CHAPTER 7: Management Measures for Wetlands, Riparian Areas, and Vegetated Treatment Systems

I. INTRODUCTION

A. What "Management Measures" Are

This chapter specifies management measures to protect and restore wetlands and riparian areas to protect coastal waters from coastal 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 and environmentally 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 contains management measures that address multiple categories of nonpoint source (NPS) pollution that affect coastal waters. The primary NPS pollutants addressed are sediment, nitrogen, phosphorus, and temperature. This chapter is divided into three management measures:

(1) Protection of Wetlands and Riparian Areas;
(2) Restoration of Wetlands and Riparian Areas; and
(3) Promoting the Use of Vegetated Treatment Systems, such as Constructed Wetlands and Vegetated Filter Strips.

Each category of management measure 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 of practices to achieve the measure.

CZARA requires EPA to specify management measures to control nonpoint pollution from various sources. Wetlands, riparian areas, and vegetated treatment systems have important potential for reducing nonpoint pollution in coastal waters from a variety of sources. Degradation of existing wetlands and riparian areas can cause the wetlands or riparian areas themselves to become sources of nonpoint pollution in coastal waters. Such degradation can result in the inability of existing wetlands and riparian areas to treat nonpoint pollution. Therefore, management measures are presented in this chapter specifying the control of nonpoint pollution through (1) protection of the full range of functions of wetlands and riparian areas to ensure continuing nonpoint source pollution abatement, (2) restoration of degraded systems, and (3) the use of vegetated treatment systems.

The intent of the three wetlands management measures is to ensure that the nonpoint benefits of protecting and restoring wetlands and riparian areas, and of constructing vegetated treatment systems, will be considered in all coastal watershed water pollution control activities. These management measures form an essential element of any State Coastal Nonpoint Pollution Control Program.

There is substantial evidence in the literature, and from case studies, that one important function of both natural and human-made wetlands is the removal of nonpoint source pollutants from storm water. Much of this literature is cited in this chapter. These pollutants include sediment, nitrogen, and phosphorus (Whigham et al., 1988; Cooper et al., 1987; Brinson et al., 1984). Also, wetlands and riparian areas have been shown to attenuate flows from higher-than-average storm events, thereby protecting receiving waters from peak flow hydraulic impacts such as channel scour, streambank erosion, and fluctuations in temperature and chemical characteristics of surface waters (Mitsch and Gosselink, 1986; Novitzki, 1979).

A degraded wetland has less ability to remove nonpoint source pollutants and to attenuate storm water peak flows (Richardson and Davis, 1987; Bedford and Preston, 1988). Also, a degraded wetland can deliver increased amounts of sediment, nutrients, and other pollutants to the adjoining waterbody, thereby acting as a source of nonpoint pollution instead of a treatment (Brinson, 1988).

Therefore, the first management measure is intended to protect the full range of functions for wetlands and riparian areas serving a nonpoint source abatement function. This protection will preserve their value as a nonpoint source control and help to ensure that they do not become a significant nonpoint source due to degradation.

The second management measure promotes the restoration of degraded wetlands and riparian systems with nonpoint source control potential for similar reasons: the increase in pollutant loadings that can result from degradation of wetlands and riparian areas, and the substantial evidence in the literature on effectiveness of wetlands and riparian areas for nonpoint pollution abatement. In addition, there may be other benefits of restoration to wildlife and aquatic organisms. This measure provides for evaluation of degraded wetlands and riparian systems, and for restoration if the systems will serve a nonpoint source pollution abatement function (e.g., by cost-effectively treating nonpoint source pollution or by attenuating peak flows).

The third management measure promotes the use of vegetated treatment systems because of their wide-scale ability to treat a variety of sources of nonpoint pollution. This measure will apply, as appropriate, to all other chapters in this guidance. Placing the large amount of information on vegetated treatment systems in one management measure avoids duplication in most other 6217(g) measures and thereby limits the potential for confusion. All descriptions, applications, case studies, and costs are in one measure within the CZARA 6217(g) guidance and are cross-referenced in the management measures for which these systems are a potential nonpoint pollution control. Also, all positive and negative aspects of design, construction, and operation have been included in one place to avoid confusion in applications due to potential inconsistencies from placement in multiple measures.

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 3 of this document contains a management measure and accompanying information on forestry practices in wetlands and protection of wetlands subject to forestry operations.

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

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

5. 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 following:

    - 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. Definitions and Background Information

The preceding five chapters of this guidance have specified management measures that represent the most effective systems of practices that are available to prevent or reduce coastal nonpoint source (NPS) pollution from five specific categories of sources. In this chapter, management measures that apply to a broad variety of sources, including the five categories of sources addressed in the preceding chapters, are specified. These measures promote the protection and restoration of wetlands and riparian areas and the use of vegetated treatment systems as means to control the nonpoint pollution emanating from such nonpoint sources. Management measures for protection and restoration of wetlands and riparian areas are developed as part of NPS and coastal management programs to take into consideration the multiple functions and values these ecosystems provide to ensure continuing nonpoint source pollution abatement.

1. Wetlands and Riparian Areas

For purposes of this guidance, *wetlands* are defined as:

> Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.[1]

Wetlands are usually waters of the United States and as such are afforded protection under the Clean Water Act (CWA). Although the focus of this chapter is on the function of wetlands in reducing NPS pollution, it is important to keep in mind that wetlands are ecological systems that perform a range of functions (e.g., hydrologic, water quality, or aquatic habitat), as well as a number of pollutant removal functions.

For purposes of this guidance, *riparian areas* are defined as:

> Vegetated ecosystems along a waterbody through which energy, materials, and water pass. Riparian areas characteristically have a high water table and are subject to periodic flooding and influence from the adjacent waterbody. These systems encompass wetlands, uplands, or some combination of these two land forms. They will not in all cases have all of the characteristics necessary for them to be classified as wetlands.[2]

Figure 7-1 illustrates the general relationship between wetlands, uplands, riparian areas, and a stream channel. Identifying the exact boundaries of wetlands or riparian areas is less critical than identifying ecological systems of concern. For instance, even those riparian areas falling outside wetland boundaries provide many of the same important water quality functions that wetlands provide. In many cases, the area of concern may include an upland buffer adjacent to sensitive wetlands or riparian areas that protects them from excessive NPS impacts or pretreats the inflowing surface waters.

Wetlands and riparian areas can play a critical role in reducing NPS pollution, by intercepting surface runoff, subsurface flow, and certain ground-water flows. Their role in water quality improvement includes processing, removing, transforming, and storing such pollutants as sediment, nitrogen, phosphorus, and certain heavy metals. Thus, wetlands and riparian areas buffer receiving waters from the effects of pollutants, or they prevent the entry of pollutants into receiving waters.

The functions of wetlands and riparian areas include water quality improvement, aquatic habitat, stream shading, flood attenuation, shoreline stabilization, and ground-water exchange. Wetlands and riparian areas typically occur as natural buffers between uplands and adjacent waterbodies. Loss of these systems allows for a more direct contribution of NPS pollutants to receiving waters. The pollutant removal functions associated with wetlands and riparian area vegetation and soils combine the physical process of filtering and the biological processes of nutrient uptake and denitrification (Lowrance et al., 1983; Peterjohn and Correll, 1984). Riparian forests, for example, have been found to contribute to the quality of aquatic habitat by providing cover, bank stability, and a source of organic

[1] This definition is consistent with the Federal definition at 40 CFR 230.3, promulgated December 24, 1980. As amendments are made to the wetland definition, they will be considered applicable to this guidance.

[2] This definition is adapted from the definitions offered previously by Mitsch and Gosselink (1986) and Lowrance et al. (1988).

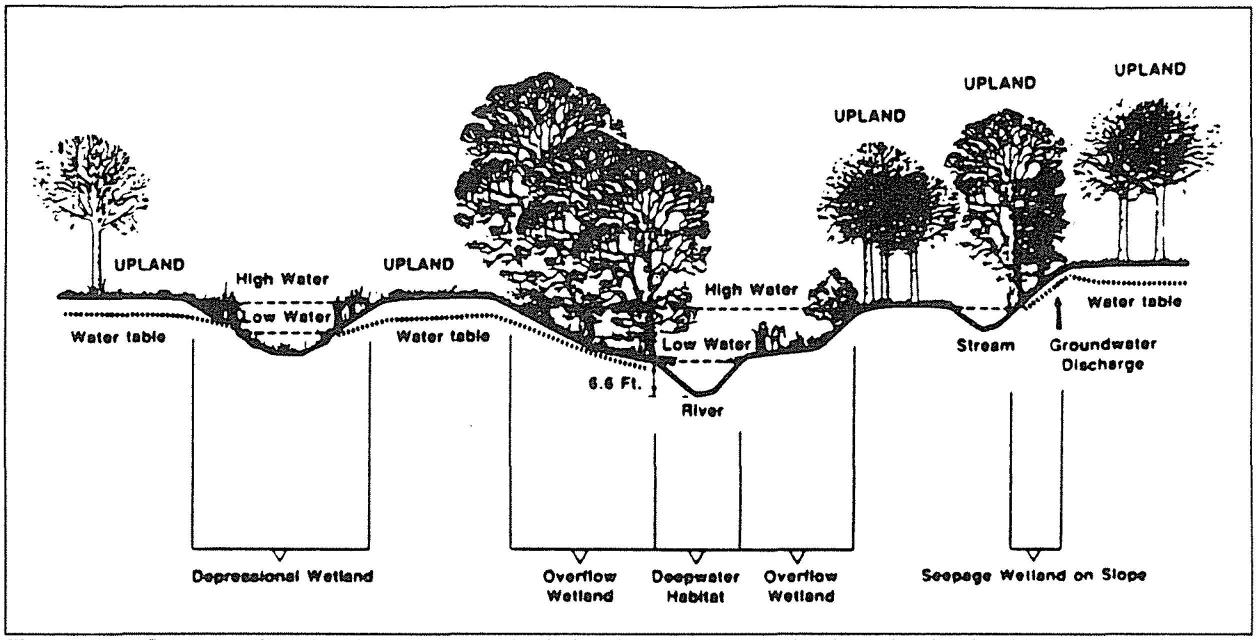

Figure 7-1. Cross section showing the general relationship between wetlands, uplands, riparian areas, and a stream channel (Burke et al., 1988).

carbon for microbial processes such as denitrification (James et al., 1990; Pinay and Decamps, 1988). Riparian forests have also been found to be effective at reducing instream pollution during flood flows (Karr and Gorman, 1975; Kleiss et al., 1989).

In highly developed urban areas, wetlands and riparian areas may be virtually destroyed by construction, filling, channelization, or other significant alteration. In agricultural areas, wetlands and riparian areas may be impacted by overuse of the area for grazing or by removal of native vegetation and replacement by annual crops or perennial cover. In addition, significant hydrologic alterations may have occurred to expedite drainage of farmland. Other significant impacts may occur as a result of various activities such as highway construction, surface mining, deposition of dredged material, and excavation of ports and marinas. All of these activities have the potential to degrade or destroy the water quality improvement functions of wetlands and riparian areas and may exacerbate NPS problems.

A wetland's position in the landscape affects its water quality functions. Some cases have been studied sufficiently to predict how an individual wetland will affect water quality on a landscape scale (Whigham et al., 1988). Wetlands that border first-order streams were found by Whigham and others (1988) to be efficient at removing nitrate from ground water and sediment from surface waters. They were not found to be as efficient in removing phosphorus. When located downstream from first-order streams, wetlands and riparian areas were found to be less effective at removing sediment and nutrient from the stream itself because of a smaller percentage of stream water coming into contact with the wetlands (Whigham et al., 1988). It has also been estimated that the portion of a wetland or riparian area immediately below the source of nonpoint pollution may be the most effective filter (Cooper et al., 1986; Lowrance et al., 1983; Phillips, 1989).

Although wetlands and riparian areas reduce NPS pollution, they do so within a definite range of operational conditions. When hydrologic changes or NPS pollutants exceed the natural assimilative capacity of these systems, wetland and riparian areas become stressed and may be degraded or destroyed. Therefore, wetlands and riparian areas should be protected from changes that would degrade their existing functions. Furthermore, degraded wetlands and riparian areas should be restored, where possible, to serve an NPS pollution abatement function.

2. Vegetated Buffers

For the purpose of this guidance, *vegetated buffers* are defined as:

> Strips of vegetation separating a waterbody from a land use that could 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.

This term is currently used in many contexts, and there is no agreement on any single concept of what constitutes a buffer, what activities are acceptable in a buffer zone, or what is an appropriate buffer width. In one usage, the term *vegetated buffer* refers to natural riparian areas that are either set aside or restored to filter pollutants from runoff and to maintain the ecological integrity of the waterbody and the land adjacent to it (Nieswand et al., 1989). In another usage, the term *vegetated buffer* refers to constructed strips of vegetation used in various settings to remove pollutants in runoff from a developed site (Nieswand et al., 1989). Finally, the term *vegetated buffer* can be used to describe a transition zone between an urbanized area and a naturally occurring riparian forest (Faber et al., 1989). In this context, buffers can be designed to provide value to wildlife as well as aesthetic value.

A vegetated buffer usually has a rough surface and typically contains a heterogeneous mix of ground cover, including herbaceous and woody species of vegetation (Stewardship Incentive Program, 1991; Swift, 1986). This mix of vegetation allows the buffer to function more like a wetland or riparian area. A vegetated filter strip (see below) can also be constructed to remove pollutants in runoff from a developed site, but a filter strip differs from a vegetated buffer in that a filter strip typically has a smooth surface and a vegetated cover made up of a homogeneous species of vegetation (Dillaha et al., 1989a).

Vegetated buffers can possess characteristics and functions ranging from those of a riparian area to those of a vegetated filter strip. To avoid confusion, the term *vegetated buffer* will not be discussed further in this chapter although the term is used in other chapters of this guidance.

3. Vegetated Treatment Systems

For purposes of this guidance, *vegetated treatment systems* (VTS) are defined to include either of the following or a combination of both: vegetated filter strips and constructed wetlands. Both of these systems have been defined in the scientific literature and have been studied individually to determine their effectiveness in NPS pollutant removal.

In this guidance, *vegetated filter strips* (VFS) are defined as (Dillaha et al., 1989a):

> Created areas of vegetation designed to remove sediment and other pollutants from surface water runoff by filtration, deposition, infiltration, adsorption, absorption, decomposition, and volatilization. A vegetated filter strip is an area that maintains soil aeration as opposed to a wetland that, at times, exhibits anaerobic soil conditions.

In this guidance, *constructed wetlands* are defined as (Hammer, 1992):

> Engineered systems designed to simulate natural wetlands to exploit the water purification functional value for human use and benefits. Constructed wetlands consist of former upland environments that have been modified to create poorly drained soils and wetlands flora and fauna for the primary purpose of contaminant or pollutant removal from wastewaters or runoff. Constructed wetlands are essentially wastewater treatment systems and are designed and operated as such though many systems do support other functional values.

In areas where naturally occurring wetlands or riparian areas do not exist, VTS can be designed and constructed to perform some of the same functions. When such engineered systems are installed for a specific NPS-related purpose, however, they may not offer the same range of functions that naturally occurring wetlands or riparian areas offer.

Vegetated treatment systems have been installed in a wide range of settings, including cropland, pastureland, forests, and developed, as well as developing, urban areas, where the systems can perform a complementary function of sediment control and surface water runoff management. Practices for use of vegetated treatment systems are discussed in other chapters of this guidance, and VTS should be considered to have wide-ranging applicability to various NPS categories.

When properly installed and maintained, VFS have been shown to effectively prevent the entry of sediment, sediment-bound pollutants, and nutrients into waterbodies. Vegetated filter strips reduce NPS pollutants primarily by filtering water passing over or through the strips. Properly designed and maintained vegetated filter strips can substantially reduce the delivery of sediment and some nutrients to coastal waters from nonpoint sources. With proper planning and maintenance, vegetated filter strips can be a beneficial part of a network of NPS pollution control measures for a particular site. Vegetated filter strips are often coupled with practices that reduce nutrient inputs, minimize soil erosion, or collect runoff. Where wildlife needs are factored into the design, vegetated filter strips or buffers in urban areas can add to the urban environment by providing wildlife nesting and feeding sites, in addition to serving as a pollution control measure. However, some vegetated filter strips require maintenance such as mowing of grass or removal of accumulated sediment. These and other maintenance activities may preclude much of their value for wildlife, for example by disturbing or destroying nesting sites.

Constructed wetlands are designed to mimic the pollutant-removal functions of natural wetlands but usually lack aquatic habitat functions and are not intended to provide species diversity. Pollutant removal in constructed wetlands is accomplished by several mechanisms, including sediment trapping, plant uptake, bacterial decomposition, and adsorption. Properly designed constructed wetlands filter and settle suspended solids. Wetland vegetation used in constructed wetlands converts some pollutants (i.e., nitrogen, phosphorus, and metals) into plant biomass (Watson et al., 1988). Nitrification, denitrification, and organic decomposition are bacterial processes that occur in constructed wetlands. Some pollutants, such as phosphorus and most metals, physically attach or adsorb to soil and sediment particles. Therefore, constructed wetlands, used as a management practice, could be an important component in managing NPS pollution from a variety of sources. They are not intended to replace or destroy natural wetland areas, but to remove NPS pollution before it enters a stream, natural wetland, or other waterbody.

It is important to note that aquatic plants and benthic organisms used in constructed wetlands serve primarily to remove pollutants. Constructed wetlands may or may not be designed to provide flood storage, ground-water exchange, or other functions associated with natural wetlands. In fact, if there is a significant potential for contamination or other detrimental impacts to wildlife, constructed wetlands should be designed to discourage use by wildlife.

II. MANAGEMENT MEASURES

A. Management Measure for Protection of Wetlands and Riparian Areas

Protect from adverse effects wetlands and riparian areas that are serving a significant NPS abatement function and maintain this function while protecting the other existing functions of these wetlands and riparian areas as measured by characteristics such as vegetative composition and cover, hydrology of surface water and ground water, geochemistry of the substrate, and species composition.

1. Applicability

This management measure is intended to be applied by States to protect wetlands and riparian areas from adverse NPS pollution impacts. 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 purpose of this management measure is to protect the existing water quality improvement functions of wetlands and riparian areas as a component of NPS programs. The overall approach is to establish a set of practices that maintains functions of wetlands and riparian areas and prevents adverse impacts to areas serving an NPS pollution abatement function. The ecosystem and water quality functions of wetlands and riparian areas serving an NPS pollution abatement function should be protected by a combination of programmatic and structural practices.

The term *NPS pollution abatement function* refers to the ability of a wetland or riparian area to remove NPS pollutants from runoff passing through the wetland or riparian area. Acting as a sink for phosphorus and converting nitrate to nitrogen gas through denitrification are two examples of the important NPS pollution abatement functions performed by wetlands and riparian areas.

This management measure provides for NPS pollution abatement through the protection of wetland and riparian functions. The permit program administered by the U.S. Army Corps of Engineers, EPA, and approved States under section 404 of the Clean Water Act regulates the discharge of dredged or fill material into waters of the United States, including wetlands. The measure and section 404 program complement each other, but the focus of the two is different.

The measure focuses on nonpoint source problems in wetlands, as well as on maintaining the functions of wetlands that are providing NPS pollution abatement. The nonpoint source problems addressed include impacts resulting from upland development and upstream channel modifications that erode wetlands, change salinity, kill existing vegetation, and upset sediment and nutrient balances. The section 404 program focuses on regulating the discharge of dredged or fill materials in wetlands, thereby protecting wetlands from physical destruction and other pollutant problems that could result from discharges of dredged or fill material.

The nonpoint source pollution abatement functions performed by wetlands and riparian areas are most effective as parts of an integrated land management system that combines nutrient, sediment, and soil erosion control. These areas consist of a complex organization of biotic and abiotic elements. Wetlands and riparian areas are effective in removing suspended solids, nutrients, and other contaminants from upland runoff, as well as maintaining stream channel temperature (Table 7-1). In addition, some studies suggest that wetland and riparian vegetation acts as a nutrient sink (Table 7-1), taking up and storing nutrients (Richardson, 1988). This function may be related to the age of the wetland or riparian area (Lowrance et al., 1983). The processes that occur in these areas include sedimentation, microbial and chemical decomposition, organic export, filtration, adsorption, complexation, chelation, biological assimilation, and nutrient release.

Pollutant-removal efficiencies for a specific wetland or riparian area may be the result of a number of different factors linked to the various removal processes:

(1) Frequency and duration of flooding;
(2) Types of soils and slope;
(3) Vegetation type;
(4) The nitrogen-carbon balance for denitrifying activity (nitrate removal); and
(5) The edge-to-area ratio of the wetland or riparian area.

Watershed-specific factors include land use practices and the percentage of watershed dominated by wetlands or riparian areas.

A study performed in the southeastern United States coastal plain illustrates dramatically the role that wetlands and riparian areas play in abating NPS pollutants. Lowrance and others (1983) examined the water quality role played by mixed hardwood forests along stream channels adjacent to agricultural lands. These streamside forests were shown to be effective in retaining nitrogen, phosphorus, calcium, and magnesium. It was projected that total conversion of the riparian forest to a mix of crops typically grown on uplands would result in a twenty-fold increase in nitrate-nitrogen loadings to the streams (Lowrance et al., 1983). This increase resulted from the introduction of nitrates to promote crop development and from the loss of nitrate removal functions previously performed by the riparian forest.

3. Management Measure Selection

Selection of this management measure was based on:

(1) The opportunity to gain multiple benefits, such as protecting wetland and riparian area systems, while reducing NPS pollution;

(2) The nonpoint pollution abatement function of wetlands and riparian areas, i.e., their effectiveness in reducing loadings of NPS pollutants, especially sediment, nitrogen, and phosphorus, and in maintaining stream temperatures; and

(3) The localized increase in NPS pollution loadings that can result from degradation of wetlands and riparian areas.

Separate sections below explain each of these points in more detail.

Table 7-1. Effectiveness of Wetlands and Riparian Areas for NPS Pollution Control

No.	Location	Wetland/ Riparian	Summary of Observations	Source
1	Tar River Basin, North Carolina	Riparian Forests	This study looks at how various soil types affect the buffer width necessary for effectiveness of riparian forests to reduce loadings of agricultural nonpoint source pollutants. • A hypothetical buffer with a width of 30 m and designed to remove 90% of the nitrate nitrogen from runoff volumes typical of 50 acres of row crop on relatively poorly drained soils was used as a standard. • Udic upland soils and sandy entisols met or exceeded these standards. • The study also concluded that slope gradient was the most important contributor to the variation in effectiveness.	Phillips, J.D. 1989. Nonpoint Source Pollution Control Effectiveness of Riparian Forests Along a Coastal Plain River. *Journal of Hydrology*, 110 (1989):221-237.
2	Lake Tahoe, Nevada	Riparian	Three years of research on a headwaters watershed has shown this area to be capable of removing over 99% of the incoming nitrate nitrogen. Wetlands and riparian areas in a watershed appear to be able to "clean up" nitrate-containing waters with a very high degree of efficiency and are of major value in providing natural pollution controls for sensitive waters.	Rhodes, J., C.M. Skau, D. Greenlee, and D. Brown. 1985. Quantification of Nitrate Uptake by Riparian Forests and Wetlands in an Undisturbed Headwaters Watershed. In *Riparian Ecosystems and Their Management: Reconciling Conflicting Issues*. USDA Forest Service GTR RM-120, pp. 175-179.
3	Atchafalaya, Louisiana	Riparian	Overflow areas in the Atchafalaya Basin had large areal net exports of total nitrogen (predominantly organic nitrogen) and dissolved organic carbon but acted as a sink for phosphorus. Ammonia levels increased dramatically during the summer. The Atchafalaya Basin floodway acted as a sink for total organic carbon mainly through particulate organic carbon (POC). Net export of dissolved organic carbon was very similar to that of POC for all three areas.	Lambou, V.W. 1985. Aquatic Organic Carbon and Nutrient Fluxes, Water Quality, and Aquatic Productivity in the Atchafalaya Basin, Louisiana. In *Riparian Ecosystems and Their Management: Reconciling Conflicting Issues*. USDA Forest Service GTR RM-120, pp. 180-185.

Table 7-1. (Continued)

No.	Location	Wetland/ Riparian	Summary of Observations	Source
4	Wyoming	Riparian	The Green River drains 12,000 mi^2 of western Wyoming and northern Utah and incorporates a diverse spectrum of geology, topography, soils, and climate. Land use is predominantly range and forest. A multiple regression model was used to associate various riparian and nonriparian basin attributes (geologic substrate, land use, channel slope, etc.) with previous measurements of phosphorus, nitrate, and dissolved solids.	Fannin,T.E., M. Parker, and T.J. Maret. 1985. Multiple Regression Analysis for Evaluating Non-point Source Contributions to Water Quality in the Green River, Wyoming. In *Riparian Ecosystems and Their Management: Reconciling Conflicting Issues.* USDA Forest Service GTR RM-120, pp. 201-205.
5	Rhode River Subwater-shed, Maryland	Riparian	A case study focusing on the hydrology and below-ground processing of nitrate and sulfate was conducted on a riparian forest wetland. Nitrate and sulfate entered the wetland from cropland ground-water drainage and from direct precipitation. Data collected for 3 years to construct monthly mass balances of the fluxes of nitrate and sulfate into and out of the soils of the wetland showed: • Averages of 86% of nitrate inputs were removed in the wetland. • Averages of 25% of sulfates were removed in the wetland. • Annual removal of nitrates varied from 87% in the first year to 84% in the second year. • Annual removal of sulfate varied from 13% in the second year to 43% in the third year. • On average, inputs of nitrate and sulfate were highest in the winter. • Nitrate outputs were always highest in the winter. • Nitrate removal was always highest in the fall (average of 96%) when input fluxes were lowest and lowest in winter (average of 81%) when input fluxes were highest.	Correll, D.L., and D.E. Weller. 1989. Factors Limiting Processes in Freshwater: An Agricultural Primary Stream Riparian Forest. In *Freshwater Wetlands and Wildlife,* ed. R.R. Sharitz and J.W. Gibbons, pp. 9-23. U.S. Department of Energy, Office of Science and Technology, Oak Ridge, Tennessee. DOE Symposium Series #61.

Table 7-1. (Continued)

No.	Location	Wetland/ Riparian	Summary of Observations	Source
6	Carmel River, California	Riparian	Ground water is closely coupled with streamflow to maintain water supply to riparian vegetation, particularly where precipitation is seasonal. A case study is presented where Mediterranean climate and ground-water extraction are linked with the decline of riparian vegetation and subsequent severe bank erosion on the Carmel River.	Groenveld, D. P., and E. Griepentrog. 1985. Interdependence of Groundwater, Riparian Vegetation, and Streambank Stability: A Case Study. In *Riparian Ecosystems and their Management: Reconciling Conflicting Issues.* USDA Forest Service GTR RM-120, pp. 201-205.
7	Cashe River, Arkansas	Riparian	A long-term study is being conducted to determine the chemical and hydrological functions of bottomland hardwood wetlands. Hydrologic gauging stations have been established at inflow and outflow points on the river, and over 25 chemical constituents have been measured. Preliminary results for the 1988 water year indicated: • Retention of total and inorganic suspended solids and nitrate; • Exportation of organic suspended solids, total and dissolved organic carbon, inorganic carbon, total phosphorus, soluble reactive phosphorus, ammonia, and total Kjeldahl nitrogen; • All measured constituents were exported during low water when there was limited contact between the river and the wetlands; and • All measured constituents were retained when the Cypress-Tupelo part of the floodplain was inundated.	Kleiss, B. et al. 1989. Modification of Riverine Water Quality by an Adjacent Bottomland Hardwood Wetland. In *Wetlands: Concerns and Successes*, pp. 429-438. American Water Resources Association.
8	Scotsman Valley, New Zealand	Riparian	Nitrate removal in riparian areas was determined using a mass balance procedure in a small New Zealand headwater stream. The results of 12 surveys showed: • The majority of nitrate removal occurred in riparian organic soils (56-100%) even though the soils occupied only 12% of the stream's border. • The disproportionate role of organic soils in removing nitrate was due in part to their location in the riparian zone. A high percentage (37-81%) of ground water flowed through these areas on its passage to the stream. • Anoxic conditions and high concentrations of denitrifying enzymes and available carbon in the soils also contributed to the role of the organic soils in removing nitrates.	Cooper, A.B. 1990. Nitrate Depletion in the Riparian Zone and Stream Channel of a Small Headwater Catchment. *Hydrobiologia*, 202:13-26.

Table 7-1. (Continued)

No.	Location	Wetland/ Riparian	Summary of Observations	Source
9	Wye Island, Maryland	Riparian	Changes in nitrate concentrations in ground water between an agricultural field planted in tall fescue (*Festuca arundinacea*) and riparian zones vegetated by leguminous or nonleguminous trees were measured to: • Determine the effectiveness of riparian vegetation management practices in the reduction of nitrate concentrations in ground water; • Identify effects of leguminous and nonleguminous trees on riparian attenuation of nitrates; and • Measure the seasonal variability of riparian vegetation's effect on the chemical composition of ground water. Based on the analysis of shallow ground-water samples, the following patterns were observed: • Ground-water nitrate concentrations beneath non-leguminous riparian trees decreased toward the shoreline, and removal of the trees resulted in increased nitrate concentrations. • Nitrate concentrations did not decrease from the field to the riparian zone in ground water below leguminous trees, and removal of the trees resulted in decreased ground-water nitrate concentrations. • Maximum attenuation of nitrate concentrations occurred in the fall and winter under non-leguminous trees.	James, B.R., B.B. Bagley, and P.H. Gallagher, P.H. 1990. Riparian Zone Vegetation Effects on Nitrate Concentrations in Shallow Groundwater. Submitted for publication in the *Proceedings of the 1990 Chesapeake Bay Research Conference.* University of Maryland, Soil Chemistry Laboratory, College Park, Maryland.
10	Little Lost Man Creek, Humboldt, California	Riparian	Nitrate retention was evaluated in a third-order stream under background conditions and during four intervals of modified nitrate concentration caused by nutrient amendments or storm-enhanced discharge. Measurements of the stream response to nitrate loading and storm discharge showed: • Under normal background conditions, nitrate was exported from the subsurface (11% greater than input). • With increased nitrate input, there was an initial 39% reduction from the subsurface followed by a steady state reduction of 14%. • During a storm event, the subsurface area exported an increase of 6%.	Triska, F.J., V.C. Kennedy, R.J. Avanzino, G.W. Zellweger, and K.E. Bencala. 1990. In Situ Retention-Transport Response to Nitrate Loading and Storm Discharge in a Third-Order Stream. *Journal of North American Benthological Society,* 9(3):229-239.

Table 7-1. (Continued)

No.	Location	Wetland/ Riparian	Summary of Observations	Source
11	Toronto, Ontario, Canada	Riparian	Field enrichments of nitrate in two spring-fed drainage lines showed an absence of nitrate depletion within the riparian zone of a woodland stream. The results of the study indicated: • The efficiency of nitrate removal within the riparian zone may be limited by short water residence times. • The characteristics of the substrate and the routes of ground-water movement are important in determining nitrate attenuation within riparian zones.	Warwick, J., and A.R. Hill. 1988. Nitrate Depletion in the Riparian Zone in a Small Woodland Stream. *Hydrobiologia*, 157:231-240.
12	Little River, Tifton, Georgia	Riparian	A study was conducted on riparian forests located adjacent to agricultural uplands to test their ability to intercept and utilize nutrients (N, P, K, Ca) transported from these uplands. Tissue nutrient concentrations, nutrient accretion rates, and production rates of woody plants on these sites were compared to control sites. Data from this study provide evidence that young (bloom state) riparian forests within agricultural ecosystems absorb nutrients lost from agricultural uplands.	Fail, J.L. Jr., Haines, B.L., and Todd, R.L. Undated. Riparian Forest Communities and Their Role in Nutrient Conservation in an Agricultural Watershed. *American Journal of Alternative Agriculture*, II(3):114-120.
13	Chowan River Watershed, North Carolina	Riparian	A study was conducted to determine the trapping efficiency for sediments deposited over a 20-year period in the riparian areas of two watersheds. ^{137}CS data and soil morphology were used to determine areal extent and thickness of the sediments. Results of the study showed: • Approximately 80% of the sediment measured was deposited in the floodplain swamp. • Greater than 50% of the sediment was deposited within the first 100 m adjacent to cultivated fields. • Sediment delivery estimates indicated that 84% to 90% of the sediment removed from cultivated fields remained in the riparian areas of a watershed.	Cooper, J.R., J.W. Gilliam, R.B. Daniels, and W.P. Robarge. 1987. Riparian Areas as Filters for Agriculture Sediment. *Soil Science Society of America Journal*, 51(6):417-420.
14	New Zealand	Riparian	Several recent studies in agricultural fields and forests showed evidence of significant nitrate removal from drainage water by riparian zones. The results of these studies showed: • A typical removal of nitrate of greater than 85% and • An increase of nitrate removal by denitrification where greater contact occurred between leaching nitrate and decaying vegetative matter.	Schipper, L.A., A.B. Cooper, and W.J. Dyck. 1989. Mitigating Non-point Source Nitrate Pollution by Riparian Zone Denitrification. Forest Research Institute, Rotorua, New Zealand.

Table 7-1. (Continued)

No.	Location	Wetland/ Riparian	Summary of Observations	Source
15	Georgia	Riparian	A streamside, mixed hardwood, riparian forest near Tifton, Georgia, set in an agricultural watershed was effective in retaining nitrogen (67%), phosphorus (25%), calcium (42%), and magnesium (22%). Nitrogen was removed from subsurface water by plant uptake and microbial processes. Riparian land use was also shown to affect the nutrient removal characteristics of the riparian area. Forested areas were more effective in nutrient removal than pasture areas, which were more effective than croplands.	Lowrance, R.R., R.L. Todd, and L.E. Asmussen. 1983. Waterborne Nutrient Budgets for the Riparian Zone of an Agricultural Watershed. *Agriculture, Ecosystems and Environment*, 10:371-384.
16	North Carolina	Riparian	Riparian forests are effective as sediment and nutrient (N and P) filters. The optimal width of a riparian forest for effective filtering is based on the contributing area, slope, and cultural practices on adjacent fields.	Cooper, J. R., J. W. Gilliam, and T. C. Jacobs. 1986. Riparian Areas as a Control of Nonpoint Pollutants. In *Watershed Research Perspectives*, ed. D. Correll, Smithsonian Institution Press, Washington, DC.
17	Unknown	Riparian	A riparian forest acted as an efficient sediment trap for most observed flow rates, but in extreme storm events suspended solids were exported from the riparian area.	Karr, J.R., and O.T. Gorman. 1975. Effects of Land Treatment on the Aquatic Environment. In *U.S. EPA Non-Point Source Pollution Seminar*, pp. 4-1 to 4-18. U.S. Environmental Protection Agency, Washington, DC. EPA 905/9-75-007.
18	Arkansas	Riparian	The Army Corps of Engineers studied a 20-mile stretch of the Cashe River in Arkansas where floodplain deposition reduced suspended solids by 50%, nitrates by 80%, and phosphates by 50%.	Stuart, G., and J. Greis. 1991. *Role of Riparian Forests in Water Quality on Agricultural Watersheds.*

Table 7-1. (Continued)

No.	Location	Wetland/ Riparian	Summary of Observations	Source
19	Maryland	Riparian	Phosphorus export from the forest was nearly evenly divided between surface runoff (59%) and ground-water flow (41%), for a total P removal of 80%. The mean annual concentration of dissolved total P changed little in surface runoff. Most of the concentration changes occurred during the first 19 m of the riparian forest for both dissolved and particulate pollutants. Dissolved nitrogen compounds in surface runoff also declined. Total reductions of 79% for nitrate, 73% for ammonium-N and 62% for organic N were observed. Changes in mean annual ground-water concentrations indicated that nitrate concentrations decreased significantly (90-98%) while ammonium-N concentrations increased in concentration greater than threefold. Again, most of the nitrate loss occurred within the first 19 m of the riparian forest. Thus it appears that the major pathway of nitrogen loss from the forest was in subsurface flow (75% of the total N), with a total removal efficiency of 89% total N.	Peterjohn, W.T., and D.L. Correll. 1984. Nutrient Dynamics in an Agricultural Watershed: Observations on the Role of a Riparian Forest. *Ecology,* 65:1466-1475.
20	France	Riparian	Denitrification explained the reduction of the nitrate load in ground water beneath the riparian area. Models used to explain the nitrogen dynamics in the riparian area of the Lounge River indicate that the frequency, intensity, and duration of flooding influence the nitrogen-removal capacity of the riparian area. Three management practices in riparian areas would enhance the nitrogen-removal characteristics, including: • River flow regulation to enhance flooding in riparian areas, which increases the waterlogged soil areas along the entire stretch of river; • Reduced land drainage to raise the water table, which increases the duration and area of waterlogged soils; and • Decreased deforestation of riparian forests, which maintains the amount of carbon (i.e., the energetic input that allows for microbial denitrification).	Pinay, G., and H. Decamps. 1988. The Role of Riparian Woods in Regulating Nitrogen Fluxes Between the Alluvial Aquifer and Aurface Water: A Conceptual Model. *Regulated Rivers: Research and Management,* 2:507-516.

Table 7-1. (Continued)

No.	Location	Wetland/ Riparian	Summary of Observations	Source
21	Georgia	Riparian	Processes within the riparian area apparently converted primarily inorganic N (76% nitrate, 6% ammonia, 18% organic N) into primarily organic N (10% nitrate, 14% ammonia, 76% organic N).	Lowrance, R.R., R.L. Todd, and L.E. Assmussen. 1984. Nutrient Cycling in an Agricultural Watershed: Phreatic Movement. *Journal of Environmental Quality*, 13(1):22-27.
22	North Carolina	Riaprian	Subsurface nitrate leaving agricultural fields was reduced by 93% on average.	Jacobs, T.C., and J.W. Gilliam. 1985. Riparian Losses of Nitrate from Agricultural Drainage Waters. *Journal of Environmental Quality*, 14(4):472-478.
23	North Carolina	Riparian	Over the last 20 years, a riparian forest provided a sink for about 50% of the phosphate washed from cropland.	Cooper, J.R., and J.W. Gilliam. 1987. Phosphorus Redistribution from Cultivated Fields into Riparian Areas. *Soil Science Society of America Journal*, 51(6):1600-1604.
24	Illinois	Riparian	Small streams on agriculture watersheds in Illinois had the greatest water temperature problems. The removal of shade increased water temperature 10-15 degrees Fahrenheit. Slight increases in water temperature over 60 °F caused a significant increase in phosphorus release from sediments.	Karr, J.R., and I.J. Schlosser. 1977. *Impact of Nearstream Vegetation and Stream Morphology on Water Quality and Stream Biota*. Ecological Research Series, EPA-600/3-77-097. U.S. Environmental Protection Agency, Washington, DC.

a. Multiple Benefits

The preservation and protection of wetlands and riparian areas are encouraged because these natural systems have been shown to provide many benefits, in addition to providing the potential for NPS pollution reduction (Table 7-2). The basis of protection involves minimizing impacts to wetlands and riparian areas serving to control NPS pollution by maintaining the existing functions of the wetlands and riparian areas, including vegetative composition and cover, flow characteristics of surface water and ground water, hydrology and geochemical characteristics of substrate, and species composition (Azous, 1991; Hammer, 1992; Mitsch and Gosselink, 1986; Reinelt and Horner, 1990; Richter et al., 1991; Stockdale, 1991).

Wetlands and riparian areas perform important functions such as providing a source of food for a variety of wildlife, a source of nesting material, habitat for aquatic animals, and nursery areas for fish and wildlife (Atcheson et al., 1979). Animals whose development histories include an aquatic phase—amphibians, some reptiles, and invertebrates—need wetlands to provide aquatic habitat (Mitsch and Gosselink, 1986). Other important functions of wetlands and riparian areas include floodwater storage, erosion control, and ground-water recharge. Protection of wetlands and riparian areas should allow for both NPS control and other corollary benefits of these natural aquatic systems.

b. Nonpoint Pollution Abatement Function

Table 7-1 is a representative listing of the types of research results that have been compiled to document the effectiveness of wetlands and riparian areas in serving an NPS pollution abatement function. Wetlands and riparian areas remove more than 50 percent of the suspended solids entering them (Karr and Gorman, 1975; Lowrance et al., 1984; Stuart and Greis, 1991). Sixty to seventy-five percent of total nitrogen loads are typically removed from surface and ground waters by wetlands and riparian areas (Cooper, 1990; Jacobs and Gilliam, 1985; James et al., 1990; Lowrance et al., 1983; Lowrance et al., 1984; Peterjohn and Correll, 1984; Pinay and Decamps, 1988; Stuart and Greis, 1991). Phosphorus removal in wetlands and riparian areas ranges from 50 percent to 80 percent (Cooper and Gilliam, 1987; Peterjohn and Correll, 1984; Stuart and Greis, 1991).

c. Degradation Increases Pollution

Tidal wetlands perform many water quality functions; when severely degraded, however, they can be a source of nonpoint pollution (Richardson, 1988). For example, the drainage of tidal wetlands underlain by a layer of organic peat can cause the soil to rapidly decompose and release sulfuric acid, which may significantly reduce pH in surrounding waters. Removal of wetland or riparian area vegetation along the shorelines of streams, bays, or estuaries makes these areas more vulnerable to erosion from storm events, wave action, or concentrated runoff. Activities such as channelization, which modify the hydrology of floodplain wetlands, can alter the ability of these areas to retain sediment when they are flooded and result instead in erosion and a net export of sediment from the wetland (Reinelt and Horner, 1990).

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 7-2. Range of Functions of Wetlands and Riparian Areas (adapted from National Research Council, 1991)

Function	Example
Flood conveyance	Riverine wetlands and adjacent floodplain lands often form natural floodways that convey floodwaters from upstream to downstream areas.
Protection from storm waves and erosion	Coastal wetlands and inland wetlands adjoining larger lakes and rivers reduce the impact of storm tides and waves before they reach upland areas.
Flood storage	Inland wetlands may store water during floods and slowly release it to downstream areas, lowering flood peaks.
Sediment control	Wetlands reduce flood flows and the velocity of floodwaters, reducing erosion and causing floodwaters to release sediment.
Habitat for fish and shellfish	Wetlands are important spawning and nursery areas and provide sources of nutrients for commercial and recreational fin and shellfish industries, particularly in coastal areas.
Habitat for waterfowl and other wildlife	Both coastal and inland wetlands provide essential breeding, nesting, feeding, and refuge sites for many forms of waterfowl, other birds, mammals, and reptiles.
Habitat for rare and endangered species	Almost 35 percent of all rare and endangered animal species either are located in wetland areas or are dependent on them, although wetlands constitute only about 5 percent of the coterminous United States.
Recreation	Wetlands serve as recreation sites for fishing, hunting, and observing wildlife.
Source of water supply	Wetlands are important in replacing and maintaining supplies of ground water and surface water.
Natural products	Under proper management, forested wetlands are an important source of timber, despite the physical problems of timber removal. Under selected circumstances, natural products such as timber and furs can be harvested from wetlands.
Preservation of historic, archaeological values	Some wetlands are of archaeological interest. Native American settlements were sometimes located in coastal and inland wetlands, which served as sources of fish and shellfish.
Education and research	Tidal, coastal, and inland wetlands provide educational opportunities for nature observation and scientific study.
Source of open space and contribution to aesthetic values	Both tidal and inland wetlands are areas of great diversity and beauty, and they provide open space for recreational and visual enjoyment.

a. Consider wetlands and riparian areas and their NPS control potential on a watershed or landscape scale.

Wetlands and riparian areas should be considered as part of a continuum of filters along rivers, streams, and coastal waters that together serve an important NPS abatement function. Examples of the practice were outlined by Whigham and others (1988). They found that a landscape approach can be used to make reasonable decisions about how any particular wetland might affect water quality parameters. Wetlands in the upper parts of the drainage systems in particular have a greater impact on water quality. Hanson and others (1990) used a model to determine the effect of riparian forest fragmentation on forest dynamics. They concluded that increased fragmentation would lead to lower species diversity and an increased prevalence of species that are adapted to isolated conditions. Naiman and others (1988) discussed the importance of wetlands and riparian areas as boundary ecosystems, providing a boundary between terrestrial and aquatic ecosystems. Wetlands and riparian areas are particularly sensitive to landscape changes and fragmentation. Wetland and riparian boundaries covering large areas may persist longer than those on smaller spatial scales and probably have different functional values (Mitsch, 1992).

Several States have outlined the role of wetlands and riparian areas in case studies of basinwide and statewide water quality plans. A basinwide plan for the restoration of the Anacostia River and associated tributaries considered in detail the impacts of wetlands creation and riparian plantings (USACE, 1990). In Louisiana and Washington State, EPA has conducted studies that use the synoptic approach to consider wetlands' water quality function on a landscape scale (Abbruzzese et al., 1990a, 1990b). The synoptic approach considers the environmental effects of cumulative wetlands losses. In addition, this approach involves assembling a framework that ranks watersheds according to the relative importance of wetland functions and losses. States are also encouraged to refine their water quality standards applicable to wetlands by assigning wetlands-specific designated uses to classes of wetlands.

b. Identify existing functions of those wetlands and riparian areas with significant NPS control potential when implementing NPS management practices. Do not alter wetlands or riparian areas to improve their water quality function at the expense of their other functions.

In general, the following practices should be avoided: (1) location of surface water runoff ponds or sediment retention basins in healthy wetland systems and (2) extensive dredging and plant harvesting as part of nutrient or metals management in natural wetlands. Some harvesting may be necessary to control the invasion of exotic plants. Extensive harvesting for surface water runoff or nutrient management, however, can be very disruptive to the existing plant and animal communities.

c. Conduct permitting, licensing, certification, and nonregulatory NPS pollution abatement activities in a manner that protects wetland functions.

There are many possible programs, both regulatory and nonregulatory, to protect wetland functions. Table 7-3 contains a representative listing of Federal, State, and Federal/State programs whose primary goals involve the identification, technical study, or management of wetlands protection efforts. Table 7-4 provides a list of Federal programs involved in the protection and restoration of wetlands and riparian areas on private lands. Federal programs with cost-share funds are designated as such in Table 7-4. The list of possible programmatic approaches to wetlands protection includes the following:

Acquisition. Obtain easements or full acquisition rights for wetlands and riparian areas along streams, bays, and estuaries. Numerous Federal programs, such as the U.S. Department of Agriculture (USDA) Wetlands Reserve, administered by USDA's Agricultural Stabilization and Conservation Service (USDA-ASCS) with technical assistance provided by USDA's Soil Conservation Service (USDA-SCS) and U.S. Department of the Interior - Fish and Wildlife Service (USDOI-FWS), and the Fish and Wildlife Service North American Waterfowl Management Plan can provide assistance for acquiring easements or full title. Acquisition of water rights to ensure maintenance of minimum instream flows is another means to protect riparian/wetland areas, and it can be a critical issue in the arid West. In Arizona, The Nature Conservancy has acquired an instream water rights certificate for its Ramsey Canyon preserve

Table 7-3. Federal, State, and Federal/State Programs for Wetlands Identification, Technical Study, or Management of Wetlands Protection Efforts

No.	Location	Type of Wetland	Summary of Observations	Source
1	New Mexico	Riparian/ Wetland	This Bureau of Land Management (BLM) document identifies planning strategies and needs for future planning for riparian-wetland area resource management in New Mexico.	USDOI, BLM, New Mexico State Office. 1990. *New Mexico Riparian-Wetland 2000: A Management Strategy.* U.S. Department of the Interior, Bureau of Land Management.
2	Washington and Oregon	Riparian	Riparian areas on BLM lands in OR and WA are managed by a combination of land-use allocations and management practices designed to protect and restore their natural functions. The riparian-stream ecosystem is managed as one unit, designated as a Riparian Management Area (RMA). Riparian areas are classified by stream order. Timber harvesting is generally restricted from those riparian areas with the highest nontimber resource values. Mitigation measures are also used to reduce impacts from timber harvesting in riparian areas with minor nontimber values.	Oakely, A.L. 1988. Riparian Management Practices of the Bureau of Land Management. In *Streamside Management: Riparian Wildlife and Forestry Interactions*, pp. 191-196.
3	Pacific Northwest	Riparian	The Bureau of Indian Affairs has no formal riparian management policy because BIA management must be done in cooperation with the tribe. This situation creates tremendous variation in Indian lands management because the individual management plans must be tailored to the needs of the individual tribe.	Bradley, W.P. 1988. Riparian Management Practices on Indian Lands. In *Streamside Management: Riparian Wildlife and Forestry Interactions*, pp. 201-206.
4	Washington	Riparian	This article discusses the riparian management policies of the Washington State Dept. of Natural Resources, including design and concems of Riparian Management Zones.	Calhoun, J.M. 1988. Riparian Management Practices of the Department of Natural Resources. In *Streamside Management: Riparian Wildlife and Forestry Interactions*, pp. 207-211.
5		Riparian	The Tennessee Valley Authority, since its inception, has promoted the protection and management of the riparian resources of the Tennessee River drainage basin. Current policies, practices, and major programs providing for protection of the riparian environment are described.	Allen, R.T., and R.J. Field. 1985. Riparian Zone Protection by TVA: An Overview of Policies and Programs. In *Riparian Ecosystems and Their Management: Reconciling Conflicting Issues.* USDA Forest Service GTR RM-120, pp. 23-26.

Table 7-3. (Continued)

No.	Location	Type of Wetland	Summary of Observations	Source
6		Riparian	Riparian zones play a major role in water quality management. Water supply considerations and maintenance of streamside zones from the municipal watershed manager's viewpoint are detailed. Management impacts affecting water quality and quantity on forested municipal watersheds are discussed in relation to the structure of the riparian zone. The impacts of management are often integrated in the channel area and in the quality of streamflow. Learning to read early signs of stress here will aid in evaluating how much "management" a watershed can take.	Corbet, E.S., and J.A. Lynch. 1985. Management of Streamside Zones on Municipal Watersheds. In *Riparian Ecosystems and Their Management: Reconciling Conflicting Issues.* USDA Forest Service GTR RM-120, pp. 187-190.
7		Riparian	Construction of small dams, suppression of woody vegetation in riparian zones, and removal of livestock from streamsides have all led to summer streamflow increase. Potential may exist to manage small valley bottoms for summer flow increase while maintaining or improving habitat, range, and watershed values.	Stabler, D.F. 1985. Increasing Summer Flow in Small Streams Through Management of Riparian Areas and Adjacent Vegetation: A Synthesis. In *Riparian Ecosystems and Their Management: Reconciling Conflicting Issues.* USDA Forest Service GTR RM-120, pp. 206-210.
8	Queen Creek, Arizona	Riparian	The interrelationships between riparian vegetation development and hydrologic regimes in an ephemeral desert stream were examined at Whitlow Ranch Dam along Queen Creek in Pinal County, Arizona. The data indicate that a flood control structure can have a positive impact on riparian ecosystem development and could be used as a mitigation tool to restore this critically threatened habitat. Only 7 years after dam completion, aerial photos documented a dramatic change in the vegetation. The riparian vegetation consisted of a vigorously expanding Sonoran deciduous forest of Gooding willow and saltcedar occupying an area of approximately 17.7 ha.	Szaro, R.C., and L.F. DeBano. 1985. The Effects of Streamflow Modification on the Development of a Riparian Ecosystem. In *Riparian Ecosystems and Their Management: Reconciling Conflicting Issues.* USDA Forest Service GTR RM-120, pp. 211-215.

Table 7-3. (Continued)

No.	Location	Type of Wetland	Summary of Observations	Source
9	Southwest	Riparian	Native American and Spanish American farmers of the arid Southwest have managed riparian vegetation adjacent to their agricultural fields for centuries. They have planted, pruned, and encouraged phreatophytic tree species for flood erosion control, soil fertility renewal, buffered field microclimate, and fuel-wood production. These practices benefit wildlife and plant genetic diversity. The benefits and stability of native riparian vegetative mosaics are difficult to assess in monetary or energetic terms, but are nonetheless significant.	Nabhan, G.P. 1985. Riparian Vegetation and Indigenous Southwestern Agriculture: Control of Erosion, Pests, and Microclimate. In *Riparian Ecosystems and Their Management: Reconciling Conflicting Issues.* USDA Forest Service GTR RM-120, pp. 232-236.
10		Riparian	Many management goals can be developed for riparian habitats. Each goal may dictate different management policies and tactics and result in different impacts on wildlife. Vegetation structure of riparian areas, expressed in terms of habitat layers, can provide a useful framework for developing effective strategies for a variety of management goals because many different land uses can be associated with habitat layers. Well-developed goals are essential both for purposeful habitat management and for monitoring the impacts of different land uses on habitats.	Short, H.L. 1985. Management Goals and Habitat Structure. In *Riparian Ecosystems and Their Management: Reconciling Conflicting Issues.* USDA Forest Service GTR RM-120, pp. 232-236.
11	Maine	Riparian	Riparian zones serve important functions for fisheries and aquatic systems: shading, bank stability, prevention of excess sedimentation, overhanging cover for fish, and energy input from invertebrates and allochtonous material. Impacts from loss of riparian areas are discussed in relation to aquatic ecosystems, and the results of two recent studies in Maine are reviewed. Intact riparian zones have inherent values to aquatic systems and though 23-m intact riparian strips are often recommended for stream protection, wildlife biologists are often recommending wider zones because of their value as animal corridors and winter deer yards.	Moring, J.R., G.C. Carman, and D.M. Mullen. 1985. The Value of Riparian Zones for Protecting Aquatic Systems: General Concerns and Recent Studies in Maine. In *Riparian Ecosystems and Their Management: Reconciling Conflicting Issues.* USDA Forest Service GTR RM-120, pp. 315-319.

Table 7-3. (Continued)

No.	Location	Type of Wetland	Summary of Observations	Source
12	Siskiyou National Forest	Riparian	The Siskiyou National Forest in Oregon has managed riparian areas along the Pacific coast where high-value conifers stand near streams bearing salmonid fisheries. Riparian areas are managed by setting objectives that allow for limited timber harvest along with stream protection. The annual sale quantity from the forest is reduced by 13% to protect riparian areas and the fishery resource. Typically, timber harvest will remove 40-50% of the standing timber volume within nonfish-bearing riparian areas and 0-10% along streams that support fish.	Anderson, M.T. 1985. Riparian Management of Coastal Pacific Ecosystems. In *Riparian Ecosystems and Their Management: Reconciling Conflicting Issues*. USDA Forest Service GTR RM-120, pp. 364-368.
13	California	Riparian	A riparian reserve has been established on the UC Davis campus. The 80-acre Putah Cr. Reserve offers the opportunity to research issues related to the typically leveed floodways that flow through California's agricultural landscape. With over 90% of the original riparian systems of California completely eliminated, the remaining "altered "systems represent environmental corridors of significant value to conservation. The key to improving the habitat value of these systems is researching floodway management alternatives that use an integrated approach.	Dawson, K.J., and G.E. Sutter. 1985. Research Issues in Riparian Landscape Planning. In *Riparian Ecosystems and Their Management: Reconciling Conflicting Issues*. USDA Forest Service GTR RM-120, pp. 408-412.
14	Pacific Northwest	Riparian	Since 1970 the National Forests in Oregon and Washington have been operating under a Regionally developed streamside management unit (SMU) concept, which is essentially a stream classification system based on the use made of the water with specific water quality objectives established for each of the four classes of streams. Inherent in the concept is the underlying premise that the land immediately adjacent to streams is key to protecting water quality. This land can be managed to protect the riparian values and in most cases still achieve a reasonable return of other resource values.	Swank, G.W. 1985. Streamside Management Units in the Pacific Northwest. In *Riparian Ecosystems and Their Management: Reconciling Conflicting Issues*. USDA Forest Service GTR RM-120, pp. 435-438.
15	Pacific Northwest	Riparian	The USDA Forest Service's concepts of multiple-use and riparian-area-dependent resources were incorporated into a district-level riparian area management policy. Identifying the degree of dependence on forest resource values and uses on specific characteristics of the riparian area is a key to determining which resources are to be emphasized during management. The linkage of riparian areas to the aquatic resource and cumulative processes is integrated into the policy designed to provide consistent direction for on-the-ground management.	Vanderhayden, J. 1985. Managing Multiple Resources in Western Cascades Forest Riparian Areas: An Example. In *Riparian Ecosystems and Their Management: Reconciling Conflicting Issues*. USDA Forest Service GTR RM-120, pp. 448-452.

Table 7-4. Federal Programs Involved in the Protection and Restoration of Wetlands and Riparian Areas on Private Lands

Agency	Type of Program	Cost Share Program	Activities and Funding
U.S. Department of the Army - Army Corps of Engineers	Dredged and fill permit program	No	• Regulates the discharge of dredged or fill material into waters of the United States, including wetlands.
U.S. Dept. of the Interior - Fish and Wildlife Service	Private Lands Program	No	• Provides funding to aid in the restoration of wetland functions. • Many efforts are targeted at restoring wetlands that offer important habitat for migratory birds and other Federal Trust species.
USDOI - FWS	North American Waterfowl Management Plan	No	• The plan includes the restoration and enhancement of several million acres of wetlands for migratory birds in Canada, Mexico, and the United States. • The NAWMP is being implemented through innovative Federal-State-private partnerships within and between States and Provinces. • Currently, a grants program exists for acquisition, restoration, enhancement, creation, management, and other activities that conserve wetlands and fish and wildlife that depend upon such habitats. Research, planning, payment of interest, conservation education programs, and construction of buildings are activities that are ineligible for funds under this program.
USDOI-FWS	Coastal Wetlands Conservation Grants Program	Yes	• Provides 50% matching grants to coastal States for acquisition, restoration, and enhancement of coastal wetlands. • States with established trust funds for acquiring coastal wetlands, other natural areas, or open spaces are eligible for 75% matching grants.
USDOI - Office of Surface Mining	Experimental practices programs	No	• Although the agency does not have a cost share program for wetlands restoration, it does assist coal companies in developing experimental practices that will provide environmental protection. • The agency also pays States for the reclamation of lands previously left by coal companies.
U.S. Dept. of Agriculture Cooperative Extension Service		No	• The national office encourages each State extension service to assist private landowners in the management and restoration of wetlands. Most State extension services provide information and technical assistance to landowners.

Table 7-4. (Continued)

Agency	Type of Program	Cost Share Program	Activities and Funding
USDA - Agricultural Stabilization and Conservation Service	Conservation Reserve Program	Yes	• More than 5,000 ha of wetlands have been restored under the CRP. • 380,000 ha of cropped wetlands and associated uplands have been reestablished in natural vegetation under 10-year contracts of up to $50,000 per person per year. • The Secretary of Agriculture shares 50% of the total cost of establishing vegetative cover and 50% of the cost to maintain hardwood trees, shelterbelts, windbreaks, or wildlife corridors for a 2- to 4-year period.
USDA - ASCS	The Water Bank Program	Yes	• Objectives of the program are to preserve, restore, and improve the wetlands of the Nation. • The WBP applies to wetlands on designated farms identified by conservation plans developed in cooperation with Soil and Water Conservation Districts. • Protecting 190,000 ha of natural wetlands and adjacent buffer areas under 10-year rental agreements. Annual payments for 1991 ranged from $7 to $66 per acre. • The agency will cost-share up to 75% of the cost for cover for adjacent land only. These payments may be made to cover the costs of installing conservation practices developed to accomplish one of the following: establish or maintain vegetative cover; control erosion; establish or maintain shallow-water areas and improve habitat; conserve surface water and contribute to flood control and improve subsurface moisture; or provide bottomland hardwood management. • States participating in the 1992 Water Bank Program are Arkansas, California, Louisiana, Minnesota, Mississippi, Montana, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin.
USDA - ASCS	Wetland Reserve Program	Yes	• The WRP is expected to restore and protect up to 400,000 ha of wetlands in cropland on farms and ranches through easements. California, Iowa, Louisiana, Minnesota, Mississippi, Missouri, New York, North Carolina, and Wisconsin are currently the only States participating in the program although participation by all States is expected by 1993. • The program currently accepts only permanent easements and provides a 75% cost share for such. If in the future less-than-permanent easements are accepted, a 50% cost share would probably be provided.

Table 7-4. (Continued)

Agency	Type of Program	Cost Share Program	Activities and Funding
USDA - ASCS	Agricultural Conservation Program	Yes	• The ASCS will cost-share with farmers up to 75% of the cost of practices that help control NPS pollution. • Cost share has been provided for the restoration of 225,000 ha of wetlands over the last 30 years for the "Creation of Shallow Water Areas" practice. • Eligible cost share practices include establishment or improvement of permanent vegetative cover; installation of erosion control measures; planting of shrubs and trees for erosion control; and development of new or rehabilitation of existing shallow-water areas to support food, habitat, and cover for wildlife.
USDA - Soil Conservation Service			• The SCS provides technical assistance to private landowners for wetland restoration.

in the Huachuca Mountains. The certificate gives the Arizona Nature Conservancy the legal right to maintain instream flows in the stretch of Ramsey Creek along their property, which in turn preserves instream and riparian habitat and wildlife (Andy Laorenzi, personal communication, 5 October 1992). in turn preserves instream and riparian habitat and wildlife (Andy Laurenzi, personal communication, 5 October 1992).

Zoning and Protective Ordinances. Control activities with a negative impact on these targeted areas through special area zoning and transferable development rights. Identify impediments to wetland protection such as excessive street standards and setback requirements that limit site-planning options and sometimes force development into marginal wetland areas.

Baltimore County, Maryland, has adopted legislation to protect the water quality of streams, wetlands, and floodplains that requires forest buffers for any activity that is causing or contributing to pollution, including NPS pollution, of the waters of the State. Baltimore County has also developed management requirements for the forest buffers, including those located in wetlands and floodplains, that specify limitations on alteration of the natural conditions of these resources. The provisions call for public and private improvements to the forest buffer to abate and prevent water pollution, erosion, and sedimentation of stream channels and degradation of aquatic and riparian habitat.

Water Quality Standards. Almost all wetlands are *waters of the United States*, as defined in the Clean Water Act. Ensure that State water quality standards apply to wetlands. Consider natural water quality functions when specifying designated uses for wetlands, and include biological and hydrologic narrative criteria to protect the full range of wetland functions.

The State of Wisconsin has adopted specific wetlands water quality standards designed to protect the sediment and nutrient filtration or storage function of wetlands. The standards prohibit addition of those substances that would "otherwise adversely impact the quality of other waters of the State" beyond natural conditions of the affected wetland. In addition, the State has adopted criteria protecting the hydrologic conditions in wetlands to prevent significant adverse impacts on water currents, erosion or sedimentation patterns, and the chemical and nutrient regimes of the wetland. Wisconsin has also adopted a sequenced decision-making process for projects potentially affecting wetlands that considers the wetland dependency of a project; practicable alternatives; and the direct, indirect, and cumulative impacts of the project.

Regulation and Enforcement. Establish, maintain, and strengthen regulatory and enforcement programs. Where allowed by law, include conditions in permits and licenses under CWA §401, §402, and §404; State regulations; or other regulations to protect wetlands.

Restoration. Programs such as USDA's Conservation Reserve and Wetlands Reserve Program provide opportunities to set aside and restore wetlands and riparian areas. Also, incentives that encourage private restoration of fish and wildlife productivity are more cost-effective than Federal acquisition and can in turn reduce property tax receipts by local government.

Education and Training. Educate farmers, urban dwellers, and Federal agencies on the role of wetlands and riparian areas in protecting water quality and on best management practices (BMPs) for restoring stream edges. Teach courses in simple restoration techniques for landowners.

Comprehensive Watershed Planning. Provide a mechanism for private landowners and agencies in mixed-ownership watersheds to develop, by consensus, goals, management plans, and appropriate practices and to obtain assistance from Federal and State agencies. Establish a framework for multiagency program linkage, and present opportunities to link implementation efforts aimed at protection or restoration of wetlands and riparian areas. EPA's National Estuary Program and the Fish and Wildlife Service's Bay/Estuary Program are excellent examples of this multiagency approach. A number of State and Federal agencies carry out programs with compatible NPS pollution reduction goals in the coastal zone. For example, Maryland's Nontidal Wetlands Protection Act encourages development of comprehensive watershed plans for addressing wetlands protection, mitigation, and restoration issues in conjunction with water supply issues. In addition, the U.S. Army Corps of Engineers (USACE) administers the CWA §404 program; USDA implements the Swampbuster, Conservation Reserve, and Wetlands Reserve Programs; EPA, USACE, and States work together to perform advanced identification of wetlands for special consideration (§404); and States administer both the Coastal Zone Management (CZM) program, which provides opportunity for consistency determinations, and the CWA §401 certification program, which allows for consideration of wetland protection and water quality objectives.

As an example of a linkage to protect NPS pollutant abatement and other benefits of wetlands, a State could determine under CWA §401 a proposed discharge or other activity in a wetland that is inconsistent with State water quality standards. Or, if a proposed permit is allowed contingent upon mitigation by creation of wetlands, such mitigation might be targeted in areas defined in the watershed assessment as needing restoration. Watershed- or site-specific permit conditions may be appropriate (e.g., specific widths for streamside management areas or structures based on adjacent land use activities). Similarly, USDA's Conservation Reserve Program or Wetlands Reserve Program could provide landowner assistance in areas identified by the NPS program as needing particular protection or riparian area reestablishment.

d. Use appropriate pretreatment practices such as vegetated treatment systems or detention or retention basins (Chapter 4) to prevent adverse impacts to wetland functions that affect NPS pollution abatement from hydrologic changes, sedimentation, or contaminants.

For more information on the technical implementation and effectiveness of this practice, refer to Management Measure C in this chapter and Sections II.A and III.A of Chapter 4.

5. Costs for All Practices

This section describes costs for representative activities that would be undertaken in support of one or more of the practices listed under this management measure. The description of costs is grouped into the following categories:

(1) For implementation of practice "a": costs for mapping, which aids in locating wetlands and riparian areas in the landscape and determining their relationship to land uses and their potential for NPS pollution abatement.

(2) For implementation of practices "b" and "c": costs for wetland and riparian area protection programs.

(3) For implementation of practice "d": costs for pretreatment such as filter strips, constructed wetlands, and detention or retention basins.

a. Mapping

The identification of wetlands within the watershed landscape, and their NPS pollution abatement potential, involves using maps to determine the characteristics as described in the management measure. These may include vegetation type and extent, soil type, distribution of fully submerged and partially submerged areas within the wetland boundary, and location of the boundary between wetlands and uplands. These types of features can be mapped through a variety of methods.

Lower levels of effort would characteristically involve the acquisition and field-checking of existing maps, such as those available for purchase from the U.S. Fish and Wildlife Service in the National Wetlands Inventory and U.S. Geological Survey (USGS) land use maps (information on these maps is available by calling 1-800-USA-MAPS). An intermediate level of effort would involve the collection and analysis of remote-sensing data, such as aerial photographs or digital satellite imagery. Depending on the size of the study area and the extent of the data to be categorized, the results of photo interpretation or of digital image analysis can be manipulated manually with a computerized database or electronically with a Geographic Information System. The most costly and labor-intensive approach involves plane-table surveys of the areas to be investigated.

Three separate costs are reported below from actual examples of recent projects involving wetland identification and assessment for purposes similar to the goal of the management measure. The examples represent different levels of effort that could be undertaken in support of practice "a" under the management measure.

(1) A project in Clarks Fork, Montana, used remote sensing data for identification of wetlands that were potentially impaired from NPS pollution originating in adjacent portions of the watershed. In addition to identifying the type and extent of wetlands and riparian vegetation along Clarks Fork and the tributary streams, the mapping effort categorized land use in adjoining portions of the landscape. The results were used to identify areas within the watershed that could possibly be contributing NPS pollution in runoff to the wetlands and riparian areas (Lee, 1991).

Total costs for this project were estimated at $0.06 per acre. The items of work include project management, collection of aerial photographs, film processing, and photo interpretation (Lee, 1991).

(2) Remote sensing data have also been used as part of a statewide assessment of wetlands in Wisconsin. The purpose of the project is to determine areas within the landscape where changes are occurring in wetlands. Three or four counties are evaluated each year. The results are used to provide an ongoing update of changes to wetlands characteristics such as hydrology and vegetation (Lee, 1991).

Total costs for this project are approximately $0.07 per acre. The items of work include collection of aerial photography, film processing, photo interpretation, and development and maintenance of a Geographic Information System (Lee, 1991).

(3) The National Wetlands Inventory (NWI) has maps for 74 percent of the conterminous United States, 24 percent of Alaska, and all of Hawaii. Wetlands maps have been updated for wetlands assessment in three areas of the southeastern United States. The purpose of the project is to provide current data on the distribution of wetlands for project reviews, site characterizations, and ecological assessment (Kiraly et al., 1990).

Total costs reported for this work are listed in Table 7-5. The items of work include staff time, travel expenses, and per diem (Kiraly et al., 1990).

It is important to note that each of these three cases is presented for illustration purposes only. It is not necessary to acquire new data or maps to implement the practices and meet the management measure. Existing maps, surveys, or remotely sensed data (such as aerial photographs) can easily be used. These typically exist in files of State and local governments or educational institutions. Additional data on wetlands functions, locations, or ecological assessments can be culled from existing environmental impact statements, from old permit applications, or from watershed inventories. These sources of information in particular should be evaluated for their usefulness in categorizing historical conditions.

Where the need for new maps is recognized to meet the management measure, several Federal agencies provide mapping products that could be useful. Examples include the following:

- USDA aerial photography. Depending on the locality, this photography is available in black-and-white, color, or color-infrared (color-IR) formats.

- USGS aerial photography. A variety of photo products are available, for example, through the National Aerial Photography Program (NAPP).

- EPA Environmental Monitoring and Assessment Program (EMAP). Some opportunities for cost-shared projects are available to collect and analyze new imagery on the ecosystem or watershed level (Kiraly et al., 1990).

b. Wetland and Riparian Area Protection Programs

Examples of programmatic costs for implementing practices "b" and "c" under this management measure include costs for personnel, the administrative costs of processing applications for permits, and costs for public information brochures and pamphlets. Since some programs may already be in place, the need for apportionment of existing programmatic capabilities to NPS-related issues regarding wetlands and riparian areas will vary widely, depending on the size of the local jurisdiction, the nature and extent of wetland and riparian ecosystems present within the jurisdictional boundaries, and the severity of the NPS problem. Other programs may need to be adapted to include NPS-related issues regarding wetlands.

Six separate examples of costs for existing State wetland programs are shown in Table 7-6 for illustrative purposes. The costs reflect a range of low to high levels of effort, as measured through the assignment of individual full-time

Table 7-5. Total Costs for Wetlands Assessment Project Examples

Location of Project	Cost Item	Cost
Northeast Shark River near Slough, Mississippi	Four weeks of staff time	$2,441
	Travel and per diem	$1,500
	Total	$3,941
West Broward County, Florida	Six weeks of staff time	$3,362
	Travel and per diem	$2,400
	Total	$5,762
Swamp of Toa, Alabama	Eight weeks of staff time	$4,882
	Travel and per diem	$2,000
	Total	$6,882

Table 7-6. Costs for Wetlands Protection Programs[a]

State	Staffing	Budget
Montana	One FTE	$100,000
South Carolina	Three part-time positions	$80,000
Alaska	Four FTEs	$400,000
Tennessee	Eleven FTEs (Field, clerical, and administrative)	$450,000
Oregon	Fifteen FTEs Five seasonal positions	$300,000
New Hampshire	Fifteen FTEs Five seasonal positions	$500,000

[a]All levels of staffing and budgeting were reported by States in response to a questionnaire distributed by the Association of State Wetlands Managers (ASWM).

equivalents (FTEs) and the task-specific dedication of discrete levels of clerical and administrative support. A low-level scenario consists of costs for one FTE. A high-level scenario consists of staffing of 10 or more FTEs, including clerical and administrative positions.

If the costs for individual FTEs are estimated at $50,000 each, which includes salary plus fringe benefits, then some of the reported program budgets on the list mentioned above exceed reasonable estimates of salaries. This indicates that additional funding has been allocated for activities ranging from office support to technical assistance in the field.

c. Pretreatment

The use of appropriate pretreatment practices to prevent adverse impacts to wetlands that ultimately affect NPS pollution abatement involves the design and installation of vegetated treatment systems such as vegetated filter strips or constructed wetlands, or the use of structures such as detention or retention basins. These types of systems are discussed individually elsewhere in this guidance document. Refer to Chapter 4 for a discussion of detention and retention basins. See the discussion of Management Measure C later in Chapter 7 for a description of constructed wetlands and filter strips. The purpose of each of these BMPs is to remove, to the extent practicable, excessive levels of NPS pollutants and to minimize impacts of hydrologic changes. Each of these BMPs can function to reduce levels of pollutants in runoff or to attenuate runoff volume before it enters a natural wetland or riparian area.

Whether these BMPs are used individually or in series will depend on several factors, including the quantity and quality of the inflowing runoff, the characteristics of the existing hydrology, and the physical limitations of the area surrounding the wetland or riparian area to be protected.

Costs are reported below for three potential scenarios to implement practice "d" under this management measure.

(1) One filter strip at a cost of $129.00

- Includes design and installation of a grass filter strip 1,000 feet long and 66 feet wide.
- Most effective at trapping sediments and removing phosphorus from surface water runoff.

(2) One constructed wetland at a cost of $5,000.00

- Includes design and installation of a constructed wetland whose surface area is 0.25 acre in size. The constructed wetland is planted with commercially available emergent vegetation.

- Most effective to remove nutrients and decrease the rate of inflow of surface water runoff into the natural wetland located further downstream.

(3) One combined filter strip/constructed wetland $5,129.00

B. Management Measure for Restoration of Wetland and Riparian Areas

Promote the restoration of the preexisting functions in damaged and destroyed wetlands and riparian systems in areas where the systems will serve a significant NPS pollution abatement function.

1. Applicability

This management measure is intended to be applied by States to restore the full range of wetlands and riparian functions in areas where the systems have been degraded and destroyed and where they can serve a significant NPS abatement function. 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

Restoration of wetlands and riparian areas refers to the recovery of a range of functions that existed previously by reestablishing the hydrology, vegetation, and structure characteristics. A restoration management measure should be used in conjunction with other measures addressing the adjacent land use activities and, in some cases, water activities as well.

The term *NPS pollution abatement function* refers to the ability of a wetland or riparian area to remove NPS pollutants from waters passing through the wetland or riparian area. Acting as a sink for phosphorus and converting nitrate to nitrogen gas through denitrification are two examples of the important NPS pollution abatement functions performed by wetlands and riparian areas.

Restoration of wetlands and riparian areas is a holistic approach to water quality that addresses NPS problems while meeting the goals of the Clean Water Act to protect and restore the chemical, physical, and biological integrity of the Nation's waters. Full restoration of complex wetland and riparian functions may be difficult and expensive, depending on site conditions, the complexity of the system to be restored, the availability of native plants, and other factors. Specific practices for restoration must be tailored to the specific ecosystem type and site conditions.

3. Management Measure Selection

Selection of this management measure was based on:

(1) The localized increase in pollutant loadings that can result from the degradation of wetlands and riparian areas (Reinelt and Horner, 1990; Richardson, 1988);

(2) The nonpoint pollution abatement function of wetlands and riparian areas (Cooper, 1990; Cooper and Gilliam, 1987; Jacobs and Gilliam, 1985; James et al., 1990; Karr and Gorman, 1975; Lowrance et al.,

1983; Lowrance et al., 1984; Peterjohn and Correll, 1984; 9Pinay and Decamps, 1988; Stuart and Greis, 1991); and

(3) The opportunity to gain multiple benefits through the restoration of wetland and riparian area systems, e.g., aquatic and riparian habitat functions for wildlife and NPS pollution reduction benefits (Atcheson et al., 1979; Mitsch and Gosselink, 1986).

Refer to Section II.A.3 of this chapter for additional information regarding the degradation, effectiveness, and multiple benefits of wetlands and riparian areas.

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. Provide a hydrologic regime similar to that of the type of wetland or riparian area being restored.

The following list identifies some important information or considerations to address in a restoration project.

- Site history - Know the past uses of the site, including past functioning as a wetland.
- Topography - Map the surface topography, including slope and relief of the existing land surface, and elevations of levees, drainage channels, ponds, and islands.
- Tide - Determine the mean and maximum tidal range.
- Existing water control structures - Identify the location of culverts, tide gates, pumps, and outlets.
- Hydrology - Investigate the hydrologic conditions affecting the site: wave climate, currents, overland flows, ground-water dynamics, and flood events.
- Sediment budgets - Understand the rates and paths of sediment inflow, outflow, and retention.
- Soil - Describe the existing soils, including their suitability for supporting wetland plants.
- Plants - Identify the existing and, if different, native vegetation.
- Salinity - Measure the existing or planned salt level at the site.
- Consider the timing of the restoration project and the duration of the construction schedule for installation activities.
- Assess potential impacts to the site from adjacent human activities.

Restoration of hydrology, in particular, is a critical factor to gain NPS benefits and to increase the probability of successful restoration.

b. *Restore native plant species through either natural succession or selected planting.*

When consistent with preexisting wetland or riparian area type, plant a diversity of plant types or manage natural succession of diverse plant types rather than planting monocultures. Deeply rooted plants may work better than certain grasses for transforming nitrogen because the roots will reach the water moving below the surface of the soil. For forested systems, a simple approach to successional restoration would be to plant one native tree species, one shrub species, and one ground-cover species and then allow natural succession to add a diversity of native species over time, where appropriate and warranted by target community composition and anticipated successional development. Information on native plant species is available from Federal agencies (e.g., USDA-SCS or USDOI-FWS), or various State or local agencies, such as the local Cooperative Extension Service Office or State departments of agriculture or natural resources. Other factors listed below need to be considered in the implementation of this practice.

Type and Quantity of Pollutant. Sediment, nitrates, phosphates, and thermal pollutants are effectively reduced by riparian areas. Riparian forests can also effectively remove nitrates from ground water. Eroded materials and attached pollutants from upslope areas are trapped on the surface. Suspended sediments and attached pollutants are removed during inundation by floodwaters (Table 7-1).

Slope. Riparian forest water quality functions have primarily been studied on cropland watersheds where slope has not been a factor. While sheet flow is not required for effective removal of NPS pollution from runoff passing through a riparian area, concentrated flows must be dispersed before upland runoff enters the riparian area.

Vegetated Area. Nonleguminous hardwoods are the most effective vegetation for nitrate removal. Where shade is critical, taller conifers may be preferred. The vegetation should be managed to retain larger trees near streams and denser, more vigorous trees on the remainder of the area. Research has also shown that a naturally rough forest floor is effective in trapping sediment (Swift, 1986).

c. *Plan restoration as part of naturally occurring aquatic ecosystems.*

States should factor in ecological principles when selecting sites and designing restoration. For example, seek high aquatic and riparian habitat diversity and high productivity in the river/wetland systems; look for opportunities to maximize connectedness (between different aquatic and riparian habitat types); and provide refuge or migration corridors along rivers between larger patches of uplands (animals are most likely to colonize new areas if they can move upstream and downstream under cover).

Planning to restore wetlands includes:

- Identifying sources of NPS problems;
- Considering the role of site restoration within a broader context, such as on a landscape basis;
- Setting goals for the restoration project based on location and type of NPS problem;
- Replicating multiple functions while still gaining NPS benefits; and
- Locating historic accounts (e.g., maps, descriptions, photographs) to identify sites that were previously wetland or riparian areas. These sites are likely to be more suitable for restoration if the original hydrology has not been permanently altered.

A few examples of wetland restoration are shown in Table 7-7.

Table 7-7. Review of Wetland Restoration Projects

No.	Location	Type of Wetland	Summary of Observations	Source
1	The Kattegat, Swedish west coast	Wetlands restoration Vegetation type not specified	The Kattegat, a semienclosed, shallow, and strongly stratified sea area, has experienced increased effects of eutrophication caused by excessive nitrogen loading. Based on a nitrogen retention model and denitrification studies, the following hypotheses will be tested in the wetland restoration program: • Annual nitrogen retention depends on nitrogen load. • A decrease in the active surface of a wetland causes an increase in the nitrogen load and retention per unit area. • Hydrological loading of a wetland can only be increased to a certain "critical" level. • Nitrogen retention is stabilized as a result of newly established plant communities and sediment formation. • When nitrogen retention is high, denitrification and sedimentation are the predominating mechanisms. • During the winter, high nitrogen load may counteract low-temperature-limited denitrification. • If nitrogen transport in a stream is known, retention in a future restored wetland can be predicted. This 5-year wetland restoration study was just getting under way in 1991.	Fleischer, S., L. Stibe, and L. Leonardson. 1991. Restoration of Wetlands as a Means of Reducing Nitrogen Transport to Coastal Waters. *Ambio: A Journal of the Human Environment*, 20(6):271-272.
2	Ballona Channel Wetlands, Marina Del Rey, Los Angeles, California	Wetlands restoration Vegetation type not specified	This paper discusses the model used to plan stormwater detention for site development, and at the same time to allow wetland restoration. Flood control, restoration of wetland habitat values, and quality control of urban stormwater runoff were some objectives of the project. This paper discusses only the model used to engineer the plan.	Tsihrintzis, V.A., G. Vasarhelyi, W. Trott, and J. Lipa. 1990. Stormwater Management and Wetland Restoration: Ballona Channel Wetlands. In *Hydraulic Engineering: Volume 2, Proceedings of the 1990 National Conference*, pp. 1122-1127.

Table 7-7. (Continued)

No.	Location	Type of Wetland	Summary of Observations	Source
3	Banana Lake headwater system, Lakeland, Florida	Restored headwaters (including hardwood and herbaceous wetlands)	As compensation for roadway environmental impacts from the development of a belt loop around Lakeland, Florida, the restoration of Banana Lake was initiated in 1983. Development of the project was undertaken by the Polk County Engineering and Water Resources Division, the Florida Department of Transportation, and the City of Lakeland. Objectives of the restoration project include: • Improvement of surface water quality; • Elimination of localized flooding and dangerous roadside ditches; • Restoration of hardwood wetland swamp system; • Restoration of the premining drainage and functions of the headwater system. Postrestoration differences are summarized: • Western basin (average water quality): - All data in mg/L unless otherwise noted. - BDL=Below detection limits. <u>Parameter</u> — <u>Change after restoration</u> Temperature-°C — -0.9 pH-units — +0.3 DO — +1.1 Specific conductance (umhos/cm) — -54 Nitrate-Nitrate as N — to BDL N, Ammonia — to BDL N, Total Kjeldahl — -2.98 N, Total — -3.03 Orthophosphate as P — -0.974 Phosphorus, Total — -0.869 Restoration of the western basin was completed in 1985. The following data compare the restored western basin water quality to the existing (1989) water quality in the unrestored eastern ditch. • Roadside ditch quality - Lakeland Highlands Rd.: <u>Parameter</u> — Western Basin <u>(Restored)</u> — Eastern Basin <u>(Unrestored)</u> Temperature (°C) — 25.3 — 22.7 pH-units — 7.1 — 7.1 DO — 7.2 — 7.0 Specific conductance (umhos/cm) — 217 — 221 Nitrate-Nitrate as N — BDL — 0.016 N, Ammonia — BDL — 0.145 N, Total Kjeldahl — 1.03 — 1.48 N, Total — 1.03 — 1.58 Orthophosphate as P — 0.233 — 0.525 Phosphorus, Total — 0.571 — 1.514	Powers, R.M., and J.F. Spence. 1989. Headwater Restoration: The Key Is Integrated Project Goals. In *Proceedings of the Symposium on Wetlands: Concerns and Successes, Sept. 17-22, Tampa, Florida*, pp. 269-279

Table 7-7. (Continued)

No.	Location	Type of Wetland	Summary of Observations	Source
4	Creekside Park, Marin County, California	Wetland restoration; Cordgrass and pickleweed planting	In 1972, the U.S. Army Corps of Engineers placed dredged spoils on the Creekside Park site in conjunction with the dredging of Corte Madera Creek. As a result of citizen pressure, a report on the feasibility of creating a salt marsh was prepared in 1973. In 1975, the site was acquired and a committee of local citizens initiated a park plan. • In 1975, the Corps of Engineers issued a permit for a small marsh plant nursery area to provide some initial experience in transplanting cordgrass and pickleweed within the future marsh area. The permit to excavate for the entire marsh restoration project was issued in 1976. • The site plan included removing spoil for channels, grading upland areas for marsh plant colonization, depositing excess material to create islands and upland areas, and creation of public access. • After the first marsh plantings failed to germinate in 1977, a second attempt was made using a number of different species of cordgrass including seeds from Humboldt Bay and Spartina marina from England. • No records were kept of success or establishment of marsh plants. However, in 1979, Royston, Hanamoto, Beck and Abbey, the landscape architect responsible for the project, was given an Award of Excellence by the American Society of Landscape Architects for the restoration plan.	Josselyn, M., and J. Buchholz. 1984. *Marsh Restoration in San Francisco Bay: A Guide to Design & Planning*. Technical Report #3. Tiburon Center for Environmental Studies, San Francisco State University. 104 pp.
5	Coyote Creek and Anza-Borrego Desert State Park, San Diego County, California	Riparian/ creek restoration	Until March 1988, all vehicles were allowed to travel on the 29-kilometer route of Coyote Canyon, including the riverine routes. The jeep trail passed through the three most significant riparian forests of Coyote Creek and by the early 1980s the impacts of approximately 1000 vehicles on the riparian system during busy weekends became too great. An annual seasonal closure of the entire Coyote Canyon watershed to all persons and vehicles was enacted. A bypass route now provides permanent protection to one of the three riparian sections. A ban on all vehicles that are not street legal, including dirt bikes, all-terrain cycles, and many dune buggies, has caused the traffic corridors to become filled in with thick stands of willow and tamarisk, which provide additional avian habitat.	USDA, Forest Service. 1989. *Proceedings of the California Riparian Systems Conference, September 22-24, 1988, Davis, California*, pp. 149-152.

Table 7-7. (Continued)

No.	Location	Type of Wetland	Summary of Observations	Source
6	Unknown	Wetland	This paper presents economically efficient policy reforms of national wetlands programs that result in enhanced maintenance of wetland stocks and accommodation of development pressures. The authors' suggestions include a fixed wetlands development fee for developers building in unprotected areas. These development tax revenues then would be used to finance a nationwide investment program to aid the replacement and management of wetlands created to offset losses to development. Alternatively, developers may choose to implement their own mitigation plans. According to the authors, this approach would offer more assurance that coastal wetlands damage will be compensated. Included in this paper are tables of summaries of costs for the following conditions: • Wetland creation with dredged material from maintenance of navigation projects; • Wetland creation with proposed 25,000- cfs controlled sediment diversions; and • Wetland creation with uncontrolled sediment diversions.	Shabman, L.A., and S.S. Batie. 1987. Mitigating Damages from Coastal Wetlands Development: Policy, Economics and Financing. *Marine Resource Economics*, 4:227-248.
7	Amana Society Farm, eastern Iowa	Poplar tree buffer strips in riparian zones	This study outlines 2 years of study of Iowa's riparian corridors by the Leopold Center. *Populus* spp. (poplar) were planted in buffer strips along creeks to produce a productive crop and a more stable riparian zone ecosystem. Planting techniques were developed so that roots grew deep enough to intercept the surficial water and dense enough to uptake most available nitrogen before it leached into the stream. During the two growing seasons, the deep-rooted poplar removed soil nitrate and ammonia nitrogen from soil water well below Maximum Contaminant Limits. Tables or graphs for the following data can be found in the paper: • Tree survival and stem and leaf growth; • Total Kjheldahl Nitrogen concentrations; • Nitrate nitrogen concentrations; • Ammonia nitrogen concentrations; and • Total organic carbon concentrations.	Licht, L.A., and J.L. Schnoor. 1990. *Poplar Tree Buffer Strips Grown in Riparian Zones for Non-point Source Pollution Control and Biomass Production.* Leopold Center for Sustainable Agriculture.

Table 7-7. (Continued)

No.	Location	Type of Wetland	Summary of Observations	Source
8	Sweetwater River Wetlands Complex, San Diego Bay, California	Construction and enhancement of salt marsh	Mitigation for lost wetland habitat is being carried out by the California Department of Transportation. The mitigation marshes include the Connector Marsh, which is a hydrologic link between Paradise Creek and the Sweetwater Marsh, and Marisma de Nacion, a 17-acre marsh excavated from the "D Street fill" in 1990. The assessment study thus far has found that: • Concentrations of free sulfide were greater in the natural marsh compared to only trace amounts in the constructed marsh. • Nitrogen fixation rates were generally twice as high in the natural salt marsh than in the man-made salt marsh. • There were two to four times more individuals in a natural marsh at San Diego Bay than in the 4-year-old man-made marsh. Abundance of species was up to nine times greater in the natural marsh. These samplings were taken at low marsh elevations. At elevations of 0.5 m above mean sea level, the numbers of species and individuals were similar for areas with high cover. • The preliminary conclusion was that the USFWS criteria for fish species and abundance have been met by the constructed marsh. • An overall comparison indicated that the constructed marsh was less than 60% functionally equivalent to the natural reference wetland (Paradise Creek Marsh) when comparing water quality, plant biomass, and number of species and individuals. • The report contains detailed tables that provide the following quantitative data: - Pore water concentrations of free sulfides; - Rates of nitrogen fixation; - Total nitrogen and phosphorus in sediment core samples; - Biomass of cordgrass; - Ammonium levels of pore water samples; - Mean number of individuals per litterbag; - Mean number of species per litterbag; - Number of channel invertebrates found at sampling stations; and - Sightings of water-associated birds.	Pacific Estuarine Research Laboratory. 1990. *A Manual for Assessing Restored and Natural Coastal Wetlands with Examples from Southern California.* California Sea Grant, La Jolla, California, pp. 19-34.

Table 7-7. (Continued)

No.	Location	Type of Wetland	Summary of Observations	Source
9	Connecticut	Created and natural wetlands	This report compares five 3- to 4-year-old created wetland sites with five nearby natural wetlands of comparable size. Hydrologic, soil, and vegetation data were compiled over a 2-year period (1988-89). Results indicated that: • Only one created site appeared to mimic the hydrology of a natural wetland because of its connection to a natural water source. • Typical wetland soils exhibiting mottling and organic accumulation were lacking in created sites. • Plant cover was higher in the natural sites because of their greater maturity. • The created sites exhibited a slightly higher number of species. This species richness can be attributed to the rapid rate of species establishment on mineral soil substrates. The small sample size also may have contributed to the high number of species in the created site. Egler's Initial Floristic Composition concept, a model of vegetation development, also explains the difference in species numbers. This model assumes a large number of species early in the development process, which may decrease over time as a result of interspecific competition. • Based on observations of bird species diversity and muskrat activity, creation of comparable wildlife habitat was achieved at more than one created site. The authors concluded that the presence of invasive species threatens the future of the created wetlands.	Confer, S., and W.A. Niering. Undated. Comparison of Created Freshwater and Natural Emergent Wetlands in Connecticut. Submitted to *Wetland Ecology and Management.*
10	Wyoming	Riparian zones	Along a degraded cold desert stream in Wyoming, instream flow structures (trash collectors), willow, and beaver are being used to reclaim riparian habitat. Trash collectors are intended to decrease streamflow velocity, causing sediment to be deposited as channel bed material. Willows will be used to stabilize new channel bank deposition. Preliminary results have shown that: • Trash collectors have survived 1 1/2 years and are trapping sediment. • Channel bed material is rising. • Beaver are using trash collectors as support for dams. • Willow plantings have survived 2 years.	Skinner, Q.D., M.A. Smith, J.L. Dodd, and J.D. Rodgers. Undated. *Reversing Desertification of Riparian Zones Along Cold Desert Streams.* pp. 1407-1414.

Table 7-7. (Continued)

No.	Location	Type of Wetland	Summary of Observations	Source
11	California	Riparian	Severe storms of 1978 through 1983 caused considerable damage to streams in California. The Soil Conservation Service used several mechanical and revegetation techniques to stabilize streambanks and reestablish riparian vegetation. Results of evaluations of 29 projects are discussed, and recommendations are made to improve success.	Shultze, R.F., and G.I. Wilcox. 1985. Emergency Measures for Streambank Stabilization: An Evaluation. In *Riparian Ecosystems and Their Management: Reconciling Conflicting Issues.* USDA Forest Service GTR RM-120, pp. 54-58.
12	Rio Grande River, New Mexico	Riparian	Riparian areas continue to be drastically altered, usually by human activities. Managers have generally been unsuccessful in using conventional techniques to replace riparian trees. Experiments with Rio Grande cottonwood, narrowleaf cottonwood, and Gooding willow have shown that a simple and inexpensive method for their reestablishment is now available (i.e., placing large, dormant cuttings into holes predrilled to known depth of the growing season water table).	Swenson, E.A., and C.L.Mullins. 1985. Revegetating Riparian Trees in Southwestern Floodplains. In *Riparian Ecosystems and Their Management: Reconciling Conflicting Issues.* USDA Forest Service GTR RM-120, pp. 135-138.
13	Savannah River, South Carolina	Wetland	Principal factors that affect seedling recruitment in mature cypress-tupelo forests include seed production, microsite availability, and hydrologic regime. Studies on the Savannah River floodplain in South Carolina show that although seed production seems adequate, microsite characteristics and water level changes limit regeneration success. Management of water levels on regulated streams must account for species regeneration requirements to maintain floodplain wetland community structure.	Sharitz, R.R., and L.C. Lee. 1985. Limits onregeneration processes in southeastern riverine wetlands. In *Riparian Ecosystems and Their Management: Reconciling Conflicting Issues.* USDA Forest Service GTR RM-120, pp.139-143.
14	Niger, West Africa	Riparian	A reforestation project in the Majjia Valley, Niger, was undertaken to improve the microclimate, to reduce water and wind erosion, and to produce fuel wood. Windbreaks were planted, wood lots were established, and trees were distributed to the inhabitants. The windbreaks were effective in reducing wind velocities and, at times, retained soil moisture. Water consumption by vegetation in the windbreaks did not affect soil moisture in the agricultural crop rooting zone. Although fuel wood has not been harvested, agricultural crop yields in the windbreaks were 125% of those in the control.	Ffolliott, P.F., and R.L. Jemison. 1985. Land use in Majjia Valley, Niger, West Africa. In *Riparian Ecosystems and Their Management: Reconciling Conflicting Issues.* USDA Forest Service GTR RM-120, pp. 470-474.

5. Costs for All Practices

This section describes costs for representative activities that would be undertaken in support of one or more of the practices listed under this management measure. The description of the costs is grouped into the following two categories:

(1) A wetlands/riparian restoration project involving a low level of effort.

The items of work would include (a) clearing the site of fallen trees and debris; (b) application of seed stock or sprigging of nursery-reared plants; (c) application of fertilizer (most typically for marsh restoration); and (d) a minimal amount of postproject maintenance until the vegetation becomes established.

A low level of effort could also include minor adjustments to the existing hydrology, such as the installation of stop-logs to raise water levels, or improvements to the existing drainage patterns undertaken to lower water levels (e.g., pulling the plug on tile fields).

(2) A wetlands/riparian restoration project involving a high level of effort.

The items of work would include (a) clearing the site of fallen trees and debris; (b) extensive site work requiring heavy construction equipment; (c) application of seed stock or sprigging of nursery-reared plants; (d) application of fertilizer (most typically for marsh restoration); and (e) postproject maintenance and monitoring.

A high level of effort is distinguished from a low level by the amount of site work required. A high level of effort typically will require heavy construction machinery, including graders, bulldozers, and/or dump trucks. These pieces of equipment will be used to accomplish several tasks, such as:

- Adding additional fill material to the site or removing excessive amounts of on-site material;
- Realigning the existing on-site substrate to appropriate lines and grades as shown on the design plan; and
- Realigning existing channels or constructing new channels, diversions, basins, or tidal flats as necessary to restore preexisting surface water flow characteristics.

In addition to the need for heavy construction equipment to perform the work, a restoration project involving a high level of effort typically requires more extensive analysis and evaluation of the site before work is started. Site surveys and preparation of formal design drawings and specifications are frequently necessary prior to starting the work. Periodic site visits are needed to inspect the work in progress. Spot surveys are frequently necessary to check the lines and grades of new channels and wetlands planting areas as they are being formed with the heavy construction machinery. Finally, a high-level restoration frequently requires postproject monitoring and adjustment as water begins to flow through the recreated surface water systems in the restored wetland.

The costs for items of work associated with either a low level or a high level of effort are reported below from actual examples of recent projects involving wetlands and riparian area restoration. The cases cited are representative of the levels of effort that could be undertaken in support of the practices under Management Measure II.B.

Each of the following examples contains a description of costs as they are reported in the source document. For ease of comparison, these costs are converted to 1990 dollars, using conversion factors published in the *Engineering News-Record*. A full explanation of the conversion factors is contained in Table 7-8.

Table 7-8. Construction Cost Index (Grogan, 1991)

Year	Annual Average	Year	Annual Average
1975	2212	1984	4146
1976	2401	1985	4195
1977	2576	1986	4295
1978	2776	1987	4406
1979	3003	1988	4519
1980	3237	1989	4606
1981	3535	1990	4732
1982	3825	1991	4775
1983	4066	1992	4946

Note: *Engineering News Record (ENR)* builds the index as follows:

200 hours of common labor at the 20-city average of common labor rates, plus 25 cwt of standard structural steel shapes at the mill price, plus 22.56 cwt (1.128 tons) portland cement at the 20-city price, plus 1,088 board-feet of 2X4 lumber at the 20-city price.

Example: To compute a construction cost increase from 1985 to 1990
(a) Divide 1990 index by 1985 index: 4732/4195 = 1.128
(b) Multiply 1985 cost by ratio: 1985 cost X 1.128 = 1990 cost.

a. Costs for "Low-Level" Restoration Projects

The two sources of wetland and riparian plants that should be used in restoration projects are seed and nursery-reared plant stock. Transplantation of wetland plant materials from other natural ecosystems is not recommended, but transplantation of young trees and shrubs growing in upland areas for riparian area restoration is acceptable, provided no other suitable source of plant stock is available. Transplantation of wetland plants is not recommended because digging up existing wetlands for removal of plant material can cause serious disturbance and dislocation of healthy systems. In addition, pests, disease, and contaminants can be carried along with the transplants and introduced into the area undergoing restoration. For this reason, even though it is possible to locate citations in the literature for transplantation costs, they are not included in the list below.

(1) Costs for a 1982 tidal wetlands project in Chesapeake Bay, Maryland, included seeding and fertilizing salt marsh cordgrass at $204.85 per acre (Earhart and Garbisch, 1983).

Cost in 1990 dollars $253.42/acre

(2) Costs reported in 1979 for tidal wetlands restoration in coastal California included seeding and fertilizing salt marsh cordgrass at $300 to $500 per acre (Jerome, 1979).

Cost in 1990 dollars . . . . $470 to 780/acre

(3) Costs reported in 1992 for nontidal wetlands included purchasing and installing nursery-reared plant stock (emergents) at $2,024 to $2,429 per acre (Hammer, 1992).

Cost in 1990 dollars . . . . $1,936 to 2,323/acre

(4) Costs reported in 1989 for bottomland forest restoration using direct seeding were $40 to $60 per acre (National Research Council, 1991).

Cost in 1990 dollars . . . . $41.20 to $61.80/acre

(5) Costs reported in 1990 for nursery-reared tree seedlings were $212.50 per acre (Illinois Department of Conservation, 1990).

Cost in 1990 dollars $212.50/acre

As this cost information indicates, nursery-reared plant materials used in nontidal wetland restoration projects are generally more expensive than plants used in restoration of tidal wetlands. This difference seems to be partly due to the greater ease with which tidal wetland plants can be grown in nurseries in sufficient quantities for commercial distribution.

The "law of supply and demand" is another factor influencing the price of these two types of items. Mitigation requirements for tidal wetlands have been imposed in many coastal regions of the United States since the mid-1970s, and the commercial market has responded by developing the methods to produce adequate quantities of nursery stock available at the appropriate planting seasons to meet the demand. The requirements for mitigation of nontidal wetlands have only more recently been enforced. Thus, in certain geographic areas of the United States, the demand for these kinds of plant materials from nurseries probably exceeds the supply, resulting in higher unit costs.

Two other factors that influence the costs of seed or plant stock are (1) using exotic or hybrid varieties or introduced species and (2) purchasing plant stock from properly certified and inspected nurseries. When considering the use of seeds or nursery stock for restoration projects, it is best to consider only strong, nonexotic strains of plant materials. Many nurseries carry exotic strains of common species, introduced species, or hybrid varieties. These types of plant stock are intended for use in the home watergarden or in landscaping projects. Always check the genus and species of the plants found in the natural wetland and riparian systems in the locality and insist on purchasing these same varieties from the nursery. In addition, several States have inspection and certification programs for nursery-reared plant stock. For example, the State of Maryland's Department of Agriculture publishes a *Directory of Certified Nurseries, Licensed Plant Dealers, Licensed Plant Brokers* (Maryland Department of Agriculture, 1990). Likewise, the Association of Florida Native Nurseries (AFNN) publishes an annual *Plant and Service Locator* (AFNN, 1989). In these cases, plants should always be obtained from properly inspected and certified dealers. In some regions of the United States, more stringent rules and regulations apply to plant stock purchased for transport across State lines. Such laws exist in part to minimize the potential for the spread of pests and disease and should be strictly adhered to.

Obtaining strains of plant material identical to those occurring in natural ecosystems, through properly certified and inspected plant dealers, frequently results in a slightly higher product cost. However, increased benefits in environmental protection and project performance will generally justify paying the slightly higher price.

b. Costs for "High-Level" Restoration Projects

Costs for projects involving extensive site work will vary widely based on several factors, including (1) the extent and complexity of the work shown on the design drawing, (2) the local availability of construction equipment, and (3) the degree of difficulty involved in gaining access to the site. In addition, as the examples of restoration projects listed below illustrate, overall project costs can be considerably increased if the land containing the proposed restoration project must be purchased before any work is undertaken.

In compiling the restoration costs for the examples listed below, the reported costs for riparian work were frequently presented in units of linear feet of streambank. For ease of comparison with the other examples, these costs were converted to dollars per acre by assigning a width along the streambank within which work is assumed to have taken place.

(1) Costs reported for the 1980 restoration of diked tidelands at the Elk River in Humboldt Bay, California, ranged from $5,000 to $7,000 per acre. The items of work included breaching of dikes to restore preexisting hydrology, construction of new dikes at a lower elevation, installation of other drainage controls, and restoration of tidal wetland vegetation (Anderson and Rockel, 1991).

Cost in 1990 dollars . . . . $7,300 to $10,000/acre

(2) Costs reported for the 1986 restoration of tidal wetlands at three California coastal sites averaged $23,700 per acre. The sites included Big Canyon in Upper Newport Bay, Freshwater Slough, and Bracut (both in Humboldt Bay). Existing fill had to be removed from the sites before wetlands restoration could be accomplished (Anderson and Rockel, 1991).

Cost in 1990 dollars $26,070/acre

(3) Costs reported for restoration of riparian areas in Utah between 1985 and 1988 were used to compute an average cost of approximately $2,527 per acre, assuming a streamside width of 100 feet for the work. The items of work included bank grading, installation of riprap and sediment traps in deep gullies, planting of juniper trees and willows, and fencing of the site (Nelson and Williams, 1989).

Cost in 1990 dollars $2,527/acre

C. Management Measure for Vegetated Treatment Systems

Promote the use of engineered vegetated treatment systems such as constructed wetlands or vegetated filter strips where these systems will serve a significant NPS pollution abatement function.

1. Applicability

This management measure is intended to be applied by States in cases where engineered systems of wetlands or vegetated treatment systems can treat NPS pollution. Constructed wetlands and vegetated treatment systems often serve a significant NPS pollution abatement function. 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

As discussed in Section I.E of this chapter, vegetated treatment systems (VTS), by definition in this guidance, include vegetated filter strips and constructed wetlands. Although these systems are distinctly different, both are designed to reduce NPS pollution. They need to be properly designed, correctly installed, and diligently maintained in order to function properly.

The term *NPS pollution abatement function* refers to the ability of VTS to remove NPS pollutants. Filtering sediment and sediment-borne nutrients and converting nitrate to nitrogen gas are examples of the important NPS pollution abatement functions performed by vegetated treatment systems.

a. Vegetated Filter Strips

The purpose of vegetated filter strips (VFS) is to remove sediment and other pollutants from runoff and wastewater by filtration, deposition, infiltration, absorption, adsorption, decomposition, and volatilization, thereby reducing the amount of pollution entering surface waters (USDA, 1988). Vegetated filter strips are appropriate for use in areas adjacent to surface water systems that may receive runoff containing sediment, suspended solids, and/or nutrient runoff. Vegetated filter strips can improve water quality by removing nutrients, sediment, suspended solids, and pesticides. However, VFS are most effective in the removal of sediment and other suspended solids.

Vegetated filter strips are designed to be used under conditions in which runoff passes over the vegetation in a uniform sheet flow. Such a flow is critical to the success of the filter strip. If runoff is allowed to concentrate or channelize, the vegetated filter strip is easily inundated and will not perform as it was designed to function.

Vegetated filter strips need the following elements to work properly: (1) a device such as a level spreader that ensures that runoff reaches the vegetated filter strip as a sheet flow (berms can be used for this purpose if they are placed at a perpendicular angle to the vegetated filter strip area to prevent concentrated flows); (2) a dense vegetative cover of erosion-resistant plant species; (3) a gentle slope of no more than 5 percent; and (4) a length at least as long as the adjacent contributing area (Schueler, 1987). If these requirements are met, VFS have been shown to remove a high degree of particulate pollutants. The effectiveness of VFS at removing soluble pollutants is not well documented (Schueler, 1987).

b. Constructed Wetlands

Constructed wetlands are typically engineered complexes of saturated substrates, emergent and submergent vegetation, animal life, and water that simulate wetlands for human use and benefits (Hammer et al., 1989). According to Hammer and others (1989), constructed wetlands typically have four principal components that may assist in pollutant removal:

(1) Substrates with various rates of hydraulic conductivity;
(2) Plants adapted to water-saturated anaerobic substrates;
(3) A water column (water flowing through or above the substrate); and
(4) Aerobic and anaerobic microbial populations.

3. Management Measure Selection

This management measure was selected because vegetated treatment systems have been shown to be effective at NPS pollutant removal. The effectiveness of the two types of VTS is discussed in more detail in separate sections below.

a. Effectiveness of Vegetated Filter Strips

Several studies of VFS (Table 7-9) show that they improve water quality and can be an effective management practice for the control of nonpoint pollution from silvicultural, urban, construction, and agricultural sources of sediment, phosphorus, and pathogenic bacteria. The research results reported in Table 7-9 show that VFS are most effective at sediment removal, with rates generally greater than 70 percent. The published results on the effectiveness of VFS in nutrient removal are more variable, but nitrogen and phosphorus removal rates are typically greater than 50 percent. The following are nonpoint sources for which VFS may provide some nutrient-removal capability:

(1) **Cropland.** The primary function of grass filter strips is to filter sediment from soil erosion and sediment-borne nutrients. However, filter strips should not be relied on as the sole or primary means of preventing nutrient movement from cropland (Lanier, 1990).

(2) **Urban Development.** Vegetated filter strips filter and remove sediment, organic material, and trace metals. According to the Metropolitan Washington Council of Governments, VFS have a low to moderate ability to remove pollutants in urban runoff and have higher efficiency for removal of particulate pollutants than for removal of soluble pollutants (Schueler, 1987).

With proper planning and maintenance, VFS can be a beneficial part of a network of NPS pollution control measures for a particular site. They can help to reduce the polluting effects of agricultural runoff when coupled with either (1) farming practices that reduce nutrient inputs or minimize soil erosion or (2) detention ponds to collect runoff as it leaves a vegetated filter strip. Properly planned VFS can add to urban settings by framing small streams, ponds, or lakes, or by delineating impervious areas. In addition to serving as a pollution control measure, VFS can add positive improvements to the urban environment by increasing wildlife and adding beauty to an area.

b. Effectiveness of Constructed Wetlands

Constructed wetlands have been considered for use in urban and agricultural settings where some sort of engineered system is suitable for NPS pollution reduction.

A few studies have also been conducted to evaluate the effectiveness of artificial wetlands that were designed and constructed specifically to remove pollutants from surface water runoff (Table 7-10). Typical removal rates for

Table 7-9. Effectiveness of Vegetated Filter Strips for Pollutant Removal

Author	Study	VFS Length (m)	Vegetation	Sediment Removal (%)	Total Nitrogen Removal (%)	Total Phosphorus Removal (%)	Other Pollutant Removal (%)
Dillaha et al., 1988	simulated feedlot runoff	4.6	orchard grass	79	64	58	
		9.1		90	74	68	
Dillaha et al., 1989a	simulated cropland runoff	4.6	orchard grass	63	50	57	
		9.1		78	67	74	
Magette et al., 1989	simulated cropland runoff	4.6	orchard grass	72	17	41	
		9.1		86	72	53	
Young et al., 1980	simulated feedlot	35-41	corn	86	92	91	Total Coliform
			orchard grass	66	87	88	70
			sorghum	82	84	81	53
			oats	75	73	70	81
			average	79	84	83	70
							NA
Dickey and Vanderholm, 1981	pumped effluent	91	mixed	73	80/86[a]	78	
		61	fescue/alfalfa	63		NA	
		152-457	foxtail	78	71/72[a]	NA	
					89/85[a]		
Dickey and Vanderholm, 1981	pumped effluent	229	NA	39	50/41[a]	NA	
		305		59	61/63[a]	16	
		381		56	66/64[a]	49	
		533		80	83/83[a]	NA	
Schwer and Clausen, 1989	milkhouse runoff	26	fescue, ryegrass, bluegrass	89	76[b]	78	
Overman and Schanze, 1985			Bermuda grass	81	67	39	

NA = not available.
[a]Total Kjeldahl Nitrogen/ammonia nitrogen.
[b]Total Kjeldahl Nitrogen.

Table 7-10. Effectiveness of Constructed Wetlands for Treatment of Surface Water Runoff

Constituent	Lake Jackson (%)	Orange County (%)	Tampa Office (%)	MWTS (%)
Total Solids				
Suspended	94	83	63	90
Organic	96			89
Nitrogen				
Total	76	30	10	50
Ammonia	37	32	34	
Nitrate	70		75	56
Nitrite	75			
Organic (TKN)		34	-8	48
Phosphorus				
Total	90	37	54	55
Ortho	78	21	63	33
Metals				
Lead		81		75
Iron			33	
Nickel			21	

Sources: **Lake Jackson**: Touvila et al. 1987. *An evaluation of the Lake Jackson (Florida) Filter System and Artificial Marsh on Nutrient and Particulate Removal from Stormwater Runoff.*
Orange County: Martin and Smoot. Undated. *Tampa Office Wet Detention Stormwater Treatment.*
Tampa Office: Rushton and Dye 1990. *Water Quality Effectiveness of a Detention/Wetland Treatment System and Its Effect on an Urban Lake.*
MWTS: Oberts and Osgood 1991. *Constituent Load Changes in Urban Stormwater Runoff Routed Through a Detention Pond-Wetland System in Central Florida.*

Notes: **Lake Jackson**: Constructed wetland system located in Tallahassee, FL. Consists of a detention pond in series with a sand filter and constructed wetland. Analysis done in 1985.
Orange County: Wetland and detention pond system in Orlando, FL. Constructed in 1980.
Tampa Office: Constructed detention pond and wetland system located in Tampa, FL. Analysis done in 1989.
MWTS: Constructed detention pond and wetland system located in Roseville, MN. Consists of a detention pond in series with six wetland cells. Constructed and studied in 1986.

suspended solids were greater than 90 percent (Table 7-10). Removal rates for total phosphorus ranged from 50 percent to 90 percent. Nitrogen removal was highly variable and ranged from 10 percent to 76 percent for total nitrogen.

Like vegetated filter strips, constructed wetlands offer an alternative to other systems that are more structural in design for NPS pollution control. In some cases, constructed wetland systems can provide limited ecological benefits in addition to their NPS control functions. In other cases, constructed wetlands offer few, if any, additional ecological benefits, either because of the type of vegetation installed in the constructed wetland or because of the quantity and type of pollutants received in runoff. In fact, constructed wetlands that receive water containing large amounts of metals or pesticides should be fenced or otherwise barricaded to discourage wildlife use.

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. Construct VFS in areas adjacent to waterbodies that may be subject to suspended solids and/or nutrient runoff.

A survey of the literature on the design, performance, and effectiveness of VFS shows that the following factors need to be considered on a site-specific basis before designing and constructing a vegetated filter strip:

(1) The effectiveness of VFS varies with topography, vegetative cover, implementation, and use with other management practices. In addition, different VFS characteristics such as size and type of vegetation can result in different pollutant loading characteristics, as well as loading reductions. Table 7-9 gives some removal rates for specific NPS pollutants based on VFS size and vegetation.

(2) Several regional differences are important to note when considering the use of VFS. Climate plays an important role in the effectiveness of VFS. The amount and duration of rainfall, the seasonal differences in precipitation patterns, and the type of vegetation suitable for local climatic conditions are examples of regional variables that can affect the performance of VFS. Soil type and land use practices are also regional differences that will affect characteristics of surface water runoff and thus of VFS performance. The sites where published research has been conducted on VFS effectiveness for pollutant removal are overwhelmingly located in the eastern United States. There is a demonstrated need for more studies located in different geographic areas in order to better categorize the effects of regional differences on the effectiveness of VFS.

(3) Vegetated filter strips have been successfully used in a variety of situations where some sort of BMP was needed to treat surface water runoff. Typical locations of VFS have included:

- Below cropland or other fields;
- Above conservation practices such as terraces or diversions;
- Between fields;
- Alternating between wider bands of row crops;
- Adjacent to wetlands, streams, ponds, or lakes;
- Along roadways, parking lots, or other impervious areas;
- In areas requiring filter strips as part of a waste management system; and
- On forested land.

VFS function properly only in situations where they can accept overland sheet flow of runoff and should be designed accordingly. If existing site conditions include concentrated flows, then BMPs other than VFS should be used. Contact time between runoff and the vegetation is a critical variable influencing VFS effectiveness. Pollutant-removal effectiveness increases as the ratio of VFS area to runoff-contributing area increases.

(4) Key elements to be considered in the design of VFS areas follow:

- **Type and Quantity of Pollutant**. Sediment, nitrogen, phosphorus, and toxics are efficiently removed by VFS (see Table 7-9). However, removal rates are much lower for soluble nutrients and toxics.

- **Slope**. VFS function best on slopes of less than 5 percent; slopes greater than 15 percent render them ineffective because surface runoff flow will not be sheet-like and uniform. The effectiveness of VFS is strongly site-dependent. They are ineffective on hilly plots or in terrain that allows concentrated flows.

- **Native/Noninvasive Plants**. The best species for VFS are those which will produce dense growths of grasses and legumes resistant to overland flow. Use native or at least noninvasive plants to avoid negatively impacting adjacent natural areas.

- **Length**. The length of VFS is an important variable influencing VFS effectiveness because contact time between runoff and vegetation in the VFS increases with increasing VFS length. Some sources recommend a minimum length of about 50 feet (Dillaha et al., 1989a; Nieswand et al., 1989; Schueler, 1987). USDA (1988) has prepared design criteria for VFS that take into consideration the nature of the source area for the runoff and the slope of the terrain. Another suggested design criterion that can be found in the literature is for the VFS length to be at least as long as the runoff-contributing area. Unfortunately, there are no clear guidelines available in the literature for calculating VFS lengths for specific site conditions. Accordingly, this guidance does not prescribe either a numeric value for the minimum length for an effective filter strip or a standard method to be used in the design criteria for computing the length of a VFS.

- **Detention Time**. In the design process for a vegetated filter strip, some consideration should be given to increasing the detention time of runoff as it passes over the VFS. One possibility is to design the vegetated filter strip to include small rills that run parallel to the leading edge of the vegetated filter strip. These rills would serve to trap water as runoff passes through the vegetated filter strip. Another possibility is to plant crops upslope of the vegetated filter strip in rows running parallel to the leading edge of the vegetated filter strip. Data from a study by Young and others (1980), in which corn was planted in rows parallel to the leading edge of the filter strip, show an increase in sediment trapping and nutrient removal.

- **Monitoring of Performance**. The design, placement, and maintenance of VFS are all very critical to their effectiveness, and concentrated flows should be prevented. Although intentional planting and naturalization of the vegetation will enhance the effectiveness of a larger filter strip, the strip should be inspected periodically to determine whether concentrated flows are bypassing or overwhelming the BMP, particularly around the perimeter. The vegetated filter strip should also be regularly inspected to determine whether sediment is accumulating within the vegetated filter strip in quantities that would reduce its effectiveness (Magette et al., 1989).

- **Maintenance**. For VFS that are relatively short in length, natural vegetative succession is not intended and the vegetation should be managed like a lawn. It should be mowed two or three times a year, fertilized, and weeded in an attempt to achieve dense, hearty vegetation. The goal is to increase vegetation density for maximum filtration. Accumulated sediment and particulate matter in a VFS should be removed at regular intervals to prevent inundation during runoff events. The frequency at which this type of maintenance will be required will depend on the frequency and volume of runoff flows. Also, if the soil is moderately erodible in the drainage area, additional precautions should be taken to avoid excessive buildup of sediment in the grassed area (NVPDC, 1987). Development of channels and erosion rills within the VFS must be avoided. To ensure effectiveness, sheet flow must be maintained at all times. The maintenance of VFS located adjacent to streams is especially important since sediment bypassing a VFS and entering a coastal waterbody will cause problems for the spawning and early juvenile stages of fish.

Dillaha and others (1989b) showed that many of the VFS installed in Virginia performed poorly because of poor design and maintenance. Consider including one or more of the following items in a VFS maintenance program to make the performance of any VFS more efficient:

- Adding a stone trench to spread water effectively across the surface of the filter;
- Keeping the VFS carefully shaped to ensure sheet flow;
- Inspecting for damage following major storm events; and
- Removing any accumulation of sediment.

b. Construct properly engineered systems of wetlands for NPS pollution control. Manage these systems to avoid negative impacts on surrounding ecosystems or ground water.

Several factors must be considered in the design and construction of an artificial wetland to ensure the maximum performance of the facility for pollutant removal:

Hydrology. The most important variable in constructed wetland design is hydrology. If the proper hydrologic conditions are developed, the chemical and biological conditions will, to a degree, respond accordingly (Mitsch and Gosselink, 1986).

Soils. The underlying soils in a wetland vary in their ability to support vegetation, to prevent percolation of surface water into the ground water, and to provide active exchange sites for adsorption of constituents like phosphorus and metals.

Vegetation. The types of vegetation used in constructed wetlands depend on the region and climate of the constructed wetland (Mitsch, 1977). When possible, use native plant species or noninvasive species to avoid negative impacts to nearby natural wetland areas. There are several guides for the selection of wetland plants such as the *Midwestern Guide to Flora* (USDA) or the Florida Department of Environmental Regulation's list of suggested wetland species.

Influent Water Quality. Characterization of influent water quality, such as the types and magnitude of the pollutants, will determine the design characteristics of the constructed wetland.

Geometry. The size and shape of the constructed wetland will influence the detention time of the wetland, the flow rate of surface water runoff moving through the system, and the pollutant removal effectiveness under "typical" conditions.

Pretreatment. Constructed wetlands should contain forebays to trap sediment before runoff enters the vegetated area of the constructed wetland system. Baffles and diversions should be strategically placed to prevent trapped sediment from becoming resuspended during subsequent storm events prior to cleanout.

Maintenance. Constructed wetlands need to be maintained for optimal performance. Since pollutant removal is the primary objective of the constructed wetland, vegetation and sediment removal are two of the more important maintenance considerations. Properly designed constructed wetlands should not need any maintenance of vegetation. Constructed wetlands must be managed to avoid any negative impacts to wildlife and surrounding areas. For example, non-native or undesirable plant species must be kept out of adjacent wetlands or riparian areas. Contamination of sediments due to toxics entering the constructed wetland must also be controlled. The Kesterson National Wildlife Refuge in California is an excellent example of a case in which selenium contamination in wetland sediments was found to cause deaths and deformities in visiting waterfowl (Ohlendorf et al., 1986). Forebays and deep water areas should be inspected periodically, and excess sediment should be removed from the system and disposed of in an appropriate manner. Other routine maintenance requirements include wildlife management, mosquito control, and debris and litter removal (Mitsch, 1990; Schueler, 1987). As debris and litter collect in the detention basins and vegetated areas, they need to be routinely removed to prevent channelization and outflow blockage from occurring. The area around the constructed wetland should be mowed periodically to keep a healthy stand of grass or other desirable vegetation growing. Structural repairs and erosion control should also be done when needed.

Effectiveness of Constructed Wetlands

Table 7-10 summarizes the pollutant-removal effectiveness of constructed wetland systems built for treatment of surface water runoff. In general, constructed wetland systems designed for treatment of NPS pollution in surface water runoff were effective at removing suspended solids and pollutants that attach to solids and soil particles (refer to Table 7-10). The constructed wetland systems were not as effective at removing dissolved pollutants and those pollutants that dissolve under conditions found in the wetland. When the overall effectiveness data are compared among systems, no discernible trends are apparent. Although attempts to correlate removal effectiveness with an area or volume ratio have not shown any significant trends, the constructed wetlands listed in Table 7-10 still served a valuable role in pollutant removal. Total solids removal ranged from 63 percent to 94 percent among the five systems. Nitrogen removal was not as effective, with effectiveness ranging from 10 percent to 76 percent. Phosphorus removal ranged from 37 percent to 90 percent among the constructed wetland systems compared in this document.

Whether constructed wetlands and VFS are used individually or in series will depend on several factors, including the quantity and quality of the inflowing runoff, the characteristics of the existing hydrology, and the physical limitations of the area surrounding the wetland or riparian area to be protected.

A schematic drawing of a system of filter strips and constructed wetland placed in the path of the existing surface water supply to a stream is shown in Figure 7-2.

5. Costs for All Practices

The use of appropriate practices for pretreatment of runoff and prevention of adverse impacts to wetlands and other waterbodies involves the design and installation of vegetated treatment systems such as vegetated filter strips or constructed wetlands, or the use of structures such as detention or retention basins. These types of systems are discussed individually elsewhere in this guidance document. Refer to Chapter 4 for a discussion of the costs and effectiveness of detention and retention basins. The purpose of each of these BMPs is to remove, to the extent practicable, excessive levels of NPS pollutants and to minimize impacts of hydrologic changes. Each of these BMPs can function to reduce levels of pollutants in runoff or attenuate runoff volume before the runoff enters a natural wetland or riparian area or another waterbody.

Several source documents contain information on costs for vegetated treatment systems. Nieswand and others (1989) published costs for vegetated filter strips employed as part of watershed management strategies for New Jersey. Costs varied over a wide range depending on whether the method of installation involved seeding, sodding, or hydroseeding. Another source of cost information on filter strips is EPA's NWQEP 1988 *Annual Report: Status of Agricultural Nonpoint Source Projects* (1988).

The most comprehensive source of cost data for filter strips was obtained from the USDA ASCS, which provides cost share reimbursement each year to individual farmers for a variety of practices contained in the *National Handbook of Conservation Practices* (1988). Information was obtained from USDA on the costs in each State for work performed in accordance with Specification No. 393 (Filter Strips) in the *National Handbook* for the base year of 1990. Based on these data, a total of 914 filter strip projects were installed with cost share assistance in 28 States. The total cost of these projects was $833,871.00. The total combined length of all projects was 6,443,800 linear feet. If an average width of 66 feet is assumed for the filter strip, then an average cost per acre is calculated at $85.41 per acre, in 1990 dollars.

For constructed wetlands, examples of cost data are as follows:

(1) Lake Jackson, Florida: A cost of $80,769 was reported in 1990 for design and construction of a 9.88-acre constructed wetland for treatment of urban nonpoint runoff (Mitsch, 1990).

Cost in 1990 dollars . . . . $ 8,175.00/acre

(2) Greenwood Urban Wetland, Minnesota: A cost of $20,370 was reported in 1990 for design and construction of a 27.2-acre wetland for treatment of urban nonpoint runoff (Mitsch, 1990).

Cost in 1990 dollars . . . . $ 748.89/acre

(3) Broward County, Florida: A cost range of $10,000 to $100,000 per acre (1992) was given for constructing surface water runoff wetlands on sites of new developments. The average cost for

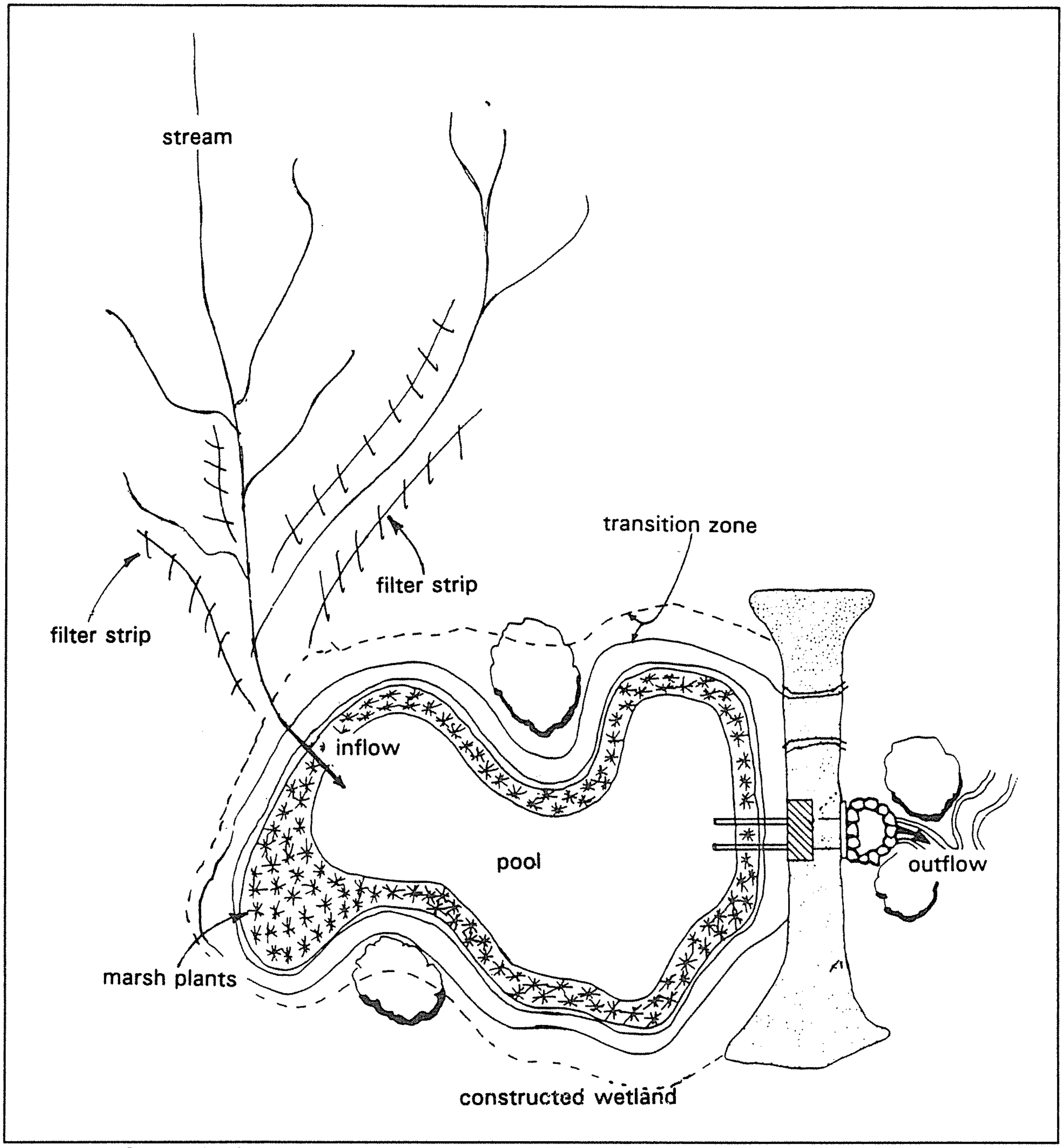

Figure 7-2. Schematic of vegetated treatment system, including a vegetated filter strip and constructed wetland. (After Schueler, 1992).

constructing a wetland was given as $20,000. The costs represent mucking (depositing organic material substrate) and planting emergent wetlands plants. Site monitoring adds $10,000 to $12,000 per year for sites up to 10 acres. (Goldasich, Broward County Office of Natural Resources Protection, personal communication, July 1992).

Cost in 1990 dollars $19,200/acre

It is important to note that the type of constructed wetland facility described in this guidance is for treatment of urban or agricultural runoff. To avoid confusion, costs of wetlands constructed for other purposes, particularly for municipal wastewater treatment, were not considered.

As illustrated by the three examples cited above, the cost per acre of constructed wetlands facilities will vary from site to site. One reason is that certain items of work have economies of scale that are rather limited. For example, costs for site surveys, design, gaining access to the site, mobilization of equipment, and installation of sediment and surface water runoff controls do not necessarily increase in proportion to the size of the project. Other factors that affect costs are regional variations in suitable plant species, treatment of existing surface water flow patterns, and detention/retention capacity.

Based on the cost data contained in the source documents, costs are reported below for three realistic hypothetical scenarios of systems of constructed wetlands and vegetated filter strips.

(1) One filter strip at a cost of . . . . $ 129.00

- Includes design and installation of a grass filter strip 1,000 feet long and 66 feet wide.
- Most effective at trapping sediments and removing phosphorus from surface water runoff.

(2) One constructed wetland at a cost of . . . . $ 5,000.00

- Includes design and installation of a constructed wetland whose surface area is 0.25 acre in size. The constructed wetland is planted with commercially available emergent vegetation.
- Most effective at removing nutrients and at decreasing the rate of inflow of surface water runoff.

(3) One combined filter strip/constructed wetland . . . . $ 5,129.00

III. Glossary

Abiotic: Not biological; not involving or produced by organisms (Merriam-Webster, 1991).

Adsorption: The accumulation of substances at the interface between two phases; in water treatment, the interface is between the liquid and solid surfaces that are artificially provided (Peavy et al., 1985).

Biological assimilation: The conversion of nonliving substances into living protoplasm or cells by using energy to build up complex compounds of living matter from the simple nutritive compounds obtained from food (Barnhart, 1986).

Biotic: Caused or produced by living beings (Merriam-Webster, 1991).

Chelation: The process of binding and stabilizing metallic ions by means of an inert complex compound or ion in which a metallic atom or ion is bound at two or more points to a molecule or ion so as to form a ring; the increasing complex stability of coordination compounds caused by an increasing number of attachments (usually to a metal ion) (Barnhart, 1986; Snoeyink and Jenkins, 1980; Merriam-Webster, 1991).

Chemical decomposition: Separation into elements or simpler compounds; chemical breakdown (Merriam-Webster, 1991).

Complexation: The process by which one substance is converted to another substance in which the constituents are more intimately associated than in a simple mixture; chelation is one type of complexation (Merriam-Webster, 1991).

Connectedness: Having the property of being joined or linked together, as in aquatic or riparian habitats.

Constructed wetland: Engineered systems designed to simulate natural wetlands to exploit the water purification functional value for human use and benefits. Constructed wetlands consist of former upland environments that have been modified to create poorly drained soils and wetlands flora and fauna for the primary purpose of contaminant or pollutant removal from wastewaters or runoff. Constructed wetlands are essentially wastewater treatment systems and are designed and operated as such even though many systems do support other functional values (Hammer, 1992).

Denitrification: The biochemical reduction of nitrate or nitrite to gaseous nitrogen, either as molecular nitrogen or as an oxide of nitrogen.

Ecosystem: The complex of a community and its environment functioning as an ecological unit in nature; a basic functional unit of nature comprising both organisms and their nonliving environment, intimately linked by a variety of biological, chemical, and physical processes (Merriam-Webster, 1991; Barnhart, 1986).

Filtration: The process of being passed through a filter (as in the physical removal of impurities from water) or the condition of being filtered (Barnhart, 1986).

Habitat: The place where an organism naturally lives or grows.

Riparian area: Vegetated ecosystems along a waterbody through which energy, materials, and water pass. Riparian areas characteristically have a high water table and are subject to periodic flooding and influence from the adjacent waterbody. These systems encompass wetlands, uplands, or some combination of these two land forms; they do not in all cases have all of the characteristics necessary for them to be classified as wetlands (Mitsch and Gosselink, 1986; Lowrance et al., 1988).

Sedimentation: The formation of earth, stones, and other matter deposited by water, wind, or ice (Barnhart, 1986).

Species diversity: The variations between groups of related organisms that have certain characteristics in common (Barnhart, 1986; Merriam-Webster, 1991).

Upland: Ground elevated above the lowlands along rivers or between hills (Merriam-Webster, 1991).

Vegetated buffer: Strips of vegetation separating a waterbody from a land use that could act as a nonpoint pollution source. Vegetated buffers (or simply buffers) are variable in width and can range in function from vegetated filter strips to wetlands or riparian areas.

Vegetated filter strip: Created areas of vegetation designed to remove sediment and other pollutants from surface water runoff by filtration, deposition, infiltration, adsorption, decomposition, and volatilization. A vegetated filter strip is an area that maintains soil aeration as opposed to a wetland, which at times exhibits anaerobic soil conditions (Dillaha et al., 1989a).

Vegetated treatment system: A system that consists of a vegetated filter strip, a constructed wetland, or a combination of both.

Wetlands: Those areas that are inundated or saturated by surface water 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, promulgated December 24, 1980. As amendments are made to the wetland definition, they will be considered applicable to this guidance.)

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