MARYLAND WATER MONITORING STRATEGY

Maryland Department of the Environment

Maryland Department of Natural Resources

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PREFACE

This Maryland water monitoring strategy report was developed by the Maryland Department of Natural Resources (DNR) and the Maryland Department of the Environment (MDE) with input from the Maryland Water Monitoring Council on certain topics. As part of the State's water quality management program, this report is focused on agency water monitoring efforts to address key issues identified by the US Environmental Protection Agency's monitoring strategy guidance (US EPA, 1984). The existing, overlapping monitoring framework of unique and common goals, media, observation scales, field and laboratory methods, data management, analyses, evaluation, and shared uses of information are described herein. Other aspects of the State's water quality management programs include the State's Continuing Planning Process for water quality management (MD Dept. Environment, 1999a), Quality Management Plans (MD Dept. Environment, 1999b; MD Dept. Natural Resources, 1999a), Nonpoint Source and Coastal Zone Management Plans (MD Dept. Natural Resources, 1999b) and biennial Section 305(b) reports (MD Dept. Natural Resources, 1999a).

This report meets two specific goals: (1) to update the State's existing monitoring strategy as a requirement of the US Environmental Protection Agency's regulations addressing water management plans (Section 106(e) of the Clean Water Act (33 USC 1256(e)) prohibits the Administrator from making Section 106 grants to any state that has not provided or is not carrying out a water quality monitoring program for use in compiling the 305(b) report) and (2) provide a baseline for an expanded Statewide water monitoring strategy that is being developed with assistance from the Maryland Water Monitoring Council. It is expected that this Statewide strategy will be an evolving document that will report on water monitoring efforts and identify specific processes to coordinate these efforts and integrate information. This enhanced strategy will define the framework of a distributed, but integrated and coordinated water monitoring effort in Maryland by federal, interstate and local government agencies, quasi-governmental groups, citizens, private and public corporations, and academia. It is expected that the first full report of this strategy will be completed in 2001.

ACKNOWLEDGEMENTS

This monitoring strategy report was developed with assistance of staff from the Maryland Department of Natural Resources' Resource Assessment Service and Chesapeake and Coastal Watershed Service and the Maryland Department of the Environment's Technical and Regulatory Services and Water Management Administrations. Comments received from citizen monitoring groups and members of the Maryland Water Monitoring Council, its standing committees and the *ad hoc* Programmatic Coordination Committee are greatly appreciated.

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Maryland has a wealth of water resources that serve a variety of needs - as drinking water sources, for industrial processes and cooling, for power generation, for agriculture, for recreational uses, as a transportation medium for cargo and passenger vessels, as a nursery and harvesting arena for important fish and shellfish species, and as vehicle for waste products. In spite of the variety and extent of water resources in Maryland, however, water resources of desired quality are limited. Managing these finite water resources for competing uses requires up-to-date information about the water quality and quantity. This report describes the State's plan to monitor its water resources.

'Water monitoring' is the effort to obtain quantitative information about the physical, chemical, biological, and/or aesthetic characteristics that define the **quality** of water and/or the volume, rate of flow or amount or load of a defined constituent being transported defining the **quantity** of water. The Intergovernmental Task Force on Monitoring Water Quality (ITFM, 1995), defined "water monitoring" as an integrated activity that addresses specific characteristics of water (*physical, chemical and biological*) for differing reasons (*human health, ecological conditions, defined uses, management measures*). These 'characteristics' may include not only direct measures of water conditions, but they also may include summary 'indicators' of water (EPA, 1998).

Water monitoring often is considered as the process of collecting samples or data. In defining a monitoring plan, however, there are other aspects of monitoring that should be addressed, including: data acquisition (network design, quality assurance/quality control, laboratory analysis, data handling, data analysis), data utilization (Sanders, et al. 1983), planning, communication and coordination. Each of these is an essential issue in this monitoring strategy.

The term, "monitoring", implies constant oversight, however, it is often not possible or it would be prohibitively expensive to continuously measure water conditions at a location or to measure these conditions at all points in a selected body of water. Even "continuous" measurements of some water conditions (e.g., flow rate, temperature, dissolved oxygen) are really measurements recorded at shorter time intervals (e.g., every 15 minutes, every hour) than other programs are likely to sample. It should be noted that when efforts to continuously monitor specific water conditions are contemplated, procedures to handle, store, review and analyze these large datasets must be considered.

Rather than developing a method to continuously monitor water conditions, a sampling of representative conditions is the most efficient means to effectively monitor the environment. Monitored chemical and physical characteristics often are affected by the physical properties of water (e.g., high specific heat, coefficient of diffusion) and often represent a continuous distribution of data with a high level of serial correlation. In other words, changes in physical and chemical water conditions usually occur slowly; sudden changes are rare events and few water monitoring variables have discontinuous distributions of data. Consequently, for many variables, it is reasonable to extrapolate sampling information to estimate physical and chemical conditions elsewhere in the waterbody and/or at other times.

There are times, however, when identifying living resource conditions or focusing on sudden changes in other water conditions can be a management goal. For example, monitoring stormwater runoff, modeling waste discharges, estimating pollutant loading, identifying toxic *Pfiesteria* outbreaks, sampling bacterial flora, exotic, rare or endangered species and sediment toxicant levels, are examples where rare, rapidly changing or discontinuous distributions of information are encountered.

These may require specific sampling strategies or analytical tools to obtain representative data for analyses.

As a management tool, water monitoring is identified as a starting point of the management process and as a feedback mechanism to identify how management efforts have affected water conditions (*Figure 1*). At times, monitoring may serve only a single purpose - either in terms of identifying water conditions or as feedback to a management decision.

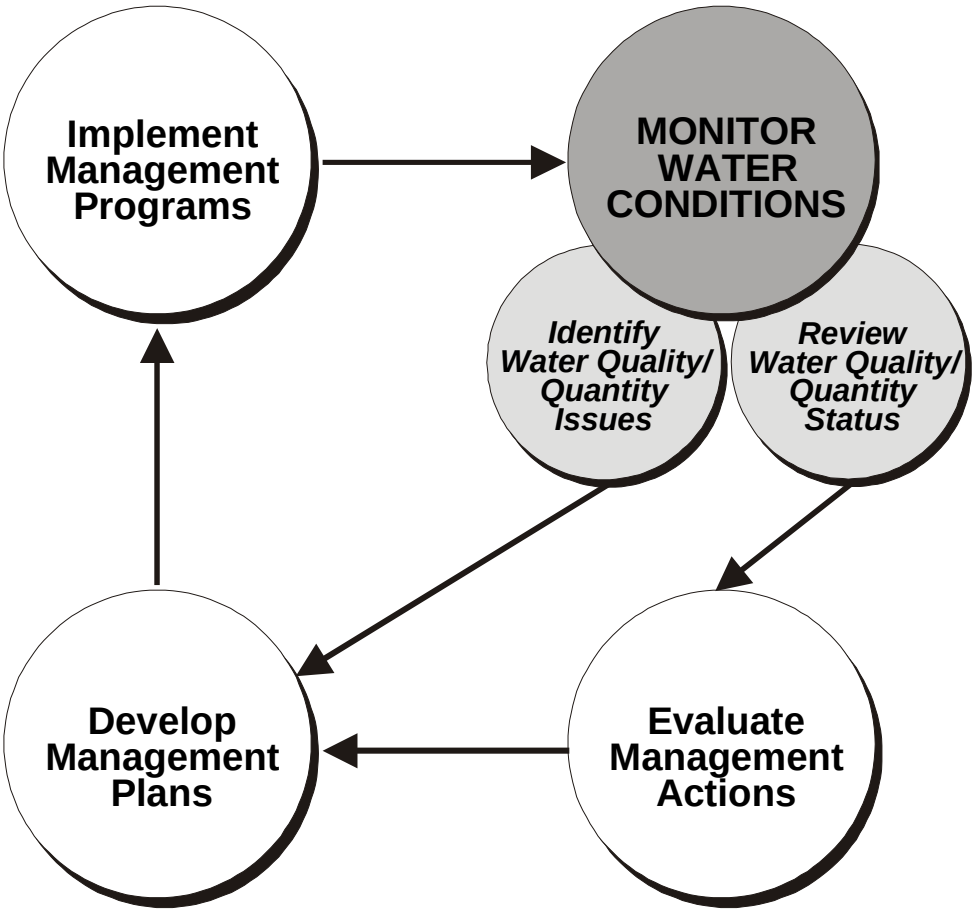

Figure 1. Role of monitoring within a water management framework.

Rationale for an updated strategy

A monitoring strategy should be flexible and updated periodically to: (1) include modifications to existing programs, (2) accommodate new monitoring efforts and changes in overall monitoring goals and objectives, (3) address new problems, and (4) identify links to other monitoring programs.

Maryland's basic Statewide water monitoring activities are principally conducted by two agencies. Water monitoring programs within the Department of the Environment (***MDE***) principally address regulatory issues (e.g., permit compliance and modeling, evaluation of water quality standards, shellfish sanitation, Total Maximum Daily Loads) while those programs within the Department of Natural Resources (***DNR***) principally address ambient water quality and aquatic resource issues. Although the goals of many basic water monitoring efforts in Maryland have remained unchanged since their inception, water management issues today are far more complicated.

Implementation of federal Water Pollution Control Act amendments have resulted in significantly improved wastewater treatment with measurably lower levels of pollution being discharged to our waterways. Attention is now focused on other water quality issues (in addition to point source pollution). Rapidly changing land uses have notably increased nonpoint source pollution impacts and affected available water supplies in areas that were not affected by point source pollution in the past. New research findings about pollution impacts on aquatic resources and human health, better analytical methods, and computerized modeling have all provided better tools and information about water impacts. Also, increased population increases the burden on available water supplies and uses and increases the public perception of environmental quality and expectation of good and adequate water supplies.

Decision-makers need to address new questions: issues affecting aquatic resources (impacts of toxic substances, identifying migration barriers, harmful exotic species, declining stocks, endangered species), human health impacts (waterborne disease, harmful algal blooms, contaminated fish, drinking water quality/quantity), nonpoint source pollution to surface and ground waters, atmospheric deposition, cumulative impacts (total maximum daily loads, sediment toxicity, water use/withdrawals). To address some of these new, specific water quality questions, new water monitoring programs have been developed and implemented. For other issues, agencies have worked to develop a more holistic, watershed-wide approach that may require integration of traditional chemical and physical measures with biological and habitat data and toxicological information. These programs and approaches need to be documented.

Maryland's water monitoring strategy report

Documenting a water monitoring strategy can take several approaches. Certain base elements need to be addressed - ensuring the collection of the right kind and amount of data and ensuring that the data are reliable and are accessible to decision-makers and others (US Environmental Protection Agency, 1984). A strategy that is little more than an embellished project plan, however, has little utility in developing future monitoring activities or encouraging integration with other monitoring efforts.

The US Environmental Protection Agency's (***EPA***) updated strategy guidance (Jones, et al., 1996) provides an overview approach, however, it leaves a number of important issues unresolved, especially in terms of interpreting or integrating other monitoring program results. For example, issues related to different temporal/spatial scales in monitoring programs are not discussed, but they are essential issues related to interpretation and possible integration of different monitoring results.

While nearly all water monitoring approaches provide information to address a specific management need, an integrated, watershed approach can help to address complex, interrelated problems, like nonpoint source pollution impacts, cumulative impacts, measuring nature's response to human activities, and identifying ways to work with natural processes. This approach significantly complicates management of these programs by using existing programs and involving multiple agencies or groups. Rather than using single measures to compare against goals (e.g., water quality standards or natural heritage goals), the watershed approach has multiple goals and objectives to address a variety of environmental problems. Water monitoring is currently applied, using this integrated watershed approach, in several major state programs, such as the Clean Water Action Plan (Maryland Clean Water Action Plan Technical Workgroup, 1998) and the Chesapeake Bay Program (Magnien, 1987), but in other programs the focus is more narrow. This report documents current agency water monitoring efforts by waterbody, but it also should be considered as the foundation for a future, more
comprehensive Statewide watershed monitoring strategy.

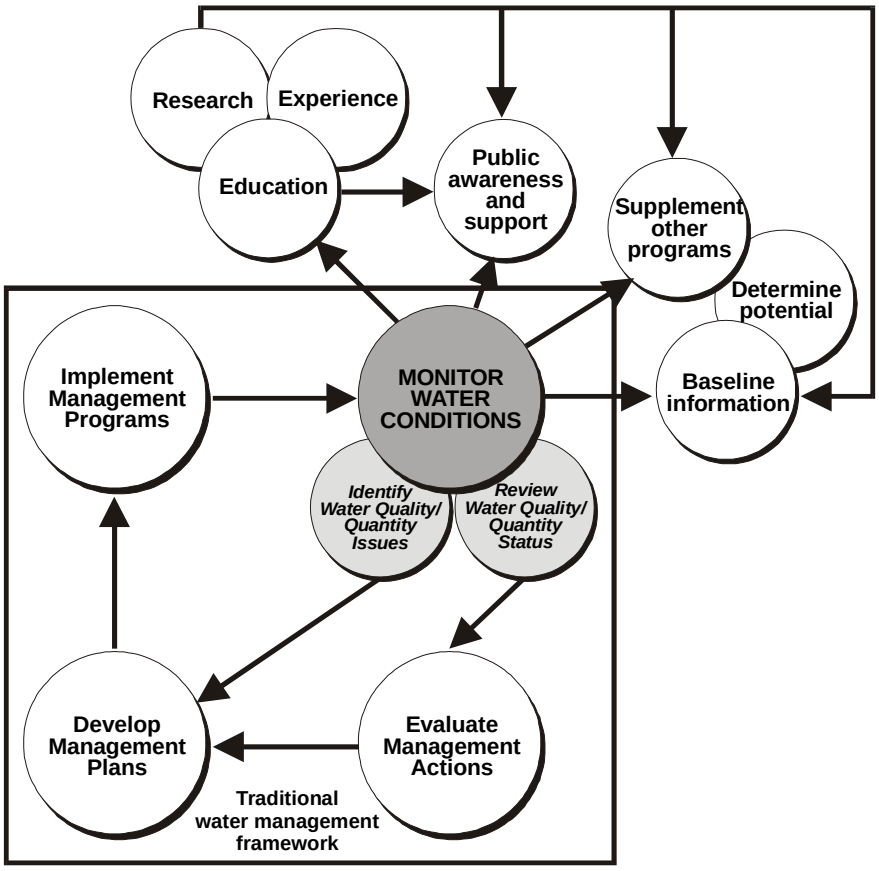

Figure 2. Role of water monitoring within a universe of uses/needs,

A future approach to a Statewide water monitoring strategy

At the same time that State agencies are collecting water information to address specific needs, water-monitoring efforts by others (academic institutions, local and federal government agencies, community groups, consultants and private industry) are underway. While some of these efforts are implemented to address traditional management goals (sometime similar to State agency goals), these efforts may have a non-management focus, including monitoring programs that addressing research,

education and supporting other programs (modified from Lovegreen, 1999). Somehow, information from these programs should be integrated as part of a statewide water monitoring strategy.

The watershed approach creates a more inclusive process that uses applicable water quality and quantity information as well as relevant living resource, geologic, geographic, and sociological information. Depending on the watershed size, the monitoring resources of an agency may not be sufficient to effectively develop a watershed approach to monitoring, so other sources of data are needed, the likely source being non-State agencies. Integrating other data is a process that requires enhanced program coordination (e.g., communication about sampling plans and goals, planning useful/equivalent measures, modeling/assessment procedures, QA, and data sharing) and it significantly increases the complexity of the water management framework (*Figure 2*).

In spite of its complexity, efforts to develop a comprehensive watershed approach to monitoring is beneficial:

(1) the system is natural and not limited by political boundaries,

(2) management efforts are continuous, and

(3) the watershed framework supports partnering, using sound science, initiating well-planned actions and achieving results.

As this plan evolves with input from other partners, especially the Maryland Water Monitoring Council, it is envisioned that this strategy will address how to integrate monitoring efforts from smaller watersheds and efforts addressing biological and physical habitat impacts into a more all-encompassing Statewide monitoring framework.

GOALS/OBJECTIVES

There are numerous reasons for collecting and utilizing water-monitoring data. Five unique objectives include:

- to characterize conditions,
- to determine trends,
- to guide pollution control and management actions,
- to respond to emergencies, and
- to protect human health and the environment

The key to developing a proper monitoring effort is to have well defined questions that need to be addressed - specific questions pertaining to overall conditions, management options, identifying problems and/or specific agency goals (US Environmental Protection Agency, 2000). Identifying the question(s) that needs to be answered is an important step in identifying the goals/objectives of each water monitoring effort. To the extent that these goals/objectives are measurable simplifies the evaluation of the monitoring effort.

Maryland's water monitoring agencies

Both the Department of the Environment (MDE) and Department of Natural Resources (DNR) have mission statements and specific management goals to protect and restore water resources of the State as embodied in its Managing Maryland for Results program (*Table 1*).

Both agencies have water monitoring programs, but specific program goals are designed to address agency responsibilities. As the State's principal environmental regulatory agency, MDE's water monitoring interests are related to providing the information necessary to manage the State's pollution control programs, including:

- discharge permit development,
- verification of permit compliance,
- protection of public health/safety,
- assessment of water quality standards
- defining total maximum daily loads
- remediation of spills/historical pollution problems

As the State's principal natural resources agency, DNR's water monitoring interests are focused on:

- status and trends of ambient water quality and quantity,
- evaluating living resource habitat, and
- determining the status of living aquatic resources.

Most of these programs are integrated to support the Department's watershed management activities to protect the Chesapeake and Coastal Bays and non-tidal streams.

Goals, sampling strategies, analytical techniques, reporting processes, and funding sources of each agency's monitoring programs usually are independent. Water information collected in these programs may complement other monitoring efforts either within or between agencies; efforts are made to use available data and minimize unintended duplication of effort.

In addition to DNR and MDE, Maryland's Department of Agriculture (MDA), Department of Health and Mental Hygiene (DHMH), local governments and the Department of Transportation (MDOT) also conduct water monitoring to address questions concerning research on specific agricultural impacts, evaluating sanitary quality of bathing beaches and evaluating water quality impacts due to

Table 1. Selected Maryland agency mission statements and water-related goals

Agency	Mission Statement	Water-related Goals
MDE - Department of the Environment	Protect and restore the quality of Maryland's air, land, and water resources, while fostering economic development, healthy and safe communities, and quality environmental education for the benefit of the environment, public health, and future generations.	• Ensure safe drinking water • Reduce the threat to public health from the presence of hazardous waste and hazardous materials in the environment • Ensure that water is clean and safe for harvesting of fish and shellfish • Improve and protect Maryland's water quality • Ensure adequate protection and restoration of Maryland's wetland resources • Prevent pollution and increase compliance assistance
DNR - Department of Natural Resources	For today and tomorrow the Department of Natural Resources inspires people to enjoy and live in harmony with their environment, and to protect what makes Maryland unique -- our treasured Chesapeake Bay, our diverse landscapes and our living and natural resources.	• A vital and life-sustaining Chesapeake and Coastal Bays and their tributaries. • Sustainable population of living resources and healthy ecosystems. • Enjoyment of diverse outdoor recreation opportunities for Maryland citizens and visitors. Vibrant local communities in balance with natural systems.

transportation projects. DHMH water monitoring activities are delegated to local health department offices. Both MDA and MDOT agencies often contract with other agencies or organizations (university research groups, consultants) to conduct water monitoring activities and address specific questions.

Other groups

There are many other organizations or groups that have an interest in collecting water monitoring information, sharing this with State agencies or are interested in obtaining State agency data. These groups include health, public works and planning departments in local governments, certain businesses and selected non-governmental environmental organizations (including citizen volunteers), and some university and school programs. Other federal agencies (US Department of Agriculture, US Department of Defense, US Department of the Interior's Fish and Wildlife Service, Geological Survey and National Park Service, US Department of Commerce's National Oceanic and Atmospheric Administration, and Environmental Protection Agency) have specific water monitoring needs that they may conduct directly or through contract. Although the focus of this report is on State agency water monitoring efforts, a planned expansion of this strategy to address the relationship between State programs and these other water monitoring efforts would create a truly Statewide water monitoring perspective.

Water monitoring goals

Some Statewide water monitoring goals are defined by external sources, such as federal statute or through agreements with the US Environmental Protection Agency (EPA). For example, the Clean Water Act requires that States report on the extent to which its waters "*…allow recreational activities in and on the water*" in its biennial (Section 305(b)) water quality report to EPA. The EPA's guidance for these reports suggest that States provide summaries of water quality impairments, causes and sources. As a more generalized measure of environmental status (including water), Maryland and the EPA define several water quality indicators in their Environmental Performance Partnership Agreement; these results are reported regularly to EPA. Finally, the State's own performance based initiative, Managing For Results, address some Statewide water resource goals. Clearly, addressing some goals requires a Statewide assessment of water conditions.
All water monitoring programs have a number of clearly identified goals which should be tangible, achievable, measurable, and documented. Setting monitoring program goals help to define many aspects of a monitoring program, from establishing sample design (setting priorities and identifying program strengths and weaknesses - possibly leading to development of more goals) to serving as criteria for the assessment process and for evaluating the success of the program.

Program goals may include long-term goals that may not be achieved within the immediate program timetable (e.g., Chesapeake Bay Program goals) as well as short-term goals (e.g., individual program goals/milestones necessary to reach long-term goals). And, while they define the basis for a monitoring activity, goals should not be written as permanent or inflexible statements. As water monitoring programs change (e.g., endpoints, sampling or analytical techniques), goals will need to change as well.

A key component of goal setting is the definition of measurable goals. While helping to determine the most appropriate study design, program goals provide for an objective and valuable program evaluation that can clearly help identify program needs for continuing monitoring efforts. For each management question/agency goal, however, one or more statements should be derived.

Examples of management questions, program goals and measurable objectives:

Question: In terms of nutrients, what is the water quality condition of non-tidal rivers?

Goal: Determine nutrient levels in non-tidal rivers

Objectives:
* Establish a suitable sampling design to evaluate non-tidal rivers (## sampling sites)
* Measure nutrient levels in non-tidal rivers within known temporal cycle (monthly/seasonally)
* Compare nutrient levels between rivers and to other sources to determine relative scale

Question: What stream reaches are impaired by low pH levels due to abandoned mine drainage?

Goal: Assess pH levels in streams around abandoned mines

Objectives:
* Identify abandoned mine sites
* Identify historic sampling sites and review pH data in streams near these mines
* Establish a systematic monitoring program to identify streams with low pH during low stream flow (## sites)

One technique to help plan data collection efforts is the use of “data quality objectives” or a ‘DQO’ process to ensure that monitoring data collected are of the right type, quantity and quality (*http://www.rti.org/units/ese/cemqa/erpd/dqo.cfm*). Developed by the US Environmental Protection Agency’s Quality Assurance Management Program, this process defines the questions that a data collection effort is intended to address, what decision-making process will be used with these data, and the level of uncertainty that is allowed in making these decisions (US Environmental Protection

Agency, 1994a). None of the State's water monitoring programs have used this formal DQO process, however, less formal goal-setting processes have served the same purpose.

SAMPLE DESIGN

In developing new water monitoring programs, evaluating existing programs and modifying others to meet changing needs, a critical stage is the development of a cost-effective and efficient sampling design, especially as monitoring resources (including cost and available capacity for manpower, laboratory and equipment/material support) are limited. A review of the literature lists various classifications of sampling design for water monitoring programs. Essentially, however, there are two principal sample designs: (1) a fixed sites approach to measure specific parameters or as a representative sample and (2) a probability-based approach (Chesapeake Bay Program, 1999b). These basic formats may increase efficiency or serve multiple purposes by combining approaches and sampling within selected strata (time, space) (e.g., the Rotating Basin-Permit Monitoring Program - an intensive, fixed sampling design within a watershed, re-sampled at a defined, multi-year interval). The sampling approach of each agency water-monitoring program is described in the next chapter.

Fixed site approach

Most water monitoring programs sample from fixed sites to provide information about water conditions. In ambient programs, results from sites sampled over a long period of time may show changes or trends in these conditions. To meet some objectives, fixed sites may be targeted in areas subject to pollution (e.g., NPDES compliance) or in areas that are expected to show changes due to projected management activities improvement/degradation (e.g., Targeted Watershed Program). While the use of fixed sites limits confidence in assessing water quality conditions over larger reaches, a primary strength of this approach is that data can be used to detect changes or trends in water quality conditions. The State's CORE program monitors water quality conditions in portions of the State's larger waterways providing a summary of conditions in those waters, but not in other, unmonitored portions of the watershed or even in smaller upstream reaches. These static CORE sites do provide viable sites for detecting changes/trends in water quality conditions.

Probability-based approach

An alternative approach is to use a probability-based sampling which estimates water conditions in a defined area even when all waters are not directly sampled. Although this estimate is statistically derived and not directly measured, a level of confidence or certainty in this estimate can be determined that is related to the natural variability of conditions and to the level of sampling effort used. For example, the Maryland Biological Stream Survey identifies sampling sites at random within low-order streams in a watershed and is able to estimate water conditions for all low-order streams in that watershed within a certain level of certainty. Where fixed sites often are used to quantify change at selected locations (surveillance of critical levels, trends, and management actions), the probability sampling approach emphasizes spatial quantification of water conditions.

To meet specific monitoring goals, both approaches (and their variants/combinations) have specific advantages and limitations - no single sampling program can address every management need. For each sampling design, the relative number of required samples, the relative bias in sampling and the basis for sample site selection vary and these should be matched to specific monitoring goals of the program. Use of these data to meet other goals (e.g., sharing data for watershed analyses) need to clearly understand the sampling design used and specific sampling program strengths and weaknesses which could affect data needs to meet these secondary and other goals.

Maryland's watershed approach

The US Environmental Protection Agency's approach to developing a monitoring strategy is that a plan can be developed once a comprehensive set of goals are established. In reality, there are

multiple agencies involved with multiple goals, funding sources and priorities. No single sampling design approach can address these different objectives and, as a result, different monitoring programs have developed. The lowest common denominator between these efforts often is the collection of water samples. Consequently, it is not surprising that differences between agency water monitoring efforts may not seem obvious. A review of program goals, sample design, details in sample collection, sample storage and transport processes, laboratory analyses, data review and analyses and dissemination of results would show great variety in these programs.

To comprehensively assess its waters, Maryland uses a layered-stratum approach. Each waterbody type (e.g., river, estuary, and lake) is a stratum. All water monitoring efforts within a stratum contributes to a comprehensive assessment approach for that waterbody. Combining these monitoring strata provides a layered framework that defines how Maryland monitors all of its waters (*Figure 3*).

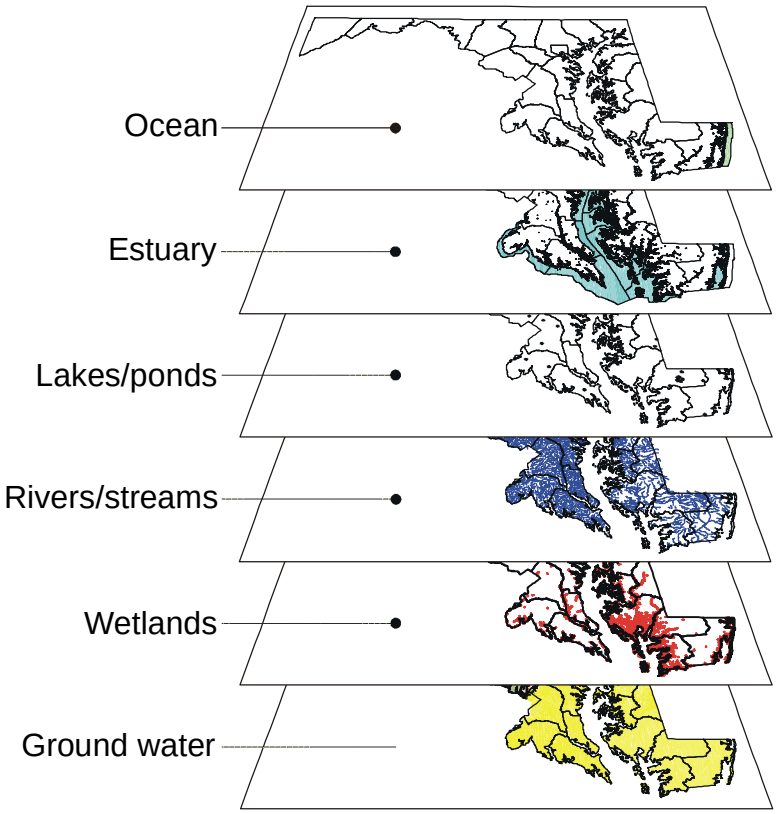

Figure 3. Maryland's multi-layered approach to comprehensive water monitoring

Other organizational approaches to monitoring can exist; any common program basis could be used (e.g., watershed, media, management goals). Except for special, comprehensive studies, all State agency programs focus their monitoring efforts within a waterbody type (e.g., only in nontidal rivers or estuarine waters, etc.). As with any sampling organization, some water monitoring programs will bridge one or more strata, but in this framework, waterbody sampling ensures that the monitoring programs are complementary. The approach permits the use of all current monitoring programs, but it also highlights areas where additional effort is needed in terms of enhancing cooperation between

programs, identifying how to cooperate with other non-agency monitoring efforts or where new monitoring efforts may be needed.

Maryland's water monitoring strategy is to utilize all existing programs to the greatest extent possible, build on those programs if they are found to not fully address identified needs, and to promote new programs to meet needs not addressed by the existing programs. Existing monitoring activities will be continued, reviewed, modified, enhanced, or reduced as necessary, and new monitoring programs will be established to address developing issues and problems. Both the Departments of the Environment and Natural Resources are committed to cooperating with all monitoring entities (federal and local agencies, academia, consultants, non-governmental organizations and volunteers) to optimize the value of the individual efforts through collaboration and cooperation.

Among the efforts to build and expand monitoring, for example is that MDE plans to rely more on biological community assessment protocols as part of its regulatory monitoring (Eskin, et al., 2000). Biological data will help identify impairments and will be used to track improvements associated with the implementation of corrective management measures. In a cooperative effort involving DNR and MDE and aided by MDE's Biocriteria Advisory Committee, MDE developed interim biological criteria based on DNR's Maryland Biological Stream Survey. DNR applied these criteria in the development of the 2000 305(b) report (Dept. Natural Resources, 2000).

Scale

When planned watershed analyses includes the use of data from other water monitoring efforts, an important consideration relates to the "scale" of the monitoring program design - essentially, the distribution of samples across the watershed of interest. A monitoring program that addresses water conditions in a large watershed (e.g., of 840 stations in Chesapeake and Delaware Bay and Pamlico Sound watersheds as part of the US Environmental Protection Agency's Mid-Atlantic Highlands Assessment) may collect fewer (if any) samples from a smaller watershed that is the focus of other government interests (e.g., about 40 MAHA sites are located in Maryland and are assessed at a scale that is greater than a scale of interest by most citizen groups, county or State agencies). Conversely, assembling watershed data might provide skewed results if some stream drainage areas have detailed water data available because of local interests, but other stream drainage areas within the watershed has no corresponding/equivalent effort (e.g., Upper Patuxent River - southern watershed has available detailed county data; northern watershed has no corresponding data).

WATER RESOURCES/MONITORING PROGRAM SUMMARY

Non-tidal rivers and streams

There are thousands of miles of free-flowing, freshwater rivers and streams throughout Maryland. These waterways drain lands and discharge groundwater into four large basins, the Delaware Bay, the North Atlantic Ocean, the Chesapeake Bay, and the Ohio River (*Figure 4*). Nontidal rivers and streams are found in all physiographic provinces, in all counties of the State and in all watersheds, except in some low-lying Coastal Plain drainages, on barrier islands and in the Chesapeake Bay.

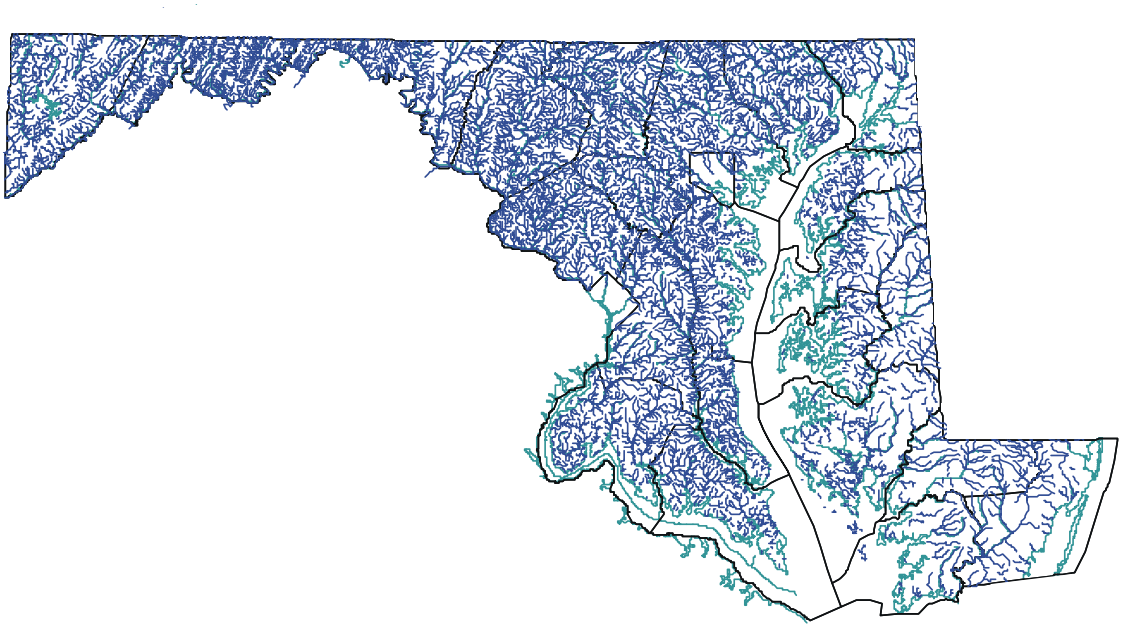

Figure 4. Stream drainage network in Maryland (overlain on county boundaries)

Using a 1:250,000 scale USGS topographic map, we currently identify 8,769 miles of non-tidal rivers and streams in Maryland. Future efforts to use larger (1:100,000) scale maps will likely identify significantly more stream mileage in the State. Stream patterns are dendritic so most stream mileage is in the smallest streams. The widely used Strahler stream classification system identifies first-order streams as the smallest, permanently flowing stream. The union of two streams of order ***n*** creates a stream of order ***n***+1 (e.g., the merger of two first order streams creates a second order stream and so on). This classification system provides a convenient way to compare streams of the same size (Allan, 1995). Distribution of stream mileage by order in Maryland is shown in Table 2. Sizes of these waterways range from centimeters to more than 900 meters in width with averaged measured flows ranging from 0 to 1,270 m^3/sec (Carpenter, 1983).

Table 2. Extent of stream miles by reach order in Maryland

Reach Order	Stream Miles	Percent of Total
1	5,807.8	66.2 %
2	1,490.2	17.0 %
3	682.5	7.8 %
4+	788.4+	9.0 %
TOTAL	**8,768.9**	

(Source: ArcView analysis - 1:250,000 scale stream trace)

Various modifications to streams occur across the State. Ditching is a common practice on the Eastern Shore designed to drain low-lying lands and to control ground water levels. Existing stream systems are modified in urban and developing areas to carry stormwater flow away from structures and roadways. Many urban streams are buried and now may flow in underground pipes. In agricultural areas, streams often are shifted to increase usable land area and have been used as natural watering facilities for livestock. Highway construction methods tend to modify streams within the right-of-way, although impacts often occur above and below the affected areas.

Non-tidal rivers and streams - Water monitoring programs

The following lists non-tidal water monitoring programs conducted by Maryland agencies that are designed to address water quality, water quantity, aquatic resources and public health issues. These summaries include contact information, watershed/media monitored, program goals and a brief description of the monitoring effort.

Water Quality - ***CORE/Trend Program***
Agency: DNR Monitoring and Non-tidal Assessment
Contact: Paul Miller (410-260-8616; pmiller@dnr.state.md.us)
Watersheds: Statewide (14 of 20 basins; 39 of 138 segments)
Media: water column
Goal: Assess status and trends for 305(b) report and Tributary Strategies and for load estimation from selected watersheds. Determine the relationship between water chemistry, river flow and benthic macroinvertebrate community resources.
Program Description: Network of fixed, non-tidal ambient water quality monitoring stations to assess Statewide water quality conditions for reporting and program evaluation. CORE stations are funded by the EPA through the Clean Water Act (Section 106).

One to three stations in 39 of 138 watersheds (54 stations) all on major streams (4^{th} order and larger) and rivers are sampled monthly for water chemistry. The benthic macroinvertebrate community is sampled annually at a subset (48 percent) of these stations. Thirty-two of these stations are co-located with a USGS flow gage. While the intent is a Statewide assessment, the distribution of sampling sites is focused on Potomac River and Central Maryland watersheds and sparse in southern Coastal Plain on Eastern and Western Shores of Chesapeake Bay. This is due to the focus on point source water quality at the time this network was established in the 1970's. Physical water properties (temperature, conductivity, pH, alkalinity, oxygen), chemical (focus on nitrogen and phosphorus nutrient species) and biological (bacteriological, chlorophyll) samples collected from surface and analyzed in University of Maryland or at Dept. Health and Mental Hygiene laboratories - some parameters assessed *in situ*.

Recommendations: Some areas are not presently sampled. Changes in existing sampling sites and sampling frequency are being evaluated to allow expansion of the network. Sites near operating stream gages are preferred to increase data value.

Aquatic resources - ***Maryland Biological Stream Survey***
Agency: DNR Monitoring and Non-tidal Assessment
Contact: Ron Klauda (410-260-8610; rklauda@dnr.state.md.us)
Watersheds: Statewide (17 of 20 6-digit basins) - wadeable, (1st, 2nd and 3rd order) non-tidal streams
Media: biological community (fish, invertebrates, amphibians, reptiles, and plants), surface water physicochemical, in- and near-stream environment (substrate)
Goal: Assess the biological resource status of wadeable, non-tidal streams, quantify how acid deposition is affecting biological resources, examine other factors that may affect the current biological resources, establish a benchmark for identification of trends, and target local-scale assessments and mitigation actions needed to restore degraded biological resources.

Program Description: Program focus is on wadeable (1st, 2nd and 3rd order) non-tidal streams in 17 of the State's 18 major basins (excluding Chesapeake Bay), however, individual site data from 300 stream segments of a fixed length sampled are being examined for local degradation issues and for targeting restoration actions.

Statewide sampling is conducted over a three to five-year rotating basis, in which samples are collected in a portion of the State's eligible streams annually. This program uses a special probability-based lattice sampling design that is stratified by year and basins (western, central and eastern) to facilitate effective use of field crews. Sampling intensity is partitioned by reach order within each basin. Biological abundance of fish, benthic macroinvertebrates, reptiles, amphibians, aquatic plants and mussels and relative community health of fish and benthic macroinvertebrate communities are examined in each selected reach as well as select chemical attributes (pH, acid-neutralizing capacity, sulfate, nitrate, conductivity, dissolved oxygen and dissolved organic carbon).. Physical habitat parameters including flow, stream gradient, depth, width, embeddedness, instream habitat, pool/riffle quality, bank stability, channel status, shading, and buffer type are measured. Other information about drainage area, land cover, population are defined using Geographical Information Systems.

Recommendations: The program design was re-evaluated in 1999. The second statewide round of stream monitoring began in spring 2000 and will: (1) focus the sampling effort at the 8-digit watershed scale rather than at the 6-digit basin scale; (2) incorporate a volunteer benthic macroinvertebrate monitoring component (Stream Waders) to achieve more complete statewide coverage at the 12-digit sub-watershed scale, (3) potentially sample tidal fresh and brackish streams, and (4) add chloride, total nitrogen, nitrite, total phosphorous and ortho-phosphate to the list of chemical parameters that are being measured.

Water Quality - ***Watershed monitoring ("Cycling Strategy") for water quality impairment determination and Total Maximum Daily Load (TMDL) development***
Agency: MDE Technical and Regulatory Services Administration
Contact: Nauth Panday (410-631-3680); npanday@mde.state.md.us;
John Steinfort (410-974-3238); jsteinfort@erols.com;
Watersheds: Statewide - focus on impaired watersheds on State's 303(d) list
Media: water column

Goals: (1) provide detailed spatial resolution water quality chemistry data throughout the State to augment CORE/trend and Chesapeake Bay monitoring data for determining whether water quality standards are being met (federal Clean Water Act Section 303(d) list development),

(2) provide the detailed spatial data needed for modeling and development of total maximum daily loads (TMDLs) necessary to achieve water quality standards, and

(3) provide detailed data for determining permit limits for all facilities in a given watershed that are operating under National Pollutant Discharge Elimination System (NPDES).

Program Description - The Clean Water Act requires that impaired watersheds be evaluated and monitored in a comprehensive manner so to identify all point and nonpoint sources of pollutants, and to allocate the pollutant loads among the various sources. This process is designed to produce the information necessary to allow managers to estimate the pollutant loads and develop total maximum daily load (TMDL) estimates so that impairments to the designated uses of the water can be corrected. When impairments or potential impairments are demonstrated by CORE/Trend water monitoring data, Maryland Biological Stream Survey data, Chesapeake Bay Monitoring Program and/or other data, the intensive watershed monitoring and evaluations conducted under this program will confirm the extent of the impairment. These data are then used to calibrate the models necessary to develop and define the TMDL and permits needed to correct the impairment.

This program has been designed to focus monitoring at a large number of sites in a portion of the State each year to augment the CORE/Trend Program and the Chesapeake Bay Monitoring Program, which provides long-term, monthly sampling data for a small subset of the sites. One fifth of the state is monitored intensively each year in order to cover the entire State in a five-year rotation. Referred to as the "Watershed Cycling Strategy", the effort includes integrated monitoring, TMDL development and permit development of each of the five regions of the state on a five year rotation (MD Dept. of the Environment, 1999c).
This monitoring program tracks the hydrologic year, sometimes termed the "water year", which begins on October 1st. This full-year monitoring allows for the collection of information on representative hydrologic flow regimes. Critical 7-day, 10-year low flow conditions and those associated with flooding are obtained from flow records maintained by the US Geological Services gaging station network. The monitoring design is to collect water quality samples from key points located throughout the water body of interest, during three low flow and three high flow periods during the annual cycle. Parameter coverage is determined each year based on the impairment being investigated. Monitoring activities include measurements of streambed geometry and/or tidal bathymetric profiles that are necessary mathematical model inputs.

This monitoring program has focussed on the State's lower Eastern Shore in 1998, Upper Eastern Shore and Upper Western Shore in 1999, and is working on the mid Western Shore during 2000. The five-year cycle will be completed with monitoring in the lower Western Shore and Potomac, and Western Maryland. Out-of-schedule monitoring will be conducted as necessary to meet urgent needs associated with new or revised permits.

Water Quality - ***NPDES point source permit monitoring***
Agency: MDE Technical and Regulatory Services Administration
Contact: John Steinfort (410-974-3238); jsteinfort@erols.com
Watersheds: Statewide - waterbodies with permitted wastewater discharges
Media: water column
Goal: The goal of this monitoring effort is to provide facility-specific water quality data essential for determining pollutant sources and pollutant loads in the vicinity of the discharge in order to support the development of facility specific permits.

Program Description: MDE conducts between four and 8 localized intensive water quality studies annually addressing specific permitting concerns. These studies are conducted to evaluate pollutant loading for resolution of disputed permit renewals or requests for increased constituent loads. This monitoring program is designed to compliment the *Watershed monitoring ("Cycling Strategy") for water quality impairment determination and TMDL development* described above.

Water Quality - ***NPDES Permit Compliance Monitoring***
Agency: MDE Technical and Regulatory Services Administration
Contact: William Beatty (410-974-3238); billbeatty@starpower.net
Melvin Knott (410-631-3605); mknott@mde.state.md.us
Watersheds: Statewide - waterbodies with permitted wastewater discharges
Media: water column
Goal: provide data to verify the accuracy of data reported by the permitted facilities under self-reporting requirements established in the permits.
Program Description: This function is a required under the Section 106 federal grant to the State. It has been conducted since the early 1980s. It involves monitoring at approximately 60 "major" domestic wastewater treatment plants that discharge more than one million gallons per day. Facilities demonstrating non-compliance with established permit limitations, regardless of flow or facility size, are also included in the monitoring program.

The monitoring protocol involves collection of a series of discreet effluent samples over a two-day period along with a composite sample (generally of 24 hours duration) which is routinely split with the facility. Composite duration may be of either 8- or 12-hour duration if the facility's permit is written for that interval. Flow measurements are made for discrete samples, and total flow is recorded for the compositing period. Pollutant loadings are then calculated and compared to permit authorizations. Samples are also secured for Whole Effluent Toxicity (WET) testing. These samples are taken to the Department's contract laboratory to determine whether the effluent demonstrates toxic effects on invertebrate and fish organisms. Any positive findings trigger additional monitoring by the State and facility with a Toxic Reduction Evaluation (TRE) conducted by the facility upon confirmation of toxic conditions.

Water Quality - ***NPDES Pretreatment Monitoring***
Agency: MDE Water Management Administration
Contact: Gary Kelman (410-631-3630); gkelman@mde.state.md.us
Melvin Knott (410-631-3605); mknott@mde.state.md.us
Watersheds: Statewide
Media: water column
Goal: The goal of the Pretreatment Monitoring program is to assure that user-provided information about pretreatment reduction of pollutants of concern from industrial facilities will not pass through or interfere with operations of publicly owned treatment works (POTWs) or to affect the beneficial uses of POTW biosolids.
Program Description: Significant industrial users which discharge wastes to municipal wastewater systems are directly regulated by MDE and are responsible for self-monitoring wastewater at least twice per year. This ensures that representative samples of the industrial wastewater discharges into local sanitary sewers are analyzed for permitted pollutants of concern. This is accomplished by MDE oversight of local industrial user pretreatment programs as well as MDE permitting of significant industrial users in non-pretreatment areas of the State. In order to confirm and amend these data, MDE samples their sanitary sewer effluent for the same pollutants of concern.

Where applicable, 24-hour composite samples are collected. Grab samples are taken for pH, oil

and grease, total petroleum hydrocarbons, volatile organics, sulfides and other parameters where this type of sampling is applicable. Flows are measured where this is a regulated parameter. All samples are collected at the same or a location equivalent to where the SIU takes its samples. All data are forwarded to the Water Management Administration's Pretreatment Section and analytical results are compared with industry permit requirements. Appropriate management and enforcement actions are taken when necessary.

Water Quality/Aquatic Resources - ***NPDES Stormwater Monitoring (Municipal - Nonpoint source)***
Agency: MDE Water Management Administration
Contact: Brian S. Clevenger (410-631-3543); bclevenger@mde.state.md.us
Watersheds: Selected watersheds in 10 large municipalities
Media: water column
Goal: The goals of the municipal NPDES stormwater monitoring program include the pollutant characterization of urban runoff from specific land uses and the assessment of receiving stream morphology and biological integrity to guide management program implementation.
Program Description: Municipal NPDES stormwater permits are intended to control storm drain system pollution from places with populations over 100,000. Among the myriad of tasks required to be performed by these permits is a significant effort to monitor the effects of stormwater runoff on urban receiving waters. These monitoring efforts include chemical, biological, and physical assessments within a very specific area.

Each of ten major Maryland jurisdictions and the State Highway Administration is required to select a major storm drain system outfall to monitor storm events throughout their respective five year permit terms. The selection of these sampling locations is crucial because each jurisdiction is requested to monitor a specific land use in order to determine the types of pollutants produced by that land use. Therefore, each NPDES municipal permit requires the most populated localities in the State to choose an outfall that discharges runoff from one homogeneous area. In addition to this selected storm drain system outfall, a second, downstream ambient monitoring station is required to be established. Storm events are monitored at this instream location in the same way as the upstream outfall. Data are submitted annually that report the results of the sampling activities that occur during the reporting period.

At both outfall and instream monitoring locations, 12 storm event samples are required to be collected and analyzed each year for a suite of constituents including: biochemical oxygen demand, total cadmium, total Kjeldahl nitrogen, nitrate+nitrite, total petroleum hydrocarbons, total phosphorus, total copper, total phenols, total zinc, fecal coliform bacteria, total lead, oil and grease (optional), and total suspended solids.
For biological assessment, the receiving stream system between the storm drain outfall and the ambient station is monitored twice annually (Spring and Fall). The United States Environmental Protection Agency's (EPA) Rapid Bioassessment Protocol III is used to determine the health and long term changes in the benthic community present. Data are submitted annually with chemical monitoring results.

Finally, within this same stream reach, a geomorphologic assessment is performed annually to detect trends with regard to instream changes. A series of permanently monumented stream channel cross sections is required to be established. These cross sections, along with stream profiles, are surveyed annually to track geomorphologic changes that occur.

Information collected as a result of this monitoring program is compiled by MDE and analyses are

performed to determine the types of pollutants found in runoff from specific urban land uses (e.g., residential, industrial, highway, etc.). Taken together with the data generated from biological and physical stream assessments, these data will help MDE determine how best to tailor management program implementation in the future. Additionally, this monitoring approach will improving the State's stormwater management program.

Water Quantity - ***Stream Gaging Network***
Agency: DNR Maryland Geological Survey
Contact: Emery Cleaves (410-554-5503);
Watersheds: Selected perennial streams Statewide
Media: water column
Goal: Stream gages are operated throughout Maryland to meet numerous water-resources management goals of federal, State, and local government agencies. Streamflow data are crucial to water-resources management goals in three fundamental ways - evaluation of current conditions, watershed management and planning, and decision-support systems.
Program Description: In recent years, the stream-gaging network in Maryland has ranged from 95 active stations in 1985 to 76 active stations by the end of 1995. Ninety-seven stations were being operated throughout Maryland as of November 15, 1999. Gaged locations range in drainage area from 0.03 square miles (mi^2) to 27,100 mi^2. Approximately one-third of the stations have 50 or more years of continuous record. Gaging stations are located in each of Maryland's physiographic provinces. The network is operated and maintained by the US Geological Survey, in cooperation with State, County, and local government agencies.
Recommendations: Based upon recommendations of the Maryland Water Monitoring Council (Cleaves and Doheny, 2000) it is recommended that Maryland's stream-gaging network be increased from 97 gages (in existence as of November 15, 1999) to 157 gages. The additional gages should be activated in stages according to six priority management goals: Coastal Plain Harmful Algal Blooms, small watershed, core network, Clean Water Action Plan, flood hazard, and other unmet coverage (CORE/trend network, unmet 6- or 8-digit Hydrologic Unit Codes, unmet spatial coverage, and unmet physical-matrix categories). Drought assessment is also a major concern, and requires the continued operation of stream gages with long-term records.

Water Quality/Aquatic Resources - ***Fish kill investigations***
Agency: MDE Technical and Regulatory Services Administration
Contact: Chris Luckett (410-974-3238); cluckett@mde.state.md.us
Charles Poukish (410-631-4434); fieldops@charm.net
Watersheds: All - wherever kill incidents are reported
Media: water column, fish, crabs
Goals: Investigation and associated monitoring of fish kill events is designed to identify the causes of events, which would lead to information that could be used to prevent or reduce the threat of similar events in the future.
Program Description: MDE has the responsibility to investigate all fish kills associated with pollution. Events that are caused by disease are investigated by DNR. Since the cause of an event cannot be determined until an investigation is conducted, MDE takes the lead in receiving and responding to reports. Although MDE is the designated lead agency, the resources of DNR are relied upon heavily to assist in the investigations.

The two agencies operate with a standard monitoring plan to ensure that basic information is

obtained in a timely manner. Depending upon the nature of the event and the condition of the fish, field investigators will collect, count, and identify affected organisms. Appropriate water and tissue samples are collected for laboratory analysis. Field measurements, such as temperature, pH, dissolved oxygen, and other related water quality measures are taken and recorded. Fish and fish tissue samples for histological and pathological examination are collected, when required, and transported to cooperating laboratories.

Water Quality/Aquatic Resources - ***Algal Bloom Response Program***
Agency: MDE Technical and Regulatory Services Administration
Contact: Chris Luckett (410-974-3238); luckett@charm.net
Watersheds: All - wherever algae and aquatic odor complaints occur
Media: water column, aquatic resources
Goals: (1) Respond to public complaints of discolored water in order to identify and document nuisance algae blooms that may be misinterpreted as gross pollution in waters of the state and

(2) Determine algae community composition in response to algae driven low dissolved oxygen induced fish kills in waters of the State, and

(3) Document pollution induced algae blooms and characterize for regulatory response.

Program Description: The Department of Environment manages a program to investigate discolored water, analyze composition, and initiate emergency containment and recovery initiatives if a pollutant is detected. This response program responds directly to public complaints. Because nuisance algae blooms are typically responsible for discoloring water, this program maintains the capability to identify common algae organisms. The program typically responds to non-toxic mahogany tide bloom organisms including *Prorocentrum minimum*, *Gyrodinium esturiale*, *Gymnodinium uncatenum*, and *Katodinium rotundatum*, and often initiates state wide response if a toxic species such as *Mirocystis* or *Pfiesteria* is suspected or confirmed. Harmful Algae Blooms (HAB) are quickly forwarded to the DNR Harmful Algal Bloom monitoring program for follow-up monitoring. HAB's are responsible for fish kills by both passive and direct association. Most of the typical non-toxic mahogany tide organisms are responsible for massive low dissolved oxygen-induced fish kills and may be indicative of habitual nutrient or gross organic pollution requiring immediate regulatory response and follow-up. This program enhances the fish kill response program as part of the Clean Water Act Section 106 grant initiative.

Water Quality/Human Health - ***Drinking water protection program***
Agency: MDE Water Management Administration
Contact: Bill Beatty - compliance (410-974-3238); billbeatty@starpower.net
John Grace - source water protection (410-631-3713); jgrace@mde.state.md.us
Watersheds: Surface water intakes/utilities in streams classified as potable water supply
Media: water column
Goals: To protect the physical, chemical and biological integrity of the ground water resource in order to protect human health and the environment, to ensure that in the future an adequate supply of the resource is available, and to manage that resource for the greatest beneficial use of the citizens of the State.
Program Description:
Source Water Protection Program - MDE's Water Management Administration oversees the surface water intake monitoring results from utilities, monitors basic water quality, documents chemical quality conditions at water intakes, and provides a basis for monitoring future trends. These sites

are tested for major dissolved ions, bacterial indicators, selected trace elements, selected volatile organic compounds, several classes of pesticides, and selected radionuclides - (***see Ground water - Source Water Protection Program***).

Finished Water Protection Program - Maryland's public drinking water monitoring program meets all Federal mandates of the Safe Drinking Water Act. This program monitors 1,024 municipal drinking water supplies for maximum contaminant levels established by the US Environmental Protection Agency. Self monitoring is required of all public supplies as specified in federal regulations. Compliance monitoring is conducted by the Department of the Environment's Water Management Administration for specific constituents including bacteriological, chemistry, THMs (trihalomethanes), VOCs (volatile organic carbons), pesticides, radiation, radon, metals, and nutrients (nitrates and nitrites). Monitoring efforts also include responses to consumer complaints and emergencies where protection of public health is a primary concern.

Water Quality/Aquatic Resources/Human Health - ***Tissue monitoring program***

Agency: MDE Technical and Regulatory Services Administration

Contact: Kevin Novo-Gradac (410-631-3606); knovogradac@mde.state.md.us

Watersheds: Selected commercial/recreational harvesting areas in non-tidal and tidal tributaries and lakes - 10 sites each year

Media: water column, aquatic resources (fish, shellfish and crabs)

Goals: The goals of this program are to ensure that aquatic resources harvested from State waters are safe for human consumption, and to provide information on potential sources and trends in water pollution levels.

Program Description: Fish and shellfish have the potential to accumulate heavy metals or organic chemicals in their tissues even when these materials cannot be measured in the water column. This makes these aquatic animals good indicators of environmental pollution in a body of water. Monitoring contaminant levels in tissues also allow the determination of potential human health effects.

The evaluation of the data in determining potential health effects considers:

- Persistence and fate of chemical contaminants in waters and sediments;
- Types of aquatic animals present in the water body;
- Fat content, feeding, and migration habits of those aquatic animals;
- Ability of each contaminant to accumulate in tissues of aquatic animals and humans;
- Human and animal health effects information for each contaminant;
- Preparation, cooking, and fish consumption behaviors of fishers/crabbers;
- Likelihood that sensitive populations eat these animals.

MDE has monitored chemical contaminant levels in Maryland's fish and shellfish since the 1960s. Fish monitoring focuses on species that are either predators (bass, perch, and sunfish) or bottom feeders (catfish, carp, and suckers). Within these categories, efforts are focused on those species with a relatively high fat content, however, game fish are preferred targets. Consistency in species throughout the State allows for the assessment of regional trends. Sampling is generally conducted from the end of summer through early fall to avoid biological extremes that can be linked to spring spawning. The goal is to composite five fish in each species sample. Where quantities and weights allow, fish fillets and whole fish samples are collected to provide for both human health and environmental evaluations. Standard procedures for collecting, handling, preserving and analysis have been established to maximize data integrity.

Historical sampling strategies have included annual and biennial collections at approximately 30 sites for general trend assessments. A triennial sampling strategy has been utilized since 1990, with 1/3 of the State sampled each year. Sampling is conducted in localized areas where special needs have been identified.

MDE also has been monitoring chemical contaminant levels in shellfish (oysters, clams) and crabs from the Bay and its tributaries. Because of low levels of contaminants and negligible yearly changes in those levels, this Bay-wide monitoring effort occurs every three years. If necessary, small intensive surveys are performed during off years. Sampling in the estuarine program from the beginning of summer to late fall prior to harvesting.

Estuarine rivers and embayments

Tidally-influenced rivers and tributaries and embayments of Chesapeake Bay and the coastal lagoons behind the Atlantic barrier islands account for an estimated 2,522.4 square miles or 20 percent of the State's total surface area (*Figure 5*). Man's modifications to estuarine waters include dredging for navigation purposes (channels, canals, anchorage areas), dredging for oyster shell and oyster bar shoreline erosion, stabilization projects (bulkheads, jetties) and shore structures (piers, wharves).

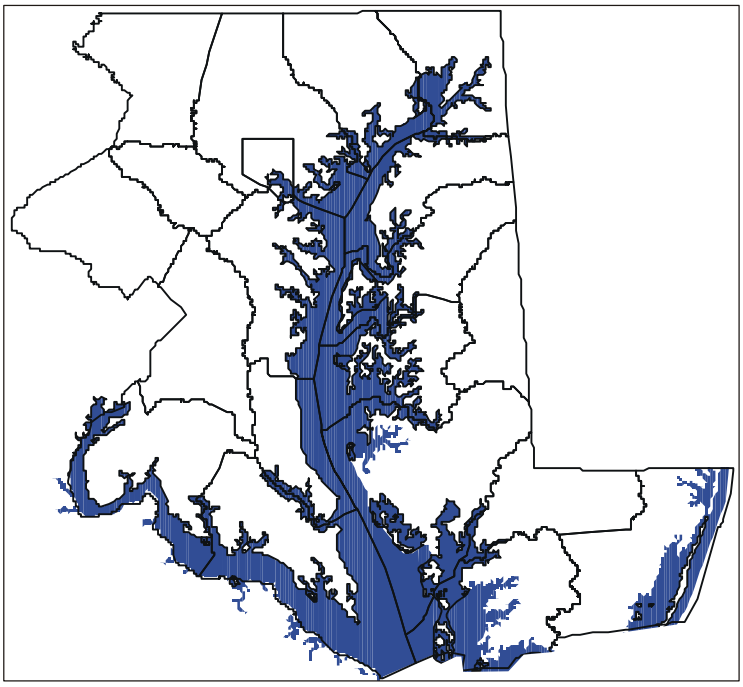

Figure 5. Estuarine waters (shaded) in Maryland

Estuarine rivers and embayments - Water monitoring programsThe following lists estuarine water monitoring programs conducted by Maryland agencies that are designed to address water quality, water quantity, aquatic resources and public health issues. These summaries include contact information, watershed/media monitored, program goals and a brief description of the monitoring effort. Some program summaries are adequately described in other waterbody programs in this report and the interested reader should refer to these summaries for information.

Water Quality/Aquatic Resources - ***Chesapeake Bay Monitoring Program***
Agency: DNR Resource Assessment Service
Contact: Bruce Michael (410-260-8627); bmichael@dnr.state.md.us
Watersheds: Maryland's Chesapeake Bay watersheds
Media: water column, sediment, aquatic resources
Goals: To assist in the development and implementation of management policies to protect and restore the economic and recreational value of Chesapeake Bay, the Department of Natural

Resources has designed and implemented a long-term monitoring program to provide State managers and policy makers with accurate, timely and comprehensive information about the Bay's existing condition and how it is responding to management initiatives. This information helps to formulate new goals and policies and provides a basis to measure progress towards meeting the ultimate goal of protecting and restoring Chesapeake Bay. This information also is widely used by citizens, elected officials and Maryland's Tributary Teams.

Program Description: The monitoring program is a carefully assembled group of monitoring components - physical measurements, chemical measurements including a full suite of nutrients, sediment chemistry and exchanges, ecosystem processes, assessment of phyto- and zooplankton, submerged aquatic vegetation, benthic invertebrates, key rate processes and resident fish communities - all integrated into a unified study. The objectives followed consistently for all components reflect major management questions and include: characterize existing conditions, detect trends in water and habitat quality indicators, and increase the understanding of ecosystem processes affecting Bay water quality and the linkage between water quality and living resources. This basic design is outlined in Magnien, et al. (1987) (Appendix) although some modifications have been initiated to address current management issues.

The design encompasses a comprehensive, Bay-wide approach that includes the most important water, habitat and biological measurements from a management and scientific perspective. These measurements take place in a coordinated fashion, in many cases at exactly the same times and places to enhances our ability to interpret linkages between monitored parameters.

A Bay-wide perspective has been applied to the location of sampling stations throughout the tidal tributaries and mainstem of Chesapeake Bay based upon a segmentation scheme that identifies major reaches of the Bay and its tributaries. Other considerations in the site selection included important habitats, such as striped bass spawning areas, and the availability of useful historical data. All stations are located in tidal waters with salinity regimes ranging from completely fresh-water in the upper tributaries and mainstem to over 20 parts per thousand in bottom waters of the mainstem near the mouth of the Potomac. This basin-wide coverage includes similar efforts in Virginia and Pennsylvania that are coordinated by these states, the District of Columbia and EPA in order to evaluate where and how pollution control measures are working, to identify regions in need of additional remedies and to better understand the fate and effect of pollutant inputs.

A critical step that determines the usefulness of the monitoring program is the analysis of data, interpretation of the findings and presentation of results. Several approaches employing unique sampling design and analytical techniques are used by the Chesapeake Bay Monitoring Program components to address specific management questions. Status or characterization assessments are conducted using fixed station observations. A Bay-wide scale was developed for each salinity zone (tidal fresh, oligohaline and mesohaline) to set a baseline on which to score water quality at each station and then compared to the most current three-year record. Long-term trends are assessed from fixed station observations using the Seasonal Kendall test for monotonic trends and the Van Belle and Hughes tests for homogeneity of trends between stations, seasons, and station-season combination.

Probability-based sampling has been implemented in the Benthic Organism component to estimate the area of the Chesapeake Bay and tributaries that meet the Benthic Restoration Goals as indicated by the Benthic Index of Biotic Integrity. In Maryland, six strata were defined and each stratum is sampled by 25 randomly allocated sites. Probability-based sampling within strata supplements data collected at fixed trend stations to allow unbiased comparisons of conditions between strata of the Bay/tributaries in the same collection year and within tributaries for data collected between different years.

Monitoring data are used extensively in mathematical modeling efforts to project water quality responses of the Bay to various management alternatives. A three-dimensional Bay and Tributary Water Quality time-variable model is presently under review. Results from earlier versions of the model have already been used to set nutrient reduction goals agreed to in the 1987 Chesapeake Bay Agreement and affirmed by the 1991 and 1997 Re-evaluations. A new Bay agreement, signed in June 2000, has a goal to de-list the Chesapeake Bay and its tidal tributaries by 2010.

Recommendations: Since 1984, the EPA Chesapeake Bay Program has funded the State's Water Quality Monitoring efforts in the mainstem Bay with a focus on the restoration of the mainstem Bay. Most tidal tributaries are characterized by only one monitoring station in the center of the estuary. Efforts are underway to increase the attention on the Bay tributaries and near-shore environments as: (1) improvements in water quality will be detected in the tributaries long before they are seen in the mainstem, and (2) more detailed information is required to focus management activities on the tributaries.

EPA's Chesapeake Bay Program has been developing a Monitoring Strategy focused on incorporating and evaluating water and habitat quality and living resource information. From this Strategy, draft recommendations have focused on expanding monitoring efforts in the tributaries to better evaluate the linkage between water and habitat quality with living resources (Chesapeake Bay Program, 1999b). These will require a more intensive spatial coverage in near-shore environments.

Water Quality/Aquatic Resources - ***Coastal Bays Monitoring Program***
Agency: DNR Resource Assessment Service
Contact: Cathy Wazniak (410-260-8638); cwazniak@dnr.state.md.us
Watersheds: Atlantic Ocean coastal bays (Worcester Co.)
Media: water column, aquatic resources
Goals: The general goals of the Maryland Coastal Bays Comprehensive Monitoring Program are:

1) to measure the effectiveness of implementing the management actions identified in the Comprehensive Conservation Management Plan (CCMP),
2) to provide information that can be used to redirect and refocus the CCMP over time,
3) to provide information that will assist in anticipating water quality responses to implementation of proposed management actions, and
4) to bring the monitoring and evaluation of Coastal Bays up to par with efforts in the Chesapeake Bay.

Program Description: Eutrophication and its impacts to living resources was identified in the Maryland Coastal Bays Program (1998) characterization report as the most pressing environmental issue facing these waters. As a result, the Scientific and Technical Advisory Committee (STAC) recommended that the initial focus of the monitoring plan be on nutrient and sediment inputs to the coastal bays and their impacts on living resources (Maryland Coastal Bays Program, 1999). Five general categories of monitoring activities were identified:

1) tracking management actions.
2) nutrient and sediment inputs from the watershed and airshed,
3) ambient water quality,
4) eutrophication impacts to habitat,
5) eutrophication impacts to living resources.

Structure: Actions in the monitoring plan have been organized into three levels: Landscape

Monitoring (Level I), Stressor Monitoring (Level II), and Response Monitoring (Level III). The lower the level, the more directly the monitoring is related to management actions. Inherent within all three levels is monitoring for both baseline and long-term trends. The resulting Comprehensive Environmental Monitoring Program was developed by DNR with extensive input from local, State, and federal agencies operating in Maryland's Coastal Bays, peered reviewed for technical merit and approved by the STAC.

Baseline monitoring determines the current status of important indicators of environmental health against which to measure change and to determine if management actions have had an impact. While sufficient baseline data are not currently available for all components of the monitoring plan, collection efforts should be instituted to establish existing conditions prior to full implementation of management actions.

Landscape monitoring (Level I) tracks activities going on in the watershed (e.g., nutrient and chemical application rates, implementation of best management practices and land cover). This can often be directly related to implementation of management actions and may not need intense field monitoring. This monitoring process may need to be reviewed, depending on the outcome of the final management plan and its goals, to evaluate the adequacy of current programs to track important aspects of landscape conditions and activities.

Stressor monitoring (Level II) determines the amount of pollutants (nutrient, sediment or chemical contaminants) entering the bays or extent of habitat alteration or loss occurring in the watershed. While it may be very difficult to do in a comprehensive fashion, the STAC decided to initiate some of the high priority monitoring elements in this category related to nutrient inputs.

Response monitoring (Level III) uses indicators to show how the system is responding to management actions (changes in stressors) over time. This monitoring information is very important to the public (e.g., - Is the water degraded? What is the condition of the fish?).

Recommendations: Now that there is a comprehensive, peer-reviewed monitoring strategy for the Coastal Bays, the most important recommendation is to work on fully implementing the approved Monitoring Plan. The State has allocated partial funding for ambient water quality monitoring; however an additional $225,000 is needed to fully implement those activities. Additional funding is needed to monitor habitat impacts from eutrophication including harmful algal blooms, macroalgae, impacts to SAV and the benthic community

Harmful algal blooms pose a threat to the coastal bays. In 1998, the presence of *Pfiesteria* and *Aureococcus* ('brown tide') were confirmed in the northern bays (Turville Creek and Assawoman Bay, respectively). Although the presence of these organisms does not yet cause problems related to health risks or impaired uses, it further stresses the need to control nutrient inputs to these highly susceptible bays.

The abundance of SAV should continue to be monitored using aerial photography. The use of macroalgae as a eutrophication indicator is still unclear and additional data is needed to document the extent in the MD coastal bays and relationship with water quality parameters.

No system-wide benthic monitoring program is currently ongoing (MDE program has some stations in the major tributaries of the St. Martin River and Newport Bay). The spatial and temporal variability due to physical and biological factors can confound attempts at detecting anthropogenic disturbances in the molluscan community over time. Indicator development and analysis of benthic/fish data as it relates to eutrophication needs more study.

Water Quality/Aquatic Resources - ***Harmful Algal Bloom monitoring program***
Agency: DNR Resource Assessment Service
Contact: Dave Goshorn (410-260-8639); dgoshorn@dnr.state.md.us
Watersheds: Selected tidal tributaries affected or potentially affected by harmful algal blooms in Maryland's Chesapeake Bay and Coastal Bays
Media: water column, aquatic resources

Goals: 1) quickly identify and evaluate HAB's in Maryland waters in order to provide data on which to base appropriate actions to protect public health and safety,

2) track HAB species and events in Maryland in order to identify trends in occurrence, and

3) identify linkages between HAB's and anthropogenic impacts (e.g., nutrient enrichment) in order to target management actions which may reduce the likelihood of future outbreaks.

Program Description: Maryland Department of Natural Resources has been developing a program to address the increasing awareness of harmful algal blooms in the State. In addition to long recognized HAB species such as *Prorocentrum* and *Microcystis*, Maryland in recent years has documented outbreaks of other HAB species such as *Pfiesteria , Aureococcus*, and, possibly, *Chattonella*. The lack of an established HAB monitoring program makes it difficult to determine if the presence and frequency of blooms of these species is increasing or a function of increased public and State awareness. Regardless, all these species have the demonstrated potential to result in major negative impacts to the ecosystem, and, in some cases, pose substantial risks to the economy and public health of the State. Maryland DNR has been working to piece together components of existing monitoring programs in order to monitor HAB's. Existing programs are insufficient to adequately track and characterize these organisms. A dedicated HAB monitoring program is necessary provide the level of information necessary to make required decisions on public health policy and to direct management actions to reduce the threat from these organisms.

Recommendations: Harmful algal blooms pose a significant threat to the public health and economic vitality of the State. Existing monitoring programs are insufficient to meet the information needs required to appropriately respond to these threats. It is recommended that funds be made available to develop a dedicated HAB monitoring program. This program will depend as heavily as possible on existing programs, but will add monitoring and analysis necessary to adequately characterize the situation. Specifically, funds would be used to:

(1) add field monitoring resources to existing programs sufficient to respond to HAB blooms as well as characterize background levels of the organisms and associated habitat conditions,

(2) contract with appropriate laboratories with expertise in analyzing collected samples,

(3) provide technical analysis of collected data in order to appropriately interpret findings, and

(4) provide outreach to public, elected officials, and managers necessary to respond appropriately.

Water Quality/Aquatic Resources - ***Pfiesteria Investigations - water quality and fisheries***
Agency: DNR Resource Assessment Service
Contact: Dave Goshorn (410-260-8639); dgoshorn@dnr.state.md.us
Watersheds: Selected tidal tributaries affected or potentially affected by *Pfiesteria* in Maryland's Chesapeake Bay and Coastal Bays
Media: water column, aquatic resources
Goals: (1) Provide for rapid response testing and reporting on fish health, water quality, habitat, *Pfiesteria*-like organisms and associated biological communities in cases of suspected toxic outbreaks.

(2) Provide fish and water quality, habitat and *Pfiesteria* data needed to fulfill DNR's obligations under the State's "Guidelines for Closing and Reopening Rivers Potentially Affected by *Pfiesteria* or *Pfiesteria*-like Events."

(3) Increase understanding of critical habitat factors contributing to the frequency of toxic outbreaks of *Pfiesteria*-like organisms and the relationship to fish health.

(4) Evaluate relationships between critical habitat factors and human activities.

(5) Identify areas vulnerable to outbreaks of toxic *Pfiesteria* or *Pfiesteria*-like organisms.

(6) Track improvements in water bodies affected by *Pfiesteria*-like organisms that have implemented management programs.

(7) Provide information on the incidence and distribution of diseased fish in Maryland's Chesapeake and Coastal Bays; this includes sampling of closed areas for diseased fish in assessing closure duration.

(8) Provide samples of healthy and diseased fish for necropsy and diagnosis by the DNR Fisheries Service's Fish Health Unit at the Sarbanes Cooperative Oxford Laboratory.

(9) Provide rigorous exposure data to epidemiologists studying the relationship between toxic *Pfiesteria*-like dinoflagellates and human health.

(10) Provide samples and data to support ongoing research investigations into fish health, harmful algal bloom ecology, and development of *Pfiesteria* identification techniques.

Program Description: To meet the above goals, the general sampling approach is categorized into four levels under the general headings of "Rapid Response" and "Comprehensive Assessments".

Rapid response (Level I) is classified as the immediate investigation of a reported fish health or suspicious human health problem. The primary objectives here are to 1) determine the nature of the fish health or human health problem, 2) ascertain if *Pfiesteria*-like organisms and their toxins may have been involved and 3) determine if the river closure criteria have been met. Teams quickly evaluate fish communities and other appropriate parameters (e.g., lesion incidence, dissolved oxygen, salinity, etc.) to determine if a toxic outbreak can be ruled out as the likely cause of the fish health problem and if the State 's river closure criteria have been met. If closure criteria are met, rivers will be monitored intensively for all parameters until re-opened. Current scientific knowledge indicates that the behavior of *Pfiesteria* and *Pfiesteria*-like organisms is seasonal and episodic in nature. Therefore, closure and re-openings will be reassessed as necessary. This protocol is based on evolving scientific knowledge and experience with *Pfiesteria* and *Pfiesteria*-like organisms and is subject to re-evaluation.

Comprehensive assessment (Levels II-IV) involve the intensive monitoring of fish health, water quality, habitat and *Pfiesteria* activity in previously affected tributaries (Level II). Additional comprehensive characterization is performed on unaffected tributaries (Level III) that, based on historical data, have water quality and habitat characteristics (nutrient enrichment, moderate salinity, etc.) similar to those associated with *Pfiesteria*-related outbreaks. Level II and III comprehensive assessment efforts involve the continuation of fish health, longitudinal water quality and habitat sampling transects on these tributaries begun in 1998. Level IV response involves the long term fish health, water quality monitoring programs from the Chesapeake Bay and tributaries. Examining data from these programs provides our broadest scale view of Maryland's waters intended for other purposes but being utilized in these investigations to provide a context for environmental conditions in areas outside of affected waterways.

Intensive research-oriented investigations are also currently underway on the Pocomoke and other affected rivers. These NOAA and EPA (EMPACT) funded programs are tightly coordinated with

the *Pfiesteria* monitoring outlined here. Coordination of field operations and data between those programs ensures maximum application of resources.

Recommendations: It is critical that this effort continue in order to:

(1) collect information necessary to protect public health from the threat of toxic *Pfiesteria* outbreaks,

(2) continue to refine our understanding of the relationships between human activities on the land, estuarine habitat quality, *Pfiesteria* activity, fish health, and human health, and

(3) track progress of the State's management efforts designed to reduce the threat of future outbreaks.

Water Quality/Aquatic Resources – ***Lower Eastern Shore pollutant inputs monitoring***
Agency: MDE Technical and Regulatory Services Administration
Contact: John Steinfort (410-974-3238); jsteinfort@erols.com
Watersheds: Selected tidal and non-tidal tributaries in Pocomoke, Wicomico and Fishing Bay watersheds (areas affected by 1997 Pfiesteria incidents)
Media: water column, aquatic resources
Goals: The goal of this program is to identify sources of major nutrients entering waters of the Lower Eastern Shore that have been identified as being potentially impacted by the algal species *Pfiesteria piscicida*.
Program Description: This effort is limited to collection of water quality samples during major storm events on the lower Delmarva Peninsula. Storm driven runoff is captured at 10 watershed outlets ranging from the Choptank to the Coastal Bays whenever a regional rain event makes significant nutrient loading likely. Constituents of concern are limited to total nutrient species along with some limited specialized forms such as urea. This is designed to compliment the DNR *Pfiesteria* monitoring program by providing nutrient input estimates for major storm events.

Water Quality/Aquatic Resources - ***Shellfish monitoring program***
Agency: MDE Technical and Regulatory Services Administration
Contact: Kathy Brohawn (410-631-3608); kbrohawn@mde.state.md.us
Watersheds: Use II (shellfish harvesting) waters
Media: water column, aquatic resources
Goals: The goals of this program are to ensure that the shellfish (oysters, clams and crabs) harvested from State waters are safe for human consumption, and to provide information on potential sources and trends in water pollution levels.
Program Description: Shellfish have the potential to accumulate human pathogens, heavy metals or organic chemicals in their tissues even when these materials cannot be measured in the water column. This makes these aquatic animals good indicators of environmental pollution in a body of water. Monitoring contaminant levels in tissues also allow the determination of potential human health effects.

The evaluation of the data in determining potential health effects considers:

- Persistence and fate of chemical contaminants when they enter waters and sediments;
- Types of aquatic animals present in the water body;
- Fat content, feeding, and migration habits of those aquatic animals;
- Ability of each contaminant to accumulate in tissues of aquatic animals and humans;

- Human and animal health effects information for each contaminant;
- Preparation, cooking, and fish consumption behaviors used by fishers and crabbers;
- Likelihood that sensitive populations eat these animals.

Surface waters overlying shellfish harvesting areas are sampled on a fixed frequency to determine bacterial levels as an indication of possible pathogen contamination. This effort is required by the US Food and Drug Administration because of the potential for raw shellfish consumption. Sampling results are used to determine whether closures of harvesting areas are required.

Since the 1960s, MDE has been surveying metal and pesticide levels in oysters and clams from the Chesapeake Bay and its tributaries. Because of low levels of contaminants and negligible yearly changes in those levels, this baywide monitoring effort occurs every three years, with the off years being devoted to analyses of results and the performance of small intensive shellstock surveys. In addition to triennial tissue monitoring for contaminants, shellstock is also sampled to measure bacterial levels as an added check on the quality of the harvesting waters, and as a check on the handling of the shellfish after harvesting.

See - Non-tidal Rivers/Streams - Tissue monitoring

See - Non-tidal Rivers/Streams - Fish kill investigations

Water Quality - ***Dredge activity monitoring program***
Agency: MDE Technical and Regulatory Services Administration
Contact: Charles Poukish (410-631-4434); cpoukish@mde.state.md.us
Watersheds: Selected tidal areas where sediment removal activities occur.
Media: water column
Goals: The goals of this program are to examine the short-term and long-term environmental impacts of dredging to waters of the Chesapeake Bay to limit or curtail activities to minimize the pollution and to ensure that the State Water Quality Standards are not exceeded by dredging activities in the Bay (turbidity and nutrients).
Program Description: The Dredging Coordination and Assessment Division in MDE's Technical and Regulatory Services Administration is responsible for coordinating and managing the compliance monitoring effort for dredging and dredged material placement activities in the Chesapeake Bay. Primary emphasis is focused on the Hart-Miller Island dredged material placement site. The compliance monitoring effort for the baseline and post-construction or post-placement dredging activities for any open water or upland dredged material placement site, examines water quality impacts resulting from construction or placement of dredged material in the Chesapeake Bay. Monitoring program elements include the assessment of discharges from dredged material placement sites through chemical characterizations and bioassay testing. Ambient conditions surrounding placement sites are monitoring for chemistry, benthological community condition, contaminant bioaccumulation in target shellfish, and sediment chemistry.

This program helps to identify what type of dredging activities are detrimental to the water quality of the State; and in designing a comprehensive monitoring plan that is effective and generally meets the needs of the site, and in conducting dredging activities that produce the least water quality pollution in the Chesapeake Bay while maximizing the dredging activity itself.

Lakes and reservoirs

All of the principal lakes in Maryland are man-made reservoirs created by impounding water behind a dammed stream or river. There are numerous, small natural lakes created by beaver dams, as coastal impoundments created by natural shoreline drift, and as natural, water-filled depressions. The State identified 58 'significant, publicly-owned lakes' as waterbodies having public access, a surface area of five acres or greater, providing public benefit, and available for other public uses (e.g., public water supply, fishing). 'Run-of-the-river' lakes, formed behind relatively low dams on rivers, are not included in this profile. Based on connecting River Reach traces (1:100,000 scale), the US Environmental Protection Agency identified 947 lakes in Maryland, however, these include many stormwater and waste treatment lagoons and impoundments surrounded by private lands or on federal property - these are often inaccessible to the public and are not considered as part of the State's public lake listing.

Maryland' significant, public lakes in are found in all physiographic provinces and in all counties except Calvert, Dorchester and Talbot Counties (*Figure 6*). These lakes range in size from 5 to 4,500 acres and account for a total surface area of 21,010 acres. Most lakes are small (the 45 smallest lakes account for 10 percent of the total lake area; the 4 largest lakes account for more than half of the State's total lake acreage).

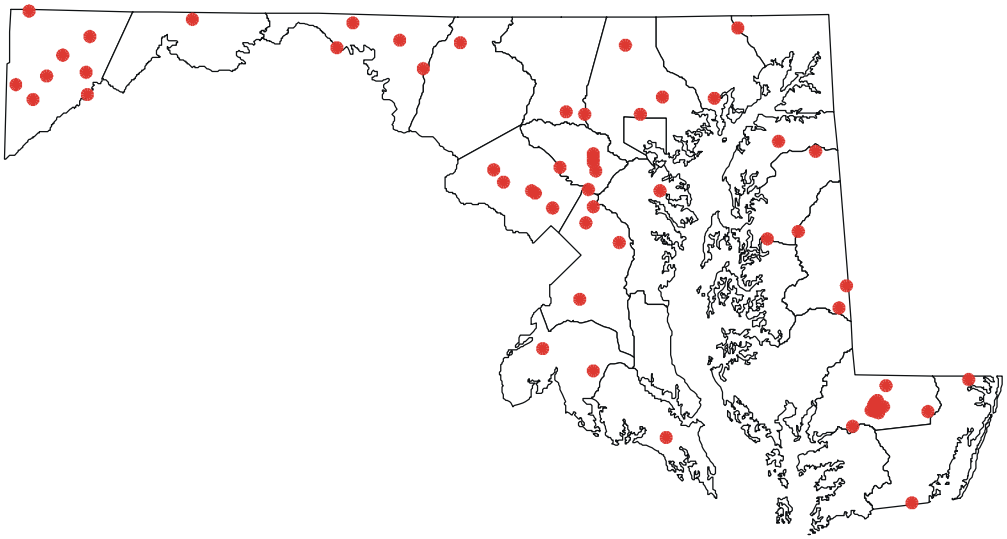

Figure 6. Distribution of significant, publicly-owned impoundments in Maryland

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Lakes and reservoirs - Water monitoring programs

The following lists water monitoring programs in lakes and reservoirs that are conducted by Maryland agencies and are designed to address water quality, aquatic resources and public health issues. These summaries are adequately described in other waterbody programs in this report and the interested reader should refer to these summaries for information.

See - Non-tidal Rivers/Streams - Drinking water protection program

See - Non-tidal Rivers/Streams - Fish kill investigations

See - Non-tidal Rivers/Streams - Tissue monitoring

Ocean

The State's Atlantic Ocean coastline extends 32 miles between the Delaware and Virginia state boundary and seaward three miles, encompassing a total of 96 square miles (*Figure 7*). The most significant modification here is centered on maintenance of the Ocean City Inlet which intercepts the southerly littoral drift and impacts the northern side of Assateague Island and periodic dredging of offshore bars to replenish primary sand dunes on the barrier islands.

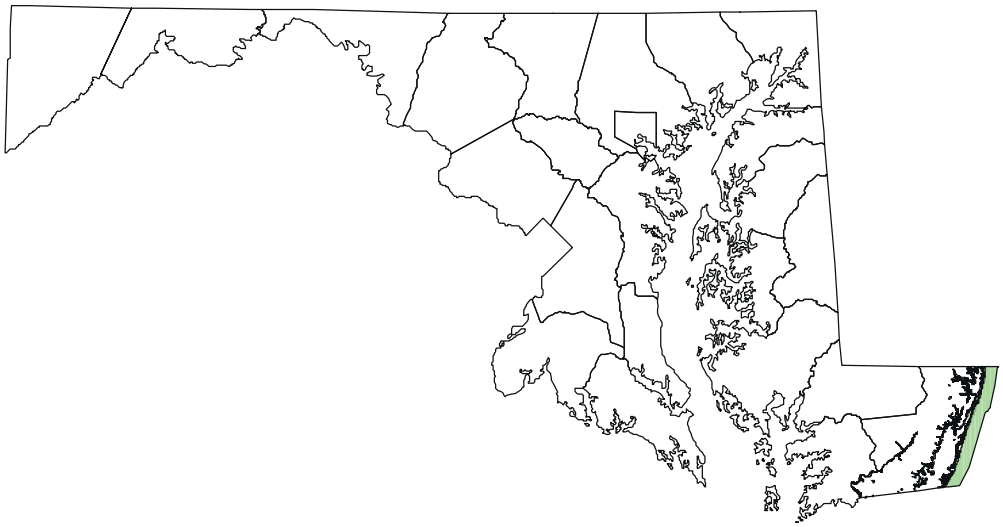

Figure 7. Maryland's ocean coastline

Ocean - Water monitoring programs

The following lists water monitoring programs in lakes and reservoirs that are conducted by Maryland agencies and are designed to address water quality, aquatic resources and public health issues. These summaries are adequately described in other waterbody programs in this report and the interested reader should refer to these summaries for information.

See - Estuaries - Shellfish monitoring program

Wetlands

There are a total of 697,657 acres of wetlands in Maryland; 342,626 acres are upland, non-tidal wetlands and 251, 542 acres are tidal wetlands. The remaining wetland areas are non-tidal shoreline

areas adjoining river and lakes (Tiner and Burke, 1995). Wetland areas occur in all physiographic areas of the State and in all counties (*Figure 8*). In Maryland most wetland areas have been lost though fill and drainage and transformation to agriculture, urban, transportation and other commercial uses.

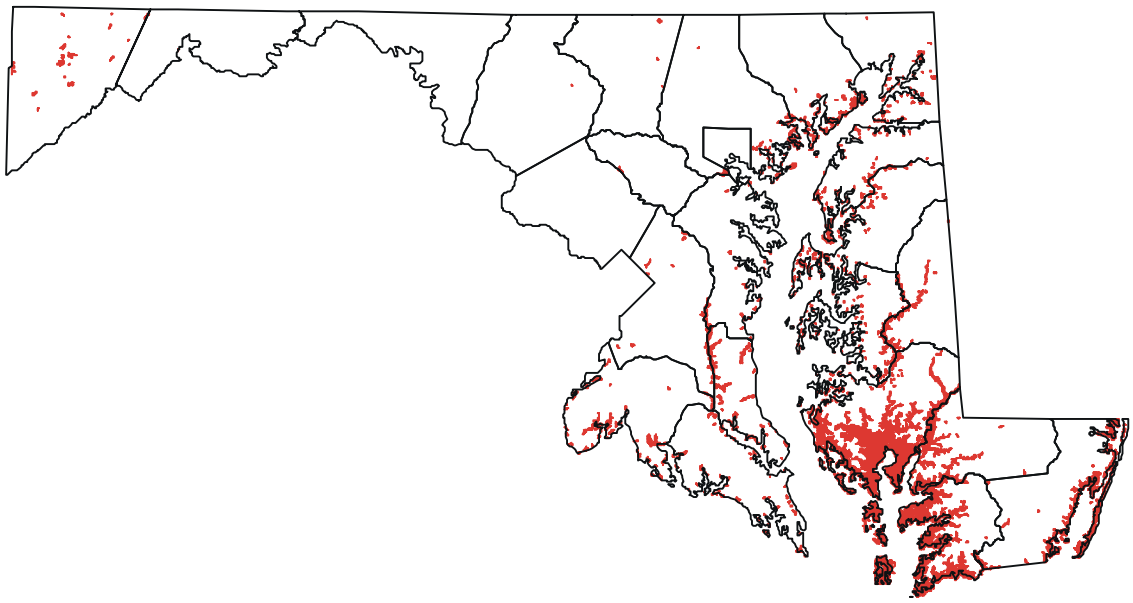

Figure 8. Tidal and nontidal wetlands (shaded) in Maryland

The US Environmental Protection Agency is working to develop guidelines to monitor tidal and non-tidal wetland condition. To date, most wetland monitoring has been in terms of identifying the amount or quantity of wetland area existing as an inventory updating the US Department of the Interior's National Wetlands Inventory or as tracking changes in wetland area as a Chesapeake Bay watershed indicator.

A number of research studies related to water monitoring in wetland areas are underway in the several research centers, including the Smithsonian Environmental Research Center, Patuxent National Wildlife Research Refuge and in the National Estuarine Research Reserve sites in Jug Bay, Monie Bay and Otter Point Creek. While not necessarily applicable to wetland areas Statewide, results from these studies should be closely followed.

Ground water

Ground water in Maryland varies between physiographic provinces and exists in one of two distinct types of aquifers - the unconsolidated Coastal Plain aquifers and the consolidated sedimentary and crystalline aquifers of the non-Coastal Plain (*Figure 9*). Ground water contributes to baseflow water in the State's rivers and streams as well as sub-surface flows to Maryland's tidal tributaries and the Chesapeake and Coastal Bays.

As a resource, ground water usage varies across the State. Outside of the Baltimore and Washington urban areas, it is often the sole source of drinking water. About 31 percent of the State's population uses ground water as a drinking water supply and other major uses include livestock water supply, irrigation and industrial uses.

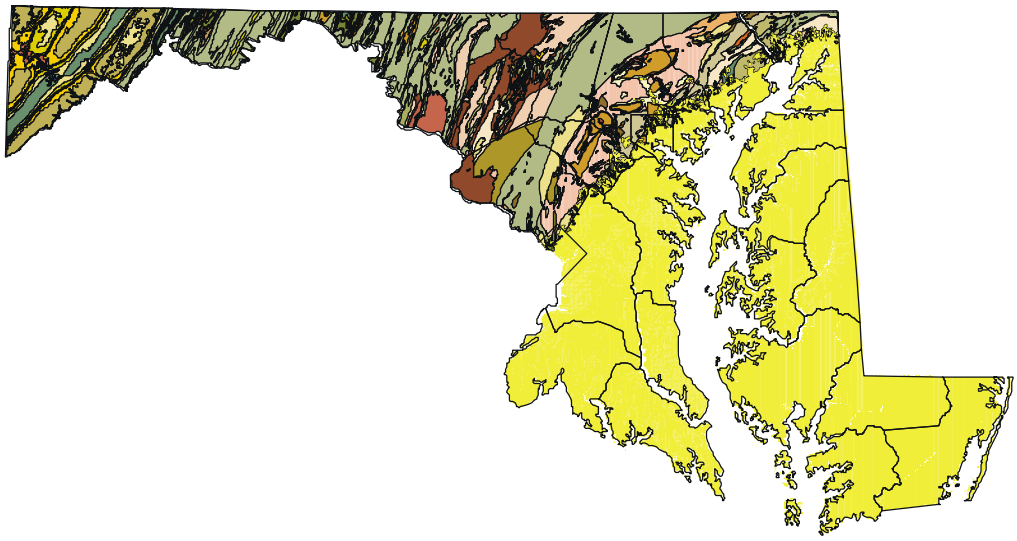

Figure 9. Coastal Plain aquifers and upland geological formations in Maryland

Ground water - Water monitoring programs

The following lists water monitoring programs in ground water that are conducted by Maryland agencies and are designed to address water quality, water quantity and public health issues. These summaries include contact information, watershed/media monitored, program goals and a brief description of the monitoring effort.

Water Quality/Human Health - ***Waste monitoring programs***
Agency: MDE Waste Management Administration
Contact: Karl Kalbacher (410-631-3437); kkalbacher@mde.state.md.us
Watersheds: Ground water wells
Media: Ground water
Goals: Obtain the data necessary to identify the highest priority sites that pose a threat to human health or the environment. Investigate, oversee remediation or perform cleanup of these high priority sites. A primary goal of remediation activities is to protect ground water by ensuring that contaminant sources are removed or contained in a manner which minimizes future impacts to ground water. To the maximum extent practicable ground water resources, which have been impacted by contamination, will be restored to their maximum beneficial use or treated to safe levels prior to end use.

Program Description:
Federal Superfund Program - The federal "Superfund' program, authorized by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), was established to identify, prioritize and cleanup hazardous waste sites. The Environmental Restoration and Redevelopment Program within the Waste Management Administration ensures that state requirements are met during investigation and cleanup of sites designated for the National Priority List (NPL) and federal facilities under the federal "Superfund" program. In Maryland, 21 sites have been placed on the NPL; 16 of these sites are currently active. The remaining five sites have been removed from the NPL or are in the final stages of completing the remediation process.

Additionally, the MDE has a memorandum of agreement with the Department of Defense (DoD) covering 44 federal facilities, 37 of which are not on the NPL. Currently, the DoD is actively working on 22 sites at which MDE is actively overseeing the investigation or remediation of ground water contamination.

State Superfund Program - A similar program under State law, the State Superfund Program, conducts investigations and oversees the remediation and cleanup of sites listed on the State Master List that are not included on the NPL or are not owned by the federal government. The State Master List contains 439 sites that have been identified statewide with known or potential contamination. In Maryland, there are approximately 35 State Superfund sites at which MDE is actively overseeing the investigation or remediation of ground water contamination.

Water Quality/Human Health - ***Storage tank monitoring program***

Agency: MDE Waste Management Administration

Contact: Mick Butler (410-631-3386); mbutler@mde.state.md.us

Watersheds: Ground water supply wells

Media: ground water

Goals: Monitoring activities conducted under the Oil Control Program are designed to identify problem conditions with historic tank operations, track the recovery of remediation efforts, and to verify that the integrity of currently installed systems is secure. These efforts are intended to protect surface waters and associated aquatic life from the harmful effects of petroleum and to ensure that potable surface and ground water quality is maintained.

Program Description: The Oil Control Program, within the Department of the Environment's Waste Management Administration, is the unit responsible for the implementation of the Underground Storage Tank (UST), Leaking Underground Storage Tank, and Aboveground Storage Tank programs. These programs provide for preventive actions to minimize ground and surface water pollution from the storage of petroleum and hazardous substances and for remedial actions to restore sites that have been contaminated by oil or hazardous substances. Under the oversight of the UST program, which began in 1988, the active universe of motor fuel underground storage tanks in the State has been reduced from over 21,000 to just fewer than 8,500. Those motor fuel underground storage tanks that remain have been required to be replaced or upgraded to meet federal standards that became effective on December 22, 1998. These standards include requirements for corrosion protection, leak detection, and spill and overfill protection. With more than 93 percent of Maryland's underground storage tank owners meeting the 1998 federal compliance deadline, the UST program is actively working with the remaining underground storage tank owners to achieve full compliance with the federal requirements. In addition to the motor fuel facilities, Maryland regulates the storage of heating fuel in over 3,700 underground storage tanks.

One of the major causes of releases from underground storage tank systems has been the corrosion of bare steel tanks and lines. Releases from these tanks are required to be investigated and those with groundwater impacts are required to define the vertical and horizontal extent of the contamination. Once defined a Corrective Action Work plan is implemented to mitigate the impact of the contamination. The effectiveness of remediation systems is normally evaluated through groundwater monitoring. The Leaking Underground Storage Tank (LUST) Program has tracked reports of over 14,500 confirmed releases throughout Maryland. Of these releases, over 7,500 cleanups have been completed while the Oil Control Program continues to provide oversight of over 7,500 ongoing cleanups.

The Oil Control Program administers the regulation of the transportation and aboveground storage of oil through a series of permitting requirements. The above ground storage facility

permits include requirements for monitoring storm water and test water discharges while petroleum contaminated soil treatment facilities are required to also monitor groundwater.

These storage tank programs all work together to prevent the pollution of surface and ground water from releases that can occur from the handling and storage of oil and hazardous substances.

Water Quality/Human Health - ***Source water protection program***
Agency: MDE Water Management Administration
Contact: Bill Beatty - compliance (410-974-3238); billbeatty@starpower.net
John Grace - source water protection (410-631-3713); jgrace@mde.state.md.us
Watersheds: Ground water supply wells
Media: ground water
Goals: The State of Maryland is committed to protect the physical, chemical and biological integrity of the ground water resource, in order to protect human health and the environment, to ensure that in the future an adequate supply of the resource is available, and in all situations, to manage that resource for the greatest beneficial use of the citizens of the State.
Program Description: *Maryland Groundwater Quality Monitoring Network* - The Maryland Geological Survey (MGS), a unit of the Department of Natural Resources, operates a Statewide network of water table wells and springs to monitor basic water quality data to document baseline chemical quality conditions of aquifers, and to provide a basis for monitoring future trends (Bolton, 1997). MGS periodically samples well sites for major dissolved ions, field parameters, selected trace elements, volatile organic compounds, classes of pesticides, and radionuclides.

Special studies are conducted, coordinated or commissioned as needed. These studies may be of large portions of Coastal Plain aquifers, or confined to localized conditions around a specific water supply well. An example of a wide scale effort would be the 1999 study of radium in the Magothy and Patapsco formations in Anne Arundel County. Examples of localized studies would include the evaluation of potential surface water contamination of the wells supplying Thurmont and Westminster. See ***(Non-tidal rivers/streams - Drinking water protection program***).

Water Quality/Human Health - ***Solid waste facility ground water monitoring program***
Agency: MDE Waste Management Administration
Contact: Edward M. Dexter, P.G. (410-631-3424); edexter@mde.state.md.us
Watersheds: Ground water supply wells
Media: ground water
Goals: The Solid Waste Program is charged with the maintenance of this monitoring program to insure that the public health, safety and comfort, and the quality of the environment, are not compromised due to pollutants discharged from the regulated solid waste and sewage sludge facilities. Several indicators relate to this important function. For Managing Maryland for Results, the Program reports the number of evaluations of groundwater quality at landfills performed each year, and the percentage of received reports reviewed (MMR Goal #3 - Insuring Safe Drinking Water). For the Environmental Partnership Agreement (EnPA) with the United States Environmental Protection Agency (EPA), SWP reports the number of active municipal waste landfills in compliance with groundwater standards.
Program Description: The Solid Waste Program (SWP) oversees the environmental monitoring of landfills and sewage sludge storage facilities. This activity includes the direction and review of

the groundwater and surface water monitoring systems at these sites, to help protect the public health and the environment from pollution, which could be caused by these facilities. Authority for the program is provided in the Environment Article, Subtitles 9-2 and 9-3 of the Annotated Code of Maryland. Also, federal regulations governing municipal waste landfills (40 CFR 258 are applicable for those sanitary landfills accepting municipal waste which operated after 1993.

Classes of facilities monitored include active municipal waste landfills; active rubble landfills; active industrial waste landfills; closed municipal waste landfills which are subject to the federal regulations; closed municipal waste landfills which are not subject to the federal regulations; closed rubble and industrial waste landfills; and sewage sludge storage lagoons. Approximately 78 facilities are monitored routinely, with over 140 separate reports submitted to the Solid Waste Program each year. In addition, one to three special projects are managed each year, which often involve sampling by SWP of surface water, groundwater, waste, and suspected discharges. Some projects also involve sampling of domestic wells, which is coordinated with the local County Health Departments.

Groundwater and surface water sampling is typically on a semiannual frequency, although due to their geologic setting some facilities are on a quarterly frequency for some parameters, while closed facilities which have stabilized or have not experienced a pollutant release may be reduced to an annual sampling frequency. Some sites only sample groundwater; others not only perform sampling for this program but also sample surface or ground water discharges under the NPDES or State Groundwater Discharge Permit programs.

Sampling is performed by contractors or technicians working for the applicants and analyzed at approved laboratories, in accordance with sampling and analysis plans approved by the Solid Waste Program. Some County governments perform sampling using their own technicians, and some have hired the Maryland Environmental Service or other companies to perform this work. The Maryland Department of Health and Mental Hygiene's laboratory performs the analytical work for some sites, whereas most of the analysis is performed by commercial laboratories approved by SWP. SWP requires that laboratories used be certified by DHMH for analysis of drinking water samples, or have an equivalent certification acceptable to SWP.

Data evaluation is performed by the staff of the Investigations and Remediation Section, consisting of a senior geologist/section head, a staff geologist, and a registered environmental sanitarian. Other duties assigned to this section include review of monitoring plans, groundwater investigations, remedial plans, landfill soil gas monitoring plans and data, and landfill closure plans.

PROGRAM COORDINATION

Communication

The national Intergovernmental Task Force on Monitoring Water Quality reported that coordination was an essential component of an integrated monitoring strategy (ITFM, 1995). One essential ingredient affecting coordination between water monitoring programs has been an inconsistent communication framework.

Meetings

Water quality staff from the Department of the Environment (MDE) and the Department of Natural Resources (DNR) often provide information about on-going monitoring efforts through participation in various interagency workgroups (e.g., 305(b) Interagency Workgroup; Interagency TMDL Workgroup; Tributary Strategies Workgroup; Biocriteria Workgroup), other Statewide and regional organizations (e.g., Maryland Water Monitoring Council; Chesapeake Bay Program Committees/Workgroups; Susquehanna River Basin Commission; Reservoir Protection Workgroup; Regional Biologist Conferences; National Nutrient Criteria Workgroup), and in other formal and informal meetings between managers and analysts. Also, in a unique arrangement, the principal water monitoring field staff for both DNR and MDE share the same physical plant, providing opportunities for information exchange at the field level. During the course of normal activities, MDE and DNR field staffs consult with each other on benthic macroinvertebrate and phytoplankton identifications and occasionally share sampling gear and supplies. Both agencies use the same laboratories for chemical analysis, providing for similar laboratory quality control.

These many opportunities have significantly improved communications between Maryland's different water monitoring agencies at all levels of participation. However, this informal communications system is not systematic. Also, there are other water monitoring programs operating in Maryland among local, federal, citizen and scientific/academic organizations that generate useful data. There are few regular forums for sharing information about all water monitoring programs. A more formal information exchange between monitoring organizations of all types is recommended and is being addressed through efforts of the Maryland Water Monitoring Council (see below)

Maryland Water Monitoring Council

To address issues identified by the ITFM reports and to provide a forum for information exchange between federal, State and local agencies and non-governmental groups (academia, business and community groups), a Maryland Water Monitoring Council was created in 1995 to foster cooperation among water monitoring groups. As a stated purpose, the Council serves as a statewide collaborative body to help achieve effective water monitoring data collection, interpretation, and dissemination of these data. Specific goals of the Council are to:

(1) provide a forum for effective communication, cooperation, and collaboration among individuals and organizations involved in monitoring,

(2) promote the development of collaborative watershed based monitoring strategies,

(3) document monitoring activities in Maryland, and

(4) promote the use of quality assured procedures for sample collection, analytical methods, assessment, and data management.

The Department of Natural Resources (DNR) sponsors the Maryland Water Monitoring Council (MWMC) and has used grant funds from the US EPA's Nonpoint Source Program (Section 319) to provide administrative support. Council membership is voluntary and open to all interested parties. Members of the Board of Directors are appointed by the Secretary of DNR from among federal, State

and local government agencies, academia, business and volunteer monitoring programs. The Council has formed several standing committees (Planning, Monitoring Methods, Assessment and Reporting, Data Management, Indicators), as well as *ad hoc* committees (Stream Gaging, Small Watershed Studies, Programmatic Coordination) to conduct the business of the Council. Staff from both DNR and the Department of the Environment are appointed to the Board of Directors and serve on the Council's committees and workgroups. Monitoring staff representing field, laboratory and managerial levels attend the Council's Annual Meeting to discuss monitoring programs with other monitoring program representatives. This informal information exchange has resulted in increased cooperation between monitoring groups; more frequent interagency and government-citizen contacts have been noted. To date, the MWMC has conducted annual meetings and sponsored, through committees, several workshops (Reference Conditions, Small Streams, Stream Gaging, Sampling Design) and draft reports on methods and minimum data elements. For more information, the Council's Internet site is located at http://www.mgs.md.gov/mwmc/

Partly as a result of the Council's efforts, several of the State's regional water monitoring programs (e.g., DNR's Maryland Biological Stream Survey; MDE's Basinwide Permit and Modeling Program) work to notify local government agencies and citizens about planned water monitoring activities. This informs local agencies about nearby monitoring activities and provides an opportunity to coordinate with State monitoring activities or to obtain further information about the State agency findings.

More formal methods for monitoring coordination are also being evaluated by the Council's Programmatic Coordination Committee. These include: a clearinghouse containing monitoring program meta-data; a comprehensive statement of water monitoring goals for Maryland agencies, the approaches that can be used to address these goals, and the programs currently in place in relation to these goals; a process for routine information exchange among monitoring groups (e.g., an annual meeting and a web-based newsletter) to encourage collaboration when locations, program goals, and approaches are compatible; and a collaborative effort in the development of a statewide monitoring strategy. For example, the format for an annual coordination meeting might be similar to the annual academic research exchange that helped to coordinate monitoring and research efforts in the Chesapeake Bay region prior to the establishment of the coordinating Chesapeake Bay Program. In this case, each program would be provided time to describe proposed monitoring plans for the year with time provided to examine cooperative sampling opportunities, explore coordination issues and exchange contact information.

The meeting format might be similar to the annual academic research exchange that helped to coordinate monitoring and research efforts in the Chesapeake Bay region prior to the establishment of the coordinating Chesapeake Bay Program. In this case, each program would be provided time to describe proposed monitoring plans for the year with time provided to examine cooperative sampling opportunities, explore coordination issues and exchange contact information.

Monitoring Reports

There are a variety of ways that information about water monitoring activities in Maryland are disseminated to managers, funding agencies and other stakeholders (agencies, businesses, scientists, and the public - individuals, students, community groups, consultants, politicians). The reporting format and media used often are dictated by the perceived needs of the audience.

Funding agencies have specific reporting requirements spelled out in the contract that may include monthly or quarterly data submissions or activity reports, summary data and/or interpretive reports. Managers often need summaries of interpretive reports to develop/support or modify management actions. Some programs produce annual technical reports (e.g., Coastal Bays Program) or reports that

focus on specific watersheds (TMDL reports, MD Biological Stream Survey basin reports). For different audiences, less technical summary reports may be developed for more diverse readership (e.g., Chesapeake Bay Program State of the Bay report, State of the Streams report, Tributary Strategy annual reports). Some programs have regular newsletters (e.g., MD Biological Stream Survey) that are mailed to an open-ended mailing list. These general water quality reports and newsletters are widely distributed to the public through mailings, meetings and exhibitions.

Maryland has a State Depository Library system which collects, documents and distributes State agency reports among State Archives and selected library systems across the State. DNR has an Information Resource Center which serves as a library for the Department and serves the public as well. Long-term document storage is available via storage at Jessup (microfiche/document).
One modern format being used extensively to provide and distribute both general and technical information about water monitoring activities is through the Internet. All State agencies have World Wide Web sites that are accessible 24 hours a day, seven days a week. Local library systems across the State have public Internet access permitting anyone access to State information.
Both DNR and MDE have posted information about water monitoring programs on their Web sites (*www.dnr.state.md.us* and *www.mde.state.md.us*, respectively). Depending on the program, this information may include descriptive information about monitoring programs, contact information (telephone, e-mail), opportunities to access data in water monitoring databases or to access close to real-time data. Some Web pages provide summaries of water monitoring results (shellfish harvesting closures, Tributary Team water quality status and trends). Technical or educational reports may be posted and read on-line or downloaded. In the near future, more water monitoring information will be accessible on the Internet as Governor Glendening has mandated that State agencies post 80 percent of their reports on agency Web sites by 2004.

Planning

Within the federal Water Pollution Control Act amendments, Section 303(e) requires that each State develop a planning process document that describes the State's water quality management program. The US Environmental Protection Agency identifies two planning documents that help develop a planning framework (see below).

Continuing Planning Process (CPP)
This document, required by Section 303 of the federal Clean Water Act and produced by the Department of the Environment (MDE), describes the State's water quality management and planning processes. This report is periodically reviewed and updated.

Water Monitoring Strategy
This interagency document describes the State's water monitoring goals and objectives and provides a summary of State programs that exist or are needed to meet the State's resource management goals.

Each agency has an independent water monitoring planning process, where, among other aspects, the previous year's efforts are reviewed as are available financial resources, proposed costs for equipment, transportation, sampling, laboratory, and data management are evaluated. Evaluation of ambient, long-term monitoring programs have been quite detailed (e.g., Maryland Biological Stream Survey; Chesapeake Bay monitoring programs).

Quality assurance/quality control

All groups involved with water monitoring should have a quality assurance plan that addresses how they implement QA/QC activities. Overlapping layers of quality assurance and quality control (QA/QC) procedures within State agency monitoring programs help to ensure that water data collected in these programs is of the highest quality.

Reinforcing the importance of quality data, EPA requires that recipients of funds for work involving environmental data collection comply with the American National Standard ANSI/ASQC E4-1994, "*Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs*". As part of the monitoring planning process, EPA requires:

1. documentation of the State agency's quality management system, and
2. documentation of the application of quality assurance and quality control activities to a specific monitoring activity (Quality Assurance Project Plan).

Using guidance provided by the US Environmental Protection Agency (1999b), both the Department of the Environment and the Department of Natural Resources have developed and implemented agency-wide plans for water monitoring QA/QC processes (MD Dept. of the Environment, 1999b and MD Dept. Natural Resources, 1999, respectively). These documents describe each agency's Quality Management System that is designed to support the quality objectives of the organization. For the multi-jurisdictional Chesapeake Bay Program, a Quality Assurance Management Plan (Chesapeake Bay Program, 1999a) has been developed following guidelines for EPA programs.

Each water monitoring program funded by the US Environmental Protection Agency (EPA) is required to have an approved Quality Assurance (QA) Project Plan which defines the layout, problem description, data quality objectives, staff training needs, documentation, sample design and methods, sample handling and analytical methods, quality control, instrument calibration, data management, assessment and reporting, and data validation.

For each water monitoring program, an approved Quality Assurance Project Plan (QA Project Plan) to document the application of quality assurance and quality control activities must be in place before field sampling occurs. EPA provides guidance (1999a) for the content of these Plans which should define the layout, problem description, data quality objectives, staff training needs, documentation, sample design and methods, sample handling and analytical methods, quality control, instrument calibration, data management, assessment and reporting, and data validation for each program. Approval is required by the assigned agency QA Officer. For monitoring programs supported by EPA funds (including programs contracted outside of State agencies as well as monitoring efforts used to match EPA-funded projects), EPA's Regional QA Officer also must approve the monitoring plan. Water monitoring programs not funded through EPA still are encouraged to develop and use the QA Project Plan process to ensure that data generated are of the highest quality.

Each field operation or laboratory has QA/QC procedures which address aspects of training, vehicle operation, sample handling, custody processes, safety, data entry, and instrument operation. These issues are addressed in Standard Operating Procedure documents that are readily available to field/laboratory staff. Updates to these basic procedures usually are focused on modifications to sampling gear, handling and instrumentation, but new programs require development of new procedures or modifications to existing procedures and training and evaluation programs.

Resource management

Severe resource restrictions due to funding limitations affects personnel, transportation, equipment, laboratory, and/or data management which directly affects the ability of an agency to collect and process desired water monitoring samples and properly manage the information. The present solution is to examine monitoring priorities. If the priority is sufficiently high, resources may be temporarily shifted to accommodate another program, otherwise, the planned monitoring effort may be halted.

Identifying and scheduling water monitoring resources necessary to conduct each water monitoring program (manpower, equipment, transportation, laboratory and other contractors) is initiated by each agency's field monitoring units (DNR - principally the Monitoring and Non-Tidal Assessment Division and the MD Geological Survey; MDE - principally the Technical and Regulatory Services Administration). Resources for other water monitoring activities conducted by or on behalf of other State agency efforts (DNR - Chesapeake and Coastal Watershed Programs; MDE - Air, Water and Waste Management Administrations, Mining Program) are scheduled by the groups responsible for those efforts.

Resource sharing

Opportunities to "piggyback" sampling efforts onto another agency monitoring program sometimes can reduce apparent duplication and costs, but the effort needed to coordinate monitoring activities is considerable and requires each program to have built-in flexibility (excess time, space) - something that limited program funding does not allow. There are differences in program goals and framework (e.g., regulatory v. long-term ambient, event-based v. random or systematic, small-stream v large river scale) that reduce the applicability of one program's data to another's needs. Intense, event-related monitoring programs, such as the initial *Pfiesteria* monitoring program or Bay-wide or river sampling after flood events, often provide sufficient pressure to coordinate sampling and laboratory activities, but such events are difficult to plan. Because financial resources to support monitoring efforts are limited, there are few monitoring resources available for use by other monitoring agencies.

Volunteer monitoring

The role of volunteers or the use of data collected by volunteers in State water monitoring programs has been a subject of considerable debate. Some agency staff have actively worked to improve community and citizen volunteer water monitoring programs while results of these efforts have not been included or recognized in agency reports. Specific reasons vary, but inconsistent quality, differing conclusions, and lack of complete information have been chief issues. Continued discussions between agency staff and volunteer groups, demonstrations of successful relationships between local government agencies and community and citizen volunteers, volunteer participation in the Maryland Water Monitoring Council and on Tributary Strategy teams, and continued improvements in quality of volunteer-collected water information have made these issues less problematic. As a result, there are increasing opportunities for community groups and citizen volunteers to participate in State water monitoring issues.

In 1998, DNR received funds from federal nonpoint source management grant (Section 319) to hire a Volunteer Water Monitoring Coordinator. The purpose of the Coordinator is to:

1) improve efficiency and economy of gathering water monitoring data by incorporating volunteers into governmental programs,
2) assist citizen organizations in documenting the quality of their data for use by resource and regulatory managers,
3) facilitate the exchange of information among government programs and citizen monitoring organizations,
4) assist citizen organizations in establishing or improving their water monitoring programs, and
5) assess the needs of citizen monitoring organizations and address those needs.

Since that position was filled, these objectives have been met in a number of ways. A Stream Waders volunteer program was established within DNR in February 2000 and has trained over 200 volunteers in stream ecology and stream sampling methods. A document describing the criteria for the acceptance of external data for use by State programs and for minimum elements for the quality assurance plan is being developed. Information exchange and assistance have been

given through a listserver of citizen monitoring organizations, presentations and workshops for watershed organizations and Tributary Strategy Teams, and web pages for citizen monitoring information and for the Stream Waders program. The needs assessment has been accomplished through meetings with citizen monitoring organizations and through individual contact. The program will strive to improving the guidance document for data acceptance, provide more workshops for citizen monitors on assessment and program development through technical assistance given to individual organizations and through periodic meetings with representatives from citizen organizations.

Data management

Principal local, State and federal water monitoring agencies have developed individual data management processes and customized data systems to store and assess collected data. All of the data management processes include a suite of field and laboratory QA processes and controls (training, process audits, sample blanks, sample duplicates, sample spikes, laboratory splits). Although the individual tests may vary, details of these practices are provided in individual QA Project Plans and field and laboratory Standard Operating Procedures guidance.

Data storage systems vary as much as water monitoring programs and these data often are not directly accessible to outside users. For example, most Maryland water data are maintained in an ACCESS database format in network-isolated Departmental servers. A number of DNR and MDE water quality data files are maintained as SAS or EXCEL datasets on these servers, as well.

The US Environmental Protection Agency maintains extensive water quality datasets on their own systems; EPA's Chesapeake Bay Program uses the Chesapeake Information System and, on a national basis, water quality data are stored in EPA's (STORET) system. Many water quality datasets developed by the US Geological Survey are housed in their proprietary WATSTORE system.

Each data system has a quality control system developed to check for accuracy, outliers, and data entry errors. These systems permit limited access to make changes to the original datasets, usually record changes as they are made and ensure that periodic duplicate datasets are created and stored safely. These precautions ensure a modest level of security.

Data access/sharing

Although computers can rapidly manipulate large datasets, the use of unique software formats on various, isolated data systems makes it difficult to access or share available information. Often, security practices reduce direct access to government agency data. The increased use of the Internet to transfer data and the ability to mirror secure agency datasets to publicly-accessible servers to maintain security are helping to improve access to these data. A brief description of two principal water quality data systems follows.

Chesapeake Information System

Using a watershed approach to disperses available monitoring resources across the watershed - the larger the watershed, the more dispersed the resources. Even in smaller watersheds, the amount of water monitoring information that may be needed can overwhelm an agency's resources. In these cases, sharing monitoring data that is collected by different agencies can reduce costs, although efforts must be expended to address differences in program goals, sample designs, sampling protocols, quality assurance, data storage formats. Sharing information can be useful when management decisions are multidisciplinary, they require up-to-date information, require buy-in by others, when these decisions affect other organizations and the public and reduce resource needs (save money).

A large watershed, like the 64,000 square mile Chesapeake Bay watershed, includes areas in a number of States and across several federal regions and offices. No single agency could adequately address water monitoring needs in this watershed and, unless data from other programs are used, information from a basinwide monitoring effort would be diluted or only a limited portion of the watershed could be addressed. The US Environmental Protection Agency's Chesapeake Bay Program developed the Chesapeake Information Management System (CIMS) (http://www.chesapeakebay.net/cims/) to provide an organized, distributed library of information and tools designed to increase basin-wide public access to Chesapeake Bay information which serves as a model of data sharing.

CIMS addresses all types of Bay information ranging from press releases to documents to raw environmental monitoring data. CIMS also provides software and Internet-based 'tools' to help users find, retrieve and analyze these data including library tools for registering and searching for information, communication tools (e.g., Watershed Profiles and Bay Atlas), data access tools for retrieving selected sets of numerical data, and data analysis tools (e.g., Chesapeake Bay Interpolator and BayStats).

The principal audience for CIMS information includes anyone with an interest in current information about the health of the Chesapeake Bay, its rivers, and its plants and animals This audience includes citizens, students, local, state and federal agencies, and non-governmental groups. The benefits of CIMS include use of the Internet to provide instant desktop access, organization of information to help speed searches, eliminates duplicative data and information handling, improved data quality (the responsibility of the data provider), technical tools and support to users, and evolves quickly to be responsive to users' needs.

Internet sites in CIMS are maintained by CIMS Partners which include states, federal agencies, academic institutions, and participating advisory groups and commissions who signed a Memorandum of Agreement providing public access to their Chesapeake Bay watershed information. Information assembled by these partners use established policies, guidelines, and data dictionaries. Metadata about the data or documents are developed registered with CIMS using COMET (http://www.chesapeakebay.net/COMET) and the information is kept current through scheduled updates. CIMS' online databases include: water quality, modeling, GIS coverage, living resources (fisheries, benthic, plankton, Bay grasses), point sources, river flow, and citizen monitoring (http://www.chesapeakebay.net/data).

In Maryland, the Department of the Environment is a CIMS partner and provides links to data about the quality of the State's air, water, and land resources. The Department of Natural Resources also is a CIMS partner and provides numerous links to tidal and non-tidal water quality data sets, sediment monitoring programs data, Maryland Biological Stream Survey data, commercial fisheries data and juvenile striped bass data, as well as the integrated watershed analysis and management system. Other CIMS partners who may provide some water monitoring data in Maryland include:

- the Alliance for the Chesapeake Bay - will provide access to water quality data obtained from its citizen monitors from sites across the Chesapeake Bay region,
- the US Geological Survey - provides information on water resources, mapping, geology, biology, and ecology and other ongoing Chesapeake Bay watershed studies,
- the Susquehanna River Basin Commission - provides water quality data from the Susquehanna River Basin watershed, and
- Versar, Inc., - provides CIMS with current benthic monitoring data, summary reports, and background information collected as part of the State's Bay Benthic Monitoring Program.

The quality of data affects the conclusions developed from monitoring programs and may ultimately affect water quality decisions based on these data. Ensuring the reliability of water monitoring data requires use of quality assurance (QA) and quality control (QC) processes. These include: development of a programmatic QA program, implementation of appropriate QA/QC procedures in all aspects of field sampling/data collection, laboratory analysis of samples and data management.

STORET

Water monitoring data collected by State and local agencies under EPA-funded programs are submitted for inclusion into EPA's STORET (STOrage and RETrieval) system. Physicochemical data collected as part of the State's Chesapeake Bay Mainstem Bay Monitoring Program and the State's Basic Water Monitoring Program (CORE network) are routinely uploaded to STORET via the Chesapeake Bay Program. STORET has been undergoing a multi-year modernization process and is nearly complete. This upgrade will provide a more flexible system, including a more accessible interface, a microcomputer version, public access and ability for a wider to store data STORET data has been limited

Data requests/transfers

Public requests for water quality data collected by DNR or MDE are often routed to designated staff who determine the needed parameters (location, date range, . If the data are readily accessible from CIMS, staff usually refer the request to the interactive CIMS data retrieval page (http://www.chesapeakebay.net/cims/). If the request is more unusual or difficult or if there is no ready access to the Internet, the designated staff may need to create a retrieval program to extract needed data and/or deliver the data in an requested format. If the data request addresses information in another office or agency, the client is referred to the appropriate office or agency.

Both DNR and MDE handle hundreds of requests for water quality data or information from citizens, students, consultants and other government agencies. The central data retrieval process developed by CIMS has significantly reduced staff time needed to address these requests.

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PROGRAM EVALUATION

Although monitoring provides the evaluation information for management, research or education activities, the monitoring process requires evaluation in terms of its success (or lack thereof) and needs. It is the evaluation phase where having defined specific monitoring program goals and objectives early in planning process comes into play. If goals are easily measurable, the "success" of the program (i.e., goals are met) and the "needs" of the program (i.e., goals are not met) are clearly identified. Evaluating programs with goals that are not easily measured requires complex and subjective, rather than objective input. Improvements to monitoring programs which have no goals or objective measures may be shortchanged and the value of information from these efforts may be diminished.

From a management perspective, a "successful" monitoring/assessment program depends on the active incorporation of goal setting, having adequate resources to collect necessary data/information and the use of the collected information in the management (decision-making) process. Programs that do not have a management focus, however, also should be identified as "successful" providing that adequate monitoring data/information are collected and used within the framework provided by the programs' goals (US Environmental Protection Agency, 1998).

Monitoring Program Evaluation

Each water monitoring program is engaged in several levels of evaluation. On a continuing basis, the effort is evaluated by the program or contract manager, senior field and laboratory staff for issues that directly affect the monitoring process. Field and laboratory audits (including the use of duplicate, split, blank and spiked samples, inter-laboratory comparisons) are used in an effort to measure precision, reduce error and maintain the highest quality data. Changes in sampling site locations, field methods, laboratory procedures, and data recording/management may be necessary for a variety of reasons. Identified resource needs or modifications in effort are communicated to field and laboratory staff to evaluate potential changes in terms of safety and supporting resources, to update Standard Operating Procedures and QA Project Plans and to implement modifications, as needed. In some programs involving other agencies, modifications may need to be approved by a coordinating workgroup.

On an annual basis, each water monitoring program is evaluated by the program or contract manager in terms of how well it has met its principal goals. Program successes/failures and disposition of results need to be documented. This evaluation needs to be provided to agencies providing financial support and to higher management levels for evaluations related to agency priorities and budgeting.

Comparing results to program goals is not the only type of monitoring evaluation that occurs. Changes in sampling locations, field methods, laboratory procedures, and data recording/management may be made during the monitoring period or prior to the initial monitoring activity. More extensive changes may require meetings with or additional training for field, laboratory or data management personnel. Updating a monitoring program's QA Project Plans provides another level of evaluation. From a project perspective, this evaluation of monitoring process helps to define future resource needs.

To provide a consistent basis for measurement, some monitoring programs have identified subject areas or questions as evaluation criteria. These measures can supplement goal evaluation, help evaluate specific portions of monitoring programs and may be used for programs that may not have defined goals or specific project plans. Example lists of program criteria measures include bioassessment evaluation (US Environmental Protection Agency, 1998), Tributary Strategy programs (Chesapeake Bay Commission, date), areawide monitoring reviews (US Geological Survey, 1997).

Development of a goals process or an applicable Project Plan can reduce the need to develop evaluation criteria after the project is underway or completed.

Agency Program Evaluation

On an annual or biennial basis, staff from the US Environmental Protection Agency (EPA) Region III office provide a formal review of the principal State water monitoring programs. This review ensures that needed water information is being collected and utilized. Although this focus is on EPA-funded monitoring programs (e.g., Basic Water Monitoring Program, Chesapeake Bay Program, nonpoint source monitoring, ground water monitoring, discharge permit monitoring), all water monitoring activities are reviewed. Recommendations may be implemented or considered for future implementation depending on the complexity of proposed changes and availability of resources needed to implement suggested changes.

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ABBREVIATIONS/ACRONYMS

BMC ..... Baltimore Metropolitan Council
COG ..... Washington Metropolitan Council of Governments
DHMH ..... Maryland Department of Health and Mental Hygiene
DNR..... Maryland Department of Natural Resources
DQO ..... data quality objectives
EPA ..... US Environmental Protection Agency
ICPRB ..... Interstate Commission on the Potomac River Commission
ITFM ..... Intergovernmental Task Force on Monitoring Water Quality
(now *National Water Monitoring Council* - see below)
MDA ..... Maryland Department of Agriculture
MDE ..... Maryland Department of the Environment
MGS ..... Maryland Geological Survey (*MD Department of Natural Resources*)
MWMC ..... Maryland Water Monitoring Council
NBS ..... National Biological Survey (*US Dept. Interior, US Geological Survey*)
NOAA ..... National Oceanic and Atmospheric Administration
NPS ..... National Park Service (*US Department of the Interior*)
NWMC ..... National Water Monitoring Council
(*http://www.epa.gov/OWOW/monitor/council.html*)
QA ..... quality assurance
QC ..... quality control
SRBC ..... Susquehanna River Basin Commission
SWQAC ..... State Water Quality Advisory Committee
UMd ..... University of Maryland
USGS ..... US Geological Survey (*US Department of the Interior*)
WSSC ..... Washington Suburban Sanitary Commission