National Management Measures to Control Nonpoint Source Pollution from Urban Areas

Management Measure 12: Evaluate Program Effectiveness

November 2005

MANAGEMENT MEASURE 12
EVALUATE PROGRAM EFFECTIVENESS

12.1 Management Measure

Develop and implement a program to evaluate and improve the effectiveness of the urban runoff management program.

12.2 Management Measure Description and Selection

12.2.1 Description

The purposes of this management measure are to:

- Determine whether implementation of the runoff management program framework is protecting and/or improving water quality by evaluating management practices that are being used to meet Management Measure 1. If these practices aren't effective, improvements to the runoff management program framework should be implemented.

- Periodically reassess the watershed (see Management Measure 2) to determine whether water quality has improved or declined. Based on this assessment, each management measure should be reevaluated to determine whether additional practices should be implemented, if improvements should be made to existing practices, or if specific practices should be discontinued.

12.2.2 Management Measure Selection

This management measure was selected because runoff management programs need to be dynamic (i.e., they need to be periodically adjusted to respond to changing conditions and optimize program effectiveness and expenditures). Areas where program improvement is possible should be identified. Programs that are periodically reviewed and evaluated also are perceived as being more effective, and they will be more likely to receive the public and political support necessary to achieve success. The basic elements of a successful program evaluation are described in this management measure.

12.3 Management Practices

12.3.1 Assess the Runoff Management Program Framework

It is important for watershed managers to objectively assess the runoff management program framework to determine whether the goals of the Program Framework and Objectives Management Measure (Management Measure 1) are being met. This effort should be undertaken periodically to identify aspects of the program that need to be strengthened or revised. Each aspect of the program framework will require a different type of measurement. Watershed managers can choose from both qualitative and quantitative measures as indicators of program effectiveness, using the watershed baseline conditions as a point of reference (see Management Measure 2: Watershed Assessment). Quality assurance and quality control procedures should be followed regardless of whether qualitative or quantitative measures are used.

There are several factors that should be considered when designing an evaluation program. First, some urban management practices, or aspects of their implementation that can be analyzed, vary with time of year, phase of construction, or length of time after installation. Another consideration is that variables generally will not directly relate to management measure implementation, as most urban management measures are combinations of several management practices. Evaluation of management measure implementation, therefore, usually will be based on separate assessments of two or more management practices, and the implementation of each management practice will be based on a unique set of variables. Finally, it is very important to consider the purpose of the program when selecting the variables for which the information is collected.

EPA has developed the Web-based *Measurable Goals Guidance for Phase II MS4s* to assist small municipal separate storm sewer system (MS4) owners and operators in complying with the requirement to select measurable goals to evaluate the effectiveness of individual control measures and the storm water management program as a whole. Even though this document is intended for use by NPDES-permitted MS4 operators, it contains guidance valuable to any institution developing a storm water management program that includes management practices and methods for program evaluation. It includes examples of management practices with corresponding measurable goals and environmental indicators that can be used to document the effectiveness of both management practices and storm water programs. The guidance is available online at http://cfpub.epa.gov/npdes/stormwater/measurablegoals/index.cfm.

12.3.1.1 Qualitative measures

Urban runoff management programs can be evaluated using any number of qualitative measures, such as those presented by WMI (1997a):

- Project permit review times
- Frequency of inspections
- Evaluation by targeted groups
- Appearance of control practices on sites
- Response time for complaints
- Number of permits issued
- Number of individuals trained
- Recognition by others
- Enforcement actions taken
- Maintenance activities
- Reduced number of complaints

For example, Delaware uses the number of individuals attending training courses and receiving state certification as one measure of program success. In addition to monitoring water chemistry, sediments, and the biological community, Florida measures program success by the number of local government storm water utilities implemented, as well as the number of educational and public involvement activities.

Watershed managers can use a combination of measures to assess their program framework based on goals and priorities that were identified at the outset of program implementation. In addition to the qualitative measures listed above, watershed managers can track the implementation, operation, and maintenance of management practices as indicators of the success of a program framework. See Section 12.3.2 for a discussion of management practice tracking.

12.3.1.2 Quantitative measures

Another way for watershed managers to gauge the effectiveness of their runoff management program framework is to quantitatively determine if water quality or habitat has improved. Quantitative measures include:

- Chemical monitoring of practices
- Chemical monitoring of receiving waters
- Biological monitoring of receiving waters (bioassessments)
- Habitat assessments
- Stream flow monitoring
- Stream shoreline condition assessments
- Sediment monitoring (deposition, chemistry)
- Measuring the volume of material removed by street sweeping and catch basin cleaning
- Temperature monitoring

See the section 12.3.3, “Gauge Improvements in Water Quality Resulting from Management Practice Implementation” for a more thorough discussion of the different types of monitoring that can be used to gauge changes in water quality after practice implementation.

12.3.1.3 Quality assurance/quality control

An integral part of the design phase of any monitoring project is quality assurance/quality control (QA/QC). Development of a quality assurance project plan (QAPP) is the first step for incorporating QA/QC into a monitoring project. The QAPP is a critical document for the data collection effort inasmuch as it is used to integrate the technical and quality aspects of the planning, implementation, and assessment phases of the project. The QAPP documents how QA/QC elements will be implemented throughout a project’s life. It states expectations and requirements and provides procedures for data collection and data management that are specific to the project. Development and implementation of a QA/QC program, including preparation of a QAPP, can require up to 10 to 20 percent of project resources (Cross-Smiecinski and Stetzenback, 1994). A thorough discussion of QA/QC is provided in Chapter 5 of EPA’s *Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls* (USEPA, 1997).

12.3.2 Track Management Practice Implementation

Implementation monitoring can be used to determine the extent to which management measures and practices are implemented in accordance with relevant standards and specifications. This involves establishing a program that tracks either whether the practices have been implemented or whether management practices have been operating and maintained as designed. For example, some states and municipalities have developed programs that track and record septic tank maintenance or erosion and sediment control practices, or that inventory all runoff control structures.

It is not always possible to track the implementation of every management practice of interest. Sampling a subpopulation and extrapolating the findings to the entire population may be preferred due to time, funding, or personnel constraints. Lack of adequate legal authority may also hinder the collection of data sufficient to track management practice implementation. If an inventory of all management practices of interest is not possible, care should be taken to prepare a statistically valid sampling plan. The primary basis for selecting a design approach should be based on a careful review of study objectives and the pros and cons of each sampling method. An extensive discussion of the different sampling designs and methods for analysis can be found in *Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures: Urban* (USEPA, 2000), which is available on EPA's Nonpoint Source Web site at http://www.epa.gov/owow/nps/urban2.html. Below are several tools that can be used to track management practice implementation.

12.3.2.1 Track permits

States and local agencies employ a variety of legal mechanisms, including nuisance prohibitions, general water pollution discharge prohibitions, land use planning and regulation laws, building codes, health regulations, and criminal laws to regulate urban nonpoint source water pollution (Environmental Law Institute, 1997). Although not all pollutant-generating activities are covered by these mechanisms, they present opportunities for inventorying management practice implementation. Activities that are typically regulated in some manner include erosion and sediment control, onsite sewage disposal systems, runoff from development sites, construction activities, and industrial activities. A permitting system places on the applicant the burden of obtaining and supplying all necessary data and information to obtain the permit. Issuance of these permits encourages compliance with local laws and regulations in the construction and operation of management practices.

12.3.2.2 Use operation and maintenance records

In many instances, proper operation and maintenance of a management practice are as important as proper design and installation. Regular inspection of management practices can identify the need for repairs or retrofits in addition to identifying areas in the watershed that require additional management resources. If the right types of information are collected when a management practice is installed, it becomes much easier to track operation and maintenance activities and ascertain the cost and effectiveness of the practice.

12.3.2.3 Use geographic information systems

Geographic information systems (GISs) are useful tools for inventorying management practice implementation. A GIS can detect and track trends in management practice implementation, land treatment, changes in land use, and virtually any data related to management practices and water quality. Another advantage is the ability of a GIS to update information and integrate it with existing data in a timely manner. GISs allow watershed managers to do more than just manage information in a database—they are powerful analysis tools that can be used to design sampling protocols for tracking studies and help watershed managers analyze program effectiveness by integrating land treatment and water quality information.

12.3.2.4 Develop surveys

Surveys of property managers and developers can be used to collect background information about management practice implementation, such as:

- Type, number, and size of management practices installed
- Management practice location/watershed
- Land use (i.e., residential, commercial, industrial)
- Percent impervious area
- Inspection results
- Operation and maintenance practices

Maryland's GIS-Based Restoration Project Tracking Database

The Maryland Department of Natural Resources has developed a Restoration Project Tracking Database that provides a list of riparian forest buffer and stream restoration projects by watershed and county with details such as waterway; length, width, area, and other quantifiers as appropriate; and details about the project such as owner type, planting reason, year established or completed, and project components. These data can be displayed in tabular format and are linked on the Web site to an interactive GIS for the public and interested parties to browse (MDNR, 2004). The database can be accessed at http://dnrweb.dnr.state.md.us/watersheds/surf/tracking/track_map.htm.

Maryland also has a "BMP Tracking Reports" Web site (http://dnrweb.dnr.state.md.us/watersheds/surf/bmp/) that provides tributary-specific information regarding implementation of management practices. This information is used to help measure Maryland's progress in reducing nonpoint source pollution and meeting the goals of the Chesapeake Bay 2000 agreement. Users can choose a statewide management practice summary report or they can generate a report by tributary. They list 3 categories of practices: urban practices, resource protection and improvement practices, and agricultural practices. The data for each management practice type is summarized by year in units appropriate for the practice. For example, the urban practice "Erosion and Sediment Control" was implemented on 2,213 acres in 2000, 11,133 acres in 2001, and 10,442 acres in 2002. More information is provided for each practice, including a photo, a brief description, and general pollutant removal information for different land use applications (if the practice is applicable in multiple settings). The pollutant removal information is limited to nitrogen, phosphorus, and sediment.

To complete these efforts, Maryland DNR developed estimates from the Departments of Agriculture, Environment, and Natural Resources. This information was compiled from data received from volunteer groups and county, state, and federal reports provided to each department.

- Dates of management practice installation
- Design specifications
- Type of water body or area protected
- Previous management practices used
- Erosion and sediment control plans (for construction)
- Dates of plan preparation and revisions
- Date of initial plan implementation
- Total acreage under management
- Certification requirements

Watershed managers can use the information obtained from these surveys to identify locations for new management practices and to more closely examine practices used upstream of waters known to be degraded to determine if they are operating as designed or if they require redesign or maintenance.

12.3.2.5 Consider expert evaluations

Expert evaluations may be needed to augment or verify information provided in surveys. Experts are especially useful in determining the following:

- Proper design
- Proper installation
- Adequacy of operation and maintenance plans and activities
- Verification of conclusions derived from self-evaluations (i.e., an objective third party's review of data and reports)

Each of these tools can be used to help watershed managers locate management practices and identify those that are not performing as expected (i.e., not meeting the goals of the management measures). These tools can be used separately or in combination to obtain and organize management practice data and use it to better meet the goals of the management measures.

12.3.3 Gauge Improvements in Water Quality Resulting from Management Practice Implementation

Watershed managers can determine the effectiveness of the runoff program by monitoring changes in water quality after the management measures and practices are implemented. The most fundamental step in the development of a monitoring plan is to define the goals of the monitoring program. Monitoring goals are broad statements such as "to measure improvements in Elephant Butte Reservoir" or "to verify nutrient load reductions into the Chesapeake Bay." Designing a monitoring plan also includes selecting sampling variables, a sampling strategy, station locations, data analysis techniques, the length of the monitoring program, and the overall level of effort to be invested.

Once the monitoring goals have been established, existing data and constraints should be considered. A thorough review of literature pertaining to water quality studies previously conducted in the geographic region of interest should be completed before starting a new study.

The review should help determine whether existing data provide sufficient information to address the monitoring goals and what data gaps exist.

The next step should be to identify project constraints such as finances, staffing, and time. Clear and detailed information should be obtained on the time frame for management decisions, the amounts and types of data that must be collected, the level of effort required to collect them, and the equipment and personnel needed to conduct the monitoring. This will determine whether available personnel and budget are sufficient to implement or expand the monitoring program.

As with its design, the program's level of monitoring is largely determined when goals and objectives are set, although there is some flexibility for achieving most monitoring objectives. Watershed managers should determine the appropriate timeframe and geographic scope of the monitoring program based on program goals and objectives. For example, if the objective is to determine the effectiveness of a nutrient management program for reducing nutrient inputs to a downstream lake, monitoring a subwatershed for five years or longer might be necessary.

Watershed managers also need to determine the size of the watershed, because many have an influence on stream characteristics and water quality, and therefore on the complexity of the monitoring program design. These factors include drainage patterns, stream order, stream type, climate, number of landowners in the area, homogeneity of land uses, watershed geology, and geomorphology. An analysis of these considerations in combination with budgetary and time constraints will determine the exact nature of the monitoring program.

It is important to ensure that expectations for the monitoring program are realistic. Ward et al. (1990) identify the following key steps to ensure that policymakers and other stakeholders know the types of information that a monitoring program can produce:

- Perform a thorough review of the legal basis for the management effort and define the resulting implications for monitoring.
- Review the administrative structure and procedures developed from the law in order to define the information expectations of the management staff.
- Review the ability of the monitoring program to supply information.
- Formulate an information expectations report for the monitoring system.
- Present the information expectations report to all users of the information.
- Develop consensus as to an agreeable formulation of information expectations and related monitoring system design criteria.

The next task when developing a monitoring program plan is to set monitoring objectives, which are more specific statements than goals and can be used to complete the monitoring design process. The objectives must be detailed enough to allow the designer to define precisely what data will be gathered and how the resulting information will be used.

Another important aspect of setting up a monitoring and evaluation program is variable selection. Variables should be selected based on the monitoring objectives. For example, if a dissolved oxygen problem is suspected, then dissolved oxygen should be monitored in addition to biochemical oxygen demand, sediment oxygen demand, temperature, and nutrients. Surrogate measures can also be used to satisfy monitoring objectives. For example, if the objective is to monitor the condition of salmon spawning areas, surrogate measures are necessary because the condition of salmon spawning areas is a composite of many factors. Good surrogate variables would be stream bank undercut, embeddedness, and vegetative overhang (Platts et al., 1983). The corresponding surrogate goals could be to reduce cobble embeddedness and to increase vegetative overhang to appropriate levels for salmon spawning. Subsequent monitoring goals could be to document changes in cobble embeddedness and vegetative overhang.

Because there are numerous variables to choose from and monitoring budgets are limited, some method to prioritize variable selection is often necessary. Table 12.1 shows groups of variables and examples of each. When available, existing data should be used to guide variable selection. Further discussion on variable selection, prioritization, and optimization are provided by USDA (1996), MacDonald et al. (1991), and Sherwani and Moreau (1975). In some cases, optimal variable selection is not possible, which may be due to lack of local data. In such cases, the researcher might need to rely on professional judgement and the review of monitoring programs of similar nature and scope.

Table 12.1: Examples of variables that can be measured to assess changes in management practice implementation and water quality.

Variable Type	Examples
Physical and chemical water quality data	Flow (streams), temperature, transparency, suspended sediment, sedimentation transparency, suspended sediment, sedimentation rate, dissolved oxygen, pH, conductivity, alkalinity/acid neutralizing capacity (lakes), and nutrients.
Biological data	Bacteria, algal biomass, macrophyte biomass and location, macroinvertebrate and fish populations.
Precipitation data	Total rainfall, rainfall intensity, storm interval, and storm duration.
Land use data	Treatments applied to land, current and historical use of the land, spatial and temporal information on land use activities, and changes in land use made before and during a project.
Topographic data	Slope length, slope steepness, slope shape, channel slope, channel side slope.
Soil characteristics data	Hydrologic soil group, soil organic carbon content, depth to water, net recharge, aquifer media, and vadose zone characteristics.

Designing and implementing a monitoring program often requires an interdisciplinary approach that may require interagency coordination and input. In many cases, technical staff will need to integrate “new” monitoring with what is already being done to demonstrate to program managers that duplicate work is not proposed. The most effective way to achieve this goal is to bring all the involved agencies and other stakeholders in the monitoring effort together. One or more agencies should coordinate to clarify project roles and responsibilities. Agreements to participate can be formalized as commitments and specified in the quality assurance project plan.

Such coordinated cooperation permits each involved party to offer the results of its ongoing activities to the monitoring effort, lessens the burden on each participating agency, and may decrease overall project costs. For example, USGS might already have a tracking system for management practices, while other agencies, including the U.S. Fish and Wildlife Service and EPA, might have other ongoing monitoring programs. When multiple agencies are involved in the monitoring program, each can benefit from the others' efforts.

Two types of objectives will be discussed in this section: analyzing trends in water quality and measuring the effectiveness of management practices.

12.3.3.1 Conduct trend monitoring

Trend monitoring can be useful for determining whether there has been a change in the extent to which management measures and management practices are being implemented. Trend monitoring involves long-term tracking of changes in one or more parameters. Public attitudes, land use, and the use of various urban management practices are examples of parameters that could be measured with trend monitoring.

Isolating the impacts of either individual or sets of management measures and management practices on water quality also requires trend monitoring. Because trend monitoring involves measuring a change (or lack thereof) in some parameter over time, it is necessarily of longer duration and requires establishment of a baseline. Any changes in the measured parameter are then detected in reference to the baseline. Baseline monitoring requires ascertaining the existing conditions before some management action or change in land use occurs. Factors such as weather conditions should be considered if baseline monitoring is to be used as a reference point for trend analysis and management decisions. The ability to relate water quality changes to changes in land management depends on the quality and quantity of data collected on land management practices.

Public attitudes, land use, and the use of various urban management practices are examples of parameters that could be measured with trend monitoring. Isolating the impacts of management measures and management practices on water quality also requires trend monitoring. For example, an objective of trend analysis can be to answer the question, "Is water quality changing over time?"

12.3.3.2 Conduct effectiveness monitoring

Effectiveness monitoring involves evaluating individual management practices or groups of management practices to determine the extent of pollution control they provide. Monitoring for individual management practices can typically be conducted on a plot or field scale, whereas monitoring for management practice systems is usually conduced on a watershed scale. Studies of some individual practices can be conducted in a relatively short time (less than five years), while others might take longer. Evaluation of management practice systems is typically conducted over a long term (more than five years) because management practice implementation can take years to affect water quality. In fact, there may be a lag in response time that may be 10 to 20 years or longer. This type of monitoring is difficult due to the presence of pollutant reserves in soil and sediments, the effect of many land uses within a study area, the variety of approaches that landowners use to implement similar management practice systems, and the need to track land management as well as water quality and climatic variables.

A guidance manual describing protocols for monitoring the effectiveness of storm water management practices, *Urban Stormwater BMP Performance Monitoring*, is available for download in PDF format from the International Stormwater Best Management Practices Database Web site (http://www.bmpdatabase.org/docs/Urban Stormwater BMP Performance Monitoring.pdf). Along the same lines, EPA's Environmental Technology Verification Center offers the *Protocol for the Verification of Stormwater Source Area Treatment Technologies* (http://www.epa.gov/etv/pdfs/vp/04_vp_stormwater.pdf).

12.3.4 Develop and Implement a Schedule to Improve the Management Program Framework

Data on management practice effectiveness and water quality should be carefully reviewed to determine where deficiencies in the runoff management exist. Effectiveness monitoring results should be compared with expected values published in the literature or with values provided with proprietary products. If the system is underperforming, possible causes should be considered:

- Is the practice properly designed and sized?
- Are site conditions (geology, land use, etc.) inappropriate for this practice?
- Were maintenance activities not performed as scheduled or needed?
- Were influent pollutant concentrations different than expected?

The next step is to determine whether the management practice needs to be retrofitted, replaced, or removed. Is pretreatment needed? Should a treatment train approach be used? Should additional capacity be added? Should maintenance be scheduled more frequently? A plan should be developed to implement proposed changes on a practice-by-practice basis.

A review of monitoring data on ambient water quality should be conducted to determine if water quality is improving. Consideration should be given to activities or events that might have skewed results (i.e., flooding, drought, landslides, significant changes in surrounding land use). If water quality has not improved, the following questions should be asked:

- Are management practices not performing as well as they should be?
- Were the wrong practices selected?
- Are additional practices needed?

Monitoring data should be examined to determine which pollutants and sources (if known) are a problem, and additional activities to address these sources should be proposed.

Once a list of planned changes to the program has been compiled, each project should be prioritized. Projects that should receive a higher priority are those that are most likely to improve water quality, those that the community has shown support for or is likely to support, and those that are relatively straightforward or inexpensive to implement. Implementation of proposed projects should be completed before the next program evaluation (usually within five years).

12.4 Information Resources

Restoring Life in Running Waters: Better Biological Monitoring (Karr, 1998) describes how and why biological monitoring and multi-metric indices can be used to assess environmental degradation and how this information can be integrated into regulatory and policy decisions. This book can be purchased at bookstores or ordered from Island Press at http://www.islandpress.com/.

Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls, published by EPA's Office of Water in 1997, gives an overview of nonpoint source pollution and covers the development of a monitoring plan, data analysis, quality assurance/quality control, and biological monitoring. It can be ordered through EPA's National Service Center for Environmental Publications at http://www.epa.gov/ncepihom/index.htm.

Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures: Urban (USEPA, 1998) helps local officials to focus limited resources by establishing statistical sampling to assess, inspect, or evaluate a representative set of management practices, erosion and sediment controls, and onsite wastewater treatment systems. The document can be downloaded in PDF format at http://www.epa.gov/owow/nps/urban.pdf, or it can be ordered through EPA's National Service Center for Environmental Publications at http://www.epa.gov/ncepihom/index.htm.

EPA's Volunteer Monitoring Program provides technical assistance, serves as a regional contact for volunteer programs, manages grants to state agencies that organize volunteer monitoring programs, and provides information exchange services for volunteers. A listserver is available for volunteer monitoring program coordinators on the EPA Web site, http://www.epa.gov/owow/monitoring/volunteer. Also available are a national newsletter for volunteer monitors, a directory of volunteer monitoring programs, and manuals on volunteer monitoring methods and planning and implementing volunteer programs.

Urban Stormwater BMP Performance Monitoring: A Guidance Manual for Meeting the National Stormwater BMP Database Requirements presents monitoring protocols for studies measuring the effectiveness of storm water management practices and is available for download in PDF format from the International Stormwater Best Management Practices Database Web site (http://www.bmpdatabase.org/docs/Urban Stormwater BMP Performance Monitoring.pdf).

EPA's Environmental Technology Verification Center developed the *Protocol for the Verification of Stormwater Source Area Treatment Technologies* (http://www.epa.gov/etv/pdfs/vp/04_vp_stormwater.pdf), which establishes guidelines for measuring the effectiveness of storm water treatment technologies. The protocol was developed to ensure that technology verification studies are carried out in a consistent and objective manner that assesses the appropriate performance characteristics.

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