacteria is tested and results should be positive. This is used to detect errors in the laboratory analysis and equipment.

Negative Control: A non-target bacteria is tested and results should be negative. This is used to detect laboratory or growth media contamination.

Split Sample: One sample is divided equally and analyzed by different analyst or lab. This is used to compare the results from different labs.



2.4 Equipment and Materials

Some general equipment you will need for sample collection include:

- Sterile sample bags, such as Whirl-pak, or sterile bottles (contracted labs may provide these items)
- Labels and clear tape to label bottles or bags (contracted labs may provide these items)
- Rubber gloves
- Cooler with ice
- Clipboard
- Pencil (better for wet weather)
- Data sheets/ field sheets (example sheets found in resources section)
- First aid kit
- Permanent marker
- Clock/watch
- Chain of custody record (some agencies may require this)
- Important phone numbers, including contact person for local agency to report immediate pollution concerns
- Site map
- Camera

Whirl-pak bags or bottles

Traditionally, plastic or glass bottles are used to collect samples. These containers must be sterilized in an autoclave, which is typically only available in laboratories. Plastic and glass bottles can be reused for a very long time and are easier to use during analysis because they stand upright. Whirl-pak bags are one-time use, sterile bags made by Nasco. They are convenient because they do not need to be autoclaved, but cannot be reused. There are also pre-sterilized single use bottles, but these are usually more expensive than Whirl-pak bags.

The equipment needed for the bacterial analysis depends primarily on which method you use and secondarily on cost and accuracy. For bacteria analysis, the primary options are to do the laboratory analysis in-house or to contract with a local laboratory. If you decide to use a contract lab, the only supplies that you will need are the sampling materials listed above. The lab may have specific sampling and storage procedures for you to follow.

If you are performing the analysis in-house, you may need an incubator plus other equipment and supplies, depending on the method that you choose to use. An inexpensive incubator such as the Hovabator (~$60) is worth the minimal expense and will produce more reliable results than room temperature incubation. It is important to note that for regulatory use, a professional incubator will be needed due to the temperature variability and limitations of the inexpensive incubators.

2.5 Bacterial Analysis

There are multiple methods that can be used for bacteria testing, depending on your resources and goals. For all of the methods, the area where you perform the analysis should be wiped clean with lab quality paper products, such as Kimwipes, and alcohol to decrease chances of cross contamination. Gloves should be worn during the entire analysis. For direct inoculation, membrane filtration and most probable number analyses, the sample is either plated or mixed with a growth media (sterile pipettes might be needed). The sample is typically incubated at a specific temperature per the media manufacturer. Sterile water is used for dilutions (if needed) and to plate blanks (see the Quality Control section). Dilutions may be needed if you believe that there is a high bacteria count in your sample. See the instructions for the analysis method you are using for how to perform a dilution. For IDEXX and Multiple Tube Fermentation, the results are reported as Most Probable Number (MPN). 1 MPN is assumed to be equal to 1 CFU.

You will need to dispose of your waste in accordance with provisions for incubated samples. If you do not plan on using the data beyond educating the volunteers and local community or getting a general baseline reading, then simpler methods such as 3M Petrifilm plates or Coliscan easy-gel are probably sufficient. If compliance with EPA-approved methods is necessary, the more stringent procedures should be used in order to have more accurate results. To comply with these requirements, all materials used must be sterile, either by autoclave or using one-time use sterile equipment.

Table 3 presents a summary of the most common bacteria analysis methods. The summary includes which indicator bacteria is tested, if the method is approved by the EPA, relative cost of the analysis, and equipment needed. Specific details can be easily found through the EPA website or on the manufacturers' websites, and in the resources section of this document. References are provided in the resources section for the different methods.

Table 3: Bacterial Analysis Methods

Method	Type	E. coli	Enterococci	Coliform	EPA Approved Method for Ambient Water	Relative Startup Cost	Relative Cost per Sample	Other Materials Needed	Comment
Direct Inoculation (cfu)	Coliscan Easygel	x		x	Only approved for drinking water	$	$	• Coliscan Easy gel bottles • Petri dishes • Incubator (optional)	Easy to use, low level of training
	3M Petrifilm Plates	x	x	x	None	$	$	• 3M Petrifilm plates • Incubator	Easy to use, low level of training
Membrane Filtration (cfu)	mTEC, modified mTEC	x			1103.1, 1603	$-$$	$-$$	• Nutrient/culture medium, agar • Petri dishes • Filter and vacuum • Forceps and flame source • Incubator • Autoclave (optional)	Commonly used method
	MI	X		x	1604 (Total Coliform)	$-$$			
	mE-EIA, mEI		x		1106.1, 1600	$-$$			
	mColiBlue24®	x		x	10029 (Total Coliform)	$-$$			
Most Probable Number (MPN)	Multiple Tube Fermentation			x	1680 (Total Coliform), 1681 (Fecal Coliform)	$$	$-$$	• Nutrient or culture medium • Test tubes, rack • Pipettes • Incubator • Sterile flame set up • Autoclave	Labor and glassware intensive relative to membrane filtration and IDEXX
	IDEXX: Enterolert		x		Approved, ASTM #D6503-99, 9230D	$$$	$$	• IDEXX Quanti-Tray Sealer, rubber insert, and trays • 100-ml plastic IDEXX bottles • Reagent • UV light • Sterile water (if sampling in salt water)	Easy to use after sufficient training. Less potential of cross contamination than other methods due to single use materials.
	IDEXX: Colilert, Colilert-18	x		x	Approved, SM9223B	$$$	$$		
Quantitative Polymerase Chain Reaction (qPCR)			x	Others	Not approved for Ambient water: 1609, 1611	$$$$	$$$	*Extensive and expensive materials- This is not feasible to be performed outside of the laboratory setting and extensive training is needed*	A developing technology not typically accessible to communities. Could work with a university. Expensive, but accurate

$: Average cost <$3 per test. Minimal (<$200) laboratory equipment.
$$: Average cost <$5 per test. Less than $4,000 in essential laboratory equipment startup costs
$$$: Average cost >$5 per test. $4,000 to $7,000 in essential laboratory startup costs.
$$$$: >$7,000 in essential laboratory startup costs.
**These costs estimates were made in 2014. Prices are subject to change.*

2.6 Collecting a Water Sample

You will need to properly train your volunteers how to collect water samples. For compliance with EPA methods, it is essential that you follow the instructions below to ensure that the sample is not contaminated. Appendix B contains the guidance from the EPA on collecting samples using bottles and sterile bags.

Dos and Don'ts of Sampling

Do:

- Develop quality assurance and quality control procedures – see Section 2.3
- If using a contract lab, make sure it is accredited by either the state or a national accreditation body such as NELAC or A2LA.
- Contact the lab where you plan on sending your samples to ensure they are prepared to analyze the sample
- Label the bag/bottle with location, date, and sample code or number with a permanent market before you sample
- Sample in the main current of streams and wadeable rivers. For lakes and swimming beaches, sample where most people recreate, at knee depth (12-24 inches deep). Check with your local authorities to see if there is a specified depth range.
- To minimize potential for cross-contamination, stand facing upstream and reach as far upstream as possible to collect the sample
- If sampling from a boat, make sure that the vehicle is securely anchored and do not bring up the anchor until sampling is completed. Sample well away from the propeller.
- Fill out a field sheet for each event (see below)
- Store the samples in a cooler, on ice for up to 6 hours (general recommendations from EPA; holding time may vary with parameter and analysis method)
- Note the length of time between collecting and processing on the field sheet
- Allow sufficient time to get the samples to the lab within the specified holding period

Do not:

- Disturb bottom sediment (as much as feasible)
- Touch the inside of the sterile bag or bottle or the cap with your fingers or with any other equipment
- Hold the sample for more than the recommended holding time. EPA recommends up to 6 hours; however you will need to check with the regulatory authority (if used for regulation purposes) because your state may have a more flexible holding time (e.g., 24-48 hours if held on ice), and this can vary with the parameter and analysis method
- Collect your sample from stagnant water

In addition to collecting the water sample, volunteers should always be on the lookout for environmental clues that might help explain the data. A visual assessment of the monitoring site can provide invaluable information and make interpretation of other data easier and more meaningful. The most value is gained when volunteers assess the same area each time they collect samples. In this way, the volunteers will become the local experts—growing familiar with baseline conditions and land and water uses, and being better able to identify changes over time.

On the data sheet, record basic information that describes conditions during your sampling event. This may include:

- Stream level (normal, high, low)
- Current weather conditions – rainy, clear, cloudy
- Depth of rainfall in past 48 hours
- Turbidity
- Water temperature

Also record any unusual conditions. Descriptive notes should be as detailed as possible. Volunteers should bring such conditions to the attention of the program leaders so that they can report them to the appropriate authority, if warranted. Some things to be on the look-out for while monitoring include:

- Obvious pollution issues (e.g. leaking sanitary pipe);
- Visible discharge from a pipe or outfall into the water;
- Discolored or foul-smelling water;
- Toilet paper and other materials commonly flushed;
- Outfall pipes flowing during dry weather;
- Patches of algal growth or vegetation;
- Scums or films on or under outfall pipes;
- Potential sources of bacteria such as pet, wildlife or livestock waste; and
- Other unusual conditions.

2.7 Determining Exceedance

As described in Section 1, your state's Water Quality Standards or Beach Action Values will contain the necessary information to determine what levels of bacteria are considered unsafe for recreational use. Some calculations may be required to compare your results to the established thresholds. The geometric mean is a popular metric used to keep track of long term conditions because it can show how the data may fluctuate with natural events, such as rain or tide, and it accounts for extreme variability in data points. See Costa (N.D.) in the reference section for an explanation of how to calculate the geometric mean for your data.

2.8 Resources

Other Monitoring Guides

- EPA Volunteer Monitoring: https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/nonpoint-source-volunteer-monitoring

- EPA Volunteer Estuary Monitoring: https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/nonpoint-source-volunteer-monitoring

- Volunteer Monitor Supplies, Field Sheets, Methods, Sample Training Agenda and More: http://www.usawaterquality.org/volunteer/EColi/June2008Manual/Chpt_Appendices_ecoli.pdf

- Vermont Citizen Monitoring Guide: http://www.vtwaterquality.org/lakes/docs/lp_citbactmonguide.pdf

- Virginia Citizen Monitoring Guide: http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/WaterQualityMonitoring/CitizenMonitoring/Guidance.aspx

- Neighborhood Water Watch, A Guide for Developing a Volunteer Bacteria Monitoring Program: http://chattahoochee.org/wp-content/uploads/2013/05/NWW-guide_FINALFINAL.pdf

Field Methods

- Maine Healthy Beaches Program Field Methods: http://www.mainehealthybeaches.org/documents/Field_methods.pdf

Volunteer Quality Assurance Quality Control Plans, QAPP

- https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/nonpoint-source-volunteer-monitoring

Tips for Safety

- http://www.usawaterquality.org/volunteer/EColi/June2008Manual/Final_ecoli_06c1.pdf
- https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/nonpoint-source-volunteer-monitoring

Example Data Sheets

- http://www.usawaterquality.org/volunteer/EColi/June2008Manual/Final_ecoli_06c1.pdf
- https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/nonpoint-source-volunteer-monitoring

Bacterial Analysis Methods

- https://www.epa.gov/cwa-methods
- http://www.usawaterquality.org/volunteer/EColi/June2008Manual/Chpt5_ecoli.pdf
- https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/nonpoint-source-volunteer-monitoring
- http://www.ohiowea.org/docs/E_Coli_Presentation.pdf

Method	Instructions
3M Petrifilm Plates	http://multimedia.3m.com/mws/media/236246O/petrifilm-ecoli-coliform-interpretation-guide.pdf
mTEC, Method 1103.1	https://www.epa.gov/sites/production/files/2015-08/documents/method_1103-1_2010.pdf
Modified mTEC, Method 1603	https://www.epa.gov/sites/production/files/2015-08/documents/method_1603_2009.pdf
MI, Method 1604	https://www.epa.gov/sites/production/files/2015-08/documents/method_1604_2002.pdf
mE-EIA, Method 1106.1	https://www.epa.gov/sites/production/files/2015-08/documents/method_1106-1_2009.pdf
mEI, Method 1600	https://www.epa.gov/sites/production/files/2015-08/documents/method_1600_2009.pdf
mColiBlue24®	http://www.hach.com/asset-get.download.jsa?id=7639984023
Multiple Tube Fermentation, Method 1680	https://www.epa.gov/sites/production/files/2015-08/documents/method_1680_2010.pdf
Multiple Tube Fermentation, Method 1681	https://www.epa.gov/sites/production/files/2015-08/documents/method_1681_2006.pdf

The EPA also provides a website containing all EPA approved laboratory methods for the Clean Water Act at www.epa.gov/cwa-methods

3 Investigating Potential Pollutant Sources

The baseline monitoring program described in Section 2 will generate data that can be compared to established water quality benchmarks to determine if the water exceeds these thresholds and whether it is safe for recreational use. While for recreational waters, such as swimming beaches, the more immediate concern is to notify the public of the health risk and/or close the beach (see Section 4), it is also important to begin to narrow down the source of the bacteria so that the problem can be corrected. In addition, volunteer monitors can use the methods described in this section to investigate complaints.

As described in Section 1, there are numerous sources of bacteria in urban watersheds, such as stormwater runoff, sewer overflows, and failing septic systems. The number of sources combined with the complexity of the urban drainage system and the patchwork of public and private lands make tracking down bacteria to a specific source a challenge. While not all sources of fecal contamination can be identified, targeting human sources first should result in a measurable improvement in water quality and decrease in health risk.

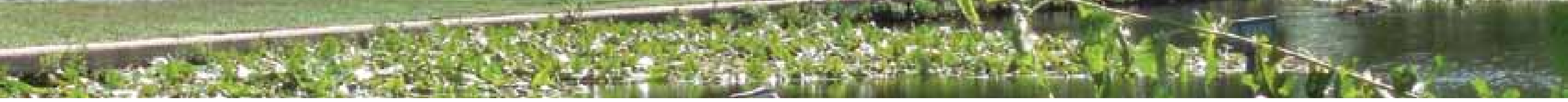
Prior to setting up your baseline monitoring program, you will have already reviewed existing plans and data to identify the primary sources of bacteria in your watershed. A more detailed analysis is needed to further narrow down these sources. The first step is to plot the problem stations (sites with exceedances) on a map. The next step is to begin to narrow down the potential sources of bacteria though a survey of pollutant sources. If the number of stations with high bacteria concentrations is very large and/or the problems are widespread throughout the watershed, you may want to begin with the sites that are most heavily used for recreation. This is followed up by supplemental sampling at stormwater outfalls, the results of which can be provided to the local authority to help them identify pollutant sources. As this is an iterative process, the supplemental sampling may require going back to do a more detailed survey of pollutant sources for a particular outfall where bacteria concentrations are high, followed again by more detailed sampling with co-indictors (see Section 3.2) until the source is narrowed down as far as possible without the assistance of the local government authority. When contacting the local government, it is important for you to provide all of your evidence of a potential sewage leak and be fairly certain there is a violation as the resources needed to investigate potential hotspots can be substantial. The supplemental sampling described in this section is investigative and may require adjusting the sampling sites as you go–unlike the baseline monitoring program, where consistency of sampling sites over time is important. For both types of sampling, the protocols described in Section 2 should be followed.

Rainfall Data

When analyzing your data results, comparison of the bacteria concentrations with the rainfall conditions recorded at the time of sample collection can tell you how much of the bacteria problem is associated with rainfall events, and can be used to inform recommendations on beach closings and notification of the public about potential health risks of water contact in the days following a storm. Access to rainfall data is important for this step. Weather Underground (wunderground.com) has hourly precipitation data for many locations. If stormwater is suspected to be a significant source, and the area is used for recreation, a rainfall threshold study may be useful to determining peak bacteria concentrations for given rainfall amounts and the potential duration of impairment. This would be used to inform beach closures.

3.1 Survey of Potential Pollutant Sources

A survey of potential pollutant sources for a particular bacteria hotspot can help to narrow down the sources of bacterial contamination so that they can be eliminated. This type of survey is not necessarily a linear process and involves both desktop analysis and field assessment. In addition to better understanding local pollution sources through maps and data, conversations with the local government or community members may be helpful to identify hotspots or begin to narrow down sources.



Evaluate drainage areas

For each sampling site that exceeds recommended bacteria concentrations (or for each reported complaint), the first step is to evaluate the land area draining to that point. This can help to narrow down probable sources of bacteria to the waterbody. Drainage areas or watersheds may already be available in geographic information system (GIS) format from your local planning or environmental agency. These layers can be viewed using free online mapping software such as ArcGIS Explorer: http://www.esri.com/software/arcgis/explorer/. More savvy GIS users can delineate the drainage areas themselves using hydrologic, stormwater infrastructure, and topographic maps (see the Resources section). If neither of these are options, online aerial photos such as Google Earth can be used to get an approximate view of the land and land use types draining to the site. It is important to note that sewersheds do not necessarily follow surface drainage lines. Although surface water may flow downstream to the selected waterway, a storm sewer system could collect and divert some stormwater from outside of the drainage area to the waterway, making it important to know both the drainage area and the sewershed. A sewershed delineation may be available from local agencies or can be done through detailed delineation using GIS layers of the storm sewer system.

Leverage information from other sources

Land use maps and existing water-related studies of the area are great tools to help find potential bacteria sources. Land use maps can be used to identify the location of properties with high potential for discharges of bacteria and other pollutants. Maps of stream networks and storm drainage systems can help to determine the potential flow path of the contamination and identify supplemental sampling locations. For groups with limited GIS capability, this step can be done using paper maps or online mapping sources such as Google Earth and Bing Maps. For more savvy GIS users, (or where the local planning agency is willing to provide maps), GIS layers and other data may be available from national, state, and local sources and can help to form a picture of where potential bacteria sources are in relation to the problem site (Table 4).

Table 4. Types of Data

Type of Data	Where to Find it	How to Use it
Tax maps/parcels	Local planning or tax assessment agency	To identify older developed areas with higher likelihood of sewer problems; identify land owners of suspected problem sites
Land use/zoning maps	Local planning agency	To identify land use types with higher potential for pollution
EPA Envirofacts	http://www.epa.gov/enviro/index.html	To determine locations of permitted dischargers (and in some cases, discharge info)
Sanitary sewer system maps	Local sewer authority	To identify location of sewer pipes and infrastructure
Storm sewer system maps	Local stormwater /public works agency	To identify location of stormwater outfalls for sampling
SSO/CSO occurrences	Some state agencies may track SSOs in a database; local sewer authority should have data on CSOs	To identify any known CSO locations or sites with a history of SSOs
Water resource studies	Local or state environmental agency	To locate previously identified sources of bacteria

In addition to mapping data, historical data may be useful to determine if any past land use or recent land use changes could be contributing to the problem, and complaint records can tell you about the history of any previous problems or investigations at that site.

Conduct a visual field study of bacteria hotspots

Once you have a better understanding of the drainage area and its potential bacteria sources, the next step is to return to the problem sampling sites to perform a visual field survey. An example field data sheet is provided in the resource section. If the area is accessible and does not require landowner permission, you can drive and/or walk around the area on public roads and trails to evaluate the characteristics of the waterway and note potential problem areas. Storm drain outfalls, manholes, and catch basins, significant wildlife, marinas, recreational uses, and impervious surfaces should all be noted. The presence of specific operations that have higher potential to generate waste, such as wastewater facilities, vets and kennels, should also be noted. Volunteers should not survey private areas without local government staff and/or landowner permission. If your focus area is large, you may need to narrow down the area in which you perform your field study using information from the previous sections.

Figure 4: Visual Evidence of Sewage Debris

3.2 Supplemental Sampling

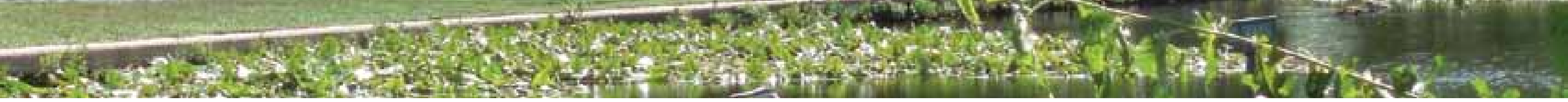
Your review of mapping data and relevant plans and the visual survey of the sampling site should give you some ideas of where in the drainage area additional sampling would be useful. For example, if there are a handful of potential sources in the watershed that are highly suspect (e.g., point sources with previous discharge violations, a stretch of sewer line with a history of leaks and overflows), you may want to sample above and below these locations (called "bracket sampling"). If no one source stands out over the other, you could simply work your way up the drainage network from the original sampling site and sample at stormwater outfalls or right above each major stream confluence as you go to help narrow down which sub-drainage area may be the source of the problem. The extent of your sampling will depend to some degree on your available time and budget. If you have a very limited budget for supplemental sampling, you may want to choose one point (at a major stormwater outfall or just above the confluence with another stream, for example) about midway up the drainage area. If that sample is "clean," you can assume that everything above that is clean and choose another sampling site midway between there and the original bacteria hotspot. In this manner, you can continually "zoom-in" to a more refined target area and collect additional samples. This approach is most applicable for smaller drainage areas. As with the baseline bacteria monitoring, it is helpful to sample during both wet and dry weather, and preferably at several different times, to catch any intermittent discharges.

Conduct investigative sampling at selected stormwater outfalls

An outfall is the point where stormwater from pipes and ditches empties into a river, lake or stream. Sampling the flow from stormwater outfalls is a common practice to identify illicit discharges and is a requirement for some communities under the Clean Water Act. Outfall sampling is particularly important for narrowing down sources of bacteria in urban watersheds because so much of the stream network has been put in pipes underground and outfalls are the most convenient sampling location. Outfall screening is typically performed after at least 48 hours of dry weather because the intent is to identify non-stormwater sources of pollution (e.g., sewage). For a citizen monitoring program, it is not likely that these guidelines can be strictly adhered to, however it is recommended to record recent rainfall conditions during sampling so that the resulting bacteria concentrations can be related to rainfall to give a better sense of whether any exceedances are related to wet or dry weather.

The same methods that are described in Section 2 can be used for the sampling. It is important to choose a location that can be safely accessed. Flow should be measured using different methods outlined in the Illicit Discharge Detection and Elimination Manual, chapter 11 (Brown et. al, 2004). It is also important to note the odor, color, turbidity and floatables to help determine the source of pollution. Some other visual indicators are corrosion, cracking or chipping in the pipe; oily water; staining of the pipe or rocks around it; and suds or excessive algae in the water.

Trends in concentrations should be examined for "hotspots" within the drainage network and the investigation locations should be adjusted based on the results. For example, if a monitoring station has high bacteria levels and the next station upriver is clean, continue to adjust the location of the upriver site to further narrow the problem area.



Conduct Co-indicator water quality tests

Many sources of bacteria are derived from human sewage. To determine if a high bacteria sample is potentially due to human sources, sampling for co-indicators at your regular monitoring station or at suspect locations can be conducted. Sampling with co-indicators other than bacteria provides you with more reasonable assertion of potential human sources. Some co-indicators are only useful in either freshwater or saltwater due to interference with test methods. The co-indicators listed in Table 5 are recommended for this approach.

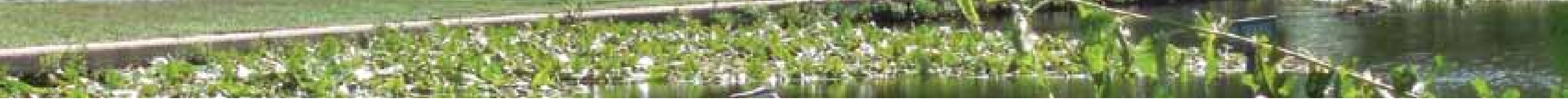
Table 5. Co-indicators of Human Sewage Sources

Co-indicator	Appropriate for Freshwater?	Appropriate for Saltwater?	Notes	Suggested Methodology
Ammonia	Yes	Yes	Presence of ammonia is a human waste indicator	Colorimetric techniques
Caffeine	Yes	Yes	A developing co-indicator for human waste. Not useful if sampling a short distance downstream of a wastewater plant outfall	Lab analysis recommended
Optical brighteners	Yes	No	Optical brighteners are found in detergents and indicate the presence of washwater or wastewater. Simple presence / absence studies can be conducted or a more sophisticated analysis using a fluorometer.	Optical brightener pads Fluorometry
Detergents / Anionic Surfactants	Yes	No	Detergents and anionic surfactants indicate the presence of washwater or wastewater.	Colorimetric techniques
Boron	Yes	Yes	An indicator for sewage or washwater	Spectrophotometer or Colorimetric techniques
Potassium	Yes	Yes	Indicator for sewage or industrial or commercial liquid waste	Spectrophotometer or Colorimetric techniques
Conductivity	Yes	No	Indicator of sewage discharge. History of conductivity readings at the site are needed	Conductivity meter
pH	Yes	Yes	Indicator for washwater	Meter

3.3 Track Down Methods

With the data collected in the previous section, the next step would be to track down the pollutant source. Although there are various different track down methods, most of these processes are time consuming and may take several months to perform. The methods used for track down require technical expertise and equipment and also usually involve entering private property so are not typically appropriate for a citizen group. Some activities, such as dye-testing septic systems and checking sewer connections, require the expertise and training of professionals like code enforcement officers, plumbing inspectors, public utility staff, and state and federal agency staff. The different methods are discussed below as background, but citizen groups should not perform these tasks without the assistance of trained professionals and permission from the appropriate authorities.

Once a bacteria problem is tracked as far up the stream/storm network as possible, the local government could be brought in to perform Storm drain Investigations to pinpoint the pollutant source. Storm drain investigations narrow the source of a discharge problem to a single segment of a storm sewer. The investigation starts at the outfall, and the



field crew must decide how it will explore the upstream pipe network. Inspection can begin at the furthest upstream point in the storm drain pipe network and work towards the outfall, or work upstream in the pipe network from the outfall. Each method may be appropriate for different circumstances depending on access to manholes, level of contamination, and configuration of the pipe network. Next, crews select the most appropriate investigative methods to track down the source. Common methods include:

- Visual inspection at manholes: field crew can inspect manholes to inspect for physical indicators that can isolate discharge to a specific segment of the network
- Sandbagging or damming the trunk: A sandbag or other material is used to block flow in a storm drain pipe for a period of at least 24 hours. Flow behind the dam is assessed using chemical or physical indicators.
- Dye testing: Release non-toxic dye into toilets, sinks, shop drains, and other plumbing fixtures and if there is dye at the storm drain, an illicit connection exists.
- Smoke testing: Release smoke into a storm drain and track where the smoke exits the pipe. Smoke tests can find improper connection or damages to the storm drain.
- Video testing: A mobile video camera is guided down a storm drain pipe to locate the connection producing an illicit discharge.
- Thermal imaging: An infrared camera is used to determine if there is a temperature difference at storm drains, which may indicate a sewage source.
- Canine scent tracking: Canines are trained to alert the presence of human fecal sources and ignore animal sources. See Case Study #6 for an example

In conjunction with these track down methods, a more detailed desktop assessment of potential pollution sources is usually made, following the methods for Drainage Area Investigations described in Brown et al (2004).

3.4 Resources

Outfall Screening:

- Center for Watershed Protection Illicit Discharge Detection and Elimination Guidance Manual https://www.epa.gov/sites/production/files/2015-11/documents/idde_manualwithappendices_0.pdf

Delineating watersheds:

- http://www.personal.psu.edu/acb5054/blogs/abisher/Instruction%20Set.pdf
- http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_014819.pdf

Field Data Sheets:

- http://www.epa.gov/npdes/pubs/idde_appendix-d.pdf

4 Sharing Your Findings & Taking Action

Testing water for the sake of building a repository of bacteria data can be useful for historical and academic ends; however, your data is put to better use if they are shared in a meaningful way. Your group's findings can be shared narrowly (e.g., with your local utility department) or widely (e.g., to the general public). How and to whom you communicate your findings and what actions you take as a result of those findings will depend on: the severity of bacteria problems in your areas of concern, the known and potential sources of bacteria in problem areas, and the resources and skills available (or absent) to your group.

Citizen groups and watershed organizations around the country have used a wide array of approaches to communicate their water quality findings to their members, the general public and regulatory agencies. Many of their strategies are described in this section. In addition, the case studies in Appendix C tell the real-life stories of volunteers doing the hard work of testing bacteria levels in their local waters, sharing their data, and being the catalyst for positive change.

4.1 Communicating Your Findings

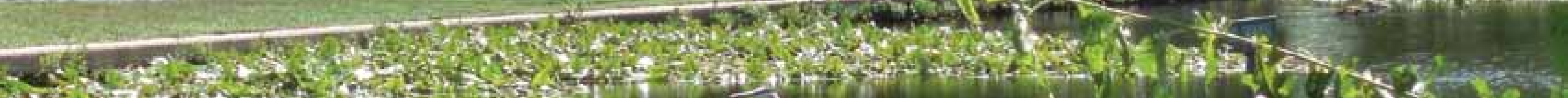
In this section, we present a range of communication strategies your group may consider adopting in your bacteria monitoring program. Some approaches are best suited for sharing data findings throughout the year on a regular basis, while others may be used semi-annually or annually. Even other means of analysis may only be useful once significant data have been collected for several years in a row.

Reporting Immediate Pollution Concerns

Because volunteer groups cannot fix public sewer pipes or enforce illicit discharge regulations, having a good rapport with your local utility or water resources department may be the most effective way to ensure that bacteria sources are eliminated quickly. Prior to sampling, it may be useful (especially in larger jurisdictions with numerous agencies that deal with water) to meet in person or by phone with agency contacts to identify the appropriate contact and clarify the process for reporting complaints. The benefits to having volunteers sampling regularly go beyond just collecting bacteria data. As mentioned in Section 3, volunteers' regular visits to waterways make for more eyes on the water, which greatly increases the likelihood that an illicit discharge will be noticed and reported. Perhaps this is the greatest benefit of all.

In the case that your volunteers come across visible signs of an illicit discharge at their monitoring site (e.g., cloudy water from paint dumping, strong smell from leaking sewage pipe) they should be armed with a map or GPS to record the specific location and with the appropriate contact information to report any such pollution sources. This information should already be included in the monitoring program plan. A picture taken on a smart phone is a great way to keep track of the location, as most phones will mark the location where the picture was taken. They should either have on hand the phone number for the volunteer water quality program coordinator who can then contact the local authorities or know how to contact the appropriate local authorities directly. There are some mobile applications, such as Creek Watch, that are created for this purpose and leveraging those resources can be valuable.

If a piece of public infrastructure has been found as a source (e.g., broken sewer pipe), the local utility staff should be able to respond quickly to fix and eliminate the discharge. It may be helpful to have a protocol in place for following up with the utility and/or notifying the enforcement agency if, for example, more than 48 hours has gone by without a response. Sometimes the source will be on private property (e.g., leaking septic system or grease container at a restaurant). In most communities, one department is designated as the starting point for reporting illicit discharges from both private and public properties. We recommend that you research which specific departments(s) to contact in your community for bacteria discharges of different types and sources. If the local utility or business does not respond within 48 hours, it is advised to follow-up with a phone call and notify the local utility or business that the enforcement agency will also be notified of the issue.



Sharing Data with Regulatory Agencies

If your water quality monitoring program intends to provide its data to regulatory agencies, you will want to become familiar with how those agencies prefer to receive your data. This may influence how you organize your own database so that your data can easily be transferred into the agency's database on a routine or annual basis. Consider researching the following, as well as meeting with the agencies in question, if you intend to share your data beyond the local level.

- *State Water Quality Agency:* Certain states will accept water quality data from volunteer monitoring groups to use in identifying officially "impaired" waterways. As mentioned previously, each of these states sets minimum requirements for the level of quality assurance and quality control needed for the data to qualify for regulatory use.
  - *Example:* In developing its 2012 list of impaired waters in the state, the Virginia Department of Environmental Quality used its own monitoring data, plus the data from 27 citizen groups and academic institutions. These non-agency groups provided data for 695 sites across the state. Just over half of those sites were tested for bacteria levels (VADEQ, 2013).

- *EPA's STOrage and RETreival (STORET) Data Warehouse* – This is a national "repository for water quality, biological, and physical data and is used by state environmental agencies, EPA and other federal agencies, universities, private citizens, and many others." Data is submitted to STORET through the Water Quality Exchange (WQX) tool which has a set template for how to format data entries.
  - EPA's STORET Database: http://www.epa.gov/storet/
  - Water Quality Exchange tool for uploading data to STORET: http://www.epa.gov/storet/wqx/index.html

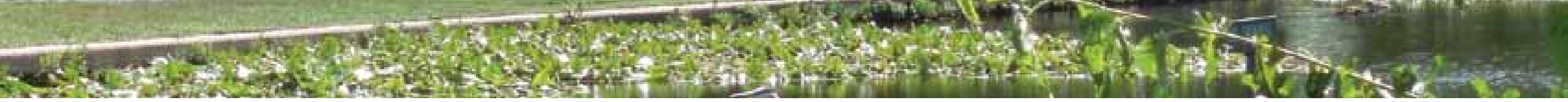
- *Other National Water Quality Databases* –
  - USGS, EPA and the National Water Quality Monitoring Council's Water Quality Portal: http://www.waterqualitydata.us/
  - USGS Water Quality Data for the Nation website: http://water.usgs.gov/owq/data.html

Sharing Findings with Members and the Public

Citizen groups should strive to reach their local "constituents" frequently to share the findings of their bacteria monitoring. After all, a major reason we test bacteria is out of concern for public health. Volunteers will want to learn about what other monitors are finding at their sites and your organization's larger membership body is probably curious too. Below are several strategies your group can consider using to share your water quality data and trends with not only your membership, but also your community at-large.

- *Present to Local Boards & Associations* – Speaking directly to City/Town/County Councils, Boards of Supervisors, Neighborhood Associations, and other decision-making bodies is an excellent way to bring attention to your most significant water quality findings and garner local support for your group's monitoring efforts. Present your action plan to your stakeholders, what you hope to accomplish and how you plan to accomplish it.

- *Online Database & Map* – Volunteers or staff upload data to a database or spreadsheet after data have received quality control check. Public can access and view and/or download data freely. Advanced databases that also generate charts and graphs can help users better interpret data and trends. Often included is an interactive map that allows users to see the specific locations of monitoring stations. These maps often allow users to also view and download the data for a specific station by clicking on its reference point.
  - *Examples*:
    - Chattahoochee Riverkeeper Neighborhood Water Watch Monitoring Data: http://www.chattahoochee.org/nww/
    - Virginia Save Our Streams Public Access webpage: http://vasos.wrayesian.com/form_submissions/list
    - Santa Barbara Channelkeeper: http://www.sbck.org/current-issues/water-quality-monitoring/download-our-data/



- Hudson Riverkeeper: http://www.riverkeeper.org/water-quality/citizen-data/
- http://www.bwdh2o.org/beaver-lake/lakesmart/
- Illinois River Watershed Partnership: http://www.irwp.org/water-quality-monitoring/monitoring-projects/

- *Press Releases* – A tried and true means of reaching the general public via newspapers, radio, and television outlets. This may be most useful for sharing major findings of public health concern or reflecting on annual or multi-year trends in your monitoring data. As much as possible, findings should be presented in simple, non-technical language.
  - *Examples*:
    - Rivanna River StreamWatch Program press release: http://www.cvilletomorrow.org/news/article/18329-streamwatch-releases-water-quality-findings/

- *Member Newsletters* – Your organization's newsletters provide an opportunity to inform your membership of water quality results. Consider including regular updates about bacteria levels at priority sites and/or an annual look back on trends from the past year.
  - *Examples*:
    - Lake Pend Oreille Waterkeeper: http://www.lakependoreillewaterkeeper.org/semi-annual-report.html#.VBdSgaOTHOk
    - White River Partnership Spring 2014 *Currents* Newsletter: http://whiteriverpartnership.org/wp-content/uploads/2014/04/Spring-2014-Currents.pdf

- *Social Media* – Facebook, Twitter, Tumbler, etc. Especially good for success stories and issues conducive to short snippets. Beware of creating misinformation or even panic due to lack of detailed explanation. May not be an appropriate venue for sharing topics that require longer explanations.
  - Examples:
    - Great Miami Citizens' Water Quality Monitoring Facebook page: https://www.facebook.com/pages/Great-Miami-Citizens-Water-Quality-Monitoring/125510374198280
    - Friends of Casco Bay Twitter page: https://twitter.com/CascoBay
    - TAPP Twitter page: https://twitter.com/TAPP_Water

- *Smart Phone Apps* – Formatted for smart phones, apps can especially be useful for people interested in current conditions at recreational areas.
  - *Examples*:
    - Waterkeeper Swim Guide: https://www.theswimguide.org/#29.88960612352294/-113.09555499999999/43.126158746668736/-70.90805499999999/6
    - Kansas City KCWaterBug app: http://www.kcwaters.org/kcwaterbug.html

- *Annual Reports*: An annual review of bacteria data from all your monitoring sites can provide a comprehensive look at variability related to weather events and other environmental conditions as well as trends across several years.
  - *Examples*:
    - Charles River Watershed Association: http://cdn2.hubspot.net/hub/311892/file-955523132-pdf/Our_Work_/Field_Science/Volunteer_Monthly_Monitoring_Program/Water_Quality_Reports_and_Data/Year_End_Reports/VMM_2013_Final.pdf?t=1410364824593
    - Wicomico Creekwatchers 2012 Water Quality Monitoring Results: http://www.salisbury.edu/wicomicocreekwatchers/docs/Wicomico%20Creekwatchers%202012%20FINAL.pdf
    - Hudson Riverkeeper "How's the Water?" reports: http://www.riverkeeper.org/about-us/publications/reports/

- *Annual Report Card* – This is often a simplified version of the annual report which gives a score and/or ranking to each monitoring site. This type of tool can easily convey to readers the relative level of bacteria pollution at each site using "grades".

- *Examples*:
    - 2010 - 2012 Reedy Creek Report Card: https://allianceforthebay.org/wp-content/uploads/2010/08/Reedy-Creek-Report-Card-2012_web.pdf
    - Milwaukee Riverkeeper 2012 River Report Card: http://www.mkeriverkeeper.org/content/2012-river-report-card

- *Annual Forum/Presentation* – Once a year, organize a forum or workshop for your volunteers and the public to discuss the results of the group's collective bacteria monitoring. This also gives volunteers a rare opportunity to see each other in person and compare notes and stories.
  - *Examples*:
    - Huron River Watershed Council 2013 Field Data Presentation for Volunteers: http://www.hrwc.org/wp-content/uploads/2013/12/2013_Volunteer_WQ.pdf

- *Warning Signs or Flags at Recreational Areas* – Posting flags of different colors to rank level of bacteria in water and risk to swimmers and boaters. Used most commonly at beaches. It is only appropriate to set such warnings based on predictive model or real-time/immediate data (i.e., for minimal lag time).
  - *Examples*:
    - Charles River Watershed Association Water Quality Notification System: http://www.crwa.org/fieldscience/water-quality-notification
    - Indiana Beaches Alert: http://www.in.gov/beachesalert/signs.html
    - Chicago Park District's Flag Notification System: http://www.chicagoparkdistrict.com/facilities/beaches1/

4.2 Strategies to Reduce Bacterial Pollution

There will likely come a time when your group finds a specific point source of bacteria pollution that needs to be dealt with. How that source is reduced or eliminated depends on a number of factors. In this section we provide a list of common urban sources of bacterial pollution you may identify through your monitoring efforts and an introduction to just some of the strategies that can be used to mitigate them. Most of these strategies must be undertaken by a governmental agency, but your group can be the catalyst to start the process and can advocate for follow-through. It is important to note that complete removal of all indicator bacteria may not be achievable. There are sources of fecal indicator bacteria (pathogenic and non-pathogenic) that occur natural that may not necessarily be removed.

Broken or Leaking Sewer Pipes

While most sewer breaks are underground and are not easily detected, breaks can occur alongside, above, and under waterways. Pipe junctions, especially where the sewer infrastructure is old, are vulnerable to leaking. And sections of pipe that are exposed to the force of floodwaters are vulnerable to breakage or collapse. Therefore, these are not uncommon sources of chronic bacteria pollution. Volunteer monitors who discover sewer breaks or leaks should contact the appropriate utility department right away so that their staff can make repairs or replacements. If the pipe in question is on private property, the local or regional water quality agency will have to enforce illicit discharge rules in order to have the leak fixed by the property owner.

Combined Sewer Overflows

Common in older cities, combined sewer systems use a single pipe to collect stormwater and sanitary sewage. All stormwater and sanitary sewage flows are pumped to and treated at the wastewater treatment plant. However, large storms can overburden the system and cause the stormwater/sewage mixture to overflow into waterways. Cities with this type of infrastructure are required by federal regulation to reduce these combined sewer overflows (CSOs) over time by creating more storage for treatment and/or separating the stormwater pipes from sewage pipes.

In conducting these infrastructure renovations, some sanitary sewer pipes may be overlooked and accidently remain connected with the stormwater network. It is possible that volunteer water quality monitors will isolate a specific stormwater outfall with consistently high bacteria levels in its flow. If the local utility department confirms a connected sanitary sewer pipe (through tracking methods described in Section 3) the best mitigation strategy is, of course, to separate the sewer line from the stormwater network. In many situations, dry weather CSOs can also occur that are maintenance-related. These can be identified through citizen monitoring and can be readily corrected. See Case Study #4 in Appendix C for an example of this situation.

Sanitary Sewer Overflows

Sanitary sewer overflows (SSOs) can occur for a variety of reasons. Sometimes sewage surcharges out of manholes during very heavy rainfall when too much stormwater leaks into the sanitary sewer pipes via cracks and manholes. Other times blockages from debris or grease or power failures at pumping stations cause the sewage to back-up and overflow onto street surfaces or into waterways. Like CSO events, these sanitary sewer overflows are usually transient occurrences that cause the bacteria levels in surface water to spike temporarily. Toilet paper on the ground or a misplaced sewer manhole cover are potential signs of a past SSO event. Volunteer monitors who come across an active or recently past SSO should contact the appropriate utility department right away so that their staff may remove any blockages that may still exist or attend to a pumping station that may have lost power.

Failing Septic Systems

Sewage discharges from failing septic systems are often quite difficult to isolate because they seep out from the ground rather than from a pipe. However, if your group has confirmed a failing septic system, several potential options exist to mitigate the problem. They include:

- Pump out the septic tank
- Repair failing septic system
- Replace old, failing septic system with newer technology
- Connect septic areas to sewer (large scale, long term approach)

The last two of these options is not always feasible in every location. Contact your local or regional health department to find out if there are any regulations requiring periodic septic tank pump outs or system upgrades. Some regions have cost-share funding available to help property owners to pay for having their septic systems pumped out or upgraded. Your role may be to provide information to property owners about their options and advocate that they take action to fix the source.

Marinas and Boats

Volunteer groups monitoring in coastal areas should pay special attention to marinas and boats as potential sources of sewage. If dumping of on-board sewage is common in your area of concern, consider working with marina owners and coastal resource management agencies to adopt the following strategies (USEPA, 2005):

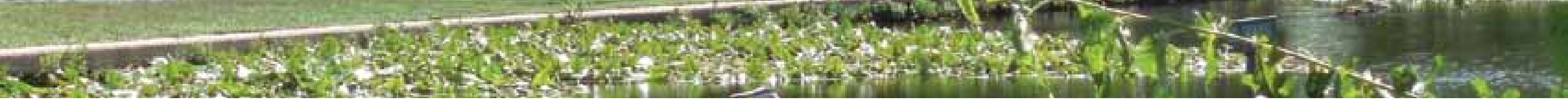
- Distribute educational materials about the impact of improper vessel sewage discharges on beach closures, shellfish contamination, etc.
- Encourage marina owners to provide clean and safe onshore restrooms and pumpout facilities for sewage from boats.
- Encourage boaters to install and properly maintain a Coast Guard certified Marine Sanitation Device (MSD) that is appropriate for their vessel.
- Petition the State for the creation of a No Discharge Area where bacteria levels near shore are too high.

Pet Waste

Animals, of course, can also be sources of fecal bacteria pollution. Bacteria from pet waste are only likely to be confirmed through water monitoring when waste is found in concentration. Such sources include dog parks, veterinary clinics, SPCAs and kennel facilities where dogs are walked outside. Local watershed organizations can play a meaningful role in reducing both point sources and non-point sources of pet waste pollution. Consider the following strategies (U.S.EPA 2005):

- Compose and distribute "pooper scooper" public service announcements and signage about picking up after pets.
- Encourage park authorities and other property managers to install pet waste receptacles and pet waste composters in their dog parks and dog-walking areas.

- Work with vet clinics and kennels to encourage them to keep dogs away from waterways and contain or compost pet waste.
- Ensure that swimming areas are either off-limits to pets or subject to certain ordinances to control fecal contamination.



- If they do not already exist, campaign for local ordinances that require pet owners to correctly dispose of pet waste.
- Look for outfalls from vet clinics and kennels where the kennel cleanout is flushed down floor drains and potentially out to the waterway

Wildlife

Wildlife can also be a significant source of bacteria pollution even in urban areas. Certain types of wild animals are easier to control than others. Ducks and geese can be especially problematic in urban waterways such as ponds. They can be found in large concentrations where people feed them. Therefore, one of the first strategies to reduce waterfowl numbers should be to request property managers to post "no feeding" signs at such locations and enforce that rule. If this is a significant problem in your waterways, consider also campaigning for a community-wide ordinance to prohibit feeding of wildlife. An example can be found in the Town of Bourne, Massachusetts which incorporated into its bylaws a rule prohibiting feeding waterfowl. Other urban communities have used herding dogs to scare away waterfowl.

4.3 Resources

- Detection of Septic Effluent in Lake Coves:
  http://www.ozarkswaterwatch.org/wp-content/uploads/2016/02/SepticEffluentStudy20-2.pdf

Appendix A: References

- Brown, E., D. Caraco, and R. Pitt. 2004. Illicit discharge detection and elimination: A guidance manual for program development and technical assessments. Prepared by the Center for Watershed Protection and University of Alabama. EPA X-82907801-0. Washington, DC: US Environmental Protection Agency, Office of Wastewater Management.

- Costa, J. N.D. Calculating Geometric Means. Buzzards Bay National Estuary Program. http://www.waterboards.ca.gov/water_issues/programs/swamp/docs/cwt/guidance/3413.pdf

- Doolittle, M., 2002. Presentation of EPA-funded Wollaston Beach EMPACT study. Meeting of USEPA Regional Workgroup on Beach Monitoring and Closures, Chelmsford, MA.

- Johnson, B. 1998. The Impact of On-site Sewage Systems and Illicit Connections in the Rouge River Basin. Unpublished manuscript. Rouge River Program Office. Camp Dresser and McKee. Detroit, MI.

- Lim, S. and V. Olivieri. 1982. Sources of Microorganisms in Urban Runoff. John Hopkins School of Public Health and Hygiene. Jones Falls Urban Runoff Project. Baltimore, MD. 140 pp.

- Pitt, R. 1998. "Epidemiology and Stormwater Management." In Stormwater Quality Management. CRC/Lewis Publishers. New York, NY.

- Schueler, T. 2000. Microbes in Urban Watersheds: Concentrations, Sources, & Pathways: The Practice of Watershed Protection. Center for Watershed Protection, Ellicott City, MD. Pages 74-84.

- Town of Bourne. 2012. Town of Bourne Bylaws. Section 3.4.3. Bourne, MA. http://www.townofbourne.com/sites/bournema/files/file/file/14_town_bylaw_thru_2014_oct_stm.pdf

- U.S. Census Bureau. 2007. "American Housing Survey for the United States: 2007". Government Printing Office, Washington D.C. 20401.

- U.S. Environmental Protection Agency, 2002. "National BEACH Guidance and Required Performance Criteria - Appendix 4B1: Data Quality and Sampling Design Considerations".

- U.S. Environmental Protection Agency, 2003. "Voluntary National Guidelines for Management of Onsite and Clustered (decentralized) Wastewater Treatment Systems". Office of Water. EPA 832-B-03-001.

- U.S. Environmental Protection Agency, 2005. Mitigation Measures to Address Pathogen Pollution in Surface Waters: A TMDL Implementation Guidance Manual for Massachusetts. Environmental Protection Agency, New England Region 1.

- U.S. Environmental Protection Agency, 2012. "Recreational Water Quality Criteria". Office of Water. 820-F-12-058.
- U.S. Environmental Protection Agency, 2015. National Summary of State Information. http://iaspub.epa.gov/waters10/attains_nation_cy.control
- van der Wel, B. 1995. Dog Pollution. The Magazine of the Hydrological Society of South Australia. 2(1)1.
- Vermont Department of Environmental Conservation (VDEC). 2014. Vermont Surface Water Assessment and Listing Methodology. Montpelier, VT: Vermont Department of Environmental Conservation.
- Virginia Department of Environmental Quality (VADEQ). 2013. 2013 Citizen/Non-Agency Monitoring Activity Report. http://www.deq.virginia.gov/Portals/0/DEQ/Water/WaterQualityMonitoring/CitizenMonitoring/2013_Citizen_Report.pdf

Appendix B: How To Collect Samples

This information is taken directly from the EPA's "Volunteer Stream Monitoring: A Methods Manual," available at *https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/nonpoint-source-volunteer-monitoring*.

In general, sample away from the streambank in the main current. Never sample stagnant water. The outside curve of the stream is often a good place to sample, since the main current tends to hug this bank. In shallow stretches, carefully wade into the center current to collect the sample.

A boat will be required for deep sites. Try to maneuver the boat into the center of the main current to collect the water sample.

When collecting a water sample for analysis in the field or at the lab, follow the steps below.

For Whirl-pak® Bags

1. Label the bag with the site number, date, and time.

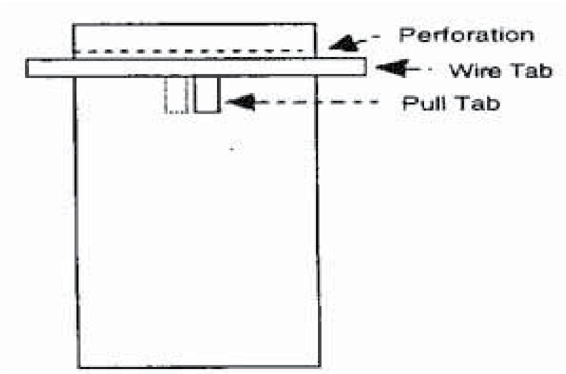
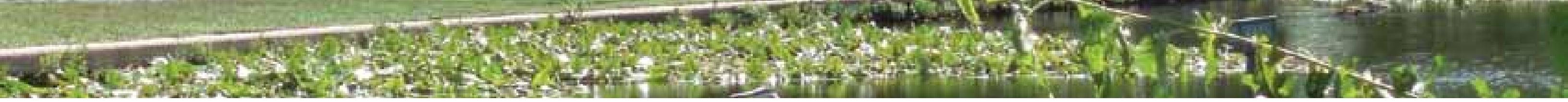


Figure 5.1 Sketch of a Whirl-pak® bag
Volunteers can be easily trained to use these factory-sealed, disposable water sample collection bags.

2. Tear off the top of the bag along the perforation above the wire tab just prior to sampling (Fig. 5.1). Avoid touching the inside of the bag. If you accidentally touch the inside of the bag, use another one.
3. *Wading*. Try to disturb as little bottom sediment as possible. In any case, be careful not to collect water that contains bottom sediment. Stand facing upstream. Collect the water sample in front of you.
   Boat. Carefully reach over the side and collect the water sample on the upstream side of the boat.
4. Hold the two white pull tabs in each hand and lower the bag into the water on your upstream side with the opening facing upstream. Open the bag midway between the surface and the bottom by pulling the white pull tabs. The bag should begin to fill with water. You may need to "scoop" water into the bag by drawing it through the water upstream and away from you. Fill the bag no more than 3/4 full!
5. Lift the bag out of the water. Pour out excess water. Pull on the wire tabs to close the bag. Continue holding the wire tabs and flip the bag over at least 4-5 times quickly to seal the bag. Don't try to squeeze the air out of the top of the bag. Fold the ends of the wire tabs together at the top of the bag, being careful not to puncture the bag. Twist them together, forming a loop.



6. Fill in the bag number and/or site number on the appropriate field data sheet. This is important! It is the only way the lab coordinator know which bag goes with which site.
7. If samples are to be analyzed in a lab, place the sample in the cooler with ice or cold packs. Take all samples to the lab.

For Screw-cap Bottles

To collect water samples using screw-cap sample bottles, use the following procedures (Fig. 5.2 and 5.3):

Figure 5.2 Getting into position to take a water sample
Volunteers should sample in the mail current, facing upstream.

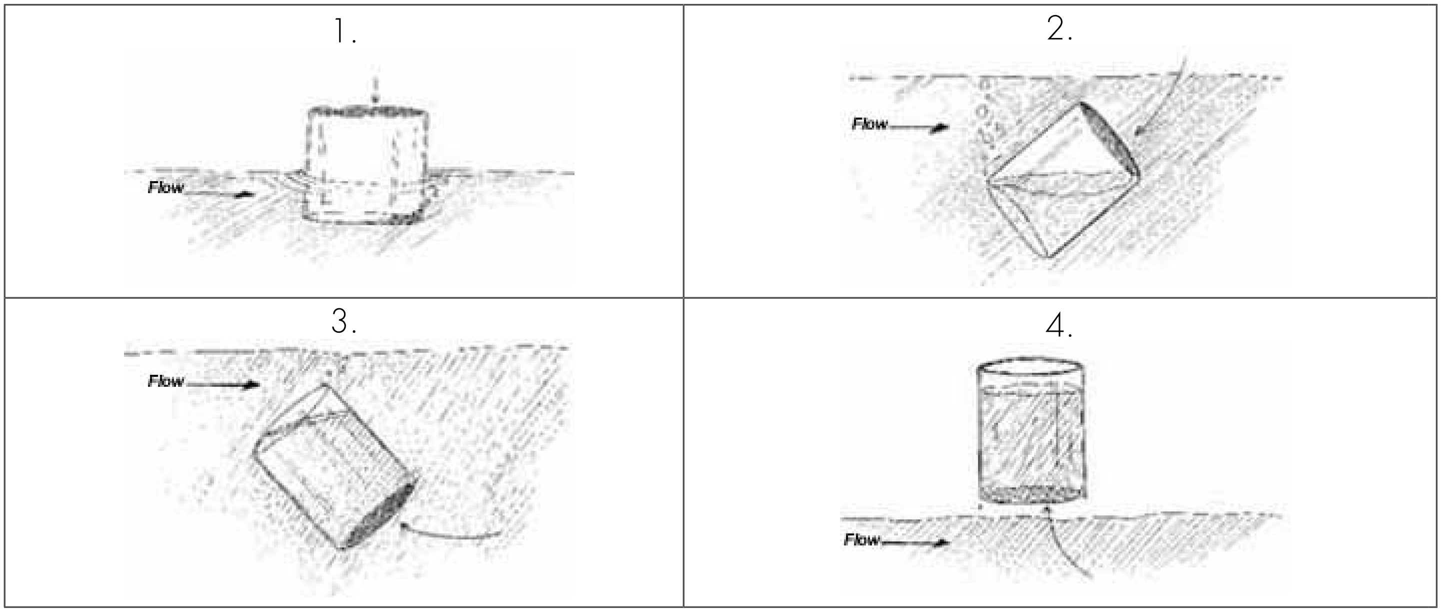
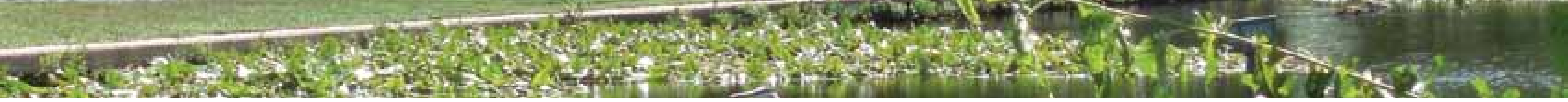


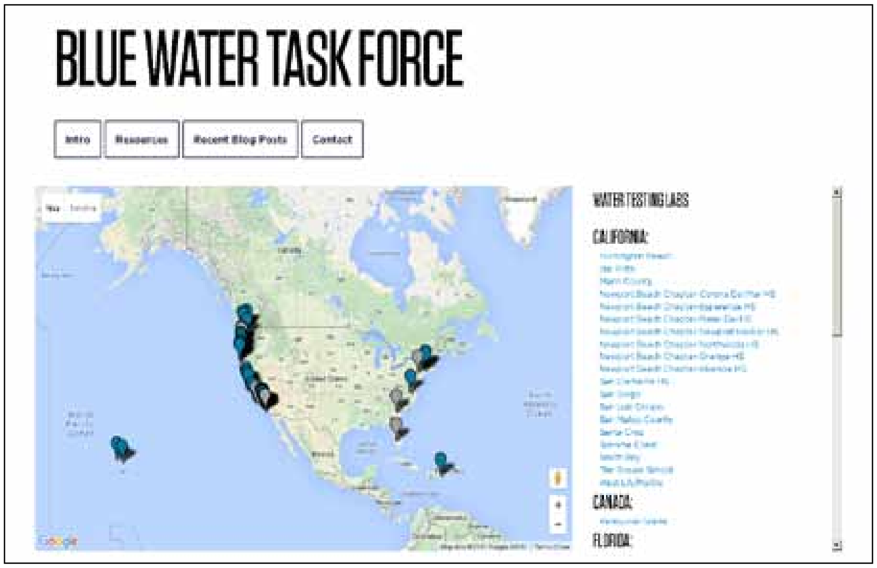
Figure 5.3 Taking a water sample
Turn the bottle into the current and scoop in an upstream direction.



1. Label the bottle with the site number, date, and time.
2. Remove the cap from the bottle just before sampling. Avoid touching the inside of the bottle or the cap. If you accidentally touch the inside of the bottle, use another one.
3. *Wading*. Try to disturb as little bottom sediment as possible. In any case, be careful not to collect water that has sediment from bottom disturbance. Stand facing upstream. Collect the water sample on your upstream side, in front of you. You may also tape your bottle to an extension pole to sample from deeper water.
   Boat. Carefully reach over the side and collect the water sample on the upstream side of the boat.
4. Hold the bottle near its base and plunge it (opening downward) below the water surface. If you are using an extension pole, remove the cap, turn the bottle upside down, and plunge it into the water, facing upstream. Collect a water sample 8 to 12 inches beneath the surface or mid-way between the surface and the bottom if the stream reach is shallow.
5. Turn the bottle underwater into the current and away from you. In slow-moving stream reaches, push the bottle underneath the surface and away from you in an upstream direction.
6. Leave a 1-inch air space (Except for DO and BOD samples). Do not fill the bottle completely (so that the sample can be shaken just before analysis). Recap the bottle carefully, remembering not to touch the inside.
7. Fill in the bottle number and/or site number on the appropriate field data sheet. This is important because it tells the lab coordinator which bottle goes with which site.
8. If the samples are to be analyzed in the lab, place them in the cooler for transport to the lab.

Appendix C: Case Studies

Case Study #1: Surfrider's Blue Water Task Force



Source: Surfrider Foundation

About the Group

Surfrider Foundation's **Blue Water Task Force** (BWTF) is a water quality monitoring program organized at the local chapter level. In 2013, there were 28 labs actively monitoring water quality and 3,127 samples reported in total for the year.

Most of the chapters conducting monitoring are on the West Coast, with more than half in California. BWTF primarily monitors beaches, especially surfing areas, and locations where freshwater sources discharge onto the beach.

Goals of Monitoring

Blue Water Task Force members monitor water quality to meet several goals, including:

1. To identify the healthiest areas for surfing and swimming and those areas which require further testing.
2. To fill in gaps in geography and time. Chapters that monitor tend to focus especially where and when there is no other monitoring by local or state agencies.
3. They also test where they suspect pollution, such as below stormwater outfalls and at the mouth of streams. (Wave breaks popular with surfers are often located where rivers meet the sea).

Monitoring Approach

Each Surfrider chapter that participates in BWTF designs its own monitoring program based on local resources available and based on their priorities. In choosing monitoring sites, for example, chapters that are primarily interested in engaging many volunteers take water samples from areas that are most accessible and convenient. In contrast, other chapters may decide to focus their sampling at beaches with known sources of pollution or at beaches that are not covered by local agencies because they are more remote. Many chapters monitor weekly and others sample monthly, based on how much funding and how many volunteers they have. In addition to taking water samples, volunteers collect environmental observations on a data sheet. They note air and water temperature, recent rainfall, current weather, wind strength and direction, wave height, and tide stage.

In terms of analyzing water samples, some chapters collect water samples for an existing local or state monitoring program and deliver the samples to those agencies' laboratories. Some chapters partner with universities, aquariums, or other research institutions who conduct the water quality tests for the BWTF program. And others run their own labs using EPA approved methodology to test for *enterococcus* bacteria with the IDEXX Enterolert and Quantitray/2000 system. The IDEXX method is easy for volunteers to perform, scientifically thorough, and produces quantifiable results.

Surfrider Chapters present their *Enterococcus* bacteria results as High, Medium, or Low based on the EPA's water quality recommendations for recreational exposure, as follows (MPN/100 ml):

- (0-35) Low Bacteria
- (36-104) Medium Bacteria
- (> 104) High Bacteria

How Are Data Shared/Reported?

All of the BWTF water quality data is posted online in an interactive map on the national BWTF website, open to the public. The website is simple to use – data can be viewed on the map or downloaded into a spreadsheet. As a culmination of the BWTF effort each year, Surfrider headquarters also compiles an annual report of the water quality findings nationally.

At the chapter level, BWTF members use a variety of methods to share their water quality data. Each chapter posts its data on its own chapter website and often shares results via social media outlets. Some chapters send out email blasts with weekly or monthly water quality reports and make presentations in the community and to local governments (e.g., city council meetings). Some also have good relationships with local media outlets that will run press releases written up by Surfrider volunteers.

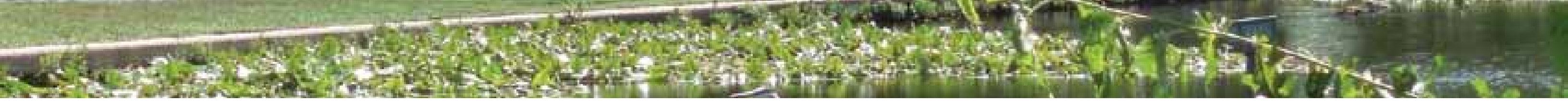
Most importantly, the chapters share their data with local governments and other agencies, especially when problems are found. BWTF volunteers provide the service of collecting and sometimes testing water quality samples, but their authority and resources are limited when it comes to correcting certain bacteria sources (e.g., sewage leaks). Therefore, Surfrider's partnerships with these agencies are essential for tracking down sources of pollution, brainstorming solutions, and implementing them.

Surfrider chapters have especially good connections with local and state beach programs and share their data with the agencies that administer them. The BWTF data is not used to 'close' beaches, but rather to build evidence of chronic pollution problems and to alert the agencies that they need to conduct follow up monitoring in those areas. There are a few exceptions where a Surfrider lab has an approved QAPP and submits its data for use in official beach closings or impaired waters designations. This has happened in Oregon for TMDL work and in Kauai where the Surfrider chapter is contracted to perform official beach testing for Hawaii Department of Health.

Source: Surfrider Foundation

What Was the Outcome of Providing Data?

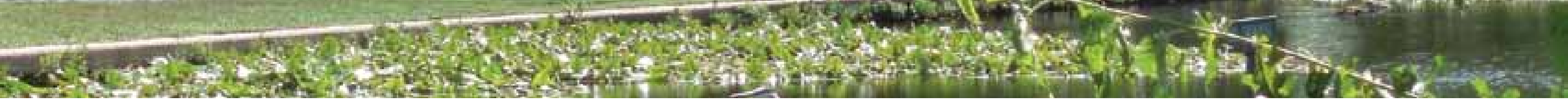
As mentioned above, water monitoring by Surfrider volunteers has often served as a catalyst to mobilize local agencies to look for and solve sources of pollution problems. One specific example comes out of the **Eastern Long Island, NY Chapter** of Surfrider. This new chapter started monitoring in 2013 in partnership with Concerned Citizens of Montauk (CCOM). Chapter volunteers monitor popular ocean and bay beaches in and around Montauk, NY as well as several freshwater inputs and a large coastal pond in downtown.



Three of their monitoring stations are located at an enclosed bay beach on Lake Montauk that is a popular swimming spot for families with young children. Unfortunately, the Chapter's water quality tests have showed that bacteria levels at the beach and in two of the incoming freshwater creeks frequently exceed health standards, especially after rainfall events. In response to the data that the volunteers have collected, the Town of East Hampton has posted permanent signage to warn the public about the chronic pollution problem at the beach. The Town has also taken account of the Chapter's water quality data while developing a watershed management plan for Lake Montauk. One of the recommendations outlined in the draft watershed plan (completed in July 2014) is to do more water monitoring, especially to locate failing septic systems. It appears that the Surfrider volunteers will have plenty more work to do!

References & Links

- Blue Water Task Force homepage: http://www.surfrider.org/blue-water-task-force
- Blue Water Task Force 2013 Annual Report: http://www.surfrider.org/images/uploads/publications/BWTF_Annual_Report_2013.pdf
- Eastern Long Island Chapter of Surfrider, Blue Water Task Force page: http://easternli.surfrider.org/blue-water-task-force-water-testing-program/
- Surfrider Blog. July 22, 2014. "New Beach Signs Warn the Public of Polluted Conditions." http://www.surfrider.org/coastal-blog/entry/new-beach-signs-warn-the-public-of-polluted-conditions
- Lake Montauk Watershed Management Plan (July 2014 DRAFT): http://www.town.east-hampton.ny.us/HtmlPages/NaturalResources/LakeMTKStudy.html
- The East Hampton Star. June 16, 2014. "Lake Montauk Pollution Solutions." http://easthamptonstar.com/Lead-article/2014619/Lake-Montauk-Pollution-Solutions
- 27east.com. June 10, 2014. "Montauk Lake Watershed Study Finished, Recommendations Include Testing And Remediation." http://www.27east.com/news/article.cfm/Montauk/65945/Montauk-Lake-Watershed-Study-Finished-Recommendations-Include-Education-Testing-And-Septic-Remediation



Case Study #2: Hudson River – Riverkeeper

About the Group

Riverkeeper is a member-supported watchdog organization dedicated to defending the Hudson River and its tributaries and protecting the drinking water supply of nine million New York City and Hudson Valley residents. The group has helped to establish globally recognized standards for waterway and watershed protection and serve as the model and mentor for the growing Waterkeeper movement that includes more than 200 Keeper programs across the country and around the globe.

Source: Riverkeeper

To conduct its fecal contamination monitoring program in the Hudson River Estuary, Riverkeeper partners with scientists from Lamont-Doherty Earth Observatory of Columbia University and CUNY Queens College. It also partners with watershed groups, environmental advisory committees, and concerned local residents to conduct citizen-led monitoring on waterfront areas and tributaries of the Hudson River. These groups include the Catskill Creek Watershed Awareness Project, the New York City Water Trail Association, the Quassaick Creek Watershed Alliance, Save the Wallkill, the Sparkill Creek Watershed Alliance, and the environmental advisory boards in the towns of Gardiner, Montgomery, Rosendale, Rochester and Wawarsing.

Goals of Monitoring

The three primary goals of Riverkeeper's citizen science program are to:

1- **Fill a data gap.** In New York State, testing for fecal contamination is required only at official swimming beaches. There are only four official swimming beaches along the 212 miles of tributaries where Riverkeeper and its citizen partner's sample, but these waterways contain numerous informal swimming areas that are heavily used but not monitored by the state.

2- **Inform the public about fecal contamination in their watersheds.** In most of the places where Riverkeeper samples, their data is the only source of information about fecal contamination. By involving local residents in collecting data, and educating the public about its findings, Riverkeeper is raising awareness about this issue.

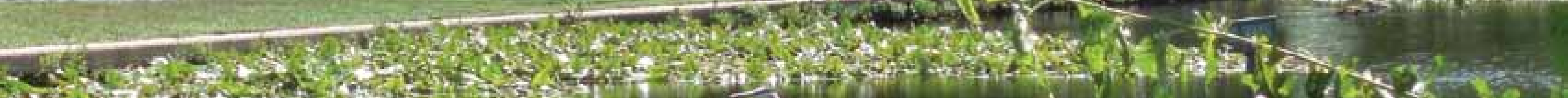
3- **Involve local citizens in finding and eliminating sources of contamination.** Fecal contamination sources vary by location and over time, and the potential solutions depend on local conditions and priorities. Riverkeeper engages local citizens and leaders to generate further inquiry and discussion and to advocate for improvements.

Monitoring Approach

Riverkeeper and its citizen partners test for *Enterococcus*, an EPA-recommended indicator of fecal contamination. They sample at least monthly from May to October (the recreational season) in seven tributary watersheds and along the NYC waterfront. In most areas, Riverkeeper coordinates samplers and processes the samples in its onboard lab. Some of the partners operate more independent programs; in these cases, Riverkeeper has helped design the study and train samplers, but samples are processed at other laboratories. In all cases, Riverkeeper publishes the data on its website, helps interpret the data, and shares the lessons learned from monitoring throughout the Hudson Valley.

How Are Data Shared/Reported?

Riverkeeper categorizes water quality at each site as "Acceptable" or "Beach Advisory" for the date sampled, according to the EPA's recommended primary contact standard. Riverkeeper publishes the data on its website and also emails results to samplers.



Riverkeeper makes public presentations and produces a digital monthly 'Trib Report' that is featured on their Boat Blog and e-mailed to members. Riverkeeper also displays and discusses its water quality monitoring results at tabling events throughout the Hudson River watershed, and shares the data with local leaders in both public and one-on-one meetings.

What Was a Particularly Successful Outcome of Doing this Monitoring?

Since tributary monitoring began at a handful of sites in 2010 as an outgrowth of Riverkeeper's Hudson River study, the program has grown to include monthly (or more) monitoring of 148 sites in seven tributary watersheds and along the NYC waterfront. This reflects a growing awareness throughout the Hudson Valley and New York City area of the potential threat of fecal contamination in these waterways, as well as a strong desire for swimmable water.

Source: Riverkeeper

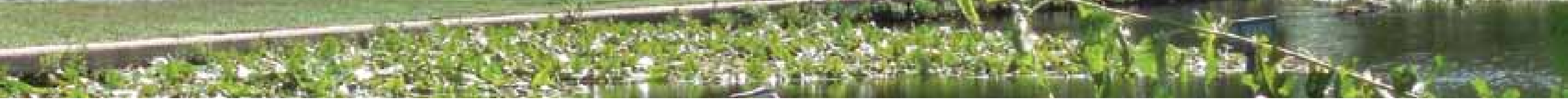
Source: Riverkeeper

Riverkeeper and its partners can point to several specific positive outcomes of this monitoring program:

1. The **Quassaick Creek** Watershed Alliance began testing for *Enterococcus* in August 2014, with a sampling plan that includes locations upstream of drinking water sources for two municipalities. On the first sampling day, one of the City of Newburgh's drinking water reservoir feeder streams had a very high Entero count (1300 cells/100 mL). On the next sampling outing, QCWA members investigated upstream of the sampling site and smelled raw sewage at a permitted outfall. They reported the issue to the City of Newburgh, which immediately shut off inflow from this stream to the reservoir, reported the incident to the NYS Department of Environmental Conservation, and launched an investigation of possible fecal contamination sources to the reservoir feeder stream. The City is currently conducting additional *Enterococcus* sampling in the area as a step toward permanently addressing fecal contamination (which has continued to be observed on subsequent sampling dates) in this stream.

2. In early 2012, the Town of Orangetown, in Rockland County, voted unanimously to spend $104,000 on the first repairs to the Piermont pump station since it was built in 1964. This station failed dozens of times in 2011 alone, resulting in sewage discharges to the Sparkill Creek. As of 2012, the **Sparkill Creek** Watershed Alliance had been testing water quality on the creek for a year. Their engagement and advocacy were instrumental in the decision to make repairs to the system.

3. Suspected illegal sewage discharges in the lower **Catskill Creek** prompted the Catskill Creek Watershed Awareness Project to partner with Riverkeeper in 2010. Citizen samplers began testing for *Enterococcus* at a suspect outfall, plus upstream and downstream reference locations, and gradually expanded testing to cover about 10 miles of the creek. The data was submitted to state and local agencies investigating the illicit connections, and enforcement action was taken in 2012. In 2014, Riverkeeper expanded the Catskill Creek monitoring program to the creek's headwaters and brought several new citizen samplers into the fold.



References & Links

- Riverkeeper Citizen Testing Data: http://www.riverkeeper.org/water-quality/citizen-data/

- Riverkeeper Boat Blog (often features water quality): http://www.riverkeeper.org/blog/patrol/

- How's the Water? 2014: Water Quality Monitoring, Fecal Contamination and Achieving a Swimmable Hudson River: http://www.riverkeeper.org/wp-content/uploads/2014/07/Riverkeeper_Water_Quality_Hows-the-Water-Report_2014-lr.pdf

- Hudson Riverkeeper Water Quality Program: http://www.riverkeeper.org/water-quality/testing/

- Riverkeeper. 2012. *How is the Water? 2012: Sewage Contamination in the Hudson River Estuary 2006-2011.* http://www.riverkeeper.org/wp-content/uploads/2012/12/RvK_How-Is-the-Water-2012.pdf

Case Study #3: StreamWatch

About the Group

StreamWatch is a community-based water monitoring program ofthe Rivanna Conservation Alliance in central Virginia. StreamWatch volunteers have conducted macroinvertebrate sampling in the Rivanna River watershed since its inception in 2002. Inspired by a bacteria impairment in Moore's Creek (tributary to the Rivanna) and the TMDL process, the group decided to start testing for E. coli in 2012. The Rivanna River Basin Commission was also a partner during the first phases of the work, which started as a pilot project.

Goals of Monitoring

The major goal for StreamWatch's bacteria monitoring is to provide the public with information about the safety of the waters in which they swim and boat. The group also wants to get a general picture of what the baseline values are for fecal bacteria in local waters to supplement the stream health information gathered through their macroinvertebrate sampling)

Monitoring Approach

During the first two years of bacteria monitoring, StreamWatch members sampled at seven recreational sites – primarily boat launches and other common access points for recreation – and 6 sites in the Moores Creek watershed. After they were able to see trends at each station, they adjusted their sampling locations slightly. They moved away from stations that showed consistently good bacteria results and added more monitoring locations on stream reaches with higher bacteria levels. By honing in geographically to problem areas, the group is able to maximize its resources.

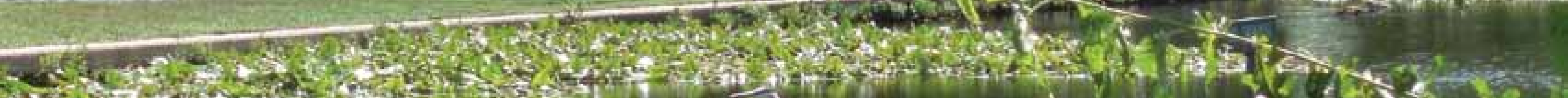
Source: StreamWatch

StreamWatch volunteers sample each monitoring station every first Sunday of the month from about February through October, which generally mirrors the sampling season used by the Virginia Department of Environmental Quality (VADEQ). (In winter time, bacteria levels are assumed to be relatively low.) Approximately 40 volunteers are available to collect water samples. Those who collect samples in a given month bring their bottles to put on ice at a central location – a local government building. A set of four volunteers then take the samples to the StreamWatch office on the following Monday to process them for bacteria.

StreamWatch has chosen to use Coliscan Easygel. This is a method that VADEQ staff has taught citizen water monitoring groups across the state to use because it is relatively low cost and easy to use. StreamWatch works closely with VADEQ which is the agency that approved their QAPP. The agency also provides StreamWatch with advice on where to position the monitoring stations.

How Are Data Shared/Reported?

StreamWatch's bacteria data are posted to its website immediately, below a map which shows the locations of the monitoring sites. The bacteria levels that do not meet the state standards for recreational waters are shown in red. Each month, Rivanna Conservation Alliance posts a "Can you Swim Here" poster at those boat launches that have kiosks, which show the most current bacteria results. When bacteria results show something newsworthy, the group will issue a press release to local news outlets. They will also occasionally do presentations to local governments and community organizations, sharing their findings.



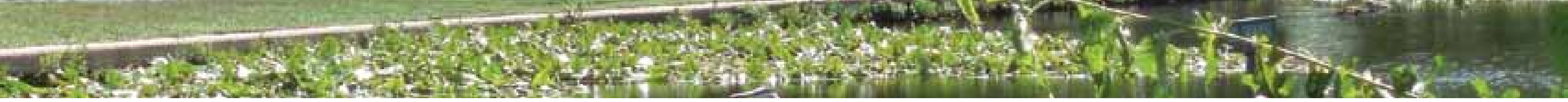
At the end of each monitoring season, StreamWatch staff put together a report for their members and the public, synthesizing all the bacteria data. They send out this report to local partnering organizations and localities in which they test for bacteria. Finally, StreamWatch sends its data to VADEQ for use as "Level 2" data which is not used for listing or de-listing impaired streams, but which can at least inform the agency's own monitoring efforts.

What Was a Particularly Successful Outcome of Doing this Monitoring?

Luckily, *E. coli* levels in most of the stream reaches where StreamWatch volunteers have been monitoring have met state water quality standards. However, one particular stretch of stream in a highly urban area tested very high for *E. coli* three months in a row. Upon seeing these results, StreamWatch staff contacted the environmental officials from the City of Charlottesville. The city responded immediately by walking the stretch of stream and then conducting dye testing to look for any leaking sewer lines. The dye testing relatively quickly revealed a broken underground sewer lateral pipe on private property. Within days, the landowner had the pipe fixed to stop the sewage leak. By partnering closely with the City, StreamWatch had one of its first illicit discharge elimination successes!

References & Links

- StreamWatch Bacteria Monitoring website: http://streamwatch.org/stream-conditions/bacteria-monitoring
- StreamWatch's bacteria monitoring results from 2012-2013: http://streamwatch.org/bacteria
- Local article about one of StreamWatch's successes: http://www.cvilletomorrow.org/news/article/18329-streamwatch-releases-water-quality-findings/



Case Study #4:
Chattahoochee Riverkeeper – Neighborhood Water Watch

Source: Chattahoochee Riverkeeper

About the Group

Chattahoochee Riverkeeper is a watershed-based advocacy organization out of Atlanta, GA that was established in 1994. The group works to protect and preserve the Chattahoochee and its tributaries through a variety of programs, many of which involve citizen volunteers.

In 2010, the organization initiated Neighborhood Water Watch (NWW), a large-scale *E. coli* monitoring effort by local volunteers. Since its inception, the program has grown significantly and in 2014 they monitored over 70 sites throughout Atlanta and Gainesville, Georgia. The program is coordinated in partnership with 30 groups such as schools and neighborhood associations. Through the work of Riverkeeper staff and approximately 50 volunteers, the Neighborhood Water Watch program collects more than 1,600 samples a year. NWW is described in detail in a new publication produced by Chattahoochee Riverkeeper entitled, *Neighborhood Water Watch: A Guide for Developing a Volunteer Bacteria Monitoring Program*. Much of the information contained in this case study is distilled from that document.

Goals of Monitoring

The Neighborhood Water Watch Program has set 5 overarching goals for its bacteria monitoring efforts:

1. *Increase public awareness of water quality issues and local waterway conditions.*
2. *Provide citizen groups with tools and training to protect their local waterways.*
3. *Collect quality baseline data.*
4. *Form new partnerships between citizen groups, non-profit organizations and government agencies.*
5. *Address and resolve poor water quality detected during monitoring.*

Monitoring Approach

Throughout the year, NWW volunteer monitors collect water from creeks and river segments every Thursday and drop off their samples at the closest Riverkeeper office. The volunteers monitor at parks, swimming areas, and other recreational areas (which are of highest priority). The stream reaches to monitor were originally chosen according to where the volunteers were most interested in sampling and then Riverkeeper staff helped identify specific locations on each stream reach where the volunteers should collect a sample. Volunteers participating in NWW commit to being part of the program for the long term. The initial commitment is one year minimum, but most volunteers have continued beyond that timeframe. By observing conditions and water quality results at a particular site over a long period, each volunteer starts to understand what is considered "normal" or baseline for that stream. Conversely, he/she knows when conditions are problematic and should be brought to the attention of the City.

Source: Chattahoochee Riverkeeper

Each of the three Chattahoochee Riverkeeper offices now has a lab set up for analyzing the water samples. After the volunteers drop off the water samples each Thursday, the samples are immediately tested for turbidity, specific conductivity, optical brighteners, and *E.coli* using the IDEXX Colilert system. Combining all these parameters can provide a more robust indication of illicit discharges than bacteria tests alone and, over time, reveal the baseline conditions for each site. On Friday mornings the Colilert tests are ready to be analyzed. Riverkeeper interns provide most of the labor force to process the water samples and analyze the bacteria tests. Funding for NWW comes primarily from EPA grants.

Where an unusually high bacteria level is found, Riverkeeper staff (and sometimes volunteers) goes out to do further monitoring and/or try to track down any obvious sources of the problem. Almost every week one or more hits of concern are found – often due to sewage line or manhole leaks. For this reason, Riverkeeper employees stay in fairly regular contact with the City's Department of Watershed Management (who is in charge of drinking water, sewer, and stormwater) to inform them of problem spots. The City has expressed its gratitude for and support of the NWW program, as evident by the letters of support it provides when Chattahoochee Riverkeeper submits grant proposals to fund the program. An example of such a letter is included at the end of this case study.

How Are Data Shared/Reported?

All of the Neighborhood Water Watch data is made publically available through several outlets: (1) on an in-house database on the NWW websites, (2) through the state-run Georgia Adopt-A-Stream database, and (3) in the federal EPA STORET database. The program has an EPA-approved quality assurance plan (QAPP), which is how Riverkeeper is able to submit its data to the state and national databases. The data for some of the monitoring sites is also shared with neighborhood associations.

Every year Chattahoochee Riverkeeper hosts an annual forum attended by NWW volunteers and anyone else who is interested. Prior to the forum, they do a full analysis of all the water quality data collected by the group and share the results at the forum. This event also gives volunteers an opportunity to share stories from the field and exchange ideas.

What Was the Outcome of Providing Data?

In its short lifetime so far, Neighborhood Water Watch has had an impressive number of successes. Just a few of these are described below:

Source: Chattahoochee Riverkeeper

In the mid-2000s, the City of Atlanta renovated an underground pipe system that had served as combined sewers for decades. The renovation was intended to separate stormwater flows from sewage being sent to the wastewater treatment plant. In 2013, Riverkeeper volunteers tested one area of Proctor Creek in the city where they kept finding chronically high levels of bacteria. They contacted City staff about their findings. The City followed up by conducting an extensive camera survey (over 20 miles of stormwater pipe) in proximity to the problem area to look for sources of sewage into the stormwater pipes. What they found was at least thirteen sewer pipes that had inadvertently remained connected to the stormwater system and had been discharging raw sewage to the stream since the renovations. Since this discovery, eleven of the illicit connections have been fixed.

In Orme Creek, in the winter of 2013-201414, Chattahoochee Riverkeeper and the Piedmont Park Conservancy identified a sewage overflow in a local park. While investigating the source of elevated *E. coli* levels in the creek, they discovered an outfall pipe sending untreated waste directly into the creek within this popular park. Riverkeeper immediately notified the city's Department of Watershed Management who responded quickly. City crews found that the sanitary sewer was clogged with debris and grease. Sewer crews cleared the blockage and jetted the sewer to restore normal operation. This stopped the overflow of the untreated waste from entering Orme Creek. Subsequent monitoring of the stream shows bacteria levels have returned to typical baseline levels.

In partnership with the Watershed Alliance of Sandy Springs and Kennesaw State University, Chattahoochee Riverkeeper conducted bacteria testing on a series of stations along Long Island Creek in June 2014. Regular testing at one of the monitoring stations had indicated periodic increases in bacteria levels that exceeded EPA surface-water quality standards. Large scale tests and tracking revealed high bacteria concentrations in a tributary of Long Island Creek. Once tests indicated the source of pollutants, the group notified officials with the city of Sandy Springs who worked with Fulton County's Department of Water Resources to find and stop the source - an overflowing manhole that had been invaded and compromised by vegetative roots. Recent tests in this area indicate that repairs made have caused dramatic improvements in water quality in this stretch of the creek.

References & Links

- Chattahoochee Riverkeeper. 2014. *Neighborhood Water Watch: A Guide for Developing a Volunteer Bacteria Monitoring Program*. Atlanta, GA.

- Chattahoochee Riverkeeper's *Neighborhood Water Watch* website: http://www.chattahoochee.org/neighborhood-water-watch.php

Kasim Reed
MAYOR

CITY OF ATLANTA
DEPARTMENT OF WATERSHED MANAGEMENT
72 MARIETTA STREET NW
ATLANTA, GEORGIA 30303

Jo Ann J. Macrina, PE
COMMISSIONER

December 13, 2013

US EPA Urban Waters Small Grants Program – Letter of Commitment

To Whom It May Concern,

The City of Atlanta Department of Watershed Management expresses its continued commitment to partner with Chattahoochee Riverkeeper (CRK), West Atlanta Watershed Alliance (WAWA), and other project partners for the next two years as part of CRK's Neighborhood Water Watch (NWW) Program within the Proctor Creek watershed. The City has had many successful partnerships with CRK in the past, including previous involvement in the NWW program which was funded under the initial Urban Waters Small Grants Program. The initial program resulted in the identification and remediation of significant sources of pollution to urban streams including Proctor Creek. We are confident that the continuation and expansion of the NWW program within the Proctor Creek watershed will result in additional improvements to water quality and a more informed and engaged public.

As part of this project, the City will:

- Work with CRK and project partners to evaluate data generated by the project and to communicate with stakeholders about any pollutant tracking or hot spot identification that results from the project data.

- Participate in the annual NWW citizen workshops by utilizing project data to educate the public on urban water quality issues and the City's water quality programs.

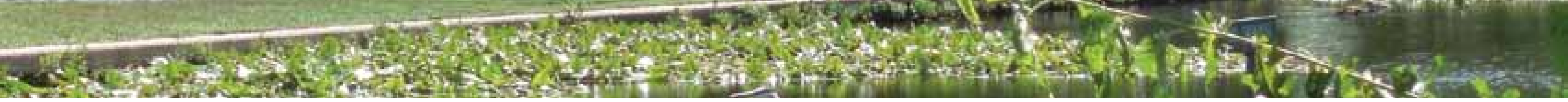
- Investigate and, where appropriate, implement source tracking activities using advanced technologies such as closed caption TV systems to help track possible sources of pollution identified by the project.

Thank you for your consideration. We look forward to resolving water quality issues in partnership with the Neighborhood Water Watch Program.

Sincerely,

JMacrina

Jo Ann J. Macrina, P.E.
Commissioner



Case Study #5:

Poultney Mettowee Natural Resources Conservation District – Pawlet Village Septic Survey

About the Group

The Poultney Mettowee Natural Resources Conservation District (the District) is located in Rutland County, Vermont. Created in 1940, the District is a local government entity that is governed by an elected volunteer supervisory board. The mission of the District is to provide educational outreach, technical assistance, and financial support to communities and landowners to protect healthy soil and clean water and preserve the ecological integrity and economic vitality of communities. The District brings together the efforts of citizens and organizations that share the common goals of conserving, protecting, and enhancing the natural and cultural resources of the watershed.

Source: PMNRCD

The District and the Vermont Agency of Natural Resources monitor the water quality in Flower Brook. In 2012, Flower Brook in the Village of Pawlet was listed as impaired for bacteria. *E. coli* concentrations exceeded the State standard of 235 colonies per single grab sample of 100 ml of water, or the geometric mean of six or more samples not to exceed 126 colonies per 100 ml of water. Bacteria levels were found to be chronically high, regardless of the water level or weather conditions. The presence of fecal bacteria in streams during low-flow conditions can indicate that septic systems may be leaking partially-untreated effluent to the groundwater. The Vermont Department of Environmental Conservation and the US Geologic Survey's Microbial Source Tracking Study also confirmed the presence of bacteria of human origin in downstream reaches near Pawlet.

Goals of Monitoring

Sewage treatment throughout most of Pawlet is provided through on-site wastewater treatment systems. The District conducted a septic survey in the Town to better understand where septic leaks could be coming from and work towards eliminating those sources. They also wanted to know the potential risk of leaks from the different types of septic systems, including holding tanks, leach fields, mound systems, and dry wells. The District also felt it was important to educate the public on septic issues and the required maintenance associated with the systems. During the same time frame, Watershed Consulting, Inc. conducted an illicit discharge survey at stormwater outfalls in Pawlet, and the District collected samples from Flower Brook at two locations in the Pawlet Village. The results of these studies were used to target certain pipes and stream sections for field surveys using sewage sniffing dogs to narrow down sources of human sewage (Case Study #6).

Monitoring Approach

The septic survey involved walking door-to-door to interview landowners about the type and location of wastewater treatment system they use. In addition to collecting anecdotal information about the type of septic system, the survey included questions about maintenance frequency and activities, condition of the tank and treatment area, and any landowner concerns or comments. It also included recording GPS coordinates of drinking water wells, septic tank locations, and septic treatment area locations.

The District conducted the survey from June to September of 2015. Data was collected at various times during the day and on both weekdays and weekends to facilitate conversations with all residents in town. Sixty-one parcels in the Pawlet Village were targeted for this survey. The parcels were located in areas where groundwater and/or the stormdrain system appear to drain to Flower Brook. The data was analyzed with respect to on-site septic treatment type, proximity to the stream, and parcel size to develop scores representing potential risk of septic effluent reaching groundwater for each parcel.

How Are Data Shared/Reported?

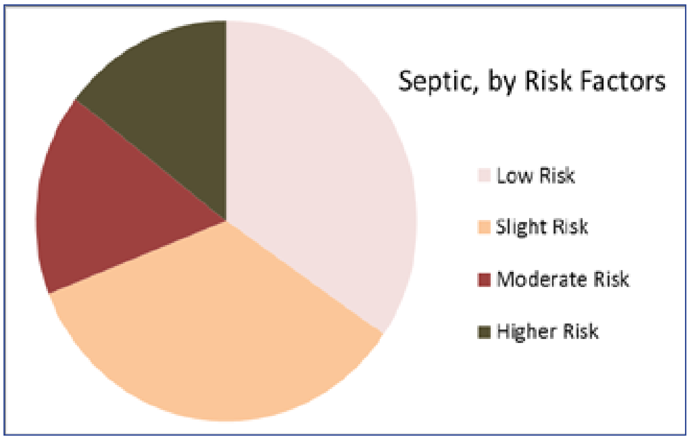
The District provided ongoing communication to Pawlet landowners and town officials through multiple meetings and information published in the Pawlet Newsletter and the Lakes Region Free Press. Another avenue of information dissemination was the local wastewater advisory committee, which consisted of landowners and town officials and helped to field questions from the residents. The illicit discharge survey results are available through Vermont Department of Environmental Conservation's Stormwater Division, the Village offices, and the District.

Source: PMNRCD

What Was the Outcome of Providing Data?

The results of the septic risk analysis indicate that approximately 17 properties have moderate to high risk of causing groundwater contamination under certain conditions. The remaining 38 properties are evenly split within the low and slight risk categories. These data are useful to provide an estimate of the potential collective risk posed by the group of systems found in the Village.

Through the illicit discharge survey, one system was found to potentially connect to the storm drain system and officials are working with the property owner to explore the path of the connection. Several other locations were identified as having potential groundwater contamination, though bacteria found at these locations were suspected to originate from older systems outside the properties in question.

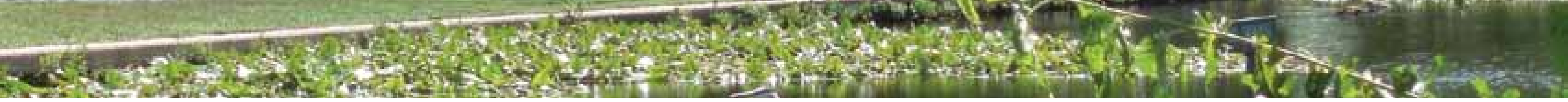


Source: PMNRCD

The continued high bacteria levels measured in the brook through the District's summer water quality monitoring program indicate that a source (or sources) of bacteria exists in the Village of Pawlet. The District recommends that the Village exercise their authority to continue investigating potential septic leaks and may want to revisit their zoning and septic regulations to help address the bacteria levels in Flower Brook. The latest septic rules ensure that as septic systems fail, they will be replaced with modern, state-approved systems. This may help to slowly decrease the bacteria levels in the brook.

References & Links

- Poultney Mettowee Natural Resources Conservation District, 2016. Pawlet Village Septic Survey, Final Report.
- Poultney Mettowee Natural Resources Conservation District website. www.pmnrcd.org



Case Study #6: Canine Sewage Sniffers

About the Group

Approximately six years ago, Karen and Scott Reynolds took it upon themselves to start training dogs to identify the smell of human sewage to assist with IDDE efforts. They created the consulting company Environmental Canine Services, LLC (ECS) to help various organizations detect human sewage contamination in stormwater systems, streams, rivers, and lakes. ECS has worked in over 10 states around the US, with offices in the east coast, west coast, and the Midwest.

The Center for Watershed Protection recently worked with ECS and other partners to identify human sewage hotspots in the Town of Bennington and the Village of Pawlet in southwestern Vermont. The Vermont Department of Environmental Conservation has been systematically supporting illicit discharge investigations in different parts of the state with the overall aim of reducing bacteria levels in its waterways and has been focusing its efforts recently in Bennington and Pawlet. In early 2015, Watershed Consulting Associates had inspected outfall pipes in both locations to identify indicators of sewage discharges. At the same time, the Poultney Mettowee Natural Resources Conservation District conducted a door-to-door septic system survey in Pawlet to provide insight into whether and where failing septics are contributing to the bacteria problem (see Case Study #5). The project partners used the results of these efforts to target certain pipes and stream sections in each locality and brought in Environmental Canine Services to use their sewage sniffing dogs to detect human sewage.

Goals of Monitoring

The goal of the canine sewage sniffers is to detect potential human sewage in streams, springs, outfalls, catch basins, and manholes. Since the dogs are trained specifically to identify human sewage, it is not only quicker than conventional bacteria sampling; it also narrows down the source of the contaminant. The dogs' noses are able to pick up traces of sewage that may otherwise go undetected using conventional tracking methods.

Monitoring Approach

Once trained, the canines can take a sniff at catch basin or an outfall and identify within seconds if human wastewater is (or recently was) present, even at very low concentrations. On the other hand, it takes minutes for us humans to arrive at the same conclusion using field and lab equipment – IF there is even enough flow available to take a sample. Each of ECS's dogs has adopted a different way to alert their human handlers that they have found a positive hit for sewage: Logan sits down, and Sable barks. Their noses have different levels of sensitivity, so when the canines work as a team, they can even provide some perspective on where sewage presence is mild and where it is strong.

The dogs' ability to sniff out sewage is not completely protected from outside interference, such as smells from nearby sewage vent stacks. Even so, the canine method is quite innovative for IDDE field work, which can often be clunky and slow going. The dogs decrease the amount of time spent in the field and allow the investigator to track down sources that the normal equipment might have otherwise missed.

How Are Data Shared/Reported?

ECS has completed over 50 projects in 10 different states for cities, counties, environmental organizations, and private consulting companies. Based on the success of ECS on projects in Michigan, in 2011 the Michigan Department of Environmental Quality added ECS's canine source tracking procedures to their Quality Assurance Project Plan (QAPP) template for all beach monitoring projects. When these QAPPs have been used to apply for federal grants to fund projects, the QAPPs have been reviewed and approved by the US EPA. Currently, the state of New Hampshire is undergoing a similar process to add ECS's canine source tracking procedures to their QAPP template.
Results from these studies have been shared in local press releases and social media.

What Was a Particularly Successful Outcome of Doing this Monitoring?

After three days of field work in Bennington and Pawlet, the canine team found at least three highly likely sources of wastewater pollution. Findings include: an underground spring flow that may be intermingling with a residential septic system and leaching sewage into the stream; a roof drain that may be funneling septic field leachate into a road-side ditch; and a sanitary sewer leaking into a storm drain pipe where they are in close proximity to each other under a street. A smoke test was conducted at one of these locations and an illegal connection was found. The property owner, the State, and the town are working to resolve this issue.

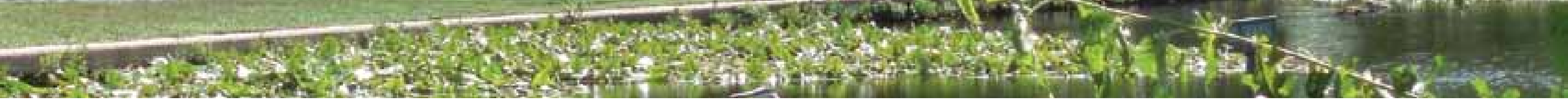
Two studies have documented the success of this innovative approach. The City of Santa Barbara Creeks Division and the University of California, Santa Barbara conducted a study in 2010 to evaluate how canine source tracking compared to traditional sewage identification methods. Side-by-side lab testing for bacterial, chemical, and human DNA markers was done for the locations investigated by the canines. The final research report found:

- The canines were 100% accurate on sites/samples where the lab results did not find any human waste indicators.
- One canine was 100% accurate and the other was 86% accurate (when factoring for a scent volume phenomena) where the lab results found at least 1 human waste indicator.
- There are benefits to adding canine scent tracking to the source tracking toolbox. The major advantages include real time results, the ability to test a high number of sites per day, and low cost per sample.

A follow up to this Water Environment Research Foundation-funded study found that ECS canine source tracking is a useful approach for prioritizing sampling sites for which DNA-based and other expensive laboratory tests can then confirm and quantify the human waste contamination.

References & Links

- http://www.cwp.org/working-with-dogs-to-sniff-out-sewage-leaks/
- http://vtwatershedblog.com/2015/09/11/dogs-helping-in-water-quality/
- http://www.townofbennington.org/TOB/2015/08/28/press-release-town-stormwater-study-being-conducted-over-next-60-days/



Case Study #7: Reedy Creek Coalition and Alliance for the Chesapeake Bay

About the Groups

The Reedy Creek Coalition is a volunteer organization "*committed to restoring the health and beauty of Reedy Creek through education, training, and collaboration with all residents and users of the Reedy Creek Watershed and its natural resources.*" Reedy Creek is a small, highly urbanized stream in Richmond, Virginia that is just under 4.0 miles long and encompasses a watershed area under 3,000 acres in size. Impervious surface covers approximately 40% of the drainage and Reedy Creek has been subjected to many of the typical insults of urban streams including over 1.0 mile of concrete channel. Reedy Creek is on the state's impaired waters list for elevated fecal bacteria. A TMDL implementation plan for the James River and tributaries, including Reedy Creek, was completed in 2014. The Reedy Creek Coalition initiated a comprehensive monitoring plan in 2010 with the assistance of the Alliance for the Chesapeake Bay and the City of Richmond Department of Public Utilities.

The Alliance for the Chesapeake Bay leads, supports, and inspires local action to restore and protect the land and waters of the Chesapeake Bay watershed. The Alliance's *RiverTrends* volunteer water quality monitoring program has been providing support to local monitoring groups for thirty years. Reedy Creek Coalition volunteers are trained to collect high-quality data, which is shared with the City of Richmond and the Virginia Department of Environmental Quality and used to identify pollution issues.

Goals of Monitoring

The monitoring plan has three related goals:

1. Obtain baseline data so improvements to Reedy Creek can be documented over time.
2. Localize and ultimately help identify specific sources of pollution.
3. Provide training and educational opportunities for citizen scientists.

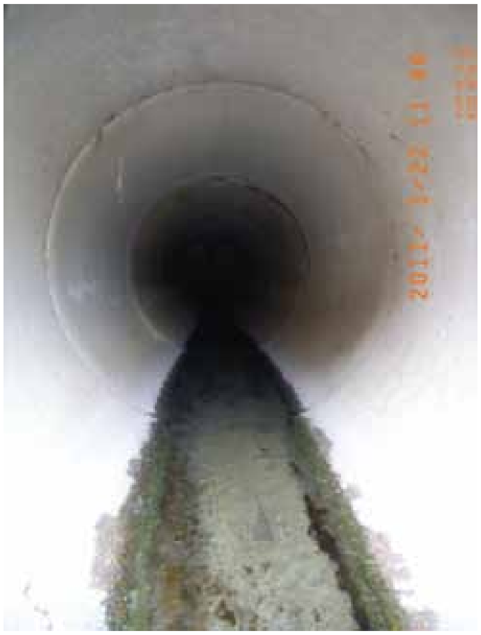
Monitoring Approach

Starting in 2010, volunteers monitored 4 sites on a monthly basis. Three of the sites are scattered along the "mainstem" of Reedy Creek and the fourth site is located on a perennial tributary (known locally as Crooked Branch) that is buried underground until it daylights a few hundred yards from its mouth. In addition to fecal bacteria samples, monitors also collect samples for nutrient and suspended solid analysis and record field data (temperature, pH, dissolved oxygen, water clarity). For the first 18 months, the City of Richmond provided in-kind analytical services at its wastewater treatment laboratory.

Over the years, the monitoring program has continually evolved in response to new information and resource availability. Starting in 2011, volunteers started performing *E. coli* analysis using Coliscan Easygel when City of Richmond analytical resources were no longer available. In 2012, a fifth site was added for *E. coli* testing to determine whether the source of an *E. coli* hotspot was stormwater pipes discharging into the long concrete channel and/or a small tributary that daylights and enters Reedy Creek just upstream of the identified hotspot. (Answer: It is both.) During the last three years, the Reedy Creek Coalition switched to bimonthly monitoring at the baseline sites and began performing streamwalks in the alternate months. This strategy has provided valuable new information about the creek, saved on analytical costs for other parameters, and provided monitors with new skills and motivation.

During streamwalks, trained volunteers document the condition of all stormwater pipes and ditches that discharge to Reedy Creek; test outfalls with flowing water during dry weather conditions for *E. coli* as well as temperature, pH, and dissolved oxygen; assess stream conditions (erosion, sedimentation, in-stream habitat, riparian area, floodplain connection, etc.); and identify areas that should be considered for green infrastructure improvements. Over the last four years, volunteers have walked nearly the entirety of Reedy Creek and all of its tributaries.

How Are Data Shared/Reported?



Data is entered into the Alliance for the Chesapeake Bay volunteer monitoring database. From there, it is easily provided to Virginia DEQ and the City of Richmond on an annual basis. In addition, the Alliance for the Chesapeake Bay obtained funding to do a report card in 2012 summarizing the first two and one-half years of monitoring data. The Reedy Creek Coalition periodically provides monitoring information on its website and also incorporates monitoring data into presentations at neighborhood meetings and educational workshops.

What Was a Particularly Successful Outcome of Doing this Monitoring?

Reedy Creek Coalition has identified several illicit discharges over the span of the monitoring program. In 2011, during a streamwalk, a dry weather discharge was detected at a large stormwater pipe, along with a strong sanitary sewer odor and bacteria growth. This along with follow up testing from Randolph Macon College students, which showed very high levels of E. coli, prompted the City of Richmond to investigate. They discovered a damaged sanity sewer line nearby and repaired it.

Also, in 2012, the water quality monitors identified foul odors and elevated E. coli counts at a monitoring site on Crooked Branch, a tributary of Reedy Creek. The RCC notified the City of Richmond's Department of Public Utilities (DPU) regarding their observations and the DPU Pretreatment Program began an investigation. Their monitoring confirmed the volunteers' findings and they traced the contamination to a blocked sanitary sewer line. This was fixed, and follow up sampling showed much lower concentrations of E. coli.

References & Links

- Reedy Creek Coalition: www.reedycreekcoalition.org
- Alliance for the Chesapeake Bay *RiverTrends* program: https://allianceforthebay.org/our-work/connecting-people/rivertrends/

The Center for Watershed Protection, Inc. is a 501(c)(3) non-profit organization dedicated to fostering responsible land and water management through applied research, direct assistance to communities, award-winning training, and access to a network of experienced professionals. The Center is your first source for best practices in stormwater and watershed management. The Center was founded in 1992 and is headquartered in Ellicott City, Maryland. As national experts in stormwater and watersheds, our strength lies in translating science into practice and policy, and providing leadership across disciplines and professions. To learn more about the Center's commitment to protect and restore our streams, rivers, lakes, wetlands and bays, go to www.cwp.org.

Center for Watershed Protection

3290 North Ridge Road, Suite 290
Ellicott City, MD 21043
410-461-8323