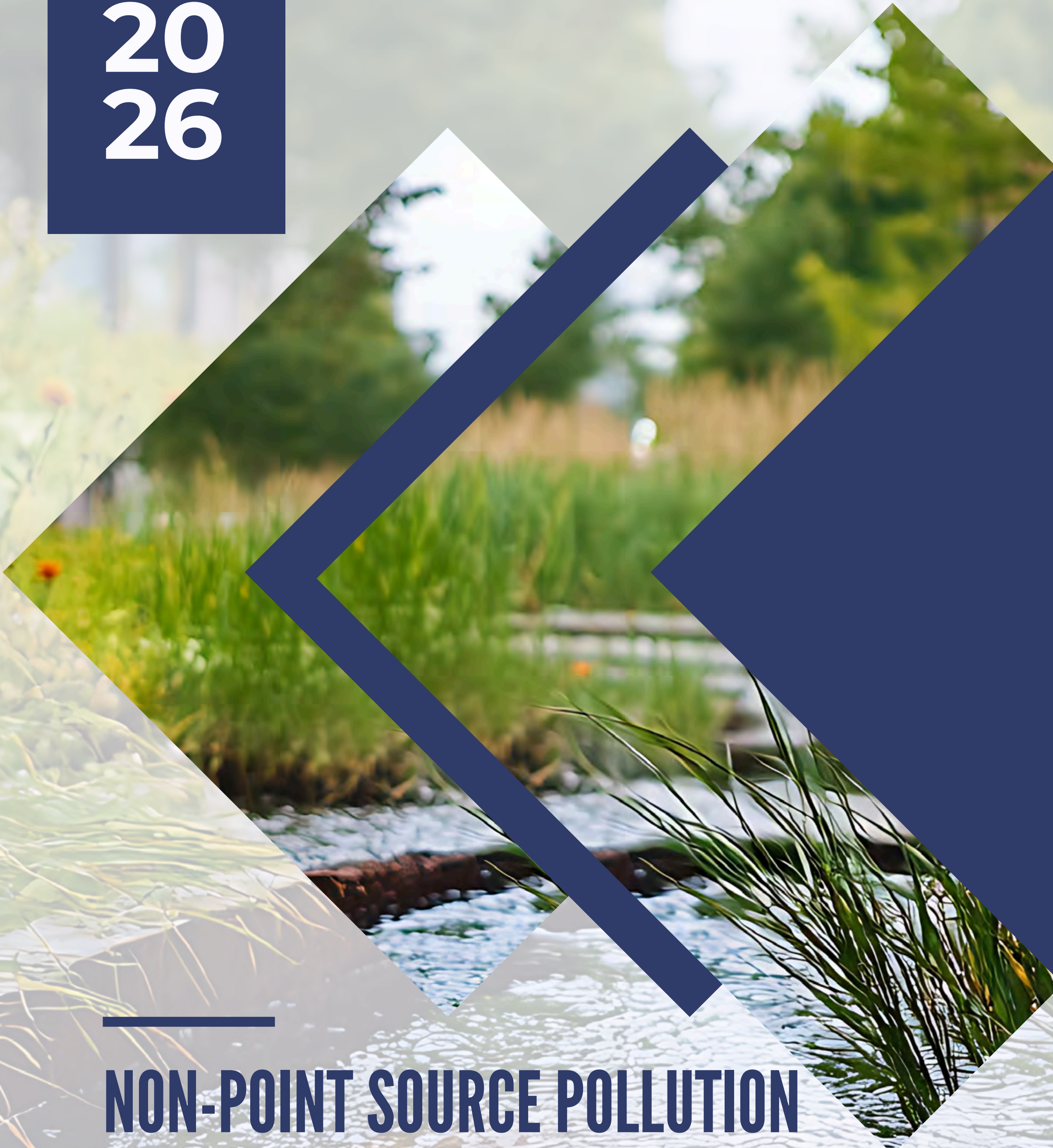
NCF- ENVIROTHON MISSISSIPPI

CURRENT ENVIRONMENTAL ISSUE

2026



NON-POINT SOURCE POLLUTION MITIGATION - IT BEGINS AT HOME!

STUDY RESOURCES

PART B

Current Issue Study Resources – Part B

Non-Point Source Pollution: It Begins at Home

Table of Contents

Assessment of NPS Pollutants of Concern in Surface Waters (Water Quality Monitoring)	How do we measure water quality—and what does it tell us? Introduces core physical, chemical, and biological indicators used to assess surface waters and detect nonpoint source pollution. Builds skills in interpreting monitoring data, understanding baseline conditions, and evaluating change over time in relation to watershed health and designated uses.
Watershed Planning	How do we plan at the watershed scale—and what constraints must we consider? Examines watershed-based planning approaches used to address nonpoint source pollution. Highlights how land use decisions, trade-offs, and practical limitations influence the selection of BMPs and the achievement of realistic environmental outcomes.
Low-Impact Development (LID) and Best Management Practices	How can design reduce runoff and pollution before problems begin? Focuses on low-impact development and green infrastructure strategies used to manage stormwater in developed landscapes. Compares BMPs across residential, recreational, and commercial settings while reinforcing connections to infiltration, evapotranspiration, and baseflow protection.
Community Engagement & Watershed Stewardship	Who protects water resources—and how do people drive change? Highlights the role of residents, organizations, and communities in addressing nonpoint source pollution. Explores education, outreach, and monitoring strategies that encourage BMP adoption, shared responsibility, and long-term watershed stewardship. Emphasizes shared responsibility and the behavioral and social drivers of water quality outcomes.

Any hyperlinks included in the study resources, apart from those explicitly listed as Resources on the Key Topics page and featuring a dedicated page in the resources (such as YouTube videos), are considered supplemental material ONLY. While they can provide extra information, they are not mandatory study resources.

NCF-Envirothon 2026 Mississippi

Current Issues: Part B Study Resources

Key Topic #1: Assessment of NPS Pollutants of Concern in Surface Waters – Water Quality Monitoring

1. Identify key parameters used to assess surface water quality and detect NPS pollution (e.g., turbidity, nutrients, bacteria, DO, temperature).
2. Explain the purpose and application of a monitoring and evaluation plan, including baseline data and post-development tracking.
3. Recognize the importance of designated use and how water quality is measured against it.
4. Interpret data results in the context of watershed health and designated uses.

Resource Title	Source	Located on Page
Managing Stormwater for Healthy Watersheds in Coastal Mississippi: Best Practices: Section 1	*Mississippi Department of Environmental Quality. (2023). Managing stormwater for healthy watersheds in coastal Mississippi: best practices. MDEQ.*	4
Mississippi Surface Monitoring Program | Element 4: Core and Supplemental Indicators	*Mississippi Department of Environmental Quality. (2022). Mississippi Surface Water Monitoring Program Strategy 2022-2025. MDEQ.*	10
Mississippi Nonpoint Source Pollution Water Management Program Overview	*Mississippi Department of Environmental Quality. (n.d.) MDEQ*	11

1. Introduction

Protecting and conserving the quality of Mississippi's water resources is critical to ensuring a healthy environment and a thriving, productive economy. As is common to coastal watersheds nationwide, there are constant challenges to sustaining the quality of surface water and groundwater resources that support a variety of uses, such as drinking water supplies, commercial and recreation fishing, and swimming. Mississippi is fortunate to have an abundance of water resources, but the demands of communities and urban development are evolving and increasing. As landscapes are developed and populations grow, work must be done to mitigate the impact of these changes on the environment.

Stormwater runoff from urban areas can be a significant contributor of pollution in developed and developing watersheds. The purpose of this guidance manual is to provide information to communities in coastal Mississippi on protecting water quality by managing stormwater runoff from new and existing development. This document provides information for public officials, local program staff, developers, and engineers in counties and communities in coastal and near-coastal watersheds, particularly in areas not regulated by the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit program. Use of this guidance manual does not replace regulatory requirements. Section 404 of the Clean Water Act (CWA) and other federal, state, and local regulatory requirements still apply.

Watershed: A geographical area that drains to a specified point on a water course, usually a confluence of streams or rivers. Also known as drainage area, catchment, or river basin.

This guidance focuses on coastal and near-coastal watersheds located in southern Mississippi (**Figure 1-1**). These watersheds compose the majority of the lands in Hancock, Harrison, Jackson, George, Marion, and Pearl River counties as well as smaller portions of Lamar, Stone, and Walthall counties (**Figure 1-2**). Hancock, Harrison, Jackson, and Lamar counties are subject to NPDES permits under the MS4 program and, therefore, have plans that have been developed specifically to address stormwater planning and mitigation needs. These counties have the largest populations and the most significant impacts from development occurring on the land (MDMR and MDEQ 2020). For counties not currently covered by requirements under the MS4 permit program, the recommendations from this guidance document along with county and/or local requirements and/or ordinances should be used to address the environmental impacts associated with development.

Figure 1-1. Saint Martin Bayou. (Photo: James Starnes, MDEQ)

Communities can use sections of the guidance manual or the entire manual as a guide to managing stormwater for new developments, including residential, commercial, and office developments as well as for redevelopment projects that add impervious cover. Impervious cover is any man-made surface that inhibits the ability of rainwater to be absorbed naturally into the ground, thereby increasing surface runoff. Emphasis is placed on sustainable and resilient development design approaches that reduce the environmental impact while retaining and enhancing the overall purpose of the development. The guidance also includes information related to protecting water quality during construction and identifying stormwater performance objectives, design approaches for new development, and how to incorporate sustainable and resilient designs into areas that are already developed.

1.1. Surface Water Quality

Mississippi has approximately 758 square miles of estuaries with around 84 miles of coastline (**Figure 1-3**). Some of the larger estuaries include St. Louis Bay, Back Bay of Biloxi, Pascagoula Bay, and Mississippi Sound with the state boundary extending three miles south of the Barrier Islands into the Gulf of Mexico (MDEQ 2020). Water quality along Mississippi's coastline and in tidal streams, bays, and estuaries is directly influenced by the quality and volume of fresh water draining from upland areas. Fresh water flowing into the coastal and marine ecosystems is provided by streams, rivers, groundwater, and stormwater runoff. Therefore, to ensure good water quality along Mississippi's beaches and in estuaries, it is critical to protect the integrity and health of water resources in the upper parts of the watershed.

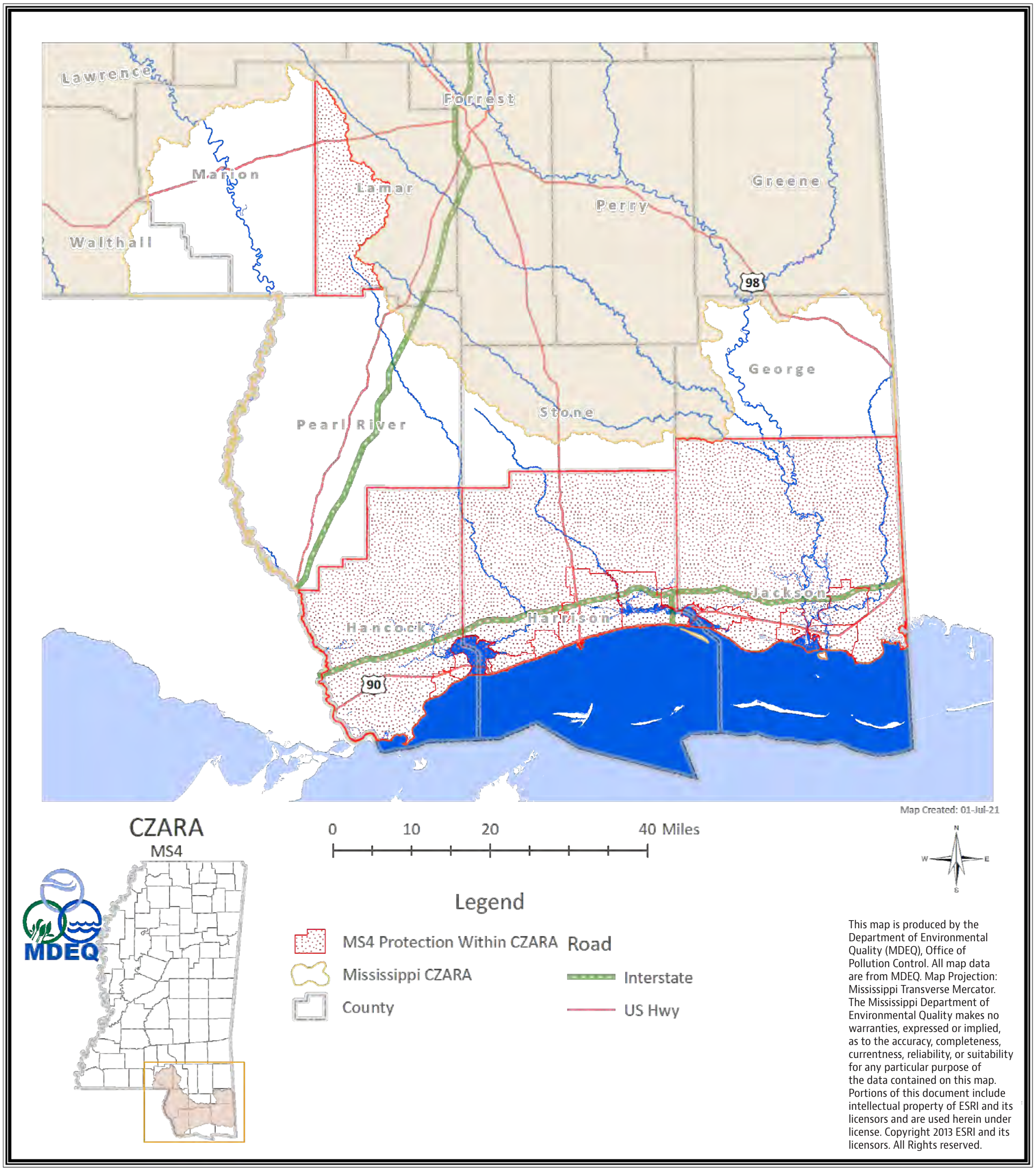


Figure 1-2. **Mississippi's coastal watersheds include portions of nine counties, four of which are covered by the NPDES MS4 program.**

Figure 1-3. Mississippi coastline. (Photo: James Starnes, MDEQ)

Water quality can be influenced by a wide array of pollutants, originating from both "point" and "nonpoint" sources of pollution. Point sources of pollution are from a single point or a discrete pipe such as a municipal wastewater treatment plant. Nonpoint source (NPS) pollution originates from diffuse sources primarily associated with stormwater runoff. Typical pollutants transported in stormwater runoff include metals, bacteria, sediment, organic matter, and nutrients. Protecting water quality in Mississippi's coastal region will require ongoing commitments from businesses, developers, homeowners, landowners, and drainage districts as well as municipal, county, and state governments. Pollution associated with stormwater runoff from development activities on the land is the primary focus of the recommendations and strategies described in this guidance document.

1.2. Rainfall and Runoff: Stormwater Basics

On average, Mississippi gets approximately 60 inches of rainfall each year, with areas closer to the Mississippi Gulf Coast receiving anywhere from 60–65 inches annually (NOAA 2022). When it rains, water is either absorbed into the ground, where it can be used by plants or for groundwater recharge, evaporates back into the air, or hits rooftops, roads, and other impermeable surfaces and runs off into storm drains. In areas with denser populations and more roads, buildings, and sidewalks, the water cannot be absorbed, causing issues with stormwater runoff. As this water moves across the landscape, whether that is over grass, off roofs, along roads, or off pavement, it picks up pollutants along the way that eventually make their way into downstream rivers, creeks, lakes, and estuaries.

In urban areas, stormwater often flows into storm drains where it is piped to a location where it can discharge into streams and rivers. Although this can reduce flooding and standing water in cities, it does not allow the water to absorb naturally into the ground, limiting opportunities for pollutant removal that happens in natural systems. Over time, pollution from stormwater runoff can harm the quality of water in downstream systems. This is why understanding how development is linked to water quality is critically important to supporting healthy watersheds, ecosystems, and communities.

When land is converted from its more natural state (e.g., forests, pastures, and grasslands) into housing, roads, parking lots, and buildings, it drastically changes how rainfall is stored and moved across this altered landscape. There are fewer places where rainfall can be absorbed, and it often moves much more quickly, resulting in increased flooding. Development also often causes increased soil compaction, which limits overall opportunities for infiltration. **Figure 1-4** shows the difference in how rainfall is processed in landscapes with more natural features and how rainfall is processed on landscapes with higher densities of impervious surface. As development occurs and more hard surfaces are created on the landscape, the volume of runoff increases while the overall quality of the stormwater decreases. If stormwater management is considered in the planning process and new development is designed to follow best practices to mitigate impacts from stormwater, however, it is possible to reduce the amount of stormwater leaving the developed area while improving the overall quality of the stormwater runoff. The diagrams in **Figure 1-5** illustrate several processes employed in managing stormwater through the implementation of best management practices (BMPs). Practices that detain, retain, and filter water and increase evapotranspiration can all contribute to healthier ecosystems.

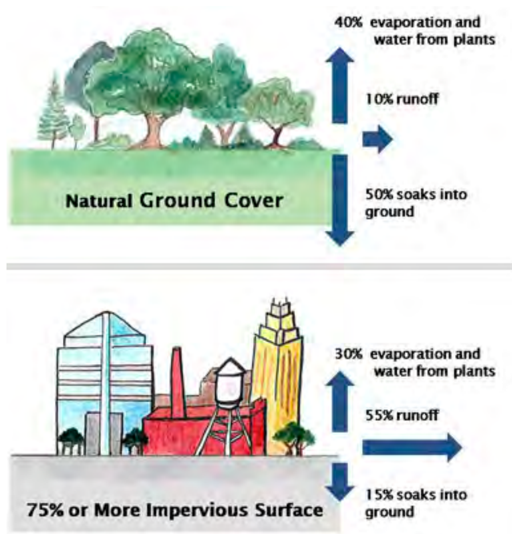


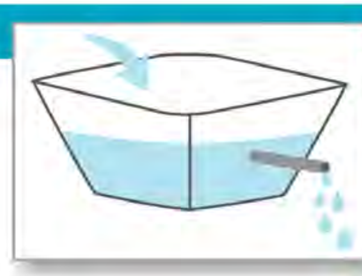
Figure 1-4. Influence of impervious cover on runoff. (Courtesy of City of Durham, NC)

Evapotranspiration is the sum of evaporation and transpiration.

Evaporation is the movement of water from its liquid form on the Earth's surface to its gaseous form in the atmosphere. **Transpiration** is the movement of water to the atmosphere through plants.

DETENTION

The temporary storage of stormwater runoff (in ponds, underground systems, or depressed areas) to allow for controlled discharge at a later time. The outlet structure restricts outflow to pre-development rates.



RETENTION

The storage of stormwater runoff on site and not released at a later time.

FILTRATION

The removal of sediment and other pollutants from stormwater runoff by the movement of runoff across a vegetated area and through media.

INFILTRATION

The vertical movement of stormwater through plants and soil. In systems without an under drain or liner, infiltration recharges groundwater.

EVAPOTRANSPIRATION

The combined amount of evaporation and plant transpiration from the soil surface or from the plant's vascular system to the atmosphere.

Figure 1-5. Processes employed in stormwater best management practices. (Source: Hegemier et al. 2019)

Element 4: Core and Supplemental Indicators

To assess the overall health of water bodies and to address specific water quality questions, the SWMP utilizes a suite of indicators that may include physicochemical and/ or biological

measures. Each indicator or parameter either measures a general or specific cause of pollution (i.e. nutrients, Dichloro-Diphenyl-Trichloroethane (DDT)) or measures a general or specific response to pollution (i.e.,biological integrity, fish kills). The SWMP includes a core group of indicators that represents each applicable designated use of a water body (aquatic life support, contact recreation, fish consumption, shellfish consumption, and drinking water supply), and a supplemental group that is used on a site or project specific basis. These indicators include parameters for which numeric and/or narrative WQS criteria are established. Table 2 outlines the core group of indicators used in MDEQ's SWMP. While physicochemical parameter analyses may allow for the predictability of water quality condition(s), assessment based upon biological parameters allows for a measure of the effect(s). Mississippi uses macroinvertebrate assemblages as indicators of localized conditions due to limited migration patterns and the ability of macroinvertebrates to integrate the effects of short-term environmental changes with varying degrees of sensitivity.

The SWMP uses supplemental indicators collected by FSD for special studies to support MDEQ management and regulatory programs, and to address public interest needs. They address numerous water quality issues, and occur on an as-needed basis. Projects range from one-time limited parametric surveys to in-depth ecological assessments or synoptic surveys involving physical, chemical, bacteriological, biological, and/or fish tissue monitoring. Examples of special studies undertaken by FSD include:

- SI studies for biologically-impaired waters,
- Biological assessments for WLA/NRDA investigations below point source discharges and/or spills;
- Intensive surveys for TMDL modeling, NPS pollution monitoring before and after BMP implementation, and;
- Studies that involve specialized monitoring for public health/aquatic life concerns for specific pollutants such as dioxin, mercury, DDT, and bacteria.

Special studies include gathering water quality information in areas where data are limited or nonexistent, investigating known or suspected water quality problems below both point and nonpoint pollution sources, identifying or confirming stressors, and resolving public health issues. Indicators selected for use in these studies usually include a combination of both core and supplemental indicators.

Supplemental indicators are chosen based upon the identified impairment or problem, pollution sources potentially affecting the water body, historical data collected on the water body or facility, the type of water body, the designated use (i.e. aquatic life, contact recreation, etc.), time and resource limitations, laboratory capabilities, and staff expertise. Examples of supplemental indicators include Land Use/Land Cover, community metabolism (i.e. photosynthesis/respiration/sediment oxygen demand measurements), Biological Oxygen Demand Ultimate (BOD_u), sediment toxics, geomorphology, screening level rapid biological assessments, as well as other indicators utilized by other organizations that provide MDEQ data for use in assessments.

MISSISSIPPI

Nonpoint Source Pollution Water Management

PROGRAM OVERVIEW

Figure 1: Examples of Point and Nonpoint sources of Pollution in a Watershed. Credit EPA

What is Nonpoint Source Water Pollution?

When most people think about sources of water pollution, what comes to mind is a pipe releasing wastewater into a stream from a treatment plant. Wastewater treatment plants – municipal or industrial – represent a type of finite, individual water pollution referred to as a point source of pollution. Point sources of pollution are governed by water quality rules and regulations set at the state and national levels.

However, when pollution comes from a dispersed, variety of sources (abandoned mines, forestry, urban streets, highways, cropland, pasture) and is carried into waterbodies by rainfall moving over and through the ground (Figure 1), it is called a nonpoint source of pollution (NPS). As stormwater runoff moves, it picks up and carries natural and human-made pollutants to lakes, reservoirs, rivers, streams, wetlands, and coastal waters. NPS pollution can also be transported into groundwater as runoff percolates through the soil. While point source discharges can occur continuously, in Mississippi NPS pollution is primarily driven by periods of rainfall.

Why is a NPS Pollution Management Program Needed?

Point sources are federally regulated under the Clean Water Act which means that nearly all municipal and industrial point sources are controlled to minimize their impact on water quality. Yet, issues such as fish kills, harmful algal blooms, and high levels of bacteria still occur and impact the safety and health of people and wildlife. To conserve and improve water quality for present and future generations of Mississippians, while sustaining the wildlife and aquatic animals who depend on Mississippi's water resources, MDEQ's Nonpoint Source Pollution Management Program was developed.

The NPS Management Program maintains a statewide focus on activities to reduce the impacts from NPS pollution. To do so, however, the agency must first understand the extent to which the waterbodies are impacted. As such, every two years MDEQ evaluates and reports on the water quality of Mississippi waterbodies – streams, rivers, lakes, reservoirs, estuaries, and coastal waters. This statewide assessment can be found on MDEQ's website here: **Mississippi's Section 305(b) Water Quality Assessment Report**. When the specific beneficial uses ("designated uses") outlined in the federal and Mississippi water quality standards are not met, the waterbody's water quality is characterized as impaired.

What Happens When a Waterbody is Impaired?

When water bodies are impaired, those waters are compiled into a list as required by Section 303(d) of the Clean Water Act. This list represents waters that are deemed impaired for one or more designated use(s) and as a result, a total maximum daily load (TMDL) for the pollutant causing the impairment must be developed. The biennial Section 303(d) List of Impaired Water Bodies can be found on MDEQ's website here: **Mississippi's Section 303(d) List of Impaired Water Bodies**. The TMDL is representative of a stream budget where allowable loads for specific pollutants are developed to ensure the water body can meet appropriate water quality criteria and designated uses.

Currently, Mississippi has 191 water bodies with TMDLs for nutrient impairments (i.e. total nitrogen and/or total phosphorus), and 307 water bodies with TMDLs for sediment. In Mississippi, nutrient loading and sediment are the two largest contributors to NPS pollution management concerns.

What Does the Nonpoint Source Program Do?

NPS water pollution, unlike point sources, is managed primarily through the voluntary actions of individual people that are instigated after they become aware of the multiple economic, social, and environmental benefits that can be

Award-Winning Program: Environmental Education & Outreach Mobile Classroom

realized if they participate in management effort. The Mississippi NPS Pollution Management Program achieves this through two primary approaches. First, it emphasizes awareness, education and outreach about the effects of NPS pollution, the costs associated with NPS pollution, and solutions to manage NPS pollution. Awareness addresses the first critical step of answering "So What?" and motivates people to change their behavior by making them aware of what is in the best interest of an individual and the public at large. Education builds

Cover crops reduce erosion, add organic matter, retain nutrients, and improve irrigation effectiveness

individuals' abilities to perform the new behavior and must begin at an early age (pictured above). Outreach moves education-based activities to the communities most in need by providing the knowledge and skills through field days, training, workshops, YouTube videos, and other interactive platforms.

Second, the Mississippi NPS Pollution Management Program uses outreach and funding assistance to encourage landowners to use cover crops, rain gardens, and similar practices that reduce NPS pollution while providing other benefits. Management practices implemented in communities throughout the state are proof that the awareness and education approaches are changing beliefs and behaviors about NPS pollution. These NPS pollution management practices are supported by effective outreach efforts. Outreach starts with neighbor to neighbor exchanges and proceeds through agency and institutional programs, including financial assistance. Ultimately, NPS management implements practices throughout a watershed to reduce NPS pollution and improve water quality for everyone. Specifically, the NPS Program uses the Basin Management Approach (BMA) to achieve its targeted, watershed-based goals. The key strategy of this approach is to leverage collaboration among agencies, organizations, institutions, and stakeholders. The mission of the BMA is to foster stewardship of Mississippi's water resources through place-based, collaborative water resources planning, education, protection, and restoration initiatives. The BMA catalyzes collaborative identification and responses to a variety of water resources concerns. The building blocks of the BMA are smaller sub-divisions of teams such as Basin Teams and Watershed Implementation Teams.

Is the Program Making a Difference in Reducing NPS Pollution?

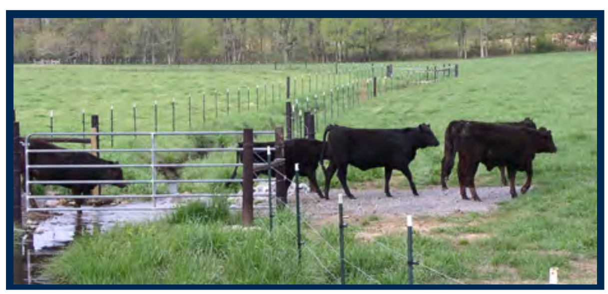
The greatest measure of success for the Mississippi NPS Pollution Management Program is restoring impaired water bodies to full use. Using this metric, the Mississippi NPS Pollution Management Program is, and has been, a success for over 30 years. Each year, the Program, with its partners, initiates between 2-4 projects to improve water quality and restore water body uses across the state. Three examples include:

> The Mississippi NPS Management Program has been restoring water body uses impaired by NPS pollution for over 30 years. That's success!

Lake Hazel – Lake Hazel was not attaining its aquatic life use due to stormwater runoff from commercial and residential development carrying sediment, nutrients, and oil and grease into the lake. Through partnerships with Mississippi Soil and Water Conservation Commission (MSWCC), the City of Hazlehurst, participating landowners, and other interested stakeholders, stormwater runoff was addressed by implementing various management practices. These practices included water and sediment control basins, restoration of vegetation in heavily eroded areas, and grade stabilization of earthen structures, to reduce loads of sediment, nutrients, and other pollutants entering the lake. Local newspaper articles, field tours of management practices, and educational materials created awareness of the success of these practices for landowners and the public. This project started in 1990 and the lake was removed from the Mississippi list of impaired waterbodies in 2004.

Caney Creek – Caney Creek, in Tishomingo County, was not attaining its aquatic life use because of sediment loading from silviculture and agricultural sources, organic enrichment from agricultural sources, and habitat alternations. Partnerships of MSWCC, USDA Natural Resources Conservation Service (NRCS), Conservation Districts, and local landowners resulted in implementation of nutrient management practices, grade stabilization structures, prescribed grazing, tree and shrub planting, and animal watering facilities. This project started in 2007 and in 2014 Caney Creek was removed from the Mississippi list of impaired waterbodies.

Limekiln Creek – Limekiln Creek, in central Mississippi, was not attaining its aquatic life use because of low dissolved oxygen/organic enrichment, low pH, and excess nutrients from agricultural activity. Through partnerships of MSWCC, NRCS, Conservation Districts, and local landowners, a NPS project began in 2005. Over 75 management practices, including grade stabilization structures, water and sediment control basins, pasture planting, fencing, heavy use area protection, stream crossing areas (pictured above), and permanent vegetation were implemented in the watershed. These practices significantly reduced sediment, nitrogen and phosphorus loading to Limekiln Creek. In 2014, Limekiln Creek was removed from



Controlled stream crossing access for cattle the Mississippi list of impaired waterbodies.

The Mississippi NPS Pollution Management Program, through its awareness, education, and outreach programs, including its watershed management partnerships, is making a difference in reducing NPS pollution in Mississippi. However, as shown in each of the examples above, it takes time. Success is not immediate, but, through continual effort, success is, and can be, attained.

How Does the Nonpoint Source Program Help Mississippians?

An added value of the Mississippi NPS Pollution Management Program are the federal dollars being injected into the state and local economies to achieve these environmental benefits. Over the last five years (2015-2019), the Mississippi NPS Pollution Management Program has received approximately $15 million in federal grant funding from the EPA Section 319 Grant Program. Over $9 million of these dollars were awarded to local projects focused on the management and reduction of NPS pollution in Mississippi. These funds not only directly benefited local communities in our state, but were leveraged by other agencies and organizations via funds matching to provide additional funds. These partnerships also support other management practices in the same watersheds.

Who Do I Contact About the MS NPS Management Program?

MDEQ welcomes and encourages your participation in, and comments on, the Mississippi NPS Pollution Management Program. If you are interested in NPS pollution management in Mississippi, please contact the Basin Management and NPS Branch of the Surface Water Division of the MDEQ's Office of Pollution Control at PO Box 2261, Jackson, MS 39225, or by phone at 601-961-5171.

Take Back Our Waters Mississippi! Find a Local Watershed Team or Group. Engage with Your Local Governments on Water Quality Issues. Get Involved. Have a Voice. YOU Can Help Protect and Restore Our Waters!

It takes everyone's efforts to manage NPS pollution in our streams, rivers, reservoirs, lakes, wetlands, and estuaries. From those of us that live in more urban environments in Mississippi's cities and towns to those of us living in the more rural areas of the state, we can all take action to improve our environment. Together, through actions both small and large, we can make a difference. Below is a list of the top 10 things you can do to reduce NPS pollution:

1. Water your lawn only when it is necessary. Conserve water used in the house as well.
2. Limit the use of pesticides and fertilizers. Be sure to follow the instructions on the labels.
3. Plant hardy vegetation. Cover the bare spots in your yard to reduce run off.
4. Put litter in its place; not on the ground.
5. Compost or mulch yard waste. Don't leave it in the street or sweep it into storm drains.
6. Inspect and service your septic system at least every 2 years.
7. Wash your car at a commercial car wash or on the lawn.
8. Recycle used oil and antifreeze and dispose of household chemicals properly. MDEQ sponsors household waste disposal days.
9. Dispose of deer carcasses properly. Place in garbage bag and discard with the trash; or bury correctly (see MS Bureau of Animal Health regulations.)
10. Pick up after your pet. Scoop your poop please! This prevents bacteria from running off into our streams, river, reservoirs, lakes, and estuaries.

NCF-Envirothon 2026 Mississippi

Current Issues: Part B Study Resources

Key Topic #2: Watershed Planning

5. Explain the components of a comprehensive watershed-based plan (e.g., 9-element plans).
6. Describe how land use planning affects water quality and NPS pollution.
7. Identify trade-offs and constraints in selecting BMPs and setting realistic watershed goals.
8. Explain how policies and outreach strategies influence individual and community behaviors that affect nonpoint source pollution.

Resource Title	Source	Located on Page
Watershed Plans	*Watershed Plans – MDEQ. (n.d.). MDEQ - Mississippi Department of Environmental Quality.* *https://www.mdeq.ms.gov/water/surface-water/nonpoint-source-pollution-program/water-surface-water-nonpoint-source-pollution-program-watershed-plans/*	16
A Quick Guide to Developing Watershed Plans to Restore and Protect Our Waters: Section 1	*United States Environmental Protection Agency & Office of Wetlands, Oceans, and Watersheds. (2013). A quick guide to developing watershed plans. epa.gov.* *https://www.epa.gov/sites/default/files/2015-12/documents/watershed_mgmnt_quick_guide.pdf*	18
Land Use & Water Quality	*Land use & water quality. (n.d.). Purdue University Extension.* *https://engineering.purdue.edu/SafeWater/watershed/landuse.html*	37

Watershed Plans

Mississippi's NPS Program works collaboratively with partners to target priority watersheds throughout the state. Prioritization of these watersheds involves coordination with Basin Team members, stakeholders, and resource agency partners as part of the BMA.

Over the years, the process used to prioritize and target watersheds for NPS pollution management has evolved. The focus of water resources management nationwide has moved to implementation and measuring success on smaller scales, mostly watersheds classified at the hydrologic unit code (HUC) 12 scale (i.e., 25,000 to 30,000 acres) or smaller. The Mississippi watershed prioritization process reflects this focus on a smaller scale planning framework. Instead of focusing on entire river basins or larger HUC 8 scales, prioritization and planning is now focused on these smaller HUC 12 watersheds.

In Mississippi there are 1,468 HUC 12 watersheds. To help manage the workload of selecting priority and targeted watersheds from 1,468 HUC 12 watersheds, the Mississippi NPS Program relies on partnerships established through the Basin Management Approach. Partners help first identify watersheds of interest for the state, and then work within our Basin Teams to recommend priority watersheds to target for NPS pollution management projects funded from Section 319 grant funds.

In order to fund watershed scale implementation projects using Section 319 dollars, the watershed must have been identified as a "priority" and listed in the Mississippi NPS Program Plan. Every 5 years, the Mississippi NPS Program works with state and federal resource agency partners, institutes of higher learning, non-profit governmental organizations, and local partners and stakeholders to develop a statewide list of watersheds of interest for water quality management. This list is reviewed annually and revised, based on partner interest, agency priorities, and leveraging opportunities, so it represents an inclusive list of watersheds that have priority status for implementation of NPS pollution management projects. This final list is the starting point for all Basin Teams when the process of ranking watersheds begins. See Appendix B for a full list of priority watersheds identified by MS's NPS Program for FY20-24.

For each watershed identified as a priority for NPS pollution management through the Mississippi NPS Program, a Watershed Implementation Team (WIT) is formed. This team is generally composed of local stakeholders, resource agency partners, and any other interested party located within the watershed boundaries. The first responsibility of a WIT is to help gather the necessary information and write a Watershed-based Plan (WBP) for their watershed. Information used in preparing WBPs includes the results of water quality assessments, stressor identification studies, water quality modeling, and TMDLs. This information guides WIT decisions on the types and location of restoration and protection activities to plan in a watershed. In watersheds that have TMDLs, they are used to provide water quality restoration objectives and pollutant load reduction goals for the WBP.

These WBPs are intended to be holistic in nature addressing the wide range of water management concerns unique to that watershed. The primary focus of these plans is water quality, and as a result, provides a roadmap for how conservation and education activities can be implemented in the watershed to achieve water quality improvement goals. To the extent possible, WBPs identify all sources of water pollution, both point source and NPS, regulated and unregulated. Thus, most WBPs address more than one category of NPS pollution. Along with identifying pollution sources, these plans also outline potential solutions to reduce and/or prevent NPS pollution and restore or protect designated uses in a watershed.

Although many different types of information is useful and can be included in a watershed plan, EPA has identified nine key elements that are critical for achieving improvements in water quality. To be eligible for funding through §319 subgrant, NPS pollution management watershed projects must be associated with a WBP that includes the“nine key elements” identified by EPA (Figure 1). Thus, the Mississippi NPS Program requires that these key elements be included in all WBPs. To assist WITs in this effort, the MDEQ Basin Management and NPS Branch developed a guidance document entitled Mississippi Watershed Implementation Plan Guidance Compatible with Section 319 Grant Requirements to help develop plans that address all nine elements.

A Quick Guide to Developing Watershed Plans to Restore and Protect Our Waters

Introduction

Watershed Planning as an Overarching Management Framework

The U.S. Environmental Protection Agency (EPA) has for many years encouraged states and others to develop watershed plans to help protect and restore our waters. Due to the complex and diffuse nature of nonpoint source pollution, the substantial costs to address it, and frequent reliance on voluntary action by individual landowners, successfully addressing nonpoint source pollution to achieve water quality standards often requires years of support from a coalition of stakeholders, programs, and funding sources. Watershed planning helps address water quality problems in a holistic manner by fully assessing the potential contributing causes and sources of pollution, then prioritizing restoration and protection strategies to address these problems.

Why a Quick Guide to Watershed Management?

In 2008 EPA published the *Handbook for Developing Watershed Plans to Restore and Protect our Waters* (the Handbook) to provide users with a comprehensive resource to develop more effective watershed plans as a means to improve and protect the nation's water quality. The Handbook also provides guidance on how to incorporate the nine minimum elements from the Clean Water Act section 319 Nonpoint Source Program's funding guidelines into the watershed plan development process. Since the Handbook was issued, EPA and other entities have stepped up watershed plan implementation, introduced new initiatives, developed new tools, and provided additional funding sources.

Over the past 5 years, thousands of copies of the Handbook have been printed. The Handbook has been used by watershed practitioners, incorporated into training courses, and even adopted as part of college curricula. The purpose of this Quick Guide, developed in response to feedback on the length and complexity of the Handbook, is to provide a streamlined, easy-to-read summary of the Handbook. The guide also incorporates key watershed-related topics not included in the Handbook. The Quick Guide is not meant to replace the Handbook, but rather to provide a brief guide to watershed planning and highlight new information that can be used for more effective decision-making leading to improved management of our water resources.

> **Use the following icons to help locate specific information in the Quick Guide**
>
> ❾ Indicates where one of the **nine minimum elements** is discussed.
>
> 🗁 Indicates a **case study** that highlights the use of the nine minimum elements in watershed plans.
>
> 🗐 Refers the reader to specific sections in **the Handbook** for more detailed information.

Organization of the Quick Guide

The Quick Guide is divided into two sections:

- **Section I: The Basics** provides a streamlined summary of the Handbook. It includes the major steps in the watershed planning process and a brief overview of the nine minimum elements to be included in watershed plans under EPA's Clean Water Act section 319 Nonpoint Source Program.
- **Section II: What's New** highlights recent EPA watershed-related initiatives and presents new tools that practitioners can access to improve water quality across the country.

Section I

SECTION I: THE BASICS

This section presents a streamlined summary of the watershed handbook, *Handbook for Developing Watershed Plans to Restore and Protect Our Waters*, and walks you through the basic watershed planning and implementation process. In addition, this section highlights where in the planning process to incorporate the nine minimum elements (see the box to the right) required for watershed-based plans that are developed and implemented with section 319 funds.

Summary of the nine minimum elements to be included in section 319-funded watershed plans for threatened or impaired waters

a. Identify causes and sources of pollution
b. Estimate pollutant loading into the watershed and the expected load reductions
c. Describe management measures that will achieve load reductions and targeted critical areas
d. Estimate amounts of technical and financial assistance and the relevant authorities needed to implement the plan
e. Develop an information/education component
f. Develop a project schedule
g. Describe the interim, measurable milestones
h. Identify indicators to measure progress
i. Develop a monitoring component

Watershed plans provide an analytic framework for managing efforts to both restore water quality in degraded areas and to protect overall watershed health. Watershed plans assist states and tribes in addressing nonpoint source pollution by providing a comprehensive assessment of nonpoint source pollution and a set of management measures to address them.

EPA recognizes that not all watersheds are threatened or impaired and that in many cases watershed stakeholders want to develop and implement watershed plans to continue protecting high-quality watersheds. The watershed planning and implementation steps are similar for healthy and impaired watersheds, but the overall watershed plan goals and management strategies will vary depending on local and regional priorities, conservation programs, and regulatory requirements or other approaches used to achieve them.

NOTE: A waterbody is **impaired** if it does not attain the water quality criteria associated with its designated use(s). **Threatened** waters are those that meet standards but exhibit a declining trend in water quality such that they will likely exceed standards in the near future.

In this section of the Quick Guide, you will learn about the framework to conduct a successful watershed planning effort. The basis for this framework is the **six steps of watershed planning,** which are discussed in detail in the Handbook (http://water.epa.gov/polwaste/nps/handbook_index.cfm). An additional goal of the Handbook (and, subsequently, of this guide) is to show both how the **nine elements** presented in the Clean Water Act section 319 grant guidelines serve as building blocks to develop watershed plans and where these elements fit within the six steps of the watershed planning process (Figure 1). The nine elements are the components of the watershed planning process that EPA believes are the most critical to preparing effective watershed plans and are generally required for watershed projects funded under section 319. EPA finalized its updated section 319 *Nonpoint Source Program and Grant Guidelines for States and Territories* in 2013, and it includes the nine elements discussed in the Handbook and this Quick Guide (see www.epa.gov/nps/319).

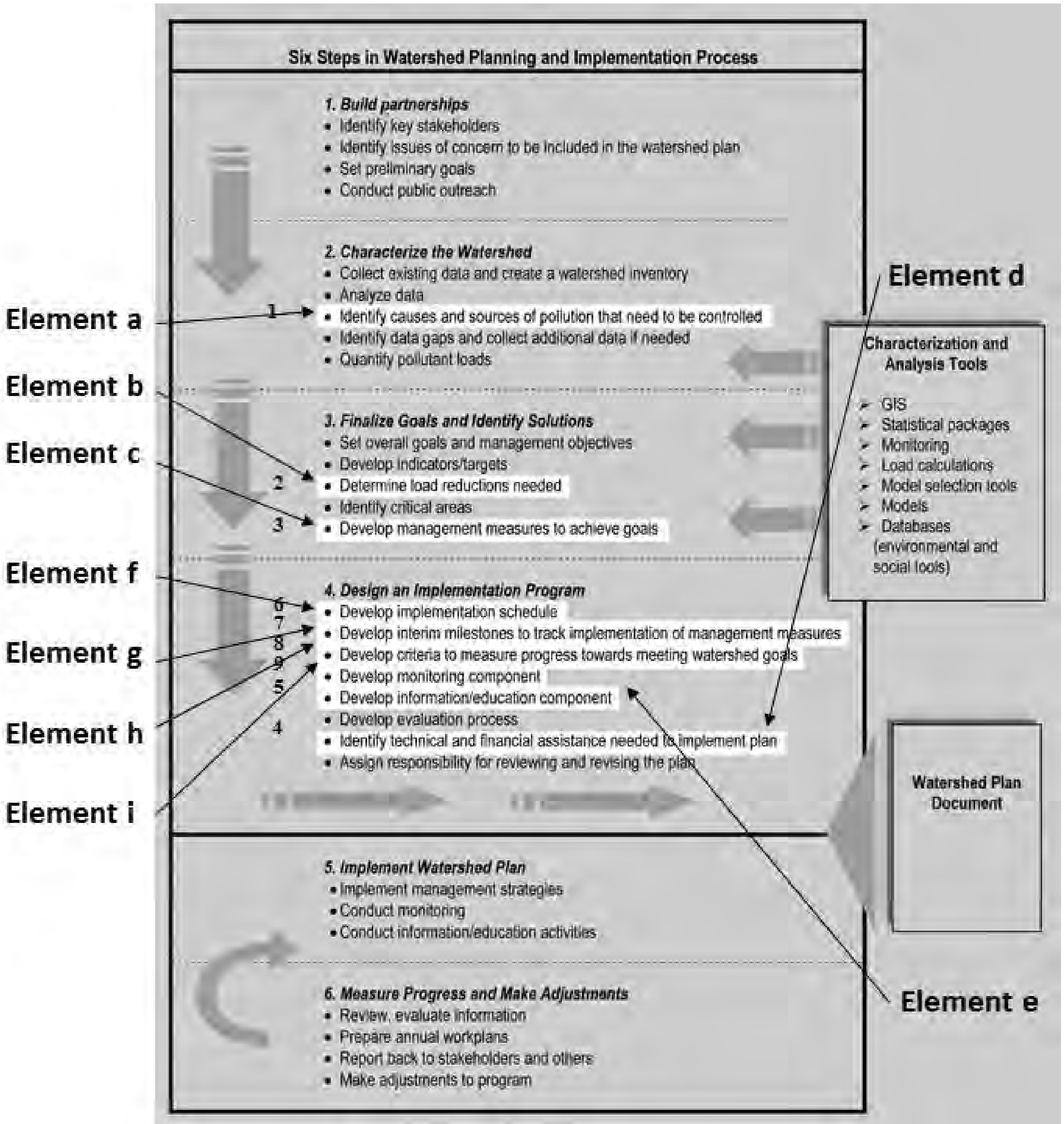


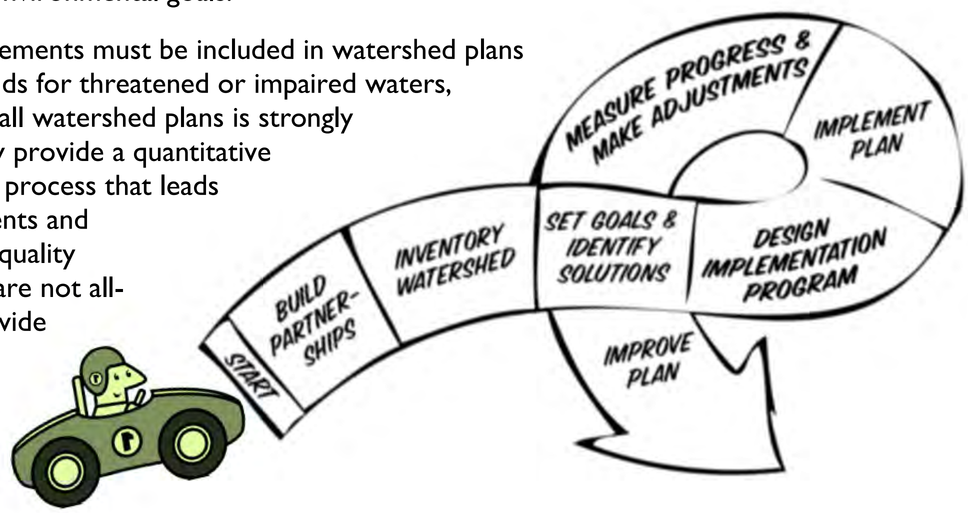
Figure 1. Crosswalk between the six steps of watershed planning and the section 319 nine minimum elements.

Understanding the Nine Minimum Elements of Watershed-Based Plans

EPA developed the nine minimum elements to help watershed managers address some of the most common pitfalls seen in watershed plans, particularly those for impaired waters. Watershed plans often lack quantified estimates of current and projected pollutant loads and the reductions needed to achieve water quality standards and other watershed goals. These loading estimates and estimates of load reductions from proposed pollution control measures provide the analytic link between actions on the ground and attainment of water quality standards. In the absence of such a framework, it is difficult to develop and implement a watershed plan that can be expected to achieve water quality standards or other environmental goals.

> **NOTE:** EPA's Watershed Central (http://water.epa.gov/type/watersheds/datait/watershedcentral/index.cfm), including its wiki, can be used to assist watershed practitioners in each of the watershed planning and implementation steps.

Although these minimum elements must be included in watershed plans funded with section 319 funds for threatened or impaired waters, including these elements in all watershed plans is strongly recommended because they provide a quantitative framework for the planning process that leads to water quality improvements and restoration to attain water quality standards. These elements are not all-encompassing, but they provide the basic components needed to produce a watershed plan that can lead to water quality improvements.



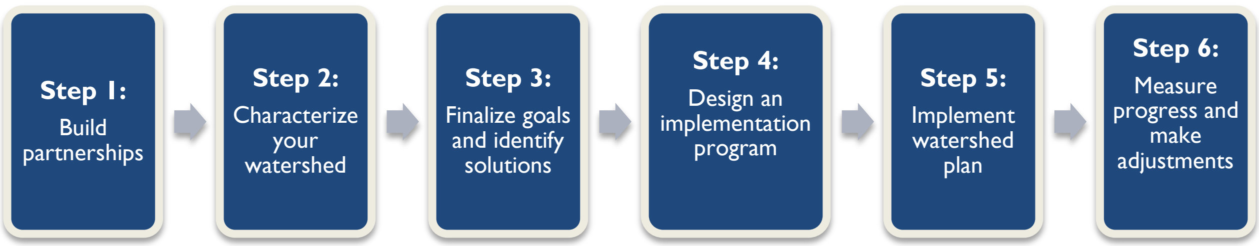
The elements are labeled *a* through *i* to reflect how they are presented in the 319 guidelines. The first three elements (*a* through *c*) are considered during the characterization and goal-setting phases to address the primary sources of pollution in the watershed and to determine the management strategies needed in specific areas to reduce the pollution to meet water quality goals. The remaining six elements (*d* through *i*) are used to develop a specific plan of action with measureable targets and milestones, as well as the necessary financial and technical resources needed to restore the waterbody.

Under section 303(d) of the Clean Water Act, states, territories, and authorized tribes are required to develop lists of impaired waters—waters that are too polluted or degraded to meet their water quality standards. The law requires that these jurisdictions establish priority rankings for waters on the lists and, in most cases, develop total maximum daily loads (TMDLs) for these waters. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive from both point and nonpoint sources and still meet water quality standards.

TMDLs provide an important starting point for water quality planning. Some TMDL development reports also contain an implementation strategy or plan. The point source allocations in TMDLs provide water quality targets for point sources such as wastewater treatment plants and stormwater treatment systems that go into their regulatory permits. Nonpoint source allocations are usually managed according to a TMDL implementation plan or watershed-based plan, which must include the nine elements described in this guide and in the Clean Water Act section 319 funding guidelines.

Steps to Effective Watershed Management

This section uses six basic steps to describe how to develop and implement an effective watershed plan. These steps provide a road map for you to follow to achieve your watershed goals.



Notice that in the picture on the previous page the road includes a loop. That is because watershed planning is an iterative process: As you collect new information, you should refine or modify your approach and incorporate lessons learned into your planning and implementation program. The remainder of Section I proceeds through each of the six steps and includes case studies and relevant tools and resources you can access for more information.

Step 1. Build Partnerships

Step 1: Build Partnerships

- **Identify key stakeholders**
- **Identify issues of concern**
- **Set preliminary goals**
- **Develop indicators**
- **Conduct public outreach**

The first step in the watershed planning process is to build partnerships. The very nature of working at a watershed level means you should work with local stakeholders and other partners. New ideas and input provided by partners not only provide a more solid commitment to solutions but also help to pool resources and skill sets. The stakeholders that you involve in the watershed plan development process will help you identify critical issues, set preliminary goals based on areas of mutual concern, and develop an initial set of indicators that will be crucial in monitoring progress. This step will also help you to develop an effective information/education component, which is one of the nine minimum elements (discussed in Step 4). Stakeholder involvement also increases the probability of long-term success through trust, commitment, and personal investment.

Identify Key Stakeholders

Stakeholders are those who make and implement decisions, those who are affected by the decisions made, and those who can assist or impede implementation of the decisions. Key stakeholders also include those who can contribute resources and assistance to the watershed planning effort and those who are working on similar programs that can be integrated into a larger effort. It is important to remember that stakeholders are more likely to get involved if you can show them a clear benefit to their participating.

In general, there are at least five categories of participants to consider when identifying stakeholders:

- Those who will be responsible for implementing the watershed plan
- Those who will be affected by implementation of the watershed plan
- Those who can provide information on the issues and concerns in the watershed

- Those who have knowledge of existing programs or plans that you might want to integrate into your plan (e.g., soil and water conservation districts, irrigation districts)
- Those who can provide technical and financial assistance in developing and implementing the plan (e.g., state and federal agencies, colleges and universities).

🗐 *Refer to Worksheet 3 on page 3-7 of the Handbook for a checklist of skills and resources that stakeholders can contribute to the planning process.*

🗐 *Refer to* Getting in Step: Engaging Stakeholders in your Watershed *for more information on the tools needed to effectively engage stakeholders to restore and maintain healthy environmental conditions through community support and cooperative action (http://cfpub.epa.gov/npstbx/getinstep.html).*

Identify Issues of Concern

It is important for stakeholders to assist in identifying issues of concern in the watershed. They often have a historical perspective on problems in the watershed and a sense of whether conditions are improving or deteriorating. These issues will help shape the overall goals of the watershed plan and determine what information is needed to accurately define and address the concerns. This step will also help determine the geographic scope of your watershed planning effort on the basis of where the problems are located and areas that need to be protected.

🗐 *Refer to the Healthy Watersheds website for more information and resources related to watershed protection.*

Set Preliminary Goals

A fundamental step in the partnership-building process is to ask stakeholders to list their long-term goals for the watershed. These goals will be refined throughout the planning process to represent shared goals among the stakeholders. Concrete objectives with measureable targets and indicators to measure progress will then be developed for each goal the stakeholder group selects.

🗐 *See Figure 4-4 on page 4-9 of the Handbook; it is a conceptual diagram of how watershed goals grow and evolve during the watershed planning process.*

Using Stakeholders to Identify Indicators

🗁 **Case Study: Barataria-Terrebonne National Estuary Program, Louisiana**

The Barataria-Terrebonne National Estuary Program (NEP) began an indicator development process by forming a planning committee with federal, state, and university participants. The planning committee decided to conduct an indicator development workshop with local stakeholders so that the stakeholders could recommend a suite of indicators. During the workshop, the stakeholders separated into breakout groups and were asked to identify indicators to address specific focus questions. Workshop participants selected the following indicators to answer Question 1: *Are our waters healthy?*

Indicator(s):

- Level of chlorophyll *a* in the estuary over time
- Size of dead zone (off coastal Louisiana) over time
- Number of petroleum spill reports in the estuary over time.

The NEP continues to use a similar process every 5 years to update its indicators. A full description of the process and indicators developed can be found at http://water.epa.gov/type/oceb/nep/indicators.cfm.

Develop Preliminary Indicators

Indicators are direct or indirect measurements of a component in a system. For example, an indirect indicator to demonstrate the improved water clarity of a lake might be the depth at which you can see your white sneakers as you wade into the lake. A direct indicator would be total suspended solids samples taken quarterly at predetermined depths. Indicators provide a powerful means of communicating to various audiences about the watershed status, and they are used throughout the planning and implementation process. Stakeholders should be actively involved in selecting the indicators, and they should be asked to identify for each goal how progress toward that goal will be measured. Just as the preliminary goals will be refined throughout the watershed planning process, the indicators selected will be refined to ensure they are quantifiable and include environmental, social, and programmatic examples.

Conduct Public Outreach

Information/education activities should be initiated at the outset of the watershed planning effort to familiarize potential partners and stakeholders with the issues, outline the watershed planning process, and enlist their participation. Developing an information/education component is one of the nine minimum elements; it is discussed further in Step 4 of the watershed planning process (refer to page 23).

Chapter 12 (PDF, 713 KB, 38 pp.) of the Handbook provides more detail on the information/education component.

Step 2. Characterize the Watershed

Characterizing the watershed, its problems, and pollutant sources provides the basis for developing effective management strategies to meet water quality goals. The characterization and analysis process helps to focus management efforts on the most pressing needs within the watershed. During this step the first of the nine elements is addressed: The watershed plan should include ❾ a. *An identification of the causes and sources or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this watershed-based plan (and to achieve any other watershed goals identified in the watershed-based plan).*

Step 2: Characterize Watershed

- **Gather existing data**
- **Create a watershed inventory**
- **Identify data gaps**
- **Collect additional data if needed**
- **Analyze data**
- **Identify causes and sources of impairments**
- **Estimate pollutant loads**

Gather Existing Data and Create a Watershed Inventory

You will first identify existing information through reports and data sets. Data needed for watershed planning include the following:

Physical and Natural Features	Land Use and Population Characteristics	Waterbody Conditions	Pollutant Sources	Waterbody Monitoring Data
Watershed boundaries, hydrology, topography, soils, etc.	Land use, land cover, existing management, etc.	305(b) reports, 303(d) reports, TMDLs, source water assessments, etc.	Permitted point sources, nonpoint sources, atmospheric deposition, etc.	Water quality and flow, biology, geomorphology, etc.

Reports and data should be obtained from local governments (city and county planning offices, environmental departments, soil and water conservation districts), state natural resource agencies, and federal agencies (EPA, USFWS, USDA, NRCS, FAS, USGS). You will then create a watershed inventory to organize the data into a common format (in a spreadsheet or database) for further analysis.

🗐 *For more information on types of data typically collected for watershed characterization and the data's potential uses, see Table 5-1 (PDF, 1.42 Mb, 56 pp.) on page 5-8 of the Handbook.*

Identify Data Gaps and Collect Additional Data if Necessary

There will always be more data to collect, but you need to keep the process moving forward and determine whether you can reasonably characterize watershed conditions with existing information. This process may involve:

- Conducting a data review of your watershed inventory to examine data quality and identify any significant temporal or spatial data gaps
- Examining the data to determine whether you can link the impairments seen in the watershed to the causes and sources of pollutants
- Considering whether you have gathered data of the right types and of adequate quality.

If you determine that you need to collect additional data, first develop a sampling plan. This will save you time and resources down the road, and you might be able to use portions of the sampling plan to construct the long-term monitoring program discussed in Step 4.

🗐 *For more information on designing a sampling plan, see EPA's* Guidance on Choosing a Sampling Design for Environmental Data Collection *(PDF, 1.02 MB, 178 pp.) and EPA's Quality Management Tools website at http://www.epa.gov/QUALITY/qa_docs.html.*

Analyze Data

Once you have gathered existing and newly collected data and consolidated the data into a database or spreadsheet, you will analyze the information to identify watershed pollutant sources and causes of any impairments, as well as important areas to protect. In this phase of the watershed planning process, you will identify the causes and sources of pollutants that need to be controlled. It is critical to have an understanding of the watershed conditions and sources of pollutants to determine the appropriate method for quantifying the pollutant loads.

🗐 *Refer to Chapters 7 and 8 (PDF, 781 KB, 22 pp.) of the Handbook for details on instream data, watershed data, and an in-depth discussion of pollutant load estimation. Refer to Table 7-1 (PDF, 781 KB, 22 pp.) on page 7-3 of the Handbook for examples of data analysis activities and the tools used in various steps of the watershed planning process.*

Identify Causes and Sources That Need to Be Controlled

Together with the input from stakeholders and their local knowledge of the watershed, analyzing your data should lead you to an understanding of where and when problems occur in your watershed and what could be causing the problems. Without knowing where the pollutants are coming from, you cannot effectively control them and restore and protect your watershed. Pollutant sources, along with associated pollutants, timing, and impact on the watershed, are critical to developing an effective management strategy. It is also important to identify critical areas (i.e., those that generate the most pollution) to focus on and to give priority to conservation practice implementation.

> **NOTE:** The new EPA Recovery Potential Screening tool described in Section II can be used to assess the recovery potential of sites within a watershed based on a series of factors. This tool can be used in conjunction with other data collected to assess the impaired sites that have the highest potential to recover and meet watershed goals.

In identifying the sources, you will begin to identify the critical areas to address with targeted management strategies. The location of pollutant sources and the associated critical areas will feed into selecting the management measures needed to control the sources. This is outlined in element *c* of the nine minimum elements. ❾Element *c* states: "*A description of the nonpoint source management measures that will need to be implemented to achieve load reductions and a description of the critical areas in which those measures will be needed to implement this plan.*" The critical areas for each primary source can be indicated on a map. In the next step you will quantify the magnitude of the pollutant loads.

Estimate Pollutant Loads

A quantified estimate of pollutant loads and the related sources of those loads are often missing from watershed plans, and filling this gap is critical to effectively control sources, develop the load reductions needed to meet watershed goals, and restore watershed health.

Various approaches can be used to conduct the loading analysis. The most appropriate method depends on several factors, including water quality parameters, time scale of the analysis, source types, data needs, and user experience. First check whether a previous study that required the development of loading estimates, such as a TMDL or a Clean Lakes study, was conducted. Such studies can often be used as a basis to provide loading estimates appropriate for developing the watershed plan.

TMDLs describe the allowable point and nonpoint source load reductions or allocations that will be necessary to meet water quality standards. The TMDL sets maximum pollutant loads for the most critical conditions to ensure that the applicable water quality standards will be attained at all times and will also provide a loading scenario that addresses all seasonal conditions. The TMDL analysis also describes the pollutant load from natural or background sources and establishes a margin of safety to ensure the standards will be met. In some cases, there might be an opportunity to trade pollution allocations or develop local ordinances or other programs to achieve equitable and effective pollutant reductions from all sources. In any watershed analysis where both point and nonpoint sources are present, it is important to determine the regulatory requirements for the point sources and the feasibility of controlling the nonpoint sources using existing local, state, tribal, and federal programs. This aspect of the TMDL (referred to as reasonable assurance) provides a degree of certainty for achieving the needed pollutant reductions.

Some loading analyses are focused on determining how much load is acceptable, whereas others are focused on source loads that attribute loading to each category of sources in the watershed. There are two general types of techniques for estimating pollutant loads: (1) techniques that use actual monitoring data or literature values and (2) techniques that use models to predict the estimated pollutant loads. Monitoring data or literature values are fairly simple approaches that provide a coarse estimate of the pollutant loads entering a waterbody. These techniques are best suited to conditions where fairly detailed monitoring and flow gauging are available and the major interest is in total loads from a watershed.

Models provide another approach for estimating loads, providing source load estimates, and evaluating various management alternatives. They can be used to forecast or estimate conditions that might occur under various scenarios. In some cases, landscape and loading models are developed, and they can be supplemented with a receiving water model as well. Although you might not be the person who will run the model, you should have an understanding of what types of questions you want answered so that the most appropriate model is used. Typical questions you might want a watershed model to address include:

- Will the management actions result in meeting water quality standards?
- Which sources are the main contributors to the pollutant load targeted for reduction (e.g., land use or land cover types)?
- What are the loads associated with the individual sources (e.g., point sources versus nonpoint sources)?
- Which combination of management actions will most effectively meet the identified loading targets (e.g., stormwater management, wastewater treatment, best management practices (BMPs) for croplands)?
- When does the impairment occur? Is it seasonal or flow-dependent?
- Will the loading or impairment get worse under future land use conditions?
- How can future growth be managed to minimize adverse impacts?
- How can the watershed plan ensure that downstream water quality is also protected?

The modeling approaches developed are ultimately designed to support decision-making. Essential to decision-making is the application of the model to identify various alternatives. How you use the model to support decision-making is as important as the various steps that go into building and testing the model. Regardless of what model you use, the analysis should be field-checked before you use the results.

A summary of various approaches used to estimate pollutant loads in watersheds is included in Table 8-1 on page 8-3 of the Handbook.

Step 3. Set Goals and Identify Solutions

Now that you have characterized and quantified the problems in the watershed, you need to refine the preliminary goals and develop more detailed objectives, measurable targets, and indicators. The pollutant loads calculated in Step 2 will provide the basis for identifying the reductions needed to meet watershed goals (including meeting water quality standards) and determine which management practices will be used in the critical areas to achieve those reductions.

Step 3: Set Goals and Identify Solutions

- **Set overall goals and management objectives**
- **Develop indicators/targets**
- **Determine load reductions needed**
- **Identify critical areas**
- **Develop management measures to achieve goals**

Set Overall Goals and Management Objectives

You identified preliminary goals and associated environmental indicators with your stakeholders earlier in the characterization process, but now you will refine those goals on the basis of your data analysis. You will also establish more detailed objectives and targets that will guide the development of your management strategies.

For example, a preliminary goal developed during the scoping phase, in Step 1 of the watershed planning process, might have been to "restore aquatic habitat." Based on the information collected during data analysis, in Step 2 of the watershed planning process, you might determine that the causes contributing to poor aquatic habitat include upland sediment erosion and delivery, streambank erosion, and near-stream land disturbance (e.g., livestock, construction). Linking the preliminary goal to the source and impacts of pollution will help you define your management objectives. In this case, appropriate management objectives could include (1) reducing sediment loads from upland sources and (2) improving riparian vegetation and limiting livestock access to stabilize streambanks.

Develop Indicators/Targets

Next you will develop indicators and numeric targets to quantitatively measure whether you are meeting your objectives. You identified indicators with your stakeholders earlier to determine the current health of the watershed; now you will refine the indicators to measure implementation. When developing your indicators and targets, also work to establish interim milestones that will measure the implementation of activities in your watershed plan, including the costs associated with those activities. Refer to the Milestones section of Step 4 of this Quick Guide for more information.

NOTE: Section II provides updated information on how to develop and use social indicators to measure watershed management progress.

It is important to use different types of indicators to reflect where you are in the watershed management process and the audience with which you are communicating. You'll first select environmental indicators to measure the current conditions in the watershed and help to identify the stressors and the pollutant sources. Environmental indicators are a direct measure of the environmental conditions that plan implementation seeks to achieve. As you develop your management objectives and actually assemble your watershed plan, you will add performance indicators, such as social and programmatic indicators, to help measure progress toward meeting your goals. An example of each type of indicator is provided in Table 1.

Table 1. Examples of performance indicators

Environmental	Programmatic	Social
• Number (or percentage) of river/stream miles that fully meet all water quality standards • Reduction in pollutant loadings from nonpoint sources	• Number of public water systems with source water protection plans • Number of management measures implemented in a watershed (e.g., number of acres under nutrient management, number of riparian buffers created)	• Increase in the number of residents signing watershed stewardship pledge • Rates of participation in education programs specifically directed toward solving particular nonpoint source pollution problems

Successful Use of Aerial Photography to Track Streambank Erosion

Case Study: Bog Brook Channel Stabilization Project, New Hampshire

Past removal of woody riparian shrubs along Bog Brook made the banks of the stream susceptible to erosion. As erosion continued over time, the stream channel became wider and more unstable, exacerbating the erosion problem and sending tons of sediment into the stream. Analysis of aerial photographs showed that the stream channel had eroded laterally up to 35 feet between 1999 and 2003, consuming 4,000 square feet of land. This translated to 120 tons of sediment—approximately the amount needed to fill nine dump trucks—entering the stream each year, harming water quality and smothering fish habitat.

In an effort to halt the degradation of Bog Brook, the landowner adjacent to the eroding channel worked with the town of Stratford and a consultant to secure a section 319 grant from the New Hampshire Department of Environmental Services. The project called for a comprehensive stream morphology assessment, a design plan, and reconstruction of a 275-foot stretch of the stream to a more natural condition. Project partners returned the stream channel to a more natural state and planted vegetation at the site. As a result, the channel stabilized and erosion subsided. In 2006, New Hampshire upgraded the stream from *Impaired* by *other flow regime alterations* to *Fully Supporting Aquatic Life Use* in its 305(b) surface water quality report.

For more information see http://water.epa.gov/polwaste/nps/success319/nh_bog.cfm.

Determine Load Reductions Needed

Using the load estimates from Step 2, you must determine the extent to which the pollutant loads need to be reduced to meet watershed goals. For waters for which EPA has approved or established TMDLs, the plan should identify and incorporate the TMDLs. The estimate should account for reductions in pollutant loads from point and nonpoint sources identified in the TMDL as necessary to attain the applicable water quality standards. The load reduction estimates are based on the planned management measures to be implemented in the critical areas. Elements *b* and *c* of the nine minimum elements are directly linked: ❾Element *b* states that the watershed plan should include *"An estimate of the load reductions expected for the management measures described in element (c) below."* ❾Element *c* states that you should include *"A description of the NPS management measures that will need to be implemented to achieve the load reductions estimated in element (b) above, and an identification (using a map or a description) of the critical areas in which those measures will be needed to implement this plan."*

To estimate the load reductions expected once the management measures are implemented, you need to understand the cause-and-effect relationship between pollutant loads and the waterbody response. Establishing this link allows you to evaluate how much of a load reduction from watershed sources is needed to meet waterbody targets. As with your approach for quantifying pollutant loads, selecting the appropriate approach will depend on several factors, including availability, pollutants, waterbody type, types of sources, time frame, and spatial scale. Most important, the approach must be compatible with the method used to quantify loads and must be able to predict the necessary load reductions to meet targets.

Numerous models are available to determine which BMPs are more appropriate for reducing pollutant loads and to aid in selecting the locations most likely to achieve the greatest load reductions. All models have limitations that you must document to ensure decision-makers understand them before using the data.

🗐 *Refer to Table 9-4 in the Watershed Handbook for a summary of many of the receiving water models available to support linkage of sources and indicators for watershed planning.*

Process to Select Management Practices

1. Inventory existing management efforts in the watershed, taking into account local priorities and institutional drivers.
2. Quantify the effectiveness of current management measures.
3. Identify new management opportunities.
4. Identify critical areas in the watershed where additional management efforts are needed.
5. Identify possible management practices.
6. Identify relative pollutant reduction efficiencies.
7. Develop screening criteria to identify opportunities and constraints.
8. Rank alternatives and develop candidate management opportunities.

Identify Management Practices to Achieve Goals

In general, management practices are implemented immediately adjacent to the waterbody or upland to address the sources of pollutant loads. As part of your screening process, you will want to identify which management practices can be implemented in the critical areas that you identified as part of Step 2.

In most parts of the country, land uses are changing, and you will need to understand how these changes affect pollution loads and water quality. Some watershed pollution models allow you to factor in various development and agricultural scenarios as well as changing climate. Watershed planning is an opportunity to work with new partners to identify actions that reduce pollution, restore damaged ecosystems, and protect valuable habitat.

You can then use screening criteria to screen potential practices, narrowing the options down to those which are the most effective and acceptable. These criteria are based on factors such as pollutant reduction efficiencies, legal requirements, and physical constraints. Once you have identified and screened various management options, calculate the effectiveness of the management practices, compare the costs and benefits, and select the final management strategies that will be the most effective in achieving the load reductions needed to meet the goals for your watershed.

Step 4. Design an Implementation Program

By the end of Steps 1, 2, and 3, you should have reached out to stakeholders and identified watershed goals, characterized the sources of pollutants in the watershed (element *a*), estimated pollutant loads and the necessary reductions to meet your goals (element *b*), and identified the types and locations of management practices in the watershed that will achieve the required load reductions (element *c*). Now you must design an implementation program that shows how you will implement your watershed plan.

Step 4: Design Implementation Program

- **Develop an implementation schedule**
- **Develop interim milestones to track implementation of management measures**
- **Develop criteria to measure progress toward meeting watershed goals**
- **Develop monitoring component**
- **Develop information/education component**
- **Develop evaluation process**
- **Identify technical and financial assistance needed to implement plan**
- **Assign responsibility for reviewing and revising the plan**

Develop an Implementation Schedule

The schedule component of a watershed plan involves turning goals and objectives into specific tasks. The schedule should include a timeline of when each phase of the step will be implemented and accomplished, as well as the agency/organization responsible for implementing the activity. In addition, your schedule should be broken down into increments that you can reasonably track and review. For example, the time frame for implementing tasks can be divided into quarters. It is important to include an estimate of when water quality standards will be achieved, even if that date extends beyond the project period. This phase will fulfill element *f* of EPA's nine minimum elements, which states that you should include a ❾ *"Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious."*

🗐 *Worksheet 12-1, in Appendix B of the Handbook* (PDF, 320 KB, 28 pp.)*, is an example of an implementation matrix.*

Milestones

When designing your implementation schedule, you should establish interim milestones that will help you measure the implementation of activities in your watershed plan. Developing interim measurable milestones will address element *g* of EPA's nine elements. ❾Element *g* requires *"A description of interim measureable milestones for determining whether nonpoint source management measures or other control actions are being implemented."* It usually helps to develop milestones using relevant time scales like the following: short-term (1 to 2 years), mid-term (2 to 5 years), and long-term (5 to 10 years or longer). When developing schedules and interim milestones, be sure to account for weather and seasonal factors when implementing BMPs or performing other field work.

First, outline the subtasks involved and the level of effort and funding requirements associated with each to establish a baseline for time estimates. Then provide milestones that can be reasonably accomplished within those short-term, mid-term, and long-term time frames.

See Worksheet 12-3 (PDF, 320 KB, 28 pp.) *of the Handbook for example milestones.*

Example Milestones

Short-Term (< 2 years)
Achieve 5 percent reduction in sediment load on 1,000 acres of agricultural land in the Cross Creek subwatershed by implementing rotational grazing practices.

Eliminate direct sources of organic waste, nutrients, and fecal coliform bacteria to the stream by installing 5,000 feet of fencing to exclude direct access to cattle along Cross Creek.

Mid-Term (< 5 years)
Reduce streambank erosion and sediment loading rate by 15 percent by reestablishing vegetation along 3,600 feet of Cross Creek.

Long-Term (5 years or longer)
Achieve the fecal coliform water quality standard in the upper section of Cross Creek above Highway 64.

Benchmarks to Measure Progress

As you implement your watershed plan, you will need benchmarks to track progress through monitoring. These interim targets can be direct measurements that reflect a water quality condition (e.g., fecal coliform concentrations, dissolved oxygen content, pounds of nitrogen) or indirect indicators of load reduction (e.g., number of beach closings, pounds of trash removed, length of stream corridor revegetated).

You should also indicate how you'll determine whether the watershed plan needs to be revised if interim targets are not met. These revisions need to focus on changing management practices, updating/reevaluating critical source areas/loading analyses, and reassessing the time it takes for pollution concentrations to respond to treatment; they should not focus on changing the plan's goals.

This phase of the watershed planning process will address element h of EPA's nine minimum elements. ❾Element *h* states *"A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards."*

Table 12-1 of the Handbook demonstrates how you can use a suite of indicators to measure progress in reducing pollutant loads depending on the issues of concern.

Monitoring Program

Your monitoring program will address element *i*, which states that you should include ❾ *"A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item h."*

Monitoring programs can be designed to track progress in meeting load reduction goals and attaining water quality standards and other goals. Measurable progress is critical to ensuring continued support of watershed projects, and progress is best demonstrated with the use of monitoring data that accurately reflect water quality conditions relevant to the identified problems. Monitoring programs should include baseline (before), project-specific (during), and post-project (after) monitoring.

When developing a monitoring design to meet your objectives, it is important to understand how the monitoring data will be used. Ask yourself questions like the following:

- What questions are we trying to answer?
- What techniques will be used?
- What statistical accuracy and precision are needed?
- Can we account for the effects of weather and other sources of variation?
- Will our monitoring design allow us to attribute changes in water quality to the implementation program?

Information/Education Component

Every watershed plan should include an information/education component that involves the watershed community. Because many water quality problems result from individual actions and the solutions are often voluntary practices, effective public involvement and participation promote the adoption of management practices; help to ensure the sustainability of the watershed management plan; and, perhaps most important, encourage changes in behavior that will help you achieve your overall watershed goals. This phase of the watershed planning process will address element e, which calls for ❾*"An information and education component used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented."*

The objectives of the public outreach program should directly support your watershed management goals and implementation of the watershed management plan. They should also include measurable indicators for tracking progress. The information/education component of your watershed plan should build on the outreach efforts you initiated in Step 1 as part of building partnerships. To develop an effective information/education plan, you should use the following steps:

- Define information/education goals.
- Identify and analyze the target audiences.
- Create the messages for each audience.
- Package the message for the various audiences.
- Distribute the messages.
- Evaluate the information/education program.

🗐 *For more information please see* Getting in Step: A Guide for Conducting Watershed Outreach Campaigns *(http://cfpub.epa.gov/npstbx/files/getnstepguide.pdf), which explains the steps needed to develop and implement an effective watershed outreach campaign and includes a set of practical worksheets to help you get on your way.*

Evaluation Process

There are two primary reasons to evaluate your watershed program. First, you want to be able to demonstrate that by implementing the management measures, you are achieving your watershed goals. Second, you want to be able to continually improve your program in terms of efficiency and quality.

In general, you will evaluate three major components of your watershed implementation program—inputs, outputs, and outcomes (Figure 2). Your evaluation framework should include indicators to measure each component. A brief description of each component is included below:

- Inputs—the elements of the process used to implement your program (i.e., resources of time and technical expertise, stakeholder participation)
- Outputs—the tasks conducted and the products developed (i.e., implementation activities such as installing management practices)
- Outcomes—the results or outcomes realized from implementation efforts (i.e., environmental improvements like water quality).

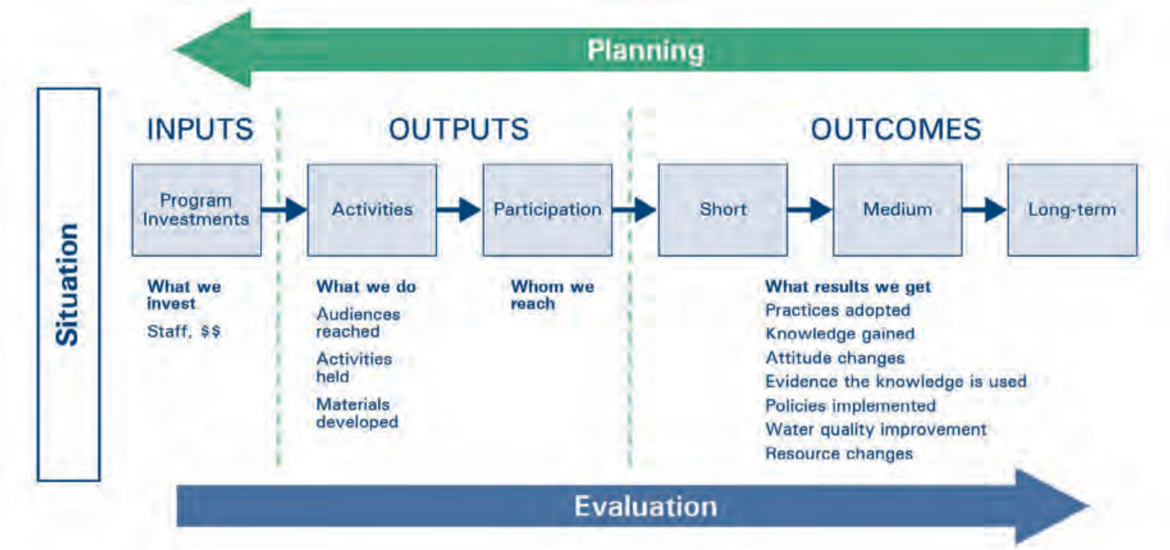


Figure 2. Using a logic model to evaluate your watershed program.

Identify Technical and Financial Assistance

A critical factor in turning your watershed plan into action is the ability to fund implementation. Funding might be needed for multiple activities, such as management practice installation, information/education activities, monitoring, and administrative support. In addition, you should document what types of technical assistance are needed to implement the plan and what resources or authorities will be relied on for implementation, in terms of both initial adoption and long-term operation and maintenance. The identification and estimation of financial and technical assistance should take into account the following:

- Administration services, including salaries, regulatory fees, supplies, and in-kind services
- information/education efforts
- Installation, operation, and maintenance of management measures
- Monitoring, data analysis, and data management activities.

Identifying the technical and financial assistance needed will address element d of EPA's nine elements: ❾*"Provide an estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan."*

Keys to Successful Implementation

Although there is no single component that defines success, several factors, if implemented, will enhance your chances of a successful watershed implementation plan:

- Measurable goals and objectives
- Dedicated staff to carry out administrative duties
- Consistent, long-term funding
- Involvement of stakeholders in planning efforts
- Dedicated individuals who are supported by local government agencies
- Local ownership of the watershed plan
- A method for monitoring and evaluating implementation strategies
- Open communication between organization members.

Step 5: Implement the Watershed Plan

Although much of the watershed planning process is focused on developing the plan, results will not happen until the plan is actually implemented. Implementation activities should follow the road map developed in your plan. This means that individual projects should be coordinated by a plan-designated project manager or implementation team to ensure that BMPs are not just implemented but also fit the schedules, achieve specific milestones, and are integrated with various monitoring and outreach efforts.

Step 5: Implement the Watershed Plan

- **Prepare work plans**
- **Implement management strategies**
- **Conduct monitoring**
- **Conduct information/education activities**
- **Share results**

Prepare Work Plans

You will use your overall watershed plan as the foundation for preparing work plans, which will outline the activities in 2- to 3-year time frames. Think of your watershed plan as a strategic plan for long-term success and annual work plans as the specific to-do lists to achieve that vision. Work plans can also be useful templates for preparing grant applications to fund implementation activities. Depending on the time frame associated with your funding source, your work plans might need to be prepared annually with quarterly reporting.

Implement Management Strategies

Implementing the watershed management plan involves a variety of expertise and skills, including project management, technical expertise, group facilitation, data analysis, communication, and public relations. The management practices you identified in your plan will probably include a combination of structural and nonstructural controls. Be sure to set and track the milestones to measure the rate of progress in implementing the management strategies. Your tracking should include the progress made in BMP implementation, maintenance activities, and (if applicable) point source treatment improvements and monitoring of social indicators.

Conduct Monitoring

As part of the development of your watershed plan, you should have developed a monitoring component to track and evaluate the effectiveness of your implementation efforts. There are many ways to monitor water conditions. To monitor the constituents in water, sediments, and fish tissue—such as levels of dissolved oxygen, suspended sediments, nutrients, metals, oils, and pesticides—monitoring specialists perform chemical measurements. Physical measurements of general conditions such as temperature, flow, water color, and the condition of streambanks and lakeshores are also important. Biological measurements of the abundance and variety of aquatic plant and animal life and the ability of test organisms to survive in sample water are also widely used to monitor water conditions. In addition to government monitoring programs, trained volunteers have been able to provide important data for watershed management.

Project Effectiveness Monitoring

🗁**Case Study: Otter Creek Watershed, Wisconsin**

Section 319 funding was sought to improve water quality conditions in the Otter Creek watershed. Modeling and field inventories identified critical areas needing treatment to achieve the project goals of improving dissolved oxygen levels and reducing bacterial levels. Best management practices (BMPs) were implemented on area dairy farms; they include rainwater diversions, concrete loading areas, filter screens to trap large solids in runoff, and grassed filter strips for treating runoff. The following monitoring activities are conducted to track project effectiveness:

- Paired watershed and upstream/downstream monitoring studies covering eight monitoring sites are used to evaluate the benefits of the BMPs. The monitoring sites are above and below a dairy with barnyard and streambank stabilization BMPs.
- Habitat, fish, and macroinvertebrates are sampled each year during the summer.
- Water chemistry is tracked through analysis of 30 weekly samples collected each year from April to October at the paired watershed and upstream/downstream sites.
- Runoff events are also sampled at the upstream/downstream sites and at the single downstream station site at the outlet of Otter Creek.

Read more about this project at http://www.epa.gov/owow/NPS/Section319III/pdf/319_all.pdf.

Analyze Your Data

Two types of analyses should be considered during the implementation phase: (1) routine summary analysis that tracks progress, assesses the quality of data relative to measurement quality objectives (i.e., whether the data are of adequate quality to answer the monitoring questions), and provides early feedback on trends, changes, and problems in the watershed and (2) intensive analysis to determine status, changes, trends, or other issues that measure the response to watershed plan implementation.

In general, intensive data analysis should be conducted at least annually in a multiyear watershed plan. The types of data analyses you perform on the monitoring data depend on the overall goals and objectives, the management approach, and the nature of the monitoring program; several types of analyses might be appropriate depending on the monitoring questions. Where analysis and evaluation of management practices are the focus of monitoring, it might be feasible to use relatively simpler analyses, such as t-tests comparing indicator levels before and after implementation, levels above and below implementation sites, or pollutant levels in areas where management options were implemented and areas where they were not. Where adequate pre-implementation data are not available, trend analysis can be used to look for gradual changes in response to your implementation program. In some cases, more sophisticated statistical techniques such as analysis of covariance might be required to control for the effects of variations in weather, streamflow, or other factors.

Conduct Information/Education Activities

Although it is important to let people know about the water quality problems in the watershed, sometimes simply informing and educating people on the issues is not enough to encourage adoption of practices over time. First, audiences should be made aware of the issue. Then they should be educated on the problems facing the watershed. Finally, they should learn what actions they can take to help address those problems.

Share Results

Continuous communication is essential to building the credibility of and support for the watershed implementation process. As part of your information/education activities, you should be highlighting key activities and results to the stakeholders and the larger community. This helps to keep them engaged and to show them how their participation is making a difference.

Step 6. Measure Progress and Make Adjustments

You will periodically review the implementation activities outlined in your work plan, compare the results with your interim milestones, provide feedback to stakeholders, and determine whether you want to make any corrections. The adaptive management approach is not linear but circular, to allow you to integrate results back into your program. You need to create decision points at which you will review information and then decide whether to make changes in your program or stay the course.

Make Adjustments

- **Track progress**
- **Make adjustments**

Track Progress

As part of your plan implementation, you will track progress in several areas, such as meeting the milestones you set for management practice implementation. You will also analyze monitoring data to determine water quality improvements. It is helpful to set time frames for the review and assessment of your watershed plan. Simple basic data analysis should be done routinely as part of the review process. Your review should also address several key areas:

- The process being used to implement your program
- Progress on your work plan
- Implementation results
- Feedback from landowners and other stakeholders.

Make Adjustments

If you have determined that you are not meeting the implementation milestones or interim targets that you set for load reductions and other goals, you need to make adjustments. Perhaps you have determined that you need additional management measures or you need to apply the management measures in another location. Be sure to ask the right questions before making any changes. In some cases you might not have met your milestones because of weather conditions, or perhaps you lacked the funding to implement some of the measures.

Land Use & Water Quality

Introduction

Indiana's increasing population and expanding economy are placing unprecedented pressure on its land. Urban sprawl (particularly the paving of large segments of the landscape) can have significant and usually negative impacts on water resources. Although growth and land use change may be inevitable in many communities, the way in which growth takes place affects its impact on water quality. With careful planning and a commitment to protect streams, rivers, and ground water, land use practices can be implemented that balance the need for jobs and economic development with protection of the natural environment. Development that takes place without such considerations, however, can lead to significant degradation of streams and ground water, and loss of aquatic life.

All land uses have an effect on water quality, whether positive or negative. In forests and other areas with good vegetation cover and little disturbance from humans, most rainfall soaks into the soil rather than running off the ground, stream flows are fairly steady, and water quality is good. In built-up areas with pavement and buildings, little rainfall soaks into the soil, causing high runoff, stream flows with high peaks and low flows in between, and poorer water quality. In fact, land use and practices are probably the most important factor in determining water quality in most Indiana landscapes.

Most people realize that development affects water quality and are raising questions like the following when communities are making land use decisions:

- How will increased development affect the quality of our streams?
- How do the water quality impacts of proposed land use changes compare to impacts of current land use?
- How can we make decisions that will allow our community to grow yet protect our streams?

This publication addresses such questions by discussing land use effects on runoff, water quality impacts from specific land uses, and strategies for reducing the negative impacts of development on water quality while accommodating growth.

Rainfall, Runoff, & Land Use

The fate of rain that falls on the land is strongly affected by land use. In a forest or grassy area, most rain soaks into the soil (infiltrates), where it eventually is used by growing plants or percolates to ground water. Ground water flows slowly into streams, usually over a period of months, providing steady base flow (flow in streams in times without rainfall) that fish and other aquatic life need. By contrast, most rain that falls on a parking lot runs off immediately, often draining into storm sewers that transport it to a stream or ditch. The most common land use in Indiana is agriculture, which lies somewhere between these two extremes. On agricultural land, some rainfall runs off, while some infiltrates into the ground where it can be used by plants or provide base flow for streams.

Table 1 shows typical runoff amounts for four land uses. The first column shows runoff from a 4-inch rainfall. (On average in Indiana, this amount of rain falls in one day every 10 years.) On forest, meadow, or good-quality turf grass, less than 1 inch (out of that 4-inch rainfall) becomes runoff. These land uses have little disturbance, and the vegetative cover is good year round. On a cropped field (corn or soybeans are considered the same in this type of analysis) the runoff is 2 inches, representing about half the rainfall. On roofs or pavement the runoff is 3.9 inches, which represents about 97% of the rainfall. (The other 3% gets caught in puddles or depressions and evaporates.) The second column shows the estimated runoff volume in gallons from a 1-acre area, to illustrate the differences in runoff volume among these land uses.

The third column in Table 1 shows the average runoff for that land use over many years from typical precipitation amounts (which average 39.4 inches per year) in central Indiana. These amounts would be slightly higher towards the south, where annual precipitation is higher, and lower towards the northeast, where precipitation is lower.

Table 1. Runoff Expected from Four Types of Land Use

Land uses	Runoff from a 4-inch rainfall (inches)	Runoff volume from 4-inch rainfall on 1 acre (gallons)	Average yearly runoff* from this land use in central Indiana
Forest	0.5 inch	13,600	0.3 inches
Grass (meadow, lawns, parks)	0.8 inches	21,700	0.4 inches
Corn/soybeans	2.0 inches	54,300	1.1 inch
Roofs/pavement	3.9 inches	105,900	19 inches

Note: NRCS "Curve Number" method of estimation; Hydrologic soil group B; Corn/soybeans have 30% residue coverage; Curve numbers are 55 (forest), 61 (grass), 75 (corn/soybeans), and 98 (roofs/pavement). Soil moisture before storm is average.

Roofs, pavement, and other hard surfaces that generate such high runoff amounts are often referred to as impervious areas. Impervious areas include both buildings (such as houses, factories, and stores) and transport-related areas (such as roads, driveways, and parking lots). Although the area occupied by both is increasing, transport-related areas are increasing at a faster rate. Transport-related areas now often comprise more than half the impervious area in residential and commercial areas. The sharp rise over the last 20 years in vehicle ownership and miles travelled, both total and on a per capita basis, have caused planners to increase the size of the transport component. This increase usually affects water resources

Most land uses represent a combination of pervious and impervious surfaces. Residential areas, which combine roofs, sidewalks, driveways, and roads with grassed areas, represent a typical combination. Table 2 shows the predicted runoff for two types of residential areas (1-acre lots and ¼-acre lots), commercial, and industrial development, using the same assumptions as above. Most people are surprised to find that the runoff predicted in residential areas using this method is about the same as the runoff from the cropped field. Although the runoff from the roofs, driveways, and roads is much higher than the cropped field, the runoff from the grassed area is lower, and the weighted average typically used to perform such calculations results in the same total runoff. The industrial and commercial land uses represent higher percentages of impervious areas, and do result in higher runoff.

Table 2. Runoff Expected from Combination Land Uses

Land uses	Runoff (inches)	Runoff volume 1 acre (gallons)	Average yearly runoff (if located in central Indiana)
Residential (1-acre lots)	1.2 inches	32,600	0.2 inches
Residential (1/4-acre lots)	1.7 inches	46,200	1.1 inch
Industrial	2.7 inches	73,350	4.1 inches
Commercial	3.7 inches	100,520	7.3 inches

Note: Curve numbers are 68 (1 acre lots), 75 (1/4 acre lots), 88 (industrial), 92 (commercial).

The Long-term simulations in Tables 1 and 2 show that over the course of many years the runoff is more than 20 times as great for commercial developments as forest land. Besides total runoff, the peak flow increases with increasing impervious areas, not only because the total volume of flow is greater but because in most cases runoff can reach the stream more quickly. The objective of "providing good drainage" in most communities has resulted in construction of storm sewers that provide a direct and easy pathway for runoff to be carried to the stream. Runoff that may take several hours from a grassy meadow can reach a stream from a parking lot connected by storm sewers in a matter of minutes. This increase in the speed of runoff, in combination with increased runoff volume, is the major cause of flooding problems.

Effects of Runoff back to top

Some people might assert (correctly) that the total volume of water remains the same under the different land use scenarios; it is simply the pathway that the rain follows that changes. More or less rainfall runs off the surface rather than infiltrating into the ground. Although this is true, the pathway followed makes a major difference in stream characteristics and health. Some of the results of increased runoff are described below:

- **Increased frequency and severity of flooding**. If the runoff from a storm is greater, the chance of the flow exceeding the stream capacity and causing flooding increases.
- **Reduced ground water recharge**. Water that runs off, particularly if it is channeled through storm sewers, never has a chance to recharge ground water. This could be cause for concern, because 60% of drinking water in Indiana is provided from ground water, and ground water provides base flow to streams throughout the year.
- **Decreased base flow in streams**. Base flow is the water that flows even during dry periods. Aesthetically, most people prefer to look at a stream that has water throughout the year rather than one that is periodically dry. More important, continuous base flow is vital to the health of aquatic life in the stream.
- **Increased erosion**. Stream channel erosion is an important source of sediment in channels. Erosion is very dependent on flow. Doubling of the flow may cause the streambank erosion to increase by a factor of 4 or more.
- **Reduced natural filtration of the water.** The process of passing through the soil is one of the most important purifiers of water. Many pollutants are filtered, attached to soil particles, or eaten by microbes as water passes through the soil. Bypassing this route has a severe negative effect on water quality.
- **Negative impact on stream health.** Streamflow varies even under natural conditions, and most aquatic life is adapted to this. But increased streambank erosion due to higher peak flows and periods of very low flow due to the decreased base flow add stress for many organisms.

Pollution Sources & Land Use back to top

Besides the effect on flow, land use directly affects water quality in many other ways. To understand these effects, it helps to understand the difference between point source pollution and nonpoint source pollution.

Point source pollution refers to contaminants that enter the water directly, usually through a pipe. The specific location where the pollutant enters a stream can be identified, because it is usually at the end of a pipe. Examples of point source pollution are sewage treatment plants (which treat wastewater but still release a regulated amount of pollution in their discharge) and industrial sources. Point sources are easier to regulate than nonpoint sources and were the original target of the 1972 Clean Water Act that has dramatically improved the quality of many U.S. rivers and streams. Although point sources were formerly the worst culprits in impairing water quality, most point sources have greatly reduced the pollution they discharge as a requirement of the permits they must obtain.

Nonpoint source pollution, also known as "polluted runoff," is different. The exact location where this type of pollution enters a stream cannot be identified because it comes from entire landscape areas: anywhere that rain falls and carries pollutants as it runs off. Your driveway and the road near your house may be sources of pollution if spilled oil, leaves, or other contaminants flow from them to a stream. Agricultural areas, because they occupy so much of the Indiana landscape, are important sources of pollution when rainfall carries sediment, nutrients, or chemicals to streams. Urban areas also are the source of important, but sometimes different, nonpoint source pollutants. Nonpoint source pollution is currently the major water quality problem in the U.S. - and nonpoint source pollution is directly related to land use. Common nonpoint source pollutants in agricultural areas are sediment, pathogens, nutrients, and pesticides. Common nonpoint source pollutants in urban areas are sediment, pathogens, nutrients, oxygen-demanding substances, heavy metals, oil and other petroleum products, and road salt.

Sediment is the largest pollutant in Indiana by volume. It affects aquatic life, shortens reservoir life, and complicates water treatment. Its sources are cropland erosion, construction sites, washoff from streets and other impervious areas, and streambank erosion. Streambank erosion in particular is increased by the added runoff due to development.

Pathogens include E. coli (a bacteria used to indicate the presence of fecal waste) and other viruses, bacteria, and protozoa. The source of most pathogens is fecal material from any warm-blooded animal. In agricultural areas, sources include wildlife, livestock manure, and malfunctioning septic systems. In urban areas the major sources are pet wastes, wildlife that may be present in high numbers (such as birds), septic systems in unsewered areas, and sewage treatment plant discharges (which are considered a point source). A particularly significant source is the outfall from combined sewers, where raw sewage in combination with urban runoff is allowed to bypass the treatment plant during storms. Although combined sewer overflows are an urban source, they are rarely a concern related to current development, because new areas have separate sanitary and storm sewers.

Nutrients of concern are primarily nitrogen and phosphorus. High concentrations of nitrate in drinking water are toxic to infants and may be harmful to pregnant women. Nitrate in the Mississippi River is one cause of hypoxia in the Gulf of Mexico. Hypoxia is a zone of low oxygen where fish cannot live. Phosphorus leads to overproduction of algae that clog lakes and reservoirs. Sources of nutrients in agricultural areas include fertilizer, livestock manure, and septic systems. Sources of nutrients in urban areas are fertilizer used on lawns, gardens, and golf courses; pet waste runoff; and discharge from sewage treatment plants or industry.

Pesticides can be a concern in drinking water supplies that use surface water. Pesticide concentrations in most Indiana streams in agricultural areas rise above drinking water standards after application in the spring, but these elevated concentrations do not typically last long enough to be a violation of drinking water standards. Sources of pesticides are simpler to identify than sources of pathogens or nutrients. They are limited to pesticide application, either in agricultural or urban areas. Studies by the US Geological Survey in the White River Basin found that concentrations of primarily agricultural pesticides such as atrazine are much higher than concentrations of any pesticide used primarily in urban areas. However, concentrations of certain pesticides, such as diazinon, an insecticide for lawns and gardens, were higher in urban areas.

Oxygen-demanding substances consist of organic matter that depletes dissolved oxygen when decomposed by microorganisms. Dissolved oxygen is critical to maintaining water quality and aquatic life. Studies have shown that urban runoff with high concentrations of decaying organic matter (such as leaves, grass clippings, and other organic debris) can severely depress dissolved oxygen levels after storm events.

Metals include lead, copper, cadmium, zinc, mercury, and chromium. They can accumulate in fish tissues and affect sensitive animal and plant species. One of the major causes of fish consumption advisories in Indiana is mercury. Sources of metals are automobiles (copper is lost from brake pads, for example), industrial activities, illicit sewage connections, and atmospheric deposition (for example, mercury that is released into the air from combustion and then falls to earth in rainfall at another location).

Oil and other petroleum products degrade the appearance of water surfaces, impair fish habitats, and may be toxic to sensitive species. Sources are oil leaks; auto emissions coming off parking lots, roads, and driveway; and improper disposal of waste oil. Concentrations of petroleum-based hydrocarbons are often high enough to cause mortalities in aquatic organisms.

Road salt increases levels of sodium and chlorides in surface and ground water. Snow runoff produces high salt/chlorine concentrations at the bottom of ponds and lakes. Not only does this condition prove toxic to certain organisms, but it also prevents crucial vertical spring mixing.

Imperviousness & Water Quality

The nonpoint source pollutants described above are deposited on the land through normal application of fertilizer, pesticides, and road salt; atmospheric deposition; poor disposal practices; automobile emissions; and litter. In urban areas, these pollutants are usually deposited on impervious surfaces such as parking lots and roads. Impervious surfaces that are connected to streams through a pipe (typically a storm sewer) more directly affect water quality than do pervious areas, even if equivalent amounts of a pollutant are present. This is because filtration through soil, which is completely absent in sewered areas, is an important factor in reducing many pollutants. Storms quickly wash off pollutants from impervious areas and deliver them to streams and lakes, in many cases without any chance for infiltration and the purifying effects of the soil. The most important factor determining the negative impact of development on water quality appears to be the number and extent of impervious areas directly connected to the drainage network by storm sewers or other piping systems. Impervious areas drained by storm sewers form the major part of many developments, where the goal is to remove water as quickly as possible. Yet we now realize that removing water quickly can have significant negative impacts.

How much impervious area is too much? Many people have suggested that water quality deterioration begins when 10% to 20% of the watershed area is impervious. Studies in many areas of the country have found that concentrations of various contaminants increase with increasing impervious cover, while stream biodiversity decreases. It should be noted that many of these studies are in areas where the dominant land use outside of urban areas is forest, rather than agriculture, as is the case in Indiana. Because stream water quality and biodiversity depend on such a wide range of factors, including management practices that are implemented, it is unlikely that specific details of relationships found in one area can be assumed to be true in another area. Research is underway to identify other methods of relating development and water quality impacts.

What Can Be Done?

Strategies such as the following can minimize the effects of development on water quality:

- Minimize impervious areas
- Slow stormwater that comes from the impervious areas
- Reduce pollutant sources on all surfaces.
- Protect critical areas such as buffer areas around streams.
- Plan development on a watershed basis.

The last strategy is an approach that involves thinking beyond the boundaries of one or two developments in question to establish a more comprehensive view of the cumulative impacts of all the development on a stream or watershed. These strategies are discussed below.

Minimize Impervious Areas

Impervious areas can be reduced by incorporating open spaces into urban areas, reducing road width, planning subdivisions so that driveways are smaller, reducing parking requirements, and using permeable alternatives to pavement such as gravel or porous pavement. These approaches are sometimes called "conservation design." Some of these techniques may require changes in zoning before they can be implemented.

Slow Stormwater

Avoiding direct connections from impervious areas to streams has an important effect on runoff. Examples of eliminating direct connections include spreading rootfop runoff over pervious areas and routing road or parking lot runoff to grassy swales rather than to storm sewers. The most common way stormwater is slowed, however, is by requiring stormwater basins.

Stormwater basins are a response to the increased flow due to impervious areas. Stormwater basins hold back the peak stormflow, releasing it at pre-development release rates. No Indiana state law requires stormwater basins, but many county ordinances do. A typical requirement is that peak runoff from a 100-year storm after development must be less than the peak runoff from a 10-year storm before development. The outlet of the basin is usually a pipe sized small enough to allow only the pre-development flow rate. The basin is large enough to hold the flow that arrives from the developed areas, allowing it to discharge at the allowable rate. The release time for stormwater basins is usually 24 hours or less, so stormwater basins do not replace base flow in streams.

Figure 1 shows the effect of a stormwater basin on runoff amounts over time. The peak runoff rate is reduced but the total runoff amount remains at a much higher level than before development. Thus, stormwater basins are an important tool for reducing peak flows, but by themselves they do not solve the problem of increased flow due to development.

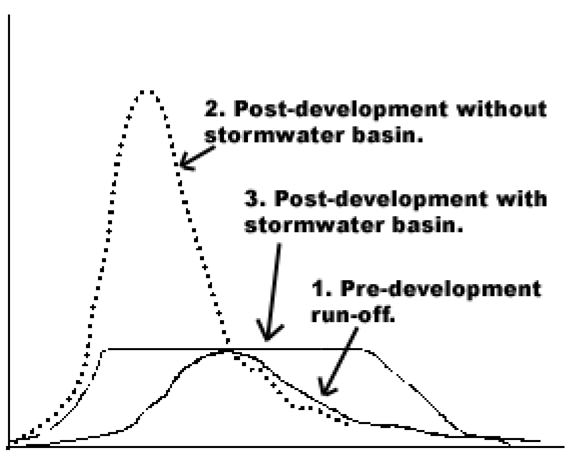


Figure 1. Effect of development and construction of stormwater basins on storm runoff.

Stormwater basins can be either dry (detention ponds) or wet (retention ponds). In some cases constructed wetlands are also used for stormwater management. Dry detention basins are grass or stone-lined depressions that can potentially be used as recreation areas during dry periods, but often they are not designed to be aesthetically pleasing. Although they lower peak flows, they provide minimal water quality treatment. Wet basins are permanent pools of water, designed to store drainage above the normal pool elevation during storm events. They are often used in current subdivisions, because many people enjoy living near water. They also have the benefit of a longer storage time (if the stormwater mixes with the permanent pool), which often results in better water quality treatment. In addition, a certain amount of water can infiltrate between storms and filter out contaminants.

Reduce Pollution Sources

It is generally less expensive to prevent contaminants from entering stormwater than to treat contaminated water. Many contaminants can be prevented from getting into stormwater through good management practices such as encouraging proper disposal of pet wastes; reducing fertilizer and pesticide use on lawns, gardens, cemeteries, and golf courses; and community hazardous waste and waste oil recycling centers. Regular street and parking lot cleaning can reduce the transport of sediment-bound pollutants. New street sweeping machines pick up much finer materials than older models. Disposal of street sweeping wastes may pose a problem because of possible high levels of lead, copper, zinc and other wastes from automobile traffic, but this clearly shows the importance of removing them before they enter streams. In areas where salt is used, alternative practices such as relying first on plowing rather than salting, anti-icing (preventative salting before a storm), or using sand, cinders, or chemicals such as calcium magnesium acetate (CMA) instead of salt will reduce pollution of area water bodies.

Establish Protected Areas such as Stream Buffers. Although all land use affects water quality, the riparian areas along the edges of streams and waterways have a particularly important effect. Buffer zones or "green belts" along streams can improve water quality while providing recreational areas for residents. Buffer zones are particularly effective at reducing streambank erosion, filtering out sediment and sediment-bound contaminants, and promoting healthy aquatic life in the stream. They also promote infiltration, and if the primary pathway followed by runoff water is overland (rather than through pipes), they will reduce dissolved contaminants. Stream buffers can be protected by regulations, purchase of the land, or easements to prevent development on the critical riparian areas. Protecting these areas usually has a disproportionately large effect on water quality and should be a priority in any development planning.

Plan development on a watershed basis

Subdivisions usually require approval by the local or area plan commission, and a detailed drainage or water management plan for the proposed development is often part of the approval process. In most cases a drainage plan for the site itself is all that is considered, rather than how the development affects the entire watershed. In order to protect streams and watersheds, a broader approach is needed.

A watershed approach would require an analysis of the watershed in which the proposed development is located, and how the proposed development fits into the cumulative impacts of all development planned in the watershed. The advantage of planning on a watershed basis is that it may be most beneficial to the stream as a whole if development is concentrated in certain high-density areas, while other areas are left as open space. Another aspect of watershed-based planning is preparing an inventory of important natural resources throughout the watershed, and implementing setback distances from critical resources. Development should be concentrated in areas that are not classified as critical resources. Geographic Information Systems (GIS) can make the analysis of larger areas more feasible.

The Future

Stormwater runoff is one of the leading remaining causes of water quality problems in the United States. Cities over 100,000 people have already been required to respond to stormwater runoff rules which required that they obtain Clean Water Act (NPDES) discharge permits. Phase II stormwater regulations expand controls of storm water runoff to cover smaller cities (with populations under 100,000) and small construction sites (under five acres). The proposed stormwater regulation, which will be finalized in 1999, promotes public education and outreach on stormwater impacts, public involvement and participation in stormwater planning, and the use of best management practices to minimize stormwater impacts as part of a municipal stormwater program.

There is no doubt that it is easier to plan for good stormwater management before development takes place rather than retrofitting existing development to reduce stormwater impacts. Balancing the needs of growth and protection of the environment (particularly streams, rivers, and lakes) requires planning and commitment, but it is well worth the effort. All citizens benefit when clean streams with healthy aquatic life flow in and around their communities.

Acknowledgments

This publication was strengthened through thoughtful reviews by the following Purdue University faculty:

- Bernard Engel, Department of Agricultural and Biological Engineering
- Jon Harbor, Department of Earth and Atmospheric Sciences
- William Hoover, Department of Forestry and Natural Resources

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Northeastern Illinois Planning Commission. Date? Pavement Deicing: Minimizing the Environmental Impacts. 222 S. Riverside Plaza, Suite 1800, Chicago IL 60606.

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The Purdue University/EPA Web site. "Long-Term Hydrologic Impact Assessment" enables the user to input any combination of land use and soil type and find the long-term runoff amounts. The program can be found at http://danpatch.ecn.purdue.edu/~sprawl/LTHIA

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NCF-Envirothon 2026 Mississippi

Current Issues: Part B Study Resources

Key Topic #3: Low-Impact Development (LID) and Best Management Practices

9. Define LID and describe how it reduces stormwater volume and pollutant loads in urbanized settings.
10. Compare green infrastructure tools (e.g., rain gardens, pervious pavement, bioswales) and explain their appropriate use in residential, recreational, and commercial zones.
11. Analyze how LID supports infiltration, evapotranspiration, and baseflow protection.

2. Sustainable and Resilient Development Design

Sustainable and resilient development design involves protections and practices employed during the site development process that reduce the environmental impact of a project while retaining and enhancing the owner/developer's purpose and vision for the site (**Figure 2-1**). This section expands on the definitions of *sustainability* and *resiliency* in the context of urban development and redevelopment and provides guidance to support these objectives and minimize effects of NPS pollution on the environment.

Sustainability is the support of long-term ecological integrity. Where lands are slated for development, there are conservation and sustainable site design approaches that can be used to help meet important watershed protection objectives, including the following:

- Avoiding and minimizing land cover conversion in areas susceptible to erosion
- Preserving areas that provide important water quality benefits and habitat features
- Developing sites in a manner that protects water bodies and natural drainage systems

Figure 2-1. Sustainable and resilient design practices help maintain a healthy environment. (Photo: James Starnes, MDEQ)

Sustainable site design practices mimic predevelopment hydrologic conditions by preserving natural features and reducing impervious cover to the maximum extent possible (**Figure 2-2**). Many of these practices can reduce the cost of infrastructure while maintaining or even increasing the value of the property compared to conventionally designed developments. Typical elements of sustainable site design (adapted from Hegemier et al. 2019) include the following:

- Preserving natural areas and native vegetation, especially minimizing disturbance of existing, mature stands of vegetation
- Reducing the impact on watershed hydrology
- Incorporating natural drainage pathways as a framework for site design
- Preventing stormwater impacts rather than having to mitigate for their effects
- Managing stormwater quantity and quality as close to the source as possible and minimizing the use of large, regional collection and conveyance structures
- Using simple conservation methods for stormwater management, which are often lower cost and lower maintenance than structural controls
- Reducing the amount of soil compaction during construction to maintain infiltration capacities of the soil

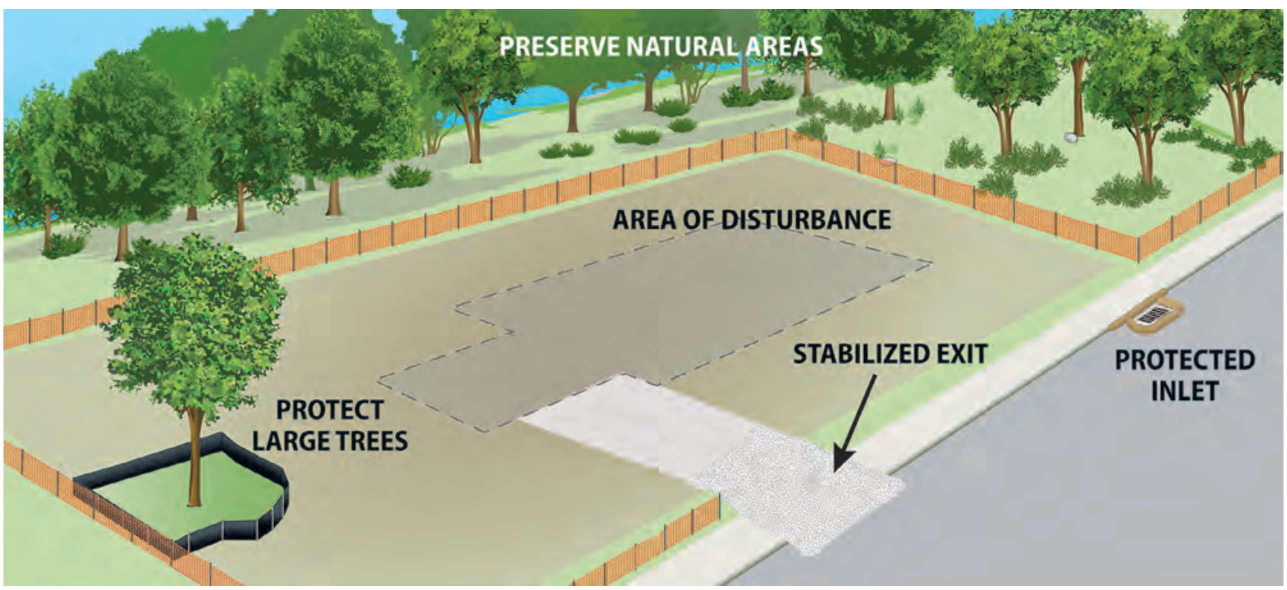


Figure 2-2. Examples of sustainable site design elements.

Many of the elements in sustainable site design also increase resiliency. **Resiliency** is the ability of a system to respond to, or recover readily from, stresses or disruptive forces. New development should be guided away from known hazards, such as areas subject to extreme high tides, hurricane surges, flood waters, and potentially subsiding ground. Consistent with this approach, this guidance manual supports implementing practices in new developments and communities to be resilient, strong, and flexible. When areas are identified for development, one primary goal is to design systems that can continue functioning in the face of these types of threats and hazards (Hegemier et al. 2021). Additionally, natural environmental protective systems should be conserved to maintain their valuable hazard mitigation functions. One example of stressors that developed areas face is higher frequency and intensity of rainfall, which can cause inland or coastal flooding. Resilient design can help a developed area more readily recover from heavy rains through practices such as preserving natural vegetation around streams and coastal areas, encouraging infiltration and rainwater storage by maximizing pervious areas and tree canopy, and incorporating storage and conveyance of excess runoff into site design features.

An area's resiliency is important to consider during the site assessment process for new and existing developments. Consider possible hazards early in the design process. This type of comprehensive approach to new developments can protect communities and businesses from losses associated with flooding and other extreme weather. Hazard mitigation activities include:

- Planning to identify hazards and vulnerability
- Implementing smart growth and hazard mitigation plans before disasters occur
- Avoiding known or previously affected vulnerable areas (e.g., floodplains), and directing new development away from hazardous locations (Hegemier et al. 2021)

Hazard mitigation also seeks to address identified hazards using appropriate structural and nonstructural approaches.

The Center for Watershed Protection's (CWP's) *Better Site Design: A Handbook for Changing Development Rules in Your Community* provides 22 model design principles in three categories as options for more environmentally sustainable designs that reduce impervious cover and retain natural land cover. The three types of recommendations are related to conservation of natural areas, appropriate design of streets and parking lots, and appropriate site and lot development plans (CWP 1998). For example, the handbook describes how to design a development to protect a site's natural features by reducing overall street lengths or narrowing street widths. The principles touch on benefits such as a reduced need for clearing and grading, greater community open space, more forest canopy, and opportunities for conservation incentives (CWP 1998). Mississippi Department of Environmental Quality (MDEQ) recommends practices outlined in CWPs Better Site Design Manual and provides further details in its own handbook, the Stormwater Runoff Management Manual, Volume 2 (MDEQ 2011b).

This guidance document provides conservation and development approaches that will enhance resiliency and function while managing NPS pollution. This guidance encourages low-impact approaches that will serve multiple functions: protecting water quality, managing runoff, minimizing long-term maintenance, and promoting public safety.

Section 2.1 discusses the benefits of identifying and preserving wetlands, streams, floodplains, forests, and other natural features before development occurs. These features are abundant in Mississippi's coastal areas and provide valuable protections for water quality and the environment. State and federal regulations protect some of these features; however, conservation strategies can be incorporated into the development process to provide further protections.

As discussed in Section 2.2, sustainable development practices include site assessment, low impact development (LID) and green infrastructure design, conservation design, and reducing and disconnecting impervious cover. Additionally, these practices should include special considerations for road, highway, and bridge design; channel modification; and erosion protection.

2.1. Protecting Natural Lands

Preserving natural features involves identifying and protecting areas that are beneficial to water quality and provide natural habitat. Preservation efforts can include setting aside a large contiguous area as a preservation zone or several smaller areas designated as important to maintain in undeveloped condition. Protecting existing lands and vegetation from development can help reduce the risk of erosion, protect wildlife habitat and water resources, maintain healthy ecosystems, and reduce revegetation requirements.

Protecting natural features is a key consideration during the planning phase of a development project and can include implementing appropriate BMPs during construction and properly maintaining them after a site is established. The MDEQ *Stormwater Runoff Management Manual* provides detailed approaches and guidance for protecting natural features throughout project planning, implementation, and maintenance (MDEQ 2011b).

Benefits of preserving natural vegetation include the following:

- An immediate finished, aesthetically pleasing landscape that requires no time for vegetation to reestablish
- Enhanced stormwater infiltration by mature vegetation that will soak up more stormwater runoff than newly seeded areas
- Reduced runoff volume and velocity because plants will intercept rainfall, promote infiltration, and lower the water table through transpiration
- A buffer against noise and visual disturbance during and following construction
- Less maintenance than clearing land and planting new vegetation

Development plans should prioritize protection of sensitive habitats and unique natural resources. Key habitats and natural features to target for preservation include wetlands, streams, floodplains, forests, and forested riparian buffers. Areas with erodible soils, natural depression storage, steep slopes, special ecological value, or other undevelopable land also are good candidates for preservation.

2.1.1. Wetlands

Wetlands provide critical ecological and water quality functions, serving as wildlife habitat, attenuating floodwaters, processing nutrients, and serving as a natural filter that improves water quality in adjacent waterways (**Figure 2-3**). Generally, wetlands are areas where regular or intermittent saturation supports specific wetland soils and vegetation.

The U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency (EPA) define wetlands as those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. In general, wetlands include swamps, marshes, bogs, and similar areas.

Nontidal wetlands occur in floodplains along rivers and streams, in isolated depressions surrounded by dry land, along the margins of lakes and ponds, and in other low-lying areas (**Figure 2-4**). Wetland plants and soils filter stormwater before it drains into streams and rivers or soaks through the soil into groundwater. Nontidal wetland types in Mississippi include bogs, swamps, riverbanks, bottomland forests, bayheads, coastal flatwoods, and savannas. Bottomland forests (forested wetlands), swamps (forested or scrub-shrub wetlands), and freshwater marshes (emergent wetlands) account for most of Mississippi’s wetland acreage (NAWM 2015). Tidal wetlands are found at the edge of coastal waters and provide habitat for birds and a nursery for shrimp, fish, and other aquatic life. Tidal wetlands include salt and brackish marshes, freshwater marshes and swamps, mud flats, and tidal openwater habitats such as bayous, rivers,

Figure 2-3. Pond with wetlands. (Photo: Adam McWilliams, MDEQ)

oyster beds, and other coastal waters. Common trees in tidal swamps include bald-cypress and tupelo gum. In total, woody and herbaceous wetlands make up about 32% of the land area in Mississippi's coastal watersheds (**Figure 2-5**).

Figure 2-4. Forested wetland. (Photo: James Starnes, MDEQ)

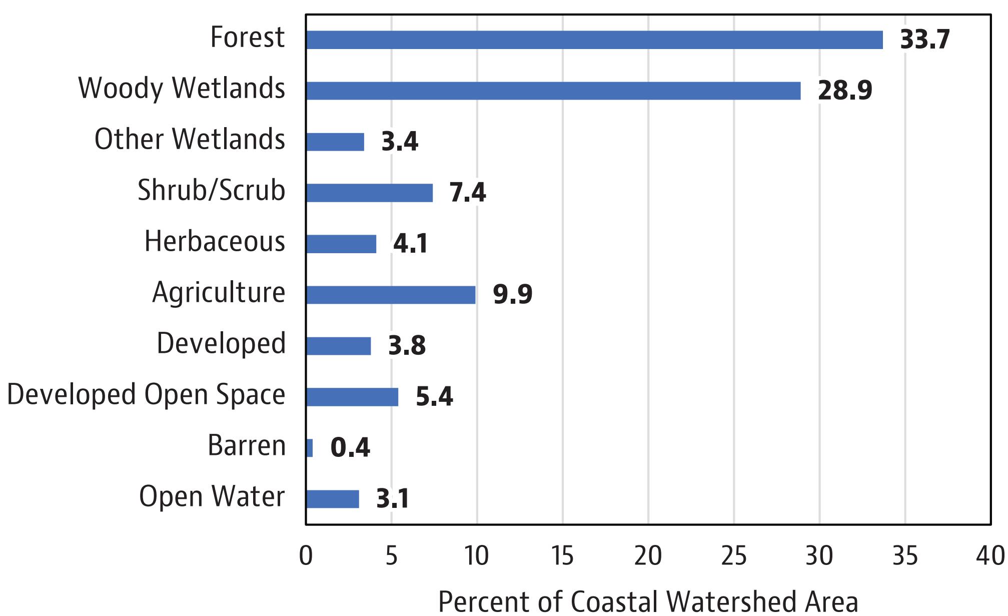


Figure 2-5. Land Use/Land Cover in Mississippi's coastal watersheds (Data Source: MDMR and MDEQ 2020)

There are state and federal programs that regulate impacts on wetlands from development. The MDEQ *Erosion and Sediment Control Practices, Volume 1 of the MDEQ Handbook* (MDEQ 2011a), emphasizes the importance of protecting intact wetlands and stream channels and provides further information on the regulatory programs in place for their protection. Wetlands are considered waters of the United States and are regulated under Section 404 of the federal CWA (discharge of dredge and fill materials into waters of the United States) and Section 10 of the Rivers and Harbors Act of 1899 (all activities affecting navigable waters). The U.S. Army Corps of Engineers (USACE) must issue a federal permit for any actions that impact tidal wetlands, nontidal wetlands, and shallow water habitat. USACE issues two types of Section 404 permits: general permits and individual permits.

Activities requiring USACE authorization include the following (MDEQ 2011a):

- Construction of piers, marinas, ramps, and cable or pipeline crossings
- Dredging and excavation in or adjacent to waters of the United States
- Fill for residential, commercial, or recreational developments
- Construction of revetments, groins, breakwaters, levees, dams, dikes, and weirs
- Placement of riprap (for channel stabilization)

Federal wetlands regulations are covered in Title 40 of the *Code of Federal Regulations* (CFR) Part 230 and 33 CFR Parts 320–332. A good overview of the USACE wetlands regulatory program is provided in a "Regulatory 101" presentation prepared by the USACE Mobile District (USACE 2019).

The Section 404 permit process requires the developer to take steps to avoid or minimize wetland impacts that could be caused by implementing a project and provide compensatory mitigation for any remaining unavoidable impacts. The Mississippi Department of Marine Resources (MDMR) serves as the lead regulatory agency for projects in Hancock, Harrison, and Jackson counties and permit applications should be submitted to the MDMR Bureau of Wetland Permitting for review. For projects in all other counties, permit applications should be submitted directly to USACE. Most of the coastal watershed area in Mississippi falls within the jurisdiction of the USACE Mobile District; a portion is in the Vicksburg District. A map of the area covered by the various Districts is available on the USACE website at https://www.usace.army.mil/Missions/Locations/.

Section 401 of the CWA gives MDEQ the authority to prohibit a proposed activity, including a construction project, if the activity would degrade water quality or have other unacceptable environmental consequences. Projects that require a Section 404 permit also require a Section 401 water quality certification from MDEQ. Water quality certifications are issued under state authority and provide further water quality protection from projects undertaken in sensitive areas by adding state-specific conditions to the federal permit (MDMR and MDEQ 2020).

Early in the site planning process, the permittee should undertake efforts first to avoid, then to minimize, impacts on existing wetlands. Delineation of wetlands is an important early step to understanding the extent and location of these natural features and to tailoring the project site plan to avoid impacts on wetlands and to provide buffers where possible.

2.1.2. Natural Streams

Natural streams (**Figure 2-6**) provide habitat, flood attenuation, water quality protection, and sediment retention. Stream water quality and habitat can be degraded by disturbance to the natural landscape and channelization, which can lead to accelerated erosion and downstream flooding. Removing riparian (streamside) vegetation can degrade habitat and lead to channel erosion. In contrast, site designs that protect vegetated corridors along natural streams will avoid impacts on stream habitat, protect water quality, and reduce the risk of channel and bank erosion. It is important to provide for sufficient stormwater management across the entire developed area. Maintaining a natural hydrologic regime will reduce the potential for stream channels to be subjected to damaging, erosive flows.

Streams that are considered waters of the United States are regulated under Section 404 permits and Section 401 water quality certifications for activities affecting both wetlands and waterways. As much as possible, avoid negative impacts on streams and streamside vegetation.

Figure 2-6. **Forested riparian buffer provides protection for the adjacent stream. (Photo: Natalie Segrest, MDEQ)**

2.1.3. Floodplains

Floodplains adjacent to waterways provide area for rising waters to occupy during rain events, dissipating the energy of high flows (**Figure 2-7**). Development in floodplain areas can reduce the ability of the floodplain to convey stormwater, potentially causing safety problems or significant flooding damage to the site and any structures on it as well as to upstream and downstream properties. Ideally, the entire 100-year floodplain should be avoided for clearing or building activities and should be preserved in a natural undisturbed state.

Each of the coastal counties participates in the National Flood Insurance Program, which is managed by the Federal Emergency Management Agency (FEMA). As participants in the program, these local governments are each required by FEMA to adopt a local ordinance that restricts the placement of any structure, fill, or obstacle within the floodway of a stream or river. While this program targets flooding and flood-related issues, the ordinance requirements promote setbacks from significant streams, rivers, and waterways. These requirements have additional environmental benefits, as they help to avoid the conversion of riparian areas likely to be susceptible to erosion and sediment loss and preserve riparian areas that provide filtering for NPS pollution. They also include the review of proposed site developments within the floodway to identify alternative designs that would have the least impact on the floodway (FEMA 2020).

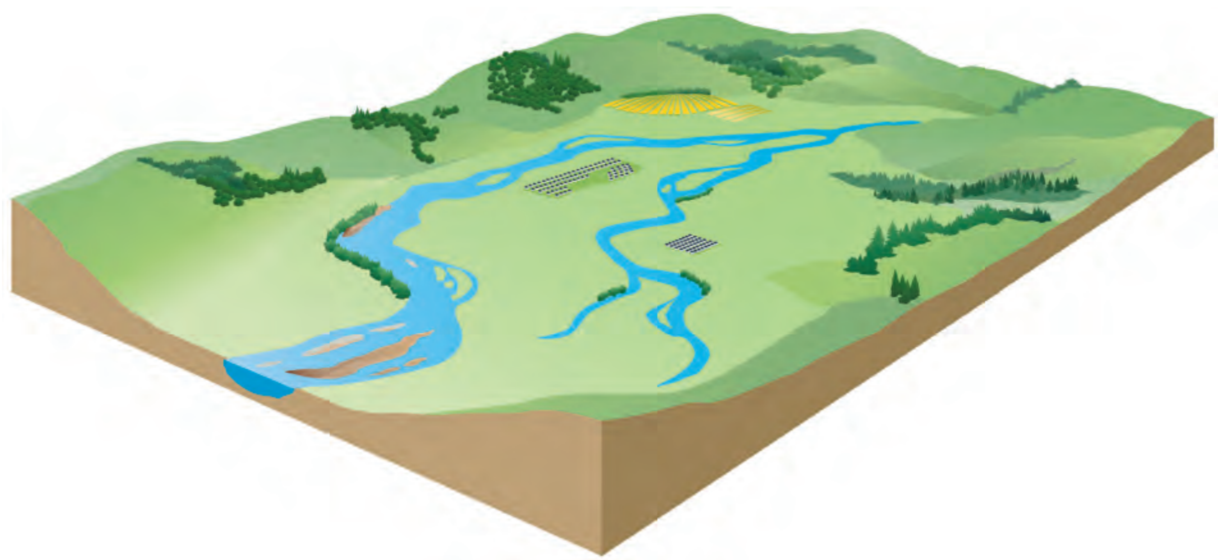


Figure 2-7. Topography and frequency of high flows define the floodplain area along a waterway.

Within Mississippi, development in floodplains is regulated by county and city floodplain and development ordinances (**Table 2-1**). The ordinances typically focus on activities that "control the alteration of natural floodplains, stream channels, and natural protective barriers which are involved in the accommodation of flood waters" and "control filling, grading, dredging and other development which may increase erosion or flood damage" (City of Picayune 2007).

Table 2-1. Floodplain and development ordinances and regulations in non-MS4 Mississippi coastal areas (adapted from MDMR and MDEQ 2020)

County or City	Flood and Development Ordinances and Regulations
George County	Flood Damage Prevention Ordinance (George County 2019)
Marion County	Marion County Road Department web page County road department is responsible for drainage (culverts, ditching, curbs, and guttering) (Marion County 2022)
Pearl River County	Subdivision Regulations (Pearl River County, 2023a) Article V: Section 503. Storm Drainage Flood Damage Prevention Ordinance (Pearl River County, 2023b) Article V: Section F. Standards for Erosion, Sediment, and Stormwater Utility Authority Regulations for Development (Pearl River County Utility Authority 2010)
Stone County	Stone County Developer's Guide (Stone County 2008) Flood Damage Prevention Ordinance Utility Authority Rules and Regulations for Development Subdivision Regulations (Stone County 2019)
Walthall County	N/A; coastal zone portion of the county is mostly rural agricultural land
City of Lucedale	Subdivision Regulations (City of Lucedale 2004) Land Development Code (City of Lucedale 2020)
City of Picayune	Ordinance Number 919, Flood Damage Prevention Ordinance (City of Picayune 2016) Modification and construction of drainage systems are covered as well, with the assistance of the engineering department. Pearl River County regulations also apply.
City of Poplarville	Land Subdivision Regulations (City of Poplarville 2011) Article V: Section 504 *20 Year Comprehensive Development Plan for the City of Poplarville, Mississippi* (City of Poplarville 2010)

2.1.4. Forests and Forest Buffers

Forest are important components of the natural landscape, not only providing habitat for birds and other wildlife, but also protecting water quality in nearby waterways, reducing soil erosion, filtering and cycling nutrients and other materials, and providing shade that moderates air and water temperatures (**Figure 2-8**). Forested land cover, including evergreen, mixed, and deciduous forest plus woody wetlands, makes up about 63% of the coastal Mississippi landscape (**Figure 2-5**).

Figure 2-8. Longleaf, slash, and loblolly pines in the DeSoto National Forest, Stone County, MS. (Source: Wikimedia Commons)

The coastal area falls within Mississippi's East Gulf Coast Plains ecoregion. Most of the forest types and subtypes found in this region are identified in Mississippi's Forest Action Plan 2020 as having a conservation status of "imperiled," "critically imperiled," or "vulnerable", pointing to the importance of sustaining the area's remaining forest resources (Mississippi Forestry Commission 2020). Although much of the larger forest area is within the region's parks, wildlife refuges, wildlife management areas, and other protected areas, forest cover on private land is still a good candidate for special consideration during development.

Forests and other naturally vegetated buffers along creeks and rivers (**Figure 2-9**) play an important role in maintaining water quality. Forest and other natural riparian vegetation stabilize stream channels and floodplain areas, reducing the potential for creek erosion. Riparian buffers also provide filtration for overland flow from adjacent developed and agricultural lands, capturing pollutants such as nitrogen, phosphorus, pesticides, fertilizers, and sediments. This filtering is beneficial during construction to retain sediment from up-gradient disturbed areas and after construction to further clean stormwater discharged from BMPs or to slow and infiltrate overland flow not captured by BMPs.

Figure 2-9. Along a stream, a vegetated riparian buffer protects the channel, filtering sediment, nutrients, and other pollutants.

Buffers provide additional benefits, including the following:

- Providing flood control
- Helping protect properties from shifting and widening of stream channels that occur over time
- Increasing property values
- Minimizing activities that degrade, destroy, or reduce the value and function of coastal marshlands
- Enhancing scenic value and recreational opportunities of wetlands
- Protecting coastal habitat for nesting and feeding wildlife
- Protecting important nursery areas for fisheries, which provide food and habitat to numerous species of fish and shellfish, including commercially important species

The purpose of establishing a riparian buffer zone is to adequately protect waterways and aquatic resources from the short- and long-term impacts of development activities by providing a contiguous protection zone along the riparian corridor. In many creeks, streams, and rivers, a defined floodplain already provides a level of protection for the stream/riparian system. In natural topography, however, some streams are constrained to narrow valleys or ravines, and the riparian zones can extend important protection beyond those narrow corridors.

In a forested ecosystem, existing forested riparian buffers should be maintained. Where no wooded buffer exists, reforestation should be undertaken. Proper reforestation should include all layers of the forest plant community, including trees, understory, shrubs, and ground cover.

Along tidal waterways and wetlands, buffer zones can be established to protect these sensitive areas from the short- and long-term impacts of upstream land activities. Buffers of forest or other vegetation reduce the potential for erosion, sediment, and pollution runoff to impact tidal waters and wetlands. Buffer vegetation also provides greater habitat connectivity with nearby tidal marshes and open waters.

In Mississippi, all development projects of more than 1 acre are subject to a 50-ft buffer requirement under the MDEQ construction general permit program for small sites (i.e., the Small Construction General Permit (SCGP) and, for developments of 5 acres or more, a 150-ft buffer is recommended in the Large Construction General Permit (LCGP) (MDEQ 2019, 2022). Section 3 provides further details on buffer requirements under the construction general permits.

2.1.5. Other Features for Protection

Other features on the landscape may be identified as good candidates for protection. These include areas with erodible soils, depression storage, and steep slopes. Areas of special ecological value can include habitats for wildlife or aquatic species. In some cases, lands that are deemed undevelopable for other reasons may also be set aside for protection.

Erodible soils should be conserved as much as possible. Construction should be directed away from areas on a site with highly erodible or unstable soils to prevent erosion and sediment issues as well as potential future structural problems. Erodible soils can be identified from soil mapping information. When possible, areas with highly erodible or unstable soils should be left in an undisturbed and vegetated condition.

Depression storage is found where land retains water in natural depressions, temporarily storing stormwater and allowing it time to infiltrate into the soil. Typically, areas draining to depression generate no runoff until the storage has been filled, making depression storage a natural, effective, and cost-free method of reducing the overall volume of stormwater runoff. Often, design and construction practices remove these natural features to promote drainage; however, small, natural depressions in the landscape should be treated as sensitive resource areas and should be protected from construction activities. Because of the important role depressions play within drainage and water quality and as ecological components of the natural stormwater system, attempts should be made to incorporate depressions within localized stormwater management plans.

Steep slopes are typically unable to be developed and can be good targets for retaining natural vegetation that will prevent soil erosion. Often along riparian areas, vegetated slopes can provide good buffers.

Areas of special ecological value may include habitat for rare, threatened, or endangered species or specialized habitat (e.g., bird nesting areas) (**Figure 2-10**). These areas might make up a portion of a property and should be mapped early in the planning process.

2.2. Sustainable Development Practices

This section describes various sustainable development practices to guide local communities and development practitioners in implementing practices that will help sustain water quality and habitat within the coastal region.

2.2.1. Site Assessment

To support preservation of natural features, the first step is to identify and locate sensitive areas on the site so proposed designs can avoid or minimize negative impacts on these features (**Figure 2-12**). A site assessment is an in-depth evaluation of the ecological conditions and natural features present at the proposed development or redevelopment site and is conducted prior to developing a detailed site design. Natural conservation areas are identified with available mapping information and on-site field reconnaissance to characterize existing features. Proposed areas for protection should be identified and delineated early in the planning stage, long before site design or land clearing begins. Preservation continues through the phases of design, construction, and long-term maintenance and land management (Hegemier et al. 2019).

Conditions and features to investigate during a site assessment include the following:

- Wetlands
- Floodplains
- Riparian areas, streams, and other waterways
- Soil types, infiltration capability, and soil erodibility
- Mature forests and other woodlands
- Types and health of other existing vegetation (trees, shrubs, grasses, and forbs)
- Prominent landforms
- Steep slopes
- Depression storage
- Aquifer recharge areas

Figure 2-12. Site assessment can identify key features, such as large, mature trees. (Photo: James Starnes, MDEQ)

Identifying these aspects of the site upfront will help inform design plans, which can be customized to avoid sensitive resource areas. Buildings, roads, and parking areas should be sited to fit the terrain within areas that will have the least impact. Protection of natural features can help reduce revegetation requirements, reduce long-term erosion, preserve habitat, protect water and land resources, and maintain healthy ecosystems.

Undeveloped sites often have natural features that provide environmental, aesthetic, and recreational benefits if preserved and protected from the impacts of construction and development. Once identified, preservation areas should be incorporated into site development plans and clearly marked on all construction and grading plans. This will ensure that construction activities are kept out of these areas and that native vegetation is not disturbed.

Protecting natural areas and features is not limited only to new development sites. Properties being redeveloped also might have attractive open space, well-drained soils, natural vegetation, or riparian areas that should be identified and considered for preservation early in the planning process.

2.2.2. Green Infrastructure and Low Impact Development

Managing stormwater close to its source and using nonstructural methods for stormwater management are consistent with **green infrastructure** approaches promoted for use in Mississippi. In contrast to traditional "gray infrastructure," which uses built structures such as concrete curb and gutter systems, pipes, and retention basins, green infrastructure uses vegetation and soils to manage stormwater through the processes of infiltration (allowing water to slowly sink into the soil), evaporation/transpiration (returning water to the air through vegetation), and rainwater capture and reuse (e.g., storing runoff to water plants). Green infrastructure (also known as "green stormwater infrastructure") can be an important component of sustainable and resilient design. Sections 4 and 5 provide examples of green infrastructure practices, and additional information is provided in Mississippi's *Green Infrastructure Toolbox* (MDMR and AllenES 2017).

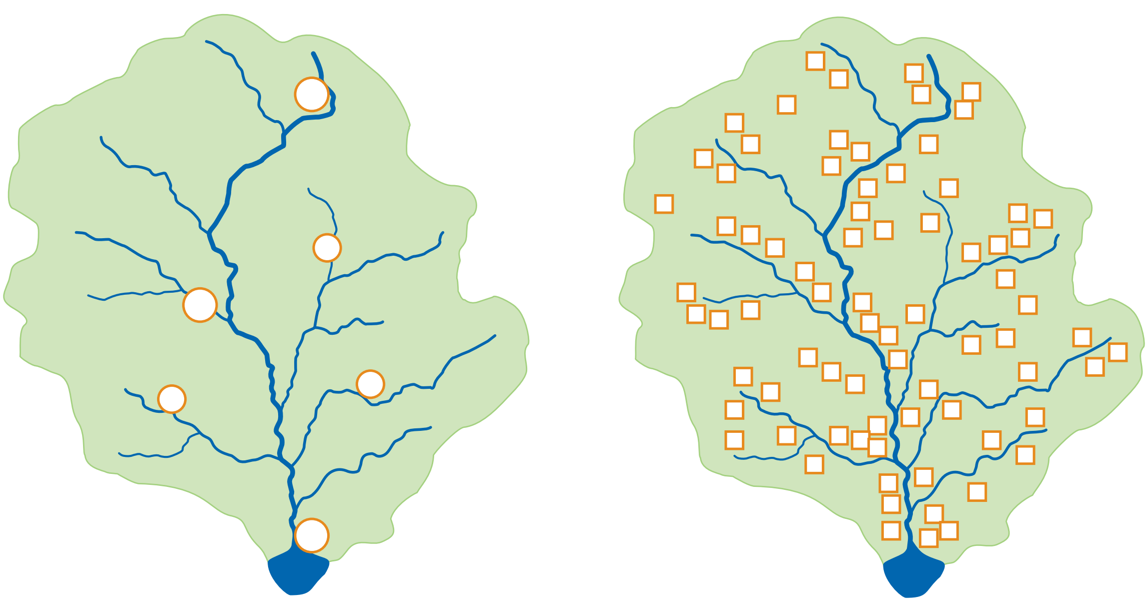
Sustainable design approaches are consistent with **LID** and other smart growth practices outlined in the MDEQ *Stormwater Runoff Management Manual* (MDEQ 2011b). Applying smart growth practices can support common goals of preserving natural areas and open space, reducing impervious cover, directing redevelopment to already developed areas with infrastructure in place, and promoting tree canopy protections. Applying concepts of smart growth to stormwater management and using a variety of available planning tools can help shift the focus toward development in appropriate areas with techniques that reduce impacts on local waterways.

LID focuses on managing rainfall at the source, using distributed, decentralized small-scale controls on the lot level that mimic natural hydrology (**Figure 2-13**) (LID 2007, cited in MDEQ 2011b). A 20-year study found that distributed stormwater management provides advantages over centralized stormwater management in several ways (Hopkins et al. 2022). Hydrologic benefits included mitigating runoff volumes and peak flows and, for small storms, replicated predevelopment conditions.

LID practices encourage infiltration and reduce the volume of stormwater discharged from a site. Key LID elements include the following (MDEQ 2011b):

- Conservation
- Small-scale controls
- Customized site design
- Pollution prevention and education
- Directing runoff to natural areas

The preservation of native trees, understory vegetation, and natural drainage processes is an important aspect of LID. LID designs are tailored to protect hydrologic processes, reduce pollutant loads, and direct stormwater to areas of infiltration to facilitate groundwater recharge. LID promotes hydrologic function at the lot level. Use of LID practices often can result in a 25–30% reduction in costs associated with site development, stormwater fees, and maintenance for residential developments (MDEQ 2011b). These savings are associated with reductions in clearing, grading, pipes, ponds, inlets, curbs, and paving. LID practices are easily applied to open space, rooftops, streetscapes, parking lots, sidewalks, and medians. Preserving open space allows for large conservation areas where stormwater can infiltrate into the ground and promote groundwater recharge. LID makes use of narrow streets and driveways, reducing impervious surfaces to reduce potential for flooding and stormwater pollution. Typically, LID designs feature sheet flow across grassy areas rather than curb-and-gutters. Placing houses closer to the street and employing shared driveways are other approaches that reduce overall impervious surface area.



Centralized Stormwater Management
A few, large practices

Distributed Stormwater Management
Many, smaller practices

Figure 2-13. LID encourages the use of smaller, distributed stormwater practices.

In general, LID design components include vegetation, pervious surfaces, and stormwater BMPs, especially those incorporating vegetation. Plants help manage stormwater through evapotranspiration and provide pollutant removal through nutrient cycling. Grassy areas, permeable pavement, and other pervious surfaces allow stormwater to infiltrate into underlying soils, promoting groundwater recharge and pollutant processing while reducing the runoff volume. Bioretention systems detain water long enough for infiltration and pollution removal to occur. BMPs may be designed as buffer strips, bioretention cells, rain gardens, constructed stormwater wetlands, and grass swales. Other LID practices covered in the MDEQ *Stormwater Runoff Management Manual* include rain barrels, cisterns, and filter strips (MDEQ 201b).

Municipal governments can promote sustainable approaches to site design through ordinances and incentives. A number of sustainable design approaches are included in the U.S. Environmental Protection Agency's (EPA's) *Water Quality Scorecard: Incorporating Green Infrastructure Practices at the Municipal, Neighborhood, and Site Scale* (USEPA 2009). EPA developed the scorecard to help local governments identify opportunities to better protect water quality by removing barriers and revising or adopting pertinent codes, ordinances, and incentives. The scorecard guides municipal staff through a review of relevant local codes and ordinances across multiple departments to ensure they work together to support a sustainable site design approach. The guide offers resources and case studies for each of five featured topics: (1) protecting natural resources (including trees) and open space; (2) promoting efficient, compact development patterns and infill; (3) designing complete, smart streets that reduce overall imperviousness; (4) encouraging efficient parking areas; and (5) adopting green infrastructure stormwater management provisions.

2.2.3. Using Conservation Design

"Conservation design," also known as "open space design" or "cluster development," includes laying out the elements of a development project to take advantage of a site's natural features and preserve sensitive areas, while also considering site constraints and opportunities to prevent or reduce environmental impacts (Hegemier et al. 2021). Conservation design begins with outlining the open space and letting its size and layout become the central organizing element for the overall design (Arendt 1996).

Conservation design techniques include the following:

- Preserving undisturbed areas
- Preserving stream buffers
- Reducing clearing and grading
- Locating projects in less sensitive areas
- Reducing front and side yard setbacks
- Aggregating shared open space rather than focusing on individual yards
- Clustering built features to minimize the amount of disturbed area

STORMWATER BEST MANAGEMENT PRACTICES FOR PROTECTING COASTAL WATERS

MISSISSIPPI DEPARTMENT OF ENVIRONMENTAL QUALITY

Implementation Considerations

- L — Land Requirement
- H — Capital Cost
- H — Maintenance Burden

Residential Subdivision Use: YES

Other Considerations:
Highly applicable for roadway projects

Pollutant Removal

Total Suspended Solids	100%
Nutrients:	
Total Phosphorus	100%
Total Nitrogen removal	100%
Metals:	
Cadmium, Copper, Lead, and Zinc removal	100%
Pathogens:	
Fecal Coliform	100%

For more information reference MDEQ's *Managing Stormwater for Healthy Watersheds in Coastal Mississippi: Best Practices*

L Low — M Medium — H High

Infiltration Practices

An infiltration practice is designed to infiltrate stormwater into the soil. Types of infiltration practices include infiltration basins, trenches, or dry wells.

Design Criteria

- Pretreatment, such as filter strips, grassed swales with check dams, concrete sumps, or forebays, must be provided upstream of all infiltration practices
- Infiltration practices should be designed to completely drain within 72 hours of the end of a rainfall event
- Underlying native soils must have an infiltration rate of 0.52 in/hr or greater
- The distance from the bottom of an infiltration practice to the top of the water table should be 2 feet or more
- Observation wells are used to monitor percolation and performance of the practice
- Infiltration practices must not be placed under pavement or concrete

Advantages/Benefits

- Helps restore pre-development hydrology on development sites and reduces post-construction stormwater runoff rates and volumes
- Provides a very high level of removal for all pollutants
- Provides for groundwater recharge
- Good for small sites with well draining soils
- Can be integrated into development plans as attractive landscaping features

Disadvantages/Limitations

- Can only be used to manage runoff from relatively small drainage areas of 5 acres or less
- Potential for groundwater contamination
- High clogging potential; should not be used on sites with fine-particle soils (clays or silts) in drainage areas
- Should not be located where they may undermine foundations or negatively affect underground utilities or other infrastructure
- Geotechnical testing required, two borings per practice

Montgomery County Planning Commission
https://www.flickr.com/photos/75012107@N05/14660267252/

STORMWATER BEST MANAGEMENT PRACTICES FOR PROTECTING COASTAL WATERS

MISSISSIPPI DEPARTMENT OF ENVIRONMENTAL QUALITY

Implementation Considerations

L — Land Requirement

M H — Capital Cost

M H — Maintenance Burden

Residential Subdivision Use: YES

Other Considerations:

May be used in conjunction with other BMP solutions

Applicable for treating street runoff

May be applicable in retrofit situations

Pollutant Removal

Pavers

Total Suspended Solids	70–80%
Nutrients	35–70%
Metals	13–90%

Porous Asphalt

Total Suspended Solids	95–100%
Nutrients	45%
Metals	75–100%

Porous Concrete

Total Suspended Solids	90%
Nutrients	N/A
Metals	75–90%

For more information reference MDEQ's *Managing Stormwater for Healthy Watersheds in Coastal Mississippi: Best Practices*

L — Low; M — Medium; H — High

Permeable Pavements

Permeable pavements are BMPs that infiltrate water through the surface layer to a crushed stone bed. The water is stored in the crushed stone bed where it infiltrates into the soil below. For areas where the native soils have low permeability, a perforated underdrain can be provided to collect water and convey it to the downstream conveyance system. Permeable pavements are considered green infrastructure practices that reduce stormwater volume and remove pollutants. Depending upon the design, permeable pavements may also provide peak flow control. There are three primary types of permeable pavement: permeable pavers, pervious asphalt pavement, and pervious concrete pavement.

Design Criteria

- Design subsurface reservoirs to hold the runoff volume from the 1-inch storm event
- Use of underdrain is recommended in low permeable soils
- If infiltration is not desired, use an underdrain and liner
- For slopes greater than 2%, terrace the subgrade base or use underdrains to intercept flow

Advantages/Benefits

- Stormwater runoff reduction
- Improved water quality
- Improved air quality
- May help to reduce the heat island effect

Disadvantages/Limitations

- Should not be used in hot spots
- Should not be used on high-volume or high-speed roadways
- Do not use in areas that may receive high sediment loads
- Should not be used where hazardous materials may be loaded, unloaded, or stored

Photo: Kristen Sorrell, MDEQ

STORMWATER BEST MANAGEMENT PRACTICES FOR PROTECTING COASTAL WATERS

MISSISSIPPI DEPARTMENT OF ENVIRONMENTAL QUALITY

Implementation Considerations

L — Land Requirement

M H — Capital Cost

M — Maintenance Burden

Residential Subdivision Use: YES

Other Considerations:
Works well in areas of high impervious cover such as parking lots.

Pollutant Removal

Total Suspended Solids	85%
Nutrients:	
Total Phosphorus	80%
Total Nitrogen removal	60%
Metals:	
Cadmium, Copper, Lead, and Zinc removal	95%
Pathogens:	
Fecal Coliform	90%

For more information reference MDEQ's *Managing Stormwater for Healthy Watersheds in Coastal Mississippi: Best Practices*

L Low — M Medium — H High

Bioretention Cell

A bioretention cell consists of a depression in the ground filled with a soil media mixture and planted with vegetation that can tolerate inundation and dry periods. Bioretention cells contain an underdrain system allowing filtered stormwater to exit the system.

Design Criteria

- Applicable for drainage areas of 5 acres or less
- Media depth should be between 2 and 4 feet
- The permeability of the filter media should be between 1 and 6 inches per hour, and 1-2 inches per hour is preferred
- Ponding depth should be 12 inches or less (9 inches is preferred)
- Provide an overflow or diversion structure to bypass larger flows around the bioretention cell
- Design with an upturned underdrain to provide internal water storage volume and enhanced water quality and infiltration

Advantages/Benefits

- Removes many different types of pollutants
- Appropriate for small areas with high impervious cover
- Good retrofit capability
- Aesthetic feature

Disadvantages/Limitations

- Not recommended for areas with steep slopes
- Soils may clog over time and require cleaning or replacing
- Landscaping plan is required

Photo: James Stribling, Tetra Tech

STORMWATER BEST MANAGEMENT PRACTICES FOR PROTECTING COASTAL WATERS

MISSISSIPPI DEPARTMENT OF ENVIRONMENTAL QUALITY

Implementation Considerations

L Land Requirement

H Capital Cost

M Maintenance Burden

Residential Subdivision Use: YES

Other Considerations:
Soils: the soils used within stormwater planter planting beds should be an engineered soil mix

May be designed as pretreatment for other BMP solutions

Pollutant Removal

Total Suspended Solids	80%
Nutrients:	
Total Phosphorus	60%
Total Nitrogen removal	60%
Metals: Cadmium, Copper, Lead, and Zinc removal	N/A
Pathogens: Fecal Coliform	80%

For more information reference MDEQ's *Managing Stormwater for Healthy Watersheds in Coastal Mississippi: Best Practices*

L Low   M Medium   H High

Stormwater Planters

A stormwater planter is a container or enclosed feature located either above ground or below ground, planted with vegetation that collects and treats stormwater using bioretention. Bioretention systems collect and filter stormwater through layers of mulch, soil, and plant root systems where pollutants such as bacteria nitrogen, phosphorus, heavy metals, oil, and grease are retained degraded, and absorbed.

Design Criteria

- Should be planted with native vegetation
- Captured runoff should drain out in 24 hours
- The structural elements of the planters should be stone, concrete, or brick
- Requires use of an underdrain
- A maximum ponding depth of 6 inches is recommended within stormwater planters

Advantages/Benefits

- Reduces stormwater runoff volumes, flow rate, and temperature
- Treats stormwater runoff
- Provides wildlife habitat and aesthetic benefits
- Requires limited space
- Flexible for use in areas of various shapes and sizes

Disadvantages/Limitations

- Small size of feature limits stormwater quantity/quality benefits
- Relatively high cost to install
- Can only receive runoff from small drainage areas (less than 2,500 square feet)

Photo: Corry Gallo, Mississippi State University

STORMWATER BEST MANAGEMENT PRACTICES FOR PROTECTING COASTAL WATERS

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Grassed Swales

Grassed swales refers to vegetated, open-channel management practices designed specifically to treat and attenuate stormwater runoff for a specified water quality volume. To enhance pollutant removal, grassed swales are designed with a filter bed that may overlay an underdrain system.

Design Criteria

- Treats runoff from small drainage areas of less than 5 acres
- Should be used on slopes of less than 4 percent; 1 to 2 percent slope is recommended
- Typically include relatively flat side slopes (flatter than 3:1)
- Designed to provide a storage volume equal to the runoff volume from the first 1-inch rainfall
- A small forebay or pea gravel diaphragm is needed for pretreatment where water enters the swale
- Minimum 2 ft clearance between the swale bottom and groundwater

Advantages/Benefits

- Ideal for linear environments
- Lower cost
- Aesthetic benefits

Disadvantages/Limitations

- Design depended on existing site conditions and topography
- Potential for bottom erosion and sediment resuspension

Photo: Kristen Sorrell, MDEQ

Implementation Considerations

- M — Land Requirement
- M — Capital Cost
- L — Maintenance Burden

Residential Subdivision Use: YES

Other Considerations: Highly applicable for roadway projects

May be designed as pretreatment for other BMP solutions

Pollutant Removal

Total Suspended Solids	80%
Nutrients: Total Phosphorus Total Nitrogen removal	 50% 50%
Metals: Cadmium, Copper, Lead, and Zinc removal	 40%
Pathogens: Fecal Coliform	 N/A

For more information reference MDEQ's *Managing Stormwater for Healthy Watersheds in Coastal Mississippi: Best Practices*

L Low — M Medium — H High

STORMWATER BEST MANAGEMENT PRACTICES FOR PROTECTING COASTAL WATERS

MISSISSIPPI DEPARTMENT OF ENVIRONMENTAL QUALITY

Implementation Considerations

- (L) Land Requirement
- (H) Capital Cost
- (L) Maintenance Burden

Residential Subdivision Use: YES

Other Considerations:

- Use to treat runoff from pervious areas
- May be designed a pretreatment for other BMP solutions
- Applicable for treating street runoff

Pollutant Removal

Total Suspended Solids	80%
Nutrients: Total Phosphorus	60%
Total Nitrogen removal	40-50%
Metals: Cadmium, Copper, Lead, and Zinc removal	40-90%
Pathogens: Fecal Coliform	N/A

For more information reference MDEQ's *Managing Stormwater for Healthy Watersheds in Coastal Mississippi: Best Practices*

L Low · M Medium · H High

Rain Gardens

Rain gardens are a type of infiltration practice featuring shallow depressions planted with native vegetation to capture and treat runoff. Rain gardens can be used in a variety of applications such as in residential lawns or within curb extensions alongside the parking zone of a street. They can be planted with groundcover, grass, shrubs, or trees depending on the site conditions, costs, and design context.

Design Criteria

- Sizing should be based on drainage area
- Infiltration testing is required, and compacted soils should be avoided
- Should be planted with native vegetation
- Does not require an underdrain

Advantages/Benefits

- Reduces stormwater runoff volumes and improves water quality
- Increases groundwater infiltration and recharge
- Treats stormwater runoff
- Provides aesthetic benefits
- Requires limited space
- Wide applicability, including urban areas and retrofits

Disadvantages/Limitations

- Small size of feature limits stormwater quantity/quality benefits
- May reduce on-street parking spaces or conflict with bike lanes if used in curb extension

Photo: Kristen Sorrell, MDEQ

STORMWATER BEST MANAGEMENT PRACTICES FOR PROTECTING COASTAL WATERS

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Vegetated Filter Strips

Vegetated filter strips are grassed surfaces that are designed to treat sheet flow from adjacent surfaces. Filter strips are often used to pretreat runoff before it enters other stormwater practices such as infiltration basins.

Design Criteria

- Should be at least 25 feet long
- Includes a pea gravel diaphragm at the top of the slope
- Slope should be between 2 and 6 percent
- Use in areas where groundwater is deeper than 2 feet
- Use a grass that can withstand relatively high-velocity flows and both wet and dry periods

Advantages/Benefits

- Provide good pretreatment for other stormwater practices
- Best suited for treating runoff from roadways, roof downspouts, very small parking lots if sheet flow can be maintained
- Low cost alternative
- Can provide groundwater recharge

Disadvantages/Limitations

- Concentrated flow within the filter strip will receive little to no pollutant removal. Sheet flow must be maintained
- Typically poor retrofit options due to space requirements
- Requires periodic repair, regrading, and sediment removal to prevent channelization

Photo: Tracy Wyman, GCCDS

Implementation Considerations

- H — Land Requirement
- H — Capital Cost
- L — Maintenance Burden

Residential Subdivision Use: YES

Other Considerations:
Highly applicable for roadway projects

May be designed as pretreatment for other BMP solutions

Pollutant Removal

Total Suspended Solids	60%
Nutrients:	
Total Phosphorus	20%
Total Nitrogen removal	20%
Metals:	
Cadmium, Copper, Lead, and Zinc removal	40%
Pathogens:	
Fecal Coliform	N/A

For more information reference MDEQ's *Managing Stormwater for Healthy Watersheds in Coastal Mississippi: Best Practices*

L Low M Medium H High

STORMWATER BEST MANAGEMENT PRACTICES FOR PROTECTING COASTAL WATERS

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Constructed Stormwater Wetland

Wetlands temporarily store stormwater runoff in shallow pools that support emergent and riparian vegetation. The storage, complex microtopography, and vegetative community in stormwater wetlands combine to form an ideal matrix for the removal of many pollutants. Stormwater wetlands can also effectively reduce peak runoff rates and stabilize flow to adjacent natural wetlands and streams.

Design Criteria

- Requires sufficiently large drainage area or adequate groundwater/surface water supplies to provide year-round hydration, typically about 25 acres
- The upstream slope should not exceed about 15% and local slopes should be relatively shallow
- The elevation drop from the inlet to the outlet should be at least 3 to 5 feet
- Should consist of six components: Inlet, deep pool, shallow water (low marsh), shallow land (high marsh), upland, and outlet

Advantages/Benefits

- High removal rate for a wide variety of pollutants
- Provides wildlife habitat and aesthetic benefits
- Ideal for use in areas with flat terrain and high groundwater

Disadvantages/Limitations

- Requires large land area
- Requires continuous baseflow for viable wetland
- Difficulties in establishing vegetation and maintaining permanent pool may arise
- Potential for escalated mosquito population

Photo: Kristen Sorrell, MDEQ

Implementation Considerations

- M H Land Requirement
- M Capital Cost
- M Maintenance Burden

Residential Subdivision Use: YES

Other Considerations:
Soils: Hydrologic group 'A' and 'B' soils may require a liner

Pollutant Removal

Total Suspended Solids	80–85%
Nutrients:	
Total Phosphorus	40–75%
Total Nitrogen removal	30–55%
Metals:	
Cadmium, Copper, Lead, and Zinc removal	50–60%
Pathogens:	
Fecal Coliform	70–85%

For more information reference MDEQ's *Managing Stormwater for Healthy Watersheds in Coastal Mississippi: Best Practices*

L Low M Medium H High

STORMWATER BEST MANAGEMENT PRACTICES FOR PROTECTING COASTAL WATERS

MISSISSIPPI DEPARTMENT OF ENVIRONMENTAL QUALITY

Implementation Considerations

- **H** Land Requirement
- **L** Capital Cost
- **L** Maintenance Burden

Residential Subdivision Use: YES

Other Considerations:
Soils: Hydrologic group 'A' soils generally require a pond liner

Pollutant Removal

Total Suspended Solids	80%
Nutrients:	
Total Phosphorus	50%
Total Nitrogen removal	30%
Metals:	
Cadmium, Copper, Lead, and Zinc removal	50%
Pathogens:	
Fecal Coliform	70%

For more information reference MDEQ's *Managing Stormwater for Healthy Watersheds in Coastal Mississippi: Best Practices*

L Low M Medium H High

Stormwater Ponds

Stormwater ponds are constructed basins that have a permanent pool of water throughout the year. The permanent pool of standing water mixes with and dilutes the initial runoff from storm events. There are two primary configurations of stormwater ponds that achieve 80% TSS removal: wet pond and wet extended detention pond. A wet pond is designed with a permanent pool volume equal to the runoff from the first inch of rainfall. A wet extended detention pond has a smaller permanent pool than a wet pond and a temporary storage volume above the permanent pool designed to hold and release runoff over two days.

Design Criteria

- Requires sufficient inflow to maintain the permanent pool
- The upstream slope should not exceed about 15% and local slopes should be relatively shallow
- Should consist of four design features: pretreatment, permanent pool, outlet structure, and safety features
- Depth of the permanent pool should not exceed 8 feet
- Side slopes to the pond should not exceed 3:1 (h:v) without safety precautions

Advantages/Benefits

- Moderate to high removal rate for urban pollutants
- High community acceptance
- Opportunities for wildlife habitat and aesthetic benefits

Disadvantages/Limitations

- Requires large land area
- May pose safety hazards
- Potential for thermal impacts/downstream warming
- Potential for increased mosquito population

Photo: Kristen Sorrell, MDEQ

Chapter 2
General Planning Concepts for Erosion Control, Sediment Control and Stormwater Management

This chapter provides important concepts and other selected information that is important for qualified design professionals to know about various aspects of erosion control, sediment control, and stormwater management. It is believed that the contents will, as a minimum, cause qualified design professionals to recognize when other professionals may need to be involved. A qualified design professional should recognize that planning involves several disciplines and that each discipline has a body of in-depth knowledge that is important and needed on complex sites. Although often discussed separately, erosion control, sediment control, and stormwater management are interrelated and, when planning occurs, the thought process must conceive a system of practices and measures that consider all three together.

The basic details of planning, including step-by-step procedures, are located in Chapter 3.

Potential Erosion and Sediment Problems Associated with Land Development

The principal effect land development activities have on the erosion process consists of exposing disturbed soils to raindrops and to storm runoff. Shaping of land for construction or development purposes alters the soil cover in many ways, often detrimentally affecting physical properties of the soil, onsite drainage and storm runoff patterns and, eventually, off-site stream and stream-flow characteristics. Adverse effects of erosion and sedimentation include impacts on soil, water quantity, water quality, and the aquatic ecosystem. Potential hazards associated with development include the following items:

1. An increase in developed areas exposed to storm runoff and soil erosion.

2. Increased volumes of storm runoff, accelerated soil erosion and sediment yield and higher peak flows caused by:

    a. Removal of existing protective vegetative cover.

    b. Exposure of underlying soil or geologic formations potentially more erodible than original soil surface.

    c. Reduced capacity of exposed soils to absorb rainfall due to compaction caused by heavy equipment.

    d. Enlarged drainage areas caused by grading operations, diversions and street construction.

    e. Prolonged exposure of unprotected disturbed areas due to scheduling problems and/or delayed construction.

f. Shortened times of concentration of surface runoff caused by altering slope steepness, slope length, and surface roughness and through installation of "improved" storm-drainage facilities.

g. Increased impervious surfaces associated with the construction of streets, buildings, sidewalks, paved driveways, and parking lots.

3. Creation of exposures facing south and west that may hinder plant growth due to adverse temperature and moisture conditions.

4. Exposure of subsurface materials that are rocky, acidic, droughty, or otherwise unfavorable to the establishment of vegetation.

Erosion and Sediment Control

A wide array of practices and measures are used for erosion and sediment control. Most of the practices and measures have application over the entire State.

There are numerous simple concepts that can provide an effective framework for minimizing erosion on a construction site and reducing delivery of sediment off of the site.

- Minimize the area disturbed by leaving existing vegetation that does not have to be removed.
- Minimize the period of bare ground by shortening construction periods and staging a project when possible.
- Sequence installation in a manner that supports shortened construction periods and permits the use of temporary and permanent seeding when the practices can be most effective.
- Use sediment control and turbidity measures that minimize sediment and turbid water from leaving the disturbed site.
- Plan appropriate erosion control for all kinds of erosion that may occur depending upon specific site conditions. Give special attention to cut and fill slopes. Give special attention to sites that are transected by streams or are in close proximity to streams or reservoirs.
- Install erosion-control plantings at every opportunity.
- Prevent sediment from leaving a construction site at entrance/exits during muddy periods.

- Maintain practices to ensure their effectiveness. This includes regular and timely inspections.

Potential Stormwater Problems Associated with Land Development

All forms of land use affect water quality. In an undeveloped area, many ongoing physical, chemical and biological processes interact to recycle most of the materials found in the stormwater runoff. As human land use intensifies, these processes are disrupted. Human activities add materials to the land surface (pesticides, fertilizers, animal wastes, oil, grease, heavy metals, etc.). These materials are then washed off by the rainfall and runoff, thereby increasing the pollutant load carried to receiving waters by stormwater runoff.

Of primary importance to water quality is the "first flush". This term describes the washing action that stormwater has on accumulated pollutants in the watershed. In the early stages of a runoff rain-event, the land surfaces, especially impervious surfaces like streets and parking areas, are flushed clean by the stormwater. This flushing creates a shock loading of pollutants. Extensive studies in Florida have determined that the first flush equates to the first 1″ of runoff which carries 90% of the pollution load from a storm (USGS, 1984). More recently, research has identified that the first ½″ of runoff provides the first flush in some instances, while other research has determined that runoff in excess of 1″, including cut/fill areas associated with construction, may be more realistic. It is proper to say at this time that the amount of runoff that creates the "first flush" depends on several factors, including the activity, site conditions and pollutants. Treatment of the first flush, whatever the runoff amount, will help ensure that the water-quality impacts of stormwater are minimized.

Finally, the value of the hydrologic environment as an amenity is primarily affected by three factors: stability of the stream channel, accumulation of trash, and disruption of the stream community. A channel which is gradually enlarged because of increased floods caused by urbanization tends to have unstable and unvegetated banks, scoured or muddy channel beds, and unusual accumulations of sediment and debris. Together with the accumulation of trash in the channel and floodplain (beverage cans, lumber scraps, lawn clippings, concrete, wire, etc.), these all tend to severely decrease the visual attractiveness of a stream. Ultimately, these factors disrupt the natural balance in the streams' biota resulting from the addition of nutrients, organics, and sediment. These disruptions increase algal growth and turbidity, lower the oxygen content of the water, and thereby change the biological character of the stream.

In summary, each progression toward more intensive land use tends to disrupt the ongoing natural processes that protect and preserve water quality. Therefore, to ensure future protection of water resources, it is imperative that land uses be managed in a responsible way.

What is Stormwater Management?

Historically, urbanization has resulted in the development of stormwater-management systems to reduce flooding. These systems were developed because of their convenience and the protection they provided to property. Often, stormwater-management systems were designed for safety and convenience without recognition of other important considerations. Therefore, no matter how large the rainfall or its duration, the stormwater system was expected to remove the runoff as quickly as possible, and to restore maximum convenience in the shortest possible time. In other words, until recently, stormwater management was concerned with only the quantitative effects of runoff.

Today, however, stormwater management is far more comprehensive. An effective program involves the implementation of actions to control water in its hydrologic cycle with the objectives of providing (1) flood control; (2) nonpoint source pollution control; and (3) off-site erosion control. Stormwater management applies to rural and urban areas alike; however, the techniques presented in this manual are most relevant to urban or urbanizing situations.

To accomplish the three objectives of stormwater management, it is necessary to ensure that the volume, rate, timing and pollutant load of runoff after development are similar to those that occurred prior to development. The approach suggested in this manual is to minimize the adverse impacts of stormwater through a coordinated system of source controls. Source controls emphasize the prevention and reduction of nonpoint pollution and excess stormwater flow before it ever reaches a collection system or receiving waters. Typical control strategies and management criteria to accomplish the objectives of stormwater management are discussed below.

Flood Control

Flood control has historically been the most common goal of local, stormwater-management programs. The property damage, safety hazards, and inconvenience that can result from increased stream flooding in urbanizing watersheds usually get wide public attention and urgent demands for government action. Two levels of drainage systems must be considered in developing a management strategy for flood control: the primary drainage system and the major drainage system.

The primary drainage system consists of the street gutters and ditches, storm sewers, culverts, and open channels that are designed to prevent inconvenience and minor property damages from relatively frequent storm events. Of course, the most effective strategy for flood control at this level is to plan and design the primary drainage system adequately in advance, keeping in mind the future development potential of the drainage area. Unfortunately, many existing drainage systems were designed on a piecemeal, “as needed” basis with little regard for future upstream development. The capacity of such systems often becomes severely inadequate as upstream development progresses, resulting in frequent minor flooding and property damages.

One strategy for dealing with this problem is to replace or modify elements of the primary drainage system to provide the required capacity. This option is often expensive and does not control the source of the problem. However, this may be the only feasible method of correcting existing problems. To prevent future problems, an alternative strategy may be employed. Persons wishing to undertake new development may be required to control runoff from their sites in a manner that will not adversely affect the downstream drainage system. This control is usually accomplished through stormwater detention criteria.

Typical detention criteria will specify that stormwater runoff from a new development must be controlled so that the post-development peak runoff rate does not exceed the pre-development peak rate for some specific frequency design-storm or range of design-storm events. In many localities, a 10-year design storm is specified to preserve the effectiveness of downstream drainage structures that were originally designed to pass a 10-year pre-development storm. Other localities require that larger storms (i.e., 50- to 100-year events) must be detained and released at a controlled rate to reduce the downstream effects of major storms.

It should be kept in mind that, as attempts are made to control larger storm events, requiring slower release rates will also require larger storage volumes in detention systems.

The major drainage system comes into play when the capacity of the primary drainage system is exceeded.

This major system consists of the floodplains and surface-flow routes that water will follow during major storms. The most effective strategy for dealing with flooding at this level is to ensure that stormwater has a route to follow which will not cause major property damage or loss of life. To implement this strategy, floodplain ordinances, zoning regulations, or other land-use controls should be used to restrict floodplain development. In areas where development has already encroached on the floodplain, land owners should be encouraged to purchase flood insurance.

Nonpoint Source Pollution Control

Pollutants that are washed from the land surface and carried into the streams, rivers, and lakes with stormwater runoff have only recently been recognized as major contributors to water-quality degradation in urban and urbanizing watersheds. The goal of controlling this problem is therefore relatively new. Nonpoint-source pollution control is likely to receive highest priority in watersheds that feed public water supplies or recreation reservoirs; however, this goal should be addressed in all local stormwater management programs.

In urban areas, most of the stormwater detention practices that are used to control runoff quantity may also be adapted for use as best management practices for nonpoint-source pollution control. The design criteria of these practices for this purpose, however, are often different. The primary design strategy for pollution removal is to maximize the detention time of captured runoff. Although there have not been many monitoring studies to produce definitive design criteria, it is believed that basin-drawdown times between 30 and 40 hours will result in significant pollutant removal. The required storage volume of detention facilities can be tied to a first-flush capture (i.e., the initial 0.1″ to 1″ of runoff).

Off-Site Erosion Control

Off-site erosion control, as a management goal, must be addressed in all local stormwater-management programs. The strategies for dealing with this problem are similar to those for flood control. The major difference is in the frequency of the storm that must be controlled.

Studies have shown that most natural stream channels are formed with a bank-full capacity to pass runoff from a storm with a 1.5- to 2-year recurrence interval. As upstream development occurs, the volume and velocity of flow from these relatively frequent storms increases. Even smaller storms with less than 1-year recurrence intervals begin to cause streams to flow full or flood.

Stream channels are often subject to a 3- to 5-fold increase in the frequency of bank-full flows in a typical urbanizing watershed. This increase in flooding frequency places a stress on the channel to adjust its shape and alignment to accommodate the increased flow. Unfortunately, this adjustment takes place in a very short time period (in geologic terms). and the transition is usually not a smooth one. Meandering stream channels which were once parabolic in shape and covered with vegetation typically become straight, wide, rectangular channels with barren, vertical banks. This process of channel erosion often causes significant property damage, and the resulting sediment which is generated is transported downstream, further contributing to channel degradation.

An old strategy for dealing with this problem is to increase the carrying capacity and stability of affected streams through channel modifications (i.e. straightening, widening, lining with non-erodible material, etc.). Modifications to natural, continuous flowing streams, however, can be the subject of intense local controversy and require special permits such as a 404 permit issued by the U.S. Army Corps of Engineers. Recent innovations based on natural, stream-hydrology concepts are rapidly gaining favor and should be considered because of their beneficial effects on the aquatic environment.

Wherever modifications to natural flowing streams are being considered, extreme care must be taken to weigh the benefits of such modifications against the cost and the concerns of the local citizens. Where channel modifications are necessary, an attempt must be made to incorporate measures that will minimize adverse impacts to fish, wildlife, and the aesthetic quality of the stream.

On-site stormwater-detention criteria for new development projects can also be an effective strategy for preventing future increases in channel erosion. However, such criteria should be tied to more frequent storm events than typical flood-control criteria. Maintaining the pre-development peak-runoff rate from a 10-year storm, for example, will probably not effectively reduce downstream erosion since the majority of storm events will pass right through the detention system unimpeded.

For example, the minimum state or local stormwater-management criteria could be tied to a 2-year storm event. Receiving channels would then be capable of passing a 2-year storm without flooding or erosion after development of the site, or stormwater would be detained on the site so that the pre-development peak-flow rate from a 2-year storm is not exceeded after development. While flows from larger, less frequent storm events may cause erosion problems downstream, it is believed that, because such events will occur less often, streams will have more time to recover and restabilize themselves.

Local stormwater-detention criteria can be made more restrictive by requiring that storms larger than a 2-year event be detained. However, the allowable release rate should be tied to the actual carrying capacity of the receiving stream or the 2-year pre-development peak-runoff rate.

Multiple-Purpose Criteria

Stormwater management criteria for flood control, erosion control, and pollution control are not necessarily mutually exclusive. In many cases, stormwater can be managed to accomplish all three goals simultaneously. For example, a stormwater-detention basin can be designed as a multipurpose structure by incorporating different release rates at different stages (storage elevations).

The first stage is designed to capture an initial volume of runoff (i.e., the first flush) and release it very slowly through a subsurface drainage system. The second stage begins with an orifice cut in the riser pipe which has the capacity to pass stormwater runoff at a 2-year pre-development rate when water elevation reaches the top of the riser. The purpose of this stage would be to control downstream channel erosion from frequent storms. The top of the riser pipe could serve as the outlet for the third stage and may be designed to pass a l0-year storm at a pre-development rate for moderate flood protection downstream. The emergency spillway should be designed to pass at least the l00-year storm. While such a multi-purpose design may not be feasible for all detention systems, there are often innovative approaches which can be taken to satisfy two or more local stormwater-management goals.

Flexibility

Flexibility is extremely important in stormwater-management programs. Each development project has a unique set of conditions and circumstances and a different potential for affecting the downstream drainage system.

Criteria which may be perfectly applicable to one project may be totally unsuitable for another. For example, requiring stormwater detention for flood control may be highly applicable to projects constructed in the upper reaches of a watershed, but may be unnecessary or even undesirable for new projects constructed near the outlet of the watershed.

A qualified design professional should be given an opportunity to design a drainage system which contributes to the achievement of established, local stormwater-management goals in the most cost-effective manner. To accomplish this, each project must be considered on an individual basis.

Principles of Stormwater Management

It is much more efficient and cost effective to prevent problems than to attempt to correct problems after the fact. Sound land-use planning decisions based on the site planning principles are essential as the first, and perhaps the most important, step in managing stormwater-related problems. All new development plans (e.g., subdivisions, shopping centers, industrial parks, office centers, etc.) and redevelopment plans should include a comprehensive stormwater-management system.

Every piece of land is part of a larger watershed. A stormwater-management system for each development project should be based on, and should support, a plan for the entire drainage basin.

Optimum design of the stormwater-management system should mimic (and use) the features and functions of the natural drainage system, which is largely capital, energy and maintenance-cost free. Every site contains natural features that contribute to the management of stormwater under existing pre-development conditions. Depending upon the site, existing features such as natural drainageways, depressions, wetlands, floodplains, highly permeable soils, and vegetation provide natural infiltration, help control the velocity of runoff, extend the time of concentration, filter sediments and other pollutants, and recycle nutrients. Each development plan should carefully map and identify the existing natural systems. “Natural” engineering techniques should be used to preserve and enhance the natural features and processes of a site and to maximize the economic and environmental benefits. Engineering design can and should be used to improve the effectiveness of natural systems, rather than negate, replace or ignore them.

The volume, rate, timing and pollutant load of stormwater after development should closely approximate the conditions that occurred before development. To accomplish these objectives, two overall concepts must be considered: (1) the perviousness of the site should be maintained to the greatest extent possible, and (2) the rate of runoff should be slowed. Preference should be given to stormwater-management systems that use measures that maintain vegetative and pervious land cover and include on-site storage mechanisms. These systems will promote infiltration and slowing of the runoff.

On-site storage of stormwater should be maximized. Provision for storage can reduce peak runoff rates; aid in groundwater recharge; provide settling of pollutants; lower the probability of downstream flooding, stream erosion and sedimentation; and provide water for other beneficial uses. Stormwater runoff should never be discharged directly into surface or ground waters. Runoff should be routed over a longer distance, through grassed waterways, wetlands, vegetated buffers, and other works designed to increase overland flow. These systems provide time for increased infiltration and evaporation, allow suspended solids to settle, and remove pollutants before they are introduced to waters of the State.

Stormwater-management systems, especially those emphasizing vegetative practices, should be planned, constructed, and stabilized in advance of the facilities that will discharge into them. This principle is frequently ignored, thereby causing unnecessary off-site impacts, extra maintenance, re-working of grades, re-vegetation of slopes and grassed waterways, and extra expense to the developer. The stormwater-management system, including erosion and sedimentation controls, should be constructed and stabilized at the start of site disturbance and construction activities.

The stormwater-management system must be designed beginning with the outlet or point of outflow from the project. The downstream conveyance system should be evaluated to ensure that it contains sufficient capacity to accept the design discharge without adverse downstream impacts such as flooding, streambank erosion, and sedimentation. It may be necessary to stabilize the downstream conveyance system, especially near the stormwater system outlet. A common problem is a restricted outlet which causes stormwater to back up and exceed the storage capacity of the collection and treatment system, resulting in temporary upstream flooding. This may lead to hydraulic failure of the stormwater-management system causing re-suspension of the pollutants and/or expensive repairs to damaged structures or property. In such circumstances, it is advisable to use more than one outlet or to increase the on-site storage volume.

Stormwater is a component of the total water resources that should not be casually discarded, but used to replenish those resources. Stormwater represents a potential resource out of place, with its location determining whether it is a liability or an asset. Given the water quantity and quality problems and challenges facing Mississippi, it is imperative that stormwater be considered an asset. Treated stormwater has great potential for providing beneficial uses such as irrigation (farm, lawn, parks, golf courses, etc.), recreational lakes, groundwater recharge, industrial cooling and process water, and other non-potable domestic uses.

Whenever practical, multiple-use, temporary-storage basins should be an integral component of the stormwater-management system. All too often, storage facilities planned as part of the system are conventional, unimaginative ponds which are aesthetically unpleasing. Recreational areas (e.g., ball fields, tennis courts, volleyball courts, etc.), greenbelt areas, neighborhood parks, and even parking facilities provide excellent settings for the temporary storage of stormwater. Such areas are not usually in use during periods of precipitation, and the ponding of stormwater for short durations does not seriously impede their primary functions. Storage areas should be designed with sinuous shorelines. Shorelines that are sinuous rather than straight increase the length of the shoreline. The increased shoreline also provides more space for the growth of shoreline vegetation, thus providing for greater pollutant filtering and for increased and diversified aquatic habitat.

Vegetated buffer strips should be retained in their natural state or created along the banks of all water bodies. Vegetated buffers prevent erosion, trap sediment, filter runoff, provide public access, enhance the site amenities, and function as a floodplain during periods of high water. They also provide a pervious strip along a shoreline which can accept sheet flow from developed areas and help minimize the adverse impacts of untreated stormwater.

The stormwater-management system must receive regular maintenance. Failure to provide proper maintenance reduces the pollutant removal efficiency of the system and reduces the system’s hydraulic capacity. Lack of maintenance, especially to vegetative systems that may require revegetating, can increase the pollutant load of stormwater discharges. The key to effective maintenance is the clear assignment of responsibilities to an established agency (local government) or organization (homeowners association) and a regular schedule of inspections to determine maintenance needs. In addition, stormwater-system designers should find ways to make their systems as simple, natural, and maintenance free as possible.

Vegetation for Erosion and Sediment Control

Introduction

A dense and healthy vegetative cover protects the soil surface from raindrop impact, a major force in erosion and sedimentation. Also, vegetation shields the soil surface from the scouring effect of overland flow and decreases the erosive capacity of the flowing water by reducing its velocity.

The shielding effect of a plant canopy is augmented by roots and rhizomes that hold the soil, improve its physical condition, and increase the rate of infiltration, further decreasing runoff. Plants also reduce the moisture content of the soil through transpiration, thus increasing its capacity to absorb water.

Suitable vegetative cover offers excellent erosion protection and sediment control. Vegetative cover is essential to the design and stabilization of many structural, erosion-control practices. Vegetative cover is relatively inexpensive to achieve and maintain. Also, it is often the only practical, long-term solution to stabilization and erosion control on many disturbed sites.

Timely vegetative establishment or retention reduces the cost of vegetation, minimizes maintenance and repairs, and makes structural, erosion-control measures more effective and less costly to maintain. Landscaping is also less costly where soils have not been eroded. Natural areas (those left undisturbed) can provide low-maintenance landscaping, shade, and screening. Large trees increase property values if they are properly protected during construction.

Besides preventing erosion, healthy vegetative cover provides a stable land surface that absorbs rainfall, cuts down on heat reflectance and dust, and complements architecture. Property values can be increased dramatically by small investments in erosion control.

Plant selection should be considered early in the process of preparing the erosion and sediment-control plan. A diversity of species can be grown in Mississippi due to the variation in both soils and climate. However, for practical, economical stabilization and long-term protection of disturbed sites, plant selection should be made with care. Many plants that will grow in Mississippi are inappropriate for soil stabilization because they do not protect the soil effectively, or they cannot be established quickly. Some plants may be very effective for soil stabilization, but are not aesthetically acceptable on some sites. In all cases, native vegetation should be the first plants considered when selecting plant materials for stabilization. Plant selection is discussed and suggestions are made in the ***Surface Stabilization*** sections of Chapter 4 entitled *Permanent Seeding*, *Temporary Seeding,* and *Shrub, Vine and Groundcover Planting*. Also, a Vegetation Schedule used by the Mississippi Department of Transportation is provided as **Appendix G**.

Stabilization of most disturbed sites requires grasses and/or legumes that grow close together to provide a thick, close-growing cover. This is true even where part of or the entire site is planted to trees or shrubs. In landscape plantings, disturbed areas between trees and shrubs must also be protected either by mulching or by permanent grass, legumes, or mixtures.

Trees are excellent for long-term soil and water protection, but they will not stabilize concentrated flow areas.

Site Planning For Tree Protection

Select and clearly identify trees to be saved before beginning construction. No tree should be destroyed or altered until the construction plans are final. Floodplains and wetlands should be left in their natural condition. Locate roadways so they cause the least damage to valuable trees. Follow contours where feasible to minimize cuts and fills. Minimize trenching by locating several utilities in the same trench. Excavations for basements and utilities should be kept away from the dripline of trees.

Storage areas for construction materials and worker-parking areas should be noted on the site plan, and located where they will not cause soil compacting over roots.

When retaining existing trees in parking areas, leave enough ground ungraded around the tree to allow for its survival. Tree protection measures should be extended from the trunk to the edge of the dripline to protect the root systems from compaction. Tree wells may be needed to protect the roots from too much soil cover, ultimate compaction, and lack of aeration. Specific tree preservation practices are discussed in Chapter 4, *Preservation of Vegetation*.

Locate erosion and sediment-control measures within the limits of clearing and not in wooded areas to prevent deposition of sediment within the dripline of trees being preserved. Sediment basins should be constructed in the natural depressions, if possible, rather than in locations where extensive grading and tree removal will be required.

Selecting Trees to Be Retained or Planted

Trees may be exposed to insufficient sunlight and water; high winds; heat radiation from highways and parking lots; pollutants from cars and industries; root amputation because of sewer, water, gas and electric lines; pruning or “topping” because of power lines; and covering of roots by pavement and compaction. These items make the selection and management of trees extremely important.

MISSISSIPPI STATE UNIVERSITY™ EXTENSION

Water Conservation in Your Landscape

Water plays a vital role in all landscapes. In addition to being required for plant life, it is also the life blood of any environment. The rainwater that leaves your property is not isolated. This water overflows into a series of roadway ditches or drainage inlets, which lead to local streams, rivers, and, ultimately, the Gulf of Mexico. This stormwater picks up sediment, nutrients, and pollutants along the way, which can cause significant impacts to the health of Mississippi's water bodies. In fact, according to the Mississippi Department of Environmental Quality (MDEQ), nonpoint source pollution (pollution that comes from many different nonspecific sources, such as subdivisions or neighborhoods) is the leading cause of water pollution in Mississippi, as well as in the nation.

There are several techniques you can do in your landscape to improve or maintain the water quality of your property. Some techniques store or detain water temporarily to prevent flooding downstream, and others capture rainwater so that it can be reused for watering plants. Each option results in a positive benefit to water management on your property.

There may be state or local water regulations that govern any changes to surface or groundwater flows on your property. Be sure to check with the MDEQ Surface Water Division for any permits that you may need for significant alterations to any existing streams or drainage swales (ditches). There may also be local ordinances regarding the health and safety of water storage devices such as cisterns or rain barrels.

How Water Runoff Impacts Water Quality

Increased Water Runoff

One average city block can generate five times more rainwater runoff than a woodland area of equal size. Why is this? Building roofs, concrete, and asphalt do not allow rainwater to filter back into the ground; instead, it is carried off by drainpipes or allowed to flow to a water collection area. This type of impermeable paving carries water very quickly and increases the amount and velocity of water to drains and collection points. Faster water can create flooding and erosion problems for others downstream.

Decreased Water Runoff

A mature woodland absorbs much of the water from an average rainfall with little runoff. Rainwater adheres to leaves and stems and is stored in the deep leaf layers on the ground. Woodland areas also have little soil compaction, allowing water to seep into the ground instead of running across a compacted surface such as a lawn. In a way, the forest acts like a giant sponge, absorbing the water before releasing it downstream. Vegetated buffers on your properties can perform similarly to the forest. Additionally, the more areas of mulch that you have on your property, the better rainwater absorption and storage will be.

Increased Water Pollution

As water travels across a surface, it picks up oils, fertilizers, soil, pesticides, manure, and other chemicals from lawns, gardens, parking lots, roads, sidewalks, construction sites, and rooftops. All of these combine to create a toxic soup that washes downstream. In areas of dense development, one good rainfall can ruin a stream's ecology. It is difficult to see the difference between poor and good water quality in a stream because the changes are mainly chemical. If excessive silt or soil is washing into a stream or ditch, the water appearance can look muddy or silty. Waters with excessive nutrients from phosphorous or nitrogen may have algal blooms that cover their surface. Excessive algae can deplete the water of oxygen, causing fish and other aquatic life to die.

What Can a Homeowner Do?

There are several ways to slow down, treat, and clean urban water runoff. Even if your property isn't next to a direct waterway or drainage channel, your runoff eventually makes its way downstream.

Here are a few steps you can take to minimize water quality impacts in your area:

- Use fertilizers, herbicides, and pesticides sparingly and only where necessary for spot control.
- Avoid excessive irrigation that causes water to run off into street drains.
- Use alternative, permeable paving types in place of traditional concrete and asphalt materials. Brick, gravel, or pavers set on sand (instead of mortared joints) for

sidewalks, patios, and driveways will allow better soil infiltration and reduce water runoff.
- Capture and store valuable rainwater in cisterns and rain barrels and reuse it to water your plants.
- Capture and treat property runoff with rain gardens.
- Remove lawn, and mulch areas underneath trees to absorb rainwater.
- Avoid excessive soil compaction from vehicles and heavy equipment on lawn areas.
- Capture water runoff from animal pens, barns, and corrals in a water detention area that will allow for soil infiltration and cleaning.
- Ensure that septic systems are inspected professionally every 3–5 years to check for leaks and proper drainfield operation.

The Stormwater Chain

Consider a drop of water that falls from the sky to the ground. Depending on where it lands on your property, it will either infiltrate into the soil or it will travel to the lowest point of your property and beyond. This is called the stormwater chain, which is the path of rainwater from the point it hits the rooftops to where it eventually ends up in rivers and lakes. Water continually follows the lowest elevation, and there are a variety of methods that you can implement to capture, slow, or treat stormwater along the way. When you capture water, it can be stored for reuse, and slowing water allows it to infiltrate into the soil to recharge aquifers and prevent flooding downstream. The following sections explain each of these methods of stormwater management.

Capturing Water for Reuse

Capturing water for reuse is a time-honored way of ensuring an adequate future water supply for outdoor use. Wells were often dug at Mississippi homesteads, but cisterns were also commonly used. Cisterns, which also include rain barrels, are simply large containers that store water. They are placed to capture water running from a central source, such as a roof gutter or downspout. Rainwater contains less salts (chlorine and fluorides) than tap water, so using rainwater prevents salt buildup and burning on salt-sensitive plants.

Rain Barrels and Cisterns

Rain barrels and cisterns are available commercially, or you can make them from recycled containers, such as food containers (olive, wine, or whiskey barrels). Any material that holds liquids, such as metal, fiberglass, plastic, or concrete may be used but, to prevent algae buildup, the sides should not be transparent. Non-food grade barrels may be used, including detergent drums, but these must be thoroughly cleaned to prevent water contamination. Rain barrel kits are also available that contain the hardware and attachments to convert them to rain barrels. It is important to use a cover or screen on open water sources to prevent mosquitoes from breeding and to reduce water hazards.

Figure 1. Two rain barrels can be linked so that, as one fills, any overflow goes into the other container. It is important to provide sturdy bases so that the barrels won't topple over.

While rainwater is fairly clean, it is recommended to install a first-flush diverter if you are catching water from a downspout or roof. The first minute of rainfall pushes all of the dust, dirt, bacteria, and bird droppings down first, and first-flush devices prevent these contaminants from going into the water-storage tank. Some rain barrel kits or cisterns include flush diverters, or you can purchase and install them separately.

Cisterns of any size may also be buried in the ground to save space in the landscape. To get water from the underground tanks, pumps can be installed. Rubber or plastic, collapsible cisterns are also available; these are portable and can save space when empty. Solar pumps are available for places that do not have access to electricity.

Using Landscaping to Capture Water

You can also manage stormwater by capturing it temporarily or permanently in the landscape. Temporary water sources are called detention ponds, and they are used to protect against flooding and prevent erosion. Detention ponds also help settle sediments such as sands, silts, and heavy metals that may be present in stormwater. Rain gardens and biofilters are common examples of detention ponds; they are not created to hold large amounts of water for extended periods of time. A landscape feature that holds water for an extended period of time is called a retention pond. Ponds and water gardens are examples of retention ponds.

Retention ponds add to the dynamic of a landscape and help store and clean stormwater.

Rain Gardens

Rain gardens are planted as stormwater drainage areas; they temporarily store rainwater until it can filter into the soil. Rain gardens do not permanently store water, and they have surface water only during and shortly after rainfall events. When properly designed, rain gardens should have surface water for only a few days, which is not long enough for mosquito eggs and larvae to develop into adults. The benefits of creating a rain garden include:

- Reducing flooding at drainage inlets and downstream areas.
- Filtering pollutants from urban runoff, which can affect streams and creeks.
- Preventing erosion by reducing stormwater volume and velocity.

Rain gardens work by collecting surface water in a depression in the ground and then filtering the water through soils and plants. The biological and chemical processes within the soil, plants, and mulch are able to store or break down pollutants and improve water quality.

Figure 2. Rain gardens, such as the one at the Mississippi State University Landscape Architecture Facility, are designed to channel and filter excess rainwater.

Rain gardens are best located in the main drainageways on a property or in lower depressions where water sometimes pools. These are easily seen during a moderate rain. Here are a few tips to consider when locating a rain garden:

- Always contact your utility company to come out and locate any buried lines or pipes on your property. Since most rain gardens require soil excavation, identify and avoid these locations.
- Do not place rain gardens in or near septic drainage fields.
- Place rain gardens downslope from any structure, and avoid locating near building foundations.
- Select areas that are open and away from large trees. Excavation can damage tree roots, and excess water in these areas could damage tree health.
- Avoid steep slope areas (over 12 percent) for rain gardens.
- Understanding the soil types on your property is key to a successful rain garden. As the purpose of a rain garden is to drain into the surrounding soil, sandy soils are typically best. Clay or compacted soils may need a larger excavation area. You may need to replace the soil with a loose soil mix, or additional underground drainage may be needed. Your local county Extension agent can provide you with soil sample boxes for soil tests. A simple way to test your soil drainage is to dig a hole about the size of a 2-gallon bucket. Fill it with a bucket of water and let it drain. If it drains less than an inch per hour, you may need to provide additional drainage, such as an outflow pipe or French drains (perforated pipe in a rock channel), that carry the overflow water safely to an outlet. If soil erosion occurs around the rain garden outflow, permanent materials such as rock or concrete may be necessary to secure the edges.

For more information on sizing rain gardens and detention ponds, see Extension Factsheet Rain Gardens.

Biofilters

Biofilters are similar to rain gardens but are often linear in shape and are constructed deeply to handle more water volume. Because of this, biofilters work well to store and cleanse water in parking lots or other impermeable paving areas (impermeable means water cannot drain through the surface). They are constructed to handle excess runoff just as drainage ditches are, except biofilters are heavily vegetated like aquatic gardens to slow and infiltrate water and remove sediments.

With the presence of soil microbes and plants, biofilters have the added advantage of cleansing water. As water filters through the soil, microbes break down the organic components and release nutrients for plants to absorb. Biofilters are designed to slow, store, and cleanse average rainfall amounts (less than 4 inches of rainfall in a 24-hour period), rather than store large amounts of water like a retention basin. The job of biofilters is to absorb and clean the silt and pollutants from the first-flush of a rainfall.

Retention Ponds or Permanent Water Gardens

The simple addition of water in the landscape can offer a new dynamic to a garden area. It can also serve important stormwater functions by storing water, preventing erosion and sedimentation, and cleansing water. It can also provide recreational and waterfowl opportunities. From quiet, shallow ponds to the spray jets in a formal pool, water can provide just the right element for the many moods of a landscaped space. Because of the wide range of options that are available, a water feature can be added to even the smallest of garden areas.

How Water Gardens Work

Water gardens can range in size from a pond of several acres to a small whiskey barrel container. Although different in water volumes, the principles of water gardening are the same for any size feature. Because every water garden needs to be maintained, you should consider how much time you want to spend taking care of your water garden. By understanding a few basic principles, problems in ponds and maintenance can be reduced. For more information on designing aquatic features, see Extension Factsheet Creating Water Features in the Landscape.

Dry Swales, Dry Creeks, and Drainageways

Roadside ditches are commonly used to drain water from roads and other surfaces. While effective at transporting water, these can often be unsightly. But drainage swales can be designed to be more attractive and carry water safely. As mentioned above, always consult with an engineer or landscape professional when designing swales that carry large water volumes or that connect to other waterways off your property.

Dry Swales

Dry swales (also called dry washes or arroyos) are dry for much of the year and only temporarily contain water after a rain. These are shallow drainage areas that are sized to accommodate maximum water levels. If the area is sunny, turfgrass is often used to stabilize the soil as water runs off quickly. If the area is in shade or receives less than a half-day of sun, turf will not grow and you will have to substitute this with other shade- and moisture-tolerant plants. See Table 1 for an abbreviated list of plants that will tolerate mostly shady, dry locations, with occasional water. Heavy materials such as large rocks, river stones, and logs can also keep the soil from eroding and offer an aesthetic touch.

Table 1. Plants for shady, dry swales.

Small and Large Trees	
Swamp red maple	*Acer rubrum* var. *drummondii*
Bald cypress	*Taxodium distichum*
Green ash	*Fraxinus pennsylvanica*
Swamp black gum	*Nyssa sylvatica* var. *biflora*
Willow oak	*Quercus phellos*
Black willow	*Salix nigra*
Sweetbay magnolia	*Magnolia virginiana*
Pond cypress	*Taxodium ascendens*
Ironwood	*Carpinus caroliniana*
Wax myrtle	*Myrica cerifera*
Shrubs	
Dwarf palmetto	*Sabal minor*
Chokeberry	*Aronia arbutifolia*
Buttonbush	*Cephalanthus occidentalis*
Summersweet	*Clethra alnifolia*
Sweetspire	*Itea virginica*
Titi	*Cyrilla racemiflora*
Buckwheat tree	*Cliftonia monophylla*
Perennials	
Stokes aster	*Stokesia laevis*
Blue flag iris	*Iris virginica*
Cinnamon fern	*Osmunda cinnomomea*
Royal fern	*Osmunda regalis*
River oats	*Chasmanthium latifolium*
Blue-eyed grass	*Sisyrinchium angustifolium*
Blazing star	*Liatris spicata*
Joe-pye weed	*Eutrochium purpureum*

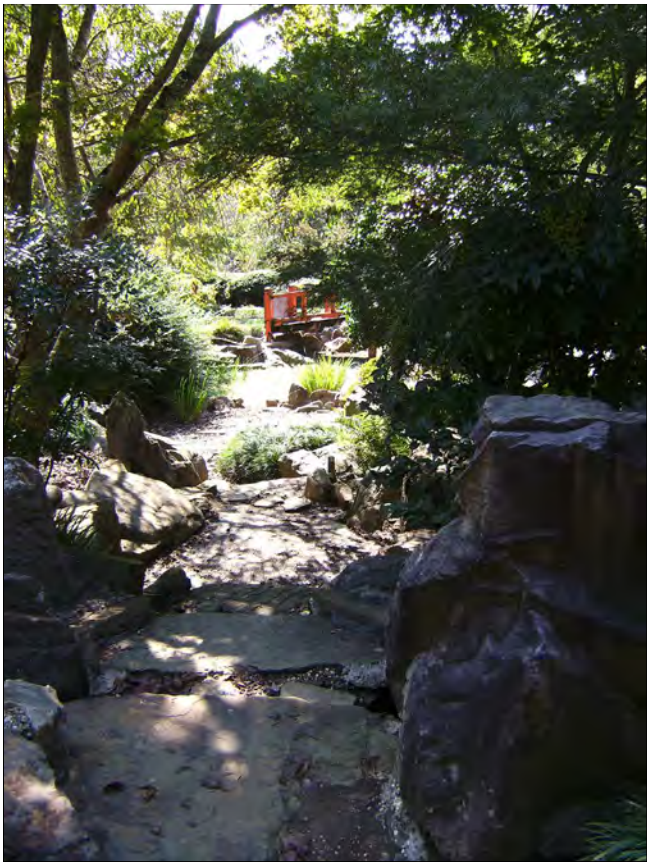

Figure 3. Dry swales contain water only during a rain and can be designed as landscape features when dry.

Protecting Water Quality for Drainage Areas, Ponds, and Stream Channels

Using Vegetative Buffer Strips

One simple and easy method of slowing and cleansing water is to use vegetative buffer strips near water areas. Vegetative buffers are simply zones of vegetation allowed to grow where water flows. Vegetative buffers are extremely effective when used adjacent to ponds, lakes, and stream edges. Lawn or pavement that allows surface drainage directly into water bodies can degrade water quality. By allowing dense vegetation to grow along the edges of water (where possible), you can achieve better water quality. The effectiveness of water cleansing depends on the buffer width. In general, the wider the buffer, the more pollutants it can capture. Studies have shown that a 30-foot-wide agricultural field along a water body can reduce soil sedimentation and pollutants.

An attractive option is to plant wetland flowering and ornamental plants. The addition of irises, cattails, pickerelweed, rushes, powdery thalia, buttonbush, and other water-loving plants at the edges of streams and water bodies creates a more aesthetically pleasing wetland garden.

Drainage areas and ditches can also be planted to slow stormwater and improve water quality. While maintaining turf in swales and ditches allows for some water infiltration, the addition of shrubs and trees enhances the effort. Check with municipal engineers for permission to alter vegetation in drainage rights-of-way on private properties. It is also important to prevent flooding near low-lying structures, roads, and residences.

Green Roofs and Green Walls

Urban and suburban areas offer little room for large ponds or other water features in the landscape. Because of this, some innovative gardens have been developed to store and treat water where it runs off the fastest—on buildings and in paved areas. Once considered experimental solutions, greens roofs and green walls are now commonly used in most cities around the world.

Figure 4. Green roofs provide many benefits, including their alternative roofing material.

Green Roofs

Green roofs are vegetative alternatives to traditional roofing materials. Instead of having asphalt, gravel, or shingles on a roof, live plants and growing media are installed. Sod-covered houses were once common throughout much of Europe and western North America, and new technologies are now allowing for their use on modern residential, commercial, and industrial buildings. Green roofs consist of vegetation, a growing medium, impermeable membranes, drainage, and sometimes supplemental irrigation. This alternative roofing material offers the following benefits to a structure:

- Reduces summer temperatures on structures (by as much as 20 degrees).
- Absorbs rainwater and reduces stormwater runoff.
- Reduces traffic and other urban noises.
- Provides an additional living environment for birds and animals.
- Provides an attractive and natural rooftop solution.
- Protects roof materials from sun exposure and temperature fluctuations.
- Provides additional insulation for building interiors.

Green roofs are either intensive or extensive, referring to the soil media depth and the ultimate weight on the roof. Intensive green roofs have growing media ranging from 8–24 inches, which allows for the inclusion of larger shrubs and even trees, with weight loads ranging from 60 to 200 pounds per square foot. Intensive roofs require more regular maintenance and are suited to structures that can support heavier loads. Extensive green roofs are shallower (2–7 inches), typically allowing for herbaceous plants and ground covers and weight loads ranging from 16 to 35 pounds per square foot. An extensive green roof is usually more suitable for existing roof types because it is lighter. Maintenance considerations are generally lower for extensive types. With any green roof project, an architect or structural engineer should determine the weight loads that the roof will support.

There are various techniques, materials, and growing media that may be used on a green roof project, and they may vary according to the structure. Typically, directly on the rooftop is a separation layer, followed by layers of insulation, a moisture barrier, waterproofing, drainage protection, drainage, filter fabric, growing media, and plants. The slope of the roof should range from 5 to 20 degrees for positive water drainage. Additional drainage layers or pipes may be needed for flat roofs. According to the U.S. Environmental Protection Agency's report on green roofs, the average national cost for an extensive green roof is approximately $8 per square foot for materials, preparation, and installation.

Publication 3146 (POD-07-24)

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Produced by Agricultural Communications.

NCF-Envirothon 2026 Mississippi

Current Issues: Part B Study Resources

Key Topic #4: Community Engagement & Watershed Stewardship

12. Explore strategies to engage residents in NPS education and watershed stewardship (e.g., storm drain art, homeowner guides, signage).
13. Design communications or policies that encourage residential BMP adoption (e.g., fertilizer/pesticide control, native planting).
14. Evaluate the effectiveness of outreach programs and community-led monitoring in protecting watershed health.

Resource Title	Source	Located on Page
Conducting Outreach Watershed Campaigns	*National Stormwater Alliance. (n.d.).* *https://ms4resource.nationalstormwateralliance.org/index.php/conducting-watershed-outreach-campaigns/*	91
City of Madison Public Works Program, *excerpts from the website*	*City of Madison, MS. (n.d.). Public Works | Madison the City.* *https://www.madisonthecity.com/departments/public-works/*	97
Adopt-a-Stream program overview	*Mississippi Wildlife Federation. (n.d.).* *https://mswildlife.org/adopt-a-stream/*	99

Conducting Watershed Outreach Campaigns

Stormwater management is an amenity that most citizens don't even think about. That's why it is important for municipal governments to communicate the benefits of stormwater management to other government agencies, community leaders, and members of the public. Public education campaigns are a useful tool for communicating that the impacts of stormwater pollution are real, and that investing in effective stormwater management can yield strong returns. Although the requirements of your MS4 permit only apply within your community's legal jurisdiction, stormwater education campaigns are most effective and most efficient when applied at the watershed scale. This also creates the opportunity for you to collaborate with neighboring jurisdictions and watershed organizations.

Contents

Understanding the importance of a watershed outreach campaign

Engaging with the public and other stakeholders can lead to valuable input and assistance to inform your municipal stormwater management program. Thus, you should provide these groups with opportunities to play an active role in both the development and implementation of your program. An active and involved community is crucial to the success of your program because it allows for:

- **Broader public support**, as citizens who participate in the development and decision-making process are partially

> Note that NPDES-permitted MS4s are legally bound to jurisdictional and political boundaries and do not always require watershed-level outreach campaigns. Developing, participating in, or collaborating with watershed outreach campaigns can help in meeting the public education and outreach and public participation requirements of your MS4 permit, but additional efforts may be needed to ensure full compliance with these requirements.

responsible for the program; therefore, they may be less likely to raise legal challenges and more likely to take an active role in its implementation.

- **Shorter implementation schedules** due to fewer obstacles in the form of public and legal challenges, and increased resources in the form of citizen volunteers.
- **A broader base of expertise** and **economic benefits**, as community members are themselves valuable resources.
- **A conduit to other programs**, as citizens involved in the stormwater program development process provide important cross-connections and relationships with other community and government programs.

Watershed outreach campaigns can be the most effective route for obtaining these important benefits and reaching the appropriate audiences, as they provide public education and awareness about the importance of protecting the lakes, rivers, streams, aquifers, and coasts that we treasure from the impacts of stormwater pollution.

You are strongly encouraged to combine your outreach campaign efforts with other MS4 programs. Messages are stronger if they are seen regionwide or statewide, and there is an economy of scale in implementing the program. You can customize materials to reflect local conditions, but strive for common themes, look and feel, and content.

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Maximizing the effectiveness of your outreach campaign

You can maximize the effectiveness of your public outreach campaign by:

- **Linking outreach to watershed planning.** Most federal, state, and local efforts to clean up pollution and protect water use a watershed approach guided by stakeholder partnerships, a geographic focus on specific drainage basins, and sound science. These efforts involve a continual need to inform, engage, and motivate water quality managers, stakeholders, cooperating agencies, elected officials, and the public using outreach campaigns.
- **Using outreach to help meet water quality goals.** Education can be a powerful way to reduce many sources of pollution. For example, in waterways affected by dog waste, education might be the simplest and most publicly acceptable way of reducing fecal coliform bacteria.
- **Using outreach to develop a successful program.** An effective outreach campaign will help gain the critical support and compliance that will lead to your program's ultimate

Partnerships can provide access to financial resources; increase effectiveness, efficiency, and public influence; allow for creativity and innovation; and improve communication between typically adversarial parties. They also lend credibility when you are seeking funding and delivering your message. Consider multiple city departments and neighboring communities when pooling resources for stormwater-related educational materials, green infrastructure demonstration projects, and other commitments under your MS4 permit.

success and help you meet EPA requirements for Section 319 grant Note that your state may have additional Section 319 grant requirements.

- **Using outreach to help change behavior.** One of the most effective ways to get people to change their behavior is through social marketing. At its most basic level, social marketing means looking at your watershed community as customers.
- **Building partnerships to achieve goals.** A partnership is a voluntary collaboration of agencies, organizations, or other groups or individuals working toward a common goal. In some states, partnerships can develop and implement operational practices that also achieve some MS4 permit requirements. Engaging a wide variety of partners early in your outreach process can create a team that will be helpful in identifying audiences, messages, and formats for your outreach campaign.

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Developing your outreach campaign plan

To develop an effective watershed outreach campaign plan, you should follow six discrete steps (see *Getting in Step: A Guide to Effective Outreach in Your Watershed* for more information on how to develop and implement your campaign in concert with your overall water quality improvement goals). You should identify the elements and information you need to complete each step before proceeding to the next step:

1. **Define the driving forces, goals, and objectives.** Ensure that your outreach goals and objectives are linked to your overall water quality improvement or protection goals. Also, open channels of communication to fully consider the views of the general public and decision-makers alike. Stakeholders should have multiple opportunities to help establish the plan vision and goals and to identify and prioritize project alternatives. Ideally, this process will yield community consensus and help reduce the number of challenges that remain when officials must determine whether to fund plan components.
2. **Identify stakeholders, target audiences, and potential partners**. Outline several key groups, including community members and organizations, local institutions, and government agencies to engage. Complete the following steps:
    - Identify key city team members and additional partners to support strategy development and outreach implementation.

To create a **compelling key message**:

• Keep it simple and focus on how these actions can help improve areas where people live, work, or play.

• Establish an emotional connection with the audience.

• Sell the benefits of your program rather than the features.

• Identify facts that can support your message.

• Explain the consequences of neglecting stormwater management (e.g., increased flooding, polluted waterbodies).

Examples key messages include:

• “There is a cost associated with stormwater management. Paying for these projects now instead of down the road will improve our community and save us money in the long run.”

• “Implementing stormwater management controls will result in a cleaner, more enjoyable community with more plants and recreational opportunities.”

- Outline the roles, responsibilities, and level of involvement of team members and stakeholders who will help implement aspects of stormwater management.
- Identify target stakeholder groups and audiences who are interested in, affected by, or could help implement activities related to stormwater management and identify the relevant goals and steps in planning and implementation for each group.
- Identify a team member to communicate with each stakeholder group, as well as the frequency and means of communication.

3. **Create the message.** Think about the aspects of stormwater management that will resonate with each of the identified target audiences when creating your key messages. For example, homeowners may be interested in impacts on property values, neighborhood aesthetics, and recreational opportunities, while city departments may be more focused on financial impacts or changes in local flooding. Remember to consider your audience's level of scientific literacy; express the science behind the problem without jargon and confusing acronyms, so it is more understandable to a wider audience.
4. **Package the message.** Know the best way to package your message to reach your community (for example, if your live in a quiet retirement community versus a college town). The best channel for your stormwater management message depends upon your constituents and their preferences and could include:
   - Targeted community events or public meetings.
   - Postings on the city's website or social media accounts.
   - Existing community meetings, like when updating master plans, developing transportation projects, etc.
   - Traditional media (e.g., newspapers, radio) and printed materials.
   - Face-to-face meetings with elected leaders, municipal departments, and local and regional stakeholder organizations.
5. **Distribute the message.** After identifying the most effective way to package your message, distribute it via the selected channels.

Example Metrics to Measure Campaign Success

- **Survey responses**: the number and percentage of positive/negative responses, or an indication of understanding of key stormwater concepts (e.g., watershed, green infrastructure).
- **Media tracking and social media impressions**: number of articles in local and regional media; social media posts (Twitter, Facebook).
- **Document downloads**: number of document views/downloads from a website.
- **Meeting attendance and contact information**: number of attendees at public meetings and contact information of participants willing to share.
- **Public comment tracking**: number of comments broken down by positive/negative.

How to Ensure Successful Long-Term Implementation of Your Campaign

- Develop an operating procedure.
- Schedule day-to-day activities.
- Determine resources and support.
- Maintain the momentum.
- Overcome barriers to success such as:
  - Poor coordination and planning.
  - Lack of communication.
  - Political wrangling and changing regulations.
  - Fear of the unknown.
  - Letting money drive the process.
  - Letting the process bog you down.

6. **Evaluate the outreach campaign.** Outline methods to measure your campaign's success by gauging public awareness or the effects of media outreach. Using a combination of metrics will ensure you reach a broader range of the public in varying socioeconomic classes and assess whether you need to make a mid-course correction to take a different approach.

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Implementing your outreach campaign over time

Use your watershed outreach plan when updating and conducting stormwater management activities over time. Outreach activities can build awareness about stormwater services, inform the public about your program's activities, communicate the value and benefits of stormwater management, access local knowledge and experience, create buy-in for infrastructure investment expenditures, and identify potentially contentious issues or deal-breakers. Scale your efforts according to local conditions and program goals. The following table summarizes some key factors to consider.

Key Factors to Consider During Outreach and Engagement

More Intensive Effort Needed for Outreach and Engagement if…	Less Intensive Efforts Needed for Outreach and Engagement if…
Stormwater issues are complex, and solutions are unclear.	Program drivers and solutions are relatively simple and straightforward.
The municipal stormwater program needs substantial new funding.	The municipal stormwater program needs modest or minimal additional funding.
Decision-makers are unfamiliar with stormwater services and needs.	Decision-makers understand that stormwater is a priority.
The community has little awareness of water issues and opportunities.	The community highly values clean water and the need for stormwater services.

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Overcoming outreach implementation challenges

Traditional methods of soliciting public input are not always successful in generating interest and subsequent involvement in all sectors of the community. For example, municipalities often rely solely on advertising in local newspapers to announce public meetings and other opportunities for public involvement. Because large sectors of the population may not read the local press, this method might only reach a limited audience.

Therefore, you should use alternative advertising methods whenever possible, including radio or television spots, social media, postings at public transit stops, announcements in neighborhood newsletters, announcements at civic organization meetings, flyers, mass mailings, door-to-door visits, telephone notifications, and multilingual announcements. These efforts, of course, are tied closely to your public education and outreach minimum control measures.

Target your advertisements and invitations for specific groups, including ethnic, minority, and low-income communities; academia and educational institutions; neighborhood and community groups; outdoor recreation groups; and business and industry. Involve a diverse cross-section of people who can offer a multitude of concerns, ideas, and connections during the program development process.

You can also overcome outreach and engagement challenges by incorporating best management practices such as:

- **Public meetings/panels** that allow citizens to discuss various viewpoints and provide input concerning appropriate stormwater management policies and practices.
- **Volunteer water quality monitoring** that gives citizens firsthand knowledge of the quality of local waterbodies and provides a cost-effective means to collect water quality data.
- **Volunteer educators/speakers** who can conduct workshops, encourage public participation, and staff special events.
- **Storm drain stenciling**, an important and simple activity that concerned citizens, especially students, can do.
- **Community clean-ups** along local waterways, beaches, and around storm drains.
- **Citizen watch groups** that can help local enforcement authorities identify polluters.
- **"Adopt A Storm Drain" programs** that encourage individuals or groups to keep storm drains free of debris and to monitor what is entering local waterways through storm drains.
- **Community input on fish consumption advisory posting signs** for waterways that are associated with stormwater pollutant inputs.

As an example of effective communication and outreach, consider an MS4 that has concluded through its Illicit Discharge Detection and Elimination program that a certain section of town has a high incidence of used motor oil dumping. The watershed has numerous automotive businesses including small repair shops, large auto dealerships, gas stations, and body shops. In addition, there are several large apartment complexes with areas that could be used as "do-it-yourself" oil change areas. The MS4 organizes a public meeting in the watershed to not only educate residents about stormwater issues and permit requirements, but also to ask for input regarding possible dumping areas and to determine if the community needs an oil recycling facility or some other way to safely dispose of used motor oil. In this way, the MS4 might better understand who the target audience is for illegal dumping control while implementing a valuable service for the watershed community.

Changing Behaviors Through Community-Based Social Marketing

Community members can contribute to effective stormwater management by choosing behaviors that prevent excess water runoff from their residences. But traditional community outreach approaches for communicating this information, like distributing brochures and fact sheets, can result in little or no behavior change.

Fostering Sustainable Behavior: Community-Based Social Marketing (CBSM) pioneered the use of CBSM to promote sustainable behavior change. The CBSM method is based in social psychology and draws from the idea that sustainable behavior change is most effective when it involves direct contact with people at the community level.

CBSM has been proven to be an effective, practical approach to fostering sustainable behavior change. It includes five major steps:

1. Select behaviors.
2. Identify behaviors and benefits.
3. Strategize behavior change.
4. Pilot the strategy.
5. Conduct broad-scale implementation.

City of Madison, Mississippi

The Department of Public Works strives to enhance the quality of life in Madison by ensuring clean, safe drinking water. It provides efficient sewer service, well-maintained city streets and all other city-related services that our citizens rely on daily. Public works employees work to provide efficient and timely services.

Madison Mississippi has been a leader in actively incorporating and educating its citizens on all aspects of stormwater management and LID.

Stormwater Management

As the City of Madison continues growing, the challenge of maintaining clean bodies of water also grows. Stormwater runoff increases as development turn natural green spaces into paved residential and commercial areas. Stormwater runoff does not flow into a treatment plant but directly into our streams and lakes. From there, it ultimately flows into the Pearl River and Ross Barnett Reservoir.

Because fewer trees, grass, and plants serve as natural filters, stormwater runoff contains more pollutants. These pollutants wash through the storm drain system and into our local streams, such as Culley Creek, Hearn Creek, Haley Creek, Brashear Creek, and Bear Creek.

Sources of stormwater pollution are driveways, streets, parking lots, construction sites, agricultural fields, lawns, pet wastes, failing sewer systems, leaking septic tanks, and illicit discharges such as dumping waste motor oil. Pollutants of concern include but are not limited to oils, grease, sediment, fertilizers, pesticides, herbicides, bacteria, debris, and litter.

The City of Madison has a stormwater runoff management program required by the U.S. Environmental Protection Agency (EPA). The program addresses water quality and reduces pollution to local waters through public education and outreach; public involvement/participation; illicit discharge detection and elimination; construction site runoff control; post-construction runoff control; pollution prevention, and good housekeeping for city facilities.

Here are tips that you can follow to minimize stormwater pollution:

- Do not dump anything down storm drains.
- Dispose of litter properly.
- Recycle

- Choose non-toxic products.
- Conserve water.
- Keep storm drains clear of debris, trash, sediment, and other litter.
- Make sure the septic system is operating properly.
- Minimize the use of fertilizers and pesticides.
- Practice clean and responsible boating.
- Wash vehicles at a car wash or where water flows into the grass

Drainage

If a storm drain malfunctions, please report the issue to Public Works.

Drainage on private property is the responsibility of the homeowner. Here are some tips that can help improve drainage on your property:

- Regularly clean gutters
- Make sure runoff from downspouts drains away from your home
- Keep inlets for drainage systems clear of leaves and debris
- Maintain swales in your yard to improve water runoff
- Check French drains for silt build-up that would restrict the flow
- Avoid installing fences or planting trees and shrubbery in drainage paths and swales

Source: https://www.madisonthecity.com/departments/public-works/

Adopt-A-Stream Mississippi

Program Spotlight

Environmental Stewardship & Watershed Protection

Program Overview

Adopt-A-Stream Mississippi is a comprehensive educational program designed to involve citizens in stream stewardship and water quality monitoring. The program operates on a central philosophy: *Caring for and learning to conserve our vital water resources.*

Financial Administration: This program is funded via a Nonpoint Source grant from the U.S. EPA to the Mississippi Department of Environmental Quality (MDEQ) under §319(h) of the Clean Water Act. It is administered by the Mississippi Wildlife Federation.

Why Our Water Matters

- Habitat — Providing homes for diverse aquatic life.
- Recreation — Supporting fishing, swimming, and canoeing.
- Utility — Serving as vital sources for drinking water, industry, and agriculture.
- Balance — Maintaining the sensitive equilibrium of our natural ecosystem.

Core Goals

1. Education — Teaching citizens about the impact of point and nonpoint source pollution.
2. Data Collection — Gathering baseline data to indicate stream health statewide.
3. Action — Using collected data to advocate for clean and restored waters.
4. Empowerment — Showing citizens how to positively impact local watersheds.
5. Sustainability — Fostering long-term behaviors that improve environmental health.

Featured Project: Storm Drain / Ditch Program

"Be Part of the Solution to Runoff Pollution" — A community service project designed for volunteers of all ages.

The Two Components of Outreach:

Method	Application	Message
Storm Drain Markers	For urban areas with drainage systems.	Permanent marker reading: **"NO DUMPING! DRAINS TO RIVER"**
Door Hangers	For neighborhoods with open drainage ditches.	Informative hangers explaining the impact of dumping waste into local ditches.

Key Vocabulary for Students

- **Watershed:** Land area that channels rainfall and snowmelt to streams and rivers.
- **Nonpoint Source Pollution:** Pollution carried by rainfall over land surfaces.
- **Stewardship:** Responsible planning and management of natural resources.

Source: Mississippi Wildlife Federation (mswildlife.org/adopt-a-stream/)