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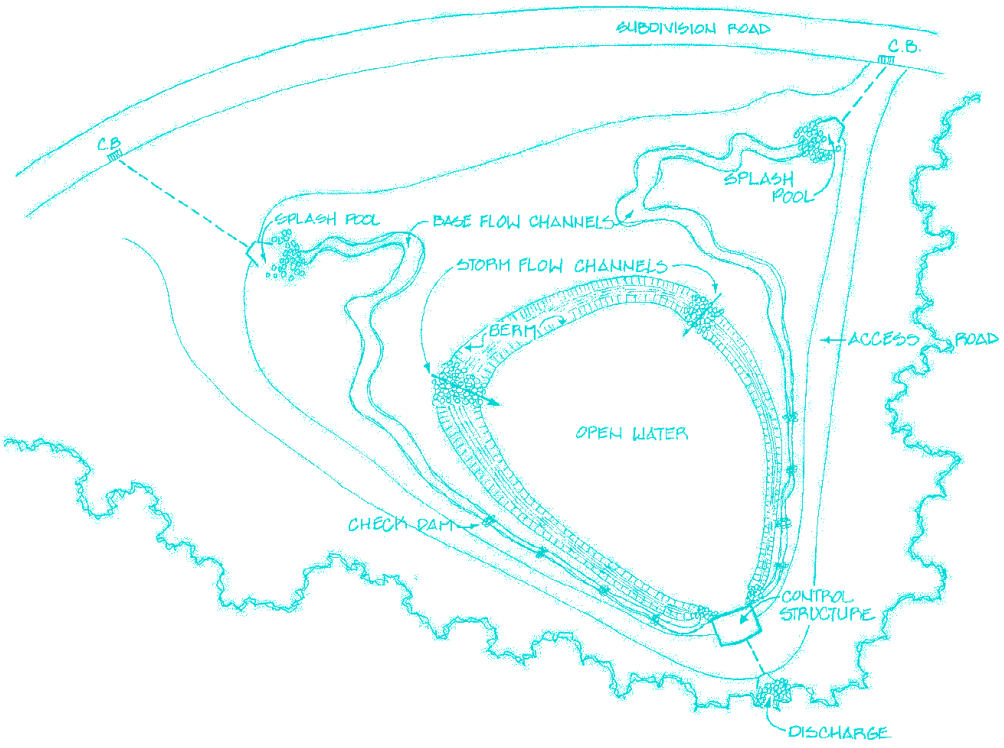
Preliminary Data Summary of Urban Storm Water Best Management Practices



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1.0 Summary

The significance of storm water runoff in affecting water quality in the United States has become an increasing concern in recent years, as further improvements are made in controlling other point sources such as municipal sewage and industrial waste. EPA conducted a broad analysis of storm water runoff characteristics in its *Nationwide Urban Runoff Program* between 1979 and 1983. During the 1980's the Agency made several attempts to promulgate regulatory controls for storm water runoff under the statutory framework of the 1972 Clean Water Act. Following enactment of the Water Quality Act of 1987, EPA began development of a more comprehensive regulatory program. During the course of these actions, the use of best management practices (BMPs) in addressing runoff problems was frequently identified, however it was known that additional research on the performance of BMPs was also needed.

EPA's Engineering and Analysis Division conducted a study on storm water best management practices during 1997 and 1998 as part of its series of preliminary studies in the effluent guidelines program. This report summarizes existing information and data regarding the effectiveness of BMPs to control and reduce pollutants in urban storm water. The report provides a synopsis of what is currently known about the expected costs and environmental benefits of BMPs, and identifies information gaps as well.

Detailed information about BMP design is beyond the scope of this report. Readers are encouraged to consult the wide range of storm water BMP design manuals available from states and localities and other organizations for detailed design guidelines. Information regarding BMP performance and selection is also provided in other EPA documents, such as *Guidance Specifying Management Measure for Sources of Nonpoint Source Pollution in Coastal Water* (US EPA, 1993a); *Urban Runoff Pollution Prevention and Control Planning* (US EPA, 1993c); and *Municipal Wastewater Management Fact Sheets: Storm Water Best Management Practices* (US EPA, 1996e). In addition, readers are encouraged to consult the ASCE/WEF Manuals of Practice, *Design and Construction of Urban Stormwater Management Systems* (ASCE/WEF, 1992) and *Urban Runoff Quality Management* (ASCE/WEF, 1998) for a more thorough discussion of storm water management design.

Summary of Findings

1. Waterways and receiving waters near urban and suburban areas are often adversely affected by urban storm water runoff. Impacts may be manifested in terms of:

- alterations in hydraulic characteristics of streams receiving runoff such as higher peak flow rates, increased frequency and duration of bankfull and sub-bankfull flows, increased occurrences of downstream flooding, and reduced baseflow levels

- changes in receiving stream morphology such as increased rates of sediment transport and deposition, increased shoreline erosion, stream channel widening, and increased stream bed scouring

- aquatic habitat impacts leading to changes in fish and macroinvertebrate populations and loss of sensitive species

- public health and recreation impacts such as increased risk of illness due to contact with contaminated water bodies, contamination of drinking water supplies, beach closures, restrictions on fishing, and shellfish bed closures.

2. A wide variety of BMPs, both structural and non-structural, are available to address urban storm water runoff and discharges.

- For various reasons (such as cost, suitability to site, etc.) some of these BMP types are widely used, some infrequently; some are relatively new designs that are not widely in use.

- Many BMPs are used primarily for water quantity control (i.e. to prevent flooding), although they may provide ancillary water quality benefits.

- Some BMP types have been analyzed for performance in terms of site-specific pollutant removal, although not extensively enough to allow for generalizations.

- The pollutant removal performance of some BMP types is essentially undocumented.

- Some BMP types, particularly non-structural and those that do not have discrete inflow or outflow points, are difficult to monitor.

- There is no widely-accepted definition of "efficiency" or "pollutant removal" for storm water BMPs.

- The role of chemical pollutant monitoring vs. receiving stream biological monitoring in evaluating BMP performance is not well documented.

3. Only a few cost studies have been conducted for storm water BMPs.

- Due to the limited cost data, a lack of clear definitions of performance, and limited "performance" data, it is difficult at this time to develop cost-effectiveness comparisons for various BMP types.

4. The benefits of individual BMPs are site-specific and depend on a number of factors including:

- the number, intensity and duration of wet weather events;
- the pollutant removal efficiency of the BMP;
- the water quality and physical conditions of the receiving waters;
- the current and potential use of the receiving waters; and
- the existence of nearby "substitute" sites of unimpaired waters.

Because these factors will vary substantially from site to site, data are not available with which to develop estimates of benefits for individual BMP types.

5. A number of researchers are continuing to work on BMP performance monitoring, and there are several attempts underway to develop comparison frameworks through the construction of comprehensive databases on BMP design characteristics and performance.

Organization of Report

This report is divided into six chapters. Chapter 1 presents a summary of the major findings of the report. Chapter 2 presents a general introduction of the purposes and goals of this evaluation. Chapter 3 summarizes existing regulations and permits developed by EPA to address urban storm water discharges, including regulations under the National Pollutant Discharge Elimination System (NPDES) and the Coastal Zone Act Reauthorization Amendments (CZARA). Chapter 4 presents an assessment of the environmental problems attributable to urban storm water discharges and Chapter 5 identifies the best management practices that can be used to control the quantity and improve the quality of storm water prior to discharge. Chapter 6 identifies the costs and benefits of storm water BMPs.

2.0 Introduction and Scope

2.1 Effluent Guidelines Program and Consent Decree Requirements

Effluent guidelines are national standards for categories of dischargers to surface waters. The program was established in 1972 under Title III of the Clean Water Act (CWA). Since that time EPA has developed effluent guideline regulations for over 50 categories, primarily industrial dischargers. In these regulations the Agency typically establishes numeric "end-of-pipe" effluent limitations for specific chemical pollutants and/or indicator parameters (e.g. BOD, oil and grease). For some categories, EPA has also issued narrative requirements for best management practices (BMPs) to address control of storm water runoff, plant maintenance schedules and training of plant personnel. The effluent limitations are generally based on the performance of available or demonstrated control and treatment technologies. Resulting effluent limitations are commonly referred to as "technology-based" standards. The regulations are implemented in National Pollutant Discharge Elimination System (NPDES) permits, which are issued by EPA and State agencies under the authority of CWA Section 402.

The Water Quality Act of 1987 added section 304(m) to the CWA. This provision requires EPA to publish a biennial Effluent Guidelines Plan and develop additional regulations. EPA's effluent guidelines program is currently subject to a consent decree ("Decree") in *Natural Resources Defense Council et al v. Browner* (D.D.C. 89-2980, January 31, 1992, as amended). The Decree requires the Agency to propose effluent guideline regulations and take final action for 20 point source categories, according to a specified schedule. Additionally, the Decree requires that the Agency conduct 11 preliminary studies to assist in selecting categories for regulation development.

The 1987 amendments also added section 402(p) to the CWA, which requires development of a national program for regulation of storm water discharges. This is discussed further in Chapter 3 of this report.

In 1996, the Natural Resources Defense Council (NRDC) recommended that EPA develop effluent guidelines for categories of storm water dischargers, to supplement the existing NPDES permit regulations covering storm water discharges. Because municipal storm water discharges present a range of complex phenomena that have not been extensively documented in the professional literature, and because there is a lack of generally accepted methods for evaluating storm water management practices, EPA determined that conducting a preliminary study would be appropriate to satisfy one of the study obligations under the Decree. This preliminary study is intended to assist decision making on initiating regulatory development projects.

2.2 Types of Discharges Addressed

This study is focused on BMPs designed to prevent, control or treat storm water discharges, and the nature and measurement of storm water discharges. Storm water discharges may flow directly into surface waters, into municipal separate storm sewer systems ("MS4s"), and/or infiltrate into groundwater. The emphasis on BMPs is intended to support the national NPDES storm water program. Some aspects of the BMPs described herein may also be relevant for other types of wet weather pollution problems, such as combined sewer overflows (CSOs).

Storm water BMPs may be organized into two major groups with multiple subgroups:

- *Structural* BMPs include:
  - infiltration systems such as infiltration basins and porous pavement
  - detention systems such as basins and underground vaults
  - retention systems such as wet ponds
  - constructed wetland systems
  - filtration systems such as media filters and bioretention systems
  - vegetated systems such as grass filter strips and vegetated swales
  - minimizing directly-connected impervious surfaces
  - miscellaneous and vendor-supplied systems such as oil/water separators and hydrodynamic devices

- *Non-Structural* BMPs include:
  - automotive product and household hazardous material disposal
  - commercial and retail space good housekeeping
  - industrial good housekeeping
  - modified use of fertilizers, pesticides and herbicides
  - lawn debris management
  - animal waste disposal
  - maintenance practices such as catch basin cleaning, street and parking lot sweeping, road and ditch maintenance
  - illicit discharge detection and elimination
  - educational and outreach programs
  - storm drain inlet stenciling
  - low-impact development and land use planning.

The impacts of storm water discharges are described in Chapter 4. Various BMP designs for addressing storm water discharges are described in Chapter 5, and the costs and economic impacts of BMP are described in Chapter 6.

2.3 Data Sources and Data Collection Techniques

ASCE National Stormwater BMP Database

Since 1995, EPA and the American Society of Civil Engineers (ASCE) have operated under a cooperative agreement to develop a database of storm water BMP design and performance. The initial version of this database provides pollutant removal data and other performance measures on approximately 75 BMPs based on published studies and reports. These studies and reports were carefully selected from a comprehensive screening of virtually all available published literature on BMP performance, amounting to about 800 bibliographic references.

A significant objective of the database is to provide a design tool for local storm water designers and planners. The database has the capacity to report extensive detail about the design of BMPs, along with descriptive information about the adjacent watershed, hydrology and other geographic data.

As of early 1999, the initial version of the database is being tested, and a public release will be available in mid-1999. EPA and ASCE are continuing to develop the database and are encouraging organizations that have conducted BMP monitoring to submit their findings to the ASCE Database Clearinghouse for entry into the database. As new data are gathered, periodic updates will be made available to the public through use of the Internet.

Center for Watershed Protection National Pollutant Removal Performance Database

In 1997, the Center for Watershed Protection developed a database for the Chesapeake Research Consortium titled, "National Pollutant Removal Performance Database for Stormwater BMPs" (Brown and Schueler, 1997a). This database focuses on the pollutant removal efficiency of commonly used and innovative urban BMPs for storm water control. The database is derived from 123 research studies developed between 1977 and 1996.

All of the studies in the database utilized data collected with automated sampling equipment and had documented methods to compute pollutant removal efficiencies. More than three-quarters of the studies were based on four or more storm samples, while the remaining studies were either based on fewer than four storms or the sample size was not stated.

Literature Cited

- EPA reports including the Nationwide Urban Runoff Program (NURP), National Water Quality Inventory, Coastal Nonpoint Pollution Program Guidance, NPDES Rules, guidance documents and fact sheets.

- Other Federal agency publications from U.S. Geological Survey and U.S. Department of Agriculture.
- Professional journals and manuals of practice such as those from ASCE and the Water Environment Federation
- Publications of research organizations such as the Center for Watershed Protection, Terrene Institute, Metropolitan Washington Council of Governments and the Watershed Management Institute
- State and local government BMP design manuals.

BMP Performance Data Developed for this Preliminary Study

EPA conducted field performance evaluations at three structural BMP sites during 1998. While these evaluations contribute to the literature on BMP performance, EPA also intended that the field testing would serve as an experimental framework for refining evaluation methodology. Three sites in the Washington, D.C. area were monitored: a constructed wetland, a peat-sand filter, and a regional wet pond. Data summaries for these monitoring activities appear in Chapter 5. Additional findings will be provided in a supplement to this report.

3.0 Existing Storm Water Regulations and Permits

Congress added Section 402(p) to the Clean Water Act in 1987 to require implementation of a comprehensive approach for addressing storm water discharges in two phases. Section 402(p)(4) required EPA to develop permit application regulations under the National Pollutant Discharge Elimination System (NPDES), submission of NPDES permit applications, issuance of NPDES permits, and compliance with NPDES permit conditions. Section 402(p)(6) requires EPA to designate storm water discharges to be regulated (within the statutory definitions provided in section 402(p)(2)) and establish a comprehensive regulatory program, which may include performance standards, guidelines, guidance, and management practices and treatment requirements.

3.1 Phase I NPDES

EPA promulgated the first phase of NPDES storm water permit application regulations ("Phase I") on November 16, 1990 (US EPA, 1990). The provisions addressing MS4s cover those systems serving a population of 100,000 or more. This includes 173 cities, 47 counties and additional systems designated by EPA or states based on such system's interrelationship with or proximity to the aforementioned systems, such as state highway departments. A total of 260 permits, covering approximately 880 operators (local governments, state highway departments, etc.) have been identified as subject to Phase I permit application requirements. As of late 1998, approximately 228 such permits have been issued in final form.

The CWA requires that MS4 permits effectively prohibit non-storm water discharges into the storm sewers as well as reduce the discharge of pollutants to the maximum extent practicable (including management practices, control techniques and system, design and engineering methods, and other provisions appropriate for the control of such pollutants).

Phase I MS4 permittees were required to submit an application that included source identification information, precipitation data, existing data on the volume and quality of storm water discharges, a list of receiving water bodies and existing information on impacts on receiving waters, a field screening analysis for illicit connections and illegal dumping, and other information.

Following this submission, MS4 permittees were to gather and provide additional information including:

- discharge characterization data based on quantitative data from 5 to 10 representative locations in approved sampling plans; estimates of the annual pollutant load and event mean concentration of system discharges for selected conventional pollutants and heavy metals; a proposed schedule to provide estimates of seasonal pollutant loads; and the mean concentration for certain detected constituents in a representative storm event;

- a proposed management program including descriptions of: structural and source control measures that are to be implemented to reduce pollutants in runoff from commercial and residential areas; a program to detect and remove illicit discharges; and a program to control pollutants in construction site runoff.

The Phase I rule also covers storm water discharges "associated with industrial activity." This includes facilities covered by effluent guidelines and other designated classes of industrial and commercial facilities, such as hazardous waste treatment, storage, or disposal; landfills; recycling; vehicle maintenance and equipment cleaning; sewage sludge handling; construction activity (sites with 5 or more acres of disturbed land); and facilities where materials are exposed to storm water. Permittees must prepare a storm water pollution prevention plan which describes pollution sources, measures and controls.

EPA and the states used several permit mechanisms for the many facilities receiving NPDES permits for the first time. EPA issued "baseline" general permits to cover a wide range of facilities with basic requirements, with the intent that more specific requirements would follow in subsequent permit cycles. Industry-specific or "group" permits were issued based on applications submitted by business associations, and other sites were issued individual permits.

The management and pollution prevention plans prepared by MS4s and industrial permittees vary in their level of detail and specificity regarding design and implementation of best management practices (BMPs). EPA and some states have issued guidance on preparation of these plans (US EPA, 1992d; US EPA, 1992e). The Agency has not conducted a nationwide review of these plans.

3.2 Phase II NPDES

EPA proposed the NPDES storm water regulations for the second phase of storm water discharge control (“Phase II”) on January 9, 1998 (US EPA, 1998c). EPA is required to promulgate the Phase II rule in 1999 under a separate consent decree.

The proposal designates two classes of facilities for automatic coverage on a nationwide basis under the NPDES program, (1) small municipal separate storm sewer systems located in urbanized areas (about 3,500 municipalities would be included in the program); and (2) construction activities (pollutants include sediments and erosion from these sites) that disturb equal to or greater than one and less than five acres of land (about 110,000 sites per year will be included in the program). Those facilities designated above would need to apply for NPDES storm water permits by 2002. EPA is anticipating that most permittees would be covered under general permits.

EPA is also proposing to conditionally exclude from the NPDES storm water program Phase I facilities that have "no exposure" of industrial activities, such as industrial products,

processes, or raw materials, to storm water, thereby reducing application of the program to many industrial activities currently covered by the program that have no industrial storm water discharges.

Some facilities that EPA is proposing to cover under the Phase II rule are currently subject to state and/or local storm water management requirements.

3.3 Coastal Zone Act Requirements

Section 6217 of the Coastal Zone Act Reauthorization Amendments (CZARA) of 1990 provides that States with approved coastal zone management programs must develop and submit coastal nonpoint pollution control programs to EPA and the National Oceanic and Atmospheric Administration (NOAA) for approval. Failure to submit an approvable program would result in a reduction of federal grants to such states under both the Coastal Zone Management Act and section 319 of the CWA.

State coastal nonpoint pollution control programs under CZARA are to include enforceable policies and mechanisms that ensure implementation of the management measures throughout the coastal management area. Section 6217(g)(5) defines management measures as "economically achievable measures for the control of the addition of pollutants from existing and new categories and classes of nonpoint sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint pollution control practices, technologies, processes, siting criteria, operating methods, or other alternatives." The amendments provide for a technology-based approach based on technical and economic achievability under the rationale that neither States nor EPA have the money, time, or other resources to create and expeditiously implement a program that depends on establishing cause and effect linkages between particular land use activities and specific water quality problems. If this technology-based approach fails to achieve and maintain applicable water quality standards and to protect designated uses, sec. 6217(b)(3) requires additional management measures.

EPA issued *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* under sec. 6217(g) in January 1993 (US EPA, 1993a). The guidance identifies management measures for five major categories of nonpoint source pollution: agriculture; forestry; urban; marinas and recreational boating; and hydromodification. The management measures reflect the greatest degree of pollutant reduction that is economically achievable for each of the listed sources. These management measures provide reference standards for the states to use in developing or refining their coastal nonpoint programs. In general, the management measures were written to describe systems designed to reduce the generation of pollutants. A few management measures, however, contain quantitative standards that specify pollutant loading reductions. For example, the new development management measure, which is applicable to storm water runoff associated with construction in urban areas,

requires (1) that by design or performance the average annual total suspended solid loadings be reduced by 80 percent and (2) to the extent practicable, that the pre-development peak runoff rate and average volume be maintained. The management measures approach was adopted to provide state officials with flexibility in selecting strategies and management systems and practices that are appropriate for regional or local conditions, provided that equivalent or higher levels of pollutant control are achieved.

Storm water discharges regulated under the existing NPDES program, such as discharges from municipal separate storm sewers serving a population of 100,000 or more and from construction activities that disturb 5 or more acres, do not need to be addressed in Coastal Nonpoint Pollution Control programs. However, potential new sources, such as urban development adjacent to or surrounding municipal systems serving a population of 100,000 or more, smaller urbanized areas, and construction sites that disturb less than 5 acres, that are identified in management measures under section 6217 guidance need to be addressed in Coastal Nonpoint Pollution Control Programs until such discharges are issued an NPDES permit. EPA and NOAA have worked and continue to work together in their activities to ensure that authorities between NPDES and CZARA do not overlap.

EPA and NOAA published *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance* (US EPA, 1993d), which addresses such issues as the basis and process for EPA/NOAA approval of State Coastal Nonpoint Pollution Control programs, how EPA and NOAA expect state programs to implement management measures in conformity with EPA guidance, and procedures for reviewing and modifying state coastal boundaries to meet program requirements. The document clarifies that states generally must implement management measures for each source category identified in the EPA guidance developed under section 6217(g). The document also sets quantitative performance standards for some measures. Coastal Nonpoint Pollution Control programs are not required to address sources that are clearly regulated under the NPDES program as point source discharges. Specifically, such programs would not need to address small municipal separate storm sewer systems and construction sites covered under NPDES storm water permits (both general and individual). The guidance also clarifies that regulatory and non-regulatory mechanisms may be used to meet the requirement for enforceable policies and mechanisms, provided that non-regulatory approaches are backed by enforceable state authority ensuring that the management measures will be implemented. Backup authority may include sunset provisions for incentive programs. For example, a state may provide additional incentives if too few owners or operators participate in a tax incentive program or develop mandatory requirements to achieve the necessary implementation of management measures.

3.4 Regional, State and Local Programs

In addition to the existing Federal storm water management programs, there are a variety of State, local and regional storm water management programs in existence. Many of these

programs pre-date the Federal programs and may include BMP design or performance standards, site plan review and inspection programs, and technical assistance. A review of these programs is outside the scope of this report.