CHAPTER 4: MANAGEMENT MEASURES FOR URBAN AREAS

I. INTRODUCTION

A. What "Management Measures" Are

This chapter specifies management measures to protect coastal waters from urban sources of nonpoint pollution. "Management measures" are defined in section 6217 of the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA) as economically achievable measures to control the addition of pollutants to our coastal waters, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint pollution control practices, technologies, processes, siting criteria, operating methods, or other alternatives.

These management measures will be incorporated by States into their coastal nonpoint programs, which under CZARA are to provide for the implementation of management measures that are "in conformity" with this guidance. Under CZARA, States are subject to a number of requirements as they develop and implement their Coastal Nonpoint Pollution Control Programs in conformity with this guidance and will have some flexibility in doing so. The application of these management measures by States to activities causing nonpoint pollution is described more fully in *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance*, published jointly by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA).

B. What "Management Practices" Are

In addition to specifying management *measures*, this chapter also lists and describes management *practices* for illustrative purposes only. While State programs are required to specify management *measures* in conformity with this guidance, State programs need not specify or require the implementation of the particular management *practices* described in this document. However, as a practical matter, EPA anticipates that the management measures generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices listed in this document have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measures. EPA has also used some of these practices, or appropriate combinations of these practices, as a basis for estimating the effectiveness, costs, and economic impacts of achieving the management measures. (Economic impacts of the management measures are addressed in a separate document entitled *Economic Impacts of EPA Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters.)*

EPA recognizes that there is often site-specific, regional, and national variability in the selection of appropriate practices, as well as in the design constraints and pollution control effectiveness of practices. The list of practices for each management measure is not all-inclusive and does not preclude States or local agencies from using other technically sound practices. In all cases, however, the practice or set of practices chosen by a State needs to achieve the management measure.

C. Scope of This Chapter

This chapter addresses six major categories of sources of urban nonpoint pollution that affect surface waters:

(1) Runoff from developing areas;
(2) Runoff from construction sites;

(3) Runoff from existing development;
(4) On-site disposal systems;
(5) General sources (households, commercial, and landscaping); and
(6) Roads, highways, and bridges.

Each category of sources is addressed in a separate section of this guidance. Each section contains (1) the management measure; (2) an applicability statement that describes, when appropriate, specific activities and locations for which the measure is suitable; (3) a description of the management measure's purpose; (4) the basis for the management measure's selection; (5) information on management practices that are suitable, either alone or in combination with other practices, to achieve the management measure; (6) information on the effectiveness of the management measure and/or of practices to achieve the measure; and (7) information on costs of the measure and/or practices to achieve the measure.

D. Relationship of This Chapter to Other Chapters and to Other EPA Documents

1. Chapter 1 of this document contains detailed information on the legislative background for this guidance, the process used by EPA to develop this guidance, and the technical approach used by EPA in the guidance.

2. Chapter 6 of this document contains information and management measures for addressing nonpoint source impacts resulting from hydromodification, which often occurs to accommodate urban development.

3. Chapter 7 of this document contains management measures to protect wetlands and riparian areas that provide a nonpoint source pollution abatement function. These measures apply to a broad variety of sources, including urban sources.

4. Chapter 8 of this document contains information on recommended monitoring techniques to (1) ensure proper implementation, operation, and maintenance of the management measures and (2) assess over time the success of the measures in reducing pollution loads and improving water quality.

5. EPA has separately published a document entitled *Economic Impacts of EPA Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters.*

6. NOAA and EPA have jointly published guidance entitled *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance.* This guidance contains details on how State Coastal Nonpoint Pollution Control Programs are to be developed by States and approved by NOAA and EPA. It includes guidance on:

   - The basis and process for EPA/NOAA approval of State Coastal Nonpoint Pollution Control Programs;
   - How NOAA and EPA expect State programs to provide for the implementation of management measures "in conformity" with this management measures guidance;
   - How States may target sources in implementing their Coastal Nonpoint Pollution Control Programs;
   - Changes in State coastal boundaries; and
   - Requirements concerning how States are to implement their Coastal Nonpoint Pollution Control Programs.

E. Overlap Between This Management Measure Guidance for Control of Coastal Nonpoint Sources and Storm Water Permit Requirements for Point Sources

Historically, overlaps and ambiguity have existed between programs designed to control urban nonpoint sources and programs designed to control urban point sources. For example, runoff that originates as a nonpoint source may ultimately may be channelized and become a point source. Potential confusion concerning coverage and implementation of these two programs has been heightened by Congressional enactment of two important pieces of legislation: section 402(p) of the Clean Water Act, which establishes permit requirements for certain municipal and industrial storm water discharges, and section 6217 of CZARA, which requires EPA to promulgate and States to provide for the implementation of management measures to control nonpoint pollution in coastal waters. The discussion below is intended to clarify the relationship between these two programs and describe the scope of the coastal nonpoint program and its applicability to storm water in coastal areas.

1. The Storm Water Permit Program

The storm water permit program is a two-phased program enacted by Congress in 1987 under section 402(p) of the Clean Water Act. Under Phase I, National Pollutant Discharge Elimination System (NPDES) permits are required to be issued for municipal separate storm sewers serving large or medium-sized populations (greater than 250,000 or 100,000 people, respectively) and for storm water discharges associated with industrial activity. Permits are also to be issued, on a case-by-case basis, if EPA or a State determines that a storm water discharge contributes to the violation of a water quality standard or is a significant contributor of pollutants to waters of the United States. EPA published a rule implementing Phase I on November 16, 1990.

Under Phase II, EPA is to prepare two reports to Congress that assess remaining storm water discharges; determine, to the maximum extent practicable, the nature and extent of pollutants in such discharges; and establish procedures and methods to control storm water discharges to the extent necessary to mitigate impacts on water quality. Then, EPA is to issue regulations that designate storm water discharges, in addition to those addressed in Phase I, to be regulated to protect water quality and is to establish a comprehensive program to regulate those designated sources. The program is required to establish (1) priorities, (2) requirements for State storm water management programs, and (3) expeditious deadlines.

These regulations were to have been issued by EPA not later than October 1, 1992. However, because of EPA's emphasis on Phase I, the Agency has not yet been able to complete and issue appropriate regulations as required under section 402(p). The completion of Phase II is now scheduled for October 1993.

2. Coastal Nonpoint Pollution Control Programs

As discussed more fully earlier, Congress enacted section 6217 of CZARA in late 1990 to require that States develop Coastal Nonpoint Pollution Control Programs that are in conformity with the management measures guidance published by EPA.

3. Scope and Coverage of This Guidance

EPA is excluding from coverage under this section 6217(g) guidance all storm water discharges that are covered by Phase I of the NPDES storm water permit program. Thus, EPA is excluding any discharge from a municipal separate storm sewer system serving a population of 100,000 or more; any discharge of storm water associated with industrial activity; any discharge that has already been permitted; and any discharge for which EPA or the State makes a determination that the storm water discharge contributes to a violation of a water quality standard or is a significant contributor of pollutants to waters of the United States. All of these activities are clearly addressed by the storm water permit program and therefore are excluded from the Coastal Nonpoint Pollution Control Programs.

EPA is adopting a different approach with respect to other (Phase II) storm water discharges. At present, EPA has not yet promulgated regulations that would designate additional storm water discharges, beyond those regulated in Phase I, that will be required to be regulated in Phase II. It is therefore not possible to determine at this point which additional storm water discharges will be regulated by the NPDES program and which will not. Furthermore, because of the great number of such discharges, it is likely that it would take many years to permit all of these discharges even if EPA allows for relatively expeditious State permitting approaches such as the use of general permits.

Therefore, to give effect to the Congressional intent that coastal waters receive special and expeditious attention from EPA, NOAA, and the States, storm water runoff that potentially may be ultimately covered by Phase II of the storm water permits program is subject to this management measures guidance and will be addressed by the States' Coastal Nonpoint Pollution Control Programs. Any storm water runoff that ultimately is regulated under an NPDES permit will no longer be subject to this guidance once the permit is issued.

In addition, it should be noted that some other activities are not presently covered by the NPDES permit requirements and thus would be subject to a State's Coastal Nonpoint Pollution Control Program. Most importantly, construction activities on sites that result in the disturbance of less than 5 acres, which are not currently covered by Phase I storm water application requirements,[1] are covered by the Coastal Nonpoint Pollution Control Program. Similarly, runoff from wholesale, retail, service, or commercial activities, including gas stations, which are not covered by Phase I of the NPDES storm water program, would be subject instead to a State's Coastal Nonpoint Pollution Control Program. Further, onsite disposal systems (OSDS), which are generally not covered by the storm water permit program, would be subject to a State's Coastal Nonpoint Pollution Control Program.

Finally, EPA emphasizes that while different legal authorities may apply to different situations, the goals of the NPDES and CZARA programs are complementary. Many of the techniques and practices used to control storm water are equally applicable to both programs. Yet, the programs do not work identically. In the interest of consistency and comprehensiveness, States have the option to implement the CZARA section 6217(g) management measures throughout the State's 6217 management area as long as the NPDES storm water requirements continue to be met by Phase I sources in that area.

F. Background

The prevention and control of urban nonpoint source pollution in coastal areas pose a distinctive challenge to the environmental manager. Increasing water quality problems and degraded coastal resources point to the need for comprehensive solutions to protect and enhance coastal water quality. This chapter presents a framework for preventing and controlling urban nonpoint sources of pollution.

Urban runoff management requires that a number of objectives be pursued simultaneously. These objectives include the following:

- Protection and restoration of surface waters by the minimization of pollutant loadings and negative impacts resulting from urbanization;
- Protection of environmental quality and social well-being;
- Protection of natural resources, e.g., wetlands and other important aquatic and terrestrial ecosystems;

[1] On May 27, 1992, the United States Court of Appeals for the Ninth Circuit invalidated EPA's exemption of construction sites smaller than 5 acres from the storm water permit program in *Natural Resources Defense Council* v. *EPA*, 965 F.2d 759 (9th Cir. 1992). EPA is conducting further rulemaking proceedings on this issue and will not require permit applications for construction activities under 5 acres until further rulemaking has been completed.

- Minimization of soil erosion and sedimentation problems;
- Maintenance of the predevelopment hydrologic conditions;
- Protection of ground-water resources;
- Control and management of runoff to reduce/prevent flooding; and
- Management of aquatic and riparian resources for active and passive recreation (APWA, 1981).

1. Urbanization and Its Impacts

Urbanization first occurred in coastal areas and this historical trend continues. Approximately 80 percent of the Nation's population lives in coastal areas. The negative impacts of urbanization on coastal and estuarine waters has been well documented in a number of sources, including the Nationwide Urban Runoff Program (NURP) and the States' §305(b) and §319 reports.

During urbanization, pervious spaces, including vegetated and open forested areas, are converted to land uses that usually have increased areas of impervious surface, resulting in increased runoff volumes and pollutant loadings. While urbanization may enhance the use of property under a wide range of environmental conditions (USEPA, 1977), urbanization typically results in changes to the physical, chemical, and biological characteristics of the watershed. Vegetative cover is stripped from the land and cut-and-fill activities that enhance the development potential of the land occur. For example, natural depressions that temporarily pond water are graded to a uniform slope, increasing the volume of runoff during a storm event (Schueler, 1987). As population density increases, there is a corresponding increase in pollutant loadings generated from human activities. These pollutants typically enter surface waters via runoff without undergoing treatment.

a. Changes in Hydrology

As urbanization occurs, changes to the natural hydrology of an area are inevitable. Hydrologic and hydraulic changes occur in response to site clearing, grading, and the addition of impervious surfaces and maintained landscapes (Schueler, 1987). Most problematic are the greatly increased runoff volumes and the ensuing erosion and sediment loadings to surface waters that accompany these changes to the landscape. Uncontrolled construction site sediment loads have been reported to be on the order of 35 to 45 tons per acre per year (Novotny and Chesters, 1981; Wolman and Schick, 1967; Yorke and Herb, 1976, 1978). Loadings from undisturbed woodlands are typically less than 1 ton per year (Leopold, 1968).

Hydrological changes to the watershed are magnified after construction is completed. Impervious surfaces, such as rooftops, roads, parking lots, and sidewalks, decrease the infiltrative capacity of the ground and result in greatly increased volumes of runoff. Elevated flows also necessitate the construction of runoff conveyances or the modification of existing drainage systems to avoid erosion of streambanks and steep slopes. Changes in stream hydrology resulting from urbanization include the following (Schueler, 1987):

- Increased peak discharges compared to predevelopment levels (Leopold, 1968; Anderson, 1970);
- Increased volume of urban runoff produced by each storm in comparison to predevelopment conditions;
- Decreased time needed for runoff to reach the stream (Leopold, 1968), particularly if extensive drainage improvements are made;
- Increased frequency and severity of flooding;

- Reduced streamflow during prolonged periods of dry weather due to reduced level of infiltration in the watershed; and

- Greater runoff velocity during storms due to the combined effects of higher peak discharges, rapid time of concentration, and the smoother hydraulic surfaces that occur as a result of development.

In addition, greater runoff velocities occur during spring snowmelts and rain-on-snow events in suburban watersheds than in less impervious rural areas (Buttle and Xu, 1988). Major snowmelt events can produce peak flows as large as 20 times initial flow runoff rates for urban areas (Pitt and McLean, 1992).

Figures 4-1 and 4-2 illustrate the changes in runoff characteristics resulting from an increasing percentage of impervious areas. Other physical characteristics of aquatic systems that are affected by urbanization include the total volume of watershed runoff baseflow, flooding frequency and severity, channel erosion and sediment generation, and temperature regime (Klein, 1985).

b. Water Quality Changes

Urban development also causes an increase in pollutants. The pollutants that occur in urban areas vary wide^Hy, from common organic material to highly toxic metals. Some pollutants, such as insecticides, road salts, and fertilizers, are intentionally placed in the urban environment. Other pollutants, including lead from automobile exhaust and oil drippings from trucks and cars, are the indirect result of urban activities (USEPA, 1977).

Many researchers have linked urbanization to degradation of urban waterways (e.g., Klein, 1985, Livingston and McCarron, 1992, Schueler, 1987). The major pollutants found in runoff from urban areas include sediment, nutrients, oxygen-demanding substances, road salts, heavy metals, petroleum hydrocarbons, pathogenic bacteria, and viruses. Livingston and McCarron (1992) concluded that urban runoff was the major source of pollutants in pollutant loadings to Florida's lakes and streams. Table 4-1 illustrates examples of pollutant loadings from urban areas. Table 4-2 describes potential sources of urban runoff pollutants.

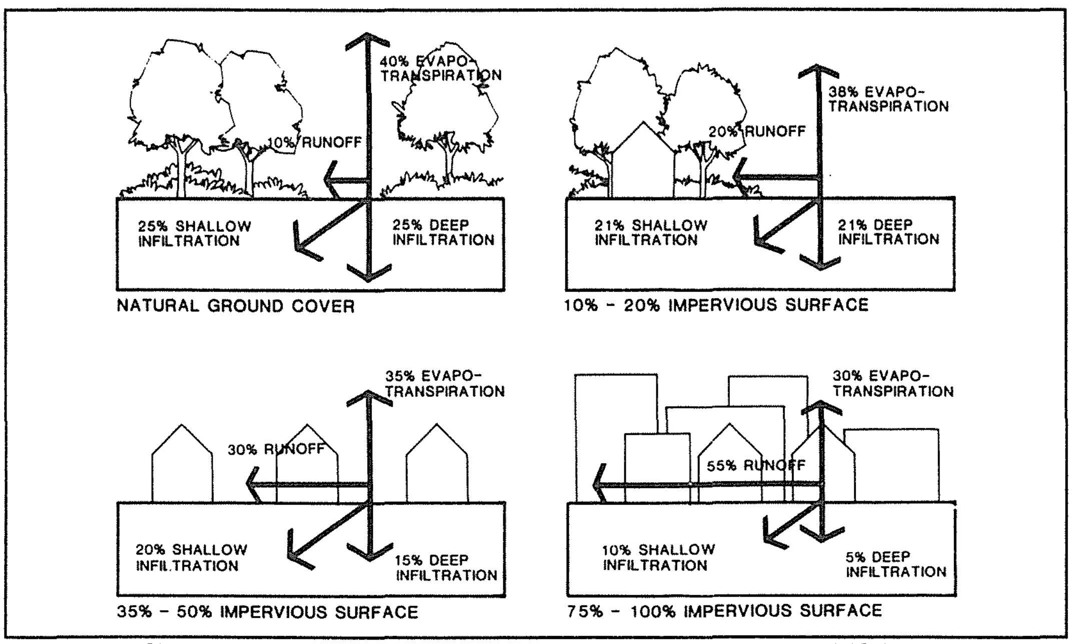


Figure 4-1. Changes in runoff flow resulting from increased impervious area (NC Dept. of Nat. Res. and Community Dev., in Livingston and McCarron, 1992).

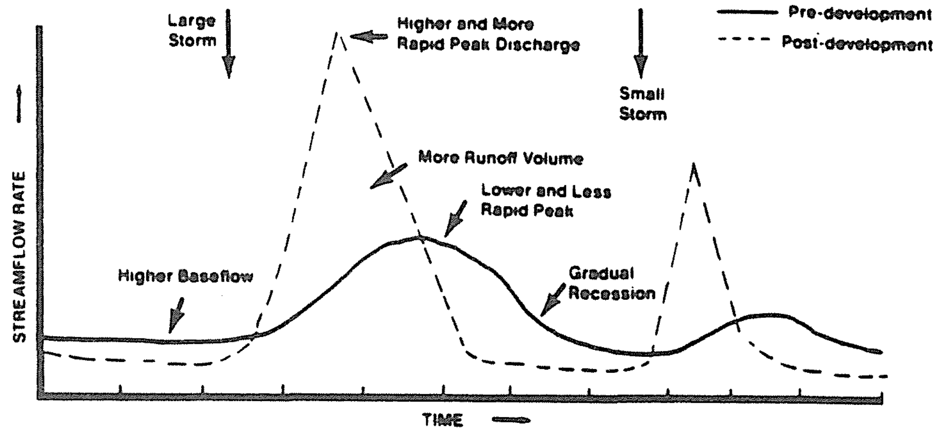


Figure 4-2. Changes in stream hydrology as a result of urbanization (Schueler, 1992).

2. Nonpoint Source Pollutants and Their Impacts

The following discussion identifies the principal types of pollutants found in urban runoff and describes their potential adverse effects (USEPA, 1990).

Sediment. Suspended sediments constitute the largest mass of pollutant loadings to surface waters. Sediment has both short- and long-term impacts on surface waters. Among the immediate adverse impacts of high concentrations of sediment are increased turbidity, reduced light penetration and decreases in submerged aquatic vegetation (SAV) (Chesapeake Implementation Committee, 1988), reduced prey capture for sight-feeding predators, impaired respiration of fish and aquatic invertebrates, reduced fecundity, and impairment of commercial and recreational fishing resources. Heavy sediment deposition in low-velocity surface waters may result in smothered benthic communities/reef systems

Table 4-1. Estimated Mean Runoff Concentrations for Land Uses, Based on the Nationwide Urban Runoff Program (Whalen and Cullum, 1989)

Parameter	Residential	Commercial	Industrial
TKN (mg/l)	0.23	1.5	1.6
$NO_3 + NO_2$ (mg/l)	1.8	0.8	0.93
Total P (mg/l)	0.62	2.29	0.42
Copper (µg/l)	56	50	32
Zinc (µg/l)	254	418	1,063
Lead (mg/l)	293	203	115
COD (mg/l)	102	84	62
TSS (mg/l)	228	168	108
BOD (mg/l)	13	14	62

Table 4-2. Sources of Urban Runoff Pollutants (Adapted from Woodward-Clyde, 1990)

Source	Pollutants of Concern
Erosion	Sediment and attached soil nutrients, organic matter, and other adsorbed pollutants
Atmospheric deposition	Hydrocarbons emitted from automobiles, dust, aromatic hydrocarbons, metals, and other chemicals released from industrial and commercial activities
Construction materials	Metals from flashing and shingles, gutters and downspouts, galvanized pipes and metal plating, paint, and wood
Manufactured products	Heavy metals, halogenated aliphatics, phthalate esters, PAHs, other volatiles, and pesticides and phenols from automobile use, pesticide use, industrial use, and other uses
Plants and animals	Plant debris and animal excrement
Non-storm water connections	Inadvertent or deliberate discharges of sanitary sewage and industrial wastewater to storm drainage systems
Onsite disposal systems	Nutrients and pathogens from failing or improperly sited systems

(CRS, 1991), increased sedimentation of waterways, changes in the composition of bottom substrate, and degradation of aesthetic value. The primary cause of coral reef degradation in coastal areas is attributed to land disturbances and dredging activities due to urban development (Rogers, 1990). Additional chronic effects may occur where sediments rich in organic matter or clay are present. These enriched depositional sediments may present a continued risk to aquatic and benthic life, especially where the sediments are disturbed and resuspended.

Nutrients. The problems resulting from elevated levels of phosphorus and nitrogen are well known and are discussed in detail in Chapter 2 (agriculture). Excessive nutrient loading to marine ecosystems can result in eutrophication and depressed dissolved oxygen (DO) levels due to elevated phytoplankton populations. Eutrophication-induced hypoxia and anoxia have resulted in fish kills and widespread destruction of benthic habitats (Harper and Gullient, 1989). Surface algal scum, water discoloration, and the release of toxins from sediment may also occur. Species composition and size structure for primary producers may be altered by increased nutrient levels (Hecky and Kilham, 1988; GESAMP, 1989; Thingstad and Sakshaug, 1990).

Occurrences of eutrophication have been frequent in several coastal embayments along the northeast coast (Narragansett and Barnegat Bays), the Gulf Coast (Louisiana and Texas), and the West Coast (California and Washington) (NOAA, 1991). High nitrate concentrations have also been implicated in blooms of nuisance algae in Newport Bay, California (NRC, 1990b). Nutrient loadings in Louisiana coastal waters have decreased productivity, increased hypoxic events, and decreased fisheries yields (NOAA, 1991).

Oxygen-Demanding Substances. Proper levels of DO are critical to maintaining water quality and aquatic life. Decomposition of organic matter by microorganisms may deplete DO levels and result in the impairment of the waterbody. Data have shown that urban runoff with high concentrations of decaying organic matter can severely depress DO levels after storm events (USEPA, 1983). The NURP study found that oxygen-demanding substances can be present in urban runoff at concentrations similar to secondary treatment discharges.

Pathogens. Urban runoff typically contains elevated levels of pathogenic organisms. The presence of pathogens in runoff may result in waterbody impairments such as closed beaches, contaminated drinking water sources, and shellfish bed closings. OSDS-related pathogen contamination has been implicated in a number of shellfish bed closings. Table 4-3 shows the adverse impacts of septic systems and urban runoff on shellfish beds, resulting in closure. This problem may be especially prevalent in areas with porous or sandy soils.

Table 4-3. Percent of Limited or Restricted Classified Shellfish Waters Affected by Types of Pollution (Leonard et al., 1991)

	Septic Systems	Urban Runoff	Ag. Runoff	POTWs	Boats	Industry
North Atlantic	26	23	3	67	17	7
Mid-Atlantic	11	58	12	57	31	20
South Atlantic	34	34	28	44	17	21
Gulf	48	35	8	27	14	14
Pacific	19	36	13	25	15	42
Nationwide	37	38	11	37	18	17

Road Salts. In northern climates, road salts can be a major pollutant in urban areas. Klein (1985) reported on several studies by various authors of road salt contamination in lakes and streams and cases where well contamination had been attributed to road salts in New England. Snow runoff produces high salt/chlorine concentrations at the bottom of ponds, lakes, and bays. Not only does this condition prove toxic to benthic organisms, but it also prevents crucial vertical spring mixing (Bubeck et al., 1971; Hawkins and Judd, 1972).

Hydrocarbons. Petroleum hydrocarbons are derived from oil products, and the source of most such pollutants found in urban runoff is vehicles—auto and truck engines that drip oil. Many do-it-yourself auto mechanics dump used oil directly into storm drains (Klein, 1985). Concentrations of petroleum-based hydrocarbons are often high enough to cause mortalities in aquatic organisms.

Oil and grease contain a wide variety of hydrocarbon compounds. Some polynuclear aromatic hydrocarbons (PAHs) are known to be toxic to aquatic life at low concentrations. Hydrocarbons have a high affinity for sediment, and they collect in bottom sediments where they may persist for long periods of time and result in adverse impacts on benthic communities. Lakes and estuaries are especially prone to this phenomenon.

Heavy Metals. Heavy metals are typically found in urban runoff. For example, Klein (1985) reported on a study in the Chesapeake Bay that designated urban runoff as the source for 6 percent of the cadmium, 1 percent of the chromium, 1 percent of the copper, 19 percent of the lead, and 2 percent of the zinc.

Heavy metals are of concern because of toxic effects on aquatic life and the potential for ground-water contamination. Copper, lead, and zinc are the most prevalent NPS pollutants found in urban runoff. High metal concentrations may bioaccumulate in fish and shellfish and impact beneficial uses of the affected waterbody.

Toxics. Many different toxic compounds (priority pollutants) have been associated with urban runoff. NURP studies (USEPA, 1983) indicated that at least 10 percent of urban runoff samples contained toxic pollutants.

a. Pollutant Loading

Nonpoint source pollution has been associated with water quality standard violations and the impairment of designated uses of surface waters (Davenport, 1990). The 1990 Report to Congress on §319 of the Clean Water Act reported that:

- Siltation and nutrients are the pollutants most responsible for nonpoint source impacts to the Nation's surface waters, and

- Wildlife and recreation, (in particular, swimming, fishing, and shellfishing) are the uses most affected by nonpoint source pollution.

The pollutants described previously can have a variety of impacts on coastal resources. Examples of waterbodies that have been adversely impacted by nonpoint source pollution are varied.

- The Miami River and Biscayne Bay in Florida have experienced loss of habitat, loss of recreational and commercial fisheries, and decrease in productivity partly as the result of urban runoff (SFWMD, 1988).

- Shellfish beds in Port Susan, Puget Sound, Washington, have been declared unsafe for the commercial harvest of shellfish in part because of bacterial contamination from onsite disposal systems (USEPA, 1991).

- Impairment due to toxic pollution from urban runoff continues to be a problem in the southern part of San Francisco Bay (USEPA, 1992).

- Nonpoint sources of pollution have been implicated in degradation of water quality in Westport River, Massachusetts, a tributary of Buzzards Bay. High concentrations of coliform bacteria have been observed after rainfall events, and shellfish bed closures in the river have been attributed to loadings from surface runoff and septic systems (USEPA, 1992).

- In Brenner Bay, St. Thomas, U.S. Virgin Islands, populations of corals and shellfish and marine habitat have been damaged due to increased nutrient and sediment loadings. After several years of rapid urban development, less than 10 percent of original grass beds remain as a result of sediment shoaling, eutrophication, and algae blooms (Nichols and Towle, 1977).

b. Other Impacts

Other impacts not related to a specific pollutant can also occur as a result of urbanization. Temperature changes result from increased flows, removal of vegetative cover, and increases in impervious surfaces. Impervious surfaces act as heat collectors, heating urban runoff as it passes over the impervious surface. Recent data indicate that intensive urbanization can increase stream temperature as much as 5 to 10 degrees Celsius during storm events (Galli and Dubose, 1990). Thermal loading disrupts aquatic organisms that have finely tuned temperature limits. Salinity can also be affected by urbanization.

Freshwater inflows due to increased runoff can impact estuaries, especially if they occur in pulses, disrupting the natural salinity of an area. Increased impervious surface area and the presence of storm water conveyance systems commonly result in elevated peak flows in streams during and after storm events. These rapid pulses or influxes of fresh water into the watershed may be 2 to 10 times greater than normal (ABAG, 1991) This may lead to a decrease in the number of aquatic organisms living in the receiving waters (McLusky, 1989).

The alteration of natural hydrology due to urbanization and the accompanying runoff diversion, channelization, and destruction of natural drainage systems have resulted in riparian and tidal wetland degradation or destruction. Deltaic wetlands have also been impacted by changes in historic sediment deposition rates and patterns. Hydromodification projects designed to prevent flooding may reduce sedimentation rates and decrease marsh aggradation, which would normally offset erosion and apparent changes in sea level within the delta (Cahoon et al., 1983).

3. Opportunities

This chapter was organized to parallel the development process to address the prevention and treatment of nonpoint source pollution loadings during all phases of urbanization. (NOTE: The control of nonpoint source pollution requires the use of two primary strategies: the prevention of pollutant loadings and the treatment of unavoidable loadings. The strategy in this chapter relies primarily on the watershed approach, which focuses on pollution prevention or source reduction practices. While treatment options are an integral component of this chapter, a combination of pollution prevention and treatment practices is favored because planning, design, and education practices are generally more effective, require less maintenance, and are more cost-effective in the long term.)

The major opportunities to control NPS loadings occur during the following three stages of development: the siting and design phase, the construction phase, and the postdevelopment phase. Before development occurs, land in a watershed is available for a number of pollution prevention and treatment options, such as setbacks, buffers, or open space requirements, as well as wet ponds or constructed urban runoff wetlands that can provide treatment of the inevitable runoff and associated pollutants. In addition, siting requirements/restrictions and other land use ordinances, which can be highly effective, are more easily implemented during this period. After development occurs, these options may no longer be practicable or cost-effective. Management Measures II.A through II.C address the strategies and practices that can be used during the initial phase of the urbanization process.

The control of construction-related sediment loadings is critical to maintaining water quality. The implementation of proper erosion and sediment control practices during the construction stage can significantly reduce sediment loadings to surface waters. Management Measures II.A and II.B address construction-related practices.

After development has occurred, lack of available land severely limits the implementation of cost-effective treatment options. Management Measure VI.A focuses on improving controls for existing surface water runoff through pollution prevention to mitigate nonpoint sources of pollution generated from ongoing domestic and commercial activities.

II. URBAN RUNOFF

A. New Development Management Measure

(1) By design or performance:

(a) After construction has been completed and the site is permanently stabilized, reduce the average annual total suspended solid (TSS) loadings by 80 percent. For the purposes of this measure, an 80 percent TSS reduction is to be determined on an average annual basis,* or

(b) Reduce the postdevelopment loadings of TSS so that the average annual TSS loadings are no greater than predevelopment loadings, and

(2) To the extent practicable, maintain postdevelopment peak runoff rate and average volume at levels that are similar to predevelopment levels.

Sound watershed management requires that both structural and nonstructural measures be employed to mitigate the adverse impacts of storm water. Nonstructural Management Measures II.B and II.C can be effectively used in conjunction with Management Measure II.A to reduce both the short- and long-term costs of meeting the treatment goals of this management measure.

*** Based on the average annual TSS loadings from all storms less than or equal to the 2-year/24-hour storm. TSS loadings from storms greater than the 2-year/24-hour storm are not expected to be included in the calculation of the average annual TSS loadings.**

1. Applicability

This management measure is intended to be applied by States to control urban runoff and treat associated pollutants generated from new development, redevelopment, and new and relocated roads, highways, and bridges. Under the Coastal Zone Act Reauthorization Amendments of 1990, States are subject to a number of requirements as they develop coastal nonpoint source (NPS) programs in conformity with this management measure and will have flexibility in doing so. The application of management measures by States is described more fully in *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance*, published jointly by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce.

For design purposes, postdevelopment peak runoff rate and average volume should be based on the 2-year/24-hour storm.

2. Description

This management measure is intended to accomplish the following: (1) decrease the erosive potential of increased runoff volumes and velocities associated with development-induced changes in hydrology; (2) remove suspended solids and associated pollutants entrained in runoff that result from activities occurring during and after development; (3) retain hydrological conditions to closely resemble those of the predisturbance condition; and (4) preserve natural systems including in-stream habitat.[2] For the purposes of this management measure, "similar" is defined as "resembling though not completely identical."

During the development process, both the existing landscape and hydrology can be significantly altered. As development occurs, the following changes to the land may occur (USEPA, 1977):

- Soil porosity decreases;
- Impermeable surfaces increase;
- Channels and conveyances are constructed;
- Slopes increase;
- Vegetative cover decreases; and
- Surface roughness decreases.

These changes result in increased runoff volume and velocities, which may lead to increased erosion of streambanks, steep slopes, and unvegetated areas (Novotny, 1991). In addition, destruction of in-stream and riparian habitat, increases in water temperature (Schueler et al., 1992), streambed scouring, and downstream siltation of streambed substrate, riparian areas, estuarine habitat, and reef systems may occur. An example of predicted effects of increased levels of urbanization on runoff volumes is presented in Table 4-4 (USDA-SCS, 1986). Methods are also available to compute peak runoff rates (USDA-SCS, 1986).

The annual TSS loadings can be calculated by adding the TSS loadings that can be expected to be generated during an average 1-year period from precipitation events less than or equal to the 2-year/24-hour storm. The 80 percent standard can be achieved by reducing, over the course of the year, 80 percent of these loadings. EPA recognizes that 80 percent cannot be achieved for each storm event and understands that TSS removal efficiency will fluctuate above and below 80 percent for individual storms.

Management Measures II.A, II.B, and II.C were selected as a system to be used to prevent and mitigate the problems discussed above. In combination, these three management measures applied on-site and throughout watersheds can be used to provide increased watershed protection and help prevent severe erosion, flooding, and increased pollutant loads generally associated with poorly planned development. Implementation of Management Measures II.B and II.C can help achieve the goals of Management Measure II.A.

Structural practices to control urban runoff rely on three basic mechanisms to treat runoff: **infiltration**, **filtration**, and **detention**. Table 4-5 lists specific urban runoff control practices that relate to these and includes information on advantages, disadvantages, and costs. Table 4-6 presents site-specific considerations, regional limitations, operation and maintenance burdens, and longevity for these practices.

[2] Several issues require clarification to fully understand the scope and intent of this management measure. First, this management measure applies only to postdevelopment loadings and not to construction-related loadings. Management measure options II.A.(1)(a) and (b) both apply only to the TSS loadings that are generated after construction has ceased and the site has been properly stabilized using permanent vegetative and/or structural erosion and sediment control practices. Second, for the purposes of this guidance, the term *predevelopment* refers to the sediment loadings and runoff volumes/velocities that exist onsite immediately before the planned land disturbance and development activities occur. Predevelopment is not intended to be interpreted as that period before any human-induced land disturbance activity has occurred. Third, management measure option II.A.(1)(b) is not intended to be used as an alternative to achieving an adequate level of control in cases where high sediment loadings are the result of poor management of developed sites (not "natural" sites), e.g., farmlands where the erosion control components of the USDA conservation management system are not used or sites where land disturbed by previous development was not permanently stabilized.

Table 4-4. Example Effects of Increased Urbanization on Runoff Volumes (USDA-SCS, 1986)

Development Scenario	Predicted Runoff
100 percent open space	2.81 inches (baseline)
70 percent of the total area divided into ½-acre lots; each lot is 25 percent impervious; 30 percent of the total area is open space	3.28 inches (24 percent increase)
70 percent of the total area is divided into ½-acre lots; each lot is 35 percent impervious; 30 percent of the total area is open space	3.48 inches (24 percent increase)
30 percent of the total area is divided into ½-acre lots - each lot is 25 percent impervious and contiguous; 40 percent is divided into ½-acre lots - each lot is 50 percent impervious and discontinuous; 30 percent of the total area is open space	3.19 inches (14 percent increase)

Infiltration devices, such as infiltration trenches, infiltration basins, filtration basins, and porous and concrete block pavement, rely on absorption of runoff to treat urban runoff discharges. Water is percolated through soils, where filtration and biological action remove pollutants. Systems that rely on soil absorption require deep permeable soils at separation distances of at least 4 feet between the bottom of the structure and seasonal ground water levels. The widespread use of infiltration in a watershed can be useful to maintain or restore predevelopment hydrology, increase dry-weather baseflow, and reduce bankfull flooding frequency. However, infiltration systems may not be appropriate where ground water requires protection. Restrictions may also apply to infiltration systems located above sole source (drinking water) aquifers. Where such designs are selected, they should be incorporated with the recognition that periodic maintenance is necessary for these areas. Long-term effectiveness in most cases will depend on proper operation and maintenance of the entire system.

NOTE: Infiltration systems, some filtration devices, and sand filters should be installed after construction has been completed and the site has been permanently stabilized. The State of Maryland has observed a high failure rate for infiltration systems. Many of these failures can be attributed to clogging due to sediment loadings generated during the construction process and/or the premature use of the device before proper stabilization of the site has occurred. In cases where construction of the infiltration system is necessary before the cessation of land-disturbing activities, diversions, covers, or other means to prevent sediment-laden runoff from entering and clogging the infiltration system should be used (State of Maryland DNR, personal communication, 1991).

Filtration practices such as filter strips, grassed swales, and sand filters treat sheet flow by using vegetation or sand to filter and settle pollutants. In some cases infiltration and treatment in the subsoil may also occur. After passing through the filtration media, the treated water can be routed into streams, drainage channels, or other waterbodies; evaporated; or percolated into ground water. Sand filters are particularly useful for ground-water protection. The influence of climatic factors must be considered in the process of selecting vegetative systems.

Detention practices temporarily impound runoff to control runoff rates, and settle and retain suspended solids and associated pollutants. Extended detention ponds and wet ponds fall within this category. Constructed urban runoff wetlands and multiple-pond systems also remove pollutants by detaining flows that lead to sedimentation (gravitational settling of suspended solids). Properly designed ponds protect downstream channels by controlling discharge velocities, thereby reducing the frequency of bankfull flooding and resultant bank-cutting erosion. If landscaped and planted with appropriate vegetation, these systems can reduce nutrient loads and also provide terrestrial and aquatic wildlife habitat. When considering the use of these devices, potential negative impacts such as downstream warming, reduced baseflow, trophic shifts, bacterial contamination due to waterfowl, hazards to

Table 4-5. Advantages and Disadvantages of Management Practices[a]

Management Practice	Advantages	Disadvantages	Comparative Cost (Schueler, Kumble, and Heraty, 1992)
Infiltration Basin	• Provides ground-water recharge • Can serve large developments • High removal capability for particulate pollutants and moderate removal for soluble pollutants • When basin works, it can replicate predevelopment hydrology more closely than other BMP options • Basins provide more habitat value than other infiltration systems	• Possible risk of contaminating ground water • Only feasible where soil is permeable and there is sufficient depth to rock and water table • Fairly high failure rate • If not adequately maintained, can be an eyesore, breed mosquitoes, and create undesirable odors • Regular maintenance activities cannot prevent rapid clogging of infiltration basins	Construction cost moderate but rehabilitation cost high
Infiltration Trench	• Provides ground-water recharge • Can serve small drainage areas • Can fit into medians, perimeters, and other unused areas of a development site • Helps replicate predevelopment hydrology, increases dry weather baseflow, and reduces bankfull flooding frequency	• Possible risk of contaminating ground water • Only feasible where soil is permeable and there is sufficient depth to rock and water table • Since not as visible as other BMPs, less likely to be maintained by residents • Requires significant maintenance	Cost-effective on smaller sites. Rehabilitation costs can be considerable.
Vegetated Filter Strip (VFS)	• Low maintenance requirements • Can be used as part of the runoff conveyance system to provide pretreatment • Can effectively reduce particulate pollutant levels in areas where runoff velocity is low to moderate • Provides excellent urban wildlife habitat • Economical	• Often concentrates water, which significantly reduces effectiveness • Ability to remove soluble pollutants highly variable • Limited feasibility in highly urbanized areas where runoff velocities are high and flow is concentrated • Requires periodic repair, regrading, and sediment removal to prevent channelization	Low

Table 4-5. (Continued)

Management Practice	Advantages	Disadvantages	Comparative Cost (Schueler, Kumble, and Heraty, 1992)
Grassed Swale	• Requires minimal land area • Can be used as part of the runoff conveyance system to provide pretreatment • Can provide sufficient runoff control to replace curb and gutter in single-family residential subdivisions and on highway medians • Economical	• Low pollutant removal rates • Leaching from culverts and fertilized lawns may actually increase the presence of trace metals and nutrients	Low compared to curb and gutter
Porous Pavement	• Provides ground-water recharge • Provides water quality control without additional consumption of land • Can provide peak flow control • High removal rates for sediment, nutrients, organic matter, and trace metals • When operating properly can replicate predevelopment hydrology • Eliminates the need for stormwater drainage, conveyance, and treatment systems off-site	• Requires regular maintenance • Possible risk of contaminating ground water • Only feasible where soil is permeable, there is sufficient depth to rock and water table, and there are gentle slopes • Not suitable for areas with high traffic volume • Need extensive feasibility tests, inspections, and very high level of construction workmanship (Schueler, 1987) • High failure rate due to clogging • Not suitable to serve large off-site pervious areas	Cost-effective compared to conventional asphalt when working properly
Concrete Grid Pavement	• Can provide peak flow control • Provides ground-water recharge • Provides water quality control without additional consumption of land	• Requires regular maintenance • Not suitable for area with high traffic volume • Possible risk of contaminating ground water • Only feasible where soil is permeable, there is sufficient depth to rock and water table, and there are gentle slopes	Information not available

Table 4-5. (Continued)

Management Practice	Advantages	Disadvantages	Comparative Cost (Schueler, Kumble, and Heraty, 1992)
Filtration Basin	• Ability to accommodate medium-size development (3-80 acres) • Flexibility to provide or not provide ground-water recharge • Can provide peak volume control	• Requires pretreatment of storm water through sedimentation to prevent filter media from prematurely clogging	Information not available
Water Quality Inlets Catch Basins	• Provide high degree of removal efficiencies for larger particles and debris as pretreatment • Require minimal land area • Flexibility to retrofit existing small drainage areas and applicable to most urban areas	• Not feasible for drainage area greater than 1 acre • Marginal removal of small particles, heavy metals, and organic pollutants • Not effective as water quality control for intense storms • Minimal nutrient removal	Information not available
Water Quality Inlet Catch Basins with Sand Filter	• Provide high removal efficiencies of particulates • Require minimal land area • Flexibility to retrofit existing small drainage areas • Higher removal of nutrient as compared to catch basins and oil/grid separator	• Not feasible for drainage area greater than 5 acres • Only feasible for areas that are stabilized and highly impervious • Not effective as water quality control for intense storms	Information not available
Water Quality Inlet Oil/Grit Separator	• Captures coarse-grained sediments and some hydrocarbons • Requires minimal land area • Flexibility to retrofit existing small drainage areas and applicable to most urban areas • Shows some capacity to trap trash, debris, and other floatables • Can be adapted to all regions of the country	• Not feasible for drainage area greater than 1 acre • Minimal nutrient and organic matter removal • Not effective as water quality control for intense storms • Concern exists over the pollutant toxicity of trapped residuals • Require high maintenance	High, compared to trenches and sand filters

Table 4-5. (Continued)

Management Practice	Advantages	Disadvantages	Comparative Cost (Schueler, Kumble, and Heraty, 1992)
Extended Detention Dry Pond	• Can provide peak flow control • Possible to provide good particulate removal • Can serve large development • Requires less capital cost and land area when compared to wet pond • Does not generally release warm or anoxic water downstream • Provides excellent protection for downstream channel erosion • Can create valuable wetland and meadow habitat when properly landscaped	• Removal rates for soluble pollutants are quite low • Not economical for drainage area less than 10 acres • If not adequately maintained, can be an eyesore, breed mosquitoes, and create undesirable odors	Lowest cost alternative in size range
Wet Pond	• Can provide peak flow control • Can serve large developments; most cost-effective for larger, more intensively developed sites • Enhances aesthetics and provides recreational benefits • Little ground-water discharge • Permanent pool in wet ponds helps to prevent scour and resuspension of sediments • Provides moderate to high removal of both particulate and soluble urban stormwater pollutants	• Not economical for drainage area less than 10 acres • Potential safety hazards if not properly maintained • If not adequately maintained, can be an eyesore, breed mosquitoes, and create undesirable odors • Requires considerable space, which limits use in densely urbanized areas with expensive land and property values • Not suitable for hydrologic soil groups "A" and "B" (SCS classification) • With possible thermal discharge and oxygen depletion, may severely impact downstream aquatic life	Moderate to high compared to conventional storm water detention

Table 4-5. (Continued)

Management Practice	Advantages	Disadvantages	Comparative Cost (Schueler, Kumble, and Heraty, 1992)
Extended Detention Wet Pond	• Can provide peak flow control • Can serve large developments; most cost-effective for larger, more intensively developed sites • Enhances aesthetic and provide recreational benefits • Permanent pool in wet ponds helps to prevent scour and resuspension of sediments • Provides better nutrient removal when compared to wet pond	• Not economical for drainage area less than 10 acres • Potential safety hazards if not properly maintained • If not adequately maintained, can be an eyesore, breed mosquitoes, and create undesirable odors • Requires considerable space, which limits use in densely urbanized areas with expensive land and property values • Not suitable for hydrologic soil groups "A" and "B"(SCS classification) • With possible thermal discharge and oxygen depletion, may severely impact downstream aquatic life	

Table 4-5. (Continued)

Management Practice	Advantages	Disadvantages	Comparative Cost (Schueler, Kumble, and Heraty, 1992)
Constructed Stormwater Wetland	• Can serve large developments; most cost-effective for larger, more intensively developed sites • Provides peak flow control • Enhances aesthetics and provides recreational benefits • The marsh fringe also protects shoreline from erosion • Permanent pool in wet ponds helps to prevent scour and resuspension of sediments • Has high pollutant removal capability	• Not economical for drainage area less than 10 acres • Potential safety hazards if not properly maintained • If not adequately maintained can be an eyesore, breed mosquitoes, and create undesirable odors • Requires considerable space, which limits use in densely urbanized areas with expensive land and property values • With possible thermal discharge and oxygen depletion, may severely impact downstream aquatic life • May contribute to nutrient loadings during die-down periods of vegetation	Marginally higher than wet ponds

[a]Much of this information has been taken from Schueler et al., 1992.

Table 4-6. Regional, Site-Specific, and Maintenance Considerations for Structural Practices to Control Sediments in Storm Water Runoff (Schueler et al., 1992)

BMP Option	Size of Drainage Area	Site Requirements	Regional Restrictions	Maintenance Burdens	Longevity
Infiltration basins	Moderate to large	Deep permeable soils	Arid and cold regions	High	Low
Infiltration trenches	Moderate	Same as for infiltration basins			
Vegetated filter strips	Small	Low-density areas with low slopes	Arid and cold regions	Low	Low if poorly maintained
Grassed swales	Small	Low-density areas with <15% slope	Arid and cold regions	Low	High if maintained
Porous pavement	Small	Deep permeable soils, low slopes, and restricted traffic	Arid and cold regions or high wind erosion rates	High	Low
Concrete grid pavement	Small	Same as for porous pavement		Moderate to high	High
Filtration basins and sand filters	Widely applicable	Widely applicable	Arid and cold regions	Moderate	Low to moderate
Water quality inlets	Small	Impervious catchments	Few restrictions	Cleaned twice a year	High
Extended detention ponds	Moderate to large	Deep soils	Few restrictions	Dry ponds have relatively high burdens	High
Wet ponds	Moderate to large	Deep soils	Arid regions	Low	High
Constructed storm water wetlands	Moderate to large	Poorly drained soils, space may be limiting	Arid regions	Annual harvesting of vegetation	High

nearby residents, and nuisance factors such as mosquitoes and odor should be considered. Siting development in wetlands and floodplains should be avoided. Where drainage areas are greater than 250 acres and ponds are being considered, inundation of upstream channels may be of concern.

Constructed wetlands and multiple-pond systems also treat runoff through the processes of adsorption, plant uptake, filtration, volatilization, precipitation, and microbial decomposition (Livingston and McCarron, 1992; Schueler et al., 1992). Multiple-pond systems in particular have shown potential to provide much higher levels of treatment (Schueler et al., 1992). In general, the potential concerns and drawbacks applicable to wet ponds apply to these systems. Many of these systems are currently being designed to include vegetated buffers and deep-water areas to provide habitat for wildlife and aesthetic benefits. Where such designs are selected, they should be incorporated with the recognition that periodic maintenance is necessary. Long-term effectiveness in most cases will depend on proper operation and maintenance of the entire system. Refer to Chapter 7 for additional information on constructed wetlands.

Water quality inlets, like ponds, rely on gravity settling to remove pollutants before ponds discharge water to the storm sewer or other collection system. Water quality inlets are designed to trap floatable trash and debris. When inlets are coupled with oil/grit separators, hydrocarbon loadings from areas with high traffic/parking volumes can be reduced. However, experience has shown that these devices have limited pollutant-removal effectiveness and should not be used unless coupled with frequent and effective clean-out methods (Schueler et al., 1992). Although no costs are currently available, proper maintenance of water quality inlets must include proper disposal of trapped coarse-grained sediments and hydrocarbons. The costs of clean-out and disposal may be significant when contaminated sediments require proper disposal.

Inadequate maintenance is often cited as one of the major factors influencing the poor effectiveness of structural practices. The cost of long-term maintenance should be evaluated during the selection process. In addition, responsibility for maintenance should be clearly assigned for the life of the system. Typical maintenance requirements include:

- Inspection of basins and ponds after every major storm for the first few months after construction and annually thereafter;
- Mowing of grass filter strips and swales at a frequency to prevent woody growth and promote dense vegetation;
- Removal of litter and debris from dry ponds, forebays, and water quality inlets;
- Revegetation of eroded areas;
- Periodic removal and replacement of filter media from infiltration trenches and filtration ponds;
- Deep tilling of infiltration basins to maintain infiltrative capability;
- Frequent (at least quarterly) vacuuming or jet hosing of porous pavements or concrete grid pavements;
- Quarterly clean-outs of water quality inlets;
- Periodic removal of floatables and debris from catch basins, water quality inlets, and other collection-type controls; and
- Periodic removal and proper disposal of accumulated sediment (applicable to all practices). Sediments in infiltration devices need to be removed frequently enough to prevent premature failure due to clogging.

Operation and Maintenance

Proper operation and maintenance of structural treatment facilities is critical to their effectiveness in mitigating adverse impacts of urban runoff. The proper installation and maintenance of various BMPs often determines their success or failure (Reinalt, 1992).

During a field study of 51 urban runoff treatment facilities, the Ocean County, New Jersey, planning and engineering departments determined that the major source of urban runoff problems was a failure of the responsible party to provide adequate facility maintenance. The causes of this failure are complex and include factors such as lack of funding, manpower, and equipment; uncertain or irresponsible ownership; unassigned maintenance responsibility; and ignorance or disregard of potential consequences of maintenance neglect (Ocean County, 1989). The analysis of the field data collected during the study indicated the following trends:

- Bottoms, side slopes, trash racks, and low-flow structures were the primary sources of maintenance problems.

- Infiltration facilities seemed to be more prone to maintenance neglect and were generally in the poorest condition overall.

- Retention facilities appeared to receive the greatest amount of maintenance and generally were in the best condition overall.

- Publicly owned facilities were usually better maintained than those that were privately maintained.

- Facilities located at office development sites were better maintained than those at commercial or institutional sites; facilities in residential areas received average maintenance.

- Highly visible urban runoff facilities were generally better maintained that those in more remote, less visible locations (Ocean County, 1989).

The following program elements should be considered to ensure the proper design, implementation, and operation and maintenance of runoff treatment and control devices (adapted from The State of New Jersey Ocean County Demonstration Study's *Storm Water Management Facilities Maintenance Manual*):

- Adoption, promulgation, and implementation of planning and design standards that eliminate, reduce, and/or facilitate facility maintenance; coordination with other regulatory authorities with jurisdiction over runoff facilities;

- Establishment of a comprehensive design review program, which includes training and education to ensure adequate staff competency and expertise;

- Design standards published in a readily understandable format for all permittees and responsible parties including regulatory authorities; the provision of clear requirements to promote the adoption of planning and standards and expedite facility review and approval;

- Publication of specific obligations and responsibilities of the runoff facility owner/operator including procedures for the identification of owners/operators who will have long-term responsibility for the facility;

- Development of a procedure for addressing maintenance default by negligent owner/operators;

- Periodic review and evaluation of the runoff management program to ensure continued program effectiveness and efficiency;

- Runoff facility construction inspection program; and

- Provisions for public assumption of runoff control facilities.

3. Management Measure Selection

This management measure was selected because of the following factors.

(1) Removal of 80 percent of total suspended solids (TSS) is assumed to control heavy metals, phosphorus, and other pollutants.

(2) A number of coastal States, including Delaware and Florida, and the Lower Colorado River Authority (Texas) require and have implemented a TSS removal treatment standard of at least 80 percent for new development.

(3) Analysis has shown that constructed wetlands, wet ponds, and infiltration basins can remove 80 percent of TSS, provided they are designed and maintained properly. Other practices or combinations of practices can be also used to achieve the goal.

(4) The control of postdevelopment volume and peak runoff rates to reduce or prevent streambank erosion and stream scouring and to maintain predevelopment hydrological conditions can be accomplished using a number of water quality and flood control practices. Many States and local governments have implemented requirements that stipulate that, at a minimum, the 2-year/24-hour storm be controlled.

Management Measure II.A.(1)(b) was selected to provide a descriptive alternative to Management Measure II.A.(1)(a). Where preexisting conditions do not already present a water quality problem, preservation of predevelopment TSS loading levels is intended to promote TSS loading reductions that adequately protect surface waters and are equivalent to or greater than the levels achieved by Management Measure option II.A.(1)(a). In some cases, local conditions (e.g., mountainous areas with arid, steep slopes) may preclude the implementation of Management Measure II.A.(1)(a). Where local conditions do not allow the implementation of BMPs such as grassed swales or detention basins, and preconstruction/predevelopment (existing conditions) TSS loadings from the site are significant, it may not be cost-effective or beneficial to require 80 percent TSS postdevelopment loading reductions. Management Measure option II.A.(1)(b) was provided to allow flexibility where such conditions exist. This flexibility will be especially important in cases where loadings from surrounding undeveloped areas dwarf the TSS loadings generated from the new development. (NOTE: Predevelopment is defined, in the context of Management Measure II.A.(1)(b), as the sediment loadings and runoff volumes/velocities that exist onsite immediately before the planned land disturbance and development occur.)

4. Practices

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.

Cost and effectiveness information for these practices is shown in Tables 4-7 and 4-8. Many of these practices can be used during site development, but the focus of this section is the abatement of postdevelopment impacts.

a. Develop training and education programs and materials for public officials, contractors, and others involved with the design, installation, operation, inspection, and maintenance of urban runoff facilities.

Training programs and educational materials for public officials, contractors, and the public are crucial to implementing effective urban runoff management programs. Contractor certification, inspector training, and competent design review staff are important for program implementation and continuing effectiveness. The State of New Jersey Ocean County Demonstration Study's *Storm Water Management Facilities Maintenance Manual* addresses many of these issues and provides guidance on programmatic elements necessary for the proper operation and maintenance of urban runoff facilities. Several other States and local governments, including Virginia, Maryland, Washington, Delaware, Northeastern Illinois Planning Commission, and the City of Alexandria, Virginia, have developed manuals and training materials to assist in implementation of urban runoff requirements and regulations.

The State of Delaware passed legislation requiring that "all responsible personnel involved in a construction project will have a certificate of attendance at a Departmental sponsored or approved training course for the control of sediment and storm water before initiation of land disturbing activity." The State provides personnel training and educational opportunities for contractors to meet this requirement and has delegated program elements to conservation

Table 4-7. Effectiveness of Management Practices for Control of Runoff From Newly Developed Areas

Management Practice		Removal Efficiency (%) TSS	TP	TN	COD	Pb	Zn	Factors	References
INFILTRATION BASIN	Average:	75	65	60	65	65	65	• Soil percolation rates • Basin surface area • Storage volume	NVPDC, 1979; EPA, 1977; Schueler, 1987; Griffin, et al, 1980; EPA, 1983; Woodward-Clyde, 1986
	Reported Range:	45-100	45-100	45-100	45-100	45-100	45-100		
	Probable Range:[a]								
	SCS Soil Group A	60-100	60-100	60-100	60-100	60-100	60-100		
	SCS Soil Group B	50-80	50-80	50-80	50-80	50-80	50-80		
	No. Values Considered:	7	7	7	4	4	4		
INFILTRATION TRENCH	Average:	75	60	55	65	65	65	• Soil percolation rates • Trench surface area • Storage volume	NVPDC, 1979; EPA, 1977; Schueler, 1987; Griffin, et al, 1980; EPA, 1983; Woodward-Clyde, 1986; Kuo et al., 1988; Lugbill, 1990
	Reported Range:	45-100	40-100	(-10)-100	45-100	45-100	45-100		
	Probable Range:[b]								
	SCS Soil Group A	60-100	60-100	60-100	60-100	60-100	60-100		
	SCS Soil Group B	50-90	50-90	50-90	50-90	50-90	50-90		
	No. Values Considered:	9	9	9	4	4	4		
VEGETATED FILTER STRIP	Average:	65	40	40	40	45	60	• Runoff volume • Slope • Soil infiltration rates • Vegetative cover • Buffer length	IEP, 1991; Casman, 1990; Glick et al., 1991; VADC, 1987; Minnesota PCA, 1989; Schueler, 1987; Hartigan et al., 1989
	Reported Range:	20-80	0-95	0-70	0-80	20-90[H]	30-90[I]		
	Probable Range:[c]	40-90	30-80	20-60	--	30-80	20-50		
	No. Values Considered:	7	4	3	2	3	3		
GRASS SWALE	Average:	60	20	10	25	70	60	• Runoff volume • Slope • Soil infiltration rates • Vegetative cover • Swale length • Swale geometry	Yousef et al., 1985; Dupuis, 1985; Washington State, 1988; Schueler, 1987; British Columbia Res. Corp., 1991; EPA, 1983; Whalen, et al., 1988; Pitt, 1986; Casman, 1990
	Reported Range:	0-100	0-100	0-40	25	3-100[H]	50-60[H]		
	Probable Range:[d]	20-40	20-40	10-30	--	10-20	10-20		
	No. Values Considered:	10	8	4	1	10	7		

Table 4-7. (Continued)

Management Practice		Removal Efficiency (%) TSS	TP	TN	COD	Pb	Zn	Factors	References
POROUS PAVEMENT	Average:	90	65	85	80	100	100	• Percolation rates • Storage volume	Schueler, 1987
	Reported Range:	80-95	65	80-85	80	100	100		
	Probable Range:	60-90	60-90	60-90	60-90	60-90	60-90		
	No. Values Considered:	2	2	2	2	2	2		
CONCRETE GRID PAVEMENT	Average:	90	90	90	90	90	90	• Percolation rates	Day, 1981; Smith, et al, 1981; Schueler, 1987
	Reported Range:	65-100	65-100	65-100	65-100	65-100	65-100		
	Probable Range:	60-90	60-90	60-90	60-90	60-90	60-90		
	No. Values Considered:	2	2	2	2	2	2		
SAND FILTER/FILTRATION BASIN	Average:	80	50	35	55	60	65	• Treatment volume • Filtration media	City of Austin, 1988; Environmental and Conservation Service Department, 1990
	Reported Range:	60-95	0-90	20-40	45-70	30-90	50-80		
	Probable Range:	60-90	0-80	20-40	40-70	40-80	40-80		
	No. Values Considered:	10	6	7	3	5	5		
WATER QUALITY INLET[g]	Average:	35	5	20	5	15	5	• Maintenance • Sedimentation storage volume	Pitt, 1896; Field, 1985; Schueler, 1987
	Reported Range:	0-95	5-10	5-55	5-10	10-25	5-10		
	Probable Range:	10-25	5-10	5-10	5-10	10-25	5-10		
	No. Values Considered:	3	1	2	1	2	1		

Table 4-7. (Continued)

Management Practice		Removal Efficiency (%) TSS	TP	TN	COD	Pb	Zn	Factors	References
WATER QUALITY INLET WITH SAND FILTER[g]	Average:	80	NA	35	55	80	65	• Sedimentation storage volume • Depth of filter media	Shaver, 1991
	Reported Range:	75-85	NA	30-45	45-70	70-90	50-80		
	Probable Range:	70-90	--	30-40	40-70	70-90	50-80		
	No. Values Considered:	1	0	1	1	1	1		
OIL/GRIT SEPARATOR[g]	Average:	15	5	5	5	15	5	• Sedimentation storage volume • Outlet configurations	Pitt, 1985; Schueler, 1987
	Reported Range:	0-25	5-10	5-10	5-10	10-25	5-10		
	Probable Range:	10-25	5-10	5-10	5-10	10-25	5-10		
	Number of References	2	1	1	1	1	1		
EXTENDED DETENTION DRY POND	Average:	45	25	30	20	50	20	• Storage volume • Detention time • Pond shape	MWCOG, 1983; City of Austin, 1990; Schueler and Helfrich, 1988; Pope and Hess, 1989; OWML, 1987; Wolinski and Stack, 1990
	Reported Range:	5-90	10-55	20-60	0-40	25-65	(-40)-65		
	Probable Range:[e]	70-90	10-60	20-60	30-40	20-60	40-60		
	No. Values Considered:	6	6	4	5	4	5		
WET POND	Average:	60	45	35	40	75	60	• Pool volume • Pond shape	Wotzka and Oberta, 1988; Yousef et al., 1986; Cullum, 1985; Driscoll, 1983; Driscoll, 1986; MWCOG, 1983; OWML, 1983; Yu and Benemouffok, 1988; Holler, 1989; Martin, 1988; Dorman et al., 1989; OWML, 1982; City of Austin, 1990
	Reported Range:	(-30)-91	10-85	5-85	5-90	10-95	10-95		
	Probable Range:	50-90	20-90	10-90	10-90	10-95	20-95		
	No. Values Considered:	18	18	9	7	13	13		

Table 4-7. (Continued)

Management Practice		Removal Efficiency (%) TSS	TP	TN	COD	Pb	Zn	Factors	References
EXTENDED DETENTION WET POND	Average:	80	65	55	NA	40	20	• Pool volume • Pond shape • Detention time	Ontario Ministry of the Environment, 1991, cited in Schueler et al., 1992 .
	Reported Range:	50-100	50-80	55	NA	40	20		
	Probable Range:	50-95	50-90	10-90	10-90	10-95	20-95		
	No. Values Considered:	3	3	1	0	1	1		
CONSTRUCTED STORMWATER WETLANDS	Average:	65	25	20	50	65	35	• Storage volume • Detention time • Pool shape • Wetland's biota • Seasonal variation	Harper et al., 1986; Brown, 1985; Wotzka and Obert, 1988; Hickock et al., 1977; Barten, 1987; Melorin, 1986; Morris et al., 1981; Sherberger and Davis, 1982; ABAG, 1979; Oberts et al., 1989; Rushton and Dye, 1990; Hey and Barrett, 1991; Martin and Smoot, 1986, Reinelt et al., 1990, cited in Woodward-Clyde, 1991
	Reported Range:	(-20)-100	(-120)-100	(-15)-40	20-80	30-95	(-30)-80		
	Probable Range[f]:	50-90	(-5)-80	0-40	---	30-95	---		
	No. Values Considered:	23	24	8	2	10	8		

NA - Not available.

[a] Design criteria: storage volume equals 90% avg runoff volume, which completely drains in 72 hours; maximum depth = 8 ft; minimum depth = 2 ft.

[b] Design criteria: storage volume equals 90% avg runoff volume, which completely drains in 72 hours; maximum depth = 8 ft; minimum depth = 3 ft; storage volume = 40% excavated trench volume.

[c] Design criteria: flow depth < 0.3 ft, travel time > 5 min.

[d] Design criteria: low slope and adequate length.

[e] Design criteria: min. ED time 12 hours.

[f] Design criteria: minimum area of wetland equal 1% of drainage area.

[g] No information was available on the effectiveness of removing grease or oil.

[h] Also reported as 90% TSS removed.

[i] Also reported as 50% TSS removed.

Table 4-8. Cost of Management Practices for Control of Runoff from Newly Developed Areas

Practice	Land requirement	Construction cost	Useful life	Annual O&M	Total annual cost	References
Infiltration Basin	High	Average: $0.5/ ft^3 storage Probable Cost: $0.4 - $0.7/ft^3 Reported Range: $0.2 - $1.2/ ft^3	25[a]	Average: 7% of capital cost Reported Range: 3% - 13% of capital cost	$0.03 - $0.05/ ft^3	Wiegand, et al, 1986; SWRPC, 1991
Infiltration Trench	Low	Average: $4.0/ ft^3 storage Probable Cost: $2.5 - $7.5/ft^3 Reported Range: $0.9 - $9.2/ ft^3	10[a]	Average: 9% of capital cost Reported Range: 5% - 15% of capital cost	$0.3 - $0.9/ft^3	Wiegand, et al, 1986; Macal, et al, 1987; SWRPC, 1991; Kuo, et al, 1988
Vegetative Filter Strip	Varies	Established from existing vegetation- Average: $0 Reported Range: $0 Established from seed- Average: $400/ acre Reported Range: $200 - $1,000/ acre Established from seed and mulch- Average: $1,500/ acre Reported Range: $800 - $3,500/ acre Established from sod- Average: $11,300/ acre Reported Range: $4,500 - $48,000/ acre	50[b]	Natural succession allowed to occur- Average: $100/ acre Reported Range: $50 - $200/ acre Natural succession not allowed to occur- Average: $800/ acre Reported Range: $700 - $900/ acre	Natural succession allowed to occur- Established from- Natural vegetation: $100/ acre Seed: $125/ acre Seed & mulch: $200/ acre Sod: $700/ acre Natural succession not allowed to occur- Established from: natural vegetation: $800/acre Seed: $825/acre Seed & mulch: $900/acre Sod: $1,400/acre	Schueler, 1987; SWRPC, 1991

Table 4-8 (continued)

Practice	Land requirement	Construction cost	Useful life	Annual O&M	Total annual cost	References
Grass Swales	Low	Established from seed: Average: $6.5/ lin ft Reported Range: $4.5 - $8.5/ lin ft Established from sod: Average: $20/ lin ft Reported Range: $8 - $50/ lin ft	50[b]	Established from seed or sod- Average: $0.75/ lin ft Reported Range: $0.5 - $1.0/ lin ft	Established from seed: $1/lin ft Established from sod: $2/lin ft	Schueler, 1987; SWRPC, 1991
Porous Pavement	None	Average: $1.5/ ft^2 [c] Reported Range: $1 - $2/ ft^2 [c]	10[d]	Average: $0.01/ ft^2 [c] Reported Range: $0.01/ ft^2 [c]	0.15/ ft^2 [c]	SWRPC, 1991; Schueler, 1987
Concrete Grid Pavement	None	Average: $1/ ft^2 [c] Reported Range: $1 - $2/ ft^2 [c]	20	Average: (-$0.04)/$ft^2$ [c] Reported Range: (-$0.04)/ ft^2 [c]	0.05/ ft^2 [c]	Smith, 1981
Sand Filter/ Filtration Basin	High	Average: $5/ ft^3 Probable Cost: $2 - $9/$ft^3$ Reported Range: $1 - $11/$ft^3$	25[d]	Average: Not Available Probable Cost: 7% of construction cost Reported Range: Not Available	$0.1 - $0.8/$ft^3$	Tull, 1990
Water Quality Inlet	None	Average: $2,000/ each Reported Range: $1,100 - $3,000/ each	50	Average: $30/each[f] Reported Range: $20-40/each[f]	$150/ each	SWRPC, 1991
Water Quality Inlet with Sand Filters	None	Average: $10,000/ drainage acre Reported Range: $10,000/ drainage acre	50	Average: Not Available Probable Cost: $100/ drainage acre Reported Range: Not Available	$700/ drainage acre	Shaver, 1991
Oil/Grit Separator	None	Average: $18,000/ drainage acre Reported Range: $15,000 - $20,000/ drainage acre	50	Average: $20/ drainage acre[f] Reported Range: $5 - $40/ drainage acre[f]	$1,000/ drainage acre	Schueler, 1987

Table 4-8 (continued)

Practice	Land requirement	Construction cost	Useful life	Annual O&M	Total annual cost	References
Extended Detention Dry Pond	High	Average \$0.5/ ft^3 storage Probable Cost: \$0.09 - \$5/ft^3 Reported Range: \$0.05 - \$3.2/ ft^3	50	Average: 4% of capital cost Reported Range: 3% - 5% of capital cost	\$0.007 - \$0.3/ft^3	APWA Res. Foundation
Wet Pond and Extended Detention Wet Pond	High	Storage Volume < 1,000,000 ft^3: Average: \$0.5/ ft^3 storage Probable Cost: \$0.5 - \$1/ft^3 Reported Range: \$0.05 - \$1.0/ ft^3 Storage Volume > 1,000,000 ft^3: Average: \$0.25/ ft^3 storage Probable Cost: \$0.1 - \$0.5/ft^3 Reported Range: \$0.05 - \$0.5/ft^3	50	Average: 3% of capital cost Probable Cost: <100,000 ft^3 = 5% of capital cost >100,000 & <1,000,000 ft^3 = 3% of capital cost >1,000,000 ft^3 = 1% of capital cost Reported Range: 0.1% - 5% of capital cost	\$0.008 - \$0.07/ft^3	APWA Res. Foundation; Wiegand, et al, 1986; Schueler, 1987; SWRPC, 1991
Stormwater Wetlands	High	Average: Not available Reported Range: Not available	50[b]	Average: Not Available Reported Range: Not Available	Not available	

[a] References indicate the useful life for infiltration basins and infiltration trenches at 25-50 and 10-15 years, respectively. Because of the high failure rate, infiltration basins are assumed to have useful life span of 25 years and infiltration trenches are assumed to have useful life span of 10 years.
[b] Useful life taken as life of project, assumed to be 50 years.
[c] Incremental cost, i.e., cost beyond that required for conventional asphalt pavement.
[d] Since no information was available for useful life of porous pavement, it was assumed to be similar to that of infiltration trenches.
[e] Since no information was available for useful life of filtration basins it was assumed to be similar to that of infiltration basins.
[f] Frequency of cleaning assumed 2 times per year.

districts, counties, and other agencies. The program has been well received and from February 1991 to July 1991, over 1,100 individuals from 300 companies and organizations participated in the program (Shaver and Piorko, 1992).

b. *Ensure that all urban runoff facilities are operated and maintained properly.*

Once an urban runoff facility is installed, it should receive thorough maintenance in order to function properly and not pose a health or safety threat. Maintenance should occur at regular intervals, be performed by one or more individuals trained in proper inspection and maintenance of urban runoff facilities, and be performed in accordance with the adopted standards of the State or local government (Ocean County, undated). It is more effective and efficient to perform preventative maintenance on a regular basis than to undertake major remedial or corrective action on an as needed basis (Ocean County, undated).

c. *Infiltration Basins*

Infiltration basins are impoundments in which incoming urban runoff is temporarily stored until it gradually infiltrates into the soil surrounding the basin. Infiltration basins should drain within 72 hours to maintain aerobic conditions, which favor bacteria that aid in pollutant removal, and to ensure that the basin is ready to receive the next storm (Schueler, 1987). The runoff entering the basin is pretreated to remove coarse sediment that may clog the surface soil pore on the basin floor. Concentrated runoff should flow through a sediment trap, or a vegetated filter strip may be used for sheet flow.

d. *Infiltration Trenches*

Infiltration trenches are shallow excavated ditches that have been backfilled with stone to form an underground reservoir. Urban runoff diverted into the trench gradually infiltrates from the bottom of the trench into the subsoil and eventually into the ground water. Variations in the design of infiltration trenches include dry wells, pits designed to control small volumes of runoff (such as the runoff from a rooftop), and enhanced infiltration trenches, which are equipped with extensive pretreatment systems to remove sediment and oil. Depending on the quality of the runoff, pretreatment will generally be necessary to lower the failure rate of the trench. More costly than pond systems in terms of cost per unit of runoff treated, infiltration trenches are suited best for drainage areas of less than 5 to 10 acres or where ponds cannot be applied (Schueler et al., 1992).

e. *Vegetated Filter Strips*

Vegetated filter strips are areas of land with vegetative cover that are designed to accept runoff as overland sheet flow from upstream development. They may closely resemble many natural ecotones, such as grassy meadows or riparian forests. Dense vegetative cover facilitates sediment attenuation and pollutant removal. Vegetated filter strips do not effectively treat high-velocity flows and are therefore generally recommended for use in agriculture and low-density development and other situations where runoff does not tend to be concentrated. Unlike grassed swales, vegetated filter strips are effective only for overland sheet flow and provide little treatment for concentrated flows. Grading and level spreaders can be used to create a uniformly sloping area that distributes the runoff evenly across the filter strip (Dillaha et al., 1987). Vegetated filter strips are often used as pretreatment for other structural practices, such as infiltration basins and infiltration trenches. Refer to Chapter 7 of this guidance for additional information.

Filter strips are less effective on slopes of over 15 percent. Periodic inspection, repair, and regrading are required to prevent channelization (Schueler et al., 1992). Inspection is especially important following major storm events. Excessive use of pesticides, fertilizers, and other chemicals should be avoided. To minimize soil compaction, vehicular traffic and excessive pedestrian traffic should be avoided.

A berm of sediment that must be periodically removed may form at the upper edge of grassed filter strips. Mowing of grassed filter strips at a minimum of two to three times per year will maintain a thicker vegetative cover, providing better sediment retention. To avoid impacts on ground-nesting birds, mowing should be limited to spring or fall (USEPA, undated). Harvesting of mowed vegetation will allow for thicker growth and promotes the retention of nutrients that are released during decomposition (Dillaha et al., 1989).

Forested areas directly adjacent to waterbodies should be left undisturbed except for the removal of trees presenting unusual hazards and the removal of small debris near the stream that may be refloated by high water. Periodic harvesting of some trees not directly adjacent to waterbodies removes sequestered nutrients (Lowrance, Leonard, and Sheridan, 1985) and maintains an efficient filter through vigorous vegetation (USEPA, undated). Exposure of forested filter strip soil to direct radiation should be avoided to keep the temperature of water entering waterbodies low, and moist conditions conducive to microbial activities in filter strip soil should be maintained (Nutter and Gaskin, 1989).

f. Grassed Swales

A grassed swale is an infiltration/filtration method that is usually used to provide pretreatment before runoff is discharged to treatment systems. Grassed swales are typically shallow, vegetated, man-made ditches designed so that the bottom elevation is above the water table to allow runoff to infiltrate into ground water. The vegetation or turf prevents erosion, filters sediment, and provides some nutrient uptake (USDA-SCS, 1988). Grassed swales can also serve as conveyance systems for urban runoff and provide similar benefits.

The swale should be mowed at least twice each year to stimulate vegetative growth, control weeds, and maintain the capacity of the system. It should never be mowed shorter than 3 to 4 inches. The established width should be maintained to ensure the continued effectiveness and capacity of the system (Bassler, undated).

g. Porous Pavement and Permeable Surfaces

Porous pavement, an alternative to conventional pavement, reduces much of the need for urban runoff drainage conveyance and treatment off-site. Instead, runoff is diverted through a porous asphalt layer into an underground stone reservoir. The stored runoff gradually exfiltrates out of the stone reservoir into the subsoil. Many States no longer promote the use of porous pavement because it tends to clog with fine sediments (Washington Department of Ecology, 1991). A vacuum-type street sweeper should be used to maintain porous pavement.

Permeable paving surfaces such as modular pavers, grassed parking areas, and permeable pavements may also be employed to reduce runoff volumes and trap vehicle-generated pollutants (Pitt, 1990; Smith, 1981); however, care should be taken when selecting such alternatives. The potential for ground-water contamination, compaction, or clogging due to sedimentation should be evaluated during the selection process. (NOTE: These practices should be selected only in cases where proper operation and maintenance can be guaranteed due to high failure rates without proper upkeep.)

h. Concrete Grid Pavement

Concrete grid pavement consists of concrete blocks with regularly interdispersed void areas that are filled with pervious materials, such as gravel, sand, or grass. The blocks are typically placed on a sand or gravel base and designed to provide a load-bearing surface that is adequate to support vehicles, while allowing infiltration of surface water into the underlying soil.

i. Water Quality Inlets

Water quality inlets are underground retention systems designed to remove settleable solids. Several designs of water quality inlets exist. In their simplest form, catch basins are single-chambered urban runoff inlets in which the bottom has been lowered to provide 2 to 4 feet of additional space between the outlet pipe and the structure bottom for collection of sediment. Some water quality inlets include a second chamber with a sand filter to provide additional removal of finer suspended solids by filtration. The first chamber provides effective removal of coarse particles and helps prevent premature clogging of the filter media. Other water quality inlets include an oil/grit separator. Typical oil/grit separators consist of three chambers. The first chamber removes coarse material and debris; the second chamber provides separation of oil, grease, and gasoline; and the third chamber provides safety relief should blockage occur (NVPDC, 1980). While water quality inlets have the potential to perform effectively, they are not recommended. Maintenance and disposal of trapped residuals and hydrocarbons must occur regularly for these devices to work. No acceptable clean-out and disposal techniques currently exist (Schueler et al., 1992).

j. Extended Detention Ponds

Extended detention (ED) ponds temporarily detain a portion of urban runoff for up to 24 hours after a storm, using a fixed orifice to regulate outflow at a specified rate, allowing solids and associated pollutants the required time to settle out. The ED ponds are normally "dry" between storm events and do not have any permanent standing water. These basins are typically composed of two stages: an upper stage, which remains dry except for larger storms, and a lower stage, which is designed for typical storms. Enhanced ponds are equipped with plunge pools near the inlet, a micropool at the outlet, and an adjustable reverse-sloped pipe as the ED control device (orifice) (NVPDC, 1980; Schueler et al., 1992). Temporary and most permanent ED ponds use a riser with an antivortex trash rack on top to control trash.

k. Wet Ponds

Wet ponds are basins designed to maintain a permanent pool of water and temporarily store urban runoff until it is released at a controlled rate. Enhanced designs include a forebay to trap incoming sediment where it can easily be removed. A fringe wetland can also be established around the perimeter of the pond.

l. Constructed Wetlands

Constructed wetlands are engineered systems designed to simulate the water quality improvement functions of natural wetlands to treat and contain surface water runoff pollutants and decrease loadings to surface waters. Where site-specific conditions allow, constructed wetlands or sediment retention basins should be located to have a minimal impact on the surrounding areas. (The State of Washington requires that constructed wetlands be located in uplands (Washington Department of Ecology, 1992).) In addition, constructed urban runoff wetlands differ from artificial wetlands created to comply with mitigation requirements in that they do not replicate all of the ecological functions of natural wetlands. Enhanced designs may include a forebay, complex microtopography, and pondscaping with multiple species of wetland trees, shrubs, and plants. Additional information on constructed wetlands is provided in Chapter 7.

m. Filtration Basins and Sand Filters

Filtration basins are impoundments lined with filter media, such as sand or gravel. Urban runoff drains through the filter media and perforated pipes into the subsoil. Detention time is typically 4 to 6 hours. Sediment-trapping structures are typically used to prevent premature clogging of the filter media (NVPDC, 1980; Schueler et al., 1992).

Sand filters are a self-contained bed of sand to which the first flush of runoff water is diverted. The runoff percolates through the sand, where colloidal and particulate materials are strained out by the cake of solids that forms, or is placed, on the surface of the media. Water leaving the filter is collected in underground pipes and returned to the stream or channel. A layer of peat, limestone, and/or topsoil may be added to improve removal efficiency.

n. Educate the public about the importance of runoff management facilities.

"... the value of a comprehensive public information and education program cannot be overemphasized. Such a program must explain the basis, purpose, and details of the proposal and must convince the public and their elected officials that it is both necessary to implement and beneficial to their interests. It must also explain the fundamentals of storm water management facilities, the vital role they play in our lives, and their need for regular maintenance. This information can be presented through flyers, brochures, posters, and other educational aids. Work sessions and field trips can also be conducted. Signs at facility sites can also be erected. Finally, presentations to planning boards, municipal councils and committees, and county freeholders by storm water management experts can also be of great assistance" (New Jersey, undated).

5. Effectiveness and Cost Information

The box and whisker plot in Figure 4-3 summarizes efficiencies for selected structural TSS removal practices, as reported by Schueler et al., 1992. The whiskers of each box represent the range of reported TSS removal efficiencies. The box ends delimit the 25th and 75th percentiles. The horizontal line represents the median, or 50th percentile. Circles represent outliers. Figure 4-3 and Table 4-7 illustrate the range of removal efficiencies, based on monitoring and modeling studies, for total suspended solids for several of the structural practices. The reviewed literature reported a median TSS removal efficiency above 80 percent for three practices—constructed wetlands, wet ponds, and filtration basins. However, it has been reported that the other practices are capable of achieving 80 percent TSS removal efficiency when properly designed, sited, operated, and maintained. More detailed information on the removal efficiencies of the practices and factors influencing the removal efficiencies is presented in Table 4-7. Costs of the practices are shown in Table 4-8.

In many cases, a systems approach to best management practice (BMP) design and implementation may be more effective. By applying multiple practices, enhanced runoff attenuation, conveyance, pretreatment, and treatment may be attained (Schueler et al., 1992). In addition, regionalization of systems (installing and maintaining a BMP or BMPs for more than one development site) may prove more efficient and cost-effective due to the economies of scale of operating one large system versus several smaller systems.

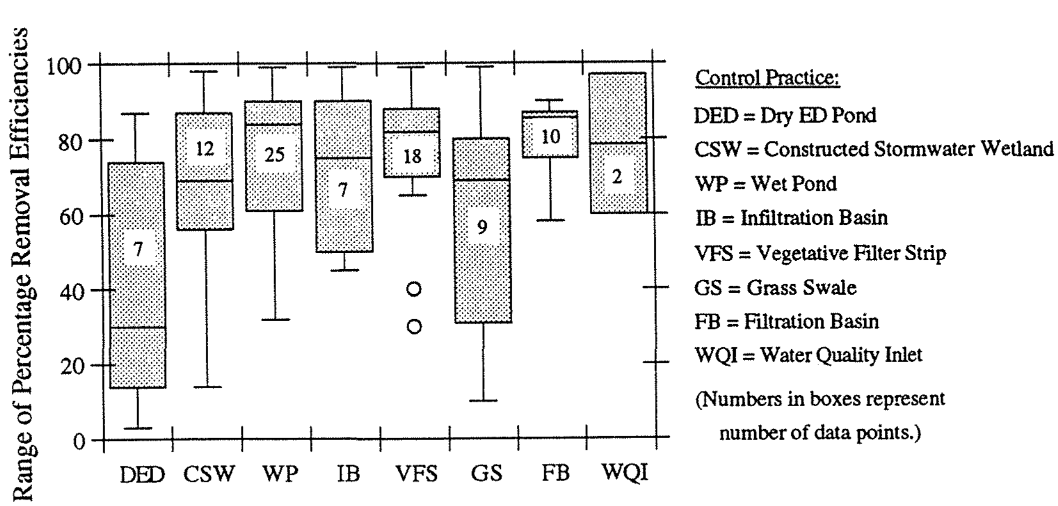


Figure 4-3. Removal efficiencies of selected urban runoff controls for TSS (adapted from Schueler et al., 1992).

B. Watershed Protection Management Measure

Develop a watershed protection program to:

(1) Avoid conversion, to the extent practicable, of areas that are particularly susceptible to erosion and sediment loss;

(2) Preserve areas that provide important water quality benefits and/or are necessary to maintain riparian and aquatic biota; and

(3) Site development, including roads, highways, and bridges, to protect to the extent practicable the natural integrity of waterbodies and natural drainage systems.

1. Applicability

This management measure is intended to be applied by States to new development or redevelopment including construction of new and relocated roads, highways, and bridges that generate nonpoint source pollutants. Under the Coastal Zone Act Reauthorization Amendments of 1990, States are subject to a number of requirements as they develop coastal nonpoint source programs in conformity with this management measure and will have flexibility in doing so. The application of management measures by States is described more fully in *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance*, published by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce.

2. Description

The purpose of this management measure is to reduce the generation of nonpoint source pollutants and to mitigate the impacts of urban runoff and associated pollutants that result from new development or redevelopment, including the construction of new and relocated roads, highways, and bridges. The measure is intended to provide general goals for States and local governments to use in developing comprehensive programs for guiding future development and land use activities in a manner that will prevent and mitigate the effects of nonpoint source pollution.

A watershed is a geographic region where water drains into a particular receiving waterbody. As discussed in the introduction, comprehensive planning is an effective nonstructural tool available to control nonpoint source pollution. Where possible, growth should be directed toward areas where it can be sustained with a minimal impact on the natural environment (Meeks, 1990). Poorly planned growth and development have the potential to degrade and destroy entire natural drainage systems and surface waters (Mantel et al., 1990). Defined land use designations and zoning direct development away from areas where land disturbance activities or pollutant loadings from subsequent development would severely impact surface waters. Defined land use designations and zoning also protect environmentally sensitive areas such as riparian areas, wetlands, and vegetative buffers that serve as filters and trap sediments, nutrients, and chemical pollutants. Refer to Chapter 7 for a thorough description of the benefits of wetlands and vegetative buffers.

Areas such as streamside buffers and wetlands may also have the added benefit of providing long-term pollutant removal capabilities without the comparatively high costs usually associated with structural controls. Conservation or preservation of these areas is important to water quality protection. Land acquisition programs help to preserve areas critical to maintaining surface water quality. Buffer strips along streambanks provide protection for stream ecosystems and help to stabilize the stream and prevent streambank erosion (Holler, 1989). Buffer strips protect and maintain near-stream vegetation that attenuates the release of sediment into stream channels and prevent excessive loadings. Levels of suspended solids increase at a slower rate in stream channel sections with well-developed riparian vegetation (Holler, 1989).

The availability of infrastructure specifically sewage treatment facilities, is also a factor in watershed planning. If centralized sewage treatment is not available, onsite disposal systems (OSDS) most likely will be used for sewage treatment. Because of potential ground-water and surface water contamination from OSDS, density restrictions may be needed in areas where OSDS will be used for sewage treatment. Section VI of this chapter contains a more detailed discussion of siting densities for OSDS.

3. Management Measure Selection and Effectiveness Information

This measure was selected for the following reasons:

(1) Watershed protection is a technique to provide long-term water quality benefits, and many States and local communities already use this practice. Numerous State and local governments have already legislated and implemented detailed watershed planning controls that are consistent with this management measure. For example, Oregon, New Jersey, Delaware, and Florida have passed legislation that requires county and municipal governments to adopt comprehensive plans, including requirements to direct future development away from sensitive areas. Several municipalities and regions, in addition to those in these States, have adopted land use and growth controls, including Amherst, Massachusetts, the Cape Cod region, Norwood, Massachusetts, and Narragansett, Rhode Island.

(2) Setting general water quality objectives oriented toward protection of environmentally sensitive areas and areas that provide water quality benefits allows States flexibility in the pursuit of widely differing water quality priorities and reduces potential conflicts that may arise due to existing State or local program goals and requirements. Although public comments on the May 1991 draft guidance suggested that much more specific criteria should be required, such as minimum setbacks from waterbodies, prohibitions on development on slopes in excess of 45 degrees, and bans on development in floodplains, such prescriptive measures are deemed unreasonable given the need for State and local determination of priorities and program direction.

(3) This measure is effective in producing long-term water quality benefits and lacks the high operation and maintenance costs associated with structural controls.

By protecting those areas necessary for maintaining surface water quality in a natural or near natural state, adverse impacts can be reduced. To illustrate the effectiveness of this management measure, two case studies are presented.

CASE STUDY 1 - RHODE RIVER ESTUARY, CHESAPEAKE BAY, MARYLAND

An evaluation of the impact of the Maryland Critical Area Act on nonpoint source pollution (nutrients and sediment) in surface runoff was completed by modeling three land use scenarios and determining the relative change in nonpoint loadings from the Rhode River Critical Area. Research findings suggest that the implementation of the Act will reduce nonpoint source nutrient and sediment loading by mandating agricultural and urban best management practices (BMPs) and limiting development in forested lands. Figure 4-4 illustrates the predicted nitrogen and phosphorus loadings from various land uses within the watershed under various development scenarios. These predictions are based on the assumption that no structural BMPs are in place.

New development allowed by the Critical Area Act is required to minimize impervious surfaces and reduce nonpoint source pollution through urban BMPs. Results from this study indicate that by limiting the impervious portion of a building site to 15 percent in the Rhode River Estuary, nutrient loadings could be reduced by one-third when compared to similar development without this practice (Houlihan, 1990).

CASE STUDY 2 - ALAMEDA COUNTY, CALIFORNIA

Pollutant loading estimates can be used to evaluate the effectiveness of land planning on controlling nonpoint source pollution. For example, Alameda County, California, has estimated seven pollutant loadings for seven parameters by type of land use, as shown in Table 4-9. By leaving larger areas in open space—through easements, buffers, clustering, or preserves—the potential pollutant loading to San Francisco Bay can be reduced. For example, it is estimated that if 50 percent of a 100-acre parcel designated for residential development is preserved in open space, pollutant loadings for zinc and total suspended solids can be reduced by 50.24 percent and 49.76 percent, respectively, when compared to residential development of the entire 100-acre parcel.

Table 4-9. Load Estimates for Six Land Uses in Alameda County, California (based on average wet weather load, lb/acre; adapted from Woodward-Clyde, 1991)

Land Use	Cadmium	Chromium	Copper	Lead	Nickel	Zinc	Total Suspended Solids
Open	N/A	N/A	N/A	N/A	N/A	0.002	0.75
Residential	0.002	0.026	0.058	0.134	0.037	0.424	52.16
Commercial	0.002	0.038	0.084	0.094	0.053	0.655	511.76
Transportation	0.003	0.050	0.112	0.259	0.071	0.274	683.23
Industrial	0.003	0.044	0.097	0.171	0.028		251.43
Industrial Park	0.002	0.026	0.057	0.101	0.017	0.479	148.88

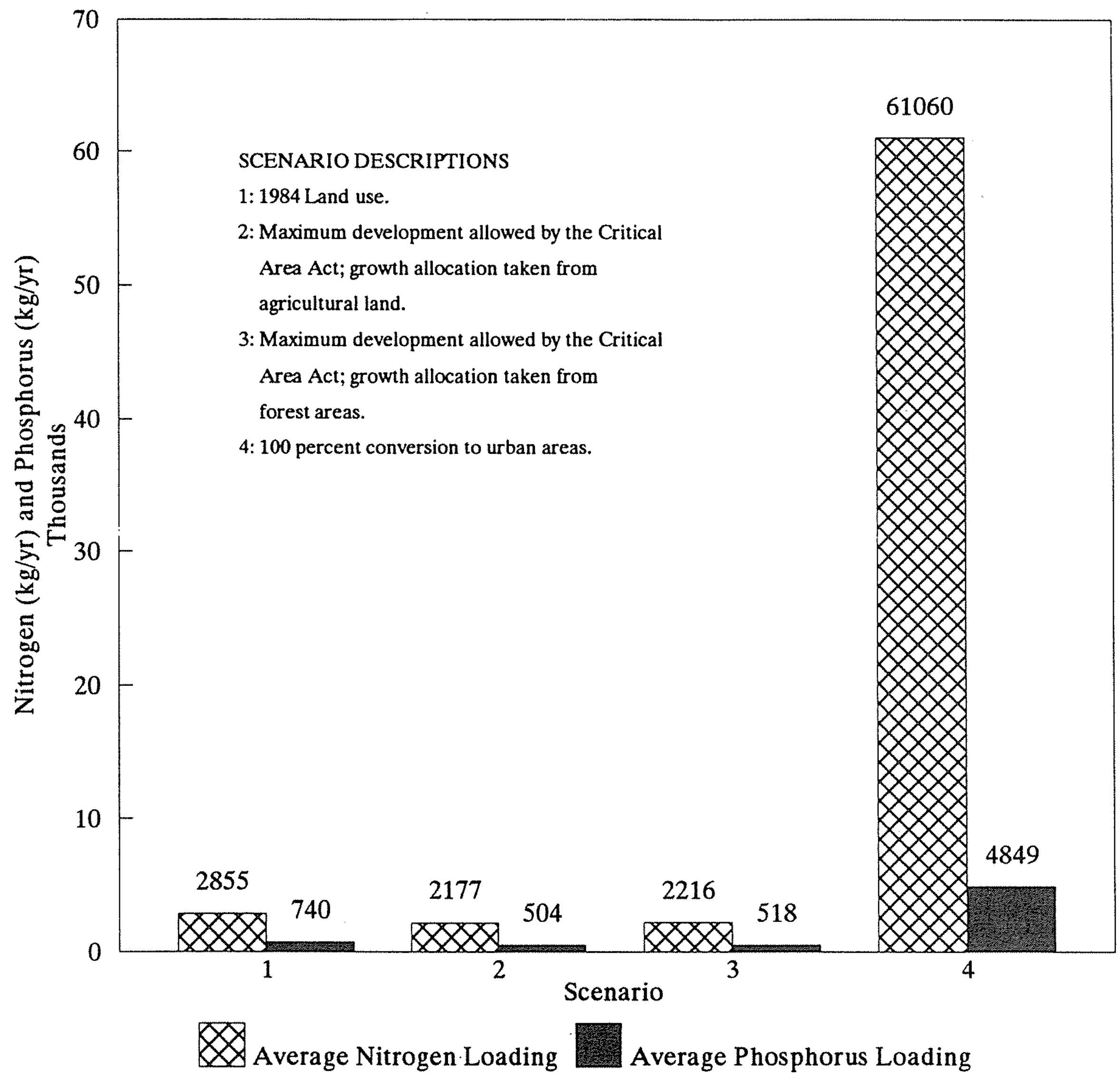


Figure 4-4. Predicted total nitrogen and phosphorus loadings in surface water after runoff from the Rhode River Critical Area under different land use scenarios (Houlihan, 1990).

Considerable uncertainty is associated with the ability to quantify load reductions from various nonstructural practices for controlling nonpoint source pollution (USEPA, 1990). Table 4-10 illustrates the general effectiveness of various planning and site design practices. Many are described in the practices section of this management measure and the Site Development Management Measure.

Table 4-10. General Effectiveness of Various Nonstructural Control Practices (Metropolitan Washington Council of Governments, 1991)

	Nutrient Control	Shellfish	Estuarine Habitat Protection	Sedimentation	Sediment Toxics	Stormwater Control	Feasibility In Coastal Areas	Maintenance Burdens	Longevity	Community Acceptance	Secondary Environmental Impacts	Cost to Developers	Cost to Local Governments	Difficulty in Local Implementation	Site Data Required	Water Dependent Use
I. COASTAL DENSITY ZONES																
Intense Zones	○	○	○	○	○	○	●	■	■	○	○	○	◍	○	◍	
Rural Zones	○	◍	◍	◍	◍	◍	●	■	■	○	◍	◍	◍	○	◍	
Protection Zones	◍	●	●	●	●	●	●	■	■	○	●	●	◍	◍	◍	
Overlay Zones	◍	●	●	◍	◍	◍	●	■	■	○	◍	◍	◍	◍	○	
Performance Zoning	◍	◍	◍	◍	◍	●	●	■	■	○	◍	◍	◍	◍	○	
II. ENVIRONMENTAL RESERVES																
Stream Buffers	◍	◍	●	◍	○	○	●	●	●	●	●	◍	●	◍	●	○
Wetland Buffers	◍	○	●	◍	○	○	●	●	●	●	●	○	●	●	●	●
Coastal Buffers	◍	●	●	◍	○	○	●	●	●	●	●	○	◍	○	●	●
Expanded Buffers	●	●	●	●	○	○	●	●	●	◍	●	◍	●	○	○	●
Floodplain Limits	◍	○	●	○	○	◍	●	●	●	◍	●	◍	●	◍	◍	○
Steep Soils Limits	○	○	◍	●	○	◍	●	●	●	◍	●	◍	●	●	●	◍
Septic Limits	◍	●	○	○	○	■	●	●	●	●	●	○	◍	○	◍	◍
Wetland Protection	●	◍	●	●	○	◍	●	●	●	●	●	◍	●	●	○	●
Forest Protection	○	◍	◍	◍	○	○	●	●	●	●	●	○	●	◍	◍	●
Habitat Protection	○	○	●	○	○	○	●	●	●	●	●	◍	●	◍	○	●
Open Space Protection	○	○	◍	○	○	○	●	●	●	●	●	○	●	◍	◍	●
	● 0 - 40% High Level of Control ◍ 30 - 40% Moderate Level of Control ○ 0 - 20% Low Level of Control ■ Ineffective	● Highly Effective ◍ Moderately Effective ○ Low Effectiveness ■ Ineffective	● Directly Protects ◍ Indirectly Protects ○ No Protection ■ Not Related	● 60% + High ◍ 30 - 60% Mod ○ 0 - 30% Low ■ Ineffective	● Highly Effective ◍ Moderately Effective ○ Low Effectiveness ■ Ineffective	● Highly Effective ◍ Moderately Effective ○ Low Effectiveness ■ Ineffective	● Widely Applicable ◍ Applicable Depending on Site ○ Seldom Applicable ■ Not Applicable	● Low Burden ◍ Moderate Burden ○ High Burden ■ Not Applicable	● Long Lived ◍ Long Lived w/Maintenance ○ Shortlived ■ Not Applicable	● Positive ◍ Neutral ○ Negative ■ Mixed	● None or Positive ◍ Slight Negative Impacts ○ Strong Negative Impacts at Some States ■ Prohibited	● Low ◍ Moderate ○ High ■ Very High	● Low ◍ Moderate ○ High ■ Very High	● Easy ◍ Moderate ○ Tough ■ Very Tough	● Simple ◍ Moderate ○ Complex ■ None	● Can be Used Moderately in These Areas ◍ Sometimes Can Be Used ○ Seldom Used ■ Not Used

Table 4-10 (continued)

	Nutrient Control	Shellfish	Estuarine Habitat Protection	Sedimentation	Sediment Toxics	Stormwater Control	Feasibility In Coastal Areas	Maintenance Burdens	Longevity	Community Acceptance	Secondary Environmental Impacts	Cost to Developers	Cost to Local Governments	Difficulty in Local Implementation	Site Data Required	Water Dependent Use
III. SITE PLANNING																
Cluster	○	◍	○	○	○	○	●	●	●	◍	●	●	●	○	◍	●
Performance Criteria	●	●	●	●	●	●	●	○	○	○	○	○	○	○	○	●
Minimize Imperviousness	○		○	○	○	◍	●									
EROSION & SEDIMENT CONTROL		○														
Time/Area Disturbance	◍	○	●	◍	■	○	●	●	●	●	●	●	◍	●	◍	●
V. POST DEVELOPMENT																
Urban Housekeeping	○	◍	○	◍	◍	■	●	◍	○	◍	◍		●	●	●	●
Fertilizer Control	◍	○	■	■	■	■	◍	○	○	◍	●		◍	◍	◍	◍
Septic Maintenance	◍	●	○	■	■	■	●	○	◍	◍	◍		◍	◍	○	◍
Household Hazardous Waste	○	■	○	■	●	■	◍	○	○	◍	◍		◍	◍	○	◍
	● 0 - 40% High Level of Control ◍ 30 - 40% Moderate Level of Control ○ 0 - 20% Low Level of Control ■ Ineffective	● Highly Effective ◍ Moderately Effective ○ Low Effectiveness ■ Ineffective	● Directly Protects ◍ Indirectly Protects ○ No Protection ■ Not Related	● 60% + High ◍ 30 - 60% Mod ○ 0 - 30% Low ■ Ineffective	● Highly Effective ◍ Moderately Effective ○ Low Effectiveness ■ Ineffective	● Highly Effective ◍ Moderately Effective ○ Low Effectiveness ■ Ineffective	● Widely Applicable ◍ Applicable Depending on Site ○ Seldom Applicable ■ Not Applicable	● Low Burden ◍ Moderate Burden ○ High Burden ■ Not Applicable	● Long Lived ◍ Long Lived w/Maintenance ○ Shortlived ■ Not Applicable	● Positive ◍ Neutral ○ Negative ■ Mixed	● None or Positive ◍ Slight Negative Impacts ○ Strong Negative Impacts at Some States ■ Prohibited	● Low ◍ Moderate ○ High ■ Very High	● Low ◍ Moderate ○ High ■ Very High	● Easy ◍ Moderate ○ Tough ■ Very Tough	● Simple ◍ Moderate ○ Complex ■ None	● Can be Used Moderately in These Areas ◍ Sometimes Can Be Used ○ Seldom Used ■ Not Used

4. Watershed Protection Practices and Cost Information

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.

The most effective way to achieve this management measure is to develop a comprehensive program that incorporates protection of surface waters with programs and plans for guiding growth and development. Planning is an orderly process, and each step builds upon preceding steps. The following practices are part of the process and can be modified to meet the needs of the community. Many of the practices can be incorporated into existing activities being carried out by a local government, such as land planning, zoning, and site plan review. Other activities, such as land acquisition programs, may have to be developed. Where cost and effectiveness information was available, it was included in the discussion of the examples. The general cost and effectiveness of planning programs are described after the practices.

a. Resource Inventory and Information Analysis

Before a comprehensive program can be developed, define the watershed boundaries, target areas, and pollutants of concern, and conduct resource inventory and information analysis. These activities can be done by using best available information or collecting primary data, depending on funding availability and the quality of available data. Activities pursued under this process include: assessment of ground-water and surface water hydrology; evaluation of soil type and ground cover; identification of areas with water quality impairments; and identification of environmentally sensitive areas, such as steep or erodible uplands, wetlands, riparian areas, floodplains, aquifer recharge areas, drainage ways, and unique geologic formations. Once environmentally sensitive areas are identified, areas that are integral to the protection of surface waters and the prevention of nonpoint source pollution can be protected.

The following are examples of resource inventory and information analysis programs:

LOCATION	PROGRAM	COST
City of Virginia Beach, Virginia	Three-phase natural areas inventory to help planners and public officials develop practices for resource protection	Phase I (data collection) $13,867; Phase II (field inventory) $54,624; and Phase III (final report) $15,225 (Jenkins, 1991).
Richmond County, Virginia	The Richmond County Resource Information System (RIS) was developed to provide a basis for responsible planning and development of shoreline areas. The compilation and mapping of resource information are part of the county's planning and zoning program.	In 1990, the program was supported by a $39,000 Federal Coastal Zone Management Grant, $45,000 from the Chesapeake Bay Foundation through a Virginia Environmental Endowment Grant, and $96,000 from the county's comprehensive plan budget (Jenkins, 1991).

b. Development of Watershed Management Plan

The resource inventory and information analysis component provides the basis for a watershed management plan. A watershed management plan is a comprehensive approach to addressing the needs of a watershed, including land use, urban runoff control practices, pollutant reduction strategies, and pollution prevention techniques.

For a watershed management plan to be effective, it should have measurable goals describing desired outcomes and methods for achieving the goals. Goals, such as reducing pollutant loads to surface water by 25 percent, can be articulated in a watershed management plan. Development and implementation of urban runoff practices, both structural and nonstructural, can be incorporated as methods for achieving the goal. Table 4-11 describes the general steps for developing a watershed management plan.

Table 4-11. Watershed Management: A Step-by-Step Guide (Livingston and McCarron, 1992)

1. **Delineate and map watershed boundary and sub-basins within the watershed.**

2. **Inventory and map natural storm water conveyance and storage systems.**

3. **Inventory and map man-made storm water conveyance and storage system.**
   This includes all ditches, swales, storm sewers, detention ponds, and retention areas and includes information such as size, storage capacity, and age.

4. **Inventory and map land use by sub-basin.**

5. **Inventory and map detailed soils by sub-basin.**

6. **Establish a clear understanding of water resources in the watershed.**
   Analyze water quality, sediment, and biological data. Analyze subjective information on problems (such as citizen complaints). Evaluate waterbody use impairment–frequency, timing, seasonality of problem. Conduct water quantity assessment–low flows, seasonality.

7. **Inventory pollution sources in the watershed.**
   Point sources—location, pollutants, loadings, flow, capacity, etc. Nonpoint sources—type, location, pollutants, loading, etc.
   - land use/loading rate analysis for storm water;
   - sanitary survey for septic tanks;
   - dry flow monitoring to locate illicit discharges

8. **Identify and map future land use by sub-basin.**
   Conduct land use loading rate analyses to assess potential effects of various land use scenarios.

9. **Identify planned infrastructure improvements—5-year, 20-year.**
   Stormwater management deficiencies should be coordinated and scheduled with other infrastructure or development projects.

10. **Analysis.**
    Determine infrastructure and natural resources management needs within each watershed.

11. **Set resource management goals and objectives.**
    Before corrective actions can be taken, a resource management target must be set. The target can be defined in terms of water quality standards; attainment and preservation of beneficial uses; or other local resource management objectives.

12. **Determine pollutant reduction (for existing and future land uses) needed to achieve water quality goals.**

13. **Select appropriate management practices (point source, nonpoint source) that can be used to achieve the goal.**
    Evaluate pollutant removal effectiveness, land owner acceptance, financial incentives and costs, availability of land operation and maintenance needs, feasibility, and availability of technical assistance.

14. **Develop watershed management Plan.**
    Since the problems in each watershed will be unique, each watershed management plan will be specific. However, all watershed plans will include elements such as:
    - existing and future land use plan;
    - master storm water management plan that addresses existing and future needs;
    - wastewater management plan including septic tank maintenance programs;
    - infrastructure and capital improvements plan

Development of a watershed management plan may involve establishing general land use designations that define allowable activities on a parcel of land. For example, land designated for low-density residential use would be limited to a density of two houses per acre, provided that all other regulations and requirements are met. All development activities allowed in a use category should be defined. By guiding uses within the planning areas, impacts to surface waters from urban runoff can be controlled. Those areas identified in the resource inventory and information analysis phase as environmentally sensitive and important to maintaining water quality can be preserved through various measures supported by State or local goals, objectives, and policies.

The following are examples of plan development:

LOCATION	PROGRAM	COST
Florida	• Local governments (counties and incorporated municipalities) were required to develop comprehensive plans based on existing information to guide growth and development in the short term (5 years) and long term (20 to 25 years). • Local plans must be consistent with the State plan and the State Growth Management law. • Each plan must identify environmentally sensitive areas and areas with water quality problems.	Cost information specific to those parts of the plans relating to NPS pollution was not available.
Fairfax County, Virginia	• The Environmental Quality Corridor (EQC) System was established to preserve floodplains, wetlands, shoreline areas, and steep valley slopes. • EQCs are defined in the county's comprehensive plan and identified on the county land use map. • If a parcel of land subject to a zoning or land use designation change contains an EQC, it is set aside by the developer as part of development approval. Since its initiation, tens of thousands of acres have been set aside through the EQC program.	The cost of implementing the program is part of the operating budget of the County Planning Department (Fairfax County Planning Department, personal communication, 1991).
Howard County, Maryland	• A Land Preservation and Recreation Plan was developed as part of the county comprehensive plan. • Open space resources are purchased for preservation and recreation.	The annual cost to update the plan, $25,000, is funded by the State. In FY 1990, the county received $1.14 million in State funds to update the plan and to acquire land (Jenkins, 1991).

c. Plan Implementation

Once critical areas have been identified, land use designations have been defined, and goals have been established to guide activities in the watershed, implementation strategies can be developed. At this point, the requirements of future development are defined. These requirements include, but are not limited to, permitted uses, construction techniques, and protective maintenance measures. Land development regulations may also prescribe natural performance standards; for example, "rates of runoff or soil loss should be no greater than predevelopment conditions" (USEPA, 1977). Listed below are examples of the types of development regulations and other implementation tools that have been successful at controlling nonpoint source pollution.

- *Development of ordinances or regulations requiring NPS pollution controls for new development and redevelopment.*

  These ordinances or regulations should address, at a minimum:

  (1) Control of off-site urban runoff discharges (to control potential impacts of flooding);

  (2) The use of source control BMPs and treatment BMPs;

  (3) The performance expectations of BMPs, specifying design storm size, frequency, and minimum removal effectiveness, as specified by the State or local government;

  (4) The protection of stream channels, natural drainage ways, and wetlands;

  (5) Erosion and sediment control requirements for new construction and redevelopment; and

  (6) Treatment BMP operation and maintenance requirements and designation of responsible parties.

- *Infrastructure planning*

  Infrastructure planning is the multiyear scheduling and implementation of public physical improvements (infrastructure), such as roads, sewers, potable water delivery, landfills, public transportation, and urban runoff management facilities. Infrastructure planning can be an effective practice to help guide development patterns away from areas that provide water quality benefits, are susceptible to erosion, or are sensitive to disturbance or pollutant loadings. Where possible, long-term comprehensive plans to prevent the conversion of these areas to more intensive land uses should be drafted and adopted. Infrastructure should be planned for and sited in areas that have the capacity to sustain environmentally sound development. Development tends to occur in response to infrastructure availability, both existing and planned. New development should be targeted for areas that have adequate infrastructure to support growth in order to promote infill development, prevent urban sprawl, and discourage the use of septic tanks where they are inappropriate (International City Management Association, 1979). Infill development may have the added advantage of municipal cost savings.

  To discourage development in the environmentally sensitive East Everglades area, Dade County, Florida, has developed an urban services boundary (USB). In areas outside the USB, the county will not provide infrastructure and has kept land use densities very low. This strategy was selected to prevent urban sprawl, protect the Everglades wetlands (outside of Everglades National Park), and minimize the costs of providing services countywide. The area is defined in the county comprehensive plan, and restrictions have been implemented through the land development regulations (Metro-Dade Comprehensive Development Master Plan, 1988).

  Congress has enacted similar legislation for the protection of coastal barrier islands. In 1981, the availability of Federal flood insurance for new construction on barrier islands was discontinued. In 1982, Congress passed the Coastal Barriers Resources Act, establishing the Coastal Barrier Resource System (CBRS), and terminated a variety of Federal assistance programs for designated coastal barriers, including grants for new water, sewage, and transportation systems. In 1988, similar legislation was passed for the Great Lakes area, adding 112 Great Lakes barrier islands. Additions to the CBRS in 1990 included parts of the Florida Keys, the U.S. Virgin Islands, Puerto Rico, and the Great Lakes (Simmons, 1991).

The result of the legislation and subsequent additions to the CBRS has been the establishment of 1,394,059 acres of barriers that are ineligible for Federal assistance for infrastructure and flood insurance (Simmons, 1991). This Act has helped to guide development away from these sensitive coastal areas to more suitable locations.

- *Local ordinances*

Zoning is the division of a municipality or county into districts for the purpose of regulating land use. Usually defined on a map, the allowable uses within each zone are described in an official document, such as a zoning ordinance. Zoning is enacted for a variety of reasons, including preservation of environmentally sensitive areas and areas necessary to maintain the environmental integrity of an area (International City Management Association, 1979).

Within zoning ordinances, subdivision regulations govern the process by which individual lots of land are created out of larger tracts. Subdivision regulations are intended to ensure that subdivisions are appropriately related to their surroundings. General site design standards, such as preservation of environmentally sensitive areas, are one example of subdivision regulations (International City Management Association, 1979).

Farmland preservation ordinances are another measure that can be implemented to provide open space retention, habitat protection, and watershed protection. Farmland protection may be a less costly means of controlling pollutant loadings than the implementation of urban runoff structural control practices. Much of the farmland currently being converted has soils that are stable and not highly erodible. Conversion of these farmlands often displaces farming activities to less productive, more erodible areas that may require increased nutrient and pesticide applications.

- *Limits on impervious surfaces, encouragement of open space, and promotion of cluster development*

As described earlier, urban runoff contains high concentrations of pollutants washed off impervious surfaces (roadways, parking lots, loading docks, etc.). By retaining the greatest area of pervious surface and maximizing open space, nonpoint source pollution due to runoff from impervious surfaces can be kept to a minimum.

The following are examples of open space requirements and cluster development:

LOCATION	PROGRAM	COST
Brunswick, Maine	• Recently adopted an allowable impervious area threshold of 5 percent of the site to be developed in the defined Coastal Protection Zone. • The remaining 95 percent must be left natural or landscaped.	Accomplished with a $28,000 grant (Brunswick Planning Department, personal communication, 1991).
Commonwealth of Virginia	• Provides general guidance with regard to minimum open space/maximum impervious areas to local governments within the Chesapeake Bay watershed. • While specific requirements are not associated with the guidance, local government plans must contain criteria and must be approved by the Chesapeake Bay Local Assistance Board.	Cost information specific to those parts of the guidance relating to NPS pollution was not available.

LOCATION	PROGRAM	COST
Carroll County, Maryland	• Amended its zoning ordinance to encourage cluster development and preserve open space. • This requirement has been applied to three subdivisions in the county and has resulted in the protection of more than 200 acres of wetlands (Carroll County Planning Department, personal communication, 1991).	Developed using existing county staff and funding.
State of Maryland	• Adopted the Forest Conservation Act of 1991. • Requires all public agency and private landowner submitting a subdivision plan or application for a sediment control permit for an area greater than 40,000 square feet to develop a forest conservation plan for retention of existing forest cover on the site. • Clearing essential to site development is allowed. • The Act also established a forest conservation fund for reforestation projects.	Not available.
Broward County, Florida	• Implements an open space program and encourages cluster development to reduce the amount of impervious surface, to protect water quality, and to enhance aquifer recharge (Broward County, Florida, Land Development Code, 1990).	Developed using existing county staff and funding.
New Hampshire	• Model shoreland protection ordinance. • Encourages grouping of residential units provided a minimum of 50 percent of the total parcel remains as open space.	Not available.

One way to increase open space while allowing reasonable development of land is to encourage cluster development. Clustering entails decreasing the allowable lot size while maintaining the number of allowable units on a site. Such policies provide planners the flexibility to site buildings on more suitable areas of the property and leave environmentally sensitive areas undeveloped. Criteria can be varied.

- *Setback (buffer zone) standards*

In coastal areas, setbacks or buffer zones adjacent to surface waterbodies, such as rivers, estuaries, or wetlands, provide a transition between upland development and waterbodies. The use of setbacks or buffer zones may prevent direct flow of urban runoff from impervious areas into adjoining surface waters and provide pollutant removal, sediment attenuation, and infiltration. Riparian forest buffers function as filters to remove sediment and attached pollutants, as transformers that alter the chemical composition of compounds, as sinks that store nutrients for an extended period of time, and as a source of energy for aquatic life (USEPA, 1992). Setbacks or buffer zones are commonly used to protect coastal vegetation and wildlife corridors, reduce exposure to flood hazards, and protect surface waters by reducing and cleansing urban runoff (Mantell et al., 1990). The types of development allowed in these areas are usually limited to nonhabitable structures and those necessary to allow reasonable use of the property (docks, nonenclosed gazebos, etc.).

Factors for delineating setbacks and buffer zones vary with location and environment and include seasonal water levels, the nature and extent of wetlands and floodplains, the steepness of adjacent topography, the type of riparian vegetation, and wildlife values.

EPA recommends that no habitat-disturbing activities should occur within tidal or nontidal wetlands. In addition, a buffer area should be established that is adequate to protect the identified wetland values. Minimum widths for buffers should be 50 feet for low-order headwater streams with expansion to as much as 200 feet or more for larger streams. In coastal areas, a 100-foot minimum buffer of natural vegetation landward from the mean high tide line helps to remove or reduce sediment, nutrients, and toxic substances entering surface waters (MWCOG, 1991).

Examples of setback or buffer requirements include the following:

LOCATION	PROGRAM	COST
Monroe County, Florida	• Requires a setback of 20 feet from high water on man-made or lawfully altered shorelines for all enclosed structures and 50 feet from the landward extent of mangroves or mean high tide line for natural waterbodies with unaltered shorelines (Monroe County, Florida, Code, Section 9.5-286).	Developed using existing county staff and funding.
Town of Brunswick, Maine	• Requires a buffer of 125 to 300 feet from mean high water within the Coastal Protection Zone (Section 315 of the Brunswick Zoning Ordinance), depending on the slope of the buffer, as designated on the land use map.	Developed using a $28,000 grant (Brunswick Planning Department, personal communication, 1991).
Queen Annes County, Maryland	• Established a standard shore buffer of 300 feet from the edge of tidal water or wetland, 50 percent of which must be forested.	Developed using existing county staff and funding; a bond of surety to cover the cost of implementation is required prior to development (Jenkins, 1991).
Maryland Critical Areas Regulations	• Requires a 25-foot buffer around nontidal wetlands and 100 feet landward of mean high water in tidal areas. • Allowable uses within the setback area are defined in the regulations (Chesapeake Bay Critical Areas Commission, 1988).	Developed as part of the Chesapeake Bay Critical Areas program.
City of Alexandria, Virginia	• Buffers are required as part of the city's Chesapeake Bay Preservation Ordinance. • Applies to all designated Resource Protection Areas (RPAs). • The buffer must achieve 75 percent reduction of sediments and 40 percent reduction of nutrients (100-foot-wide buffer is considered adequate to achieve this standard; smaller widths may be allowed if they are proven to meet the sediment and nutrient removal requirements). • Indigenous vegetation removal is limited to that necessary to provide reasonable sight lines, access paths, general woodlot management, and BMP implementation.	Not available.

LOCATION	PROGRAM	COST
Northeastern Illinois Planning Commission	• Model ordinance • Suggests 75-foot setback from the ordinary high watermark of streams, lakes, ponds, and edge of wetlands or the boundary of the 100-year floodplain (as defined by FEMA), whichever is greater. • Suggests a minimum 25-foot-wide natural vegetation strip from the ordinary highwater mark of perennial and intermittent streams, lakes, ponds, and the edge of wetlands.	Not available

- *Slope restrictions*

Slope restrictions can be effective tools to control erosion and sediment transport. Erosion rates depend on several site-specific factors including soil type, vegetative cover, and rainfall intensity. In general, as slope increases, there is a corresponding increase in runoff water velocity, which may result in increased erosion and sediment transport to surface waters (Schwab et al., 1981; Dunn and Leopold, 1978). The Maryland Chesapeake Bay Critical Areas Program prohibits clearing on slopes greater than 25 percent (Chesapeake Bay Critical Areas Commission, 1988).

- *Site plan reviews and approval*

A site plan review involves review of specific development proposals for consistency with the laws and regulations of the local government of jurisdiction. To ensure that natural resources necessary for protecting surface water quality are preserved, inspection of a potential development site should occur. Inspection ensures that the information presented in any application for development approval is accurate and that sensitive areas are noted for preservation. Inspections should also be conducted during and after development to ensure compliance with development conditions. Depending on the size of the local government and the amount of new development occurring, this inspection could be incorporated into the duties of existing staff at minimal additional cost to the local government or could require the addition of staff to conduct onsite inspections and monitoring. The effectiveness of such a program depends on the ability of the inspectors to evaluate property for its natural resource value and the practices used to protect areas necessary for the preservation of water quality.

Development approvals should contain conditions requiring steps to be taken to maintain the environmental integrity of the area and prevent degradation due to nonpoint source pollution, consistent with the goals, objectives, and policies of the comprehensive program and the requirements of the land development regulations. The criteria for new development are outlined as part of a development permit. Examples include the following:

- Areas for preservation or mitigation may be identified, similar to the Fairfax County Environmental Quality Corridor System (page 44).

- The use of nonstructural and structural best management practices described in this chapter for controlling nonpoint source pollution may be a condition of development approval.

- Setbacks and limits on impervious areas may be clearly defined in a condition for development approval, as is being done in the programs discussed earlier such as Monroe County, Florida, Queen Annes County, Maryland, State of Maryland Critical Areas Program, Town of Brunswick, Maine, and the Northeastern Illinois Planning Commission (pages 48 and 49).

- Reduce the use of pesticides and fertilizers on landscaped areas by encouraging the use of vegetation that is adaptable to the environment and requires minimal maintenance. (Xeriscaping is described later in this chapter.)

- *Designation of an entity or individual who is responsible for maintaining the infrastructure, including the urban runoff management systems*

  The responsible party should be trained in the maintenance and management of urban runoff management systems. If desired, the local government could be designated to maintain urban runoff systems, with financial compensation from the developer. Because they are not usually trained in infrastructure maintenance, homeowners groups are not the best entity for monitoring infrastructure for adequacy, especially urban runoff management systems. This responsibility should belong to a responsible party who understands the complexity of urban runoff management systems, can determine when such systems are not functioning properly, and has the resources to correct the problem. Again, this is a duty that the local government can assume, with either existing staff or additional staff, depending on the size of the local government and the amount of new development occurring. The amount of funding needed depends on the size of the local government.

- *Official mapping*

  Official maps can be used to designate and/or protect environmentally sensitive areas, zoning districts, identified land uses, or other areas that provide water quality benefits. When approved by the local governing body, these maps can be used as legal instruments to make land use decisions related to nonpoint source pollution.

- *Environmental impact assessment statements*

  To evaluate the impact that proposed development may have on the natural resources of an area, some counties and municipalities require an environmental assessment as part of the development approval processes. These assessments can be incorporated into the land development regulation process. Areas to be covered include geology, slopes, vegetation, historical features, wildlife, and infrastructure needs (International City Management Association, 1979).

d. Cost of Planning Programs

Cost information was provided for several of the practices discussed in this section. The cost of planning programs depends on a variety of factors, including the level of effort needed to complete and implement a program. As discussed earlier, many of the practices described in this section can be incorporated into ongoing activities of a State or local government.

The Florida legislature funded the development of comprehensive programs and land development regulations required by the Local Government Comprehensive Planning and Land Development Regulation Act (1985). Distribution of funds was based on population according to formulas used for determining funding for the plan and land development regulations. A base amount was given to all counties that requested it. The balance of the monies was allocated to each county in an amount proportionate to its share of the total unincorporated population of all the counties. A similar distribution process was used for local governments. A total of $2.1 million was allocated for plan development; however, not all components of the plans address NPS issues.

The effect of planning programs depends on many variables, including implementation of programs and monitoring of conformance with conditions of development approval.

5. Land or Development Rights Acquisition Practices and Cost Information

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.

An effective way to preserve land necessary for protecting the environmental integrity of an area is to acquire it outright or to limit development rights. The following practices can be used to protect beneficial uses.

a. *Fee Simple Acquisition/Conservation Easements*

The most direct way to protect land for preservation purposes and associated nonpoint source control functions is fee simple acquisition, through either purchase or donation. Once a suitable area is identified for preservation, the area may be acquired along with the development rights. The more development rights that are associated with a piece of property, the more expensive the property. Many State and local governments and private organizations have programs for purchasing land.

Conservation easements are restrictions put on property that legally restrict the present and future use of the land. For preservation purposes, the easement holder is usually not the owner of the property and is able to control property rights that a landowner could use that might cause adverse impacts to resources on the property. In effect, the property owner gives up development rights within the easement while retaining fee ownership of the property (Mantell et al., 1990; Barrett and Livermore, 1983).

b. *Transfer of Development Rights*

The principle of transfer of development rights (TDR) is based on the concept that ownership of real property includes the ownership of a bundle of rights that goes with it. These rights may include densities granted by a certain use designation, environmental permits, zoning approvals, and others. Certain properties have a bigger bundle of rights than others, depending on what approvals have been received by the owner. The TDR system takes all or some of the rights on one piece of property and moves them to another parcel. The purpose of TDRs is to shift future development potential from an area that is determined to be unsuitable for development (sending site) to an area deemed more suitable (receiving site). The development potential can be measured in a variety of ways, including number of dwelling units, square footage, acres, or number of parking spaces. Most TDR systems require a legal restriction for future development on the sending site. TDR programs can be either fixed so that there are only a certain number of sending and receiving sites in an area or flexible so that a sender and receiver can be matched as the situation allows (Mantell et al., 1990; Barrett and Livermore, 1983).

This system is useful for the preservation of those areas thought necessary for maintaining the quality of surface waters in that development rights associated with the environmentally sensitive areas can be transferred to less sensitive areas. There are several examples in the United States where TDRs have been used. Some of the more successful projects involve preservation of the New Jersey Pine Barrens and the Santa Monica Mountains in California. For the TDR concept to work, receiving and sending sites should be identified and evaluated, a program that is simple and flexible should be developed, and the use of the program should be promoted and facilitated (Mantell et al., 1990).

c. *Purchase of Development Rights*

In this process, the rights of development are purchased while the remaining rights remain with the fee title holder. Restrictions in the deed make it clear that the land cannot be developed based on the rights that have been purchased (Mantell et al., 1990).

Howard County, Maryland, has the goal of preserving 20,000 acres of farmland. Development rights are acquired in perpetuity with one-fourth of one percent of the local land transfer tax used as funding. There is no cap on the percent of assessed value that may be considered development value, and payment for development rights may be spread over 30 years to ease the capital gains tax burden on the landowner (Jenkins, 1991).

d. Land Trusts

Land trusts may be established as publicly or privately sponsored nonprofit organizations with the goal of holding lands or conservation easements for the protection of habitat, water quality, recreation, or scenic value or for agricultural preservation. A land trust may also preacquire properties that are conservation priorities if the land trust enters the development market when government funds are not immediately available by acquiring bank funding with the government as guarantor (Jenkins, 1991).

e. Agricultural and Forest Districts

Agricultural or forest districting is an alternative to acquisition of land or development rights. Jurisdictions may choose to allow landowners to apply for designation of land as an Agricultural or Forest District. Tax benefits are received in exchange for a commitment to maintain the land in agriculture, forest, or open space.

Fairfax County, Virginia, taxes land designated as Agricultural or Forest District based on the present use valuation rather than the usual potential use valuation. A commitment to agricultural or forestry activities must be shown, and sound land management practices must be used. The districts are established and renewed for 8-year periods (Jenkins, 1991).

f. Cost and Effectiveness of Land Acquisition Programs

The cost associated with land acquisition programs varies, depending on the desired outcome. If land is to be purchased, the cost will vary depending on the value of the land. An additional cost to be considered is the maintenance of the property once it is in public ownership. Easements and development rights are less expensive, and maintenance of the property is retained by the owner. Depending on the size of the local government, implementation of these programs is usually part of the operating budget of the appropriate agency (planning department or parks and recreation department, for example) and additional operational funding for implementation is dependent on the size of the local government.

The effectiveness of a land acquisition program is determined by the size of the parcel and the difference between predevelopment and potential postdevelopment pollutant loading rates. In addition, wetlands and riparian areas have been shown to reduce pollutant loadings. The acquisition and preservation of these areas can be extremely important to water quality protection and decrease the cost of implementing structural BMPs. However, the use of wetlands for urban runoff treatment, in general, should be discouraged. Where no other alternative exists, States and local governments can target upland areas for acquisition to minimize the impacts to wetlands and preserve the function of wetlands. One option for acquiring land is a public/private partnership. Several examples of such partnerships exist throughout the country. Harford County, Maryland, has targeted areas for purchase of conservation easements. The county staff is working jointly with a local land trust to acquire conservation easements and to educate people in environmentally sound land use practices. The estimated cost for the program is $60,000 per year (Jenkins, 1991). To aid in the establishment of two local land trusts, Anne Arundel County, Maryland, provided $350,000 in seed money for capital expenditures such as land and easement procurement. The county also gives staff assistance to volunteers; additional support comes from contributions of money or land, grants, and fundraisers (Jenkins 1991).

C. Site Development Management Measure

Plan, design, and develop sites to:

(1) Protect areas that provide important water quality benefits and/or are particularly susceptible to erosion and sediment loss;

(2) Limit increases of impervious areas, except where necessary;

(3) Limit land disturbance activities such as clearing and grading, and cut and fill to reduce erosion and sediment loss; and

(4) Limit disturbance of natural drainage features and vegetation.

1. Applicability

This management measure is intended to be applied by States to all site development activities including those associated with roads, highways, and bridges. Under the Coastal Zone Act Reauthorization Amendments of 1990, States are subject to a number of requirements as they develop coastal NPS programs in conformity with this management measure and will have flexibility in doing so. The application of management measures by States is described more fully in *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance*, published jointly by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce.

2. Description

The goal of this management measure is to reduce the generation of nonpoint source pollution and to mitigate the impacts of urban runoff and associated pollutants from all site development, including activities associated with roads, highways, and bridges. Management Measure II.C is intended to provide guidance for controlling nonpoint source pollution through the proper design and development of individual sites. This management measures differs from Management Measure II.A, which applies to postdevelopment runoff, in that Management Measure II.C is intended to provide controls and policies that are to be applied during the site planning and review process. These controls and policies are necessary to ensure that development occurs so that nonpoint source concerns are incorporated during the site selection and the project design and review phases. While the goals of the Watershed Protection Management Measure (II.B) are similar, Management Measure II.C is intended to apply to individual sites rather than watershed basins or regional drainage basins. The goals of both the Site Development and Watershed Protection Management Measures are, however, intended to be complementary and the measures should be used within a comprehensive framework to reduce nonpoint source pollution.

Programs designed to control nonpoint source pollution resulting from site development, both during and after construction, should be developed to include provisions for:

- Site plan review and conditioned approval to ensure that the integrity of environmentally sensitive areas and areas necessary for maintaining surface water quality will not be lost;

- Requirements for erosion and sediment control plan review and approval prior to issuance of appropriate development permits; and

- Guidance on appropriate pollution prevention practices to be incorporated into site development and use.

In addition to the preceding provisions, where applicable, the following objectives should be incorporated into the site development process:

- During site development, disturb the smallest area necessary to perform current activities to reduce erosion and offsite transport of sediment;

- Avoid disturbance of unstable soils or soils particularly susceptible to erosion and sediment loss, and favor sites where development will minimize erosion and sediment loss;

- Where appropriate, protect and retain indigenous vegetation to decrease concentrated flows and to maintain site hydrology;

- Minimize, to the extent practicable, the percentage of impervious area on-site;

- Properly manage all maintained landscapes to avoid water quality impacts;

- Avoid alteration, modification, or destruction of natural drainage features on-site; and

- Design sites so that natural buffers adjacent to coastal waterbodies and their tributaries are preserved.

The use of site planning and evaluation can significantly reduce the cost of providing structural controls to retain sediment on the development site. Long-term maintenance burdens may also be reduced. Good site planning not only can attenuate runoff from development, but also can improve the effectiveness of the conveyance and treatment components of an urban runoff management system (MWCOG, 1991).

During the site design process, planners should further identify sensitive areas and land forms that may provide water quality protection. These areas should be targeted for preservation or conservation and incorporated into site design. Highly erodible soils should be avoided. By siting development away from erodible soils, it is possible to significantly reduce the amount of erosion, although soil type, topography, vegetation, and climatological conditions affect the degree of erosion resulting from land disturbance activities both during and after construction. In the United States, it has been estimated that human activity causes the transport of nearly 4 billion tons of sediment annually, one-fourth of which eventually reaches the ocean. Sediment loads from developing areas where new construction is occurring can be 5 to 500 times greater than loadings from undeveloped rural areas (Gray, 1972). Natural erosion rates from forested areas or well-sodded prairies are in the range of 0.1 to 1.0 ton of soil per acre per year (Washington Department of Ecology, 1989). Because many nonpoint source pollutants, including heavy metals and nutrients, adsorb to sediments, it is important to limit the volume of sediment leaving a site and entering surface waters.

The Maryland State Highway Administration has developed initiatives to protect sensitive habitats as part of the governor's program to clean up and preserve the Chesapeake Bay. A selection of these initiatives include the following:

- Use of turbidity curtains to protect sensitive sections of a waterway during construction;

- Inspection and maintenance of runoff controls after every storm event;

- Immediate notification of noncompliance and follow-up inspection, when noncompliance occurs;

- A 72-hour stabilization requirement;
- Oversizing of sediment traps and basins depending on right-of-way constraints;
- Innovative scheduling for paving versus vegetative stabilization and implementation of infiltration practices to reduce thermal impacts;
- Minimal clearing of forest areas; and
- Installation of traps and basins prior to grading (Maryland State Highway Administration, 1990).

3. Management Measure Selection

This management measure was selected because the components of the measure have already been implemented, to varying degrees, by State and local governments. For example, the States of California, Maryland, Delaware, and Florida and the local governments of Montgomery, Prince Georges, and Anne Arundel counties in Maryland have implemented these concepts in State or local ordinances and in erosion and sediment control regulations. This measure is intended to provide States and local governments with general guidance on nonpoint source pollution objectives that can be integrated into the site planning process. The components of the management measure were selected to represent the minimum provisions that State and local governments must implement.

This approach was adopted to use existing programs and staff, thereby reducing administrative burdens and implementation costs as much as possible. A significant number of local governments have programs to oversee and review the site development process. In many communities, the costs of implementing this measure within the scope of existing programs may be nominal.

4. Practices and Cost Information for Control of Erosion During Site Development

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.

a. Erosion and Sediment Control Plans and Programs

Structural control measures for reducing impacts from erosion during site construction are discussed in the Construction Management Measure. These practices can be implemented as part of plans established in erosion and sediment control ordinances by local government or State laws. A well-thought-out plan for urban runoff management on construction sites can control erosion, retain sediments on the site, and reduce the environmental effects of runoff. In addition to a plan for BMP use, contractors should develop schedules that minimize the area of exposed soil at any given time, particularly during times of heavy or frequent rains. Table 4-12 lists items that should be considered in an erosion and sediment control (ESC) plan. Table 4-13 contains examples of sediment and erosion control requirements implemented at the State and local levels. All temporary erosion and sediment control practices that will be used during the construction phase should be detailed in architectural or engineering drawings to ensure that they are properly implemented. Inclusion of temporary pollution control practices on construction drawings also ensures that their costs are included in the pricing and bidding process (USEPA, 1973).

Table 4-12. Items to Consider in Developing an Erosion and Sediment Control Plan (Adapted from Goldman, 1986)

Item	Description
Schedule grading and construction to minimize soil exposure.	• Schedule projects so clearing and grading are done during the dry season or the time of minimum erosion potential. Many parts of the country have a time of year when erosion potential is relatively low and carefully planned construction scheduling could be very effective. • Stage construction so that one area can be stabilized before another is disturbed. This practice reduces the time that an area is left unstabilized.
Retain existing vegetation wherever feasible.	• Clear only those areas that are essential for completing site construction. • Avoid disturbing vegetation on steep slopes or other critical areas and locate material stockpiles, borrow areas, and access roads away from critical areas. • Route construction traffic to avoid existing or newly planted vegetation. • Physically mark off limits of land disturbance with tape, signs, or barriers. This ensures that the bulldozer operator knows the proposed limits of clearing. • Protect natural vegetation with fencing, tree armoring, retaining walls, or tree walls.
Stabilize all denuded areas within 15 calendar days after final grading. Disturbed areas that are inactive and will be exposed to rain for 30 days or more should also be temporarily stabilized.	• During favorable seeding dates and in areas where vegetation can be established, the following should be implemented: - Use seeding and fertilizing in very flat, nonsensitive areas with favorable soils. - Use seeding and mulching for less erosive soil or on moderately steep slopes with moderately erosive soils in relatively sensitive areas. - Use seeding with multiple mulching treatments or sodding for highly erosive soil, very steep slopes, or sensitive areas with highly erosive soils. • If stabilization is required during the time of year that vegetation cannot be established, implement the following practices: - On moderate slopes or soil that is not highly erodible, mulching should be employed. - On steep slopes or highly erodible soils, multiple mulching treatments should be used. • If in high elevation or desert site where grasses cannot survive due to harsh environment, at a minimum, plant native shrubs. • Before stabilizing an area, make sure necessary controls (e.g., diversion of runoff) are in place. • Where practical, stockpile topsoil and reapply to revegetate site. • Cover or stabilize topsoil stockpiles. • For high potential for wind-blown sediment transport, prior to stabilization protect with dust controls such as wind barriers, mulching, tillage, or sprinkling.
Divert runoff away from denuded areas or newly seeded slopes.	• Above disturbed areas, construct dike or swale or install pipe slope drain to intercept runoff and convey it to a permanent channel or storm drain.
Minimize length and steepness of slopes.	• On long or steep disturbed or man-made slopes, construct benches, terraces, or ditches at regular intervals to intercept runoff.

Table 4-12. (Continued)

Item	Description
Prepare drainageways and outlets to handle concentrated or increased runoff.	• Provide lining for any existing or newly constructed channel on-site or off-site so the 2-year storm channel velocity does not cause erosion. • Check dams should be installed on temporary swales that have erosive velocity but due to their short service life cannot support a vegetative lining.
Trap sediment onsite (sediment controls).	• In areas where greater than 5 acres drain to a point, sediment basin should be installed. • In areas where less than 5 acres of concentrated flow leaves the site, silt traps should be installed. • In areas where sheet flow leaves the site and the drainage area is less than 0.5 ac/100 ft of flow, filter fabric fence should be installed. • In areas where sheet flow leaves the site and the drainage area is greater than 0.5 ac/100 ft of flow, perimeter dikes should be installed and flow should be diverted to a sediment trap or sediment basin. • Install inlet protection around all storm drain inlets. • Install construction entrance (gravel pad to collect mud and sediment from wheels) and route all traffic leaving the site to the construction entrance. • Install all sediment controls prior to grading.
Inspect and maintain control measures.	• Remove sediment from sediment traps and filter fence when silted to half capacity. • Inspect and repair, as needed, all controls after each storm event.

NOTE: These are recommendations only and are not intended to be all-inclusive.

Table 4-13. State and Local Construction Site Erosion and Sediment Control Plan Requirements

State or Local Government	General Requirements
Delaware	State law requires erosion and sediment control plans as part of site development approval on construction sites over 5,000 square feet. The State has adopted an ESC handbook. Temporary or permanent stabilization must occur within 14 calendar days of disturbance.
Florida	State law requires erosion and sediment control plans on all construction sites requiring a storm water management permit.
Maine	State law requires ESC plans for construction sites adjacent to a wetland or waterbody. Measures should ensure that soil is stabilized to prevent erosion of shoreline and siltation of the waterbody. The ESC must prevent the wash of materials into surface waters. Sites must be stabilized at completion of construction or if there is no activity for 7 calendar days. If temporary stabilization is used, permanent stabilization must occur within 30 calendar days; if not, permanent stabilization is required upon completion of construction.
Maryland	State law requires ESC plans for all construction sites over 5,000 square feet. If there is no activity on a construction site for 14 calendar days, the site must be seeded. Permanent stabilization must occur within 7 calendar days.
Michigan	State law requires ESC plans for sites over 1 acre or within 500 feet of a waterbody. Permanent stabilization must occur within 15 calendar days of final grading. Temporary stabilization is required within 30 days if construction activity ceases.
New Jersey	State law requires ESC plans for sites over 5,000 square feet.
North Carolina	State law requires ESC plans on construction sites over 1 acre. Controls must be sufficient to retain the sediment generated by land disturbance activities. Stabilization must occur within 30 working days of completion of any phase of development.
Ohio	State law requires ESC plans for sites larger than 5 acres. Permanent stabilization must occur within 7 calendar days of final grading or when there has been no construction activity on the site for 45 days.
Pennsylvania	State law requires ESC plans for all development; however, the State reviews only plans for sites greater than 25 acres. Sites must be stabilized as soon as possible after grading. Temporary stabilization is required within 70 days if the site will be inactive for more than 30 days. Permanent stabilization is required if the site will be inactive for more than 1 year.
South Carolina	State law requires an ESC plan for all residential, commercial, industrial, or institutional land use, unless specifically exempted. Perimeter controls must be installed, and temporary or permanent stabilization is required for topsoil stockpiles and all other disturbed areas within 7 calendar days of site disturbance.
Virginia	For areas within the jurisdiction of the Chesapeake Bay Preservation Act, no more land is to be disturbed than is necessary to provide for the allowed development. Indigenous vegetation must be preserved to the greatest extent possible.
Washington	State law mandated development of a State storm water management plan, including erosion control provisions. In response, the Department of Ecology is to develop construction activity regulations.

Table 4-13. (Continued)

State or Local Government	General Requirements
King County, WA	King County Code requires submission of a comprehensive plan in accordance with BMPs in King County Conservation District's publication, *Construction and Water Quality: A Guide to Recommended Construction Practices for the Control of Erosion and Sedimentation in King County.*
City of Bellevue, WA	A Temporary Erosion/Sedimentation Control Plan is required for any construction requiring a storm water detention facility or a Clearing and Grading Permit.
Puget Sound Basin, WA	Program Implementation Guidance requires all exposed and unworked soils to be stabilized by suitable application of BMPs. From October 1 to April 30, no soils shall remain unstabilized for more than 2 days. From May 1 to September 30, no soils shall remain unstabilized for more than 7 days. Prior to leaving the site, stormwater runoff shall pass through a sediment pond or sediment trap, or other appropriate BMPs.
Wisconsin	State law requires ESC plans for sites over 4,000 square feet. Permanent or temporary stabilization is required within 7 days.
Colleton County, SC	The county Development Standards Ordinance requires that BMPs be used during development or land-disturbing activity affecting greater than 1 acre. The State's guidelines for BMPs are adopted by reference.
Birmingham, AL	Through the city's Soil and Erosion Sediment Control Code, a clearing and earthwork permit is required for most construction sites over 10,000 square feet. The disturbed area must be stabilized as quickly as practicable.

b. Phasing and Limiting Areas of Disturbance

This practice reduces the potential for erosion and can be accomplished by prohibiting clearing and grading from all postdevelopment buffer zones, configuring the site plan to retain high amounts of open space, and using phased construction sequencing to limit the amount of disturbed area at any given time.

c. Require vegetative stabilization.

Rapid establishment of a grass or mulch cover on a cleared or graded area at construction sites can reduce suspended sediment levels to surface waters by up to sixfold. Mandatory temporary stabilization of areas left undisturbed for 7 to 14 days is recommended, unless conditions indicate otherwise. Section III.A contains detailed information regarding vegetative stabilization practices.

d. Minimum Disturbance/Minimum Maintenance

Minimum disturbance/minimum maintenance is an approach to site development in which clearing and site grading are allowed only within a carefully prescribed building area, preserving and protecting the existing natural vegetation. Landscapes that demand significant amounts of chemical treatment should be avoided. Minimum disturbance/minimum maintenance strategies help minimize nonpoint source impacts associated with the application of fertilizers, pesticides, and herbicides that result from new land development. The retention of existing vegetation may also help maintain predevelopment runoff volumes and peak rates of discharge and thus reduce erosion.

Translation of a concept such as minimum disturbance/minimum maintenance into straightforward numerical standards and criteria is difficult. A certain level of interpretation and judgment is often necessary. Nevertheless, basic standards can be established. Assuming that land use categories have been established through the local land use plans or zoning ordinances; vegetation mapping can be used to illustrate where the proposed development can be constructed with minimal impact on existing vegetation. The area to be disturbed should be identified for all buildings, structures, roads, walkways, and activity areas. The exact dimensions of this disturbance will be subjective and will depend on factors such as lot size and site-specific conditions. For example, a single-family residential development can be constructed with a narrower zone of disturbance than a mall or office park that may require larger construction equipment with greater maneuverability. In general, an extremely conservative zone width would be 10 feet beyond the roof line of a structure or dwelling unit; a more moderate criterion might be 25 feet. Mall sites and large residential developments are typically mass-graded. Limits of Disturbance (LOD) are usually required on all erosion and sediment control plans and are always a function of grading requirements.

Program Implementation Costs

The annual costs of establishing and implementing a minimum disturbance/minimum maintenance (MD/MM) program are estimated below. In some cases, the MD/MM tasks can be incorporated within the framework of the existing land development review process and implementation costs would only be additive. A new program, however, would need trained staff responsible for ensuring that developers properly integrate the requirements for the MD/MM into their respective site plans. The need to inspect sites during construction would also result in additional costs. The annual operating costs of implementing such a program will vary depending on the size of the community and the degree of new development. For a typical program, estimated costs may be approximately $110,000 for one professional staffperson and can be divided as follows:

Professional staff	$ 60,000
Support staff	$ 30,000
Office space	$ 15,000
Office expenses	$ 5,000
Total	$110,000 per year

These figures are based on approximate average salaries and expenses for similar programs.

The manner by which a turf management or landscape control ordinance is developed or implemented varies to some extent, county by county, State by State. The process would reflect county size, the framework of existing government agencies, techniques of governance, and numerous other factors. Costs would vary as well. These specific aspects of the program would be established by any initial studies and establishment of program requirements, as discussed above. Also, as experience is gained by the staff and the minimum disturbance/minimum maintenance concept is better understood by the development community, the need for services might be expected to decrease as the result of increased program operation efficiency.

5. Site Planning Practices

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.

a. Clustering

Clustering development is used to concentrate development and construction activity on a limited portion of a site, leaving the remaining portion undisturbed. This allows for the design of more effective erosion and sediment control and urban runoff management plans for the sites, as described in Section II.A. It also provides a mechanism for preserving environmentally sensitive areas and reducing road lengths and impervious parking areas.

NOTE: A common belief is that low-density development is more environmentally sound because it results in increased open space. Minimum lot size requirements can result in suburban sprawl. Many of these areas are heavily landscaped and therefore have the potential to contribute significant loadings of nutrients and pesticides to surface waters. In many cases, clustering and infill development may be more environmentally sound strategies. They may also result in a cost savings for municipalities because clustering and infill development usually require less infrastructure, including urban runoff treatment systems. The imposition of density controls may preclude clustering. While minimum lot size requirements are useful in some instances, such as farmland preservation, zoning ordinances should not preclude the implementation of clustered development as an alternative to traditional suburban development.

b. *Performance Criteria*

Performance criteria for site development contain certain built-in safeguards to protect natural features. Performance criteria often apply not to individual zoning districts but to the site being regulated or protected and set fixed protection levels for specific resources that are not based on general zoning definitions.

c. *Site Fingerprinting*

The total amount of disturbed area within a site can be reduced by fingerprinting development. Fingerprinting places development away from environmentally sensitive areas (wetlands, steep slopes, etc.), future open spaces, tree save areas, future restoration areas, and temporary and permanent vegetative forest buffer zones. At a subdivision or lot level, ground disturbance is confined to areas where structures, roads, and rights of way will exist after construction is complete.

d. *Preserving Natural Drainage Features and Natural Depressional Storage Areas*

As discussed in the Watershed Protection Management Measure, natural drainage features should be preserved as development occurs. This can be done at the site planning stage as well as the watershed planning stage and is desirable because of the ability of natural drainage features to infiltrate and attenuate flows and filter pollutants. Depressional storage areas, commonly found as ponded areas in fields during the wet season or large runoff events, serve the purpose of reducing runoff volumes and trapping pollutants. These areas are usually filled and graded as a site is developed. Cluster development can be used to preserve natural drainage features and depressional storage areas and allow for incorporation of these features into a site design (Dreher and Price, 1992).

e. *Minimizing Imperviousness*

Through the use of various incentives, such as those found in the Maryland Chesapeake Bay Critical Areas 10 Percent Rule, a general strategy of minimizing paved areas can be implemented at the site planning level. Methods used to meet this goal include:

- Reduced sidewalk widths, especially in low-traffic neighborhoods;
- Use of permeable materials for sidewalk construction;
- Mandatory open space requirements;
- Use of porous, permeable, or gritted pavement, where appropriate;
- Reduced building setbacks, which reduces the lengths of driveways and entry walks; and
- Reduced street widths by elimination of onstreet parking (where such action does not pose a safety hazard).

f. *Reducing the Hydraulic Connectivity of Impervious Surfaces*

Pollutant loading from impervious surfaces may be reduced if the impervious area does not connect directly to an impervious conveyance system. This can be done in at least four ways:

- Route runoff over lawn areas to increase infiltration;

- Discourage the direct connection of downspouts to storm sewers or the discharge of downspouts to driveways or parking lots;

- Substitute swale and pond systems to increase infiltration; and

- Reduce the use of storm sewers to drain streets, parking lots, and back yards (NIPC, 1992)

g. *Xeriscape Programs*

Xeriscaping is a landscaping concept that maximizes the conservation of water by the use of site-appropriate plants and an efficient watering system and involves the use of landscaping plants that need minimal watering, fertilization, and pesticide application. Xeriscaping can reduce the contribution of landscaped areas to coastal nonpoint source pollution. Xeriscape designs can reduce landscape maintenance by as much as 50 percent, primarily as a result of the following:

- Reduction of water loss and soil erosion through careful planning, design, and implementation;
- Reduction of mowing by limiting lawn areas and using proper fertilization techniques; and
- Reduction of fertilization through soil preparation (Clemson University, 1991).

In 1991, the Florida Legislature adopted a xeriscape law that requires State agencies to adopt and implement xeriscaping programs. The law requires that rules and guidelines for implementation of xeriscaping along highway rights-of-way and on public property associated with publicly owned buildings constructed after July 1, 1992, be adopted. Local governments are to determine whether xeriscaping is a cost-effective measure for conserving water. If so, local governments are to work with the water management districts in developing their xeriscape guidelines. Water management districts will provide financial incentives to local governments for developing xeriscape plans and ordinances. These plans must include:

- Landscape design, installation, and maintenance standards;
- Identification of prohibited plant species (invasive exotic plants);
- Identification of controlled plant species and conditions for their use;
- Specifications for maximum percentage of turf and impervious surfaces allowed in a xeriscaped area;
- Specifications for land clearing and requirements for the conservation of existing native vegetation; and
- Monitoring programs for ordinance implementation and compliance.

There is also a provision in the law requiring local governments and water management districts to promote the use of xeriscape practices in already developed areas through public education programs. California has passed a law requiring all municipalities to consider enacting water-efficient landscape requirements.

III. CONSTRUCTION ACTIVITIES

A. Construction Site Erosion and Sediment Control Management Measure

(1) Reduce erosion and, to the extent practicable, retain sediment onsite during and after construction, and

(2) Prior to land disturbance, prepare and implement an approved erosion and sediment control plan or similar administrative document that contains erosion and sediment control provisions.

1. Applicability

This management measure is intended to be applied by States to all construction activities on sites less than 5 acres in areas that do not have an NPDES permit[3] in order to control erosion and sediment loss from those sites. This management measure does not apply to: (1) construction of a detached single family home on a site of 1/2 acre or more or (2) construction that does not disturb over 5,000 square feet of land on a site. (NOTE: All construction activities, including clearing, grading, and excavation, that result in the disturbance of areas greater than or equal to 5 acres or are a part of a larger development plan are covered by the NPDES regulations and are thus excluded from these requirements.) Under the Coastal Zone Act Reauthorization Amendments of 1990, States are subject to a number of requirements as they develop coastal NPS programs in conformity with this management measure and will have flexibility in doing so. The application of management measures by States is described more fully in *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance*, published jointly by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce.

2. Description

The goal of this management measure is to reduce the sediment loadings from construction sites in coastal areas that enter surface waterbodies. This measure requires that coastal States establish new or enhance existing State erosion and sediment control (ESC) programs and/or require ESC programs at the local level. It is intended to be part of a comprehensive land use or watershed management program, as previously detailed in the Watershed and Site Development Management Measures. It is expected that State and local programs will establish criteria determined by local conditions (e.g., soil types, climate, meteorology) that reduce erosion and sediment transport from construction sites.

Runoff from construction sites is by far the largest source of sediment in urban areas under development (York County Soil and Water Conservation District, 1990). Soil erosion removes over 90 percent of sediment by tonnage in urbanizing areas where most construction activities occur (Canning, 1988). Table 4-14 illustrates some of the

[3] On May 27, 1992, the United States Court of Appeals for the Ninth Circuit invalidated EPA's exemption of construction sites smaller than 5 acres from the storm water permit program in *Natural Resources Defense Council* v. *EPA*, 965 F.2d 759 (9th Cir. 1992). EPA is conducting further rulemaking proceedings on this issue and will not require permit applications for construction activities under 5 acres until further rulemaking has been completed.

measured sediment loading rates associated with construction activities found across the United States. As seen in Table 4-14, erosion rates from natural areas such as undisturbed forested lands are typically less than one ton/acre/year, while erosion from construction sites ranges from 7.2 to over 1,000 tons/acre/year.

Table 4-14. Erosion and Sediment Problems Associated With Construction

Location	Problem	Reference
United States	Sediment loading rates vary from 36.5 to 1,000 ton/ac/yr. These are 5 to 500 times greater than those from undeveloped land. Approximately 600 million tons of soil erodes from developed sites each year. Construction site sediment in runoff can be 10 to 20 times greater than that from agricultural lands.	York County Soil and Water Conservation District, 1990
Franklin County, FL	Sediment yield (ton/ac/yr): forest < 0.5 rangeland < 0.5 tilled 1.4 construction site 30 established urban < 0.5	Franklin County, FL
Wisconsin	Erosion rates range from 30 to 200 ton/ac/yr (10 to 20 times those of cropland).	Wisconsin Legislative Council, 1991
Washington, DC	Erosion rates range from 35 to 45 ton/ac/yr (10 to 100 times greater than agriculture and stabilized urban land uses).	MWCOG, 1987
Anacostia River Basin, VA, MD, DC	Sediment yields from portions of the Anacostia Basin have been estimated at 75,000 to 132,000 ton/yr.	U.S. Army Corps of Engineers, 1990
Washington	Erosion rates range from 50 to 500 ton/ac/yr. Natural erosion rates from forests or well-sodded prairies are 0.01 to 1.0 ton/ac/yr.	Washington Department of Ecology, 1989
Anacostia River Basin, VA, MD, DC	Erosion rates range from 7.2 to 100.8 ton/ac/yr.	USGS, 1978
Alabama	1.4 million tons eroded per year.	Woodward-Clyde, 1991
North Carolina	6.7 million tons eroded per year.	
Louisiana	5.1 million tons eroded per year.	
Oklahoma	4.2 million tons eroded per year.	
Georgia	3.8 million tons eroded per year.	
Texas	3.5 million tons eroded per year.	
Tennessee	3.3 million tons eroded per year.	
Pennsylvania	3.1 million tons eroded per year.	
Ohio	3.0 million tons eroded per year.	
Kentucky	3.0 million tons eroded per year.	

Eroded sediment from construction sites creates many problems in coastal areas including adverse impacts on water quality, critical habitats, submerged aquatic vegetation (SAV) beds, recreational activities, and navigation (APWA, 1991). For example, the Miami River in Florida has been severely affected by pollution associated with upland erosion. This watershed has undergone extensive urbanization, which has included the construction of many commercial and residential buildings over the past 50 years. Sediment deposited in the Miami River channel contributes to the severe water quality and navigation problems of this once-thriving waterway, as well as Biscayne Bay (SFWMD, 1988).

ESC plans are important for controlling the adverse impacts of construction and land development and have been required by many State and local governments, as shown in Table 4-13 (in the Site Development section of this chapter). An ESC plan is a document that explains and illustrates the measures to be taken to control erosion and sediment problems on construction sites (Connecticut Council on Soil and Water Conservation, 1988). It is intended that existing State and local erosion and sediment control plans may be used to fulfill the requirements of this management measure. Where existing ESC plans do not meet the management measure criteria, inadequate plans may be enhanced to meet the management measure guidelines.

Typically, an ESC plan is part of a larger site plan and includes the following elements:

- Description of predominant soil types;
- Details of site grading including existing and proposed contours;
- Design details and locations for structural controls;
- Provisions to preserve topsoil and limit disturbance;
- Details of temporary and permanent stabilization measures; and
- Description of the sequence of construction.

ESC plans ensure that provisions for control measures are incorporated into the site planning stage of development and provide for the reduction of erosion and sediment problems and accountability if a problem occurs (York County Soil and Water Conservation District, 1990). An effective plan for urban runoff management on construction sites will control erosion, retain sediments on site, to the extent practicable, and reduce the adverse effects of runoff. Climate, topography, soils, drainage patterns, and vegetation will affect how erosion and sediment should be controlled on a site (Washington State Department of Ecology, 1989). An effective ESC plan includes both structural and nonstructural controls. Nonstructural controls address erosion control by decreasing erosion potential, whereas structural controls are both preventive and mitigative because they control both erosion and sediment movement.

Typical nonstructural erosion controls include (APWA, 1991; York County Soil and Water Conservation District, 1990):

- Planning and designing the development within the natural constraints of the site;
- Minimizing the area of bare soil exposed at one time (phased grading);
- Providing for stream crossing areas for natural and man-made areas; and
- Stabilizing cut-and-fill slopes caused by construction activities.

Structural controls include:

- Perimeter controls;
- Mulching and seeding exposed areas;
- Sediment basins and traps; and
- Filter fabric, or silt fences.

Some erosion and soil loss are unavoidable during land-disturbing activities. While proper siting and design will help prevent areas prone to erosion from being developed, construction activities will invariably produce conditions where erosion may occur. To reduce the adverse impacts associated with construction, the construction management measure suggests a system of nonstructural and structural erosion and sediment controls for incorporation into an

ESC plan. Erosion controls have distinct advantages over sediment controls. Erosion controls reduce the amount of sediment transported off-site, thereby reducing the need for sediment controls. When erosion controls are used in conjunction with sediment controls, the size of the sediment control structures and associated maintenance may be reduced, decreasing the overall treatment costs (SWRPC, 1991).

3. Management Measure Selection

This management measure was selected to minimize sediment being transported outside the perimeter of a construction site through two broad performance goals: (1) **reduce** erosion and (2) **retain** sediment onsite, to the extent practicable. These performance goals were chosen to allow States and local governments flexibility in specifying practices appropriate for local conditions.

While several commentors responding to the draft (May 1991) guidance expressed the need to define "more measurable, enforceable ways" to control sediment loadings, other commentors stressed the need to draft management measures that do not conflict with existing State programs and allow States and local governments to determine appropriate practices and design standards for their communities. These management measures were selected because virtually all coastal States control construction activities to prevent erosion and sediment loss.

The measures were specifically written for the following reasons:

(1) Predevelopment loadings may vary greatly, and some sediment loss is usually inevitable;

(2) Current practice is built on the use of systems of practices selected based on site-specific conditions; and

(3) The combined effectiveness of erosion and sediment controls in systems is not easily quantified.

4. Erosion Control Practices

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.

Erosion controls are used to reduce the amount of sediment that is detached during construction and to prevent sediment from entering runoff. Erosion control is based on two main concepts: (1) disturb the smallest area of land possible for the shortest period of time, and (2) stabilize disturbed soils to prevent erosion from occurring.

a. Schedule projects so clearing and grading are done during the time of minimum erosion potential.

Often a project can be scheduled during the time of year that the erosion potential of the site is relatively low. In many parts of the country, there is a certain period of the year when erosion potential is relatively low and construction scheduling could be very effective. For example, in the Pacific region if construction can be completed during the 6-month dry season (May 1 - October 31), temporary erosion and sediment controls may not be needed. In addition, in some parts of the country erosion potential is very high during certain parts of the year such as the spring thaw in northern areas. During this time of year, melting snowfall generates a constant runoff that can erode soil. In addition, construction vehicles can easily turn the soft, wet ground into mud, which is more easily washed offsite. Therefore, in the north, limitations should be placed on grading during the spring thaw (Goldman et al., 1986).

b. *Stage construction.*

Avoid areawide clearance of construction sites. Plan and stage land disturbance activities so that only the area currently under construction is exposed. As soon as the grading and construction in an area are complete, the area should be stabilized.

By clearing only those areas immediately essential for completing site construction, buffer zones are preserved and soil remains undisturbed until construction begins. Physical markers, such as tape, signs, or barriers, indicating the limits of land disturbance, can ensure that equipment operators know the proposed limits of clearing. The area of the watershed that is exposed to construction is important for determining the net amount of erosion. Reducing the extent of the disturbed area will ultimately reduce sediment loads to surface waters. Existing or newly planted vegetation that has been planted to stabilize disturbed areas should be protected by routing construction traffic around and protecting natural vegetation with fencing, tree armoring, retaining walls, or tree wells.

c. *Clear only areas essential for construction.*

Often areas of a construction site are unnecessarily cleared. Only those areas essential for completing construction activities should be cleared, and other areas should remain undisturbed. Additionally, the proposed limits of land disturbance should be physically marked off to ensure that only the required land area is cleared. Avoid disturbing vegetation on steep slopes or other critical areas.

d. *Locate potential nonpoint pollutant sources away from steep slopes, waterbodies, and critical areas.*

Material stockpiles, borrow areas, access roads, and other land-disturbing activities can often be located away from critical areas such as steep slopes, highly erodible soils, and areas that drain directly into sensitive waterbodies.

e. *Route construction traffic to avoid existing or newly planted vegetation.*

Where possible, construction traffic should travel over areas that must be disturbed for other construction activity. This practice will reduce the area that is cleared and susceptible to erosion.

f. *Protect natural vegetation with fencing, tree armoring, and retaining walls or tree wells.*

Tree armoring protects tree trunks from being damaged by construction equipment. Fencing can also protect tree trunks, but should be placed at the tree's drip line so that construction equipment is kept away from the tree. The tree drip line is the minimum area around a tree in which the tree's root system should not be disturbed by cut, fill, or soil compaction caused by heavy equipment. When cutting or filling must be done near a tree, a retaining wall or tree well should be used to minimize the cutting of the tree's roots or the quantity of fill placed over the tree's roots.

g. *Stockpile topsoil and reapply to revegetate site.*

Because of the high organic content of topsoil, it cannot be used as fill material or under pavement. After a site is cleared, the topsoil is typically removed. Since topsoil is essential to establish new vegetation, it should be stockpiled and then reapplied to the site for revegetation, if appropriate. Although topsoil salvaged from the existing site can often be used, it must meet certain standards and topsoil may need to be imported onto the site if the existing topsoil is not adequate for establishing new vegetation.

h. *Cover or stabilize topsoil stockpiles.*

Unprotected stockpiles are very prone to erosion and therefore stockpiles must be protected. Small stockpiles can be covered with a tarp to prevent erosion. Large stockpiles should be stabilized by erosion blankets, seeding, and/or mulching.

i. *Use wind erosion controls.*

Wind erosion controls limit the movement of dust from disturbed soil surfaces and include many different practices. Wind barriers block air currents and are effective in controlling soil blowing. Many different materials can be used as wind barriers, including solid board fence, snow fences, and bales of hay. Sprinkling moistens the soil surface with water and must be repeated as needed to be effective for preventing wind erosion (Delaware DNREC, 1989); however, applications must be monitored to prevent excessive runoff and erosion.

j. *Intercept runoff above disturbed slopes and convey it to a permanent channel or storm drain.*

Earth dikes, perimeter dikes or swales, or diversions can be used to intercept and convey runoff above disturbed areas. An earth dike is a temporary berm or ridge of compacted soil that channels water to a desired location. A perimeter dike/swale or diversion is a swale with a supporting ridge on the lower side that is constructed from the soil excavated from the adjoining swale (Delaware DNREC, 1989). These practices should be used to intercept flow from denuded areas or newly seeded areas to keep the disturbed areas from being eroded from the uphill runoff. The structures should be stabilized within 14 days of installation. A pipe slope drain, also known as a pipe drop structure, is a temporary pipe placed from the top of a slope to the bottom of the slope to convey concentrated runoff down the slope without causing erosion (Delaware DNREC, 1989).

k. *On long or steep, disturbed, or man-made slopes, construct benches, terraces, or ditches at regular intervals to intercept runoff.*

Benches, terraces, or ditches break up a slope by providing areas of low slope in the reverse direction. This keeps water from proceeding down the slope at increasing volume and velocity. Instead, the flow is directed to a suitable outlet, such as a sediment basin or trap. The frequency of benches, terraces, or ditches will depend on the erodibility of the soils, steepness and length of the slope, and rock outcrops. This practice should be used if there is a potential for erosion along the slope.

l. *Use retaining walls.*

Often retaining walls can be used to decrease the steepness of a slope. If the steepness of a slope is reduced, the runoff velocity is decreased and, therefore, the erosion potential is decreased.

m. *Provide linings for urban runoff conveyance channels.*

Often construction increases the velocity and volume of runoff, which causes erosion in newly constructed or existing urban runoff conveyance channels. If the runoff during or after construction will cause erosion in a channel, the channel should be lined or flow control BMPs installed. The first choice of lining should be grass or sod since this reduces runoff velocities and provides water quality benefits through filtration and infiltration. If the velocity in the channel would erode the grass or sod, then riprap, concrete, or gabions can be used.

n. *Use check dams.*

Check dams are small, temporary dams constructed across a swale or channel. They can be constructed using gravel or straw bales. They are used to reduce the velocity of concentrated flow and, therefore, to reduce the erosion in a swale or channel. Check dams should be used when a swale or channel will be used for a short time and therefore it is not feasible or practical to line the channel or implement flow control BMPs (Delaware DNREC, 1989).

o. Seed and fertilize.

Seeding establishes a vegetative cover on disturbed areas. Seeding is very effective in controlling soil erosion once a dense vegetative cover has been established. However, often seeding and fertilizing do not produce as thick a vegetative cover as do seed and mulch or netting. Newly established vegetation does not have as extensive a root system as existing vegetation and therefore is more prone to erosion, especially on steep slopes. Care should be taken when fertilizing to avoid untimely or excessive application. Since the practice of seeding and fertilizing does not provide any protection during the time of vegetative establishment, it should be used only on favorable soils in very flat areas and not in sensitive areas.

p. Use seeding and mulch/mats.

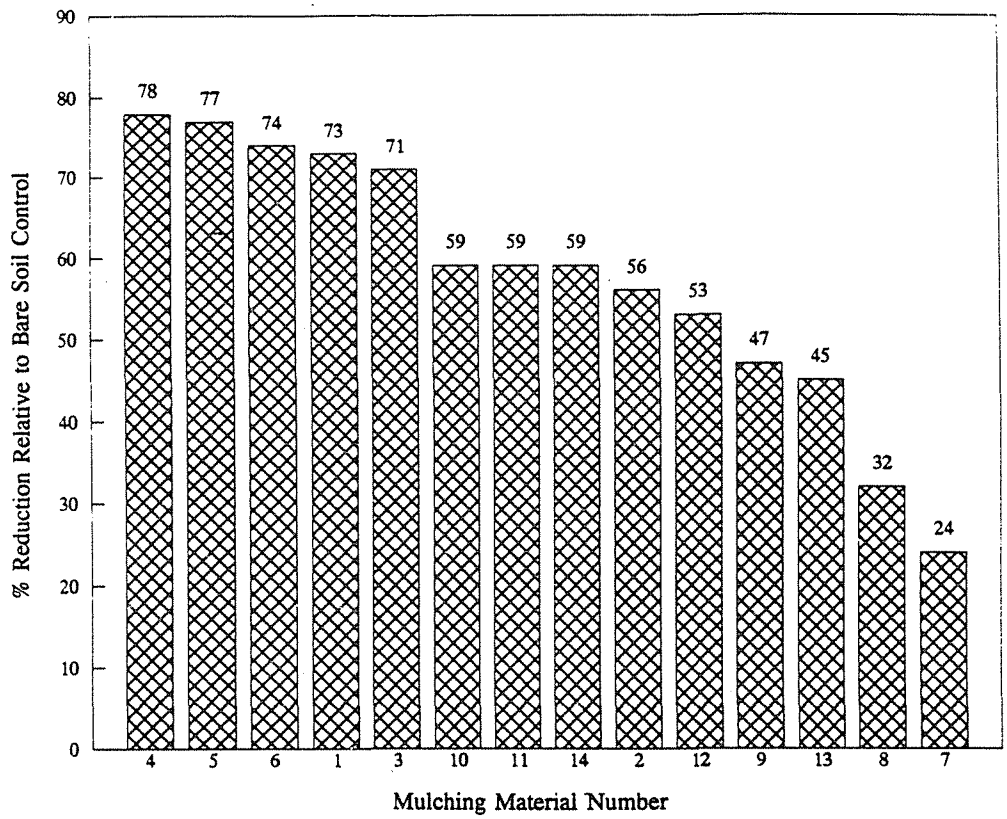
Seeding establishes a vegetative cover on disturbed areas. Seeding is very effective in controlling soil erosion once the vegetative cover has been established. The mulching/mats protect the disturbed area while the vegetation becomes established.

The management of land by using ground cover reduces erosion by reducing the flow rate of runoff and the raindrop impact. Bare soils should be seeded or otherwise stabilized within 15 calendar days after final grading. Denuded areas that are inactive and will be exposed to rain for 30 days or more should also be temporarily stabilized, usually by planting seeds and establishing vegetation during favorable seasons in areas where vegetation can be established. In very flat, non-sensitive areas with favorable soils, stabilization may involve simply seeding and fertilizing. Mulching and/or sodding may be necessary as slopes become moderate to steep, as soils become more erosive, and as areas become more sensitive.

q. Use mulch/mats.

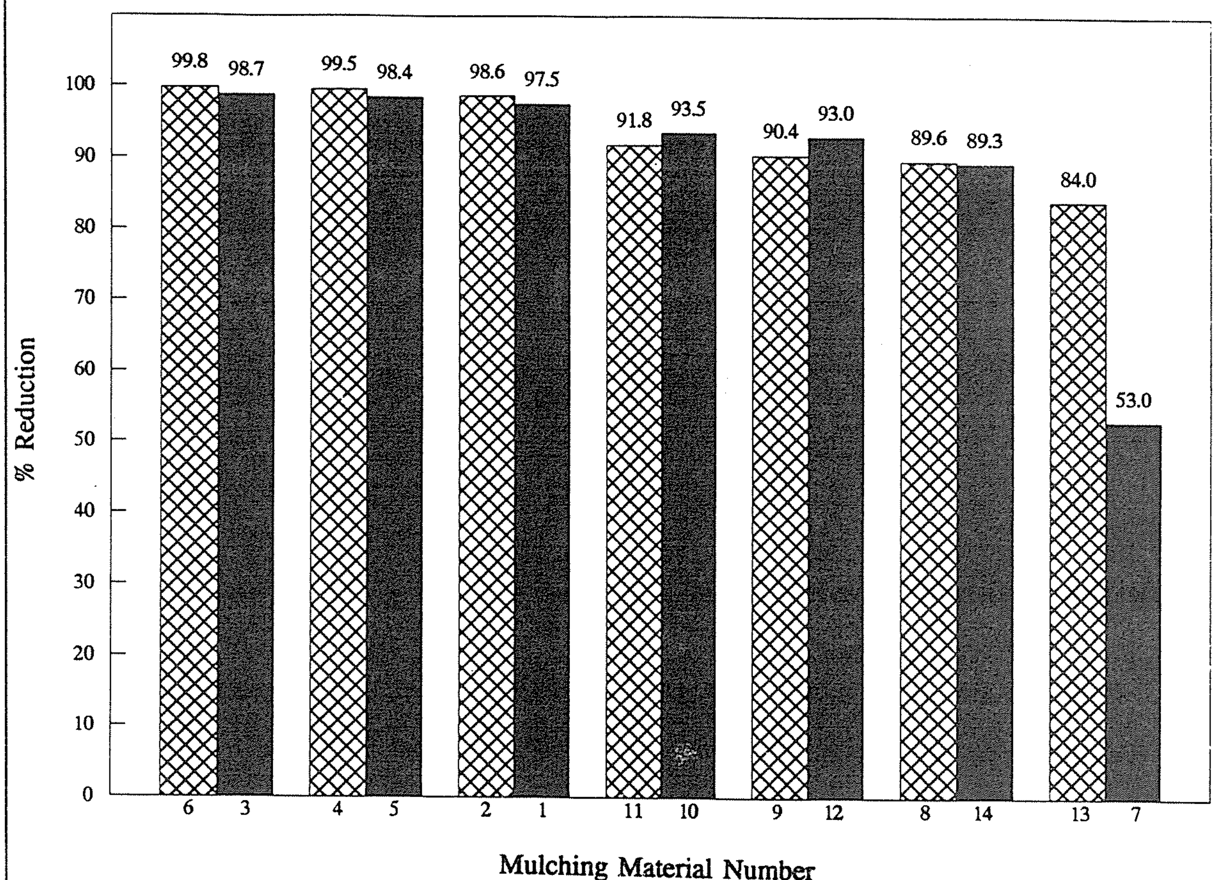
Mulching involves applying plant residues or other suitable materials on disturbed soil surfaces. Mulchs/mats used include tacked straw, wood chips, and jute netting and are often covered by blankets or netting. Mulching alone should be used only for temporary protection of the soil surface or when permanent seeding is not feasible. The useful life of mulch varies with the material used and the amount of precipitation, but is approximately 2 to 6 months. Figure 4-5 shows water velocity reductions that could be expected using various mulching techniques. Similarly, Figure 4-6 shows reductions in soil loss achievable using various mulching techniques. During times of year when vegetation cannot be established, soil mulching should be applied to moderate slopes and soils that are not highly erodible. On steep slopes or highly erodible soils, multiple mulching treatments should be used. On a high-elevation or desert site where grasses cannot survive the harsh environment, native shrubs may be planted. Interlocking ceramic materials, filter fabric, and netting are available for this purpose. Before stabilizing an area, it is important to have installed all sediment controls and diverted runoff away from the area to be planted. Runoff may be diverted away from denuded areas or newly planted areas using dikes, swales, or pipe slope drains to intercept runoff and convey it to a permanent channel or storm drain. Reserved topsoil may be used to revegetate a site if the stockpile has been covered and stabilized.

Consideration should be given to maintenance when designing mulching and matting schemes. Plastic nets are often used to cover the mulch or mats; however, they can foul lawn mower blades if the area requires mowing.



Mulch Material	Characteristics
1	100% wheat straw/top net
2	100% wheat straw/two nets
3	70% wheat straw/30% coconut fiber
4	70% wheat straw/30% coconut fiber
5	100% coconut fiber
6	Nylon monofilament/two nets
7	Nylon monofilament/rigid/bonded
8	Vinyl monofilament/flexible/bonded
9	Curled wood fibers/top net
10	Curled wood fibers/two nets
11	Antiwash netting (jute)
12	Interwoven paper and thread
13	Uncrimped wheat straw – 2,242 kg/ha
14	Uncrimped wheat straw – 4,484 kg/ha

Figure 4-5. Water velocity reductions for different mulch treatments (adapted from Harding, 1990).



Mulch Material	Characteristics
1	100% wheat straw/top net
2	100% wheat straw/two nets
3	70% wheat straw/30% coconut fiber
4	70% wheat straw/30% coconut fiber
5	100% coconut fiber
6	Nylon monofilament/two nets
7	Nylon monofilament/rigid/bonded
8	Vinyl monofilament/flexible/bonded
9	Curled wood fibers/top net
10	Curled wood fibers/two nets
11	Antiwash netting (jute)
12	Interwoven paper and thread
13	Uncrimped wheat straw – 2,242 kg/ha
14	Uncrimped wheat straw – 4,484 kg/ha

Figure 4-6. Actual soil loss reductions for different mulch treatments (adapted from Harding, 1990).

r. *Use sodding.*

Sodding permanently stabilizes an area. Sodding provides immediate stabilization of an area and should be used in critical areas or where establishment of permanent vegetation by seeding and mulching would be difficult. Sodding is also a preferred option when there is a high erosion potential during the period of vegetative establishment from seeding.

s. *Use wildflower cover.*

Because of the hardy drought-resistant nature of wildflowers, they may be more beneficial as an erosion control practice than turf grass. While not as dense as turfgrass, wildflower thatches and associated grasses are expected to be as effective in erosion control and contaminant absorption. Because thatches of wildflowers do not need fertilizers, pesticides, or herbicides, and watering is minimal, implementation of this practice may result in a cost savings (Brash et al., undated). In 1987, Howard County, Maryland, spent $690.00 per acre to maintain turfgrass areas, compared to only $31.00 per acre for wildflower meadows (Wilson, 1990).

A wildflower stand requires several years to become established; maintenance requirements are minimal once the area is established (Brash et al., undated).

5. Sediment Control Practices[4]

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.

Sediment controls capture sediment that is transported in runoff. Filtration and detention (gravitational settling) are the main processes used to remove sediment from urban runoff.

a. *Sediment Basins*

Sediment basins, also known as silt basins, are engineered impoundment structures that allow sediment to settle out of the urban runoff. They are installed prior to full-scale grading and remain in place until the disturbed portions of the drainage area are fully stabilized. They are generally located at the low point of sites, away from construction traffic, where they will be able to trap sediment-laden runoff.

Sediment basins are typically used for drainage areas between 5 and 100 acres. They can be classified as either temporary or permanent structures, depending on the length of service of the structure. If they are designed to function for less than 36 months, they are classified as "temporary"; otherwise, they are considered permanent structures. Temporary sediment basins can also be converted into permanent urban runoff management ponds. When sediment basins are designed as permanent structures, they must meet all standards for wet ponds.

b. *Sediment Trap*

Sediment traps are small impoundments that allow sediment to settle out of runoff water. Sediment traps are typically installed in a drainageway or other point of discharge from a disturbed area. Temporary diversions can be

[4]Adapted from Goldman (1986).

used to direct runoff to the sediment trap. Sediment traps should not be used for drainage areas greater than 5 acres and typically have a useful life of approximately 18 to 24 months.

c. Filter Fabric Fence

Filter fabric fence is available from many manufacturers and in several mesh sizes. Sediment is filtered out as urban runoff flows through the fabric. Such fences should be used only where there is sheet flow (i.e., no concentrated flow), and the maximum drainage area to the fence should be 0.5 acre or less per 100 feet of fence. Filter fabric fences have a useful life of approximately 6 to 12 months.

d. Straw Bale Barrier

A straw bale barrier is a row of anchored straw bales that detain and filter urban runoff. Straw bales are less effective than filter fabric, which can usually be used in place of straw bales. However, straw bales have been effectively used as temporary check dams in channels. As with filter fabric fences, straw bale barriers should be used only where there is sheet flow. The maximum drainage area to the barrier should be 0.25 acre or less per 100 feet of barrier. The useful life of straw bales is approximately 3 months.

e. Inlet Protection

Inlet protection consists of a barrier placed around a storm drain drop inlet, which traps sediment before it enters the storm sewer system. Filter fabric, straw bales, gravel, or sand bags are often used for inlet protection.

f. Construction Entrance

A construction entrance is a pad of gravel over filter cloth located where traffic leaves a construction site. As vehicles drive over the gravel, mud, and sediment are collected from the vehicles' wheels and offsite transport of sediment is reduced.

g. Vegetated Filter Strips

Vegetated filter strips are low-gradient vegetated areas that filter overland sheet flow. Runoff must be evenly distributed across the filter strip. Channelized flows decrease the effectiveness of filter strips. Level spreading devices are often used to distribute the runoff evenly across the strip (Dillaha et al., 1989).

Vegetated filter strips should have relatively low slopes and adequate length and should be planted with erosion-resistant plant species. The main factors that influence the removal efficiency are the vegetation type, soil infiltration rate, and flow depth and travel time. These factors are dependent on the contributing drainage area, slope of strip, degree and type of vegetative cover, and strip length. Maintenance requirements for vegetated filter strips include sediment removal and inspections to ensure that dense, vigorous vegetation is established and concentrated flows do not occur. Maintenance of these structures is discussed in Section II.A of this chapter.

6. Effectiveness and Cost Information

a. Erosion Control Practices

The effectiveness of erosion control practices can vary based on land slope, the size of the disturbed area, rainfall frequency and intensity, wind conditions, soil type, use of heavy machinery, length of time soils are exposed and unprotected, and other factors. In general, a system of erosion and sediment control practices can more effectively reduce offsite sediment transport than can a single system. Numerous nonstructural measures such as protecting natural or newly planted vegetation, minimizing the disturbance of vegetation on steep slopes and other highly erodible areas, maximizing the distance eroded material must travel before reaching the drainage system, and locating roads away from sensitive areas may be used to reduce erosion.

Table 4-15 contains the available cost and effectiveness data for some of the erosion controls listed above. Information on the effectiveness of individual nonstructural controls was not available. All reported effectiveness data assume that controls are properly designed, constructed, and maintained. Costs have been broken down into annual capital costs, annual maintenance costs, and total annual costs (including annualization of the capital costs).

b. Sediment Control Practices

Regular inspection and maintenance are needed for most erosion control practices to remain effective. The effectiveness of sediment controls will depend on the size of the construction site and the nature of the runoff flows. Sediment basins are most appropriate for drainage areas of 5 acres or greater. In smaller areas with concentrated flows, silt traps may suffice. Where concentrated flow leaves the site and the drainage area is less than 0.5 ac/100 ft of flow, filter fabric fences may be effective. In areas where sheet flow leaves the site and the drainage area is greater than 0.5 acre/100 ft of flow, perimeter dikes may be used to divert the flow to a sediment trap or sediment basin. Urban runoff inlets may be protected using straw bales or diversions to filter or route runoff away from the inlets.

Table 4-16 describes the general cost and effectiveness of some common sediment control practices.

c. Comparisons

Figure 4-7 illustrates the estimated TSS loading reductions from Maryland construction sites possible using a combination of erosion and sediment controls in contrast to using only sediment controls. Figure 4-8 shows a comparison of the cost and effectiveness of various erosion control practices. As can be seen in Figure 4-8, seeding or seeding and mulching provide the highest levels of control at the lowest cost.

Table 4-15. ESC Quantitative Effectiveness and Cost Summary

Practice	Design Constraints or Purpose	Percent Removal of TSS	Useful Life (years)[a]	Construction Cost	Annual Maintenance Cost (as % construction cost)	Total Annual Cost
Sod	Immediate erosion protection where there is high erosion potential during vegetative establishment.	Average: 99% Observed range: 98% - 99% References: Minnesota Pollution Control Agency, 1989; Pennsylvania, 1983 cited in USEPA, 1991	2	Average: $0.2 per ft^2 [$11,300 per acre] Range: $0.1 - $1.1 References: SWRPC, 1991; Schueler, 1987; Virginia, 1980	Average: 5% Range: 5% Reference: SWRPC, 1991	$0.20 per ft^2 $7,500 per acre
Seed	Establish vegetation on disturbed area.	After vegetation established- Average: 90% Observed range: 50% - 100% References: SCS, 1985 cited in EPA, 1991; Minnesota Pollution Control Agency, 1989; Oberts, 1984 cited in City of Austin, 1988; Delaware Department of Natural Resources, 1989	2	Average: $400 per acre Range: $200 - $1000 per acre References: Wisconsin DOT cited in SWRPC, 1991; SWRPC, 1991; Goldman, 1986; Virginia, 1980	Average: 20% Range: 15% - 25% References: Wisconsin DOT cited in SWRPC, 1991; SWRPC, 1991	$300 per acre
Seed and Mulch	Establish vegetation on disturbed area.	After vegetation established- Average: 90% Observed range: 50% - 100% References: SCS, 1985 cited in EPA, 1991; Minnesota Pollution Control Agency, 1989; Oberts, 1984 cited in City of Austin, 1988; Delaware Department of Natural Resources, 1989	2	Average: $1,500 per acre Range: $800 - $3,500 per acre References: Goldman, 1986; Washington DOT, 1990; NC State, 1990; Schueler, 1987; Virginia, 1980; SWRPC, 1991	Average: NA[b] Range: NA References: None	$1,100 per acre

Table 4-15. (Continued)

Practice	Design Constraints or Purpose	Percent Removal of TSS			Useful Life (years)[a]	Construction Cost	Annual Maintenance Cost (as % construction cost)	Total Annual Cost
Mulch	Temporary	Observed range:			Straw	Straw mulch:	Average: NA[b]	Straw mulch:
	stabilization of				mulch:	Average: $1,700 per acre	Range: NA	$7,500 per
	disturbed area.	sand:			0.25	Range: $500 - $5,000 per acre	References: None	acre
			20% slope	50% slope		References: Wisconsin DOT		
		wood fiber @ 1500 lb/ac	50-60%	0-20%		cited in SWRPC, 1991;		
		wood fiber @ 3000 lb/ac	50-85%	50-70%		Washington DOT, 1990;		
		straw @ 3000 lb/ac	90-100%	95%		Virginia, 1980		
		Silt-loam:			Wood	Wood fiber mulch:		Wood fiber
			20% slope	50% slope	fiber	Average: $1,000 per acre		mulch:
		wood fiber @ 1500 lb/ac	20-60%	40-60%	mulch:	Range: $100 - $2,300 per acre		$3,500 per
		wood fiber @ 3000 lb/ac	60-90%	60-70%	0.33	References: Washington DOT,		acre
		straw @ 3000 lb/ac	80-95%	70-90%		1990; Virginia, 1980		
		Silt-clay-loam:				Jute netting:		Jute netting:
			10-30%	30-50%		Average: $3,700 per acre		$12,500 per
			slope	slope	Jute	Range: $3,500-$4,100 per acre		acre
		wood fiber @ 1500 lb/ac	5%	--	netting:	References: Washington DOT,		
		wood fiber @ 3000 lb/ac	40%	--	0.33	1990; Virginia, 1980		
		jute netting	30-60%	30%				
		straw @ 3000 lb/ac	40-70%	20-40%		Straw and jute:		Straw and
		wood chips	60-80%	50-60%		Average: $5,400 per acre		jute:
		@ 10,000 lb/ac				Range: $4,000-$9,100 per acre		$18,000 per
		mulch blanket	60-80%	50-60%	Straw	References: Washington DOT,		acre
		excelsior blanket	60-80%	50-60%	and	1990; Virginia, 1980		
		multiple treatment	90%	90%	jute: 0.33			
		(straw and jute)						
		References: Minnesota Pollution Control Agency, 1989; Kay, 1983 cited in Goldman, 1986						

Table 4-15. (Continued)

Practice	Design Constraints or Purpose	Percent Removal of TSS	Useful Life (years)[a]	Construction Cost	Annual Maintenance Cost (as % construction cost)	Total Annual Cost
Terraces	Break up long or steep slopes.	Observed range: Land Slope — Reduction in Erosion 1-12% — 70% 12-18% — 60% 18-24% — 55% Additionally, if the slope steepness is halved, while other factors are held constant, the soil loss potential decreases 2-1/2 times. If both the slope and length are halved, the soil loss potential is decreased 4 times. References: Goldman, 1986; Beasley, 1972	2	Average: $5 per lin ft Range: $1 - $12 References: SWRPC, 1991; Goldman, 1986; Virginia, 1991	Average: 20% Range: 20% Reference: SWRPC, 1991	$4 per lin ft
All Erosion Controls	Reduce amount of sediment entering runoff.	Average: 85% Observed range: 85% Reference: Schueler, 1990	--	Varies but typically low	Varies but typically low	Varies but typically low

NA - Not available.
[a] Useful life estimated as length of construction project (assumed to be 2 years).
[b] For Total Annual Cost, assume Annual Maintenance Cost = 2% of construction cost.

Table 4-16. ESC Quantitative Effectiveness and Cost Summary for Sediment Control Practices

Practice	Design Constraints or Purpose	Percent Removal of TSS	Useful Life (years)[a]	Construction Cost	Annual Maintenance Cost (as % construction cost)	Total Annual Cost
Sediment basin	Minimum drainage area = 5 acres, maximum drainage area = 100 acres	Average: 70% Observed range: 55% - 100% References: Schueler, 1990; Engle, BW and Jarrett, AR, 1990; Baumann, 1990	2	Less than 50,000 ft^3 storage Average: \$0.60 per ft^3 storage (\$1,100 per drainage acre[c]) Range: \$0.20 - \$1.30 per ft^3	Average: 25% Range: 25% References: Denver COG cited in SWRPC, 1991; SWRPC, 1991	Less than 50,000 ft^3 storage \$0.40 per ft^3 storage \$700 per drainage acre[b]
				Greater than 50,000 ft^3 storage Average: \$0.3 per ft^3 storage (\$550 per drainage acre[c]) Range: \$0.10 - \$0.40 per ft^3 References: SWRPC, 1991		Greater than 50,000 ft^3 storage \$0.20 per ft^3 storage \$900 per drainage acre[c]
Sediment trap	Maximum drainage area = 5 acres	Average: 60% Observed range: (-7%) - 100% References: Schueler, et al., 1990; Tahoe Regional Planning Agency, 1989; Baumann, 1990	1.5	Average: \$0.60 per ft^3 storage (\$1,100 per drainage acre[c]) Range: \$0.20 - \$2.00 per ft^3 References: Denver COG cited in SWRPC, 1991; SWRPC, 1991; Goldman, 1986	Average: 20% Range: 20% References: Denver COG cited in SWRPC, 1991; SWRPC, 1991	\$0.70 per ft^3 storage \$1,300 per drainage acre[c]
Filter Fabric Fence	Maximum drainage area = 0.5 acre per 100 feet of fence. Not to be used in concentrated flow areas.	Average: 70% Observed range: 0% - 100% sand: 80% - 99% silt-loam: 50% - 80% silt-clay-loam: 0% - 20% References: Munson, 1991; Fisher et al., 1984; Minnesota Pollution Control Agency, 1989	0.5	Average: \$3 per lin ft (\$700 per drainage acre[c] Range: \$1 - \$8 per lin ft References: Wisconsin DOT cited in SWRPC, 1991; SWRPC, 1991; Goldman, 1986; Virginia, 1991; NC State, 1990	Average: 100% Range: 100% References: SWRPC, 1991	\$7 per lin ft \$850 per drainage acre[c]

Table 4-16. (Continued)

Practice	Design Constraints or Purpose	Percent Removal of TSS	Useful Life (years)[a]	Construction Cost	Annual Maintenance Cost (as % construction cost)	Total Annual Cost
Straw Bale Barrier	Maximum drainage area = 0.25 acre per 100 feet of barrier. Not to be used in concentrated flow areas.	Average: 70% Observed Range: 70% References: Virginia, 1980 cited in EPA, 1991	0.25	Average: $4 per lin ft ($1,600 per drainage acre[d] Range: $2 - $6 per lin ft References: Goldman, 1986; Virginia, 1991	Average: 100% Range: 100% References: SWRPC, 1991	$17 per lin ft $6,800 per drainage acre[d]
Inlet Protection	Protect storm drain inlet.	Average: NA Observed Range: NA References: None	1	Average: $100 per inlet Range: $50 - $150 References: SWRPC, 1991; Denver COG cited in SWRPC, 1991; Virginia, 1991; EPA cited in SWRPC, 1991	Average: 60% Range: 20% - 100% References: SWRPC, 1991; Denver COG cited in SWRPC, 1991	$150 per inlet
Construction Entrance	Removes sediment from vehicles wheels.	Average: NA Observed Range: NA References: None	2	Average: $2,000 each Range: $1,000 - $4,000 References: Goldman, 1986; NC State, 1990	Average: NA[e] Range: NA References: None	$1,500 each
				With washrack: Average: $3,000 each Range: $1,000 - $5,000 References: Virginia, 1991		$2,200 each

Table 4-16. (Continued)

Practice	Design Constraints or Purpose	Percent Removal of TSS	Useful Life (years)[a]	Construction Cost	Annual Maintenance Cost (as % construction cost)	Total Annual Cost
Vegetative Filter Strip	Must have sheet flow.	Average: 70% Observed Range: 20% - 80% References: Hayes and Hairston, 1983 cited in Casman, 1990; Dillaha et al., 1989, cited in Glick et al., 1991; Virginia Department of Conservation, 1987; Nonpoint Source Control Task Force, 1983 cited in Minnesota PCA, 1989; Schueler, 1987	2	Established from existing vegetation- Average: $0 Range: $0 References: Schueler, 1987 Established from sod- Average: $11,300 per acre Range: $4,500 - $48,000 per acre References: Schueler, 1987; SWRPC, 1991	Average: NA Range: NA References: None	NA

NA - Not available.
[a] Useful life estimated as length of construction project (assumed to be 2 years)
[e] For Total Annual Cost, assume Annual Maintenance Cost=20% of construction cost.
[b] Assumes trap volume = 1800 cf/ac (0.5 inches runoff per acre).
[c] Assumes drainage area of 0.5 acre per 100 feet of fence (maximum allowed).
[d] Assumes drainage area of 0.25 acre per 100 feet of barrier (maximum allowed).

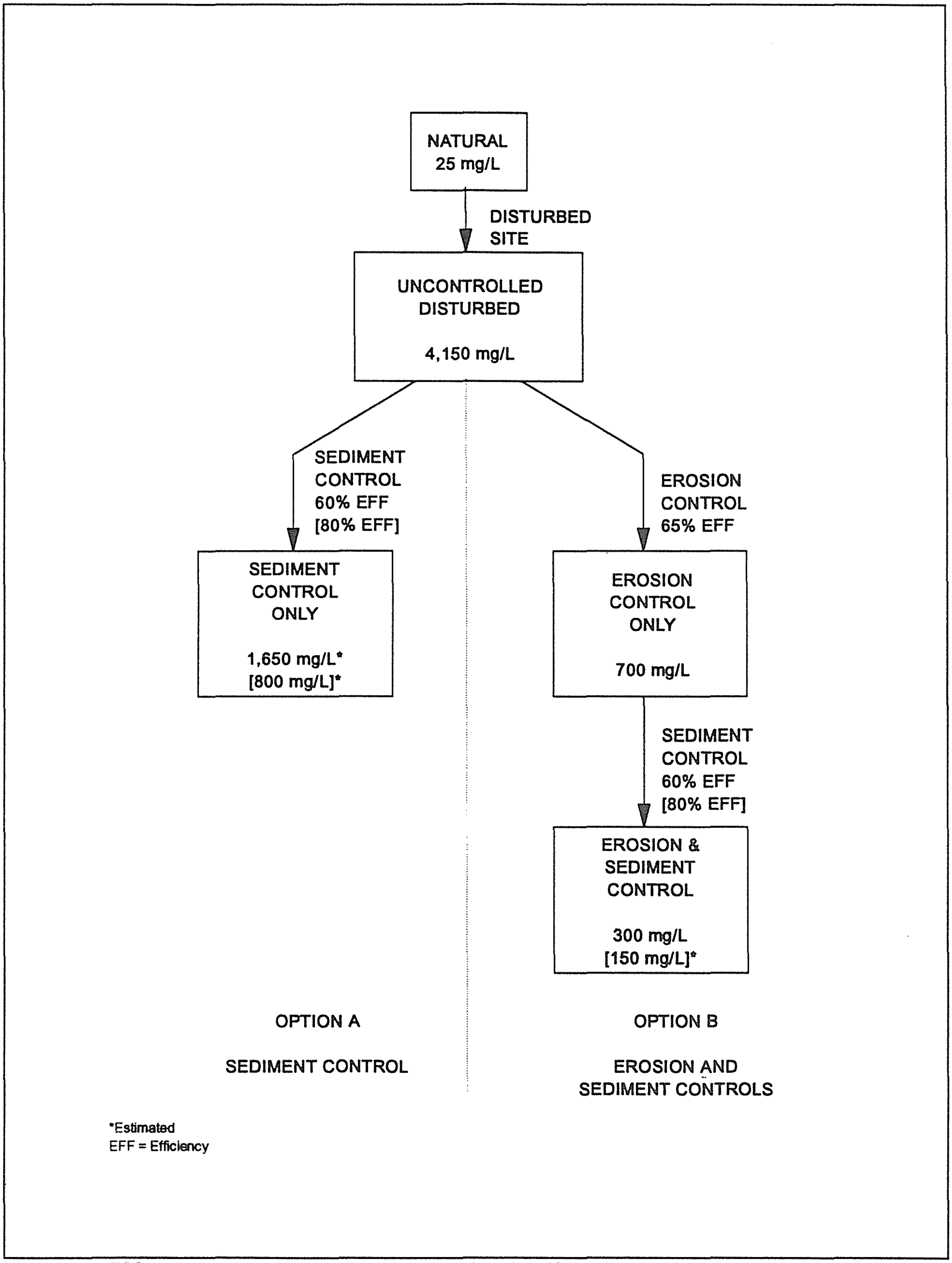


Figure 4-7. TSS concentrations from Maryland construction sites (Schueler, 1987).

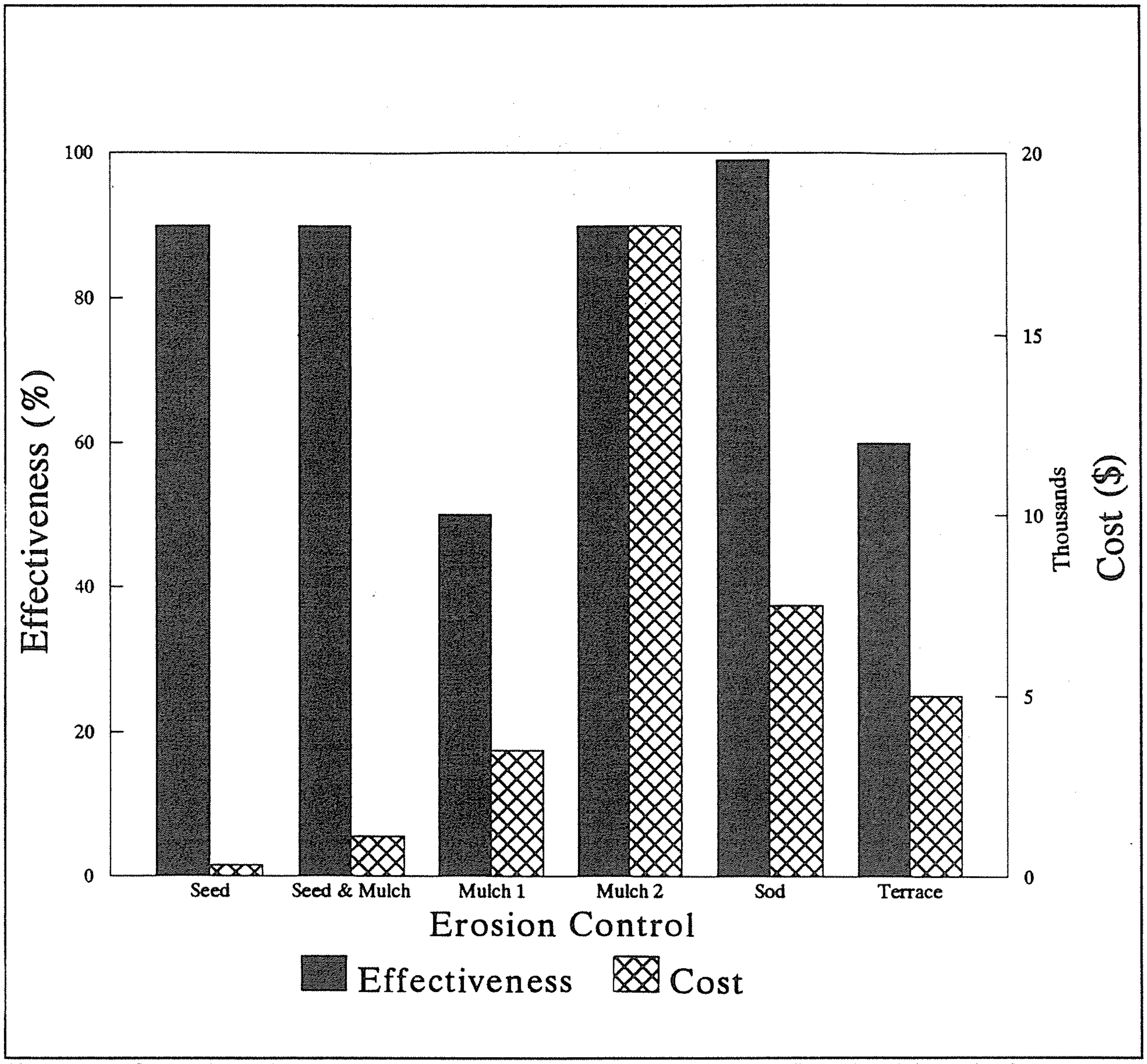


Figure 4-8. Comparison of cost and effectiveness for erosion control practices (based on information in Tables 4-15 and 4-16).

B. Construction Site Chemical Control Management Measure

(1) Limit application, generation, and migration of toxic substances;

(2) Ensure the proper storage and disposal of toxic materials; and

(3) Apply nutrients at rates necessary to establish and maintain vegetation without causing significant nutrient runoff to surface waters.

1. Applicability

This management measure is intended to be applied by States to all construction sites less than 5 acres in area and to new, resurfaced, restored, and reconstructed road, highway, and bridge construction projects. This management measure does not apply to: (1) construction of a detached single family home on a site of 1/2 acre or more or (2) construction that does not disturb over 5,000 square feet of land on a site. (NOTE: All construction activities, including clearing, grading, and excavation, that result in the disturbance of areas greater than or equal to 5 acres or are a part of a larger development plan are covered by the NPDES regulations and are thus excluded from these requirements.) Under the Coastal Zone Act Reauthorization Amendments of 1990, States are subject to a number of requirements as they develop coastal NPS programs in conformance with this management measure and will have flexibility in doing so. The application of management measures by States is described more fully in *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance*, published jointly by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce.

2. Description

The purpose of this management measure is to prevent the generation of nonpoint source pollution from construction sites due to improper handling and usage of nutrients and toxic substances, and to prevent the movement of toxic substances from the construction site.

Many potential pollutants other than sediment are associated with construction activities. These pollutants include pesticides (insecticides, fungicides, herbicides, and rodenticides); fertilizers used for vegetative stabilization; petrochemicals (oils, gasoline, and asphalt degreasers); construction chemicals such as concrete products, sealers, and paints; wash water associated with these products; paper; wood; garbage; and sanitary wastes (Washington State Department of Ecology, 1991).

The variety of pollutants present and the severity of their effects are dependent on a number of factors:

(1) **The nature of the construction activity.** For example, potential pollution associated with fertilizer usage may be greater along a highway or at a housing development than it would be at a shopping center development because highways and housing developments usually have greater landscaping requirements.

(2) **The physical characteristics of the construction site.** The majority of all pollutants generated at construction sites are carried to surface waters via runoff. Therefore, the factors affecting runoff volume,

such as the amount, intensity, and frequency of rainfall; soil infiltration rates; surface roughness; slope length and steepness; and area denuded, all contribute to pollutant loadings.

(3) **The proximity of surface waters to the nonpoint pollutant source.** As the distance separating pollutant-generating activities from surface waters decreases, the likelihood of water quality impacts increases.

a. Pesticides

Insecticides, rodenticides, and herbicides are used on construction sites to provide safe and healthy conditions, reduce maintenance and fire hazards, and curb weeds and woody plants. Rodenticides are also used to control rodents attracted to construction sites. Common insecticides employed include synthetic, relatively water-insoluble chlorinated hydrocarbons, organophosphates, carbamates, and pyrethrins.

b. Petroleum Products

Petroleum products used during construction include fuels and lubricants for vehicles, for power tools, and for general equipment maintenance. Specific petroleum pollutants include gasoline, diesel oil, kerosene, lubricating oils, and grease. Asphalt paving also can be particularly harmful since it releases various oils for a considerable time period after application. Asphalt overloads might be dumped and covered without inspection. However, many of these pollutants adhere to soil particles and other surfaces and can therefore be more easily controlled.

c. Nutrients

Fertilizers are used on construction sites when revegetating graded or disturbed areas. Fertilizers contain nitrogen and phosphorus, which in large doses can adversely affect surface waters, causing eutrophication.

d. Solid Wastes

Solid wastes on construction sites are generated from trees and shrubs removed during land clearing and structure installation. Other wastes include wood and paper from packaging and building materials, scrap metals, sanitary wastes, rubber, plastic and glass, and masonry and asphalt products. Food containers, cigarette packages, leftover food, and aluminum foil also contribute solid wastes to the construction site.

e. Construction Chemicals

Chemical pollutants, such as paints, acids for cleaning masonry surfaces, cleaning solvents, asphalt products, soil additives used for stabilization, and concrete-curing compounds, may also be used on construction sites and carried in runoff.

f. Other Pollutants

Other pollutants, such as wash water from concrete mixers, acid and alkaline solutions from exposed soil or rock, and alkaline-forming natural elements, may also be present and contribute to nonpoint source pollution.

Revegetation of disturbed areas may require the use of fertilizers and pesticides, which, if not applied properly, may become nonpoint source pollutants. Many pesticides are restricted by Federal and/or State regulations.

Hydroseeding operations, in which seed, fertilizers, and lime are applied to the ground surface in a one-step operation, are more conducive to nutrient pollution than are the conventional seedbed-preparation operations, in which fertilizers and lime are tilled into the soil. Use of fertilizers containing little or no phosphorus may be required by local authorities if the development is near sensitive waterbodies. The addition of lime can also affect the pH of sensitive waters, making them more alkaline.

Improper fueling and servicing of vehicles can lead to significant quantities of petroleum products being dumped onto the ground. These pollutants can then be washed off site in urban runoff, even when proper erosion and sediment controls are in place. Pollutants carried in solution in runoff water, or fixed with sediment crystalline structures, may not be adequately controlled by erosion and sediment control practices (Washington Department of Ecology, 1991). Oils, waxes, and water-insoluble pesticides can form surface films on water and solid particles. Oil films can also concentrate water-soluble insecticides. These pollutants can be nearly impossible to control once present in runoff other than by the use of very costly water-treatment facilities (Washington Department of Ecology, 1991).

After spill prevention, one of the best methods to control petroleum pollutants is to retain sediments containing oil on the construction site through use of erosion and sediment control practices. Improved maintenance and safe storage facilities will reduce the chance of contaminating a construction site. One of the greatest concerns related to use of petroleum products is the method for waste disposal. The dumping of petroleum product wastes into sewers and other drainage channels is illegal and could result in fines or job shutdown.

The primary control method for solid wastes is to provide adequate disposal facilities. Erosion and sediment control structures usually capture much of the solid waste from construction sites. Periodic removal of litter from these structures will reduce solid waste accumulations. Collected solid waste should be removed and disposed of at authorized disposal areas.

Improperly stored construction materials, such as pressure-treated lumber or solvents, may lead to leaching of toxics to surface water and ground water. Disposal of construction chemicals should follow all applicable State and local laws that may require disposal by a licensed waste management firm.

3. Management Measure Selection

This management measure was selected based on the potential for many construction activities to contribute to nutrient and toxic NPS pollution.

This management measure was selected because (1) construction activities have the potential to contribute to increased loadings of toxic substances and nutrients to waterbodies; (2) various States and local governments regulate the control of chemicals on construction sites through spill prevention plans, erosion and sediment control plans, or other administrative devices; (3) the practices described are commonly used and presented in a number of best management practice handbooks and guidance manuals for construction sites; and (4) the practices selected are the most economical and effective.

4. Practices

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.

a. Properly store, handle, apply, and dispose of pesticides.

Pesticide storage areas on construction sites should be protected from the elements. Warning signs should be placed in areas recently sprayed or treated. Persons mixing and applying these chemicals should wear suitable protective clothing, in accordance with the law.

Application rates should conform to registered label directions. Disposal of excess pesticides and pesticide-related wastes should conform to registered label directions for the disposal and storage of pesticides and pesticide containers set forth in applicable Federal, State, and local regulations that govern their usage, handling, storage, and disposal. Pesticides and herbicides should be used only in conjunction with Integrated Pest Management (IPM) (see Chapter 2). Pesticides should be the tool of last resort; methods that are the least disruptive to the environment and human health should be used first.

Pesticides should be disposed of through either a licensed waste management firm or a treatment, storage, and disposal (TSD) facility. Containers should be triple-rinsed before disposal, and rinse waters should be reused as product.

Other practices include setting aside a locked storage area, tightly closing lids, storing in a cool, dry place, checking containers periodically for leaks or deterioration, maintaining a list of products in storage, using plastic sheeting to line the storage area, and notifying neighboring property owners prior to spraying.

b. Properly store, handle, use, and dispose of petroleum products.

When storing petroleum products, follow these guidelines:

- Create a shelter around the area with cover and wind protection;
- Line the storage area with a double layer of plastic sheeting or similar material;
- Create an impervious berm around the perimeter with a capacity 110 percent greater than that of the largest container;
- Clearly label all products;
- Keep tanks off the ground; and
- Keep lids securely fastened.

Oil and oily wastes such as crankcase oil, cans, rags, and paper dropped into oils and lubricants should be disposed of in proper receptacles or recycled. Waste oil for recycling should not be mixed with degreasers, solvents, antifreeze, or brake fluid.

c. Establish fuel and vehicle maintenance staging areas located away from all drainage courses, and design these areas to control runoff.

Proper maintenance of equipment and installation of proper stream crossings will further reduce pollution of water by these sources. Stream crossings should be minimized through proper planning of access roads. Refer to Chapter 3 for additional information on stream crossings.

d. Provide sanitary facilities for constructions workers.

e. Store, cover, and isolate construction materials, including topsoil and chemicals, to prevent runoff of pollutants and contamination of ground water.

f. Develop and implement a spill prevention and control plan. Agencies, contractors, and other commercial entities that store, handle, or transport fuel, oil, or hazardous materials should develop a spill response plan.

Post spill procedure information and have persons trained in spill handling on site or on call at all times. Materials for cleaning up spills should be kept on site and easily available. Spills should be cleaned up immediately and the contaminated material properly disposed of. Spill control plan components should include:

- Stop the source of the spill.
- Contain any liquid.
- Cover the spill with absorbent material such as kitty litter or sawdust, but do not use straw. Dispose of the used absorbent properly.

g. Maintain and wash equipment and machinery in confined areas specifically designed to control runoff.

Thinners or solvents should not be discharged into sanitary or storm sewer systems when cleaning machinery. Use alternative methods for cleaning larger equipment parts, such as high-pressure, high-temperature water washes, or steam cleaning. Equipment-washing detergents can be used, and wash water may be discharged into sanitary sewers if solids are removed from the solution first. (This practice should be verified with the local sewer authority.) Small parts can be cleaned with degreasing solvents, which can then be reused or recycled. Do not discharge any solvents into sewers.

Washout from concrete trucks should be disposed of into:

- A designated area that will later be backfilled;
- An area where the concrete wash can harden, can be broken up, and then can be placed in a dumpster; or
- A location not subject to urban runoff and more than 50 feet away from a storm drain, open ditch, or surface water.

Never dump washout into a sanitary sewer or storm drain, or onto soil or pavement that carries urban runoff.

h. Develop and implement nutrient management plans.

Properly time applications, and work fertilizers and liming materials into the soil to depths of 4 to 6 inches. Using soil tests to determine specific nutrient needs at the site can greatly decrease the amount of nutrients applied.

i. Provide adequate disposal facilities for solid waste, including excess asphalt, produced during construction.

j. Educate construction workers about proper materials handling and spill response procedures. Distribute or post informational material regarding chemical control.

IV. EXISTING DEVELOPMENT

A. Existing Development Management Measure

Develop and implement watershed management programs to reduce runoff pollutant concentrations and volumes from existing development:

(1) Identify priority local and/or regional watershed pollutant reduction opportunities, e.g., improvements to existing urban runoff control structures;

(2) Contain a schedule for implementing appropriate controls;

(3) Limit destruction of natural conveyance systems; and

(4) Where appropriate, preserve, enhance, or establish buffers along surface waterbodies and their tributaries.

1. Applicability

This management measure is intended to be applied by States to all urban areas and existing development in order to reduce surface water runoff pollutant loadings from such areas. Under the Coastal Zone Act Reauthorization Amendments of 1990, States are subject to a number of requirements as they develop coastal NPS programs in conformity with this management measure and will have flexibility in doing so. The application of management measures by States is described more fully in *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance*, published jointly by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA).

2. Description

The purpose of this management measure is to protect or improve surface water quality by the development and implementation of watershed management programs that pursue the following objectives:

(1) Reduce surface water runoff pollution loadings from areas where development has already occurred;

(2) Limit surface water runoff volumes in order to minimize sediment loadings resulting from the erosion of streambanks and other natural conveyance systems; and

(3) Preserve, enhance, or establish buffers that provide water quality benefits along waterbodies and their tributaries.

Maintenance of water quality becomes increasingly difficult as areas of impervious surface increase and urbanization occurs. For the purpose of this guidance, urbanized areas are those areas where the presence of "man-made" impervious surfaces results in increased peak runoff volumes and pollutant loadings that permanently alter one or more of the following:[5] stream channels, natural drainageways, and in-stream and adjacent riparian habitat so that predevelopment aquatic flora and fauna are eliminated or reduced to unsustainable levels and predevelopment water quality has been degraded. Increased bank cutting, streambed scouring, siltation damaging to aquatic flora and fauna, increases in water temperature, decreases in dissolved oxygen, changes to the natural structure and flow of the stream or river, and the presence of anthropogenic pollutants that are not generated from agricultural activities, in general, are indications of urbanization.

The effects of urbanization have been well described in the introduction to this chapter. Protection of water quality in urbanized areas is difficult because of a range of factors. These factors include diverse pollutant loadings, large runoff volumes, limited areas suitable for surface water runoff treatment systems, high implementation costs associated with structural controls, and the destruction or absence of buffer zones that can filter pollutants and prevent the destabilization of streambanks and shorelines.

As discussed in Section II.B of this chapter, comprehensive watershed planning facilitates integration of source reduction activities and treatment strategies to mitigate the effects of urban runoff. Through the use of watershed management, States and local governments can identify local water quality objectives and focus resources on control of specific pollutants and sources. Watershed plans typically incorporate a combination of nonstructural and structural practices.

An important nonstructural component of many watershed management plans is the identification and preservation of buffers and natural systems. These areas help to maintain and improve surface water quality by filtering and infiltrating urban runoff. In areas of existing development, natural buffers and conveyance systems may have been altered as urbanization occurred. Where possible and appropriate, additional impacts to these areas should be minimized and if degraded, the functions of these areas restored. The preservation, enhancement, or establishment of buffers along waterbodies is generally recommended throughout the section 6217 management area as an important tool for reducing NPS impacts. The establishment and protection of buffers, however, is most appropriate along surface waterbodies and their tributaries where water quality and the biological integrity of the waterbody is dependent on the presence of an adequate buffer/riparian area. Buffers may be necessary where the buffer/riparian area (1) reduces significant NPS pollutant loadings, (2) provides habitat necessary to maintain the biological integrity of the receiving water, and (3) reduces undesirable thermal impacts to the waterbody. For a discussion of protection and restoration of wetlands and riparian areas, refer to Chapter 7.

Institutional controls, such as permits, inspection, and operation and maintenance requirements, are also essential components of a watershed management program. The effectiveness of many of the practices described in this chapter is dependent on administrative controls such as inspections. Without effective compliance mechanisms and operation and maintenance requirements, many of these practices will not perform satisfactorily.

Where existing development precludes the use of effective nonstructural controls, structural practices may be the only suitable option to decrease the NPS pollution loads generated from developed areas. In such situations, a watershed plan can be used to integrate the construction of new surface water runoff treatment structures and the retrofit of existing surface water runoff management systems.

Retrofitting is a process that involves the modification of existing surface water runoff control structures or surface water runoff conveyance systems, which were initially designed to control flooding, not to serve a water quality improvement function. By enlarging existing surface water runoff structures, changing the inflow and outflow characteristics of the device, and increasing detention times of the runoff, sediment and associated pollutants can be removed from the runoff. Retrofit of structural controls, however, is often the only feasible alternative for improving water quality in developed areas. Where the presence of existing development or financial constraints limits treatment options, targeting may be necessary to identify priority pollutants and select the most appropriate retrofits.

[5] Changes resulting from dam building and "acts of God" such as earthquakes, hurricanes, and unusual natural events (e.g., a 100-year storm), as well as natural predevelopment riverine behavior that results in stream meander and deposition of sediments in sandbars or similar formations, are excluded from consideration in this definition. For additional information, refer to Chapter 6.

Once key pollutants have been identified, an achievable water quality target for the receiving water should be set to improve current levels based on an identified objective or to prevent degradation of current water quality. Extensive site evaluations should then be performed to assess the performance of existing surface water runoff management systems and to pinpoint low-cost structural changes or maintenance programs for improving pollutant-removal efficiency. Where flooding problems exist, water quality controls should be incorporated into the design of surface water runoff controls. Available land area is often limited in urban areas, and the lack of suitable areas will frequently restrict the use of conventional pond systems. In heavily urbanized areas, sand filters or water quality inlets with oil/grit separators may be appropriate for retrofits because they do not limit land usage.

3. Management Measure Selection

Components (1) and (2) of this management measure were selected so that local communities develop and implement watershed management programs. Watershed management programs are used throughout the 6217 management area although coverage is inconsistent among States and local governments (Puget Sound Water Quality Authority, 1986).

Local conditions, availability of funding, and problem pollutants vary widely in developed communities. Watershed management programs allow these communities to select and implement practices that best address local needs. The identification of priority and/or local regional pollutant reduction opportunities and schedules for implementing appropriate controls were selected as logical starting points in the process of instituting an institutional framework to address nonpoint source pollutant reductions.

Cost was also a major factor in the selection of this management measure. EPA acknowledges the high costs and other limitations inherent in treating existing sources to levels consistent with the standards set for developing areas. Suitable areas are often unavailable for structural treatment systems that can adequately protect receiving waters. The lack of universal cost-effective treatment options was a major factor in the selection of this management measure. EPA was also influenced by the frequent lack of funding for mandatory retrofitting and the extraordinarily high costs associated with the implementation of retention ponds and exfiltration systems in developed areas.

The use of retrofits has been encouraged because of proven water quality benefits. (Table 4-17 illustrates the effectiveness of structural runoff controls for developed areas and retrofitted structures.) Retrofits are currently being used by a number of States and local governments in the 6217 management area, including Maryland, Delaware, and South Carolina.

Management measure components (3) and (4) were selected to preserve, enhance, and establish areas within existing development that provide positive water quality benefits. Refer to the New Development and Site Planning Management Measures for the rationale used in selecting components (3) and (4) of this management measure.

4. Practices

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.

a. *Priority NPS pollutants should be targeted, and implementation strategies for mitigating the effects of NPS pollutants should be developed.*

b. *Policies, plans, and organizational structures that ensure that all surface water runoff management facilities are properly operated and maintained should be developed. Periodic monitoring and maintenance may be necessary to ensure proper operation and maintenance.*

Table 4-17. Existing Development Management Practices Effectiveness Summary

Management Practice		% Removal TSS	TP	TN	COD	Pb	Zn	Main Removal Efficiency Factors	References
Water Quality Inlet - Catch Basin (1)	Average:	15	5	5	5	15	5	• Maintenance	Pitt, 1986; Field, 1985; Schueler, 1987
	Reported Range:	10-95	5-10	5-10	5-10	10-55	5-10	• Sedimentation storage volume	
	Probable Range:	10-25	5-10	5-10	5-10	10-25	5-10		
	No. Values Considered:	2	1	1	1	3	1		
Water Quality Inlet - Catch Basins With Sand Filter (1)	Average:	80	NA	35	55	80	65	• Sedimentation storage volume	Shaver, 1991
	Reported Range:	75-85	NA	30-45	45-70	70-90	50-80	• Depth of filter media	
	Probable Range:	70-90	--	30-40	40-70	70-90	50-80		
	No. Values Considered:	1	0	1	1	1	1		
Water Quality Inlet - Oil/Grid Separator (1)	Average:	15	5	5	5	15	5	• Sedimentation storage volume	Pitt, 1986; Schueler, 1987
	Reported Range:	10-25	5-10	5-10	5-10	10-25	5-10	• Outlet configurations	
	Probable Range:	10-25	5-10	5-10	5-10	10-25	5-10		
	Number of References	1	1	1	1	1	1		
Dry Pond Modified into Ed Dry Pond	Average:	45	25	35	20	45	20	• Storage volume • Detention time • Pond shape	MWCOG, 1983; City of Austin, 1990; Schueler and Helfrich, 1988; Pope and Hess, 1989; OWML, 1987; Welinski and Stack, 1990
	Reported Range:	5-90	10-55	20-60	0-40	25-65	(-40)-65		
	Probable Range (2):	70-90	10-60	20-60	30-40	20-60	40-60		
	No. Values Considered:	6	6	4	5	4	5		

Table 4-17. (Continued)

Management Practice		% Removal TSS	TP	TN	COD	Pb	Zn	Main Removal Efficiency Factors	References
Dry Pond Modified into Wet Pond	Average:	60	45	35	40	70	60	• Pool volume • Pond shape	Wetzka and Oberta, 1988; Yoosef et al., 1986; Collum, 1985; Driscoll, 1983; Driscoll, 1986; MWCOG, 1983; OWML, 1983; Wu et al., 1988; Holter, 1987; Martin, 1988; Darmay et al., 1989; OWML, 1982; City of Austin ,1990
	Reported Range:	(-30)-91	10-85	5-85	5-90	10-95	10-95		
	Probable Range:	50-90	20-90	10-90	10-90	10-95	20-95		
	No. Values Considered:	11	10	7	4	8	7		
Dry Pond or Wet Pond Modified into ED Wet Pond	Average:	80	65	55	NA	40	20	• Pool volume • Pond shape • Detention time	Ontario Ministry of the Environment, 1991
	Reported Range:	50-100	50-80	55	NA	40	20		
	Probable Range:	50-95	50-80	---	---	---	---		
	No. Values Considered:	1	1	1	0	1	1		
Streambank Stabilization	Average:	NA	NA	NA	NA	NA	NA		MWCOG, 1990
	Reported Range:	NA	NA	NA	NA	NA	NA		
	Probable Range:	--	--	--	--	--	--		
	No. Values Considered:	0	0	0	0	0	0		
Riparian Forest (assumed same as Vegetated Filter Strip)	Average:	70	50	60	70	20	50	• Runoff volume • Slope • Soil infiltration rates • Vegetative cover • Buffer length	IEP, 1991; Casman, 1990; Glick et al., 1991; VADC, 1987; Minnesota CA, 1989; Schueler, 1987; Hartigen et al., 1989
	Reported Range:	20-80	30-95	40-70	60-80	20	50		
	Probable Range (3):	40-90	30-80	20-60	--	30-80	20-50		
	No. Values Considered:	6	3	2	1	2	2		

Table 4-17. (Continued)

Management Practice		% Removal TSS	TP	TN	COD	Pb	Zn	Main Removal Efficiency Factors	References
Wetland (assumed same as Constructed Storm Water Wetlands)	Average:	65	25	20	50	65	35	• Storage volume • Detention time • Pool shape • Wetland's biota • Seasonal Variation	Harper et al., 1986; Brown, 1985; Wotzka and Obert, 1988; Hickack et al., 1977; Barten, 1987; Meloria, 1986; Morris et al., 1981; Sherberger and Davis, 1982; ABAG, 1979; Oberts et al., 1989; Rushton and Dye, 1990; Hey and Barrett, 1991
	Reported Range:	(-20)-100	(-120)-100	(-15)-40	20-80	30-95	(-30)-80		
	Probable Range (6):	50-90	(-5)-80	0-40	---	30-95	---		
	No. Values Considered:	14	14	6	2	6	4		

c. Remnant pervious areas in already-built areas should be subject to enforceable preservation requirements. For example, set green space goals to promote tree plantings and pavement reclamation projects.

d. Developed areas in need of local or regional structural solutions should be identified and put in priority order.

e. Regional structural solutions, retrofit opportunities, and nonstructural alternatives should be identified, inventoried, and put in priority order.

f. Where possible, modify existing surface water runoff management structures to address water quality.

g. As capital resources allow, implement practices such as those in Table 4-17.

5. Effectiveness Information and Cost Information

The following is a general description of various retrofit options and their effectiveness. Since each retrofit situation is different, the costs will depend on site-specific factors such as climate, drainage area, or pollutants. Table 4-17 discusses the effectiveness of several practices often implemented when correcting existing NPS pollution problems in urban areas.

a. Construction or Modification of Pollutant Removal Facilities

Many of the management practices described in Section II of this chapter cannot be used in already urbanized areas because they require space that is typically not available in urbanized areas. However, two types of pollutant removal retrofits can be used to treat runoff: new treatment facilities can be built in limited land space, and existing facilities can be modified to obtain increased water quality benefits.

New Facilities. If there is space available, the management practices described in Section II can be applied to provide water quality benefits. Typically, however, there are space constraints in urbanized areas that will not allow construction of these facilities. Water quality inlets may be appropriate in areas where space is limited and runoff from highly impervious areas such as parking lots must be treated. The effectiveness and costs of these facilities would be similar to those previously discussed. There are several types of water quality inlets—catch basins, catch basins with sand filters, and oil/grit separators. These are described in detail in Section II.

Retrofit of Existing Facilities. In the past, many surface water runoff management facilities were constructed to provide peak volume control; however, no provisions for pollutant removal were provided. These existing facilities can be modified to provide water quality benefits. Two common modifications are dry pond conversion and fringe marsh creation.

- Dry Pond Conversion. Many dry ponds for surface water runoff management that provide peak volume control, but no water quality benefits, have been constructed. Many of these ponds can be modified to provide water quality control. These modifications can include decreasing the size of the outlet to increase the detention of the dry pond. A dry pond's outlet may also be modified to detain a permanent pool of water and thus create a wet pond or extended detention wet pond. Prince George's County, Maryland, has a successful program for urban retrofits. They are usually off-line facilities with forebays, vegetative benches, and deeper portions for storage.

- Fringe Marsh Creation. Aquatic vegetation can be planted along the perimeter of constructed wet ponds or other open water systems to enhance sediment control and provide some biological pollutant uptake.

b. Stabilization of Shorelines, Stream Banks, and Channels

Urbanization can significantly increase the volume and velocity of surface water runoff that has the potential to erode streambanks and channels. This erosion can create high sediment loads in surface water. Streambanks can be stabilized by providing plantings along the streambank or by placing boulders, riprap, retaining walls, or other structural controls in eroding areas. Where feasible, vegetation and other soft practices should be used instead of hard, structural practices. See the Shoreline and Streambank Protection section of Chapter 6 for additional information.

c. Protection and Restoration of Riparian Forest and Wetland Areas

Riparian forests and wetlands are very effective water quality controls. They should be protected and restored wherever possible. Riparian forests can be restored by replanting the banks and floodplains of a stream-with native species to stabilize erodible soils and improve surface water and ground water quality. Refer to Chapter 7 for additional information.

Some examples of urban watershed retrofit programs are presented below. The first case study, the Anacostia watershed, involves a developed urban area suffering from multiple NPS pollution impacts. As with many of the examples given, the project has advanced only through the planning and early implementation stages. Therefore, performance data are not currently available.

CASE STUDY 1 - ANACOSTIA WATERSHED, MARYLAND

Opportunities for urban retrofitting are limited in developed watersheds, but they can be implemented through extensive onsite evaluations. For example, between 1989 and 1991 over 125 sites in the 179-square-mile Anacostia watershed in Montgomery County, Maryland, were identified as candidates for retrofitting after extensive on-site evaluation (Schueler et al., 1991). Retrofit options developed in the watershed included source reduction, extended detention (ED) marsh ponds or ED ponds to handle the first flush, additional storage capacity in the open channel, routing of surface water runoff away from sensitive channels, diversion of the first flush to sand-peat filters, and installation of oil/grit separators in the drain network itself. The most commonly used retrofit technique in the Anacostia watershed is the retrofit of existing dry surface water runoff detention or flood control structures to improve their runoff storage and treatment capacity. Existing detention ponds are maintained by excavation, adding to the elevation of the embankment, or by construction of low-flow orifices. The newly created storage is used to provide a permanent pool, extended detention storage, or a shallow wetland. Nearly 20 such retrofits are in some stage of design or construction in the Anacostia watershed.

CASE STUDY 2 - LOCH RAVEN RESERVOIR, MARYLAND

(Stack and Belt, 1989)

Loch Raven Reservoir, a water supply reservoir serving Baltimore, Maryland, had a eutrophication problem due to excessive phosphorus loads. To address this problem, the city examined the effectiveness of its existing phosphorus controls. They found that the more than 24 extended detention dry ponds that had been originally constructed for surface water runoff management had been designed to treat the once-in-10-year or once-in-100-year flood. The extended detention ponds were thus inefficient at treating runoff from frequent storm events, and the city was receiving few water quality benefits from these structures. Modifications, or retrofits, allowed the basins to collect runoff from smaller events and reduce pollutant loadings without affecting their capacity to contain runoff from larger storms.

Difficulties in obtaining permission from private pond owners restricted the number of ponds with planned retrofits to six ponds owned by the county and one privately owned pond. Private owners were concerned about the maintenance costs associated with the retrofits. Changes to the ponds usually involved alteration of the size of the orifice of the low-flow release structure. Computer modeling was used to determine the minimum size that would not interfere with the pond's design criteria (i.e., containing the 2-, 10- and 100-year storms) while providing sufficient detention time to settle the majority of the solids in urban runoff from the more frequent storms. Each retrofit was tailored to the basin's unique outlet and site characteristics, and costs reflect the differences in approach. For example, one of the ponds was modified as a urban runoff wetland for an estimated cost of $27,800. Retrofits of dry ponds were the least expensive, with costs of less than about $2,000. Draining and dredging boosted the cost of retrofitting a wet pond with a clogged low-flow release structure to approximately $13,000.

Monitoring of the performance of the retrofits during 12 storm events measured removal efficiencies for particulate matter of over 90 percent and removal efficiencies for total phosphorus of between 30 and 40 percent. All of the storms monitored were less than the 1-year storm, and detention times ranged from 1 to 5 hours. Trash debris collectors were effective at reducing clogging; thus no maintenance was necessary in the first year of operation.

CASE STUDY 3 - INDIAN RIVER LAGOON, FLORIDA

(Bennett and Heaney, 1991)

Improper surface water runoff drainage practices have degraded the quality of Florida's Indian River Lagoon by increasing the volume of freshwater runoff to the estuarine receiving water, as well as increasing the loading of suspended solids. Draining of wetlands for urban and agricultural development has led to nutrient loading in the lagoon.

The study area, typical of most Florida flatwood watersheds, was selected as a representative drainage catchment. EPA's Storm Water Management Model (SWMM) was used to summarize the relationship between catchment hydrology, channel hydraulics, and pollutant loads. The model, calibrated for the study region, was used to evaluate the effectiveness of the proposed watershed control program and to project performance levels expected after the study region becomes fully developed. The retrofit of multiple structural measures was undertaken as a demonstration-scale project. An existing trunk channel was modified to act as a wet detention basin. Flow from the trunk channel enters a partially disturbed, interdunal, freshwater wetland. The wetland system provides nutrient assimilation, additional water storage capacity, sediment attenuation, and enhanced evapotranspiration. SWMM predicted that the project will remove between 80 percent and 85 percent of the total suspended solids, depending on the level of future development. The cost of the project in 1989 dollars, including operation and monitoring costs over a 10-year period, was $198,960.

V. ONSITE DISPOSAL SYSTEMS

A. New Onsite Disposal Systems Management Measures

(1) Ensure that new Onsite Disposal Systems (OSDS) are located, designed, installed, operated, inspected, and maintained to prevent the discharge of pollutants to the surface of the ground and to the extent practicable reduce the discharge of pollutants into ground waters that are closely hydrologically connected to surface waters. Where necessary to meet these objectives: (a) discourage the installation of garbage disposals to reduce hydraulic and nutrient loadings; and (b) where low-volume plumbing fixtures have not been installed in new developments or redevelopments, reduce total hydraulic loadings to the OSDS by 25 percent. Implement OSDS inspection schedules for preconstruction, construction, and postconstruction.

(2) Direct placement of OSDS away from unsuitable areas. Where OSDS placement in unsuitable areas is not practicable, ensure that the OSDS is designed or sited at a density so as not to adversely affect surface waters or ground water that is closely hydrologically connected to surface water. Unsuitable areas include, but are not limited to, areas with poorly or excessively drained soils; areas with shallow water tables or areas with high seasonal water tables; areas overlaying fractured bedrock that drain directly to ground water; areas within floodplains; or areas where nutrient and/or pathogen concentrations in the effluent cannot be sufficiently treated or reduced before the effluent reaches sensitive waterbodies;

(3) Establish protective setbacks from surface waters, wetlands, and floodplains for conventional as well as alternative OSDS. The lateral setbacks should be based on soil type, slope, hydrologic factors, and type of OSDS. Where uniform protective setbacks cannot be achieved, site development with OSDS so as not to adversely affect waterbodies and/or contribute to a public health nuisance;

(4) Establish protective separation distances between OSDS system components and groundwater which is closely hydrologically connected to surface waters. The separation distances should be based on soil type, distance to ground water, hydrologic factors, and type of OSDS;

(5) Where conditions indicate that nitrogen-limited surface waters may be adversely affected by excess nitrogen loadings from ground water, require the installation of OSDS that reduce total nitrogen loadings by 50 percent to ground water that is closely hydrologically connected to surface water.

1. Applicability

This management measure is intended to be applied by States to all new OSDS including package plants and small-scale or regional treatment facilities not covered by NPDES regulations in order to manage the siting, design, installation, and operation and maintenance of all such OSDS. Under the Coastal Zone Act Reauthorization Amendments of 1990, States are subject to a number of requirements as they develop coastal NPS programs in conformity with this management measure and will have flexibility in doing so. The application of management measure by States is described more fully in *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance*, published jointly by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce.

2. Description

The purpose of this management measure is to protect the 6217 management area from pollutants discharged by OSDS. The measure requires that OSDS be sited, designed, and installed so that impacts to waterbodies will be reduced, to the extent practicable. Factors such as soil type, soil depth, depth to water table, rate of sea level rise, and topography must be considered in siting and installing conventional OSDS.

The objective of the management measure is to prevent the installation of conventional OSDS in areas where soil absorption systems will not provide adequate treatment of effluents containing solids, phosphorus, pathogens, nitrogen, and nonconventional pollutants prior to entry into surface waters and ground water (e.g., highly permeable soils, areas with shallow water tables or confining layers, or poorly drained soils). In addition to soil criteria, setbacks, separation distances, and management and maintenance requirements need to be established to fulfill the requirements of this management measure. Guidance on design factors to consider in the installation of OSDS is available in EPA's *Design Manual for Onsite Wastewater Treatment and Disposal Systems* (1980), currently under revision. This measure also requires that in areas experiencing pollution problems due to OSDS-generated nitrogen loadings, OSDS designs should employ denitrification systems or some other nitrogen removal process that reduces total nitrogen loadings by at least 50 percent. Additionally, hydraulic loadings to OSDS can be reduced by up to 25 percent by installing low-volume plumbing fixtures and enforcing water conservation measures. Garbage disposals are to be discouraged in all new development or redevelopment where conventional OSDS are employed as another means of reducing overloading and ensure proper operation of the OSDS. Regularly scheduled maintenance and pumpout of OSDS will prolong the life of the system and prevent degradation of surface waters.

States need not conduct new monitoring programs or collect new monitoring data to determine whether ground water is closely hydrologically connected to surface water, nor are States expected to determine exactly where the resulting water quality problems are significant. Rather, States are encouraged to make reasonable determinations based upon existing information and data sources.

3. Management Measure Selection

This management measure was selected to address the proper siting, design, and installation of new OSDS in the 6217 management area. OSDS have been identified as contributors of pathogens, nutrients, and other pollutants to ground water and surface waters. Nearly all coastal States have siting regulations establishing criteria for setbacks, separation distances, and percolation rates (Myers, 1991; WCFS, 1992). However, these programs often do not adequately protect surface waters from pollutants generated by OSDS. This management measure was selected to ensure that States comprehensively control new OSDS siting, design, and installation in order to protect surface waters.

The management measure components were selected to address problems known to be associated with OSDS. These management measure components were selected because proper siting of OSDS and the use of setbacks have been identified as effective methods for reducing nutrient and pathogen loadings to ground water and surface waters. All components of this management measure were selected to direct the placement of OSDS away from areas where site conditions are inadequate to allow proper treatment to occur and areas where there is a high potential for subsequent system failures that may cause contamination of waterbodies. In addition, this management measure was selected because siting and density controls can be effective complements to denitrifying systems. However, these requirements alone are often not adequate to protect surface waters, particularly in situations where installation and replacement of OSDS are allowed without thorough consideration of OSDS-related impacts. Periodic reevaluation of these requirements is necessary to ensure protection of surface waters.

Management measure components (1) (a) and (b) were selected to reduce occurrences of hydraulic overloading of conventional OSDS, which may result in inadequate treatment of septic system effluent and contamination of ground water or surface water. When excessive wastewater volumes are delivered to the soil absorption field, failure can occur. In addition, soil saturated with wastewater will not allow oxygen to pass into the soil. Hydraulic overloading often results from changes in water use habits, such as increased family size, the addition of new water-using appliances that require increased water consumption, or high seasonal use. New systems may fail within a few months if water use exceeds the system's capacity to absorb effluent (Mancl, 1985). Water conservation reduces the amount of water an absorption field must accept.

Since numerous States have responded to this concern by adopting low-flow plumbing fixture regulations (Table 4-18), requiring such fixtures is not unreasonable. In addition, a number of States have regulations prohibiting the installation of garbage disposals where OSDS are used. If low-flow plumbing fixtures are used, it is important that OSDS design not be modified to decrease the required septic tank size. The use of smaller septic tanks will negate the advantages of using low-flow plumbing fixtures.

For absorption fields to operate properly, they must have aerobic conditions. Jarrett et al. (1985) stated that 75 percent of the total number of soil absorption field failures could be attributed to hydraulic overloading. High-efficiency plumbing fixtures can reduce the total water load by as much as 60 percent (Jarrett et al., 1985) and reduce the chance of absorption field failure. Table 4-19 illustrates daily water use and pollutant loadings.

Management measure component (5) was selected to abate OSDS nitrogen loadings to surface waters where nitrogen is a cause of surface water degradation. The Chesapeake Bay Program (1990) found that 55 to 85 percent of the nitrogen entering a conventional OSDS can be discharged into ground water. Conventional septic systems account for 74 percent of the nitrogen entering Buttermilk Bay (at the northern end of Buzzard's Bay) in Massachusetts (Horsely Witten Hegeman, 1991). A study of nitrogen entering the Delaware Inland Bays found that a significant portion of the total pollutant load could be attributed to septic systems. The study determined that septic systems accounted for 15 percent, 16 percent, and 11 percent of the nitrogen inputs to Assawoman, Indian River, and Rehoboth Bays, respectively (Reneau, 1977; Ritter, 1986). Alternatives to conventional OSDS that can substantially reduce nitrogen loadings are available.

In 1980, EPA developed a design manual for onsite wastewater treatment and disposal systems. An update of this document is being prepared.

4. Practices

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.

Many of the following practices involve siting and locating OSDS within the 6217 management area. They address issues such as minimum lot size, depth to water table, and site-specific characteristics such as soil percolation rate. Table 4-20 illustrates the variability in State and local requirements for siting of OSDS. The practices were developed to address the issue of siting OSDS given the variable nature of this activity.

a. Develop setback guidelines and official maps showing areas where conditions are suitable for conventional septic OSDS installation.

Table 4-18. States That Have Adopted Low-Flow Plumbing Fixture Regulations (In gallons per flush for toilets and gallons per minute for other fixtures) (Small Flows Clearinghouse, 1991)[a]

State	Effective Date	Water Closets	Urinal	Shower Heads	Lavatory Faucets	Kitchen Faucets
California	01/01/92	1.6	1.0	2.5 @ 80 psi	2.2 @ 60 psi	2.2 @ 60 psi
Colorado	01/01/90	3.5		3.0 @ 80 psi	2.5 @ 80 psi	2.5 @ 80 psi
Connecticut	10/01/90		1.0	2.5	2.5	2.5
	01/01/92	1.6				
Delaware	07/01/91	1.6	1.5	3.0 @ 80 psi	3.0 @ 80 psi	3.0 @ 80 psi
Georgia						
Residential	04/01/92	1.6	1.0	2.5 @ 60 psi	2.0	2.5
Commercial	07/01/92	1.6	1.0	2.5 @ 60 psi	2.0	2.5
Massachusetts	03/02/89	1.6 (1-piece)	1.5			
	01/01/88			3.0		
	09/01/91	1.6 (all others)				
New Jersey	07/01/91	1.6	1.5	3.0	3.0	3.0
New York	1980			3.0 @ psi		3.0
	01/26/88		1.0			
	01/01/91				2.0	
	01/01/92	1.6				
Oregon	07/01/93	1.6	1.0	2.5	2.5	2.5
Rhode Island	09/01/90	1.6 (2-piece)		2.5 @ 80 psi	2.0 @ 80 psi	2.0 @ 80 psi
	03/01/91	1.6 (all others)	1.0			
Texas	01/01/92	1.6[b]	1.0	2.75 @ 80 psi	2.2 @ 60 psi	2.2 @ 60 psi
Washington	07/01/93	1.6	1.0	2.5 @ 80 psi	2.5 @ 80 psi	2.5 @ 80 psi

psi = pounds per square inch.
[a] Information provided by Judith L. Ranton, City of Portland, Oregon, Bureau of Water Works.
[b] 2.0 gallons or flow rate for ANSI ultra-low flush toilets, whichever is lowest for wall-mounted with flushometers.

Table 4-19. Daily Water Use and Pollutant Loadings by Source (USEPA, 1980)

Water Use	Volume (L/capita)	BOD (g/capita)	SS (g/capita)	Total N (g/capita)	Total P (g/capita)
Garbage Disposal	4.54	10.8	15.9	0.4	0.6
Toilet	61.3	17.2	27.6	8.6	1.2
Basins and Sinks	84.8	22.0	13.6	1.4	2.2
Misc.	25.0	0	0	0	0
Total	175.6	50.0	57.0	10.4	3.5

L = liters
g = grams

Both conventional and alternative OSDS usually include a soil absorption field. These absorption fields require a certain minimum area of soil surrounding the system to effectively remove pathogens and other pollutants. Setbacks from wells, surface waters, building foundations, and property boundaries are necessary to minimize the threat to public health and the environment. The setback should be based on soil type, slope, presence and character of the water table (as defined on a map developed by the implementing agency), and the type of OSDS. Setback guidelines should be set for both traditional and alternative OSDS. The *Design Manual for Onsite Wastewater Treatment and Disposal Systems* (USEPA, 1980) recommends the following setbacks for soil absorption systems, although other increased setbacks may be necessary to protect ground water and surface waters from viral and bacteria transport to account for tidal influences and accommodate sea level rise. (NOTE: Setback distance requirements may vary considerably based on local soil conditions and aquifer properties):

Water supply wells	50 to 100 feet
Surface waters, springs	50 to 100 feet
Escarpments	10 to 20 feet
Boundary of property	5 to 10 feet
Building foundations	10 to 20 feet (30 feet when located up-slope from a building in slowly permeable soils)

For mound systems, the mound perimeter requires down-slope setbacks to make certain that the basal area of the mound is sufficient to absorb the wastewater before it reaches the perimeter of the mound to avoid surface seepage. The *Design Manual for Onsite Wastewater Treatment and Disposal Systems* (USEPA, 1980) provides guidance on setbacks for mound systems.

b. OSDS should be sited, designed, and constructed so that there is sufficient separation between the soil absorption field and the seasonal high water table or limiting layer, depending on site characteristics, including but not limited to hydrology, soils, and topography.

Studies have shown that at least 4 feet of unsaturated soil below the ponded liquid in a soil absorption field is necessary to (1) remove bacteria and viruses to an acceptable level, (2) remove most organics and phosphorus, and (3) nitrify a large portion of the ammonia (University of Wisconsin, 1978). The majority of coastal States already require a minimum separation distance of at least 2 feet (Woodward-Clyde, 1992). Massachusetts requires a minimum separation of 4 feet; 5 feet is required by towns with sensitive surface waters. Several towns on Cape Cod have adopted 5 feet as the minimum. A prescribed minimum distance is necessary to prevent contaminants from directly entering ground water and surface waters. Areas with rapid soil permeabilities (e.g., a percolation rate of less than 5 minutes/inch) may require a greater separation distance. However, because of local variation, these numbers are provided only as guidance.

A study on a barrier island of North Carolina (Carlile et al., 1981) found high concentrations of nitrogen, phosphorus, and pathogens in shallow ground-water wells located beneath septic system soil absorption fields. These high concentrations were suspected to be the result of inadequate separation distance to the water table. Further analysis revealed that, at the design loading rate, a greater separation distance reduced the ground-water concentration of indicator organisms from 4.6 to 2.3 logs, and phosphorus by 93 percent. Nitrogen levels were also reduced, but this improvement (10 percent) was not as dramatic as that observed for bacteria and phosphorus.

c. Require assessments of site suitability prior to issuing permits for OSDS.

Site assessments should be performed to determine the soil infiltration rate, soil pollutant removal capacity, acceptable hydraulic loading rate, and depth to the water table prior to issuing permits for OSDS. Percolation tests are usually performed to determine the soil infiltration rate. However, Hill and Frink (1974) stated that percolation tests are often performed improperly and system failures have resulted from improper siting and inadequate percolation rates. In addition, regulatory values based on acceptable percolation rates vary considerably (e.g., Delaware - 6 to 60 min/in; Georgia - 50 to 90 min/in; Michigan - 3 to 60 min/in; and Virginia - 5 to 120 min/in

Table 4-20. Example Onsite Sewage Disposal System Siting Requirements

State	OSDS Siting Requirement
Florida	With respect to ground-water movement, the State requires that onsite systems must be placed no closer than 75 ft from a private potable water well, 100 ft from a public drinking water well, and 200 ft from a public drinking water well serving a facility with an estimated sewage flow of more than 2,000 gallons per day. Systems must not be located within 5 ft of building foundations or laterally within 75 ft of the mean high water line. Subdivisions and lots where each lot has a minimum area of at least 1/2 acre and either a minimum dimension of 100 ft or a mean of at least 100 ft from the street may be developed with private potable wells or wells serving water systems and onsite sewage disposal systems.
Massachusetts	The State requires that no septic tank shall be closer than 10 ft and no leaching facility shall be closer than 20 ft to surface water supplies; no septic tank shall be closer than 25 ft and no leaching facility shall be closer than 50 ft to watercourses. Onsite systems must be at least 4 ft above ground water.
South Carolina	No State requirement. County requirements vary. For example, the County of Charleston recommends a miniumum lot size of 12,500 ft^2 with a 70-ft front on lots with public water supplies and 30,000 ft^2 with a 100-ft front for lots with private water supplies.
Virginia	The Chesapeake Bay Act requires that no sewage system shall be placed within 25 ft of a Resource Preservation Watercourse or within 100 ft of a Resource Management Watercourse. In the event that these requirements cannot be met, the State requires minimum setbacks of 70 ft for shellfish waters, 50 ft for impounded surface waters, and 50 ft for streams.
Washington	The State requires a 1/2- to 1-acre minimum lot size, dependent upon soil type, for areas served by public water supplies and a 1- to 2-acre minimum lot size for septic tank siting, dependent upon soil type, for individual areas served by water supplies and private wells.
Wisconsin	The State requirements of lot areas and widths vary according to percolation rate (measured as time required to percolate 1 inch). For example, for a lot with a private water supply system and a percolation rate of under 10 minutes, a minimum lot area of 20,000 ft^2, a minimum average lot width of 100 ft, and a minimum continuous suitable soil area of 10,000 ft^2 are required before an OSDS can be sited. For areas served by a community water supply system, a lot with a percolation rate of under 10 minutes requires a minimum lot area of 12,000 ft^2, a minimum average lot width of 75 ft, and a minimum continuous suitable soil area of 6,000 ft.

(Woodward-Clyde, 1992). States such as Florida and Mississippi require soil evaluations to determine the suitability of an absorption field. A soil evaluation should also be used in conjunction with percolation test results to determine whether a site is acceptable, and soil percolation requirements should be phased out, if appropriate. These evaluations should examine the organic content of the soil, the grain size distribution, and the structure of the soil. In addition, hydraulic loading should be evaluated to determine the suitability of a site for septic tank use.

A system such as DRASTIC methodology (USEPA, 1987) can also be used to map areas where aquifers may be vulnerable to pollution from OSDS. DRASTIC considers soil permeability, depth to ground water, and aquifer characteristics.

d. *If OSDS are sited in areas where conditions indicate that nitrogen-limited waters may be adversely affected by excessive nitrogen loading, minimize densities of development in those areas and require the use of denitrification systems.*

In areas where nitrogen is a problem pollutant, it is important to consider the density of OSDS. As the density of residences increases, lot sizes decrease and impacts (especially from nitrogen) on underlying ground water may intensify. One-half to 5-acre lots are generally the minimal requirement for siting OSDS, but the lot size may need to be larger if nitrogen is a problem pollutant. Limits on the density of absorption fields should also reflect variations in climate (Rutledge et al., undated). In Buzzards Bay, Massachusetts, a minimum lot size of 70,000 square feet was recommended as necessary to avoid nitrogen-induced degradation (Horsely Witten Hegeman, 1991). However, this practice should not preclude implementation of the use of cluster development to retain open areas necessary for controlling NPS pollution.

A number of treatment systems are known to remove nitrogen using denitrification. Such systems include sand and anaerobic upflow filters, and constructed wetlands. These systems are described in practice "f." Most of these systems require nitrification of septic tank effluent as an initial stage of the treatment process. When properly operated, these systems have been shown to have the potential to remove over 50 percent of the total nitrogen from septic tank effluent.

e. *Develop and implement local plumbing codes that require practices that are compatible with OSDS use.*

As stated previously, the majority of OSDS soil absorption field failures are attributed to hydraulic overload. Solids loads from garbage disposals can also lead to clogging and failure of an absorption field. To address these problems, plumbing codes that minimize the potential for soil absorption field failure should be implemented.

Plumbing codes that require the use of high-efficiency plumbing fixtures in new development can reduce these water loads considerably. Such high-efficiency fixtures include toilets of 1.5 gallons or less per flush, shower heads of 2.0 gallons per minute (gpm), faucets of 1.5 gpm or less, and front-loading washing machines of up to 27 gallons per 10- to 12-pound load. Implementing these fixtures can reduce total in-house water use by 30 percent to 70 percent (*Consumer Reports* July 1990, February 1991).

f. *In areas suitable for OSDS, select, design, and construct the appropriate OSDS that will protect surface waters and ground water.*

Selection of an OSDS should consider site soil and ground-water characteristics and the sensitivity of the receiving water(s) to OSDS effluent. Descriptions and design considerations for systems have been provided below. Table 4-21 contains available cost and effectiveness data for some of these systems. Design and operation and maintenance information on these devices can be found in *Design Manual for Onsite Wastewater Treatment and Disposal Systems* (USEPA, 1980).

Conventional Septic System. A conventional septic system consists of a settling or septic tank and a soil absorption field. The traditional system accepts both greywater (wastewater from showers, sinks, and laundry) and blackwater (wastewater from toilets). These systems are typically restricted in that the bottom invert of the absorption field must be at least 2 feet above the seasonally high water table or impermeable layer (separation distance) and the percolation rate of the soil must be between 1 and 60 minutes per inch. Also, to ensure proper operation, the tank should be pumped every 3 to 5 years. Nitrogen removal of these systems is minimal and somewhat dependent on temperature. The most common type of failure of these systems is from clogging of the absorption field, insufficient separation distance to the water table, insufficient percolation capacity of the soil, and overloading of water.

Mound Systems. Mound systems are an alternative to conventional OSDS and are used on sites where insufficient separation distance or percolation conditions exist. Mound systems are typically designed so the effluent from the

Table 4-21. OSDS Effectiveness and Cost Summary

	Effectiveness[a]						Cost		
Practice	Water (%)	TSS (%)	BOD (%)	TN (%)	TP (%)	Path. (Logs)	Capital Cost[b] ($/House)	Maintenance Cost[b] ($/Year)	References
Conventional Septic System									USEPA, 1977, 1980, 1989, 1991; Sandy et al., 1988; Lamb et al., 1988; Rhode Island, 1989; Degen et al., 1991; Healy, 1982; Hanson et al., 1988; Dix, 1986; Fulhage and Day, 1988.
Average	NA	72	45	28	57	3.5	$4,500	$70	
Probable Range	NA	60-70	40-55	10-45	30-80	3-4	$2,000-$8,000	$50-$100	
Observed Range	NA	54-83	30-60	0-58	0-95	3-4	$2,000-$10,000	$25-$110	
No. Values Considered	0	7	7	13	12	2	8	4	
Mound Systems									USEPA, 1977, 1980, 1991; Small Flows Clearinghouse, undated.; Hanson et al., 1988; Degen et al., 1991.
Average	NA	NA	NA	44	NA	NA	$8,300	$180	
Probable Range	NA	60-70	40-55	10-45	30-80	3-4	$7,000-$10,000	$100-$300	
Observed Range	NA	NA	NA	44-44	NA	NA	$6,800-$11,000	$90-$310	
No. Values Considered	0	0	0	1	0	0	4	4	
Low Pressure Systems									Fulhage and Day, 1988; USEPA, 1980.
Average	NA	NA	NA	NA	NA	NA	$5,100	$150	
Probable Range	NA	60-70	40-55	10-45	30-80	3-4	$4,000-$6000	$100-$200	
Observed Range	NA	NA	NA	NA	NA	NA	$2,800-$7,400	$150-$150	
No. Values Considered	0	0	0	0	0	0	2	1	
Anaerobic Upflow Filter									USEPA, 1991; Venhuizen, 1991; Mitchell, undated.
Average	NA	44	62	59	NA	NA	$5,550	NA	
Probable Range	NA	30-60	50-75	40-75	60-80	3-4	$3,000-$8,000	$150-$400	
Observed Range	NA	24-89	46-84	20-75	NA	NA	$3,000-$8,000	NA	
No. Values Considered	0	6	6	6	0	0	2	0	
Intermittent Sand Filter									USEPA, 1977, 1980, 1991; Small Flows Clearinghouse, undated.; Venhuizen, 1991.
Average	NA	92	92	55	80	3.2	$5,400	$275	
Probable Range	NA	80-95	90-95	50-65	70-90	3-4	$4,000-$8,000	$250-$400	
Observed Range	NA	70-99	80-99	40-75	70-90	2-4	$2,300-$10,000	$100-$440	
No. Values Considered	0	7	10	7	2	6	7	5	

Table 4-21. (Continued)

Practice	Effectiveness[a] Water (%)	TSS (%)	BOD (%)	TN (%)	TP (%)	Path. (Logs)	Cost Capital Cost[b] ($/House)	Maintenance Cost[b] ($/Year)	References
Recirculating Sand Filter									Hoxie et al., 1988; Small Flows Clearinghouse, undated.; Fulhage and Day, 1988; USEPA, 1991; Venhuizen, 1991; Swanson and Dix, 1988; Lamb et al., 1988; Laak, 1986; USEPA, 1980; Sandy et al., 1988.
Average	NA	90	92	64	80	2.9	$3,900	$145	
Probable Range	NA	85-95	85-95	60-85	70-90	2-4	$5,000-$8,000	$250-$400	
Observed Range	NA	70-98	75-98	1-94	70-90	2-4	$1,850-$9,200	$15-$410	
No. Values Considered	0	12	15	13	2	8	5	7	
Water Separation System									USEPA, 1991; USEPA, 1986; USEPA, 1980; USEPA, 1977.
Average	NA	60	42	83	30	3	$8,000	$300	
Probable Range	NA	55-70	35-55	70-90	30-55	2-4	$5,000-$11,000	$300-$750	
Observed Range	NA	36-75	22-55	68-99	14-42	NA	$5,000-$11,000	$300-$300	
No. Values Considered	0	4	3	6	6	0	1	1	
Constructed Wetlands									Reed, 1991; Small Flows Clearinghouse, undated.; USEPA, 1980; Amberg, 1990; Dwyer et al., 1989.
Average	NA	80	81	90	NA	4	$710	$25	
Probable Range	NA	60-90	70-90	60-90	30-70	3-4	$1,000-$3,000	$25-$100	
Observed Range	NA	50-983	65-97	90-90	NA	4-4	$50-$350	$25-$25	
No. Values Considered	0		4	2	0	NA	19	1	
Cluster Systems									Decker, 1987; Small Flows Clearinghouse, undated.
Average	NA	NA	NA	NA	NA	NA	$4,950	$370	
Probable Range	NA	NA	NA	NA	NA	NA	$5,000-$7,000	$300-$400	
Observed Range	NA	NA	NA	NA	NA	NA	$3,000-$6,900	$370-$370	
No. Values Considered	0	NA	NA	NA	NA	NA	3	1	

Table 4-21. (Continued)

Practice	Effectiveness[a] Water (%)	TSS (%)	BOD (%)	TN (%)	TP (%)	Path. (Logs)	Cost Capital Cost[b] ($/House)	Maintenance Cost[b] ($/Year)	References
Eliminating Garbage Disposals									USEPA, 1980, 1986, 1991.
Average	NA	37	28	5	2.5	NA	NA	NA	
Probable Range	NA	35-40	25-30	5-10	2-3	NA	Negligible	Negligible	
Observed Range	NA	37-37	28-28	5-5	2-3	NA	NA	NA	
No. Values Considered	0	3	2	2	2	NA	NA	NA	
Low Phosphate Detergents									USEPA, 1980, 1991.
Average	NA	NA	NA	NA	50	NA	NA	NA	
Probable Range	NA	NA	NA	NA	40-50	NA	Negligible	Negligible	
Observed Range	NA	NA	NA	NA	50-50	NA	NA	NA	
No. Values Considered	0	0	0	0	2	0	0	0	
Water Conservation Fixtures									USEPA, 1977, 1980, 1991;
Average									Small Flows
Probable Range	45	NA	NA	NA	NA	NA	NA	NA	Clearinghouse, undated.;
Observed Range	25-80	NA	NA	NA	NA	NA	Varies	Negligible	Jarrett et al., 1985.
No. Values Considered	4-90	NA	NA	NA	NA	NA	NA	NA	
	11	0	0	0	0	0	0	0	
Holding Tanks									Small Flows
Average	NA	NA	NA	NA	NA	NA	$3,900	$1,300	Clearinghouse, undated.;
Probable Range	NA	95-100	95-100	95-100	95-100	3-4	$4,000-$6,000	$1,000-$2,000	Dix, 1986; Hanson et al.,
Observed Range	NA	NA	NA	NA	NA	NA	$1,220-$6,670	$100-$2,400	1988.
No. Values Considered	0	0	0	0	0	0	8	12	

NA - Not available.
[a] Effectiveness values reflect total system reductions including soil absorption fields.
[b] Costs are in 1988 equivalent dollars, and an average household with four occupants was assumed.

septic tank is routed to a dosing tank and then pumped to a soil absorption field that is located in elevated sand fill above the natural soil surface. There is evidence suggesting that pressure dosing provides more uniform distribution of effluent throughout the absorption field and may result in marginally better performance. A major limitation to the use of mounds is slope. In Pennsylvania, elevated sand mound beds are permitted only in areas with slopes less than 8 percent (Mancl, 1985).

Where adequate area is available for subsurface effluent discharge, and permanent or seasonal high ground water is at least 2 feet below the surface, the elevated sand mound may be used in coastal areas. This system can treat septic tank effluent to a level that usually approaches primary drinking water standards for BOD_5, suspended solids, and pathogens by the time the effluent plume passes the property line for single-family dwellings. A mound system will not normally produce significant reductions in levels of total nitrogen discharged, but should achieve high levels of nitrification.

Intermittent Sand Filter. Intermittent sand filters are used in conjunction with pretreatment methods such as septic tanks and soil absorption fields. An intermittent sand filter receives and treats effluent from the septic tank before it is distributed to the leaching field. The sand filter consists of a bed (either open or buried) of granular material from 24 to 36 inches deep. The material is usually from 0.35 to 1.0 mm in diameter. The bed of granular material is underlain with graded gravel and collector drains. These systems have been shown to be effective for nitrogen removal; however, this process is dependent on temperature. Water loading recommendations for intermittent sand filters are typically between 1 and 5 gallons per day/square foot (gpd/ft^2) but can be higher depending on wastewater characteristics. Primary failure of sand filters is from clogging, and the following maintenance is recommended to keep the system performing properly: resting the bed, raking the surface layer, or removing the top surface medium and replacing it with clean medium. In general, the filters should be inspected every 3 to 4 months to ensure that they are operating properly (Otis, undated).

Intermittent sand filters are used for small commercial and institutional developments and individual homes. The size of the facility is limited by land availability. The filters should be buried in the ground, but may be constructed above ground in areas of shallow bedrock or high water tables. Covered filters are required in areas with extended periods of subfreezing weather. Excessive long-term rainfall and runoff may be detrimental to filter performance, requiring measures to divert water away from the system (USEPA, 1980).

Recirculating Sand Filter. A recirculating sand filter is a modified intermittent sand filter in which effluent from the filter is recirculated through the septic tank and/or the sand filter before it is discharged to the soil absorption field. The addition of the recirculation loop in the system may enhance removal effectiveness and allows media size to be increased to as much as 1.5 mm in diameter and allows water loading rates in the range of 3 to 10 gpd/ft^2 to be used. Recirculation rates of 3:1 to 5:1 are generally recommended.

Buried or recirculating sand filters can achieve a very high level of treatment of septic tank effluent before discharge to surface water or soil. This usually means single-digit figures for BOD_5 and suspended solids and secondary body contact standards for pathogens (in practice, 100-900 per 100 ml). Dosed recycling between sand filter and septic tank or similar devices can result in significant levels of nitrification/denitrification, equivalent to between 50 and 75 percent overall nitrogen removal, depending on the recycling ratio. Regular buried or recirculating sand filters may require as much as 1 square foot of filter per gallon of septic tank effluent.

Anaerobic Upflow Filter. An anaerobic upflow filter (AUF) resembles a septic tank filled with 3/8-inch gravel with a deep inlet tee and a shallow outlet tee. An AUF system includes a septic tank, an AUF, a sand filter, and a soil absorption field. As with the sand filter, dose recycling can be used to enhance this system's performance. Hydraulic loading for an AUF is generally in the range of 3 to 15 gpd. An AUF resembles a septic tank or the second chamber of a dual-chambered tank. It should be sized to allow retention times between 16 and 24 hours. There is a high degree of removal of suspended solids and insoluble BOD. Dosed recycling between sand filter and AUF can result in 60 to 75 percent overall nitrogen removal.

A growing body of data at the University of Arkansas and elsewhere suggests that an AUF can provide further treatment of septic tank effluent before discharge to a sand filter. This treatment allows a drastic reduction (by a factor of 8 to 20) in the size of sand filter needed to attain the performance described above, with major reductions in cost (Krause, 1991).

Trenches and Beds. Trenches are typically 1 to 3 feet wide and can be greater than 100 feet long. Infiltration occurs through the bottom and sides of the trench. Each trench contains one distribution pipe, and there may be multiple trenches in a single system. Like conventional septic systems, they require 2 to 4 feet between the bottom of the system and the seasonally high water table or bedrock, and are best suited in sandy to loamy soils where the infiltration rate is 1 to 60 minutes per inch. Gravelly soils or poor-permeability soils (60 to 90 minutes per inch) are not suitable for trench systems. However, where the infiltration rate is greater than 1 minute per inch, 6 inches of loamy soil can be added around the system to create the proper infiltration rate (Otis, undated).

Beds are similar to trenches except that infiltration occurs only through the bottom of the bed. Beds are usually greater than 3 feet wide and contain one distribution pipe per bed. Single beds are commonly used; however, dual beds may be installed and used alternately. The same soil suitability conditions that apply to trenches apply to bed systems.

Trenches are often preferred to beds for a few reasons. First, with equal bottom areas, trenches have five times the sidewall area for effluent absorption; second, there is less soil damage during the construction of trenches; and third, trenches are more easily used on sloped sites.

The effluent from trenches or beds can be distributed by gravity, dosing, or uniform application. Dosing refers to periodically releasing the effluent using a siphon or pump after a small quantity of effluent has accumulated. Uniform application similarly stores the effluent for a short time, after which it is released through a pressurized system to achieve uniform distribution over the bed or trench. Uniform application results in the least amount of clogging.

Maintenance of trenches and beds is minimal. Dual trench or bed systems are especially effective because they allow the use of one system while the other rests for 6 months to a year to restore its effectiveness (Otis, undated).

Water Separation System. A water separation system separates greywater and blackwater. The greywater is treated using a conventional septic system, and the blackwater is contained in a vault/holding tank. The blackwater is later hauled off site for disposal.

For extreme situations or for seasonal residents, some form of separation of toilet wastes from bath and kitchen wastes may be helpful. Most nitrogen discharges in residential wastewater come from human urine. A very efficient toilet (0.8 gallon per flush), if routed to a separate holding tank, would need pumping only three or four times per year even for a family of four permanent residents.

Constructed Wetlands. Constructed wetlands are usually used for polishing of septage effluent that has already had some degree of treatment (processing through a septic tank or other aggregated system). The performance of constructed wetlands will be degraded in colder climates during winter months because of plant die-off and reduction in the metabolic rate of aquatic organisms.

Cluster Systems. For the purposes of this guidance, a cluster system can be defined as a collection of individual septic systems where primary treatment of septage occurs on each site and the resulting effluent is collected and treated to further reduce pollutants. Additional treatment may involve the use of sand filters or AUF, constructed wetlands, chemical treatment, or aerobic treatment. The use of cluster systems may provide advantages due to increased treatment capability and economy of scale.

Evapotranspiration (ET) and Evapotranspiration/Absorption (ETA) Systems. ET and ETA systems combine the process of evaporation from the surface of a bed and transpiration from plants to dispose of wastewater. The wastewater would require some form of pretreatment such as a septic tank. An ET bed usually consists of a liner, drainfield tile, and gravel and sand layers. ET and ETA systems are useful where soils are unsuitable for subsurface disposal, where the climate is favorable to evaporation, and where ground-water protection is essential. In both types of systems, distribution piping is laid in gravel, overlain by sand, and planted with suitable vegetation. Plants can transpire up to 10 times the amount of water evaporated during the daytime. For an ET system to be effective, evaporation must be equal to or greater than the total water input to the system because it requires an impermeable seal around the system. In the United States, this limits use of ET systems to the Southwest. The size of the system depends on the quantity of effluent inflow, precipitation, the local evapotranspiration rate, and soil permeability (Otis, undated). Data were unavailable on this BMP, so its cost and effectiveness were not evaluated.

Vaults or Holding Tanks. Vaults or holding tanks are used to containerize wastewater in emergency situations or other temporary functions. This technology should be discouraged because of high anticipated overloads due to difficult pumping logistics. Such systems require frequent pumping, which can be expensive.

Fixed Film Systems. A fixed film system employs media to which microorganisms may become attached. Fixed film systems include trickling filters, upflow filters, and rotating biological filters. These systems require pretreatment of sewage in a septic tank; final effluent can be discharged to a soil absorption field. Cost and effectiveness data for this BMP were not available.

Aerobic Treatment Units. Aerobic treatment units can be employed on site. A few systems are available commercially that employ various types of aerobic technology. However, these systems require regular supervision and maintenance to be effective. They require pretreatment by a septic tank, and effluent can be discharged to a soil absorption field. Power requirements can be significant for certain types of these packages. Cost and effectiveness data for this BMP were not available.

Sequencing Batch Reactor. A sequencing batch reactor is a modified conventional continuous-flow activated sludge treatment system. Conventional activated sludge systems treat wastewater in a series of separate tanks. Sequencing batch reactors carry out aeration and sedimentation/clarification simultaneously in the same tank. They are designed for the removal of biochemical oxygen demand (BOD) and total suspended solids (TSS) from typical municipal and industrial wastewater at flow rates of less than 5 MGD. Modification to the design of the basic system allows for nitrification and denitrification and for the removal of biological phosphorus to occur.

The sequencing batch reactor is particularly suitable for small flows and for nutrient removal. Sequencing batch reactors can be either used for new developments or connected to existing septic systems. Small reactors can be sited in areas of only a few hundred square feet. While sequencing batch reactor cost and operation and maintenance requirements are greater than those for conventional OSDS, sequencing batch reactors may be suitable alternatives for sites where high-density development and/or unsuitable soils may preclude adequate treatment of effluent.

Sequencing batch reactors can also be used where municipal and industrial wastes require conventional or extended aeration activated sludge treatment. They are most applicable at flow rates of 3000 gpd to 5 MGD but lose their cost-effectiveness at design rates exceeding 10 MGD (USEPA, 1992). Sequencing batch reactors are very useful for the pretreatment of industrial waste and for small flow applications. They are also optimally useful where wastewater is generated for less than 12 hours per day.

Disinfection Devices. In some areas, pathogen contamination from OSDS is a major concern. Disinfection devices may be used in conjunction with the above systems to treat effluent for pathogens before it is discharged to a soil absorption field. Disinfection devices include halogen applicators (for chlorine and iodine), ozonators, and UV applicators. Of these three types, halogen applicators are usually the most practical (USEPA, 1980). Installation of these devices in an OSDS increases the system's cost and adds to the system's operation and maintenance requirements. However, it may be necessary in some areas to install these devices to control pathogen contamination of surface waters and ground water.

(NOTE: The use of disinfection systems should be evaluated to determine the potential impacts of chlorine or iodine loadings. Some States, such as Maryland, have additional requirements or prohibit the use of these processes.)

Massachusetts has adopted a provision of its State Environmental Code that allows for "approval of innovative disposal systems if it can be demonstrated that their impact on the environment and hazard to public health is not greater than that of other approved systems" (310 CMR 15.18). Commonly referred to as Title 5, this legislation requires evaluation of pollutant loadings as well as management requirements prior to approval of alternative systems (Venhuizen, 1992).

g. Design sites so that an area for a backup soil absorption field is planned for in case of failure of the first field.

In preparation of site plans and designs for OSDS, it is recommended that a suitable area be identified and reserved for construction of a second or replacement soil absorption field, in the event that the first fails or expansion is necessary. Oliveri and others (1981) determined that continuously loaded soil absorption fields have a finite life span and that 50 percent of all fields fail within 25 years. Consequently, dual systems or a plan for a backup system is necessary. The area for the backup soil absorption field should be located to facilitate simultaneous or alternate loading of the old and new systems. With trench systems, the area between the original trenches can serve as the replacement area as long as sufficient vertical spacing exists between the trenches.

h. During construction of OSDS, soils should not be compacted in the primary or the backup soil absorption field area.

Care must be taken during the construction of OSDS so that the soil in the absorption field area is not compacted. Compaction could severely decrease the infiltration capacity of the soil and lead to failure of the absorption field.

i. Perform postconstruction inspection of OSDS.

A postconstruction inspection program should be implemented to ensure that OSDS were installed properly. The inspection should ensure that design specifications were followed and that soil absorption field areas were not compacted during construction. Many local governments in Massachusetts require postconstruction inspection for OSDS (Myers, 1991).

5. Effectiveness Information and Cost Information

Cost and effectiveness data on alternative OSDS systems are presented in Table 4-21.

The availability of high-quality, water-efficient plumbing fixtures (1.6-gallon toilets, 1.5-gpm showerheads, etc.) can provide a reduction of 50 percent in residential water use and wastewater volume, at an incremental cost of only about $20 to $100 for new homes. For on-site treatment, the higher influent concentrations are counterbalanced by longer septic tank retention time. This water conservation can allow further reductions in the size of sand filters or other forms of treatment (Krause, 1991).

The elimination of garbage disposals will reduce hydraulic loadings to OSDS and decrease the potential for solids to clog the absorption field, as shown in Table 4-22.

Performance data on sequencing batch reactors show that typical designs can achieve BOD and TSS concentrations of less than 10 mg/L and that modified systems can denitrify to limits of 1 to 2 mg/L NH_3-N (EPA, 1992). Some modified sequencing batch reactors have been shown to exhibit denitrification. Biological phosphorus removal to less than 1.0 mg/L has also been achieved (EPA, 1992).

Table 4-22. Reduction in Pollutant Loading by Elimination of Garbage Disposals

Parameter	Reduction in Pollutant Loading (%)
Suspended Solids	25-40
Biohemical Oxygen Demand	20-28
Total Nitrogen	3.6
Total Phosphorus	1.7

The costs for sequencing batch reactors, adjusted to 1991 dollars, for constructing and operating sequencing batch reactors were determined for several existing systems. The capital costs for six treatment systems were found to range from $1.93 to $30.69/gpd of design flow (USEPA, 1992). The operating costs for three existing systems, based on 1990 average flow rates, ranged from $0.17/gpd to $2.88/gpd (USEPA, 1992).

Costs for a complete mound system, including a septic tank, in the rural Midwest are typically $7,000 installed (Krause, 1991). The cost for a residential septic tank/AUF/sand filter combination in the rural Midwest normally ranges from $3,000 to $4,000 (Krause, 1991). Costs for buried or recirculatng sand filters depend on the filter size and the availability of sand of the proper texture. Costs for a complete system in the rural Midwest may range between $5,000 and $10,000 (Krause, 1991).

B. Operating Onsite Disposal Systems Management Measure

(1) Establish and implement policies and systems to ensure that existing OSDS are operated and maintained to prevent the discharge of pollutants to the surface of the ground and to the extent practicable reduce the discharge of pollutants into ground waters that are closely hydrologically connected to surface waters. Where necessary to meet these objectives, encourage the reduced use of garbage disposals, encourage the use of low-volume plumbing fixtures, and reduce total phosphorus loadings to the OSDS by 15 percent (if the use of low-level phosphate detergents has not been required or widely adopted by OSDS users). Establish and implement policies that require an OSDS to be repaired, replaced, or modified where the OSDS fails, or threatens or impairs surface waters;

(2) Inspect OSDS at a frequency adequate to ascertain whether OSDS are failing;

(3) Consider replacing or upgrading OSDS to treat influent so that total nitrogen loadings in the effluent are reduced by 50 percent. This provision applies only:

(a) where conditions indicate that nitrogen-limited surface waters may be adversely affected by significant ground water nitrogen loadings from OSDS, and

(b) where nitrogen loadings from OSDS are delivered to ground water that is closely hydrologically connected to surface water.

1. Applicability

This management measure is intended to be applied by States to all operating OSDS. Under the Coastal Zone Act Reauthorization Amendments of 1990, States are subject to a number of requirements as they develop coastal NPS programs in conformity with this management measure and will have flexibility in doing so. The application of management measures by States is described more fully in *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance*, published jointly by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce. This management measure does not apply to existing conventional OSDS that meet all of the following criteria: (1) treat wastewater from a single family home; (2) are sited where OSDS density is less than or equal to one OSDS per 20 acres; and (3) the OSDS is sited at least 1,250 feet away from surface waters.

2. Description

The purpose of this management measure is to minimize pollutant loadings from operating OSDS. This management measure requires that OSDS be modified, operated, repaired, and maintained to reduce nutrient and pathogen loadings in order to protect and enhance surface waters. In the past, it has been a common practice to site conventional OSDS in coastal areas that have inadequate separation distances to ground water, fractured bedrock, sandy soils, or other conditions that prevent or do not allow adequate treatment of OSDS-generated pollutants. Eutrophication in surface waters has also been attributed to the low nitrogen reductions provided by conventional OSDS designs.

Poorly designed or operating systems can cause ponding of partially treated sewage on the ground that can reach surface waters through runoff. In addition to oxygen-demanding organics and nutrients, these surface sources contain bacteria and viruses that present problems to human health. Viral organisms can persist in temperatures as low as -20 °F, suggesting that they may survive over winter in contaminated ice, later becoming available to ground water in the form of snowmelt (Hurst et al., undated). Although ground-water contamination from toxic substances is more often life-threatening, the majority of ground-water-related health complaints are associated with pathogens from septic tank systems (Yates, 1985).

Where development utilizing OSDS has already occurred, States and local governments have a limited capability to reduce OSDS pollutant loadings. One way to reduce the possibility of failed systems is to required scheduled pumpouts and regular maintenance of OSDS. Frequent inspections and proper operation and maintenance are the keys to achieving the most cost-effective OSDS pollutant reductions. Inspections upon resale or change of ownership of properties are also a cost-effective solution to ensure that OSDS are operating properly and meet current standards necessary to protect surface waters from OSDS-generated pollutants. Where phosphorus is a problem, phosphate bans can reduce phosphorus loadings by 14 to 17 percent (USEPA, 1992). Garbage disposal restrictions and low-volume plumbing fixtures can help ensure that conventional systems continue to operate properly. Low-volume plumbing fixtures have been shown to reduce hydraulic loadings to OSDS by 25 percent.

An option for managing and maintaining OSDS is through wastewater management utilities or districts. From a regulatory standpoint, a wastewater management program can reduce water quality degradation and save the time and money a local government or homeowner may spend maintaining and repairing systems. A variety of agencies are taking on the responsibilities of managing OSDS. Water utilities are the leading decentralized wastewater management agency (Dix, 1992). The following case studies illustrate successful wastewater management programs used where there are OSDS.

CASE STUDY 1 - GEORGETOWN DIVIDE PUBLIC UTILITIES, CALIFORNIA

The Georgetown Divide Public Utility District in California manages water reservoirs, two water treatment plants, an irrigation canal system, and two hydroelectric plants. Approximately 10 percent of the agency's resources are allocated to managing onsite systems in a large subdivision. The utility provides a comprehensive site evaluation program, designs the onsite system for each lot, lays out the system for the contractor, and makes numerous inspections during construction. There is also continued communication between the homeowners and the utility after construction, including scheduled inspections. For the service homeowners pay $12.50 per month for management of single-family systems. Owners of undeveloped lots pay $6.25 per month (Dix, 1992).

CASE STUDY 2 - STINSON BEACH COUNTY WATER DISTRICT, CALIFORNIA

In addition to monitoring the operation of septic tank systems, the Stinson Beach County Water District in California monitors ground water, streams, and sensitive aquatic systems that surround the coastal community to detect contamination from OSDS. Routine monitoring has identified people who use straight pipes and failures due to residents using overloaded systems. Homeowners pay a monthly fee of $12.90, in addition to the cost of construction or repair.

3. Management Measure Selection

This management measure was selected to control OSDS-related pollutant loadings to surface waters. Numerous States have implemented inspection requirements at title transfer, low-volume plumbing fixture regulations, garbage disposal prohibitions, and other requirements. Conventional systems are designed to operate over a specified period of time. At the end of the expected life span, replacement is generally necessary. Because failures of conventional systems may occur if systems are not properly designed and maintained, it is essential that programs are established to inspect and correct failing systems and to reduce pollutant loadings, public health problems, and inconveniences. Low-flow plumbing fixture installations and garbage disposal restrictions should be encouraged because as many as 75 percent of all system failures can be attributed to hydraulic overloading (Jarrett et al., 1985). Failure occurs when a system does not provide the level of treatment that is expected from the specific OSDS design.

National and local studies have indicated that conventional OSDS experience a significant rate of failure. Failure rates typically range between 1 and 5 percent per year (De Walle, 1981). In the State of Washington, high failure rates were observed in coastal regions (failure rates in 1971: King County - 6.1 percent; Gray's Harbor - 3.3 percent; and Skasit County - 2.6 percent). It has also been estimated in various soils of Connecticut that 4 percent of conventional OSDS fail per year. The failure rate in coastal areas may be greater because many systems (such as those in North Carolina) are approved for unsuitable soil conditions (Duda and Cromartie, 1982). Jarrett and others (1985) presented suggestions from several researchers describing the possible causes of high OSDS failure rates. These suggestions include:

- Smearing of trench bottoms during construction;
- Inadequate absorption areas;
- Improperly performed percolation tests;
- Inadequate design;
- Flooding and high water tables;
- Improper construction and installation;
- Inadequate soil permeability; and
- Use of cleaners and additives.

As stated previously, conventional OSDS do not remove nitrogen effectively and OSDS nitrogen loadings have been linked to degraded surface waters and ground water (Chesapeake Bay Program, 1990).

States should consider replacement with denitrifying OSDS in areas with nitrogen-limited waters. While all OSDS should be inspected periodically (at a recommended interval of once every 3 years) and corrected if failing, requiring that denitrifying systems be installed in all cases where existing systems fail to adequately treat nitrogen was deemed unduly burdensome and impractical.

Refer to the selection statement in the New OSDS Management Measure for additional rationale for selections relating to denitrification, garbage disposals, and low-flow plumbing fixtures.

Phosphorus reductions have been implemented in a number of States (see Table 4-23). Significant reductions in phosphorus loadings (14 to 17 percent) have resulted from such phosphate reductions, with nominal increases in costs for phosphate-free detergents.

4. Practices

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.

Table 4-23. Phosphate Limits in Detergents (The Soap and Detergent Association, 1992)

State	Phosphorus (P) Laundry Detergents	Phosphorus (P) Dishwashing Detergents	Industrial and Institutional	Effective Date
Connecticut	7 grams recommended use level			2/1/72
Florida	8.7% by weight as elemental P			12/31/72
Georgia	0.5% by weight as elemental P	8.7% by weight as elemental P		1/1/91
Indiana	0.5% by weight as elemental P			1/1/73
Maine	0.5% by weight as elemental P			7/1/93
Maryland	0.5% by weight as elemental P	8.7% by weight as elemental P	8.7% by weight as elemental P	12/1/85
Michigan	0.5% by weight as elemental P	8.7% by weight as elemental P	28% by weight as elemental P	10/1/77
Minnesota	0.5% by weight as elemental P	11% by weight as elemental P		8/30/79
New York	0.5% by weight as elemental P	8.7% by weight as elemental P		6/1/73
North Carolina	0.5% by weight as elemental P	8.7% by weight as elemental P		1/1/88
Oregon	0.5% by weight as elemental P	8.7% by weight as elemental P		7/1/92
Pennsylvania	0.5% by weight as elemental P	8.7% by weight as elemental P		3/1/91
South Carolina	0.5% by weight as elemental P	8.7% by weight as elemental P		1/1/92
Virginia	0.5% by weight as elemental P	8.7% by weight as elemental P		1/1/88
Wisconsin	0.5% by weight as elemental P	8.7% by weight as elemental P		1/1/84

a. Perform regular inspections of OSDS.

As previously stated, the high degree of failure of OSDS necessitates that systems be inspected regularly. This can be accomplished in several ways. Homeowners can serve as monitors if they are educated on how to inspect their own systems. Brochures can be made available to instruct individuals on how to inspect their systems and the steps they need to take if they determine that their OSDS is not functioning properly. Trained inspectors, such as those in Maine, also can aid in identifying failing systems.

State or local officials should also develop a program for regular inspection. By using utilities and wastewater management programs or agencies, the costs can be kept minimal. At a minimum, systems should be inspected when the ownership of a property is changed. If, prior to the transfer of ownership, the system is found to be deficient, corrective action should be taken. States and localities can also indirectly assess whether OSDS are failing through surface water and ground-water monitoring. If indicator pollutants (e.g., pathogens) are found during the course of monitoring, nearby OSDS should be inspected to determine whether they are the primary source of the indicators. USEPA (1991) has presented a method for tracing effluent from failing septic systems. This method could be followed as part of an indirect inspection program to locate failing systems.

b. Perform regular maintenance of OSDS.

OSDS are not maintenance-free systems. Huang (1983) stated that half of OSDS failures are due to poor operation and maintenance. Most septic tanks are designed so that wastewater is held for 24 hours to allow removal of solids, greases, and fats. Up to 50 percent of the solids retained in the tank decompose naturally by bacterial and chemical action (Mancl and Magette, 1991). However, during normal use, sludge accumulates on the bottom of the tank, leaving less time for the solids in the influent to settle. When little or no settling occurs, the solids move directly to the soil absorption system and may clog (Mancl and Magette, 1991). Consequently, periodic removal of the solids from the tank is necessary to protect the soil absorption system.

Management options for OSDS maintenance include (NSFCH, 1989):

- Maintenance via contract;
- Operating permits;
- Private management systems; and
- Local ordinances/utility management.

Most tanks need to be pumped out every 3 to 5 years; however, several factors need to be considered when determining the frequency of pumping required. These factors include (Mancl and Magette, 1991):

- Capacity of the tank;
- Flow of wastewater (based on family size); and
- Volume of solids in the wastewater (more solids are produced if a garbage disposal is used).

Failure will not occur immediately if a septic system is not pumped regularly; however, continued neglect will cause the system to fail because the soil absorption system is no longer protected from solids and may need to be replaced (at considerable expense).

Table 4-24 shows an estimate of how often a septic tank should be pumped based on tank and household size. The Arlington County, Virginia, Chesapeake Bay Preservation Ordinance requires that all septic tanks be pumped at least once every 5 years.

Alternative OSDS may have maintenance requirements in addition to septic tank pumping. These maintenance requirements are discussed in the descriptions of the systems presented in Management Measure V.A.

c. Retrofit or upgrade improperly functioning systems.

Improperly functioning systems are usually the result of failure of the soil absorption field. Several practices are available to retrofit these failing systems so that they operate properly. The most common reason for failure of the absorption field is hydraulic overload. Jarrett and others (1985) and other researchers have had good success in retrofitting failing systems by combining the construction of backup soil absorption fields with water conservation measures. A backup absorption system is constructed so that water can be diverted from the primary absorption system. The primary system is rested, and in many cases biological activity will unclog the system and aerobic conditions will be restored in the soil. Scheduling is then done to alternate the use of the primary and backup

Table 4-24. Suggested Septic Tank Pumping Frequency (Years) (Cooperative Extension Service - University of Maryland, 1991)

Tank Size (gal)	Household Size (number of people)									
	1	2	3	4	5	6	7	8	9	10
500	5.8	2.6	1.5	1.0	0.7	0.4	0.3	0.2	0.1	-
750	9.1	4.2	2.6	1.8	1.3	1.0	0.7	0.6	0.4	0.3
1,000	12.4	5.9	3.7	2.6	2.0	1.5	1.2	1.0	0.8	0.7
1,250	15.6	7.5	4.8	3.4	2.6	2.0	1.7	1.4	1.2	1.0
1,500	18.9	9.1	5.9	4.2	3.3	2.6	2.1	1.8	1.5	1.3
1,750	22.1	10.7	6.9	5.0	3.9	3.1	2.6	2.2	1.9	1.6
2,000	25.4	12.4	8.0	5.9	4.5	3.7	3.1	2.6	2.2	2.0
2,250	28.6	14.0	9.1	6.7	5.2	4.2	3.5	3.0	2.6	2.3
2,500	31.9	15.6	10.2	7.5	5.9	4.8	4.0	4.0	3.0	2.6

systems (e.g., use of each system 6 months of the year), so that systems in marginally permeable soils can continue to operate properly. Garbage disposals should be eliminated, and low-volume plumbing fixtures should be installed in cases where the absorption field has failed in order to reduce total pollutant and water loads to the field. (Refer to discussion in Management Measure V.A.)

In some cases, either because of improper siting (e.g., inadequate separation distance, proximity to surface water, poor soil conditions, or lack of land available for a backup absorption system) or the inadequacy of conventional OSDS to remove pollutants of concern, the above retrofit practice may not be feasible. In these cases, alternative OSDS, constructed wetlands, filters, or holding tanks may be necessary to adequately protect surface waters or ground water. Descriptions of these systems and their respective effectiveness and cost are provided in Management Meausre V.A.

d. Use denitrification systems where conditions indicate that nitrogen-limited surface waters may be adversely impacted by excessive nitrogen loading.

As stated previously, even properly functioning conventional OSDS are not effective at removing nitrogen. In areas where nitrogen is a problem pollutant, existing conventional systems should be retrofitted to denitrification OSDS to provide adequate nitrogen removal. Several systems such as sand filters and constructed wetlands have been shown to remove over 50 percent of the total nitrogen from septic tank effluent (see Table 4-21). Descriptions of these types of systems and their effectiveness and cost are presented in Management Measure V.A.

e. Discourage the use of phosphate in detergents.

Conventional OSDS are usually very effective at removing phosphorus. However, certain soil conditions, combined with close proximity to sensitive surface waters, can result in phosphorus pollution problems from OSDS. In such cases the use of detergents containing phosphates may need to be discouraged or banned. Low-phosphate detergents are commercially available from a variety of manufacturers with negligible increases in cost. Eliminating phosphates from detergent can reduce phosphorus loads to OSDS by 40 to 50 percent (USEPA, 1980).

f. *Eliminate the use of garbage disposals.*

As presented in Table 4-22, eliminating the use of garbage disposals can significantly reduce the loading of suspended solids and BOD to OSDS. Total nitrogen and phosphorus loads may also be slightly reduced because of decreased loadings of vegetative matter and foodstuffs. Eliminating garbage disposals can also reduce the buildup of solids in the septic tank and reduce the frequency of pumping required. Reduction of the solids also provides added protection against clogging of the soil absorption system.

g. *Discourage or ban the use of acid and organic chemical solvent septic system additives.*

Organic solvents used as septic system cleaners are frequently linked to pollution from septic systems. Many brands of septic system cleaning solvents are currently on the market. Makers of these solvents, which often contain halogenated and aromatic hydrocarbons, advertise that they reduce odors, clean, unclog, and generally enhance septic system operations. Manufacturers also advertise that cleaning solvents provide an alternative to periodic pumping of septage from septic tanks. However, there is little evidence indicating that these cleaners perform any of the advertised functions. In fact, their use may actually hinder effective septic system operation by destroying useful bacteria that aid in the degradation of waste, resulting in disrupted treatment activity and the discharge of contaminants.

In addition, since the organic chemicals in the solvents are highly mobile in the soils and toxic (some are suspected carcinogens), they can easily contaminate ground water and surface waters and threaten public health. Research on the common septic system cleaner constituents (methylene chloride (MC) and 1,1,1-trichloroethane (TCA), which are listed on EPA's priority pollutant list and for which EPA's Office of Drinking Water has issued health advisories) has shown that application rates recommended by the manufacturer have resulted in high MC and moderate TCA discharges to ground water.

This issue is discussed further in the pollution prevention section.

h. *Promote proper operation and maintenance of OSDS through public education and outreach programs.*

This practice is discussed in the pollution prevention section (Section VI).

VI. POLLUTION PREVENTION

A. Pollution Prevention Management Measure

Implement pollution prevention and education programs to reduce nonpoint source pollutants generated from the following activities, where applicable:

- **The improper storage, use, and disposal of household hazardous chemicals, including automobile fluids, pesticides, paints, solvents, etc.;**
- **Lawn and garden activities, including the application and disposal of lawn and garden care products, and the improper disposal of leaves and yard trimmings;**
- **Turf management on golf courses, parks, and recreational areas;**
- **Improper operation and maintenance of onsite disposal systems;**
- **Discharge of pollutants into storm drains including floatables, waste oil, and litter;**
- **Commercial activities including parking lots, gas stations, and other entities not under NPDES purview; and**
- **Improper disposal of pet excrement.**

1. Applicability

This management measure is intended to be applied by States to reduce the generation of nonpoint source pollution in all areas within the section 6217 management area. The adoption of the Pollution Prevention Management Measure does not exclude applicability of other management measures to those sources covered by this management measure. Under the Coastal Zone Act Reauthorization Amendments of 1990, States are subject to a number of requirements as they develop coastal NPS programs in conformity with this management measure and will have flexibility in doing so. The application of management measures by States is described more fully in *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance*, published jointly by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce.

2. Description

This management measure is intended to prevent and reduce NPS pollutant loadings generated from a variety of activities within urban areas not addressed by other management measures within Chapter 4. Source reduction is considered preferable over waste recycling for pollution reduction (DOI, 1991; USEPA, 1991). Everyday activities have the potential to contribute to nonpoint source pollutant loadings. Some of the major sources include households, garden and lawn care activities, turf grass management, diesel and gasoline vehicles, OSDS, illegal discharges to urban runoff conveyances, commercial activities, and pets and domesticated animals. These sources are described below. By reducing pollutant generation, adverse water quality impacts from these sources can be decreased.

a. Households

Everyday household activities generate numerous pollutants that may affect water quality. Common household NPS pollutants include paints, solvents, lawn and garden care products, detergents and cleansers, and automotive products such as antifreeze and oil. The use and disposal of these products are chronic sources of pollution (Puget Sound Water Quality Authority, 1991). Table 4-25 summarizes estimated pollutant loadings from various household chemicals that may contaminate runoff. These pollutants are typically introduced into the environment due to ignorance on the part of the user or the lack of proper disposal options. Storm drains are commonly mistaken for treatment systems, and significant loadings to waterbodies result from this misconception. Other wastes and chemicals are dumped directly onto the ground (Washington State Department of Ecology, 1990).

b. Improper Disposal of Used Oil

The improper disposal of used oil and antifreeze can significantly degrade surface waters. The Washington Department of Ecology estimated that over 4.5 million gallons of used oil are dumped in Washington State each year. Of this total, 2 million gallons eventually are discharged into the Puget Sound (USEPA, 1988). Such loadings can severely degrade surface waters. One quart of oil can contaminate up to 2 million gallons of drinking water; 4 quarts of oil can form an oil slick approximately 8 acres in size (University of Maryland Cooperative Extension Service, 1987).

Table 4-25. Estimates of Improperly Disposed Used Oil and Household Hazardous Waste

Reference	Chemical and Estimated Amount
USEPA, 1989	Estimated that 40% of used oil from DIYs[a] is poured onto roads, driveways, or yards or into storm sewers (80 million gallons per year).
Hoffman et al., 1980	Survey of Providence, RI, residents revealed that 35% were DIYs. Of this group, 42% used improper disposal methods (30% disposed of used oil by backyard dumping, 7% by dumping into sewers or storm drains, and 5% by pouring onto roads).
Stanek et al., 1987	Survey of Massachusetts households revealed that one-third changed their oil (17% dumped used oil on the ground and 3% discharged used oil into the town sewers); 17% changed their antifreeze (54% used ground disposal and 14% discharged into the sewer). The majority of the 10% who disposed of oil-based paints or pesticides annually used improper methods.
Voorhees and Temple, Baker and Sloane, Inc., 1989	Survey of studies estimated that between 52% and 64% of private vehicle owners are DIYs. Nationally, DIYs have been estimated to generate 193 million gallons of used oil per year. Of this amount, it was estimated that 61% (118 million gallons) was improperly disposed of.
King County Solid Waste Division, 1990	Estimated that 15% to 20% of household hazardous wastes end up in storm drains or runoff. Estimated that one-third of DIYs dump used oil directly into storm drains or onto the ground.
King County Solid Waste Division, 1990	Estimated that 83% of DIYs that changed their antifreeze flushed their car radiators directly into a storm sewer or street.

[a] DIYs - Do-it-yourself oil changers.

c. Landscape Maintenance and Turf Management

The care of landscaped areas, including golf courses, can contribute significantly to nonpoint source pollutant loadings. The application of fertilizers and pesticides in coastal areas can be detrimental to surface waters. After a site is developed, a significant area of maintained landscape may be regularly treated with fertilizer and pesticides. Heavily landscaped areas include residential yards, golf courses, and parks. In the coastal zone, much residential development commonly is sited on unconsolidated coastal plain with sandy soils. Where such soils are present, frequent fertilization, pesticide application, and watering must occur to maintain turf grasses. Turf management programs and landscaping ordinances that require minimum maintenance and minimum disturbance or xeriscaping can effectively reduce these loadings.

In areas where nitrogen is a problem pollutant, measures to control the introduction of nitrogen into runoff and leachate are important. Several studies have been completed that demonstrate the leaching potential of nitrogen from turf. Researchers at Cornell University found that 60 percent of nitrogen applied to turf leached to ground water (Long Island Regional Planning Board, 1984). Shultz (1989) suggests that 50 percent of the nitrogen applications are leached out and not used by plants. A study completed by Exner and others (1991) showed that as much as 95 percent of nitrate applied in late August on an urban lawn was leached below the turf grass root zone. In coastal areas, where soils are highly permeable and ground water and surface waters are hydrologically connected, reduced applications of nutrients may be necessary to control subsurface flow of nutrients into surface waters.

A recent nonpoint source loading analysis (Cahill and Associates, 1991) indicated that 10 percent of the nitrogen and 4 percent of the phosphorus applied annually in a 193-square-mile area (an area approximately 10 miles by 20 miles) of maintained landscaped residential development end up in surface waters as the result of overapplication. A total of 512.7 tons of nitrogen and 49.4 tons of phosphorus enter surface waters from this area. These estimated pollutant delivery rates are conservative. Delivery rates in coastal areas with sandy soils may be much higher. Schultz (1989) found that over 50 percent of the nitrogen in fertilizer leaches from lawns when improperly applied. In addition, the proximity of sources to waterbodies may result in increased loadings. Where waterbodies are nitrogen- or phosphorus-limited, applications of fertilizers should be reduced or prohibited. Fertilizer control programs can effectively reduce nitrogen and phosphorus loadings by encouraging the proper application of nutrients. Fertilizer costs may also be reduced.

A study in Rhode Island concluded that medium-density residential development has the highest loading factor of pesticides and fertilizers of all land uses in the State (RIDEM, 1988). These results echoed the findings of research conducted on the Chesapeake Bay watershed that identified medium- and high-density residential development as having the highest loading factors for nitrogen and phosphorus in the Bay area (Chesapeake Bay Local Advisory Committee, 1989). Table 4-26 shows a summary of results from various studies quantifying application rates of household fertilizers. Table 4-27 summarizes recommended application rates.

Home use is estimated to account for 20 percent of pesticide use in the Puget Sound area, and household users often apply pesticides excessively or in too concentrated a formulation (PSWQA, 1991). The Puget Sound Water Quality

Table 4-26. Summary of Application Rates of Fertilizers from Various Studies

Estimated Application Rates	Reference
3.3 lb/1000 ft^2 (affluent areas) 1.1 lb/1000 ft^2 (less affluent areas)	Cornell Water Resources Institute, 1985
2.2 lb/1000 ft^2/yr to 3.9 lb/1000 ft^2/yr	Long Island Planning Board, 1984
3.03 lb/ft^2/yr (Nitrogen) 0.77 lb/ft^2/yr (Phosphorus) (New Jersey)	Cahill and Associates, 1992

Table 4-27. Recommended Fertilizer Application Rates

Recommended Rate	Reference
Virginia - No more than 1 lb/1000 ft^2 at any one time — not to exceed 3 lb/1000 ft^2/yr	Hall, personal communication, 1991; No. VA Soil and Water Conservation District, 1991; VA Cooperative Extension, 1991
Virginia — 1.5 to 2 lb/1000 ft^2/yr	Bowling, personal communication, 1991
Long Island — 1 lb/1000 ft^2/yr	Long Island Regional Planning Board, 1984
Long Island — no more than 1 lb/1000 ft^2/yr on mature lawns	Myers, 1988
General — 2 lb/1000 ft^2/yr	Shultz, 1989

Authority summarized available data in a 1990 issue paper on pesticides in the Puget Sound. This research revealed that 50 to 80 percent of all household users apply some form of pesticides for lawn and garden use. EPA Region 10 and the Puget Sound Water Quality Authority (PSWQA, 1990) reviewed data and surveyed pesticide use in 12 counties in the Puget Sound basin and concluded that household pesticide use in 1988 was greater than 213,000 pounds. Unnecessary pesticide loadings to surface waters may result from homeowner overapplication, poor knowledge of proper application techniques, or applications during grass dormancy. Both the PSWQA and the Virginia Cooperative Extension Survey (1991) have determined that such improper use commonly occurs.

Consideration of the potential for exposure and toxic effects of applied fertilizers and pesticides should be an important component of golf course policy decisions. Some of the technical issues concerning intensive management of turf grass include (1) extent of nutrient and pesticide applications, (2) chronic and acute toxicity to nontarget organisms, (3) potential for exposure of nontarget organisms to applied chemicals, (4) use of increasingly scarce water resources for irrigation, (5) potential off-site movement of fertilizers and pesticides, (6) effects of maintenance and storage facilities on soil and water quality, and (7) potential loss of and effects on wetlands resulting from construction and turf grass maintenance (Balogh and Walker, 1992).

While quantitative information is not currently available regarding the effectiveness of fertilizer and pesticide control measures, it can be assumed that application reductions will result in corresponding decreases in pollutant loadings. Table 4-28 provides guidance useful for reducing fertilizer and pesticide use. This guidance was developed by the Northern Virginia Soil and Water Conservation District, the Lake Barcroft Watershed Improvement District, the Northern Virginia Planning District Commission, and the Virginia Cooperative Extension service for use by commercial lawn care companies and households that choose to use commercial lawn care services. This advice, however, is useful for all turf grass management.

d. Yard Trimmings Management

Improper disposal of yard trimmings can lead to increased nutrient levels in runoff. Yard trimmings deposited on street corners may be washed down storm sewers and result in elevated nutrient loadings to surface waters. Proper management of yard trimmings and home composting can reduce the level of nutrients in runoff and decrease overall runoff volumes through the addition of humus to the soil. Increased levels of humus enhance soil permeability, decrease erodibility, and provide nutrients in a less soluble form than commercial fertilizers.

e. Improper Installation and Maintenance of Onsite Disposal Systems

As discussed in Section V of this chapter, failing or improperly sited or designed OSDS may contribute both pathogens and nutrients to surface waters. Many engineers, contractors, surveyors, drain-layers, sanitarians, OSDS installers, waste haulers, building inspectors, local and State officials, and owners of OSDS are insufficiently informed regarding the need for proper siting, design, and maintenance of onsite systems. While a number of States

Table 4-28. Watershed Chemical Control Standards

Nutrient and Pesticide Control Standard	Estimated Savings and Impacts
Decrease fertilizer use.	The average DIY[a] applies 2 to 4 times the desirable amount of fertilizer. By reducing fertilizer amounts, costs can be reduced accordingly.
Use phosphorus-free or low-phophorus-content fertilizers.	Cost increases $1.00 to $1.50 per household where phosphate-free fertilizer are used. In the Lake Barcroft, Virginia, Water Management District, Natural Lawn estimated a 7,000-pound reduction in fall phosphorus loadings and an 80-85% decrease in spring loadings due to the use of phosphate-free fertilizers (Natural Lawn, personal communication, 1991).
Use slow-release fertilizers.	Organic fertilizers tend to be slow acting and less soluble than chemical fertilizers (Shultz, 1989). Depending on the fertilizer source, conversion to organic fertilizers would reduce costs to $0.00 where compost from a municipal or county facility is used; costs would increase $1.00 per 100 ft^2 for the purchase of commercial organic fertilizer (Cook, 1991)
Test soils to determine appropriate application rates.	Soil tests and fertilizer recommendations range in cost from $0.00 to $5.00 if done by a Cooperative Extension Service. Private soil test labs may charge $30.00 to $45.00 for the service (Carr et al., 1991).
Stagger fertilizer applications instead of using one large application.	Excess fertilizer may leach into ground water if not utilized by plants. Plants have a limited capacity to utilize fertilizer in any one application; fertilizer costs can be reduced by staggered applications so that the bulk of available nutrients are utilized and excess fertilizers are not applied.
Spot-apply pesticides to control broad-leafed weeds.	Natural Lawn Company reports that by switching from blanket applications to spot applications of herbicides, herbicide use can be reduced 85% to 90% (Bonifant, personal communication, 1991). Volume reductions will result in a comparable cost savings.
Mow lawn at the recommended height.	Shultz (1989) and Carr (1991) suggest that proper mowing techniques result in healthier lawns and can reduce pesticide and fertilizer use.
Retain grass clippings on lawns and other areas planted with turf grass.	Research conducted by Starr and DeRoo (1981) on grass grown in low-nitrogen sandy loam soils showed that grass clippings are beneficial as fertilizer for continued grass growth. Use of clippings as fertilizer can enhance grass growth, reduce the need for additional fertilizer, and decrease total fertilizer costs. *(This recommendation is promoted by the Professional Lawn Care Association of America.)*

[a] DIY - Do-it-yourself lawn caretaker.

currently license OSDS installers and waste haulers in accordance with State health standards, these licensing procedures may be out-of-date. In addition, many of these standards address only limited health-related issues and do not address the complex joint issues of water quality and public health (Myers, 1991).

Many homeowners are unaware of proper OSDS operation and maintenance principles. They often do not know how frequently their septic tanks need to be pumped, what hydraulic load their systems can accommodate, and what should or should not be disposed of in their systems (Huang, 1983). Some homeowners use septic system cleaners containing substances that may contaminate ground water, may provide little to no benefit to the OSDS, and may even be harmful to the system (RIDEM, 1988). Public education programs can help homeowners to prepare, operate, and maintain OSDS and thus help to ensure the continued pollutant removal effectiveness of the OSDS. A variety of brochures and other educational materials regarding OSDS have already been developed, and these materials have been used in many areas to educate the general public about proper OSDS operation and maintenance (e.g., the Chesapeake Bay Region, Puget Sound). State and local agencies should make use of these materials and implement mailing and information dissemination programs. Brochures mailed to homeowners as part of general utility correspondence or as special mailings are also effective. Posters and other materials distributed at libraries can help disseminate this information to the public. Educational and outreach programs should target builders, buyers, system installation contractors, inspectors, and enforcement personnel, in addition to homeowners, realtors, and pumpers.

f. Discharges Into Storm Drains

Significant loadings of NPS pollutants enter surface waters and tributaries via illegal discharges into storm drains. The public unknowingly assumes that storm drains discharge into sanitary sewers, and materials are dumped into storm drains under the assumption that treatment will occur at the sewage treatment plant. Illicit discharges may also be a problem. Public education programs, such as storm drain stenciling, and identification of illicit discharges can be effective tools to reduce pollutant loadings. Sanitary surveys are also a useful method to help managers identify the presence and entry point(s) of illicit discharges or other sources of pollutants to storm sewer systems.

g. Litter

Litter along coastal waterways, estuaries, and inland shorelines has become a significant source of nonpoint source pollution. Litter, debris, and dumped large solid items impair coastal water quality, as well as the aesthetic and recreational value of coastal waters, and may also be a hazard to wildlife. Storm sewers have been identified as a significant source of marine debris (Younger and Hodge, 1992).

Plastics are the major debris problem in the marine environment. Plastic accounts for 59 percent of the debris collected in coastal cleanup efforts (Younger and Hodge, 1992). Other litter may also be a problem. The State Adopt-a-Highway programs have revealed that beverage cans are the item most frequently removed from the side of roads. These wastes commonly have entered surface waters via storm sewers or swale systems. During 1991-1992, participants in the Virginia Adopt-a-Highway program removed 36,000 cubic yards of debris with volunteer hours valued at $2 million (M. Kornwolf, Virginia Dept. of Transportation, personal communication, 1992).

h. Commercial Activities

Nonpoint source runoff from commercial land areas such as shopping centers, business districts, and office parks, and large parking lots or garages may contain high hydrocarbon loadings and metal concentrations that are twice those found in the average urban area (Woodward-Clyde, 1991). These loadings can be attributed to heavy traffic volumes and large areas of impervious surface on which these pollutants concentrate (Long Island Sound Regional Planning Board, 1982). For example, contributions of lead to the Milwaukee River south watershed have been estimated as 20 to 25 percent from commercial areas and 40 to 55 percent from industrial areas (Wisconsin Department of Natural Resources, 1991). Where activities other than traffic, such as liquids storage and equipment use and maintenance, are associated with specific commercial activities, other pollutants may also be present in runoff. BMPs suited to the control of automotive-related pollutants and any other pollutants associated with specific commercial uses should be used to control their entry into surface waters.

Gas stations, in most communities, are designated as a commercial land use and are subject to the same controls as shopping centers and office parks. However, gas stations may generate high concentrations of heavy metals, hydrocarbons, and other automobile-related pollutants that can enter runoff (Santa Clara Valley Water Control District, 1992). Since gas stations have high potential loadings and pollutant profiles similar to those of industrial sites, the good housekeeping controls used on industrial sites are usually necessary.

i. Pet Droppings

Pet droppings have been found to be important contributors of NPS pollution in estuaries and bays where there are high populations of dogs. Fecal coliform and fecal streptococcal bacteria levels in runoff in several drainage basins in Long Island, New York, can be attributed to the dog population (Long Island Regional Planning Board, 1982). Although dogs cause the more common pet droppings problem, other urban animals, such as domestic or semi-wild ducks, also contribute to NPS pollution where their populations are high enough. Eliminating or significantly reducing the quantity of pet droppings washed into storm drains and hence into surface waters can improve the quality of urban runoff. It has been estimated that for a small bay watershed (up to 20 square miles), 2 to 3 days of droppings from a population of 100 dogs contribute enough bacteria, nitrogen, and phosphorus to temporarily close a bay to swimming and shellfishing (George Heufelder, personal communication, 1992).

The Soil Conservation Service in the Nassau-Suffolk region of New York collected data indicating that domestic animals contribute BOD, COD, bacteria, nitrogen, and phosphorus to ground water and surface waters (Nassau-Suffolk Regional Planning Board, 1978). Runoff containing pet droppings has been found to be responsible for numerous shellfish bed closures in Massachusetts (George Heufelder, personal communication, 1992; Nassau-Suffolk Regional Planning Board, 1978). In New York the large populations of semi-wild White Pekin ducks contribute heavily to runoff problems, while in a Massachusetts study, dog feces alone were found to be sufficient to account for the closures.

3. Management Measure Selection

This management measure was selected to ensure that communities implement solutions that may result in behavioral changes to reduce nonpoint source pollutant loading from the sources listed in the management measure. A number of States and local communities, including Washington, Maryland, Virginia, Florida, and Alameda County, California, are using pollution prevention activities to protect or enhance coastal water quality. Such activities include public education, promotion of alternative and public transportation, proper management of maintained landscapes, pollution prevention, training and urban runoff control plans for commercial sources, and OSDS inspection and maintenance. To allow flexibility, specific controls have not been specified in the management measure. Communities may select practices that best fit local priorities and the availability of funding. In addition, flexibility is necessary to account for community acceptance, which is often the major determinant affecting whether education and outreach activities and administrative mechanisms such as certification and training requirements are practical or effective solutions.

CASE STUDY - ARLINGTON COUNTY, VIRGINIA

Arlington County, Virginia, is drafting a source control plan for "minimizing impacts on its streams, a well as impacts to the Potomac River and the Chesapeake Bay, from pollutants entering the streams from many diverse sources." The plan is aimed at implementing individual programs for controlling sources of nonpoint pollution. Projects include:

Storm drainage master plan;
Educational programs for lawn management;
Evaluation of street sweeping programs;
Stream valley stabilization and restoration;
Evaluation of parking lot and street design requirements;
Land use planning;
Leaf and debris collection;
Household hazardous waste disposal; and
Storm drain stenciling.

4. Practices, Effectiveness Information, and Cost Information

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.

a. *Promote public education programs regarding proper use and disposal of household hazardous materials and chemicals.*

Public education is an important component of this management measure. The provision of information regarding the environmental impacts of common household activities can produce long-term shifts in behavior and may result in significant reductions in household-generated pollutants. School curricula on watershed protection, including nonpoint pollution control, have been developed for elementary and secondary school education programs. An example is the program developed by the Washington State Office of Environmental Education (Puget Sound Water Quality Authority, 1989). Incorporating such programs into regular school curricula is an effective way to educate youth about the importance of environmentally conscious behavior, which in turn can help reduce the need for and cost of technology-based pollution control.

Florida developed a comprehensive Statewide plan for environmental education coordinated by its Council on Comprehensive Environmental Education to be implemented through formal and informal education programs and State agency programs. All teachers receive the training, as well as State agency personnel and school children in grades kindergarten through 12 (Florida Council on Comprehensive Environmental Education, 1987).

Public participation is an effective means of educating the public and is also necessary for successfully creating and implementing a nonpoint pollution control plan. Public involvement should be encouraged during the planning process through attendance at meetings, workshops, and private or group consultations, and by encouraging the public to comment on planning documents. Support for the documents and the plans being developed is fostered through public involvement. Newsletters are an effective means of keeping the public informed of what planning steps are being taken and how the public can become and stay involved. Metropolitan Seattle has printed an educational brochure concerning waste oil disposal in six languages in order to reach a wider audience (Washington State Department of Ecology, 1992).

b. *Establish programs such as Amnesty Days to encourage proper disposal of household hazardous chemicals.*

Recognizing the potential impacts for environmental degradation from the improper disposal of hazardous household materials and chemicals, many communities have implemented programs to collect these chemicals. There has been an exponential growth in the number of such collection programs since the early 1980s. Two programs were in place in 1980; 822 were in place in 1990. The most common type of collection system is a 1-day event at a temporary site (often referred to as an Amnesty Day). More local governments are beginning to sponsor these programs several times a year, and many communities are establishing permanent programs, including retail store drop-off programs, curbside collection, and mobile permanent facilities (Duxbury, 1990). Table 4-29 summarizes the cost and effectiveness of some household chemical collection programs.

In spite of relatively low participation rates, collection programs can have a significant impact on the amount of hazardous chemicals and materials entering the waste stream. It has been estimated that the amount of hazardous chemicals collected in States having approved coastal management programs was approximately 51,000 drums, or 280,500 gallons, in 1990 (extrapolated from Duxbury, 1990).

c. *Develop used oil, used antifreeze, and hazardous chemical recycling programs and site collection centers in convenient locations.*

Household hazardous chemical (HHC) collection programs already exist in many counties throughout the United States. Specific days are usually designated as drop-off days and are advertised through television, newspapers,

Table 4-29. Waste Recycling Cost and Effectiveness Summary

Program Description	Effectiveness	Cost
University of Alabama - Project ROSE[a] • Initiated in 1977 • Focuses on used oil • Includes curbside collection (as part of regular garbage pick-up), collection centers (primarily service stations), and drum placement (in more rural areas) • Involves public outreach program	Of the approximately 17 million gallons of used oil generated annually in Alabama, 8 million gallons (47 percent) was reclaimed in 1990.	Annual budget is $80,000 ($45,000 is spent on public education).
Sunnyvale, CA, Curbside Used Oil Collection[b] • Curbside collection of used oil, along with other recyclable products • Residents provided with gallon containers to hold the oil • Involves large public outreach program	75 to 120 gallons of used oil from 28,000 homes collected daily. A 40 percent increase in participation was observed from FY 87-88 to FY 90-91.	Exact breakdowns were not available. Costs are kept low by incorporating the program into an existing recycling program; public information is distributed by such means as flyers in utility bills and brochures left by city employees such as repair crews and street sweepers.
Seattle, WA, Mobile Permanent Collection System • Established in 1989 by King County Solid Waste Department • 5,000 ft^2 mobile facility equipped to collect household hazardous materials ("Wastemobile") • Collected material is either recycled, detoxified, or taken to a secured hazardous waste facility • Includes extensive public outreach program	In the first 6 months of operation, 276.8 tons of material was collected; participation was twice that expected (one site recorded 875 cars in 6 days) In the first quarter, 98.3 tons were collected with the following breakdown: • 44.3 tons (45%) paint • 23.1 tons (23.5%) waste oil • 8.6 tons (8.8%) solvents • 5.9 tons (6%) pesticides. The balance was miscellaneous other household wastes.	The Wastemobile cost $110,000. King County has budgeted $1.5 million (including public outreach and staff) over a 28-month period.
San Francisco, CA, Permanent Collection Facility[d] • A permanent household waste site that was initiated as a pilot project • 65 percent of the collected material was recycled or reused	30,730 gallons of hazardous wastes (excluding batteries) were collected the first year. The most common type of waste was paint, which was recycled and used by citizens groups to paint over graffiti.	Operated by the private company that hauls the city's solid waste. Funds are obtained from the residential rate mechanism. The city is responsible for public education, waste disposal, and facility inspection.

[a] USEPA, 1989; Project ROSE Fact Sheet, 1991.
[b] USEPA, 1988.
[c] Johnston and Kehoe, 1989.
[d] Misner, 1990

flyers, and radio. In Arlington County, Virginia, collection during the week is by appointment with a water pollution chemist employed by the county and on one Saturday a month. Other HHC collection programs have once-a-week or once-a-month collection days, and some programs have a single day set aside each year for all HHC collection for the county or region. The waste collected by these programs is usually disposed of by a licensed HHC contractor. Table 4-29 presents program descriptions, effectiveness, and cost information for representative HHC collection programs. Many service stations currently provide used oil and antifreeze recycling facilities for "do-it-yourselfers" to encourage environmentally sound disposal.

d. *Encourage proper lawn management and landscaping.*

The care of landscaped areas can contribute significantly to NPS pollutant loadings. Results of a telephone survey conducted in 1982 by the Virginia Polytechnic Institute and State University showed that only 12 to 15 percent of home lawns in Virginia were being managed properly. The majority of homeowners preferred to do their own lawn work; only 8 to 10 percent of the households used commercial lawn care companies. A similar survey conducted on Long Island concluded that in affluent neighborhoods, 72 percent of the respondents used a lawn care service; in the least affluent neighborhoods, no one subscribed to commercial lawn care (Cornell Water Resources Institute, 1985). The extent of nonpoint source pollution from fertilizer application is site-specific and depends on a number of factors, including soil type, application rate, type of fertilizer, precipitation and watering amount, and socioeconomic status of residents. Because most people are not trained in proper fertilization and maintenance application, homeowner lawn care may result in significant amounts of nonpoint source pollution.

To significantly decrease homeowners' pesticide and fertilizer loadings requires a broad-based educational effort. The State Cooperative Extension Service (CES) is one educational vehicle; however, the CES reaches only a small percentage of the population. Mass media approaches are generally the most effective way to reach a large part of the population, though some other possibilities are discussed below (Puget Sound Water Quality Authority, 1991). The following practices are part of proper lawn management and landscaping.

- *Proper pesticide and herbicide use, and reduced applications*

  While few studies have been conducted to correlate pesticide and herbicide use with adverse effects on marine water quality, the magnitude of potential impacts can be inferred from incidents such as the extensive ground-water contamination in counties bordering the Puget Sound following widespread use of the pesticide ethylene dibromide (EDB) (Puget Sound Water Quality Authority, 1989). Estimates of pesticide use in the Puget Sound area reveal that 20 percent of the volume of pesticides applied is from residential sources and that these applications are typically in excess of recommended amounts or are too concentrated (Puget Sound Water Quality Authority, 1991).

  Maintaining a buffer between surface water and areas treated with pesticides is one method to increase the transport distance and reduce the potential for offsite movement of toxics. Selection of less toxic, mobile, and persistent chemicals with greater selective control of pests is encouraged (Spectrum Research, 1990).

- *Reduced fertilizer applications and proper application timing*

  Lawn fertilization has been identified as a source of excess nitrogen and phosphorus loadings that may lead to eutrophication. A modeling study of urban runoff pollution conducted in Pennsylvania, Maryland, Washington, DC, and Virginia by Cohn-Lee and Cameron (1991) estimated that the nonpoint source loadings of nutrients were equal to or greater than loadings discharged from POTWs and industries in the Chesapeake Bay area.

  Ground-water contamination also may be of concern especially where interflow exists between surface waters and ground waters. Schultz (1989) found that over 50 percent of the nitrogen in fertilizer leaches from a lawn when improperly applied. NVSWCD et al. (1991) found that up to two-thirds less fertilizer can be applied than is typically recommended by manufacturers. The use of slow-release forms of nitrogen and proper watering may also decrease nonpoint source pollution loadings (Nassau-Suffolk Regional Planning Board, 1978).

- *Limited lawn watering*

  Nonpoint source runoff from lawns can be reduced by employing efficient watering techniques. Overwatering can increase nitrogen loss 5 to 11 times the amount lost when proper watering strategies are used (Morton et al., 1988).

Soaker hoses and trickle or drip irrigation systems are an alternative to sprinkler systems. These types of systems deliver water at lower rates, which can increase the volume infiltrated, conserve water, and avoid runoff that can be associated with improperly operated sprinkler systems.

- *Use of minimum maintenance/minimum disturbance and IPM methods*

Minimum maintenance/minimum disturbance policies and strategies can effectively reduce land disturbance and associated soil loss and can reduce fertilizer, pesticide, and herbicide loadings. Where new development is occurring, community standards that limit the use of fertilizers or require commercial lawn care companies to use low-impact lawn care practices can decrease NPS loadings. Such practices can be promoted through public education programs for both new and existing developments.

Effective use of IPM strategies can further reduce nonpoint source loadings. Regional soil conservation services, agricultural extension offices, local conservation districts, or the U.S. Department of Agriculture are good sources of information on IPM. A study in Maryland on IPM for street and landscape trees in a planned suburban community demonstrated that pesticide use could be reduced by 79 to 87 percent when spot application techniques were substituted for cover spray techniques. An average annual cost savings of 22 percent also resulted from the program.

Effective IPM Strategies include (Washington State Department of Ecology, 1992):

- Use of natural predators and pathogens;
- Mechanical control;
- Use of native and resistant plantings;
- Maintainenance of proper growing conditions;
- Removal of or substitutions for less-favored pest habitat;
- Timing annual crops to avoid pests;
- Localized use of appropriate chemicals as a last alternative.

- *Xeriscaping*

Xeriscaping, creative landscaping for decreased water, energy, and pesticide/fertilizer inputs, can be used to reduce urban runoff and minimize the application of lawn care products that may adversely impact coastal waters. The use of xeriscaping practices can reduce required lawn maintenance up to 50 percent and reduce watering requirements by 60 percent (Clemson University, 1991). Florida has passed legislation requiring xeriscaping on the grounds of all State buildings. Several other States, including New Jersey and California, actively support xeriscaping efforts. A more detailed discussion of xeriscaping is in Section II.C of this chapter.

- *Reduced runoff potential*

Rainwater from roofs can be infiltrated into the ground in gravel-filled trenches in well-drained soils or collected in rain barrels for later irrigation. Wood decking or brick pavers allow greater infiltration than do solid concrete structures. Landscape terracing reduces runoff and erosion when gardening on slopes (Washington State Department of Ecology, 1992).

- *Training, certification, and licensing programs for landscaping and lawn care professionals*

Training, certification, and licensing programs are an effective method to educate lawn care professionals about potential nonpoint pollution problems associated with fertilizer, pesticide, and herbicide applications. The State Cooperative Extension Service commonly provides these services. Trained lawn care professional can also help educate the general public about the advantages of low-input approaches.

e. *Encourage proper onsite recycling of yard trimmings.*

Home composting promotes onsite recycling of plant nutrients contained in yard trimmings and reduces the potential for nutrients to enter surface waters. Unlike most commercial fertilizers, compost releases nutrients slowly and is a source of trace metals (Hansen and Mancl, 1988). When added as an amendment to lawn or garden soils, compost increases the organic content of the soil, which increases infiltration, reduces runoff, and decreases the need for watering. Sediment and bound nutrients in soils with high organic content are less mobile and less likely to migrate from the site. Compost applications may also result in increased plant health and vigor, allowing for the reduced use of pesticides (Logsdon, 1990).

Home composting programs may result in municipal cost savings. An average suburban yard generates up to 1,500 pounds of yard trimmings per year, most of which is usually landfilled (McNelly, undated). Homeowners should be encouraged to place compost piles or bins away from streams and roadways that may serve as conveyances of leached nutrients. Recycling of grass clippings and mulched leaves should also be encouraged through education programs. The retention of grass clippings and mulched leaves reduces the need for supplemental water and fertilizer inputs.

Suggested backyard composting programs include the following:

- Provide compost bins free or at cost.
- Create pamphlets explaining benefits and methods.
- Start a "Master Composter" program in which graduates receive free equipment and conduct their own workshops.
- Provide credits on waste removal fees to people who compost yard wastes.

f. *Encourage the use of biodegradable cleaners and other alternatives to hazardous chemicals.*

Improperly disposed household cleaners containing nonbiodegradable chemicals have the potential to contaminate surface waters and ground water. OSDS systems may also be adversely impacted by these substances (PSWQA, 1989). The use of nontoxic, biodegradable alternatives, which quickly break down, should be encouraged through public education efforts (Reef Relief, 1992).

g. *Manage pet excrement to minimize runoff into surface waters.*

The Soil Conservation Service in the Nassau-Suffolk region of New York collected data indicating that domestic animals contribute BOD, COD, bacteria, nitrogen, and phosphorus to ground water and surface waters (Nassau-Suffolk Regional Planning Board, 1978). Urban runoff containing pet excrement has been found to be responsible for numerous shellfish bed closures in New York and has been implicated in shellfish bed closures in Massachusetts (George Huefelder, personal communication, 1992; Nassau-Suffolk Regional Planning Board, 1978). In New York, the large populations of semi-wild Pekin ducks contribute heavily to water quality problems. A study in Massachusetts found that dog droppings alone were significant enough to cause shellfish bed closures.

Curb laws, requiring that dogs be walked close to street curbs so they will defecate on the streets near curbs, are intended to ensure that street sweeping operations collect the droppings and prevent them from entering runoff. However, traditional street sweeping has been found to be an ineffective means for controlling fines and soluble NPS pollution and the dog droppings are more often swept into sewers and delivered to bays and estuaries during rain storms (Long Island Regional Planning Board, 1982; 1984; Nassau-Suffolk Regional Planning Board, 1978). Curbing ordinances should therefore be repealed where they are in effect, and laws requiring pet owners to clean up after their pets when they are walked in public areas and to dispose of the droppings properly should be enacted.

Proper cleanup and disposal of canine fecal material and discouragement of public feeding of waterfowl are two ways of potentially controlling the adverse impacts of animal droppings. The following examples from the Long Island Regional Planning Board (1984) illustrate controls for NPS pollution from animal droppings.

Control of NPS pollution from dogs:

- Enactment of "pooper-scooper" laws requiring the removal and proper disposal of dog feces on public property.
- Enforcement of existing "pooper-scooper" and leash laws should be improved in priority target areas where animal feces are known to be an NPS pollution problem.

Control of NPS pollution from horses:

- Instituting zoning ordinances to control the keeping of horses. These ordinances should include:
  - Minimum acreage requirements per horse;
  - Specifying areas where horse waste may be stored; and
  - Designated areas where horses may be kept.
- Limiting the density of horses in deep aquifer recharge areas, in selected shallow aquifer recharge areas, in areas immediately adjacent to surface waters, and where slopes are greater than 5 percent.

Public education programs:

- The Cooperative Extension Service and similar agencies should be encouraged to develop and distribute informational material on all aspects of animal waste problems.

Owners of large animals should use BMPs similar to those for pasture management, including the fencing of animals away from surface waters, avoidance of "overgrazing," "grazing area" rotation, and limited "grazing" when soil is wet. Manure is best stored away from waterbodies on an impervious surface with a cover or roof (Washington State Department of Ecology, 1992).

The following actions can be used to help control the problem of pet excrement:

- Pass regulations controlling the disposal of excrement from domestic animals;
- Enact domestic animal clean-up regulations; and
- Require commercial domestic animal operations (e.g., pet stores, kennels) to implement BMPs for the control and proper disposal of animal excrement.

h. Use storm drain stenciling in appropriate areas.

Storm drain stenciling programs can be effective tools to reduce illegal dumping of litter, leaves, and toxic substances down urban runoff drainage systems. These programs also serve as educational reminders to the public that such storm drains often discharge untreated runoff directly to coastal waters.

A successful program was initiated in Anne Arundel County, Maryland. The program was implemented by volunteers to prevent dumping of harmful material into storm drains that ultimately discharge to the Chesapeake Bay. The county's only involvement has been to publicize the program and provide stencils and painting materials.

Approximately 60 to 70 percent of all communities in the county have participated. Several other counties around the Chesapeake Bay have inquired about the program. Data on effectiveness in terms of pounds of pollutant removed were not available; however, an informal survey that occurred after the program was implemented revealed that there is increased public understanding that storm drains should not be used for disposal of hazardous materials and dumping has decreased. Costs were nominal ($7.00 per stencil kit, including paint and brushes; the average neighborhood cost was $40.00). There is a similar program in place in Puget Sound, Washington. The total cost of implementing the stenciling program for the Sound was $2,644.39, including materials and labor. This practice is currently being used in other States and localities, including the Indian River Lagoon, Florida, drainage basin.

i. Encourage alternative designs and maintenance strategies for impervious parking lots.

Parking lot runoff accounts for a significant percentage of nonpoint source pollution in commercial areas, depending on the proportion of building size to parking lot size. Sweeping is a viable method of reducing this runoff from paved areas. If a lot is rectangular and has no parking bumpers or medians dividing it, the job is easier and less expensive. As indicated in the case study, a computer model proved to be a useful tool in evaluating the effectiveness of pavement sweeping as a method to control one source of nonpoint pollution (Broward County Planning Council, 1982).

CASE STUDY - FORT LAUDERDALE, FLORIDA

Through an EPA Continuing Planning Process Grant, the Broward County Planning Council received funding to conduct a study to determine the effectiveness of parking lot sweeping as a method to abate water pollution. A computer model, utilizing simple and multiple regression equations, was used to simulate the conditions at the study area and to predict the runoff loads from the area due to rainfall. Some results of the study are as follows: for paved commercial parking lots, the 3-day to 28-day sweeping cycle produces a pollutant removal range of 60 percent to 20 percent, respectively; as the quantity of residue increases, sweeper efficiency also increases, and there is a point of diminishing return for pollutant removal by sweeping and for sweeper efficiency in removing pollutant loadings (Broward County Planning Council, 1982).

Equipment types commonly used for street sweeping include abrasive brush and vacuum device sweepers. Both abrasive brush and vacuum sweepers have been shown to be generally inefficient at picking up fine solids of less than 43 microns. Although vacuum sweepers are more effective at removing fine particulates than brush sweepers, they are still generally considered to be inefficient. A newly developed helical brush sweeper that incorporates a steel brush with vacuum has been shown to be more effective at removing fine solids and is currently being evaluated. Although currently used sweeper technologies have been shown to be inefficient at removing fine particulates, their use in conjunction with other BMPs that are effective in trapping fine solids could improve downstream water quality (NVPDC, 1987).

Another promising method of street cleaning that concentrates on oil and grease removal is wet-sweeping. By spraying a small area with water containing biodegradable soaps or detergents that solubilize the oil and grease deposited on pavement surfaces, increased removal can occur with a combination of sweeping and vacuum action. This method, however, is a fairly new concept and requires further testing (Silverman et al., 1986).

Vegetated areas/grassed swales are another method commonly used to reduce pollutant loadings from pavement runoff. These areas can be designed to accept runoff with relatively high oil and grease concentrations from parking lots. Percolation through soil and underlying layers typically results in hydrocarbon filtration and adsorption, and degradation by naturally occurring soil bacteria.

j. Control commercial sources of NPS pollutants by promoting pollution prevention assessments and developing NPS pollution reduction strategies or plans and training materials for the workplace.

The opportunities for and advantages of pollution prevention practices vary from industry to industry, location to location, and activity to activity. Therefore, it is important to develop pollution prevention programs tailored specifically to an activity or site. Pollution prevention assessments on a site-by-site basis reduce some wastes and possibly eliminate the generation of other wastes. Such assessments are often necessary for successful pollution prevention programs (DOI, 1991).

States should promote and/or provide pollution prevention training and on-site assessments of individual facilities to help reduce the amount of hazardous wastes entering the environment from households and commercial facilities. A typical assessment for a facility will identify the types of waste produced, appropriate disposal methods and sites, and source reduction techniques. An education program to instruct personnel about proper materials handling and waste reduction strategies is also recommended.

The Alachua County, Florida, Office of Environmental Protection produced a handbook of BMPs to be applied in 12 separate commercial operations. Many of the BMPs are common to more than one type of operation, though specifics are mentioned for each category of activities. The 12 operations mentioned are small and large mechanical repair, dry cleaning, junk yards, photo processing, print and silk screening, machine shops and airport maintenance, boat manufacturing and repair, concrete and mining, agricultural, paint manufacturers and distributors, and plastic manufacturers (Alachua County Office of Environmental Protection, 1991).

The Santa Clara Valley Nonpoint Source Pollution Control Program and the San Jose Office of Environmental Management produced a handbook of BMPs for automobile service stations (Santa Clara Valley Water Control District, 1992). The handbook describes 18 BMPs that can be used to control onsite nonpoint source pollutants. Many of these BMPs require little or no investment for implementation. Most of the BMPs rely on education-induced behavior changes to minimize spills and disposal of chemicals and wastewaters down storm drains. Recycling, spill prevention and response plans, and proper material storage are also covered.

The City of Lacy, Washington, developed guidelines to control NPS pollution impacts from service stations and automotive repair facilities on Puget Sound. These include:

- Straining used solvents and paint thinner for reuse;
- Recycling antifreeze, oil, metal chips, and batteries;
- Properly disposing of wastes, including oils, machine-tool coolant, and batteries;
- Using dry floor cleaners, such as kitty litter or vermiculite; and
- Limiting use of water to clean driveways and walkways.

The city developed educational material for distribution that describes these guidelines, defines procedures for potential hazardous materials problems, and provides the State Hazardous Substance Hotline.

The City of Bellevue, Washington, Storm and Surface Water Utility, in cooperation with local businesses, has conducted a series of workshops aimed at the prevention of nonpoint pollution for automotive, construction, landscaping, food, and building maintenance businesses. The city gives recognition to businesses that attend a workshop and prepare a water quality action program. Videos of the workshops and accompanying manuals are also produced by the City of Bellevue (Washington State Department of Ecology, 1992).

k. Promote water conservation.

Excessive use of water contributes to numerous NPS pollution problems, including runoff from fertilized areas, OSDS drainfield failures, and sewage leaks. Water overuse may also contribute indirectly to NPS pollution problems: streams, rivers, and ground water may be excessively drawn down for water supply, decreasing their capacity to absorb pollutant runoff and upsetting their natural flow (Long Island Regional Planning Board, 1982; Maddaus, 1989). Additional information on water conservation is contained in the OSDS section of this chapter.

l. Discourage the use of septic system additives.

A 1980 EPA study identified 23 priority pollutants that are likely to be disposed of down household drains. Disposal of these chemicals into OSDS may impair OSDS function and contaminate ground water. Septic system cleaners are included in this category. There is little scientific evidence that septic system cleaners are effective in improving the function of septic systems. Many of the septic system cleaners contain chemicals such as chlorinated hydrocarbons, aromatic organic compounds, and acids and bases that may have an adverse affect on the biological treatment system and that may also pollute ground water. Many of these chemicals are also highly persistent in the ground water. Studies of ground-water contamination in New York and Connecticut have monitored these compounds in ground water and have found that (1) the septic system additives are not effective in improving the treatment systems and (2) the additives pass into ground water in relatively unaltered form (RIDEM, 1988).

Many States and local governments have adopted legislation prohibiting the use of septic system cleaning solvents, including the States of Maine and Delaware, the New Jersey Pinelands Regional Planning Commission, and several jurisdictions in Massachusetts. Rhode Island prohibits the disposal of acids or organic chemical solvents in septic systems and specifically discourages the use of septic tank cleaners. The State of Connecticut Department of Environmental Protection has taken the process one step further by banning the sale and use of cleaning solvents and also implementing the law through press releases, statewide surveys, direct manufacturer contact, and contact with the State Retail Merchants Association.

m. Encourage litter control.

While street sweeping historically has been found to provide little benefit in reducing fines and pollutants associated with small particulates because of outdated sweeping equipment and irregular sweeping frequencies, litter control can be an effective means to improve the quality of urban runoff. Both the Baltimore and Long Island Nationwide Urban Runoff Program (NURP) projects found that litter control substantially influenced the quality of runoff from urban areas (Myers, 1989). Suggestions for controlling litter include:

- Encouraging businesses to keep the streets in front of their buildings free of litter;
- Developing local ordinances restricting or prohibiting food establishments from using disposable food packaging, especially plastics, styrofoam, and other floatables;
- Implementing "bottle bills" and mandatory recycling laws;
- Providing technical and financial assistance for establishing and maintaining community waste collection programs;
- Distributing public education materials on the benefits of recycling; and
- Developing "user-friendly" ways for recycling, such as curbside pick-up, voluntary container buy-back systems, and drop-off recycling centers.

n. Promote programs such as Adopt-a-Stream to assist in keeping waterways free of litter and other debris.

Such programs can eliminate much of the floatable debris found in coastal waters and their tributaries. These programs involve volunteers who pick up trash along designated streambeds. Several successful programs similar to these are being implemented in Maryland, Alaska, Virginia, North Carolina, and Washington. The International

Coastal Cleanup, the largest coastal cleanup effort in the country, is coordinated by the Center for Marine Conservation (CMC). With the use of data cards, plastic gloves, and trash bags, 130,152 volunteers cleared 4,347 miles of beaches and waterways of 2,878,913 pounds of trash during the 1991 cleanup effort (Younger and Hodge, 1992).

In addition to the visible benefits of such clean-up efforts, these programs offer valuable educational opportunities for volunteers and provide a significant amount of data on the amounts and types of debris being found in waterways. The sources of various types of debris can be traced as well. Debris can be traced to a specific company or organization based on labeling or marking. Where possible, CMC contacts these organizations about the finding of their debris, informs them of the problems caused by marine debris, and asks them to join the battle against the debris problem. From the 1990 CMC coastal clean-up effort, approximately 150 organizations were identified and contacted. As a result, the majority of organizations responded positively by printing educational "Do not litter" slogans on their products, and several launched internal investigations into current waste-handling procedures (Younger and Hodge, 1992).

o. *Promote proper operation and maintenance of OSDS through public education and outreach programs.*

Many of the problems associated with improper use of OSDS may be attributed to lack of knowledge on operation and maintenance of onsite systems. Training courses for installers and inspectors and education materials for homeowners on proper maintenance may reduce some of the incidences of OSDS failure.

VII. ROADS, HIGHWAYS, AND BRIDGES

NOTE: Management Measures II.A and II.B of this chapter also apply to planning, siting, and developing roads and highways.[6]

A. Management Measure for Planning, Siting, and Developing Roads and Highways

Plan, site, and develop roads and highways to:

(1) Protect areas that provide important water quality benefits or are particularly susceptible to erosion or sediment loss;

(2) Limit land disturbance such as clearing and grading and cut and fill to reduce erosion and sediment loss; and

(3) Limit disturbance of natural drainage features and vegetation.

1. Applicability

This measure is intended to be applied by States to site development and land disturbing activities for new, relocated, and reconstructed (widened) roads (including residential streets) and highways in order to reduce the generation of nonpoint source pollutants and to mitigate the impacts of urban runoff and associated pollutants from such activities. Under the Coastal Zone Act Reauthorization Amendments of 1990, States are subject to a number of requirements as they develop coastal NPS programs in conformity with this management measure and will have some flexibility in doing so. The application of management measures by States is described more fully in *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance*, published jointly by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce.

2. Description

The best time to address control of NPS pollution from roads and highways is during the initial planning and design phase. New roads and highways should be located with consideration of natural drainage patterns and planned to avoid encroachment on surface waters and wet areas. Where this is not possible, appropriate controls will be needed to minimize the impacts of NPS runoff on surface waters.

This management measure emphasizes the importance of planning to identify potential NPS problems early in the design process. This process involves a detailed analysis of environmental features most associated with NPS pollution, erosion and sediment problems such as topography, drainage patterns, soils, climate, existing land use, estimated traffic volume, and sensitive land areas. Highway locations selected, planned, and designed with consideration of these features will greatly minimize erosion and sedimentation and prevent NPS pollutants from entering watercourses during and after construction. An important consideration in planning is the distance between

[6] Management measure II.A applies only to runoff that emanates from the road, highway, and bridge right-of-way. This management measure does not apply to runoff and total suspended solid loadings from upland areas outside the road, highway, or bridge project.

a highway and a watercourse that is needed to buffer the runoff flow and prevent potential contaminants from entering surface waters. Other design elements such as project alignment, gradient, cross section, and the number of stream crossings also must be taken into account to achieve successful control of erosion and nonpoint sources of pollution. (Refer to Chapter 3 of this guidance for details on road designs for different terrains.)

The following case study illustrates some of the problems and associated costs that may occur due to poor road construction and design. These issues should be addressed in the planning and design phase.

CASE STUDY - ANNAPOLIS, MARYLAND

Poor road siting and design resulted in concentrated runoff flows and heavy erosion that threatened several house foundations adjacent to the road. Sediment-laden runoff was also discharged into Herring Bay. To protect the Chesapeake Bay and the nearby houses, the county corrected the problem by installing diversions, a curb-and-drain urban runoff conveyance, and a rock wall filtration system, at a total cost of $100,000 (Munsey, 1992).

3. Management Measure Selection

This management measure was selected because it follows the approach to highway development recommended by the American Association of State Highway and Transportation Officials (AASHTO), Federal Highway Administration (FHWA) guidance, and highway location and design guidelines used by the States of Virginia, Maryland, Washington, and others.

Additionally, AASHTO has location and design guidelines (AASHTO, 1990, 1991) available for State highway agency use that describe the considerations necessary to control erosion and highway-related pollutants. Federal Highway Administration policy (FHWA, 1991) requires that Federal-aid highway projects and highways constructed under direct supervision of the FHWA be located, designed, constructed, and operated according to standards that will minimize erosion and sediment damage to the highway and adjacent properties and abate pollution of surface water and ground-water resources.

4. Practices

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.

a. Consider type and location of permanent erosion and sediment controls (e.g., vegetated filter strips, grassed swales, pond systems, infiltration systems, constructed urban runoff wetlands, and energy dissipators and velocity controls) during the planning phase of roads, highway, and bridges. (AASHTO, 1991; Hartigan et al., 1989)

b. All wetlands that are within the highway corridor and that cannot be avoided should be mitigated. These actions will be subject to Federal Clean Water Act section 404 requirements and State regulations.

c. *Assess and establish adequate setback distances near wetlands, waterbodies, and riparian areas to ensure protection from encroachment in the vicinity of these areas.*

Setback distances should be determined on a site-specific basis since several variables may be involved such as topography, soils, floodplains, cut-and-fill slopes, and design geometry. In level or gently sloping terrain, a general rule of thumb is to establish a setback of 50 to 100 feet from the edge of the wetland or riparian area and the right-of-way. In areas of steeply sloping terrain (20 percent or greater), setbacks of 100 feet or more are recommended. Right-of-way setbacks from major waterbodies (oceans, lakes, estuaries, rivers) should be in excess of 100 to 1000 feet.

d. *Avoid locations requiring excessive cut and fill. (AASHTO, 1991)*

e. *Avoid locations subject to subsidence, sink holes, landslides, rock outcroppings, and highly erodible soils. (AASHTO, 1991; TRB, Campbell, 1988)*

f. *Size rights-of-way to include space for siting runoff pollution control structures as appropriate. (AASHTO, 1991; Hartigan, et al., 1989)*

Erosion and sediment control structures (extended detention dry ponds, permanent sediment traps, catchment basins, etc.) should be planned and located during the design phase and included as part of the design specifications to ensure that such structures, where needed, are provided within the highway right-of-way.

g. *Plan residential roads and streets in accordance with local subdivision regulations, zoning ordinances, and other local site planning requirements (International City Managers Association, Model Zoning/Subdivision Codes). Residential road and street pavements should be designed with minimum widths.*

Local roads and streets should have right-of-way widths of 36 to 50 feet, with lane widths of 10 to 12 feet. Minimum pavement widths for residential streets where street parking is permitted range from 24 to 28 feet between curbs. In large-lot subdivisions (1 acre or more), grassed drainage swales can be used in lieu of curbs and gutters and the width of paved road surface can be between 18 and 20 feet.

h. *Select the most economic and environmentally sound route location. (FHWA, 1991)*

i. *Use appropriate computer models and methods to determine urban runoff impacts with all proposed route corridors. (Driscoll, 1990)*

Computer models to determine urban runoff from streets and highways include TR-55 (Soil Conservation Service model for controlling peak runoff); the P-8 model to determine storage capacity (Palmstrom and Walker); the FHWA highway runoff model (Driscoll et al., 1990); and others (e.g., SWMM, EPA's stormwater management model; HSP continuous simulation model by Hydrocomp, Inc.).

j. *Comply with National Environmental Policy Act requirements including other State and local requirements. (FHWA, T6640.8A)*

k. *Coordinate the design of pollution controls with appropriate State and Federal environmental agencies. (Maryland DOE, 1983)*

I. Develop local official mapping to show location of proposed highway corridors.

Official mapping can be used to reserve land areas needed for public facilities such as roads, highways, bridges, and urban runoff treatment devices. Areas that require protection, such as those which are sensitive to disturbance or development-related nonpoint source pollution, can be reserved by planning and mapping necessary infrastructure for location in suitable areas.

5. Effectiveness Information and Cost Information

The most economical time to consider the type and location of erosion, sediment, and NPS pollution control is early in the planning and design phase of roads and highways. It is much more costly to correct polluted runoff problems after a road or highway has already been built. The most effective and often the most economical control is to design roads and highways as close to existing grade as possible to minimize the area that must be cut or filled and to avoid locations that encroach upon adjacent watercourses and wet areas. However, some portions of roads and highways cannot always be located where NPS pollution does not pose a threat to surface waters. In these cases, the impact from potential pollutant loadings should be mitigated. Interactive computer models designed to run on a PC are available (e.g., FHWA's model, Driscoll et al., 1990) and can be used to examine and project the runoff impacts of a proposed road or highway design on surface waters. Where controls are determined to be needed, several cost-effective management practices, such as vegetated filter strips, grassed swales, and pond systems, can be considered and used to treat the polluted runoff. These mitigating practices are described in detail in the discussion on urban developments (Management Measure IV.A).

B. Management Measure for Bridges

Site, design, and maintain bridge structures so that sensitive and valuable aquatic ecosystems and areas providing important water quality benefits are protected from adverse effects.

1. Applicability

This management measure is intended to be applied by States to new, relocated, and rehabilitated bridge structures in order to control erosion, streambed scouring, and surface runoff from such activities. Under the Coastal Zone Act Reauthorization Amendments of 1990, States are subject to a number of requirements as they develop coastal NPS programs in conformity with this management measure and will have some flexibility in doing so. The application of management measures by States is described more fully in *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance*, published jointly by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce.

2. Description

This measure requires that NPS runoff impacts on surface waters from bridge decks be assessed and that appropriate management and treatment be employed to protect critical habitats, wetlands, fisheries, shellfish beds, and domestic water supplies. The siting of bridges should be a coordinated effort among the States, the FHWA, the U.S. Coast Guard, and the Army Corps of Engineers. Locating bridges in coastal areas can cause significant erosion and sedimentation, resulting in the loss of wetlands and riparian areas. Additionally, since bridge pavements are extensions of the connecting highway, runoff waters from bridge decks also deliver loadings of heavy metals, hydrocarbons, toxic substances, and deicing chemicals to surface waters as a result of discharge through scupper drains with no overland buffering. Bridge maintenance can also contribute heavy loads of lead, rust particles, paint, abrasive, solvents, and cleaners into surface waters. Protection against possible pollutant overloads can be afforded by minimizing the use of scuppers on bridges traversing very sensitive waters and conveying deck drainage to land for treatment. Whenever practical, bridge structures should be located to avoid crossing over sensitive fisheries and shellfish-harvesting areas to prevent washing polluted runoff through scuppers into the waters below. Also, bridge design should account for potential scour and erosion, which may affect shellfish beds and bottom sediments.

3. Management Measure Selection

This management measure was selected because of its documented effectiveness and to protect against potential pollution impacts from siting bridges over sensitive waters and tributaries in the coastal zone. There are several examples of siting bridges to protect sensitive areas. The Isle of Palms Bridge near Charleston, South Carolina, was designed without scupper drains to protect a local fishery from polluted runoff by preventing direct discharge into the waters below. In another example, the Louisiana Department of Transportation and Development specified stringent requirements before allowing the construction of a bridge to protect destruction of fragile wetlands near New Orleans. A similar requirement was specified for bridge construction in the Tampa Bay area in Florida (ENR, 1991).

4. Practices

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.

Additional erosion and sediment control management practices are listed in the construction section for urban sources of pollution (Management Measure IV.A).

a. Coordinate design with FHWA, USCG, COE, and other State and Federal agencies as appropriate.

b. Review National Environmental Policy Act requirements to ensure that environmental concerns are met (FHWA, T6640.8A and 23 CFR 771).

c. Avoid highway locations requiring numerous river crossings. (AASHTO, 1991)

d. Direct pollutant loadings away from bridge decks by diverting runoff waters to land for treatment.

Bridge decks should be designed to keep runoff velocities low and control pollutant loadings. Runoff waters should be conveyed away from contact with the watercourse and directed to a stable storm drainage, wetland, or detention pond. Conveyance systems should be designed to withstand the velocities of projected peak discharge.

e. Restrict the use of scupper drains on bridges less than 400 feet in length and on bridges crossing very sensitive ecosystems.

Scupper drains allow direct discharge of runoff into surface waters below the bridge deck. Such discharges can be of concern where the waterbody is highly susceptible to degradation or is an outstanding resource such as a spawning area or shellfish bed. Other sensitive waters include water supply sources, recreational waters, and irrigation systems. Care should be taken to protect these areas from contaminated runoff.

f. Site and design new bridges to avoid sensitive ecosystems.

Pristine waters and sensitive ecosystems should be protected from degradation as much as possible. Bridge structures should be located in alternative areas where only minimal environmental damage would result.

g. On bridges with scupper drains, provide equivalent urban runoff treatment in terms of pollutant load reduction elsewhere on the project to compensate for the loading discharged off the bridge.

5. Effectiveness Information and Cost Information

Effectively controlling NPS pollutants such as road contaminants, fugitive dirt, and debris and preventing accidental spills from entering surface waters via bridge decks are necessary to protect wetlands and other sensitive ecosystems. Therefore, management practices such as minimizing the use of scupper drains and diverting runoff waters to land for treatment in detention ponds and infiltration systems are known to be effective in mitigating pollutant loadings. Tables 4-7 and 4-8 in Section II provide cost and effectiveness data for ponds, constructed wetlands, and filtration devices.

C. Management Measure for Construction Projects

(1) Reduce erosion and, to the extent practicable, retain sediment onsite during and after construction and

(2) Prior to land disturbance, prepare and implement an approved erosion control plan or similar administrative document that contains erosion and sediment control provisions.

1. Applicability

This management measure is intended to be applied by States to new, replaced, restored, and rehabilitated road, highway, and bridge construction projects in order to control erosion and offsite movement of sediment from such project sites. Under the Coastal Zone Act Reauthorization Amendments of 1990, States are subject to a number of requirements as they develop coastal NPS programs in conformity with this management measure and will have some flexibility in doing so. The application of management measures by States is described more fully in *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance*, published jointly by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce.

2. Description

Erosion and sedimentation from construction of roads, highways, and bridges, and from unstabilized cut-and-fill areas, can significantly impact surface waters and wetlands with silt and other pollutants including heavy metals, hydrocarbons, and toxic substances. Erosion and sediment control plans are effective in describing procedures for mitigating erosion problems at construction sites before any land-disturbing activity begins. Additional relevant practices are described in Management Measures III.A and III.B of this chapter.

Bridge construction projects include grade separations (bridges over roads) and waterbody crossings. Erosion problems at grade separations result from water running off the bridge deck and runoff waters flowing onto the bridge deck during construction. Controlling this runoff can prevent erosion of slope fills and the undermining failure of the concrete slab at the bridge approach. Bridge construction over waterbodies requires careful planning to limit the disturbance of streambanks. Soil materials excavated for footings in or near the water should be removed and relocated to prevent the material from being washed back into the waterbody. Protective berms, diversion ditches, and silt fences parallel to the waterway can be effective in preventing sediment from reaching the waterbody.

Wetland areas will need special consideration if affected by highway construction, particularly in areas where construction involves adding fill, dredging, or installing pilings. Highway development is most disruptive in wetlands since it may cause increased sediment loss, alteration of surface drainage patterns, changes in the subsurface water table, and loss of wetland habitat. Highway structures should not restrict tidal flows into salt marshes and other coastal wetland areas because this might allow the intrusion of freshwater plants and reduce the growth of salt-tolerant species. To safeguard these fragile areas, the best practice is to locate roads and highways with sufficient setback distances between the highway right-of-way and any wetlands or riparian areas. Bridge construction also can impact water circulation and quality in wetland areas, making special techniques necessary to accommodate construction. The following case study provides an example of a construction project where special considerations were given to wetlands.

CASE STUDY - BRIDGING WETLANDS IN LOUISIANA

To provide protection for an environmentally critical wetland outside New Orleans, the Louisiana Department of Transportation and Development (DOTD) required a special construction technique to build almost 2 miles of twin elevated structures for the Interstate 310 link between I-10 and U.S. Route 90. A technique known as "end-on" construction was devised to work from the decks of the structures, building each section of the bridge from the top of the last completed section and using heavy cranes to push each section forward one bay at a time. The cranes were also used to position steel platforms, drive in support pilings, and lay deck slabs, alternating this procedure between each bay. Without this technique, the Louisiana DOTD would not have been permitted to build this structure. The twin 9,200-foot bridges took 485 days to complete at a cost of $25.3 million (*Engineering News Record*, 1991).

3. Management Measure Selection

This management measure was selected because it supports FHWA's erosion and sediment control policy for all highway and bridge construction projects and is the administrative policy of several State highway departments and local governmental agencies involved in land development activity. Examples of erosion and sediment controls and NPS pollutant control practices are described in AASHTO guidelines and in several State erosion control manuals (AASHTO, 1991; North Carolina DOT, 1991; Washington State DOT, 1988). A detailed discussion of cost-effective management practices is available in the urban development section (Section II) of this chapter. These example practices are also effective for highway construction projects.

4. Practices

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.

Additional erosion and sediment control management practices are listed in the construction section (Section III) of this chapter.

a. Write erosion and sediment control requirements into plans, specifications, and estimates for Federal aid construction projects for highways and bridges (FHWA, 1991) and develop erosion control plans for earth-disturbing activities.

Erosion and sediment control decisions made during the planning and location phase should be written into the contract, plans, specifications, and special provisions provided to the construction contractor. This approach can establish contractor responsibility to carry out the explicit contract plan recommendations for the project and the erosion control practices needed.

b. Coordinate erosion and sediment controls with FHWA, AASHTO, and State guidelines.

Coordination and scheduling of the project work with State and local authorities are major considerations in controlling anticipated erosion and sediment problems. In addition, the contractor should submit a general work schedule and plan that indicates planned implementation of temporary and permanent erosion control practices, including shutdown procedures for winter and other work interruptions. The plan also should include proposed methods of control on restoring borrow pits and the disposal of waste and hazardous materials.

c. Install permanent erosion and sediment control structures at the earliest practicable time in the construction phase.

Permanent or temporary soil stabilization practices should be applied to cleared areas within 15 days after final grade is reached on any portion of the site. Soil stabilization should also be applied within 15 days to denuded areas that may not be at final grade but will remain exposed to rain for 30 days or more. Soil stabilization practices protect soil from the erosive forces of raindrop impact and flowing water. Temporary erosion control practices usually include seeding, mulching, establishing general vegetation, and early application of a gravel base on areas to be paved. Permanent soil stabilization practices include vegetation, filter strips, and structural devices.

Sediment basins and traps, perimeter dikes, sediment barriers, and other practices intended to trap sediment on site should be constructed as a first step in grading and should be functional before upslope land disturbance takes place. Structural practices such as earthen dams, dikes, and diversions should be seeded and mulched within 15 days of installation.

d. Coordinate temporary erosion and sediment control structures with permanent practices.

All temporary erosion and sediment controls should be removed and disposed of within 30 days after final site stabilization is achieved or after the temporary practices are no longer needed. Trapped sediment and other disturbed soil areas resulting from the disposition of temporary controls should be permanently stabilized to prevent further erosion and sedimentation (AASHTO, 1991).

e. Wash all vehicles prior to leaving the construction site to remove mud and other deposits. Vehicles entering or leaving the site with trash or other loose materials should be covered to prevent transport of dust, dirt, and debris. Install and maintain mud and silt traps.

f. Mitigate wetland areas destroyed during construction.

Marshes and some types of wetlands can often be developed in areas where fill material was extracted or in ponds designed for sediment control during construction. Vegetated strips of native marsh grasses established along highway embankments near wetlands or riparian areas can be effective to protect these areas from erosion and sedimentation (FHWA, 1991).

g. Minimize the area that is cleared for construction.

h. Construct cut-and-fill slopes in a manner that will minimize erosion.

Cut-and-fill slopes should be constructed in a manner that will minimize erosion by taking into consideration the length and steepness of slopes, soil types, upslope drainage areas, and ground-water conditions. Suggested recommendations are as follows: reduce the length of long steep slopes by adding diversions or terraces; prevent concentrated runoff from flowing down cut-and-fill slopes by containing these flows within flumes or slope drain structures; and create roughened soil surfaces on cut-and-fill slopes to slow runoff flows. Wherever a slope face crosses a water seepage plane, thereby endangering the stability of the slope, adequate subsurface drainage should be provided.

i. Minimize runoff entering and leaving the site through perimeter and onsite sediment controls.

j. Inspect and maintain erosion and sediment control practices (both on-site and perimeter) until disturbed areas are permanently stabilized.

k. *Divert and convey offsite runoff around disturbed soils and steep slopes to stable areas in order to prevent transport of pollutants off site.*

l. *After construction, remove temporary control structures and restore the affected area. Dispose of sediments in accordance with State and Federal regulations.*

m. *All storm drain inlets that are made operable during construction should be protected so that sediment-laden water will not enter the conveyance system without first being filtered or otherwise treated to remove sediment.*

5. Effectiveness Information and Cost Information

The detailed cost and effectiveness information presented under the construction measure for urban development is also applicable to road, highway, and bridge construction. See Tables 4-15 and 4-16 in Section III.

D. Management Measure for Construction Site Chemical Control

(1) Limit the application, generation, and migration of toxic substances;

(2) Ensure the proper storage and disposal of toxic materials; and

(3) Apply nutrients at rates necessary to establish and maintain vegetation without causing significant nutrient runoff to surface water.

1. Applicability

This management measure is intended to be applied by States to new, resurfaced, restored, and rehabilitated road, highway, and bridge construction projects in order to reduce toxic and nutrient loadings from such project sites. Under the Coastal Zone Act Reauthorization Amendments of 1990, States are subject to a number of requirements as they develop coastal NPS programs in conformity with this management measure and will have some flexibility in doing so. The application of management measures by States is described more fully in *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance*, published jointly by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce.

2. Description

The objective of this measure is to guard against toxic spills and hazardous loadings at construction sites from equipment and fuel storage sites. Toxic substances tend to bind to fine soil particles; however, by controlling sediment mobilization, it is possible to limit the loadings of these pollutants. Also, some substances such as fuels and solvents are hazardous and excess applications or spills during construction can pose significant environmental impacts. Proper management and control of toxic substances and hazardous materials should be the adopted procedure for all construction projects and should be established by erosion and sediment control plans. Additional relevant practices are described in Management Measure III.B of this chapter.

3. Management Measure Selection

This management measure was selected because of existing practices that have been shown to be effective in mitigating construction-generated NPS pollution at highway project sites and equipment storage yards. In addition, maintenance areas containing road salt storage, fertilizers and pesticides, snowplows and trucks, and tractor mowers have the potential to contribute NPS pollutants to adjacent watercourses if not properly managed (AASHTO, 1988, 1991a). This measure is intended to safeguard surface waters and ground water from toxic and hazardous pollutants generated at construction sites. Examples of effective implementation of this measure are presented in the section on construction in urban areas. Several State environmental agencies are using this approach to regulate toxic and hazardous pollutants (Florida DER, 1988; Puget Sound Basin, 1991).

4. Practices

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.

The practices that are applicable to this management measure are described in Section III.B.

5. Effectiveness Information and Cost Information

The detailed cost and effectiveness data presented in the Section III.A of this chapter describing NPS controls for construction projects in urban development areas are also applicable to highway construction projects.

E. Management Measure for Operation and Maintenance

Incorporate pollution prevention procedures into the operation and maintenance of roads, highways, and bridges to reduce pollutant loadings to surface waters.

1. Applicability

This management measure is intended to be applied by States to existing, restored, and rehabilitated roads, highways, and bridges. Under the Coastal Zone Act Reauthorization Amendments of 1990, States are subject to a number of requirements as they develop coastal NPS programs in conformity with this management measures and will have some flexibility in doing so. The application of measures by States is described more fully in *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance*, published jointly by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce.

2. Description

Substantial amounts of eroded material and other pollutants can be generated by operation and maintenance procedures for roads, highways, and bridges, and from sparsely vegetated areas, cracked pavements, potholes, and poorly operating urban runoff control structures. This measure is intended to ensure that pollutant loadings from roads, highways, and bridges are minimized by the development and implementation of a program and associated practices to ensure that sediment and toxic substance loadings from operation and maintenance activities do not impair coastal surface waters. The program to be developed, using the practices described in this management measure, should consist of and identify standard operating procedures for nutrient and pesticide management, road salt use minimization, and maintenance guidelines (e.g., capture and contain paint chips and other particulates from bridge maintenance operations, resurfacing, and pothole repairs).

3. Management Measure Selection

This management measure for operation and maintenance was selected because (1) it is recommended by FHWA as a cost-effective practice (FHWA, 1991); (2) it is protective of the human environment (Puget Sound Water Quality Authority, 1989); (3) it is effective in controlling erosion by revegetating bare slopes (AASHTO, 1991b); (4) it is helpful in minimizing polluted runoff from road pavements (Transportation Research Board, 1991); and (5) both Federal (Richardson, 1974) and State highway agencies (Minnesota Pollution Control Agency, 1989; Pitt, 1973) advocate highway maintenance as an effective practice for minimizing pollutant loadings.

Maintenance of erosion and sediment control practices is of critical importance. Both temporary and permanent controls require frequent and periodic cleanout of accumulated sediment. Any trapping or filtering device, such as silt fences, sediment basins, buffers, inlets, and check dams, should be checked and cleaned out when approximately 50 percent of their capacity is reached, as determined by the erodible nature of the soil, flow velocity, and quantity of runoff. Seasonal and climatic differences may require more frequent cleanout of these structures. The sediments removed from these control devices should be deposited in permanently stabilized areas to prevent further erosion and sediment from reaching drainages and receiving streams. After periods of use, control devices may require replacement of deteriorated materials such as straw bales and silt fence fabrics, or restoration and reconstruction of sediment basins and riprap installations.

Permanent erosion controls such as vegetated filter strips, grassed swales, and velocity dissipators should be inspected periodically to determine their integrity and continued effectiveness. Continual deterioration or damage to these controls may indicate a need for better design or construction.

4. Practices

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully apply to achieve the management measure described above.

a. Seed and fertilize, seed and mulch, and/or sod damaged vegetated areas and slopes.

b. Establish pesticide/herbicide use and nutrient management programs.

Refer to the Management Measure for Construction Site Chemical Control in this chapter.

c. Restrict herbicide and pesticide use in highway rights-of-way to applicators certified under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) to ensure safe and effective application.

d. The use of chemicals such as soil stabilizers, dust palliatives, sterilants, and growth inhibitors should be limited to the best estimate of optimum application rates. All feasible measures should be taken to avoid excess application and consequent intrusion of such chemicals into surface runoff.

e. Sweep, vacuum, and wash residential/urban streets and parking lots.

f. Collect and remove road debris.

g. Cover salt storage piles and other deicing materials to reduce contamination of surface waters. Locate them outside the 100-year floodplain.

h. Regulate the application of deicing salts to prevent oversalting of pavement.

i. Use specially equipped salt application trucks.

j. Use alternative deicing materials, such as sand or salt substitutes, where sensitive ecosystems should be protected.

k. Prevent dumping of accumulated snow into surface waters.

l. Maintain retaining walls and pavements to minimize cracks and leakage.

m. Repair potholes.

n. Encourage litter and debris control management.

o. Develop an inspection program to ensure that general maintenance is performed on urban runoff and NPS pollution control facilities.

To be effective, erosion and sediment control devices and practices must receive thorough and periodic inspection checks. The following is a suggested checklist for the inspection of erosion and sediment controls (AASHTO Operating Subcommittee on Design, 1990):

- Clean out sediment basins and traps; ensure that structures are stable.
- Inspect silt fences and replace deteriorated fabrics and wire connections; properly dispose of deteriorated materials.
- Renew riprapped areas and reapply supplemental rock as necessary.
- Repair/replace check dams and brush barriers; replace or stabilize straw bales as needed.
- Regrade and shape berms and drainage ditches to ensure that runoff is properly channeled.
- Apply seed and mulch where bare spots appear, and replace matting material if deteriorated.
- Ensure that culverts and inlets are protected from siltation.
- Inspect all permanent erosion and sediment controls on a scheduled, programmed basis.

p. Ensure that energy dissipators and velocity controls to minimize runoff velocity and erosion are maintained.

q. Dispose of accumulated sediment collected from urban runoff management and pollution control facilities, and any wastes generated during maintenance operations, in accordance with appropriate local, State, and Federal regulations.

r. Use techniques such as suspended tarps, vacuums, or booms to reduce, to the extent practicable, the delivery to surface waters of pollutants used or generated during bridge maintenance (e.g., paint, solvents, scrapings).

s. Develop education programs to promote the practices listed above.

5. Effectiveness Information and Cost Information

Preventive maintenance is a time-proven, cost-effective management approach. Operation schedules and maintenance procedures to restore vegetation, proper management of salt and fertilizer application, regular cleaning of urban runoff structures, and frequent sweeping and vacuuming of urban streets have effective results in pollution control. Litter control, clean-up, and fix-up practices are a low-cost means for eliminating causes of pollution, as is the proper handling of fertilizers, pesticides, and other toxic materials including deicing salts and abrasives. Table 4-30 presents summary information on the cost and effectiveness of operation and maintenance practices for roads, highways, and bridges. Many States and communities are already implementing several of these practices within their budget limitations. As shown in Table 4-30, the use of road salt alternatives such as calcium magnesium acetate (CMA) can be very costly. Some researchers have indicated, however, that reductions in corrosion of infrastructure, damage to roadside vegetation, and the quantity of material that needs to be applied may offset the higher cost of CMA. Use of road salt minimization practices such as salt storage protection and special salt spreading equipment reduces the amount of salt that a State or community must purchase. Consequently, implementation of these practices can pay for itself through savings in salt purchasing costs. Similar programs such as nutrient and pesticide management can also lead to decreased expenditures for materials.

CMA Eligible for Matching Funds

Calcium magnesium acetate (CMA) is now eligible for Federal matching funds under the Bridge Program of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. The Act provides 80 percent funding for use of CMA on salt-sensitive bridges in order to protect against corrosion and to extend their useful life. CMA can also be used to protect vegetation from salt damage in environmentally sensitive areas.

Table 4-30. Effectiveness and Cost Summary for Roads, Highways, and Bridges Operation and Maintenance Management Practices

	% Removal						
Management Practice	TSS	TP	TN	COD	Pb	Zn	Cost
MAINTAIN VEGETATION							
For Sediment Control							Natural succession allowed to occur -
Average:	90	NA	NA	NA	NA	NA	Avg: $100/ac/year
Reported Range:	50-100	NA	NA	NA	NA	NA	Reported Range: $50-$200/ac/year
Probable Range:	80-100	-	-	-	-	-	
For Pollutant Removal							Natural succession not allowed to occur -
Average:	60	40	40	50	50	50	Avg: $800/ac/year
Reported Range	0-100	0-100	0-70	20-80	0-100	50-60	Reported Range: $700-$900/ac/year
Probable Range:	0-100	0-100	0-100	0-100	0-100	0-100	
PESTICIDE/HERBICIDE USE MANAGEMENT							Generally accepted as an economical program to control excessive use
Average:	NA						
Reported Range:	NA						
Probable Range:							
STREET SWEEPING							
Smooth Street, Frequent Cleaning (One or More Passes Per Week)							Avg: $20/curb mile Reported Range: $10-$30/curb mile
Average:	20	NA	NA	5	25	NA	
Reported Range:	20	NA	NA	0-10	5-35	NA	
Probable Range:	20-50	-	-	0-10	20-50	10-30	
Infrequent Cleaning (One Pass Per Month or Less)							
Average:	NA	NA	NA	NA	5	NA	
Reported Range:	NA	NA	NA	NA	0-10	NA	
Probable Range:	0-20	-	-	-	0-20	0-10	
LITTER CONTROL							Generally accepted as an economical approach to control excessive use
Average:	NA						
Reported Range:	NA						
Probable Range:							

Table 4-30. (Continued)

Management Practice	% Removal TSS	TP	TN	COD	Pb	Zn	Cost
GENERAL MAINTENANCE (e.g., pothole and roadside repairs)							Generally accepted as an economical preventive maintenance program by local and State agencies
Average:	NA						
Reported Range:	NA						
Probable Range:							
PROTECTION OF SALT PILES							For salt storage building -
Average:	NA						Ave: $30/ton salt
Reported Range:	NA						Reported Range: $10-$70/ton salt
Probable Range:	90-100[a]						
MINIMIZATION OF APPLICATION OF DEICING SALTS							Generally accepted as an economical preventive maintenance program by local and State agencies
Average:	NA						
Reported Range:	NA						
Probable Range:	Deicing salts that are not applied to roads will not enter runoff[a]						
SPECIALLY EQUIPPED SALT APPLICATION TRUCKS							For spread rate control on truck -
Average:	NA						Ave: $6,000/truck
Reported Range:	NA						Reported Range: $6,000/truck
Probable Range:	Deicing salts that are not applied to roads will not enter runoff[a]						
USE OF ALTERNATIVE DEICING MATERIALS							CMA -
Average:	NA						Ave: $650/ton
Reported Range:	NA						Reported Range: $650/ton (note: cost of salt $30/ton)
Probable Range:	Deicing salts that are not applied to roads will not enter runoff[a]						
CONTAIN POLLUTANTS GENERATED DURING BRIDGE MAINTENANCE							Varies with method of containment use
Average:	NA						
Reported Range:	NA						
Probable Range:	50-100[b]						

NA = Not applicable.
[a]Measured as reduction in salt.
[b]Measured as reduction of all pollutants.

F. Management Measure for Road, Highway, and Bridge Runoff Systems

Develop and implement runoff management systems for existing roads, highways, and bridges to reduce runoff pollutant concentrations and volumes entering surface waters.

(1) Identify priority and watershed pollutant reduction opportunities (e.g., improvements to existing urban runoff control structures; and

(2) Establish schedules for implementing appropriate controls.

1. Applicability

This management measure is intended to be applied by States to existing, resurfaced, restored, and rehabilitated roads, highways, and bridges that contribute to adverse effects in surface waters. Under the Coastal Zone Act Reauthorization Amendments of 1990, States are subject to a number of requirements as they develop coastal NPS programs in conformity with this management measure and will have some flexibility in doing so. The application of management measures by States is described more fully in *Coastal Nonpoint Pollution Control Program: Program Development and Approval Guidance*, published jointly by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce.

2. Description

This measure requires that operation and maintenance systems include the development of retrofit projects, where needed, to collect NPS pollutant loadings from existing, reconstructed, and rehabilitated roads, highways, and bridges. Poorly designed or maintained roads and bridges can generate significant erosion and pollution loads containing heavy metals, hydrocarbons, sediment, and debris that run off into and threaten the quality of surface waters and their tributaries. In areas where such adverse impacts to surface waters can be attributed to adjacent roads or bridges, retrofit management projects to protect these waters may be needed (e.g., installation of structural or nonstructural pollution controls). Retrofit projects can be located in existing rights-of-way, within interchange loops, or on adjacent land areas. Areas with severe erosion and pollution runoff problems may require relocation or reconstruction to mitigate these impacts.

Runoff management systems are a combination of nonstructural and structural practices selected to reduce nonpoint source loadings from roads, highways, and bridges. These systems are expected to include structural improvements to existing runoff control structures for water quality purposes; construction of new runoff control devices, where necessary to protect water quality; and scheduled operation and maintenance activities for these runoff control practices. Typical runoff controls for roads, highways, and bridges include vegetated filter strips, grassed swales, detention basins, constructed wetlands, and infiltration trenches.

3. Management Measure Selection

This management measure was selected because of the demonstrated effectiveness of retrofit systems for existing roads and highways that were constructed with inadequate nonpoint source pollution controls or without such controls. Structural practices for mitigating polluted runoff from existing highways are described in the literature (Silverman, 1988).

4. Practices

As discussed more fully at the beginning of this chapter and in Chapter 1, the following practices are described for illustrative purposes only. State programs need not require implementation of these practices. However, as a practical matter, EPA anticipates that the management measure set forth above generally will be implemented by applying one or more management practices appropriate to the source, location, and climate. The practices set forth below have been found by EPA to be representative of the types of practices that can be applied successfully to achieve the management measure described above.

a. Locate runoff treatment facilities within existing rights-of-way or in medians and interchange loops.

b. Develop multiple-use treatment facilities on adjacent lands (e.g., parks and golf courses).

c. Acquire additional land for locating treatment facilities.

d. Use underground storage where no alternative is available.

e. Maximize the length and width of vegetated filter strips to slow the travel time of sheet flow and increase the infiltration rate of urban runoff.

5. Effectiveness Information and Cost Information

Cost and effectiveness data for structural urban runoff management and pollution control facilities are outlined in Tables 4-15 and 4-16 in Section III and discussed in Section IV of this chapter and are applicable to determine the cost and effectiveness of retrofit projects. Retrofit projects can often be more costly to construct because of the need to locate the required structures within existing space or the need to locate the structures within adjacent property that requires purchase. However, the use of multiple-use facilities on adjacent lands, such as diverting runoff waters to parkland or golf courses, can offset this cost. Nonstructural practices described in the urban section also can be effective in achieving source control. As with other sections of this document, the costs of loss of habitat, fisheries, and recreational areas must be weighed against the cost of retrofitting control structures within existing rights-of-way.

6. Pollutants of Concern

Table 4-31 lists the pollutants commonly found in urban runoff from roads, highways, and bridges and their sources. The disposition and subsequent magnitude of pollutants found in highway runoff are site-specific and are affected by traffic volume, road or highway design, surrounding land use, climate, and accidental spills.

The FHWA conducted an extensive field monitoring and laboratory analysis program to determine the pollutant concentration in highway runoff from 31 sites in 11 States (Driscoll et al., 1990). The event mean concentrations (EMCs) developed in the study for a number of pollutants are presented in Table 4-32. The study also indicated that for highways discharging into lakes, the pollutants of major concern are phosphorus and heavy metals. For highways discharging into streams, the pollutants of major concern are heavy metals—cadmium, copper, lead, and zinc.

Table 4-31. Highway Runoff Constituents and Their Primary Sources

Constituents	Primary Sources
Particulates	Pavement wear, vehicles, atmosphere, maintenance
Nitrogen, Phosphorus	Atmosphere, roadside fertilizer application
Lead	Leaded gasoline (auto exhaust), tire wear (lead oxide filler material, lubricating oil and grease, bearing wear)
Zinc	Tire wear (filler material), motor oil (stabilizing additive), grease
Iron	Auto body rust, steel highway structures (guard rails, bridges, etc.), moving engine parts
Copper	Metal plating, bearing and bushing wear, moving engine parts, brake lining wear, fungicides and insecticides
Cadmium	Tire wear (filler material), insecticide application
Chromium	Metal plating, moving engine parts, break lining wear
Nickel	Diesel fuel and gasoline (exhaust), lubricating oil, metal plating, bushing wear, brake lining wear, asphalt paving
Manganese	Moving engine parts
Cyanide	Anticake compound (ferric ferrocyanide, sodium ferrocyanide, yellow prussiate of soda) used to keep deicing salt granular
Sodium, Calcium, Chloride	Deicing salts
Sulphate	Roadway beds, fuel, deicing salts
Petroleum	Spills, leaks or blow-by of motor lubricants, antifreeze and hydraulic fluids, asphalt surface leachate

In colder regions where deicing agents are used, deicing chemicals and abrasives are the largest source of pollutants during winter months. Deicing salt (primarily sodium chloride, NaCl) is the most commonly used deicing agent. Potential pollutants from deicing salt include sodium chloride, ferric ferrocyanide (used to keep the salt in granular form), and sulfates such as gypsum. Table 4-33 summarizes potential environmental impacts caused by road salt. Other chemicals used as a salt substitute include calcium magnesium acetate (CMA) and, less frequently, urea and glycol compounds. Researchers have differing opinions on the environmental impacts of CMA compared to those of road salt (Chevron Chemical Company, 1991; Salt Institute, undated; Transportation Research Board, 1991).

Table 4-32. Pollutant Concentrations in Highway Runoff (Driscoll et al., 1990)

Pollutant	Event Mean Concentration for Highways With Fewer Than 30,000 Vehicles/Day[a] (mg/L)	Event Mean Concentration for Highways With More Than 30,000 Vehicles/Day[a] (mg/L)
Total Suspended Solids	41	142
Volatile Suspended Solids	12	39
Total Organic Carbon	8	25
Chemical Oxygen Demand	49	114
Nitrite and Nitrate	0.46	0.76
Total Kjeldahl Nitrogen	0.87	1.83
Phosphate Phosphorus	0.16	0.40
Copper	0.022	0.054
Lead	0.080	0.400
Zinc	0.080	0.329

[a]Event mean concentrations are for the 50% median site.

Table 4-33. Potential Environmental Impacts of Road Salts

Environmental Resource	Potential Environmental Impact of Road Salt (NaCl)
Soils	May accumulate in soil. Breaks down soil structure, increases erosion. Causes soil compaction that results in decreased permeability.
Vegetation	Osmotic stress and soil compaction harm root systems. Spray causes foliage dehydration damage. Many plant species are salt-sensitive.
Ground Water	Mobile Na and Cl ions readily reach ground water. Increases NaCl concentration in well water, as well as alkalinity and hardness.
Surface Water	Causes density stratification in ponds and lakes that can prevent reoxygenation. Increases runoff of heavy metals and nutrients through increased erosion.
Aquatic Life	Monovalent Na and Cl ions stress osmotic balances. Toxic levels: Na - 500 ppm for strickleback; Cl - 400 ppm for trout.
Human/Mammalian	Sodium is linked to heart disease and hypertension. Chlorine causes unpleasant taste in drinking water. Mild skin and eye irritant. Acute oral LD_{50} in rats is approximately 3,000 mg/kg (slightly toxic).

VIII. GLOSSARY

Unless otherwise noted, the source of these definitions is *Glossary of Environmental Terms and Acronym List* (USEPA, 1989).

Bankfull event (also bankfull discharge): A flow condition in which streamflow completely fills the steam channel up to the top of the bank. In undisturbed watersheds, the discharge condition occurs on average every 1.5 to 2 years and controls the shape and form of natural channels. (Schueler, 1987)

Berm: An earthen mound used to direct the flow of runoff around or through a best management practice (BMP) (Schueler, 1987).

Constructed urban runoff wetlands: Those wetlands that are intentionally created on sites that are not wetlands for the primary purpose of wastewater or urban runoff treatment and are managed as such. Constructed wetlands are normally considered as part of the urban runoff collection and treatment system.

Conveyance system: The drainage facilities, both natural and human-made, which collect, contain, and provide for the flow of surface water and urban runoff from the highest points on the land down to a receiving water. The natural elements of the conveyance system include swales and small drainage courses, streams, rivers, lakes, and wetlands. The human-made elements of the conveyance system include gutters, ditches, pipes, channels, and most retention/detention facilities (Washington Department of Ecology, 1992).

Denitrification: The anaerobic biological reduction of nitrate nitrogen to nitrogen gas.

Discharge: Outflow; the flow of a stream, canal, or aquifer. One may also speak of the discharge of a canal or stream into a lake, river, or ocean. (Hydraulics) Rate of flow, specifically fluid flow; a volume of fluid passing a point per unit of time, commonly expressed as cubic feet per second, cubic meters per second, gallons per minute, gallons per day, or millions of gallons per day. (Washington Department of Ecology, 1992)

Drainage basin: A geographic and hydrologic subunit of a watershed (Washington Department of Ecology, 1992).

Ecosystem: The interacting system of a biological community and its nonliving environmental surroundings.

Erosion: The wearing away of the land surface by wind or water. Erosion occurs naturally from weather or runoff but can be intensified by land-clearing practices related to farming, residential or industrial development, road building, or timber cutting.

Forebay: An extra storage space provided near an inlet of a BMP to trap incoming sediments before they accumulate in a pond BMP (Schueler, 1987).

Heavy metals: Metallic elements with high atomic weights, e.g., mercury, chromium, cadmium, arsenic, and lead. They can damage living things at low concentrations and tend to accumulate in the food chain.

Illicit discharge: All nonurban runoff discharges to urban runoff drainage systems that could cause or contribute to a violation of State water quality, sediment quality, or ground-water quality standards, including but not limited to sanitary sewer connections, industrial process water, interior floor drains, car washing, and greywater systems (Washington Department of Ecology, 1992).

Impervious surface: A hard surface area that either prevents or retards the entry of water into the soil mantle as under natural conditions prior to development and/or a hard surface area that causes water to run off the surface in greater quantities or at an increased rate of flow from the flow present under natural conditions prior to development. Common impervious surfaces include, but are not limited to, rooftops, walkways, patios, driveways, parking lots, storage areas, concrete or asphalt paving, gravel roads, packed earthen materials, and oiled, macadam, or other surfaces that similarly impede the natural infiltration of urban runoff. Open, uncovered retention/detention facilities shall not be considered as impervious surfaces. (Washington Department of Ecology, 1992)

Invasive exotic plants: Non-native plants having the capacity to compete and proliferate in introduced environments (Washington Department of Ecology, 1992).

Land conversion: A change in land use, function, or purpose (Washington Department of Ecology, 1992).

Land-disturbing activity: Any activity that results in a change in the existing soil cover (both vegetative and nonvegetative) and/or the existing soil topography. Land-disturbing activities include, but are not limited to, demolition, construction, clearing, grading, filling, and excavation. (Washington Department of Ecology, 1992)

Local government: Any county, city, or town having its own incorporated government for local affairs (Washington Department of Ecology, 1992).

Municipal separate storm sewer systems: Any conveyance or system of conveyance that is owned or operated by the State or local government entity, is used for collecting and conveying storm water, and is not part of a publicly owned treatment works (POTW), as defined in EPA 40 CFR Part III (Washington Department of Ecology, 1992).

Onsite disposal system (OSDS): Sewage disposal system designed to treat wastewater at a particular site. Septic tank systems are common OSDS. (Washington Department of Ecology, 1992)

Organophosphate: Pesticide chemical that contains phosphorus; used to control insects. Organophosphates are short-lived, but some can be toxic when first applied.

Postdevelopment peak runoff: Maximum instantaneous rate of flow during a storm, after development is complete (Washington Department of Ecology, 1992).

Retrofit: The creation or modification of an urban runoff management system in a previously developed area. This may include wet ponds, infiltration systems, wetland plantings, streambank stabilization, and other BMP techniques for improving water quality and creating aquatic habitat. A retrofit can consist of the construction of a new BMP in a developed area, the enhancement of an older urban runoff management structure, or a combination of improvement and new construction. (Schueler et al., 1992)

Soil absorption field: A subsurface area containing a trench or bed with clean stones and a system of distribution piping through which treated sewage may seep into the surrounding soil for further treatment and disposal.

Turbidity: A cloudy condition in water due to suspended silt or organic matter.

Urban runoff: That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, underflow, or channels or is piped into a defined surface water channel or a constructed infiltration facility (Washington Department of Ecology, 1992).

Vegetated buffer: Strips of vegetation separating a waterbody from a land use with potential to act as a nonpoint pollution source; vegetated buffers (or simply buffers) are variable in width and can range in function from a vegetated filter strip to a wetland or riparian area.

Watershed: The land area that drains into a receiving waterbody.

Wetlands: Areas that are inundated or saturated by surface or ground water at a frequency and duration to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions; wetlands generally include swamps, marshes, bogs, and similar areas. (This definition is consistent with the Federal definition at 40 CFR 230.3; December 24, 1989. As amendments are made to the wetland definition, they will be considered applicable to this guidance.)

Xeriscaping: A horticultural practice that combines water conservation techniques with landscaping; also known as dry landscaping (Clemson University Cooperative Extension Service, 1991).

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