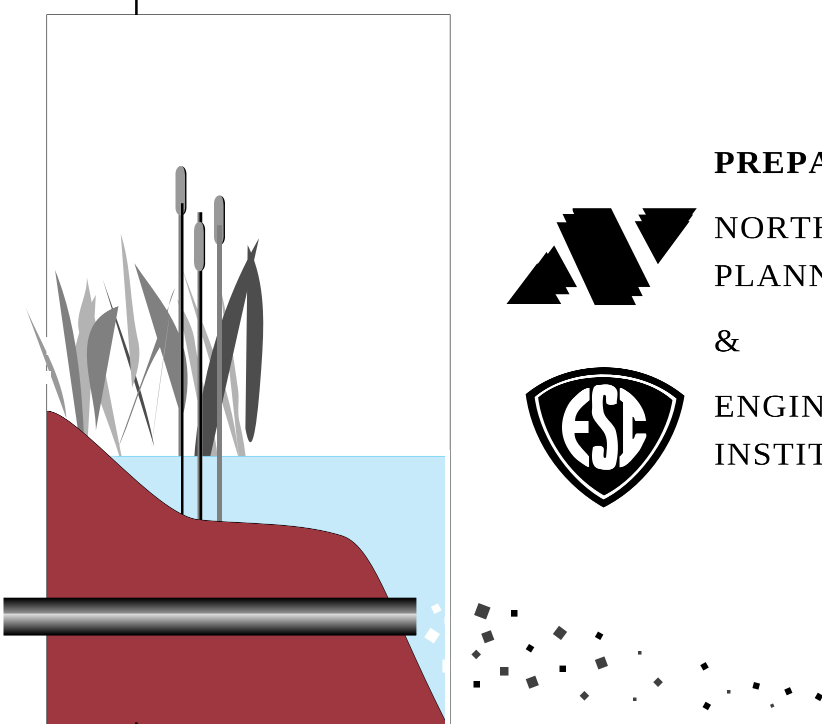
NORTHERN VIRGINIA BMP HANDBOOK

A GUIDE TO PLANNING AND DESIGNING BEST MANAGEMENT PRACTICES IN NORTHERN VIRGINIA



PREPARED BY

NORTHERN VIRGINIA
PLANNING DISTRICT COMMISSION

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ENGINEERS AND SURVEYORS
INSTITUTE

ABSTRACT

TITLE:	Northern Virginia BMP Handbook: A Guide to Planning and Designing Best Management Practices in Northern Virginia
AUTHOR:	Northern Virginia Planning District Commission (NVPDC) Engineers and Surveyors Institute (ESI)
SUBJECT:	Information, recommendations, and design aids for Best Management Practices (BMPs) which are used to improve surface water quality by preventing pollutants from entering major water courses.
DATE:	November 6, 1992
SOURCE OF COPIES:	Northern Virginia Planning District Commission 7535 Little River Turnpike, Suite 100 Annandale, Virginia 22003 Telephone: (703) 642-0700 Fax: (703) 642-5077
PAGES:	302

ABSTRACT:

The contribution of urban stormwater runoff to the problems of surface water quality has received increasing attention and regulation in recent years. *The Northern Virginia BMP Handbook*, which is a regionalized update of the nationally acclaimed *BMP Handbook for the Occoquan Watershed*, is intended for use by designers and reviewers of urban BMPs in meeting the water quality requirements of Northern Virginia. The Handbook includes discussion of the theory and practice of implementing BMP controls, and presents the requirements set by local jurisdictions for calculating phosphorus removal (Occoquan and Chesapeake Bay Methods) as well as for determining site coverage, storage volume, and orifice size requirements for BMPs necessitated by the development of land. Three structural BMPs, including wet ponds, extended detention dry ponds, and infiltration trenches, for which local jurisdictions have accepted pollutant removal efficiencies, are presented. Guidance is provided for when and how experimental and non-conventional BMP facilities may be allowed by local jurisdictions. Non-conventional BMPs which are discussed include both structural (porous pavement, water quality inlets, and underground storage tanks) and nonstructural (street sweeping, grassed swales, vegetative buffer areas, and marsh vegetation) BMPs. Discussions of factors to consider when designing or planning a facility include both physical site constraints (soil suitability, depth to water table, depth to bedrock, slopes, and watershed size) and site usage constraints (proximity to potable water sources and foundations, land availability and cost, recreational use potential, aquatic and terrestrial wildlife habitat values, and maintenance requirements). Also included in the Handbook is a general BMP maintenance guide for privately owned and operated BMP facilities in Northern Virginia. The Handbook was developed as a joint project under the coordinated efforts of Northern Virginia Planning District Commission (NVPDC) and the Engineers and Surveyors Institute (ESI). It was prepared and reviewed by stormwater staff from Northern Virginia jurisdictions and received input from the consulting engineering community.

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Acknowledgments

The Northern Virginia BMP Handbook was made possible through the coordinated efforts of numerous dedicated people from both the public and private community. As a result of their efforts, the Handbook has proven to be a model of interjurisdictional cooperation towards a common objective. While everyone involved with the production of the Handbook deserves recognition, the Northern Virginia Planning District Commission (NVPDC) and the Engineers and Surveyors Institute (ESI) wish to thank the following people as having made particularly significant contributions.

John Friedman of the Fairfax County DEM and Mark Graham of the Arlington County DES deserve special recognition for their work in developing the calculations procedures, as does Ross Fugill with the Fairfax County Soils Science Office for contributing his extensive expertise on infiltration trenches. Fernando Pasquel of the Prince William County Division of Watershed Management also deserves recognition for his role as Chairman of the ESI Joint Public/Private BMP Handbook Committee.

Warren Bell, of the Alexandria Department of Engineering, Transportation and Environmental Services contributed significantly to the area of ultra-urban BMPs by producing the Alexandria Supplement to the Northern Virginia BMP Handbook. Thanks are also in order for Bob Wilson, Director of the Prince William County DPW, John di Zerega, Director of the Fairfax County DPW and their respective staffs for their invaluable input into making the Handbook conform with local regulations.

Perhaps the most significant contributors to the Handbook are the men and women on the ESI Joint Public/Private BMP Handbook Committee who dedicated countless valuable hours during the formulation process and also spent many hours reviewing and re-reviewing the Handbook. The members of this committee are:

Warren Bell	John Friedman	Dave Guetig	Fernando Pasquel
Paul Brazier	Bill Frost	Oscar Guzman	Pete Rigby
David Bulova	Tony Gaffey	William Henry	Jeff Sikes
Jeff Cowan	Mark Graham	Hank Hulme	J. Keith Sinclair
Kimberly Davis	Normand Goulet	Wilson Kirby	Jim Zeller
Linda Erbs-Nagy			William Zink

A complete list of the ESI Joint Public/Private BMP Handbook Committee listing each member's respective place of employment and address is located in Appendix 1-3.

The time and talent put forth by Laz Calfee of the Fairfax County Soil Science Office in creating, designing, and editing the graphics within the text is especially appreciated.

ESI and NVPDC staff that dedicated time to the completion of this project include H. S. Hulme, Jr., Executive Director of ESI, Kimberly V. Davis, Director of Environmental and Planning Services, NVPDC, David L. Bulova, NVPDC, and Normand A. Goulet, NVPDC. The members of the Occoquan Watershed Technical Advisory Committee (Appendix 1-2) have also contributed significantly through their comments. Credit must also be given to those past and present employees of NVPDC and others who compiled the original BMP Handbook for the Occoquan Watershed, much of which is the basis for the current Handbook.

Requirements for Plan Submission

The basic requirements for a BMP plan submission in Northern Virginia are listed below. The designer should check with the individual jurisdiction in which the BMP is to be built for specific plan submission requirements.

1) A brief narrative summarizing how water quality control requirements are being provided for the site.

2) A map showing all subareas used in the computation of weighted average “C” factors, BMP storage, and phosphorus removal including offsite areas, open space, and uncontrolled areas.

3) Open space used for BMP credit should be delineated on the plan sheets with the note: “Water quality management area. BMP credit allowed for open space. No use or disturbance of this area is permitted without the express written permission of (insert local jurisdiction)."

4) Open space used for BMP credit which is not already in a flood plain easement should be placed in a conservation easement with metes and bounds shown on the plat.

5) Computations used to determine BMP outflow rates and size outlet structures.

6) Computation of BMP facility storage requirements.

7) Computation of BMP phosphorus removal for the site.

8) Computation of BMP site coverage.

9) A statement of maintenance responsibility for each BMP (public or private) should be stated on the plans.

Additional information may be required by the director of the plan review agency to justify the use of privately maintained nonstandard designs or in unusual circumstances. The following list indicates the agencies responsible for the review of BMP plans for further questions regarding submission requirements.

Page amended 9/9/94

The *Northern Virginia BMP Handbook* provides general design and planning guidance for designers and reviewers of BMPs in Northern Virginia. It also presents a format for the presentation of BMP design computations required with development plan submissions. However, it should be noted that each individual jurisdiction's public facilities manual (PFM), or its equivalent, ultimately governs the design of facilities which are constructed for the purpose of meeting stormwater quality requirements. Each jurisdiction's PFM is the source reference guide for the designer and in the case of conflicting guidance with the Handbook, the PFM will prevail. It should be recognized that stormwater quality technology, design criteria, and requirements, as well as federal, state, and local laws and regulations, may periodically change. NVPDC and ESI will make every attempt to keep purchasers and recipients of the Handbook informed of these changes.

<u>In all cases, it is advisable and necessary for users of the Handbook to consult the local PFM in conjunction with the Handbook. The following departments are responsible for BMP review in each jurisdiction and should be consulted prior to plan submission.</u>

Local Agencies Responsible for BMP Plan Review

Jurisdiction	Agency	Phone Number
City of Alexandria	Department of Transportation and Environmental Services	838-4327
Arlington County	Department of Public Works	338-3629
Town of Dumfries	General	221-4133
City of Fairfax	Department of Public Works	385-7820
Fairfax County	Department of Environmental Management, Special Projects Branch	324-1780
City of Falls Church	Department of Public Works	240-5080
Fauquier County	Department of Community Development	347-8660
Town of Herndon	Department of Public Works	435-6853
Town of Leesburg	Department of Public Works	771-2790
Loudoun County	Department of Building and Development	777-0397
City of Manassas	Department of Public Works	257-8252
City of Manassas Park	Department of Public Works	257-8372
Prince William County	Department of Public Works, Watershed Management Division	792-7070
Town of Vienna	Department of Public Works	255-6381

NORTHERN VIRGINIA BMP HANDBOOK

Chapter 1
Introduction

I. Introduction

The contribution of stormwater runoff to the problems of surface water quality has received increasing attention and regulation in recent years. The contaminants involved in this stormwater runoff problem are primarily sediment, nutrients, and to a lesser extent toxics, such as heavy metals and hydrocarbons. The diffuse source of these stormwater contaminants has led to the term *non-point source* (NPS) pollution. This term is intended to distinguish such overland runoff from *point source* pollution, which involves a direct pollution source such as effluent that flows from a pipe. Examples of point source pollution are wastewater treatment plant discharges and industrial effluent. Depending on the land use over which the stormwater flows, the impact that NPS pollution has on the environment will vary. This document is aimed primarily at the runoff generated by developed land, sometimes called *urban runoff*.

The techniques developed to improve stormwater quality are referred to by the general environmental control term, “Best Management Practices” (BMPs). This document includes discussion of the theory and practice of implementing BMP controls, and presents the requirements set by local jurisdictions for calculating phosphorus removal as well as determining site coverage and storage volume requirements for BMPs necessitated by development of land in Northern Virginia. Wet ponds, extended detention dry ponds, and infiltration trenches are the only BMPs that have sufficient data available regarding phosphorus removal efficiencies to approve their use based on formal calculations intended to demonstrate compliance with numerical phosphorus removal standards. However, non-conventional and innovative BMPs, which include porous pavement, underground detention tanks, and water quality inlets, and nonstructural BMPs, which include grassed swales, street cleaning, and fertilizer application control, may be appropriate alternatives to conventionally accepted BMPs under some circumstances. Guidance for when they may be allowed by local jurisdictions and associated monitoring requirements to contribute additional data to our understanding of non-point source pollution control are discussed.

This document was developed as a joint project under the coordination efforts of the Northern Virginia Planning District Commission (NVPDC) and the Engineers and Surveyors Institute (ESI). NVPDC is a voluntary council of local jurisdictions which was organized in 1968 to facilitate regional solutions to the area's common problems. ESI is a non-profit organization composed of engineering and surveying firms in Northern Virginia, the Virginia Department of Transportation, and the Counties of Fairfax, Prince William, and Loudoun. The organization was established in 1987 to improve the quality of engineering design plans being submitted to local jurisdictions and to improve the quality of review of those plans. This Handbook is based largely on the "BMP Handbook for the Occoquan Watershed," which was produced by NVPDC in 1987 under the direction of the Occoquan Watershed Policy Board and Technical Advisory Committee. (Refer to Appendix 1-1 and 1-2 for membership rosters). It was prepared and reviewed by staff from Northern Virginia jurisdictions and the Occoquan Watershed Technical Advisory Committee, and received invaluable input from the consulting engineering community. The Handbook has been formally referenced in Public Facilities Manuals or their equivalent, either directly or indirectly, by the jurisdictions listed below:

City of Alexandria	Prince William County
Arlington County	Town of Vienna
City of Fairfax	Town of Leesburg
Fairfax County	
City of Falls Church	
Town of Herndon	
City of Manassas	
City of Manassas Park	

For the remainder of the jurisdictions in Northern Virginia, the Northern Virginia BMP Handbook may be used as a reference guide. The Northern Virginia Planning District Commission and the Engineers and Surveyors Institute will provide periodic updates of the Handbook as changes in technology and public policy occur. Space has been left to update the above list as required. Refer to Figure 1-1 for a location map of Northern Virginia.

Figure 1-1: Location Map of Northern Virginia

II. History of Non-Point Source Pollution Management in Northern Virginia

The Northern Virginia Planning District Commission (NVPDC) has staffed the Occoquan Watershed Non-Point Source Management Board since its inception in 1982. Jurisdictions which participate on this Board include the Counties of Fairfax, Fauquier, Loudoun, and Prince William, and the Cities of Manassas and Manassas Park. Between 1976 and 1978, a special ‘208’ (Clean Water Act) planning study of the Occoquan River Basin was carried out for the Metropolitan Washington Water Resources Planning Board. The results of the study indicated that non-point source pollution loadings in the 580 square mile Occoquan River Watershed (see Figure 1-2) were a significant contributor to water quality problems in the watershed’s receiving waters relative to point source contributions from wastewater treatment plants. Further, these NPS loadings were much higher than originally assumed.

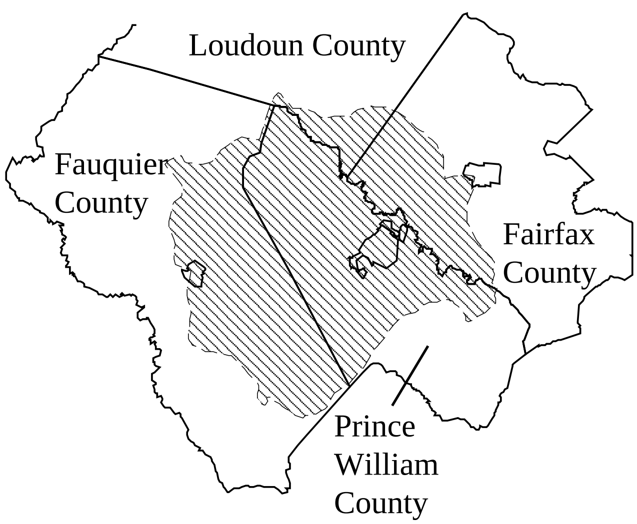


Figure 1-2: Location Map of the Occoquan Watershed

Before Chesapeake Bay controls were instituted for the reaches of the Potomac River downstream from the “Upper Potomac” water supply intake, the most critical receiving water body in Northern Virginia affected by non-point source pollution loadings was the Occoquan Reservoir. The reservoir, located between Fairfax and Prince William Counties, is a primary water supply for approximately 800,000 Northern Virginians. The primary water quality concern in the reservoir, as in many freshwater systems, is eutrophication. Eutrophication is characterized by undesirable growth of algae and is caused by an excess of nutrients (particularly nitrogen and phosphorus), which originate from non-point sources in the watershed. The undesirable algal growth can lead to taste and odor problems in drinking water, fish kills, and unsightly conditions in the reservoir, which would necessitate higher treatment costs to purify drinking water. As a result of the '208' planning study, a Policy for Non-Point Pollution Management in the Occoquan River Basin was included in the Washington Metropolitan Area '208' Plan adopted in 1978.

In accordance with this section of the '208' Plan, NVPDC coordinated the development of a multi-jurisdictional Non-Point Pollution Management Program to supplement the benefits of the watershed's advanced wastewater treatment (AWT) plant. These efforts, begun in 1978, culminated in the establishment of the Occoquan Basin Non-Point Pollution Management Program in February, 1982, which formed a permanent vehicle for managing non-point source pollution in the Occoquan Watershed. The reader is referred to Profile of Non-Point Pollution Management Activities in the Occoquan Basin (NVPDC, 1985) for further information on the history and institutional structure of this unique Watershed Management Program.

III. Regulatory Context

In addition to the implementation of NPS controls to protect the Occoquan Reservoir, non-point source pollution control regulations affecting Northern Virginia localities are governed by the Chesapeake Bay Preservation Act, enacted in 1988, and its pursuant Regulations. The Act is applicable to all Tidewater jurisdictions within Virginia including the Northern Virginia Counties of Arlington, Fairfax, and Prince William, the Cities of Alexandria, Fairfax, and Falls Church, and the Towns of Clifton, Dumfries, Haymarket, Herndon, Occoquan, Quantico, and Vienna. The Act requires that each affected local government designate Chesapeake Bay Preservation Areas which "encompass land features which, if improperly developed, would contribute to the significant degradation of the water quality of the Chesapeake Bay and its tributaries" (CBLAD, 1989). Preservation areas under the Act are to be designated as Resource Protection Areas (RPAs) or Resource Management Areas (RMAs). RPAs are land features which have intrinsic water quality benefits. All tidal wetlands, tidal shores, non-tidal wetlands hydrologically connected by surface flow and bordering on tidal wetlands or tributary streams, and 100 foot buffer areas landward of wetlands, shores, and tributaries must be designated as RPAs. Because of their intrinsic value, RPAs are the most stringently regulated areas. RMAs are those lands which, if not properly managed, have the potential to degrade water quality or diminish the effectiveness of RPAs. Examples of RMAs include, but are not limited to, floodplains, highly erodible or permeable soils, and non-tidal wetlands. To aid in the implementation of these Regulations, the Chesapeake Bay Local Assistance Department (CBLAD) was established and subsequently published the Chesapeake Bay Local Assistance Manual, 1989.

For the local planning and land development community, these Regulations require that all areas within Chesapeake Bay Preservation Areas comply with performance criteria as established by the Chesapeake Bay Act. The "keystone" pollutant used for these performance criteria to determine adequate water quality protection is phosphorus. At a minimum, the Act sets forth a "no net increase in non-point source pollution" policy for new development and mandates a non-point source pollution reduction of 10% for redevelopment. However, localities have the option to adopt local ordinances that are more stringent than the State's minimum requirements.

In addition, the Federal Environmental Protection Agency has issued Regulations (40 CFR Parts 122, 123, and 124) pursuant to the Clean Water Act that require selected jurisdictions to present a plan to improve stormwater quality, and to obtain National Pollution Discharge Elimination System (NPDES) permits for their stormwater outfalls. The standard invoked by the Federal regulations is the Maximum Extent Practicable (MEP) standard, rather than a numerical standard or criteria.

Therefore only the Chesapeake Bay Preservation Act, with its “no net increase” criteria for new development, invokes numerical standards for phosphorus removal. In Northern Virginia, several localities, including the Counties of Fairfax and Prince William, are demonstrating equivalency with this criteria by utilizing a single post-development phosphorus removal requirement of 40 and 50 percent respectively. This method has been designated the "Occoquan Method." The remaining jurisdictions in Northern Virginia utilize the “Chesapeake Bay Method” (a modification of the “Simple Method” developed by the Metropolitan Washington Council of Governments, 1987), as outlined in the Chesapeake Bay Local Assistance Manual, Appendix C, to demonstrate compliance with the phosphorus reduction requirements.

IV. Scope and Organization

The purpose of this Handbook is to provide general design and planning guidelines for designers and reviewers of BMP facilities in Northern Virginia. The criteria and recommendations in this Handbook are based on the combined regulations of Northern Virginia’s local jurisdictions. General BMP screening criteria are presented in Chapter 3. General design calculations which are applicable for all BMP facilities in order to receive phosphorus removal credit are outlined in Chapter 4. General planning guidelines for individual BMP facilities are presented in Chapter 5. Also mentioned are associated considerations for the use of such facilities. The reader should note that these guidelines address considerations regarding the mitigation of water quality impacts, and do not address hydrology, hydraulics, dam design, and stormwater quantity objectives.

The primary emphasis of this Handbook is on permanent structural measures used in urban areas to serve residential, commercial, and industrial uses. However, certain nonstructural urban measures, which may be used in conjunction with structural BMPs, are also addressed. Further, because not all sites are suited for conventional BMPs, several non-conventional and experimental BMP facilities are discussed (Chapter 7). The reader is also referred to the Alexandria Supplement to the Northern Virginia BMP Handbook (Alexandria Department of Transportation and Environmental Services, 1992) for more information on the planning and designing of "ultra-urban" BMP facilities. Non-conventional and experimental BMPs must meet with the approval of the appropriate local plan review agency. Monitoring requirements and other special requirements may apply. Readers interested in agricultural and silvicultural BMPs are referred to other manuals which present detailed design information on those measures. Temporary measures utilized for sediment and erosion control during construction are not addressed in this Handbook. Interested readers should consult the Virginia Erosion and Sediment Control Handbook prepared by the Virginia Division of Soil and Water Conservation (VDSWC, 1992) for detailed design information on such measures.

A summary of minimum submission requirements for BMP plans in Northern Virginia is included at the beginning of this Handbook (page x).

Chapter 2
Theory of BMP Operation

I. Assumptions

Due to the inherent nature of predicting the efficiency of BMP facilities in an extremely variable natural environment, certain assumptions must be made in order to assure uniformity in designing and planning for water quality purposes in the Northern Virginia region. These assumptions are determined in a variety of ways. When possible, they are based on the most recently available scientific evidence; however, because BMP facilities are often subject to uncontrollable elements and also must take into account policy implications for political, social, and economical institutions, assumptions may have a public policy aspect as well. This chapter will cover the major assumptions which have been used throughout this Handbook.

II. The Nature of Non-Point Source Pollution

Non-point source (NPS) pollution is defined as pollution which is generated from diffuse sources, such as stormwater runoff and atmospheric fallout, as opposed to a "point source," such as an industrial wastewater outfall. The primary pollutants in NPS runoff include soil sediment, nutrients, heavy metals, and hydrocarbons. Under natural conditions, any pollutants and nutrients which may collect are neutralized through biological uptake, chemical breakdown, and soil infiltration, and an ecosystem develops in balance with the amount of nutrients in that natural environment. However, urbanization renders much of the land surface impervious, thus greatly increasing both the volume and velocity of runoff. In a moderately developed watershed, peak discharges are generally two to five times greater than pre-development discharges (MWCOG, 1987). Figure 2-1 presents the changes in a stream's hydrology before and after the urbanization of a watershed. During storm events, pollutants are picked up and flushed directly into local streams without being filtered by the soil or natural vegetative cover. Nationally, urban runoff accounts for approximately 5 percent of non-point source pollution in rivers and 12 percent of non-point source pollution in lakes (USDA, 1991). In rapidly urbanizing areas such as Northern Virginia, the percentage of non-point source pollution resulting from urban runoff will be much higher.

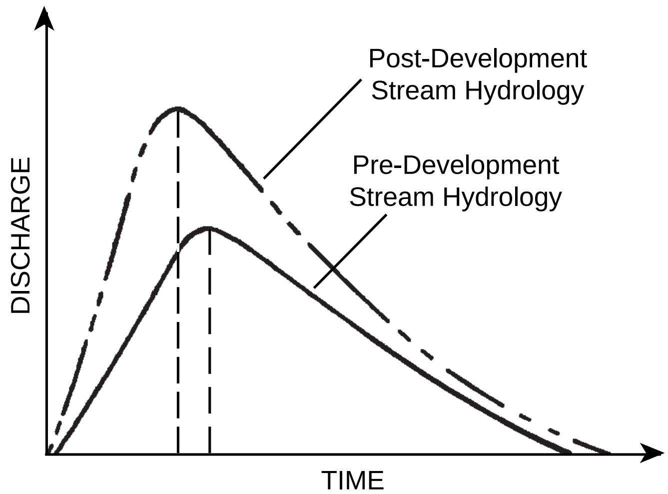


Figure 2-1: Pre and Post-Development Stream Hydrology
(Adapted from DeGroot, 1982)

In the Northern Virginia region, the greatest threats posed by non-point source pollution are excess nutrients, particularly phosphorus, which is the controlling pollutant for eutrophic conditions in fresh water environments. As demonstrated in Figure 2-2, nutrients and sediments account for approximately 80 percent of all non-point source pollution to the nation's lakes. Some common sources of phosphorus include weathering and solution of phosphate materials, atmospheric deposition, groundwater, agricultural and urban runoff, domestic and industrial sewage, septic systems, and waterfowl waste. Excessive phosphorus loadings are of great concern to local water systems, such as the Occoquan Reservoir and the Potomac River, because they result in eutrophication which

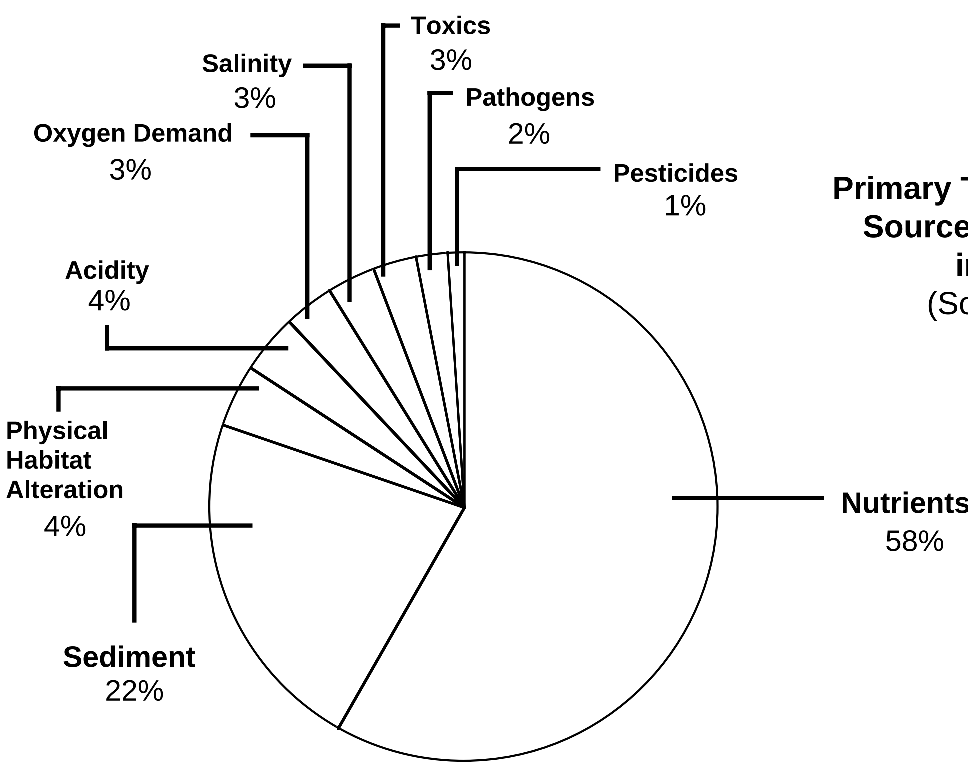


Figure 2-2: Primary Types of Non-Point Source Pollution in Lakes in the United States
(Source: USDA, 1991)

greatly reduces the useful lifespan of the water resource. Eutrophic conditions, as opposed to oligotrophic conditions, are characterized by low dissolved oxygen levels and high algal growth (refer to Figure 2-3). The primary detrimental effect of eutrophication on a water resource is algal blooms, which block sunlight from aquatic life and deplete the dissolved oxygen content during decay. Eutrophication also destroys the recreational use of a water resource and results in strong odor and undesirable taste.

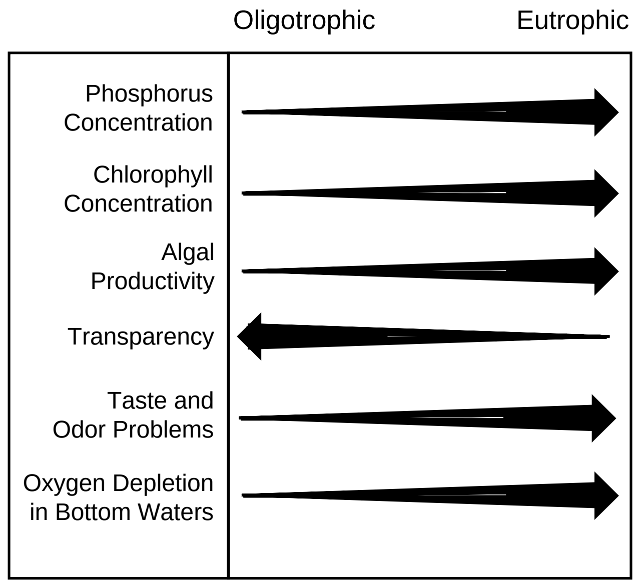


Figure 2-3: Symptoms of Fresh Water Eutrophication
(Adapted from Novotny and Chesters, 1981)

Phosphorus exists in two physical forms, particulate and dissolved. The particulate form accounts for 40 to 50 percent of the total phosphorus, while the dissolved form accounts for the remaining 50 to 60 percent based on typical Northern Virginia soils. For BMP devices which rely primarily on sedimentation, such as the extended detention dry pond, phosphorus removal is limited to a maximum of 40 to 50 percent because only the particulate form will settle out. However, the addition of other factors, such as biological uptake and chemical break-down by the vegetative cover and soils, may enhance the efficiency of these devices.

Uncontrolled urban runoff can also lead to erosion and rilling of non-protected surfaces due to the increased volume and velocity of runoff during storm events. This results in the degradation of the topsoil and the undercutting of streambanks and building structures. Due to increased velocity, sediment particles do not have the opportunity to settle out before reaching lakes and reservoirs. The extended detention time provided by BMP facilities, however, allows these sediment and nutrient particles to settle out before reaching the water course. According to the Army Corps of Engineers, 4.7 million cubic yards of sediment were dumped into the Chesapeake Bay by its tributary rivers in 1990 alone (U.S. Army Corps of Engineers, 1991). Sediments have the effect of clogging natural stream and river outlets, blocking sunlight, and killing benthic aquatic life which forms the base of the food chain. Sediments are also efficient carriers of toxic materials and other pollutants. The costs of excessive sedimentation include expensive dredging of navigable rivers and a reduction in recreational value.

III. Purpose and Function of BMPs

"Best Management Practices," or BMPs, are structural or nonstructural practices, or a combination of practices, designed to act as effective, practicable means of minimizing the impacts of development on surface water quality. BMPs operate by trapping stormwater runoff and detaining it until unwanted phosphorus, sediment, and other harmful pollutants are allowed to settle out or be filtered through the underlying soil. These trapped pollutants should then be disposed of through periodic maintenance in an environmentally sound manner.

The most common examples of structural BMPs include extended detention dry ponds, wet ponds, and infiltration trenches. Some nonstructural BMPs, which may be used in conjunction with structural controls, include street cleaning, vegetative buffer areas, grassed swales, and fertilizer application control. Most nonstructural BMPs do not have an assigned phosphorus removal efficiency and therefore their use will require approval from the local jurisdiction.

IV. Principles of Mitigating Water Quality Impacts

The basic mechanisms of pollutant removal operating in BMP facilities are the gravitational settling of pollutants, infiltration of soluble nutrients through the soil profile, and to a lesser extent, biological and chemical stabilization of nutrients. Extended detention dry ponds utilize settling as the primary removal process, with some nutrient uptake by the vegetative cover and soils. Wet ponds utilize settling as their principle removal method as well, but the existence of a permanent pool also promotes biological and chemical uptake and some infiltration through the soil horizon. Wet ponds also serve to diminish turbulent conditions which may result in the resuspension of sediments and pollutants. Infiltration trenches rely heavily on filtration through the soil profile for pollutant removal with some biological and chemical stabilization of pollutants.

A) Settling

The establishment of a temporary or permanent pool of water, such as is utilized in both extended detention dry and wet ponds, results in quiescent conditions which can settle out particulate pollutants between storms. This method can remove up to 40 to 50 percent of the total phosphorus in stormwater. The particulate materials settle into the pond bottom sediments while some of the soluble pollutants may pass through the sediment to the soil profile below by means of infiltration. The pollutants are not typically resuspended unless pool depths are so shallow as to allow resuspension by the effects of influent velocity or wave action.

B) Biological and Chemical Processes

Removal of soluble pollutants is accomplished primarily through the mechanisms of chemical and biological stabilization of nutrients. The biological activities of some species of plants, algae, and other aquatic organisms can serve as a mechanism for removing soluble nutrients from the water column. Dissolved oxygen levels, temperature, sunlight, and pH affect the biological stabilization of the pond. The underlying soil has also been identified as contributing to chemical transformation of nutrients in wetlands and BMP facilities.

C) Soil Infiltration

Infiltration is usually achieved by lining a trench with a stone aggregate and a surrounding filter fabric to act as a filter medium and to remove much of the suspended sediments and attached contaminants before entering the soil horizon. Subsequent passage of water through the underlying soil column provides further filtering and pollutant removal through aerobic decomposition and chemical precipitation. This method is most effective in removing certain amounts of dissolved phosphorus in addition to the particulate portion.

An important concern which arises from the infiltration process is the potential infiltration of polluted stormwater through the soil column to the water table. In some instances this could add contaminants to the underlying aquifer system. This is of special concern if the aquifer is to be used as a potable water supply in nearby areas. In addition, the contribution of nutrients to groundwater may affect local streams whose baseflow derives significantly from groundwater, thereby re-introducing nutrients into the surface water that the BMP was designed to protect. This concern is discussed in Chapter 3, “Screening Criteria for BMPs,” Section II (B).

Chapter 3
Site Selection Screening Criteria for BMPs

I. Introduction

In order to most effectively implement a BMP system, it is necessary for the designer to determine which type of BMP facility is most appropriate for the physical characteristics of the site as well as the intended usages of the site. Physical site constraints may include soil suitability, depth to water table, depth to bedrock, slope, and watershed size. Site usage and other constraints may include proximity to potable water sources and foundations, land availability and cost, recreational use potential, aquatic and terrestrial wildlife habitat values, and maintenance requirements. In many instances, individual BMP facilities may be modified to account for site constraints, while in other cases, it may eliminate a BMP facility as an option altogether. These considerations must then be reconciled to meet the criteria presented in Chapter 4 of this Handbook.

Designers often combine BMPs to create a more efficient system. A BMP system may incorporate one major type of structural facility in combination with grassed swales, vegetative buffer areas, marsh vegetation, and other nonstructural BMPs in order to achieve the desired storage volume and site coverage requirements. At times, nonstructural BMPs may be required or desirable in order for the structural BMP to operate at maximum efficiency. The prudent designer will consider and take advantage of the site's topography.

The following sections outline the more common screening considerations for BMPs when dealing with physical site constraints and site usage. Other site specific BMP selection screening considerations, including stormwater volume management and pollutant removal efficiencies, are addressed separately for individual BMP facilities in Chapter 5. For detailed information regarding screening for environmental amenities and stormwater management benefits, refer to MWCOG's BMP Handbook (1987).

II. Screening for Physical Site Attributes

A) Soil Suitability

Soil suitability is a major consideration when designing a BMP facility. This is particularly true when designing infiltration trenches and wet ponds. In determining the suitability of wet ponds, it is recommended to conduct a soil investigation of the material at the depth representing the bottom of the pond to determine whether the soil will maintain a permanent pool. Special treatment of the *in situ* soil or the addition of low permeable fill may be required in the final design.

Because much of Northern Virginia has soils poorly suited for infiltration trenches, it is strongly suggested that the feasibility of the proposed site for an infiltration trench be established early in the planning process. It is recommended to consult each jurisdiction's soil scientist for a feasibility assessment before considering an infiltration trench at a particular site. In those jurisdictions which do not have a soil scientist, a soil survey may be used. If a soil survey is not available, then a private soil consultant may be retained to do a site feasibility assessment.

Texture Class	Minimum Infiltration Rate	Hydrologic Soil Grouping
Sand	8.27 in/hr	A
Loamy Sand	2.41 in/hr	A
Sandy Loam	1.02 in/hr	B
Loam	0.52 in/hr	B
Silt Loam	0.27 in/hr	C
Sandy Clay Loam	0.17 in/hr	C
Clay Loam	0.09 in/hr	D
Silty Clay	0.04 in/hr	D
Clay	0.02 in/hr	D

Table 3-1: Hydrologic Soil Properties Classified by Soil Texture
(Source: Rawls, Brakensiek, and Saxton, 1982)

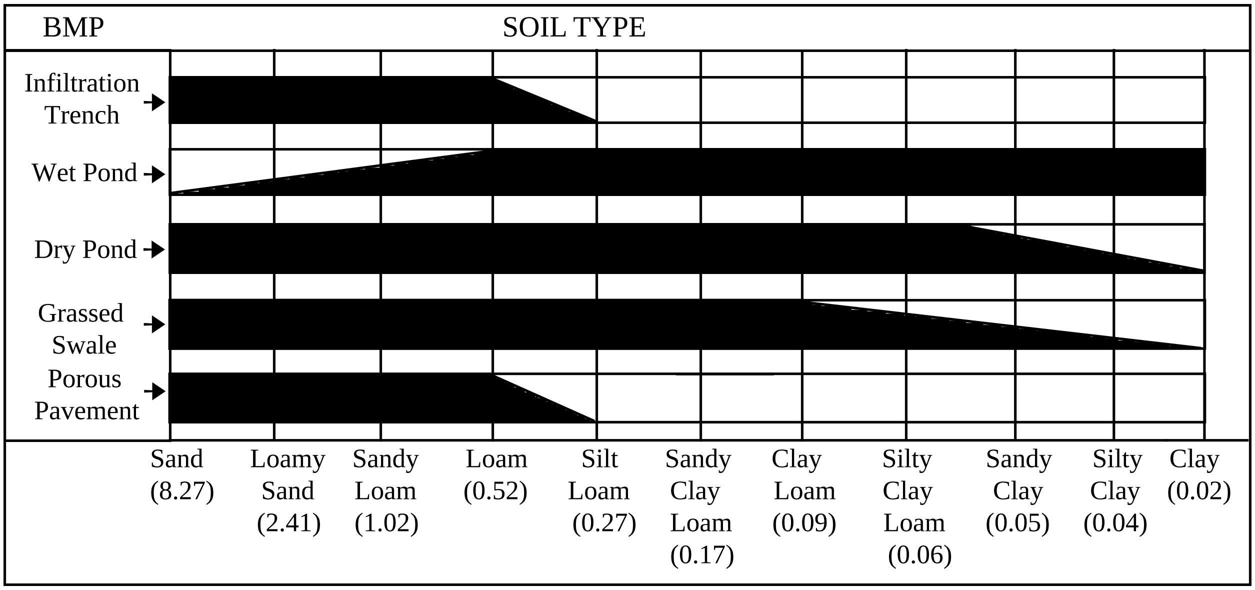


Figure 3-1: Soil Type and BMP Suitability
(Adapted from MWCOG, 1987)

The soil conditions which limit infiltration facilities are shallow depth to seasonal high water table, shallow depth to bedrock, and slow permeability. Typically, soils with an estimated permeability of less than 0.27 in/hr are not suitable for infiltration BMPs. Table 3-1 presents hydrologic soil properties classified by soil texture. This limitation generally excludes soil series categorized in the SCS Hydrologic Groups “C” and “D." USDA soils texture can be used to make a rough estimate of soil permeability (see Appendix 3-1). The approximate suitable permeability range for each type of BMP facility is shown in Figure 3-1.

B) Depth to Water Table

For BMP facilities which depend upon infiltration through the soil, such as infiltration trenches, the depth to the seasonal high water table is an important consideration. The movement of water from the structure into the underlying soil (exfiltration) can be impeded by a high water table. The size and shape of the facility, as well as the hydrologic properties of the soil, determine the impact of water table elevation on infiltration performance. For screening purposes, one should consider soils having a seasonal high water table at depths less than four feet below the surface to be unsuitable for infiltration trenches.

C) Depth to Bedrock

For BMP facilities which rely upon infiltration, the depth to bedrock becomes a consideration. Exfiltration of water from the facility into the underlying soil can be impeded by a shallow depth to bedrock. For screening purposes, one should consider soils having bedrock within four feet of the surface to be generally unsuitable for infiltration trenches. Depth to bedrock may also become a consideration during the excavation process for both extended detention dry ponds and wet ponds.

D) Slopes

The slope of a site will greatly limit the type of BMP facility which may be utilized on a particular site. Grassed swales and porous pavement, in order to be effective, must not be situated on a slope greater than 5 percent. Infiltration trenches are limited to a maximum slope of 20 percent. Infiltration trenches are prohibited from being utilized in fill sites due to the possibility of slope failure.

E) Watershed Area to be Served

The size of the watershed area to be served by a BMP facility is a significant consideration when designing a BMP system. Depending on the size of the watershed, certain BMP facilities may be more efficient and/or cost effective than others.

Generally, infiltration trenches should not be used for drainage areas of more than 10 acres and are most efficient for drainage areas of 5 acres or less, where soil considerations permit their application. Above this threshold, other BMP facilities are likely to be more effective. Extended detention dry ponds and wet ponds, depending upon site suitability, are applicable for a very broad range of drainage areas. For sites in which baseflow becomes a consideration, extended detention dry ponds must have structural provisions to accommodate the baseflow. A reliable baseflow is necessary to establish a wet pond. Baseflow, in general, will become a consideration with BMPs serving more than 50 acres. However, springs or other site specific considerations must be taken into consideration to establish whether or not a baseflow exists in any sized drainage area. As a general rule, four (4) acres of drainage area can support one (1) acre foot of permanent storage in a wet pond facility.

Refer to Figure 3-2 for selected general site constraints for infiltration trenches.

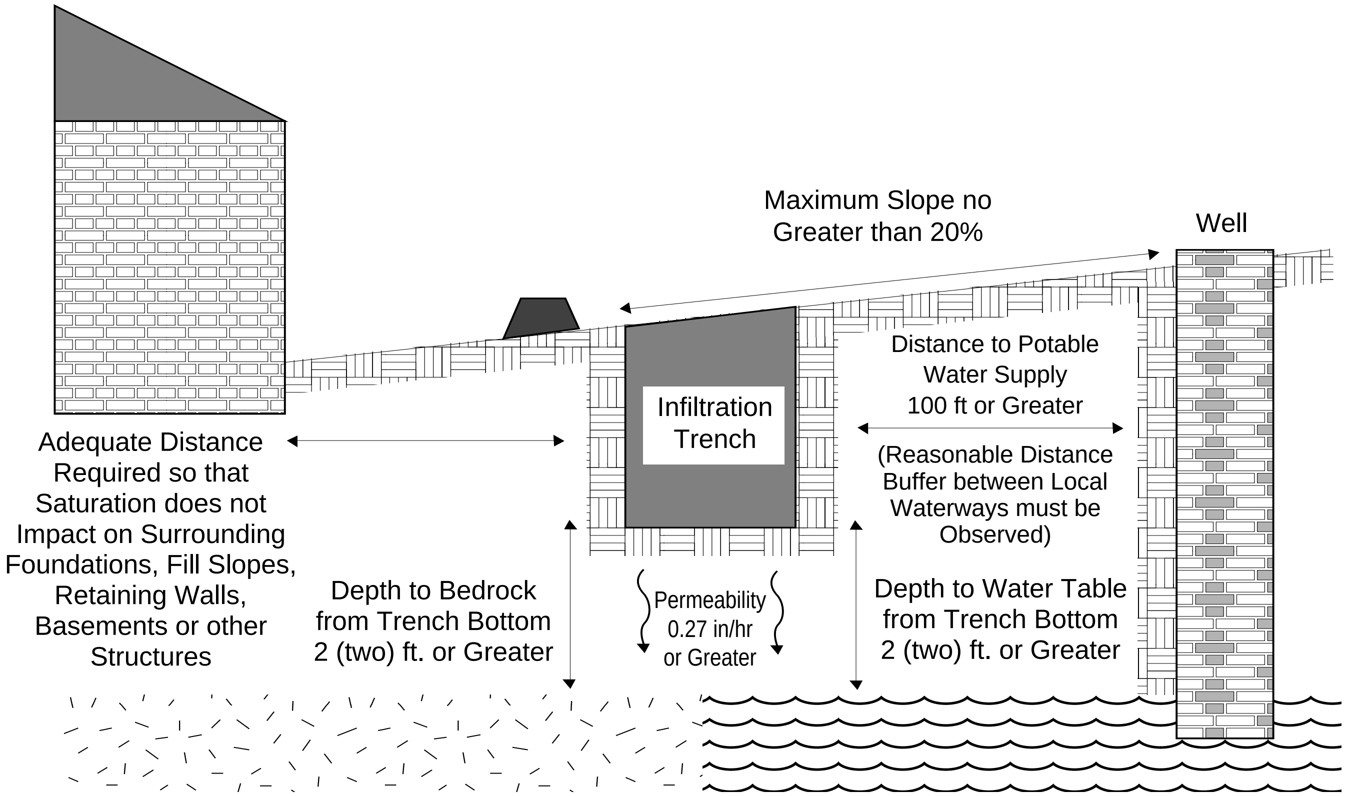


Figure 3-2: Selected General Site Constraints for Infiltration Trenches

III. Screening for Site Usage and Other Considerations

A) Proximity to Water Sources and Foundations

For BMPs utilizing infiltration, several considerations arise concerning soil saturation and the introduction of pollutants into nearby water sources. In order to avoid damage to nearby structures as a result of soil saturation, infiltration trenches are not to be situated where the soil saturation would be expected to impact building foundations, fill slopes, retaining walls, basements, or other underground structures.

To avoid contaminating any surrounding potable water supplies, infiltration trenches must not be located closer than 100 feet from an active water supply well. Further, the BMP should not be situated where the expected zone of saturation would impact an onsite sewage disposal facility which could result in the contamination of the storage reservoir with effluent. Finally, infiltration trenches should observe a reasonable distance buffer from local waterways and streams.

B) Land Availability

Because land availability may be limited and/or land prices prohibitive, it is necessary to screen for the amount of space which may be required by individual BMP facilities. Infiltration trenches are primarily used for areas which are too small to situate a wet pond or other related facility. They can also be incorporated into multi-use areas. Conversely, infiltration trenches are not useful for sites serving a drainage area of more than 5 acres. Wet ponds utilize the greatest amount of space and may be impractical for smaller lots, or areas where land prices are prohibitive. The extended detention dry pond is of intermediate size and applicability.

C) Recreational Use Potential

Since BMP facilities utilize valuable space, designers may want to consider the potential recreational uses for individual BMP facilities. Recreational uses can be active or passive.

Passive uses, which may include jogging trails, bird watching, and picnic tables, are often incorporated into open spaces. Extended detention dry ponds may also be configured for use as a playing field (an active recreational use) when the facility is not inundated. Particular care must be taken when dealing with the recreational use of a facility so that human and/or other activity does not contribute to erosion or pollution processes.

Active uses for wet ponds include boating, fishing, swimming, and skating. These activities, however, may require supervision for safety and liability reasons. In most cases, these activities are discouraged unless the facility is managed by a local park authority or private recreational corporation.

D) Aquatic and Terrestrial Wildlife Habitat Values

Potential BMP sites are often located along streams or in other areas with potentially significant aquatic and/or terrestrial wildlife habitat values. The wildlife habitat values of BMP sites should be given consideration during site screening, planning, design, preparation, and construction. Sites with high habitat values should be avoided and/or efforts made to minimize adverse impacts to the habitat and disruption of wildlife corridors. Opportunities to enhance or protect wildlife habitat, e.g. with conservation easements, should be pursued.

E) Maintenance

All BMP facilities require maintenance. However, there is a substantial difference among BMP designs in the degree of maintenance required for efficient performance. When selecting a BMP, the maintenance requirements for each BMP (see Chapter 6) should be evaluated in terms of cost, responsibility (public/private), feasibility, and access.

The first screening consideration is the frequency of maintenance which the facility will require. As a general rule, infiltration trenches require the most attention. This is because they are extremely vulnerable to being damaged by the clogging effects of sediment. Special attention must be given to sediment control systems in the long-term maintenance program. Failure to keep sediment out of an infiltration trench can result in a costly and disruptive repair. Wet ponds and extended detention dry ponds generally require less frequent maintenance than infiltration trenches; however, a schedule of regular maintenance is required for these types of facilities. In order to extend the effective life span of wet ponds, extended detention ponds, and particularly infiltration trenches, it is imperative that the facility be properly maintained.

The second consideration is the cost of maintaining the facility. Wet ponds are the most expensive to maintain because they require periodic dredging and de-watering of sediment. The single most effective measure to reduce the costs of maintaining a wet pond is by providing dredge spoil areas onsite. Maintenance costs for an infiltration trench can be reduced if it has an effective sediment control system. Conversely, an infiltration trench which is allowed to clog with sediment may be the most expensive practice in the long term due to the cost of restoration (NVPDC, 1992a). Copies of Maintaining BMPs: A Guidebook for Private Owners and Operators in Northern Virginia, (NVPDC, 1992b) which provides general BMP maintenance guidelines for private owners and operators of BMPs, are available from NVPDC free of charge.

NOTE: This section provides only an overview of the most common BMP screening considerations. The designer should take into account aesthetic or stormwater management considerations as well. Designers should consult their local jurisdiction for specific requirements and regulations concerning screening of individual BMPs.

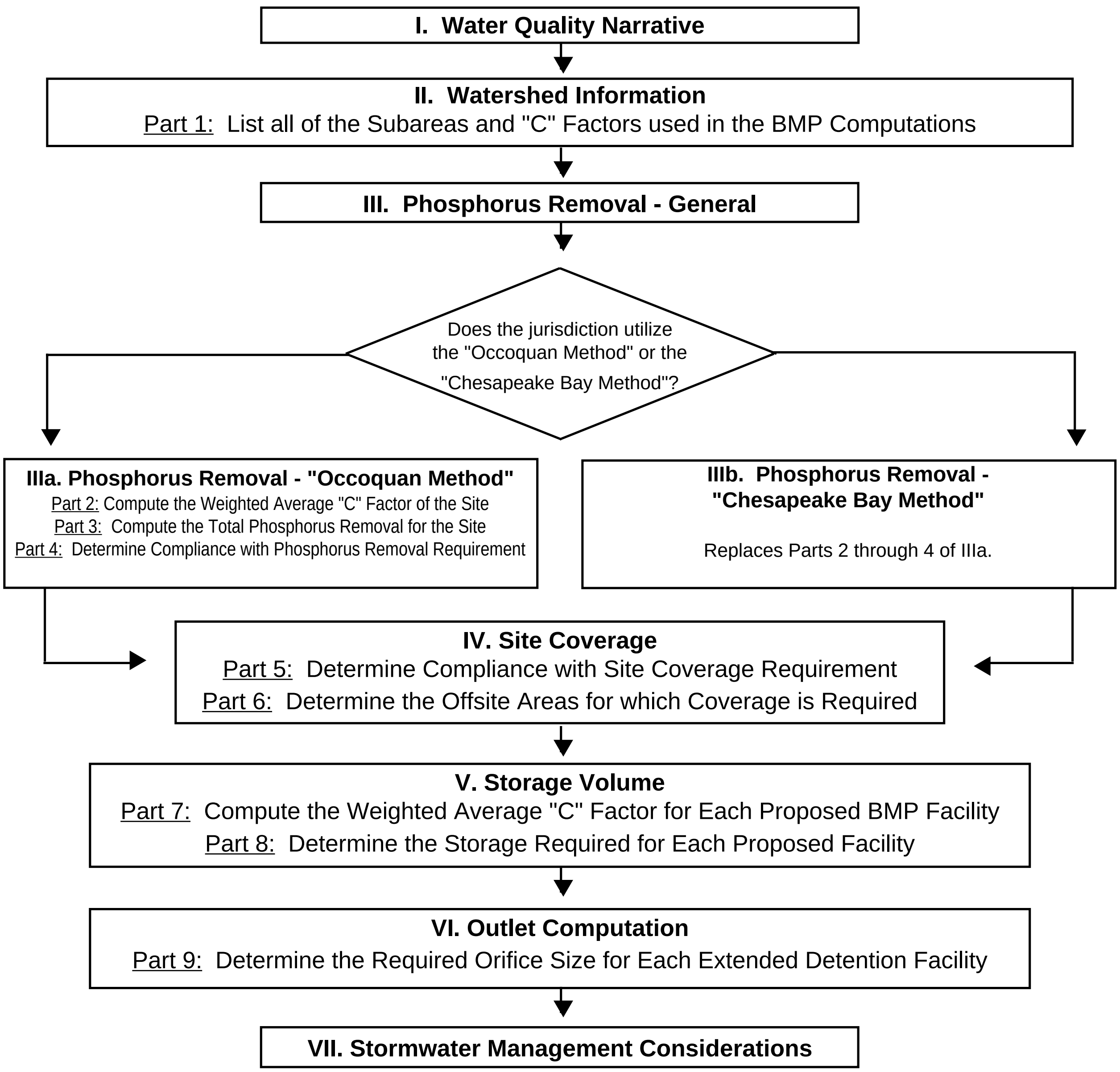
Chapter 4
General Design Calculations

This chapter presents the calculations required for the overall design of a BMP system for a site. The chapter will focus on the calculations required to show compliance with the water quality requirements and general facility design parameters related to these requirements. Procedures for computing phosphorus removal and determining storage volume, site coverage requirements, and orifice size requirements are included. Stormwater quantity considerations are addressed in general terms with references to the appropriate jurisdictional requirements. The reader must note that the considerations detailed in this chapter do not address stormwater quantity management requirements unless specifically noted. Specific requirements regarding BMP facilities may apply for individual jurisdictions and the reader should check with the appropriate review agency accordingly. Blank worksheets are provided in Appendix 4-4 and sample calculations are provided in Appendix 4-5. General plan submission requirements are found on page x at the beginning of the Handbook.

The most effective control of all is to reduce the generation of pollutants at the source. This is best accomplished by setting aside areas of land in a natural and undisturbed state and preserving it from future development and/or activities which would generate pollutants, such as the application of herbicides and pesticides. Qualifying open space can be either forested or natural meadow and must be placed in floodplain or conservation easements without overlying encumbrances. For example, utility easements within floodplains cannot be considered qualifying open space because land disturbance and vegetation growth control may occur as the result of maintenance activities within the easement. Under normal circumstances, conservation and floodplain easements on private residential lots do not qualify as open space because the easement requirements for conservation of natural vegetation are not enforceable from a practical standpoint. It should be noted that in some instances, best practical design dictates that significant natural undisturbed areas may occur on land that local jurisdictions may find unenforceable from an easement standpoint. These areas, which may include large tree save areas on private lots, may be considered on a case by case basis by the regulatory agency as qualifying open space. Additionally, land areas that are creatively engineered to reclaim land to a natural state such as wetland mitigation areas may be given consideration as a qualifying open space. Qualifying open space is treated as a land use credit rather than a control. Check with the local review agency for specific requirements and credits allowed for open space.

BMP Facilities Design Calculations

The remainder of Chapter 4 consists of BMP facility design calculations worksheets with the accompanying explanations. Blank design calculations worksheets are found in Appendix 4-4 of this Handbook. Examples of design calculations are presented in Appendix 4-5. General plan submission requirements are found on page x at the beginning of the Handbook. The following flow-chart presents the organization of Chapter 4.



The design calculations, with the exception of Section IIIb, which was developed by the Arlington County Department of Environmental Services, were developed by the Fairfax County Department of Environmental Management. All criteria were reviewed by Northern Virginia localities and local consulting engineers.

I. Water Quality Narrative

All BMP facility designers will be required to submit a Water Quality Narrative to the appropriate reviewing agency. The water quality control narrative consists of a brief description of what the requirements are, how they will be met, and what type(s) of controls will be used. Although it is presented first in the design format, it is generally written after all design computations are completed.

The narrative will include the following information where applicable:

- What the water quality control requirements are (e.g. 50% phosphorus removal, water quality inlets, etc.); what areas of the site are subject to the requirements; and, what creates the requirement (e.g. Water Supply Overlay District, Resource Management Area, Resource Protection Area, proffered condition, or special permit condition).
- The number and types of structural BMPs used.
- Use of qualifying open space for BMP credit.
- Offsite areas which are being controlled.
- Contributions to the construction of regional BMPs.
- Interim water quality control requirements and BMPs for sites with permanent BMP facilities to be built in the future.
- Waivers, deferrals, or approved modifications to normal design criteria related to the BMPs.
- Maintenance responsibility for the BMPs (public or private).
- Any related agreements with offsite property owners.

The BMP facility designer should consult with the appropriate reviewing agency for any additional items which may be required in the water quality narrative. A list of BMP regulatory agencies and their phone numbers is listed at the beginning of this Handbook.

II. Watershed Information

Part 1: List all of the Subareas and "C" Factors used in the BMP Computations

Subarea Designation and Description (1)	"C" (2)	Acres (3)

NOTE: Rational formula "C" factors are taken from the general zoning values listed in Appendix 4-1 or 4-2 depending on the location of the BMP facility [Fairfax County Public Facilities Manual Chart A6-19 (1988) or Prince William County Design and Construction Standards Manual, Exhibit 1 (1985)].

List all of the subareas with their associated "C" factors that are to be used in the BMP design computations. These subareas and "C" factors will also be shown on an accompanying map.

- In developing the subareas to be used in the design computations, remember that the purpose is to be able to compute weighted average "C" factors for the site and for each proposed BMP facility, and to perform the phosphorus removal computations. Additional guidance in developing the required subareas is available in Parts 3, 4, 5, 6, and 7 of these instructions. At a minimum, you will need one subarea for each BMP utilized, including open space, and for all uncontrolled onsite areas. If offsite areas are being controlled, they should be listed as separate subareas.

- In order to determine the required number of subareas, first select a suitable map base and overlay the drainage divides based on the final site grading and locations of proposed and existing structural BMP controls. The map base should cover all of the areas draining through the site. Next, further divide these areas by overlaying the proposed land use. For offsite areas, always assume the maximum density possible. This would correspond to the greatest of the existing density, existing zoning, or planned land use from the comprehensive plan. If only a portion of the site is subject to water quality controls, delineate those areas on the map. Finally, show on this map all of the open space qualifying for BMP credit. This procedure should yield all of the subareas needed to perform the BMP computations. Remember, in preparing the list of subareas, list each subarea only once. A short description of each subarea included with the list will aid in the review of the plan (e.g. "A1 onsite uncontrolled" or "B3 onsite open space" or "C2 onsite controlled to Pond 2").

- Rational formula “C” factors are to be selected from the general zoning values listed in Appendix 4-1 or 4-2 depending on the jurisdiction in which the BMP facility is to be built. The percent imperviousness can be substituted for the rational formula “C" factor directly in the design of extended detention facilities and infiltration facilities. If % imperviousness is used and “C” factors are needed to compute storage requirements, the designer should estimate “C” factors from the % imperviousness, soil type, and slope. For the purposes of computing BMP storage only, the relationship between % imperviousness and rational formula “C” factor can be expressed as : (“C” = 0.00714 x % imp. + 0.20). [This formula was derived from Fairfax County PFM Chart A6-40 and is not to be used in performing other types of hydrologic computations. Refer to Appendix 4-3.]

- If the offsite property is undeveloped or developed without controls, use 0.20 x the area of the property draining to the facility. The site coverage requirement of 80% implies that a maximum of 20% of the undeveloped or redeveloped offsite property will be uncontrolled. Whenever these areas appear in computations, they should be preceded by the multiplier of 0.20 in parentheses and the area reduction performed as part of the computation so that there is no confusion regarding whether or not the area reduction has been performed. For example, in the watershed data listing in this section, the offsite area would be shown as:

Subarea Designation and Description (1)	"C" (2)	Acres (3)
B3 Offsite Undeveloped	0.65	(0.20) 46.5

or when computing the weighted average "C" factor in Part 7 the area would be shown as:

Subarea Designation (1)	"C" (2)		Acres (3)		Product (4)
B3 Offsite Undeveloped	0.65	X	(0.20) 46.5	=	6.045

- If the offsite property has BMPs, use the actual uncontrolled offsite area draining to the proposed facility.

- Under some circumstances, full credit may be allowed for control of offsite areas which are undeveloped or developed without BMPs provided there is sufficient reason to believe that they cannot be practically controlled by other means. In these instances, the 0.20 multiplier would not be used. Two examples of these kinds of areas are existing highways and areas too small to be controlled by individual facilities.

III. Phosphorus Removal - General

For those designing BMP facilities within Northern Virginia, it is necessary to calculate the phosphorus removal capability of the proposed system. Phosphorus removal in Northern Virginia will be calculated differently depending on the particular local jurisdiction in which the BMP facility is to be built. For Northern Virginia jurisdictions that do not utilize the Chesapeake Bay Local Assistance Department's (CBLAD) "Chesapeake Bay Method," which is a modification of MWCOG's "Simple Method," for phosphorus removal calculations, Section IIIa should be utilized. The method presented in Section IIIa is referred to as the "Occoquan Method" and was developed by Fairfax County. For jurisdictions which utilize the "Chesapeake Bay Method," Section IIIb, which was designed by Arlington County, should be used. The designer should check with the local jurisdiction to determine the appropriate method to use.

BMP phosphorus removal efficiencies are the same for Northern Virginia jurisdictions unless otherwise noted. Table 4-1 presents the accepted removal efficiencies for BMPs in Northern Virginia.

Facility Type	Removal Rate
• Extended Detention Dry Pond	
Design (i) (Chart "A")	40%
Regional	50%*
• Wet Pond	
Design (i) (4.0 x Vr)	50%
Design (ii) (2.5 x Vr + Extended Detention)	45%
Regional (4.0 x Vr)	65%*
• Infiltration Trench	
Design (i) (0.5 in/imp. ac.)	50%
Design (ii) (1.0 in/imp. ac.)	65%
Design (iii) (2-year 2-hour storm)	70%

* *NOTE:* Phosphorus removal credit and specific requirements for the establishment of regional ponds may vary between jurisdictions. The designer should contact the appropriate agency before consideration of such a facility.

Table 4-1: Phosphorus Removal Efficiencies for Different BMP Facilities

Phosphorus removal efficiencies can be increased as shown in Table 4-1 for regional stormwater management (SWM) facilities that meet the following criteria:

- The regional SWM facility is part of a watershed-wide SWM plan which considers environmentally sensitive features and minimizes negative impacts on them. The locality may permit onsite SWM facilities to be considered as regional facilities, if the drainage area served and controlled by the facility is approximately 100 acres or greater.

- The design of the regional SWM facility may include sediment forebays and aquatic benches, if applicable.

- The entire drainage area is used in determining BMP volume and phosphorus removal requirements.

Table 4-1a lists individual jurisdictions and the appropriate phosphorus removal calculations method to be used with this Handbook as determined by each local jurisdiction. It is advised that the reader contact the individual jurisdiction to confirm that the method listed below is the current method being utilized.

Table 4-1a: Phosphorus Removal Calculation Method to be Used for Local Jurisdictions

Jurisdiction	Phosphorus Removal Calculation Method
Arlington County	Chesapeake Bay Method
City of Alexandria	Chesapeake Bay Method
Town of Dumfries*	Chesapeake Bay Method
Fairfax County	Occoquan Method
City of Fairfax	Chesapeake Bay Method
City of Falls Church	Chesapeake Bay Method
Town of Herndon	Chesapeake Bay Method
Town of Leesburg	Chesapeake Bay Method
County of Loudoun**	Not Applicable
City of Manassas	Occoquan Method
City of Manassas Park	Occoquan Method
Prince William County	Occoquan Method
Town of Vienna	Chesapeake Bay Method

*The Town of Dumfries does not officially reference the Handbook. The user should contact the Town for direction on which calculation method is preferred.

**The County of Loudoun does not presently utilize this Handbook for the calculation of phosphorus removal. The user should contact the County for direction.

IIIa. Phosphorus Removal - "Occoquan Method"

This section is for use in the jurisdictions which do not utilize CBLAD's "Chesapeake Bay Method" for phosphorus removal calculations. The "Chesapeake Bay Method" is addressed in Section IIIb of this chapter. Please check with your local jurisdiction to determine which method to use.

The following general principles have been used in developing the worksheets provided in this Handbook for the computation of phosphorus removal.

1. A minimum of 80% of the site should be served by a combination of structural and nonstructural controls.

2. Offsite land use must always be assumed to be at ultimate density.

3. Both extended detention dry pond and wet pond pollutant removal rates fall off rapidly as storage capacity is reduced below the design storage. In order to achieve the listed pollutant removal efficiency, proposed BMP facilities should provide storage for all of the uncontrolled areas flowing into them.

4. Credit for control of offsite areas which do not provide their own controls is allowed. If the offsite areas are undeveloped or may be redeveloped, it is assumed that 80% site coverage will be provided and only 20% of the offsite area will be controlled for credit. Under some circumstances, full credit may be allowed for control of offsite areas which are undeveloped or developed without BMPs provided there is reason to believe that they can not be practicably controlled by other means.

5. The phosphorus removal credit achieved by each facility is proportional to the "C" factor and the land area served by that facility.

Part 2: Compute the Weighted Average “C” Factor for the Site

The weighted average “C” factor (Rational Formula) is computed for the area of the site subject to BMP requirements.

(A) Area of the site (a) ____________ acres

Enter the area of the site in the space marked (a)_______. This establishes the base area for which BMP requirements are to be satisfied.

- For multi-phase projects, a single BMP computation can be performed for the entire development and the combined area of all phases entered here (optional).
- If you are providing coverage for an adjoining development through a legal agreement, include the combined area of both developments here as if it was a single project with two phases.
- If you are claiming full or partial credit for control of an offsite area, do not include the offsite area here.
- If the site is within an RPA or an RMA and one section of the project would be considered redevelopment, separate worksheets should be used for the new development and the redevelopment portions.

(B) Subarea Designation (1)	"C" (2)		Acres (3)		Product (4)
________________	_______	X	_______	=	__________
________________	_______	X	_______	=	__________
________________	_______	X	_______	=	__________
________________	_______	X	_______	=	__________
________________	_______	X	_______	=	__________
________________	_______	X	_______	=	__________
________________	_______	X	_______	=	__________
________________	_______	X	_______	=	__________
________________	_______	X	_______	=	__________
________________	_______	X	_______	=	__________
			(b) Total	=	__________

Select the subareas of the site corresponding to the above from the list in Part 1 and enter the information in the appropriate columns. The product of the "C" factors and the corresponding areas is computed, totaled, and entered in the space marked (b)_______.

- At this stage, the site need only be divided into the number of subareas necessary to account for variations in land use which would cause differences in "C" factors. However, the need to superimpose the drainage divides based on the final site grading and BMP locations will create additional subareas.

(C) Weighted average "C" factor (b) / (a) = (c) __________

The weighted average "C" factor is computed by dividing Line 2(b) by Line 2(a) and entering the results in the space marked (c)_______.

Part 3: Compute the Total Phosphorus Removal for the Site

Subarea Designation (1)	BMP Type (2)	Removal Eff. (%) (3)		Area Ratio (4)		"C" Factor Ratio (5)		Product (6)
________	________	________	X	____________	X	____________	=	_________
________	________	________	X	____________	X	____________	=	_________
________	________	________	X	____________	X	____________	=	_________
________	________	________	X	____________	X	____________	=	_________
________	________	________	X	____________	X	____________	=	_________
________	________	________	X	____________	X	____________	=	_________
________	________	________	X	____________	X	____________	=	_________
________	________	________	X	____________	X	____________	=	_________
________	________	________	X	____________	X	____________	=	_________
________	________	________	X	____________	X	____________	=	_________
________	________	________	X	____________	X	____________	=	_________

(a) Total = _________%

Column (1): List all of the subareas of the site, as defined in Part 2, here; and, any additional offsite areas which are being controlled.

- At a minimum, there should be one subarea for each BMP utilized, including open space, and all uncontrolled areas. Because of variations in land use, it would not be considered unusual to have more than one subarea for each facility.

- Offsite areas should always be listed as separate subareas.

- The subareas listed here for the structural BMPs should match those used in the storage design computations in Part 7.

Column (2): List the type of BMP controlling each subarea. Additional credit for practices in series is not allowed without prior approval from the reviewing agency. If practices in series are being used, list them in the order that the water flows through them.

Column (3): List BMP efficiencies in percent. Uncontrolled areas should be assigned an efficiency of 0%. BMP efficiencies may be found in Table 4-1.

Column (4): The ratio of the area of each subarea to the area of the site computed in Part 2(A) is listed here. Remember to use the (0.20) multiplier for offsite undeveloped areas as appropriate.

Column (5): The ratio of the "C" factor of each subarea to the "C" factor of the site computed in Part 2(C) is listed here. The "C" factor ratio for open space should be set to 1.0 since open space is treated as a land use credit rather than a structural control.

Column (6): The Removal Efficiency (3) is multiplied by the Area Ratio (4) and the "C" Factor Ratio (5) and the product is listed in column (6).

Add the products listed in column (6) and show the total in the space marked (a)_______. This is the total phosphorus removal achieved for the site including all credits for control of offsite areas.

Part 4: Determine Compliance with Phosphorus Removal Requirement

(A) Select Requirement (a) _______

- Water Supply Overlay District
  (Occoquan Watershed) = 50% (Fairfax County and Prince William County)
- Chesapeake Bay Preservation Area
  (New Development) = 40% (Fairfax County)
  50% (Prince William County)
- Chesapeake Bay Preservation Area
  (Redevelopment) =
  [1-0.9 x (“I”pre / “I”post)] x 100 = __%

In situations where more than one of the requirements applies, the most stringent shall be used.

(B) If Line 3(a) ______ ≥ Line 4(a) ______ then Phosphorus removal requirement is satisfied.

IIIb. Phosphorus Removal Calculations - "Chesapeake Bay Method"

Section IIIb is to be used by those designing BMP facilities in jurisdictions which utilize the phosphorus removal requirements outlined by the Chesapeake Bay Local Assistance Department's (CBLAD) Local Assistance Manual, Appendix C. CBLAD has designated total phosphorus as the "keystone pollutant" which is to be used as the measure of pollutant removal to conform with the Virginia Chesapeake Bay Preservation Act. The calculation method used to determine compliance with the Act is known as the "Chesapeake Bay Method," which is largely modelled after MWCOG's "Simple Method." This method is intended for areas of one square mile or less. For larger areas, the applicant may propose a more sophisticated analysis if it is based on sound engineering principles. The calculation for the "Chesapeake Bay Method" is as follows:

$$L = P \times Pj \times \{0.05 + 0.009(I)\} \times C \times A \times 2.72 / 12$$

Where:

- L = phosphorus loadings (lbs / yr)
- P = average rainfall depth (inches)
  - P = 40 inches per year for Northern Virginia
- Pj = unitless correction factor for storms that produce no runoff
  - Pj = 0.9
- I = the percent of site imperviousness in whole numbers.
- C = flow-weighted mean pollutant concentration (mg / l)
  - C = 0.26 mg / l when $I<20\%$
  - C = 1.08 mg / l when $I>20\%$
- A = area of development site (acres)

The method makes a distinction between new development and redevelopment. New development, as defined by CBLAD, means the construction, or substantial alteration, of residential, commercial, industrial, institutional, recreational, transportation, or utility facilities or structures. Redevelopment means the process of developing land that is or has previously been developed. Using CBLAD's methodology, this establishes which base condition applies, either the average watershed condition for new development or 90% of the existing runoff for redevelopment. Provisions are also made for a reduced buffer equivalency. The following calculations were developed by the Arlington County Department of Environmental Services. No claims are made as to the accuracy and reliability of these calculations. A Lotus spreadsheet of the Arlington calculations is available free upon request. For more information, contact the Arlington County Department of Public Works at (703) 338-3629.

NOTE: Phosphorus Removal Calculations Replace Parts 2 Through 4 of Section IIIa.

1) Enter Site Name ______________________________________

2) Calculate Existing Site Imperviousness

(A) Pavement Area
(Include roads, driveways, sidewalks, paved trails, etc.) ____________S.F.
(B) Structures Area
(Include houses, sheds, patios, etc.) ____________S.F.
(C) Landscaped Areas
(Include lawns, gardens, unpaved walks or trails, etc.) ____________S.F.
(D) Undisturbed Areas
(Include woods, wetlands, unmaintained or natural areas) ____________S.F.

Total area (E) = ____________S.F.
/ 43,560 = __________acres
Site imperviousness {(A+B)/E} x 100 = _____________%

3) Calculate Proposed Site Imperviousness

(A) Pavement Area
(Include roads, driveways, sidewalks, paved trails, etc.) ____________S.F.
(B) Structures Area
(Include houses, sheds, patios, etc.) ____________S.F.
(C) Landscaped Areas
(Include lawns, gardens, unpaved walks or trails, etc.) ____________S.F.
(D) Undisturbed Areas
(Include woods, wetlands, unmaintained or natural areas) ____________S.F.

Total area (E) = ____________S.F.
/ 43,560 = __________acres
Site imperviousness {(A+B)/E} x 100 = _____________%

4) Site Conditions

(A) Enter Name of Watershed ____

(B) Enter Watershed Imperviousness as a Percentage from Figure 4-1 _______%

(C) Determine Whether Proposal is Considered New Development
or Redevelopment ____

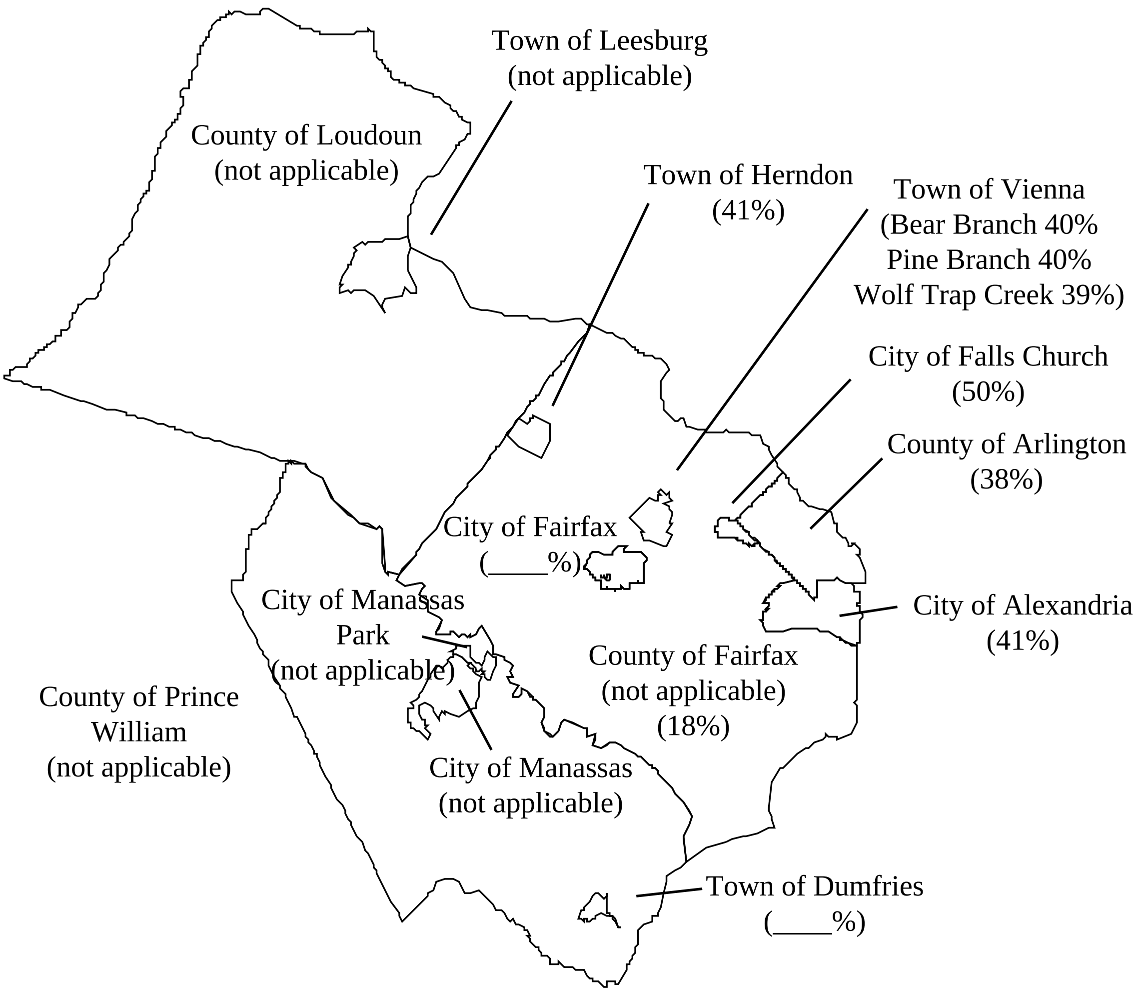


Figure 4-1: Local Watershed Imperviousnesses by Jurisdiction

NOTE: While Arlington County and the City of Alexandria use one jurisdiction-wide imperviousness, other localities may distinguish between separate watersheds. The designer should refer to individual jurisdictions for the appropriate definitions of "new development" and "redevelopment."

N/A refers to not applicable.

5) Phosphorus Loadings

- Refer to the description of the "Chesapeake Bay Method" presented at the beginning of Section IIIb for further explanation of variables used for the phosphorus removal calculations.

(A) Existing Phosphorus Loading:

New Development:
L(pre)= 36 x {0.05 + 0.009(Iwshed_______)} x (C)______ x (A)______ x 2.72 / 12

Redevelopment:
L(pre)= 36 x {0.05 + 0.009(Isite/pre_______)} x (C)______ x (A)_____ x 2.72 / 12

L(pre) = _________Lbs/Year

(B) Proposed Phosphorus Loading:

New Development:
L(post) = 36 x {0.05 + 0.009(Isite/post______) x (C)_____ x (A)______ x 2.72 / 12

Redevelopment:
L(post) = 36 x {0.05 + 0.009(Isite/post______) x (C)_____ x (A)______ x 2.72 / 12

L(post)= _________Lbs/Year

6) Phosphorus Removal Required

(A) Phosphorus Removal Required:
New Development
Removal Required = Lpost ________- Lpre________ = ___________Lbs/year

Redevelopment
Removal Required = Lpost ________- 0.9 (Lpre______) = __________Lbs/year

(B) BMP Removal Required:
Removal Required__________ x 100 / Lpost __________= ____________%

7) Phosphorus Removal Satisfaction

(A)

- Site coverage may consist of onsite and offsite credits. Credit given for offsite areas covered by the proposed BMP facility will vary depending on the particular jurisdiction and the nature of the offsite areas to be covered. Please consult the individual jurisdiction for more information.

- Site coverage is measured from the percentage of impervious area covered by a BMP facility and is to be expressed in decimal form, i.e., 100% onsite coverage =1.0.

- Not for use with BMPs in series.

BMP Facility	Removal Eff. (%/100)	x	Imp. Site Coverage (Onsite) + (Offsite)	x	Lpost (lbs/yr)	=	Load Removed (lbs/yr)
________	__________		(_______ + _______)		_______		__________
________	__________		(_______ + _______)		_______		__________
________	__________		(_______ + _______)		_______		__________
					Total =		__________

x 100/Lpost = (A) ____________%

(B)

If Line 6(B) _____ < Line 7(A) _____ then phosphorus removal is satisfied.

If Line 6(B) _____ > Line 7(A) _____ then phosphorus removal is <u>not</u> satisfied.

IV. Site Coverage

Part 5: Determine Site Coverage

Sum all the uncontrolled onsite areas and compute a weighted average "C" factor. Do not include qualifying open space.

Subarea Designation (1)	"C" (2)		Acres (3)		Product (4)
______________________	_______	X	_______	=	_________
______________________	_______	X	_______	=	_________
______________________	_______	X	_______	=	_________
______________________	_______	X	_______	=	_________
______________________	_______	X	_______	=	_________

(A) Total equivalent uncontrolled area (a) Total = _________

List all of the uncontrolled onsite areas and their associated "C" factors. Do not include qualifying open space. The product of the "C" factors and their corresponding areas is computed, totaled, and entered in the space marked (a) _______.

(B) Total uncontrolled area (b) _________

Enter the total uncontrolled area (sum of the areas in column 3) in the space marked 5(b) _______. Compute uncontrolled area by multiplying Line 5(b) by 100 and dividing by Line 2(a) = _______%. If the uncontrolled area is less than 80%, the designer should attempt to provide at least 80% site coverage whenever feasible.

(C) Weighted average "C" factor (a)/(b) = (c) ___________

The weighted average "C" factor is computed by dividing Line 5(a) by Line 5(b) and entering the quotient in the space marked (c) ________.

Divide the uncontrolled area of the site, Line 5(b), by the total area of the site from Line 2(a); multiply by 100 and enter in the space marked (d) ________. If this value is less than 20%, then the site coverage requirement is satisfied.

Part 6: Determine the Offsite Areas for which Coverage is Required

(A) For the offsite areas listed in Part 1 which flow to proposed onsite BMPs compute the equivalent areas.

Subarea Designation (1)	"C" (2)		Acres (3)		Product (4)
____________________	________	X	________	=	__________
____________________	________	X	________	=	__________
____________________	________	X	________	=	__________
____________________	________	X	________	=	__________
____________________	________	X	________	=	__________
____________________	________	X	________	=	__________
____________________	________	X	________	=	__________
____________________	________	X	________	=	__________
____________________	________	X	________	=	__________

(a) Total = __________

For the offsite areas listed, which are not considered part of the base site area listed in Part 2(B), compute the equivalent onsite areas based on the "C" factor of the offsite area. The product of the "C" factors and the corresponding areas is computed, totaled, and entered in the space marked (a) __________.

- If the equivalent offsite area, Line 6(a), draining to all proposed BMP facilities is greater than the equivalent uncontrolled area of the site shown in Line 5(a); then, the offsite area controlled by the proposed BMP facilities may be reduced until the two are equal. Otherwise, all uncontrolled offsite areas draining to the proposed BMP facilities must be included. All offsite areas thus reduced should be marked with an "*" wherever they appear in the computations.

- The purpose here is not to require compensating control of offsite areas for uncontrolled onsite areas; but to assure proper functioning of the BMPs. When storage is not provided for the uncontrolled offsite water draining through a facility, the facility will be hydraulically overloaded and not function at its design efficiency. In order to address this issue, some control of offsite areas will be required for all sites which do not achieve 100% site coverage if their facilities are located such that offsite water flows through them. Since a small site may have a large drainage area, and in the interest of fairness, an upper limit on the offsite area for which control would be required is established. However, controls may be provided for as much of the uncontrolled offsite area draining through each facility as desired in order to obtain additional phosphorus removal credit.

V. <u>Storage Volume</u>

Part 7: Compute The Weighted Average "C" Factor for Each Proposed BMP Facility

The weighted average "C" factor (Rational Formula) is computed for the total area to be controlled by the proposed BMP facility. This step should be repeated for each proposed facility.

(A) List the areas to be controlled by the proposed BMP.

Subarea Designation (1)	"C" (2)		Acres (3)		Product (4)
________________	________	X	________	=	________
________________	________	X	________	=	________
________________	________	X	________	=	________
________________	________	X	________	=	________
________________	________	X	________	=	________
________________	________	X	________	=	________

(a) __________

Enter the total of the onsite and offsite areas (including qualifying open space) to be controlled by the proposed BMP facility in the space marked (a) ________.

- The drainage area to the proposed BMP facility should be divided into the number of subareas necessary to account for variations in land use which would cause differences in "C" factors and between onsite and offsite areas.

- The onsite area controlled by the proposed facility normally includes all of the area draining to that facility except for areas which are to be controlled by other proposed or existing facilities. Qualifying open space is to be included even though it does not contribute materially to the storage requirement.

- The offsite area controlled by the proposed facility should include all of the uncontrolled offsite area draining to that facility. When storage is not provided for the uncontrolled offsite water draining through a facility, the facility will be hydraulically overloaded and not function at its design efficiency. In order to address this issue, some control of offsite areas will be required for all sites which do not achieve 100% site coverage if their facilities are located such that offsite water flows through them. An upper limit (see Part 5) has been placed on the extent of the offsite areas for which control will be required. However, controls may be provided for as much of the uncontrolled offsite area draining through each facility as desired in order to obtain additional phosphorus removal credit.

- If the offsite property is undeveloped or developed without controls, use 0.20 x the area of the property draining to the facility. The site coverage requirement of 80% implies that a maximum of 20% of the undeveloped or redeveloped offsite property will be uncontrolled. If the offsite property has BMPs, use the actual uncontrolled offsite area draining to the proposed facility.

- Under some circumstances, full credit may be allowed for control of offsite areas which are undeveloped or developed without BMPs provided there is sufficient reason to believe that they cannot be practically controlled by other means. Two examples of these kinds of areas are existing highways and areas too small to be controlled by individual facilities.

- "C" factors for undeveloped offsite areas should be based on ultimate "build-out" conditions.

(B) (b) _________

Compute the product of the "C" factors and the areas and enter in column (4). Total the products and list in the space marked (b) _________.

(C) Weighted average "C" factor (b)/(a) = (c) ___________

The weighted average "C" factor is computed by dividing Line 7(b) by Line 7(a) and entering the quotient into the space marked (c) _________.

Part 8: Determine the Storage Required for Each Proposed Facility

(A) Extended Detention Dry Pond

Chart "A" value (Appendix 4-3) for BMP storage per acre
[(4375 x "C") - 875] or [31.25 x %Imp.] = (a) __________ cf/ac

• Design 1 (48 hour drawdown)
Line 7(a) ________ x Line 8(a) _________ = __________ cf

Determine the BMP storage volume required per acre for extended detention using Appendix 4-3 or either of the formulas provided and enter in the space marked (a).

Multiply the area to be controlled, Line 7(a), by the BMP storage per acre, Line 8(a) to compute the required storage.

- Chart "A" (Fairfax County PFM Chart A6-40) was derived from the results of a study performed by NVPDC (1979). The "Storage-Treatment" model developed by NVPDC was used to investigate potential detention basin design modifications. The purpose of the investigation was to determine storage volumes which would allow improved sedimentation of runoff from minor to moderate storm events. A range of rainfall depths over a variety of land uses was used in the model and compared to the amount and size of sediment particles that could settle out. The results of the study, shown in Chart "A," reflect the fact that areas of lower imperviousness should store runoff from a small storm (0.1 inch) while areas of higher imperviousness should store runoff from a more intense storm (0.78 inch) in order to achieve the same pollutant removal rates. For more information, the reader is referred to the Guidebook for Screening Urban Non-Point Pollution Management Strategies (NVPDC, 1979).

(B) Wet Pond

Volume of runoff per acre from mean storm.
[1452 x "C"] = 1452 x Line 7(c) = (b) __________ cf/ac

• Design 1 (2.5 x Volume of runoff from mean storm event in wet storage with extended detention above the permanent pool)

Wet Storage
2.5 x Line 7(a) _______ x Line 8(b) ________ = _________ cf

Extended Detention
Line 7(a) ________ x Line 8(a) _________ = __________ cf

• Design 2 (4.0 x Volume of runoff from mean storm)
4.0 x Line 7(a) _______ x Line 8(b) ________ = _________ cf

Determine the volume of runoff from the mean storm from the formula provided using the "C" factor and enter in the space marked (b) _______.

Multiply the area to be controlled, Line 7(a), by the BMP storage per acre, Line 8(b) to compute the required storage.

- The formula is based on an average annual rainfall of 40.0 inches per year and an average of 100 storms per year. The expanded formula would be [(40.0 in/100) / (12 in/ft) x (43,560 sf/ac) x area].

(C) Infiltration Trench

• Design 1 (0.50 inch per impervious acre)
0.50 x 36.30 x (% imp.) _____ x Line 7(a) ______ = _______ cf

• Design 2 (1.0 inch per impervious acre)
1.0 x 36.30 x (% imp.) _____ x Line 7(a) _______ = _______ cf

• Design 3 (2-year 2-hour storm)
(2.0/12) x 43,560 x "C" _____ x Line 7(a) ______ = _______ cf

Enter the % imp. (e.g. 20% not 0.20) or "C" factor as appropriate and the area to be controlled, Line 7(a), and perform the indicated multiplication to compute the required storage.

VI. Outlet Computation

Part 9: Determine The Required Orifice Size for Each Extended Detention Facility

The orifice size for extended detention storage is computed using the standard orifice equation with a 48 hour drawdown time from the full pool BMP volume and an orifice coefficient of 0.60. The BMP (extended detention) volume and the maximum head at the BMP volume are the only information required to perform the computation.

(A) BMP storage requirement (S) from Part 8. (a) __________

The extended detention volume from line 8(a) ______ is entered in the space marked (a) ______.

- Please note that the volume to be placed here is the required BMP volume not the BMP volume actually provided. If the BMP volume provided is greater than the volume required and the orifice size is computed on that basis, the result will be inadequate detention times on smaller storms because of too large an orifice.

(B) Maximum Head (h) at the required BMP storage from the elevation-storage curve for the facility. (b) __________

Enter maximum head (h) at the required BMP storage from the elevation-storage curve for the facility.

- Measure the head from the BMP water surface elevation to the centroid of the orifice not the invert of the orifice.

(C) Peak outflow rate (Q_p) at the maximum head for a drawdown time of 48 hrs [Q_p = S/(0.5 x 3600 x 48)].

0.0000116 x Line 9(a) _________ = (c) __________

Compute the peak outflow rate (Qp) at the maximum head for a drawdown time of 48 hours from the BMP volume in line 9(a) ________ and enter in the space marked (c) ________.

(D) Required orifice area (A) [$A = Q_p / (0.6 \times (64.4 \times h)^{0.5})$]
Line 9(c) _______ / [0.6 x (64.4 x Line 9(b) ________)$^{0.5}$] = (d) __________

Compute the required orifice area from the peak outflow rate and maximum head and enter in the space marked (d) _________.

(E) Diameter of a circular orifice.
2.0 x (Line 9(d) _________ / 3.1415927)$^{0.5}$ = (e) ____________

Compute the diameter of a circular orifice from the required orifice area and enter in the space marked (e) ________.

VII. Stormwater Management Considerations

In addition to being designed for stormwater quality control, BMPs are typically designed for stormwater quantity control. If BMPs are proposed to be used to control the quantity of stormwater runoff by reducing peak flow rates, then the jurisdiction's stormwater management requirements will apply in addition to the BMP requirements.

For communities that have not established local stormwater management criteria, the State's criteria must be followed. These criteria are set forth in Chapter 4 of the Virginia Erosion and Sediment Control Handbook prepared by the Virginia Division of Soil and Water Conservation (VDSWC, 1992).

Most watershed jurisdictions require flood routing calculations to show that the volume of storage provided by all facilities incorporated into a site plan is adequate to handle the stormwater volume of a particular design storm. Table 4-2 gives the appropriate unit hydrographs and storm durations and frequencies for each jurisdiction that must be used in stormwater management calculations.

Criteria	Fairfax County	Loudoun County	Prince William County	Virginia State Regulations
Frequency	2-Year/10-Year 100-Year (Four Mile Run)	2-Year	2-Year (vel.) 10-Year (25-Year for Crit. Watersheds)	2-Year (vel.) 10-Year >Accepted
Duration	2-Hr < 20 Ac 24-Hr > 20 Ac		2-Hr < 200 Ac 24-Hr > 20 Ac	24-Hr
Distribution	FFX unit Hyd. for 2-Hr duration SCS Type II for 24-Hr duration		FFX unit Hyd. for 2-Hr duration SCS Type II for 24-Hr duration	SCS Type II

Table 4-2: Local Stormwater Management Requirements

The reader should note that the offsite area draining to the stormwater management facilities must be included in these stormwater calculations.

Chapter 5
BMP Facility Planning Considerations

I. Introduction

BMP ponds and infiltration devices are the measures most commonly accepted by local governments for improving water quality in the Northern Virginia area. This chapter describes the general planning guidelines that should be considered when designing a BMP in Northern Virginia. Planning criteria for extended detention dry ponds and for wet ponds are presented in sections (II) and (III) respectively. Planning and design considerations and procedures for infiltration trenches are outlined in section (V). Engineering and design considerations for dams and impoundments, due to their highly technical nature, are outside the scope of this Handbook. Designers are referred to several resources throughout this chapter which may be used when actually designing a BMP facility.

II. Extended Detention Dry Ponds

A) Facility Description

Effective management for water quality benefits requires controlling smaller, more frequent runoff events. However, it may also be desirable to control the impacts of quantity runoff from large, infrequent events. A useful method of managing both the quantity and quality of runoff involves the temporary storage of surface runoff with the controlled release of the stored water. When storage time is sufficient to allow sediments to settle out of the stormwater -- up to 48 hours -- the surface storage facility is known as an extended detention dry pond.

The main parameters which govern the effectiveness of removing pollutants in an extended detention dry pond are the volume of runoff which can be stored and the release rate of the impounded water. Storage calculation requirements for the effective impoundment of stormwater runoff are set forth in Chapter 4. Release of impounded water is controlled by an outlet device. The outlet of an extended detention dry pond provides for a prolonged period of release which enhances the pollutant removal capabilities of the facility. A typical profile of an extended detention dry pond is presented in Figure 5-1.

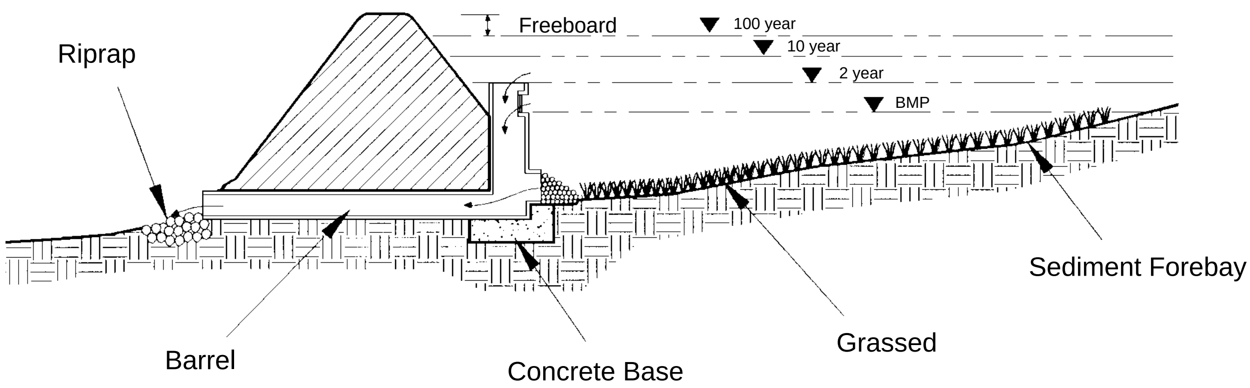


Figure 5-1: Profile of a Typical Extended Detention Dry Pond

B) Pollutant Removal Rates

Phosphorus removal in extended detention facilities occurs primarily through the physical process of sedimentation with some minimal biological and chemical uptake by rooted plants and soil interactions. Reported results on the pollutant removal capabilities of extended detention dry ponds indicate that these facilities are more effective in removing particulates, rather than soluble forms of pollutants (NVPDC, 1979; US EPA, 1983). Sedimentation basins are typically modelled as plug-flow reactors operating under ideal settling conditions. Under these assumptions, the maximum removal efficiency is limited to 40 to 50 percent, since that is the amount of particulate phosphorus available in stormwater runoff. Settling column studies conducted under ideal conditions have also indicated a maximum phosphorus removal of 40 to 50 percent. However, it should be recognized that extended detention BMPs do not operate under ideal conditions and rarely achieve maximum efficiency.

C) Applicability and Practicability

1) *Applicability*

In general, the site specific conditions that potentially affect the designer's choice of extended detention dry ponds include such factors as the value of land, site topography, environmental benefits, soil characteristics, and site size. These factors should be considered in comparing the advantages and disadvantages of this type of BMP facility.

The high cost of land may deter the developer from selecting these ponds for use as BMPs; however, this can often be overcome by incorporating the pond into green or open spaces within the site. Landscaping around extended detention dry ponds should be carefully considered. By utilizing the natural terrain and topography, the designer can minimize costs of land use and embankment construction. The amount and shape of available areas on the site for a facility may limit flexibility in setting depth and side slopes.

Since extended detention dry ponds only slightly utilize infiltration processes and do not permanently retain water, the soils characteristics of the site are not as important as for other types of BMPs such as infiltration measures or wet ponds. In areas with poor infiltration properties or high water tables, extended detention dry ponds may be a feasible option.

NOTE: Extended detention dry ponds are the preferred BMP for residential developments in Fairfax County and should be considered for use in all areas of the County

Extended detention dry ponds may be used for a wide range of drainage areas. However, the upper range for contributing drainage area applicable for extended detention dry ponds without having to take baseflow into consideration is about 50 to 75 acres. Above this range, wet ponds may be more applicable. If the jurisdiction allows the dry pond to be configured to handle the baseflow, special measures must be taken to avoid erosion. Such special measures would include:

- Concrete trickle ditches to carry baseflows in a confined area. This channel and the outlet for the baseflow should be sized so that any runoff from storm events will overtop the channel and flow to the pond floor where runoff will be stored for BMP purposes.

- The application of riprap or gabion to line the baseflow channel. The use of riprap or gabions to line the baseflow channel, in lieu of a concrete trickle ditch, is not acceptable in Fairfax County. The designer should consult the individual local jurisdiction for more details.

Because these measures may interfere with first flush pollution removal, the individual jurisdiction should be consulted to establish requirements.

2) *Practicability*

The advantages of properly designed extended detention dry ponds include:

- The mitigation of impacts of stormwater velocity on downstream channel banks.
- Water quality and quantity control.
- The effective control of soil erosion and sediment deposition.
- The minimization of adverse impacts to existing wetlands and wildlife habitats.

Effective operation requires proper design, particularly with regard to the appropriate balance of storage volume and release rate. Potential disadvantages which designers should note include:

- The need for maintenance and precautionary overflow measures.
- Questionable acceptance by the public of these facilities based on aesthetic and safety concerns.
- In comparison to wet ponds, extended detention dry ponds have a greater potential for scouring velocities resulting in poor settling conditions and for resuspension of previously settled pollutants by subsequent runoff events.
- Extended detention dry ponds depend almost exclusively on outlet hydraulics for pollutant removal and provide little opportunity for biological or chemical stabilization in the vegetation and soil of soluble nutrients.

Extended detention dry ponds are less expensive than some other types of BMPs, including wet ponds, since less storage and, therefore, less excavation is required. The reader is referred to work by the Metropolitan Washington Council of Governments (MWCOG, 1983 and 1987) or Woodward-Clyde Federal Services (1991) for more detailed information on costs for construction and operation of these and other types of BMP facilities in the Washington area.

D) Planning Considerations

1) *Overview*

For extended detention dry ponds, the size can be based on the volume for which BMP credit is desired; however, the volume is dictated by stormwater management (i.e. quantity) requirements as these facilities are usually designed for both water quality and stormwater management needs. Volume for the BMP facility is determined in Chapter 4, Section V. The shape of these facilities is often dictated by site constraints and topography.

The recommended steps for the design of extended detention dry ponds for water quality purposes are outlined in the following sections.

2) *Basic Dimensions of the Pond*

Estimating the appropriate dimensions of a BMP facility is largely based on a trial and error process in which the designer tries to fit the required BMP volume so that it works well with the site. Each site has its own unique limiting factors. Some constraints other than the existing topography include, but are not limited to, the location of existing and proposed utilities, depth to bedrock, location and number of existing trees, and wetlands. The designer can analyze possible pond configurations by varying the surface area and depth and then determining the corresponding available storage.

In order to enhance the effectiveness of BMP ponds, the dimensions of the pond must be sized appropriately. Merely providing the required storage volume will not ensure maximum pollutant removal. By effectively configuring the pond, the designer will create a long flow path, promote the establishment of low velocities, and avoid having stagnant areas of the pond. To promote settling and to attain an appealing environment, the design of BMP ponds should consider the length to width ratio, cross sectional areas, basin slopes and pond configuration, and aesthetics.

- <u>Length and Width</u>
  The length to width ratio of a pond is one design aspect that can significantly affect pollutant removal. The prudent planner will increase residence time by maximizing the distance between inlet and outlet points, thereby giving greater opportunity for pollutant settling. If the inlet and outlet are too close together, the

opportunity for the suspended solids to settle out in the pond is reduced. The length is defined as the flow path from the inflow point to the outflow point and the width is calculated as the surface area of the pond divided by the length. If, due to site constraints, an adequate length is unachievable, then baffles and flow directors may provide an acceptable alternative if they are allowed by the local jurisdiction. It should be noted that baffles and/or flow directors are not acceptable for public maintenance in Fairfax County.

- Cross Sectional Areas

  Minimizing the velocity of the flow through the pond can greatly improve the pollutant removal efficiency of the pond. Increasing the pond depth and cross sectional area will help to establish low flow velocities. Basins which taper outward from inlet to outlet are also effective in slowing influent velocities by increasing the cross sectional flow area. In general, the goal is to provide conditions where the velocity of flow through the facility for a typical storm event is less than the settling velocity of the pollutants of concern (NVPDC, 1979).

- Basin Slopes

  It is recommended that the sides of the basin be designed to permit ease of equipment access to the basin floor and for safety considerations. Neither should basin slopes be steep enough to allow erosive velocities to occur. In order to promote facility effectiveness, it is highly desirable to avoid resuspension of materials collected on the pond floor. In general, the potential for resuspension is minimized by reducing inflow velocities and maintaining vegetative cover. The use of baffles, riprap, and other types of energy dissipaters is encouraged; the most effective location for these depends on the pond geometry.

- Two Stage Pond

  NOTE: Fairfax County currently does not accept two stage ponds for County maintenance. Two stage ponds may, however, be approved for private maintenance with the execution of a private maintenance agreement.

  Another pond configuration to consider is the two stage pond. This pond configuration is meant to address both water quality and quantity. The lower part of a two stage pond is graded as a small basin to detain the first flush stormwater where the bulk of pollutants are carried. The pond volume is equal to the BMP storage requirement and acts as water quality control. The remainder of the pond is graded as a flat overbank area and provides storage only for storms larger than the BMP event to provide quantity control. A marsh-like environment in the lower section allows for some biological uptake of soluble materials and provides quiescent conditions which promotes sedimentation of particulates. The main advantage of this configuration is that the frequently inundated areas are localized in one section of the pond. This allows the upper portion of the BMP facility to be used for certain low intensity recreational uses. Special maintenance considerations are involved with the operation of a two stage BMP facility. Arrangements with the appropriate local jurisdiction should be made before consideration of this design. Figure 5-2 presents a profile of a typical two stage extended detention dry pond.

- Aesthetics

  If properly designed, the pond configuration can enhance pollutant removal without negatively impacting the aesthetic appeal of the site. A major consideration affecting the configuration of the pond should be the preservation of the natural appeal of the site. The shape of the pond should complement the natural topography of the site.

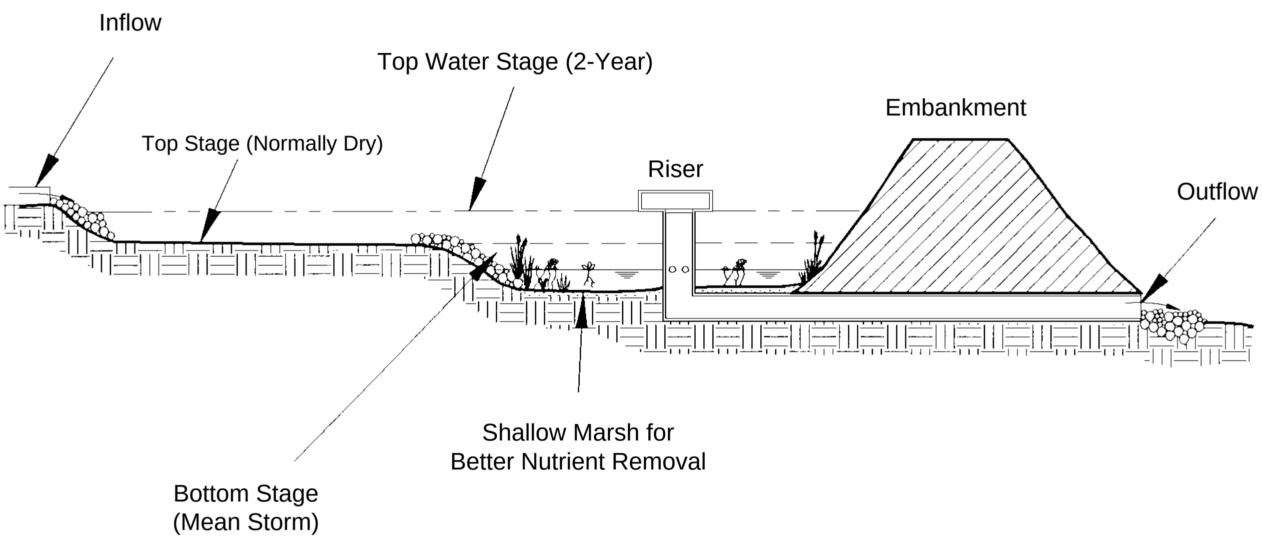


Figure 5-2: Profile of a Typical Two Stage Detention Pond
(Adapted from MWCOG, 1987)

III. <u>Wet Ponds</u>

A) Facility Description

Unlike stormwater management practices which are designed to control the volume of runoff resulting from relatively large infrequent storm events, the design of water quality facilities requires the control of smaller, more frequent events. The guidelines presented in this section are intended for application on small scale pond planning considerations.

The controlling factor associated with wet pond design is the establishment of a permanent pool of water above which storm inflow is stored and released at lower rates. The depth of the permanent pool must accommodate the pond volume required for dry weather uses and pollutant trapping mechanisms. In most localities the design of the wet pond must also consider stormwater management (i.e. quantity) needs.

Wet ponds are depressions partially filled with water from a constant baseflow, which are constructed by excavation and embankment procedures. The most important consideration when planning a wet pond is that the soil must have the ability to retain a standing pool of water. The release of overflow is regulated by an outlet device designed to discharge flows at various elevations and peak rates. A typical profile of a wet pond is presented in Figure 5-3.

B) Pollutant Removal Rates

Unlike extended detention BMPs, wet ponds avoid resuspension and can achieve removal of dissolved pollutants through biological and chemical mechanisms in the water column and bottom sediments. Nutrient cycling in these ponds is generally thought to operate much as in natural lakes and consequently a controlled eutrophication model for lakes has been applied successfully to the prediction of their pollutant removal capabilities. The principal factors governing nutrient cycling in lakes are the loading and decay rates for phosphorus, the hydraulic residence time, and mean depth.

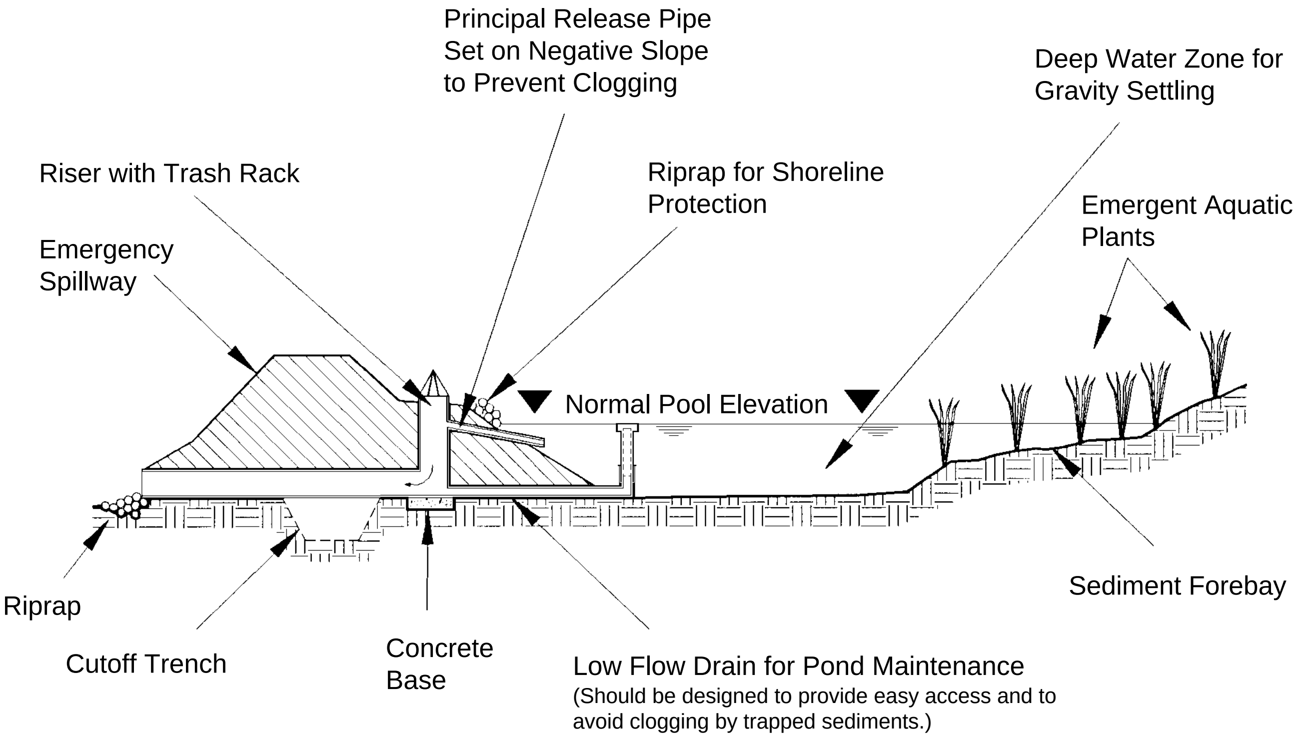


Figure 5-3: Profile of a Typical Wet Pond
(Adapted from Maryland Department of Natural Resources, 1986)

C) Applicability and Practicability

1) Applicability

The decision to use a wet pond for water quality protection must be based on certain site specific considerations. The most important aspect is the existence of an adequate baseflow to ensure that a permanent pool can be maintained. It should be noted that various state or federal permitting requirements may be triggered by impounding perennial streams. Other factors to consider in the evaluation of a site are topography, soil characteristics, groundwater location and use, depth to bed-rock, land value, accessibility, and aesthetic and environmental concerns. The location of the pond should utilize the natural characteristics of the site in order to obtain maximum storage volume with minimum earth removal.

An evaluation of the topography of the drainage area to the proposed wet pond is necessary to ensure that an adequate baseflow exists to retain a permanent pool of water. The Maryland Water Resources Administration has developed a table which gives guidance on sizing a pond based on the watershed size, the type of development, and the soil types (Md DNR, 1986). A Soil Conservation Service rule of thumb states that four acres of drainage area will support one acre-foot of permanent storage in a pond in the Occoquan Watershed (USDA, 1982). This guide can be used to estimate the maximum normal pool storage that can be expected for a given drainage area.

Soil permeability should be evaluated to determine the ability of the pond site to maintain a permanent pool of water. Identification of groundwater levels may also provide information concerning the available baseflow for the proposed pond. Inadequate baseflow can lead to nuisance situations such as the growth of unattractive vegetation and the development of mosquito breeding areas. Depth to bedrock should also be checked in advance to determine whether or not blasting will be required.

Land value and existing utility locations are other factors to be considered in the initial site evaluation. High land values may prevent the use of wet ponds due to the large surface area required. In making this determination, one must be certain that the benefits of creating a recreational open space and improving the aesthetic environment are properly assessed. If existing utilities are in an area which is being considered for wet pond construction, the cost of relocating the utilities may have a significant impact on the site selection.

2) *Practicability*

In comparison with other standard types of BMPs, wet ponds have been shown to be the most effective means of providing water quality protection. The increased pollutant removal rates, due to the longer retention times and the enhancement of biological and chemical degradation, results in a strong recommendation for using wet ponds on suitable sites.

In addition to providing higher pollutant removal rates, wet ponds are also amenable to the objectives of stormwater management and erosion and sediment control. If the pond structure is to be used temporarily during construction of the site as a sedimentation control it will be the developer's responsibility to remove sediment and to dispose of it properly before any bonds can be released. Any streams that will remain natural after development must be protected from erosion and scouring during the land disturbing activities even though they will convey flow to the sedimentation pond.

Higher property values of adjacent residential lots and potential groundwater recharge are additional benefits to be associated with the use of wet ponds. Disadvantages to be considered affecting the practicability of the use of wet ponds include safety factors and the higher costs of construction. Cost considerations must also be addressed by the design engineer. Wet ponds are typically more cost effective for larger sites/ drainage areas. For a detailed outline of costs of construction, operation, and maintenance, consult MWCOG (1987) or Woodward-Clyde Federal Services (1992).

D) Planning Considerations

1) *Basic Dimensions of the Pond*

This is a trial and error process in which the designer tries to fit the required BMP volume (and stormwater management volume if required) into a pond which works well with the site. Each site has its own unique limiting factors. Some constraints other than the existing topography include the location of existing and proposed utilities, depth to bedrock, location and number of existing trees, etc. The designer can analyze possible pond configurations by varying the surface area and depth and then determining the corresponding available storage.

2) *Depth of Permanent Pool*

To determine the proper depth for a wet pond, numerous factors must be considered. Of primary concern is the need to provide an adequate permanent pool so as to ensure efficient pollutant removal during long-term combination of dynamic and quiescent conditions (Illinois EPA, 1986). The volume of the permanent pool will determine the amount of pollutant removal that can be achieved.

Utilization of an adequate pond depth is also important in minimizing the effects of wind and velocity currents. For wet ponds with a surface area greater than about one acre, it is recommended to have riprap placed along the shoreline to prevent undercutting. Excessive inlet velocities, which may lead to resuspension of pollutants, can be avoided by providing adequate depth at the inlets.

It is recommended that ponds be designed to provide an average depth which will allow for efficient pollutant removal and will prevent the growth of vegetation. If the pond is too shallow, vegetation will tend to grow throughout the pond area. Excessive depths in wet ponds can have negative effects on the pollutant removal efficiency of the facility particularly due to increased potential for thermal stratification and anoxic conditions in the bottom layer. Stratification of deep water bodies lessens the volume of water available for biological degradation of pollutants. The increased potential for release of certain nutrients and heavy metals from the sediment under anoxic conditions will lessen the effectiveness of the wet pond as a BMP facility.

3) *Outlets*

A riser pipe-barrel system for release of runoff in excess of the BMP volume should be sized according to standard peak shaving design procedures. The use of an inverted siphon is recommended. The riser must have a base attached with a watertight connection and have sufficient weight to prevent flotation of the riser. It is highly recommended to include a drainpipe or other appropriate means (preferably gravity driven) to empty the pond for emergency or maintenance purposes. If desired to draw the water down only partially (e.g. for weed control) then vertical sections of pipe can be attached to the drain with the top of the pipe set at the desired water surface elevation.

4) *Enhancing Sedimentation*

- Sediment Forebays

  Sedimentation can be enhanced by providing a settling area, or sediment forebay, at the principal inlet to the pond. The accumulated sediment can be removed efficiently since it will be present in a localized area which is easy to access. There are two commonly used configurations. The first one (Figure 5-4a) incorporates a shallow, flat entrance to the pond which allows velocities to be greatly reduced and causes particulates to settle out of the water. The second configuration (Figure 5-4b) is effective because a relatively deep area is separated from the rest of the pond by an underwater berm. Again, the large surface area acts to reduce velocities and the underwater berm prevents the settled sediment from migrating to the downstream portion of the pond.

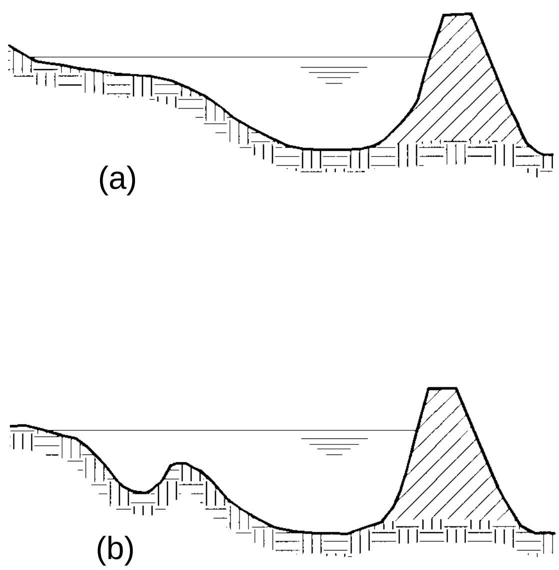


Figure 5-4: Pond Configurations to Enhance Settling

  A major aesthetic consideration affecting the configuration of the pond should be the preservation of the natural appeal of the site. The shape of the pond should compliment the natural topography of the site.

- Peripheral Ledges

  Peripheral ledges may be added as a safety precaution, to establish perimeter vegetation, and as a method of enhancing sedimentation and biological and chemical uptake. Two types of peripheral ledges are recommended for wet ponds. Either a safety ledge or an aquatic bench can be provided beneath the normal pool and extend around the perimeter of all wet ponds (except at the inlet where a sediment forebay will be located). The depth and side slopes to the peripheral ledge will be selected based on the fact that aquatic vegetation will thrive in water with depths less than three feet.

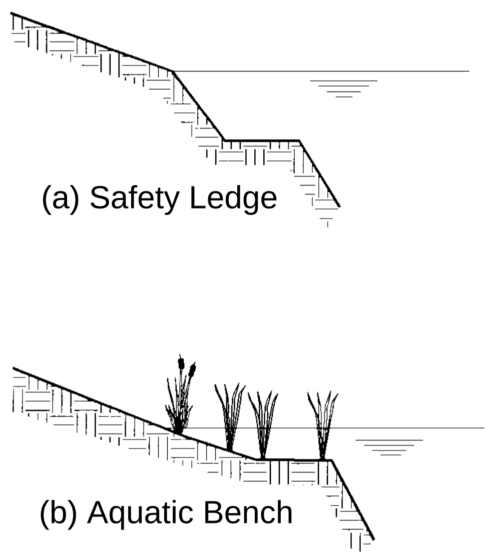


Figure 5-5: Two Types of Peripheral Ledges for Wet Ponds

If it is desired to prevent vegetative growth along the edge of the pond, the underwater side slopes should be steep so that deep water will be encountered quickly. However, to prevent children from getting into deep water too quickly, a safety ledge should be incorporated. See Figure 5-5a. Below the safety ledge, the pond sides would slope to meet topographic or volumetric constraints.

An aquatic bench can be used to promote the establishment of vegetation along all or part of the periphery of the pond. See Figure 5-5b. In addition to benefiting wildlife and creating a natural buffer, the vegetative zone can provide hydraulic resistance and serve as an additional sink for soluble pollutants.

- Extended Detention Wet Ponds

  By having small, negatively sloped drainage pipes connected to the riser, it is possible to discharge storm volumes slowly from below the level of the permanent pool. While there is no minimum distance between the orifice and the bottom of the pond, the designer should take the distance into consideration. This method is used in Montgomery County, Maryland to prolong the detention time of storm volumes above the level of the permanent pool. This type of pond is also referred to as an extended detention wet pond. By detaining the storm runoff, quiescent conditions are maintained and the opportunity for sedimentation is improved. By discharging flow from below the water surface, the chances of the outlet being clogged are reduced.

IV. General Criteria Affecting Extended Detention Dry Ponds and Wet Ponds

Any proposals for the construction of dams to form extended detention dry and wet ponds or lakes shall be fully supported by detailed engineering plans and calculations. Specific submission requirements for dams can be obtained from each municipality.

Items to be considered in the design of dams should include, but are not limited to, the following:

- Embankment
  Type of material, placement of material, compaction, permeability of material, settlement, vegetative cover, cross section shape, stability, site geology, deformation, foundation contact conditions, and emergency spillway considerations.

- Seepage Consideration
  Placement of impervious material, cutoff trench, drains and anti-seep collars, drainage blankets and internal drains, differential settlement, local ground water condition, and foundation underseepage.

- Outlet Structure (Riser and Culvert)
  Materials, joint connections, trash control, clogging, anti-vortex device, structural strength and stability, flotation, lake drawdown device, and differential settlement.

- Hydrology and Hydraulics
  Ultimate upstream land use, freeboard, erosive velocities, water surface fluctuation, storage capacity, spillway capacity, staff gage, and storm durations and distributions.

- Downstream Area
  Existing development, existing zoning, ultimate land use, dam failure and analysis, and determination of inundated area with and without dam.

- Maintenance
  Vehicular access and safety of dam and appurtenances.

- Soils

  Soil structures and characteristics shall be investigated. Plans and data prepared by a professional engineer and subsurface investigations conducted by a professional geologist shall be submitted. These submissions should consider and offer design solutions for frost heave potential, shrink-swell potential, soil bearing strength, water infiltration, soil settling characteristics, and fill and backfilling techniques as required to protect the improvements or structures.

Designers of dams and impoundments within Northern Virginia must check with the local jurisdiction in which the BMP facility is to be built in order to comply with requirements set forth by individual Public Facilities Manuals (or their equivalents) and referenced documents. It should be noted that the construction of impoundments with a dam height of 25 feet or greater and/or with an impoundment capacity of 50 acre feet or more requires compliance with the Commonwealth of Virginia standards under the Dam Safety Act, Code of Virginia §10.1-604, as amended, and corresponding regulations as administered by the Virginia Division of Soil and Water Conservation, Department of Flood Plain Protection.

V. Infiltration Trenches

A) Facility Description

Infiltration facilities are structures which collect stormwater runoff and allow it to infiltrate into the soil strata. This section will be confined to those facilities which provide temporary underground storage in the form of a storage chamber filled with an open-graded coarse stone aggregate. These include infiltration trenches, dry wells, and porous pavements. This section will concentrate on the design of infiltration trenches. However, the pollution removal mechanisms, soil suitability investigation, sizing procedure, and design requirements for infiltration trenches are generally applicable to porous pavements and dry wells.

Infiltration trench BMPs can route stormwater runoff into the aggregate filled storage chamber by two means, dispersed input and concentrated input. Dispersed input allows the input water to enter the top of the trench as overland sheet flow directed over a gently sloping grassed filter strip to the surface of the storage chamber (Figure 5-6). Concentrated input transports collected runoff to the storage chamber by means of gutters, curb inlets, and pipes. Generally, the water enters the facility at one or more point sources. Some infiltration trench designs combine stormwater detention and water quality objectives by storing the entire stormwater volume with the water quality (BMP) volume committed to infiltration. Usually this is achieved with a slow release of the stormwater management volume through an orifice set at a specified level in the storage reservoir. The BMP volume equals the storage below the orifice level which must infiltrate to exit (Figure 5-7).

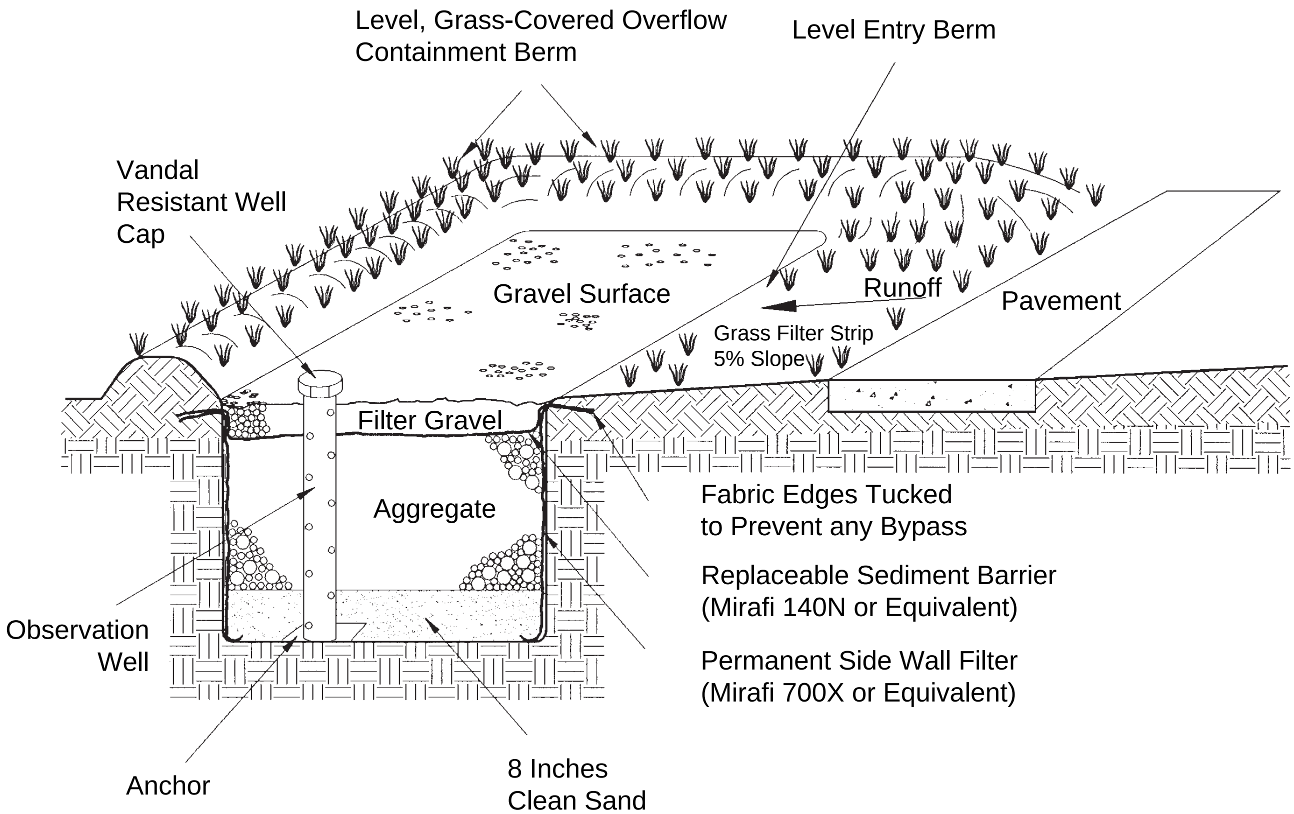


Figure 5-6: Typical Infiltration Trench
(Source: Fairfax County Soils Office, 1991)

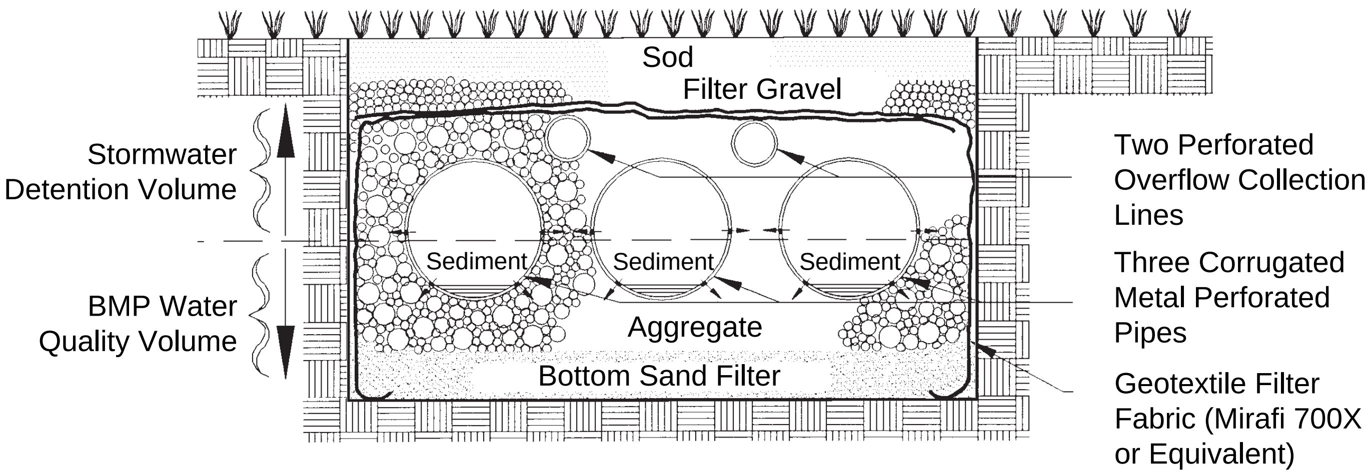


Figure 5-7: Infiltration Trench with Concentrated Input and Augmented Pipe Storage
(Source: Fairfax County Soils Office, 1991)

B) Principles of Mitigating Water Quality Impacts

It is imperative that suspended sediment be removed from runoff water before it enters the infiltration trench storage chamber. Experience has shown that clogging by sediment has been the principle cause of past failure of these facilities. Keeping this design requirement in mind, one can view the pollution removal system of an infiltration trench as two separate mechanisms. The sediment control system needed to maintain the function of the trench removes those pollutants associated with suspended solids. These include adsorbed phosphorus, certain heavy metals, and some exchangeable ions. Upon infiltration into the soil, the water enters an environment where several chemical and biological processes attenuate the levels of an array of pollutant species. Of principal interest is the ability of most soils to irreversibly fix large amounts of soluble orthophosphate by chemical precipitation and by surface adsorption to soil minerals. Infiltration trenches located in a landscape position that is hydrologically connected to vegetated, poorly drained soils may have the singular ability to remove nitrate nitrogen (NO_3) through denitrification to nitrogen gas (N_2).

Two important concerns should be addressed when planning an infiltration facility. One is the requirement to provide an effective sediment removal system in the design and to ensure a reliable long-term maintenance program. The other is to guard against the facility introducing contaminants into the water supply aquifer. The ability of the soil to treat polluted water is largely limited to fairly dilute concentrations of most pollutants. Infiltration facilities which could receive spills or slugs of concentrated contaminants such as petroleum, industrial solvents, chemical fertilizers, etc., could potentially contaminate groundwater used as a water supply source. These potential hazards must be recognized and appropriate measures taken to contain any potential contamination prior to entry into the facility.

Paved areas subject to heavy use by motor vehicles, fueling stations, vehicle maintenance facilities, and similar areas subject to high hydrocarbon loads should be serviced by a water quality inlet (oil/grit separator) as an in-line pretreatment to any infiltration structure.

The pollution removal processes which occur during infiltration are more complex than those occurring in wet ponds and extended detention dry ponds. Hydrogen ion activity (pH), redox potential, clay mineralogy, organic matter, microbial populations, temperature, as well as the physical characteristics of the soil environment, determine the behavior of target pollutants. Each pollutant species is subject to a particular set of possible reactions which will determine its fate. The chemical and biological environment to which a given pollutant is subjected changes with depth and lateral distance as the infiltrated water undergoes its hydrologic journey.

C) Site Selection

1) *Applicability*

Infiltration is the most efficient BMP and offers several advantages to the user. These facilities can be incorporated into multi-use areas, such as along parking lot perimeters. They can be located in small areas which can not readily accommodate wet ponds or similar facilities. Infiltration is attractive in that it tends to reverse the hydrologic consequences of urban development by reducing peak discharge and increasing baseflow to local streams. Conversely, infiltration trenches are not practical for larger areas. Generally, infiltration trenches are not considered for sites larger than five acres. Other comparative disadvantages involve the need for extensive site investigation and a long-term maintenance and monitoring program.

2) *Strategy*

A suitable site for the infiltration facility should be established early in the planning process. These facilities are totally dependent upon suitable native soil constraints on the site. Unsuitable soils can rarely be made suitable. Any commitment of an infiltration facility to a specific location prior to establishing suitable soils should be stringently avoided. The following considerations should be addressed in determining prospective locations:

- The suitable location must be at a lower hydraulic elevation than the target drainage area.
- Overflow from the facility will need to be routed to a suitable outfall.
- Maximum allowable ground surface slope is 20 percent for infiltration trenches.
- Avoid potential negative impacts on adjacent structures including water supply wells, sewage disposal facilities, building foundations, basements, and retaining walls.
- Avoid areas where saturation of soils could destabilize fill or cut slopes and other earth structures.
- Underground infiltration structures must not discharge into fill material but only into natural soils suitable for adsorption.
- Locating a temporary sediment pond at the future location of an infiltration trench should be avoided if possible. A pond may be located at the trench site provided that at least two feet of undisturbed soil is maintained as a buffer between the bottom of the pond and the established bottom of the trench. Note that establishment of the trench bottom requires a soil suitability investigation.

The soil suitability investigation is performed within the prospective location to determine if the location has soils suitable for an infiltration trench. The investigation will also provide specific design parameters regarding emptying time, size, and depth. Once the soil dependent design parameters are established by the soil investigation, specific proximity concerns and separation distances can be addressed.

D) Soil Suitability Investigation

1) *Overview*

The soil-dependent design parameters which must be established and approved for infiltration facilities are the acceptable depth within the soil profile and the design exfiltration rate for the proposed system. Examination of soil morphology at the proposed location by means of a detailed field investigation is basic to all soil suitability evaluations. The soil investigation involves the thorough description of soil characteristics of each horizon, layer, or stratum representing the material at, and below, the potential level of the bottom of the facility. The soil investigation report submitted to the local plan review authority shall include detailed soil profile descriptions. Permeability test results will be considered as supporting information in the context of the soil profile morphology. The determination of soil suitability and optimum depth is based upon the soil morphology while the exfiltration rate value used in designing the facility is based upon reconciling permeability test results with the soil morphology of specific horizons or strata.

2) *Qualifications*

The soil investigation shall be performed by an experienced professional of the geosciences who has experience and ability in determining soil characteristics by the methods presented below. In jurisdictions which have a county soil scientist, the soil investigation and report shall be subject to review and approval by that office. In jurisdictions without a county soil scientist, the qualified geoscientist will be required to attest that, to the best of his professional knowledge, the observations, date and recommendations presented to the reviewing authority are unbiased, accurate, and soundly grounded in the applicable sciences. This attestation will be required in the form of a letter to the reviewing authority at two stages in the planning and design process. First, the soils at the facility location must be determined to be suitable. This determination includes the establishment of the two design parameters, exfiltration rate and optimum depth. The second stage is an affirmation that the final facility design conforms to the soil dependent parameters and constraints.

3) *Methodology*

The soil investigation consists of a pit or test boring which allows the soil characteristics to be determined for each horizon, layer, or strata encountered. The investigation must extend to a depth of at least one foot below any seasonal high water table or restrictive layer encountered. Any permeability tests or samples collected for particle size analysis must be representative of the layer or layers in which the anticipated bottom of the proposed infiltration trench is to be situated.

The following soil characteristics are to be determined and recorded for each test pit or boring. USDA/National Cooperative Soil Survey methods are presented in the 1991 Soil Survey Manual.

- <u>Soil Characteristics</u>
  Depth of upper and lower boundary of horizons or strata, soil textural class, soil texture modifier (if applicable), estimated percent, kind and size of coarse fragments, soil color, color patterns (mottles), concentrations of iron and manganese, pores, roots, soil and/or rock structure, and consistence.

- <u>Additional Information in the Soil Description Shall Include</u>
  Name of soil scientist who described the soil, date, elevation above mean sea level at each sample point, location of sample points with respect to proposed trench, means and methods of investigation and equipment used, depth to free water (if encountered), depth to hard rock or restrictive layers, depth to seasonal high water table, geologic unit or substratum (if known), soil map unit (if known), landscape position (geomorphological land form), and additional comments pertaining to soil permeability, soil morphology, hydrology, etc.

4) *Investigative Procedure*

The soil description shall record the depth and characteristics of all soil horizons, layers, or strata which have a marked difference from the overlying material in particle size, distribution, color, mottling, or consistence. Special attention must be made to detect and record the depth of low chroma (gray) mottles, concretions of iron or manganese, and other indications of seasonal high water table or restrictive drainage conditions.

As a general guideline, two sample points should be considered the minimum number for each facility location. Infiltration trenches over 100 feet in length should include at least one additional sample point for each 50 foot increment greater than 100 feet. The actual number and locations of sample points will depend upon the soil limitations and individual characteristics of each site.

All investigations using test pits shall be made in compliance with current Occupational Safety and Health Administration Excavation Safety Regulations (OSHA, 1977).

- Determination of Optimum Depth

  Determination of a suitable range in depth for the bottom of the storage reservoir is the principle objective and is a prerequisite to any permeability testing. The determination is based upon an examination of the soil morphology. Critical elements to assess are the depth of seasonal high water table, depth and thickness or restrictive layers of bedrock, and the characteristics which determine soil permeability.

  The determination of the seasonal high water table should be given a high priority because this condition can render an infiltration structure non-functional during periods of high precipitation. Determination of adequate separation distance from a restrictive layer or seasonal high water table is dependent upon both soil characteristics and facility design. Groundwater mounding and its effect on adsorption is controlled not only by such soil factors as hydraulic conductivity, but by the physical dimensions of the trench itself. Because of this interdependence, the minimum allowable separation distance must be established on a facility specific basis. In all cases, the absolute minimum separation distance from a seasonal high water level shall be two feet. A groundwater observation well study may be required for questionable or marginal sites. The need for an observation well study may be expected for certain soils of the Triassic Basin in Northern Virginia. Some soils in this physiographic providence are known to have parent materials containing chemically stable red-colored iron minerals. These soils often do not contain the low chroma (gray) mottles indicative of seasonal saturation. Observation well studies for the determination of seasonal high water table shall be conducted within the period between January 15 and March 31. A minimum of six observations of water levels shall be made over a study period duration of at least 45 days.

For the purposes of this investigation, restrictive layers are defined to include any soil horizons or geologic strata which have an estimated permeability of less than 0.27 in/hr. Restrictive layers include structured argillic soil horizons with USDA textures of sandy clay loam or finer, dense pans, structureless strata of silt loam or finer textured soils, and dense saprolite or bedrock. As a general rule, the bottom of the infiltration trenches should be 2 to 4 feet above any underlying restrictive layer depending upon soil conditions and the dimensions of the trench. In the case of dense layers, such as fragipans, the bottom of the structure must be completely below the level of restricted permeability. Estimations of soil permeability based upon soil texture (Appendix 5-1) should be assessed with consideration to other soil properties which determine permeability (Appendix 5-2).

Selecting the optimum depth is a process of avoiding constraints and seeking the soil horizons which have a permeability which will allow the structure to empty within the target time-frame after a design storm event. Corroborative permeability tests must represent all the described soil horizons within the established optimum depth.

- <u>Permeability Tests</u>

  Analytical tests of the soil material representing the previously identified optimum depth should be regarded as empirical observations used to confirm, adjust, or refine the soil permeability estimate based upon soil morphology. Great variability among individual tests and among methods can be expected. Individual test results should not be considered absolute values directly representative of the expected draw-down rate of water in the storage reservoir of the infiltration facility. Instead, the test results should be interpreted along with permeability estimations based upon soil texture, structure, pore geometry, and consistence.

- <u>Determination of Exfiltration Rate</u>

  The exfiltration rate (ER) is a design value used in computing the rate in which water will exit the storage reservoir by infiltrating into the soil through the bottom of the storage reservoir. For the purposes of design, this rate will be considered a flux. Flux is the rate in which a three dimensional volume moves through a two dimensional plane ($L^3/L^2/T$) simplified as length per unit time (L/T).

The determination of the ER value involves analysis of soil permeability information and expected hydrologic conditions such as groundwater mounding. The basic approach is to establish the saturated vertical hydraulic conductivity class of the optimum depth using Appendix 5-1 and 5-2. This range is then refined by the results of permeability tests of the optimum depth. It is important to realize that there is no hard data at this time on how well any testing method will predict exfiltration of water from a trench. Designers should keep in mind that the ER value is the most imprecise of all the design parameters and that one should oversize the storage capacity for any facility which depends upon infiltration for stormwater management.

5) *Report*

A soil investigation report, prepared by the investigating soil scientist in collaboration with the design engineer, shall be submitted to the local plan review authority for review and soil suitability decision. The report shall include complete soil descriptions and a map or site plan drawing showing the location of each sample point. If a certain soil characteristic is absent or inapplicable to a given soil horizon or sampling location, then it should be noted as such rather than eliminated from the description.

Permeability test methods shall be identified and described. Depth, elevation, and location shall be included with the results, as well as identification of the soil horizon or strata represented.

Interpretation of the soil morphology by the investigating soil scientist is recommended. For example, the investigating soil scientist would want to note if low chroma colors reported in a schist saprolite represented foliation in a high chroma matrix and that he was of the opinion that they were not indicative of a seasonal water table.

Also recommended is a summary of the soil properties for the study area with interpretations of acceptable depth and location of the proposed facility. A schematic cross sectional diagram is suggested as a useful tool in summarizing and compiling soil information, topography, and the limits of the physical dimensions of the facility (Appendix 5-3). This type of diagram is particularly applicable to linear transects representing infiltration trench locations. The diagram should include the following:

- Surface topography
- Major soil strata
- Depth of bedrock or auger refusal
- Seasonal high water table
- Proposed invert elevation of the bottom of the storage reservoir
- Invert elevations of any pipe inlets or overflow risers

6) *Interpretation of Results*

The limitations and parameters of the infiltration trench design which are controlled by soil properties and morphology will be established by the reviewing County soil scientist upon submission of the report for soil suitability approval. In those jurisdictions which do not have a soil scientist, a letter of attestation shall be submitted to the reviewing authority by the consulting geoscientist.

E) Location

The following concerns must be addressed when determining the location of the infiltration facility.

1) Reconcile the invert elevation of the bottom of the storage reservoir with the range in optimum depth for the entire length and width of the location. Ensure that the storage reservoir will fit within the limits of the separation distances from restrictive layers and seasonal high water table, and the surface topography.

2) Proximity Concerns: Underground infiltration structures shall not be located within the following:

- 100 feet of an active water supply well.

- Where the zone of saturation would be expected to impact the function of an onsite sewage disposal facility or where such a facility could contaminate the storage reservoir with effluent.

- Where the zone of saturation would be expected to impact building foundations, fill slopes, retaining walls, basements, or other underground structures.

3) Establish the vehicular access right-of-way required for maintenance and repair.

F) Physical Dimensions and Sizing Procedure

Storage capacity and gross exfiltration rate from the storage reservoir (Volume Out/T) are determined by the width and depth of the reservoir. Generally, soils of relatively slow permeability will require a wide reservoir with a high ratio of bottom surface area to storage volume. Soils of rapid permeability can accommodate a narrower reservoir with a lower bottom surface area to storage ratio.

Soil morphology also must be considered in determining the dimensions of the storage reservoir to utilize the optimum horizons or strata. The presence of a thin, slowly permeable soil horizon may require a trench depth which completely penetrates it to more permeable underlying material. Conversely, the presence of an underlying water table or restrictive material would favor a long, shallow trench configuration.

The determination of the minimum and maximum time for the facility to empty by infiltration of the design stormwater volume into the soil is based upon balancing optimum pollutant removal and assuring adequate stormwater management performance. The infiltration facility shall be designed with a maximum drain time of 48 hours for the water quality volume, 72 hours for the total volume, and with a minimum retention time of 24 hours for the water quality volume.

The minimum storage capacity of the storage reservoir is equal to the volume of the runoff from the design storm times the pore volume ratio of the crushed stone fill. Recent tests performed by the Fairfax County Soil Science Office have verified that the pore volume ratio (% porosity/100) of 0.40 is a realistic value for VDOT #57, #56, and #357 open-graded coarse aggregate. (Refer to Appendix 5-4 for VDOT #57 specifications.) These materials are readily available in Northern Virginia and are recommended as porous aggregate fill for the storage chambers of infiltration facilities.

The infiltration of a volume of water into the unsaturated zone of a natural soil is an extremely variable and complex phenomenon. Although the physical principles involved have been extensively researched, application to facility design defies the development of a single comprehensive model for the reliable prediction of drain-time. A simple model used by the State of Maryland has been adapted by the Soils Science Office for determining the target drain-time.

The Maryland model assumes that drain-time will be controlled by one-dimensional flow through the bottom surface of the storage reservoir into the underlying soil. The flux (ER) will determine the rate of exfiltration per unit of bottom surface area. Volume of water per unit surface area can be simplified as depth of water in the reservoir. The maximum and minimum depths of the stone aggregate reservoir, and the minimum required surface area of the trench bottom may be defined as:

$$d_{max} = \frac{ER * T_{max}}{PVr} \qquad d_{min} = \frac{ER * T_{min}}{PVr} \qquad SA_{min} = \frac{FSV}{ER * T_{max}}$$

Where: ER = Exfiltration rate in length per unit time (ft./hr.)

T = Target drain-time in hours

PVr = Pore volume ratio of stone aggregate (%porosity/100)

FSV = Fluid storage volume requirement in $ft.^3$

SA = Trench bottom surface area in $ft.^2$

The storage volume of the facility is defined as: L * W * D * PVr

The determination of the dimensions of the storage reservoir is made by fitting the length, width, and depth into a configuration which satisfies drain-time and storage volume requirements while keeping the storage reservoir bottom within the optimum depth for infiltration. It is recommended that the first step in this process be the determination of the minimum trench bottom surface area required (SA). A long, narrow trench is less affected by water table mounding. If depth to seasonal high water table or bedrock is within 5 feet of the trench bottom, it is advisable to design the trench as long and narrow as possible. Long trenches may need to be curved parallel to the topographic contour in order to keep the trench bottom elevation within the optimum depth in the soil profile. After the minimum surface area criterion is met by a tentative width times length configuration, check to see if the storage volume is equal to, or greater than the design storm volume requirement. If greater storage is needed, adjust the trench dimensions by the following order of recommendations:

1) If the seasonal high water table or bedrock is within 5 feet of the trench bottom, then increase the length of the trench.

2) If the length cannot be increased due to site constraints, then increase the width.

3) If the seasonal high water table and bedrock are known to be at a depth greater than 5 feet below the bottom of the trench, then it is permissible to increase the depth provided that the new bottom elevation meets the same criteria for optimum depth.

Although most infiltration trenches are generally greater than 2 feet in depth, a factor to consider in shallow trench designs is the frost depth. The bottom of the structure should be 18 inches below the surface to avoid freezing of the trench bottom surface.

G) Handling Overflow

Proper design of any structural BMP facility must include provisions for handling overflow from the facility. Overflow must be controlled so as to avoid channel-forming erosion or downstream impacts. For infiltration measures, the design should include an appropriate mechanism to dispose of excess water when the storage capacity is exceeded. Any overland flow path must be designed to avoid uncontrolled, erosive, concentrated flow.

Those infiltration trenches with dispersed input refuse additional input at capacity which results in ponded water on top of the trench. This ponded water may be released by controlled sheet flow or by a concentrated outflow to a storm sewer or adequate outfall. Sheet flow is controlled by a level berm on the downstream side. The berm should be shaped and vegetated to prevent the development of erosion channels. Concentrated outflow may be collected by a pipe with a riser, or perforated pipe section, set at an elevation which allows ponded water to exit before reaching the level which would breach the containment berm.

Trenches and dry wells with concentrated input require a means of collection located at the level of the top of the storage reservoir and below the overlying sediment barrier. The collected overflow is routed to a storm sewer or adequate outfall.

It is recommended that the outlets from an infiltration facility be designed so that they "daylight" (i.e. the invert of the pipe is at the surface of natural ground at the outfall) for access during maintenance. Pins or a flap gate at the pipe end should be installed as a means of excluding rodents.

H) Other Requirements

1) The sides and top of infiltration trenches and dry wells receiving concentrated input shall be lined with an appropriate geotextile fabric.

2) The top sediment barrier relied upon to filter water for dispersed input infiltration trenches shall be a separate, replaceable section of the appropriate geotextile filter fabric.

3) An observation well shall be installed in infiltration trenches to monitor performance as part of routine maintenance. The exact depth of the observation well shall be permanently marked on the well cap.

4) The bottom of the storage reservoir of infiltration trenches, dry wells, and porous pavement facilities shall be covered with a layer of clean sand (VDOT Fine Aggregate-Grading A or B). Filter fabric should not be placed on the trench bottom.

I) Sediment Control

The potential for failure of infiltration practices due to clogging by sediments is of great concern. It has been reported that a high percentage of infiltration trenches built in the past have failed because sediment was not trapped before entering the trench. Viable means of sediment control must be incorporated into the facility design and Phase II of the Erosion and Sediment Control Plan (E&S-Phase II) to ensure reasonable durability of the system. It shall be stated in the site plan narrative that construction of the infiltration facility is to be performed after the drainage area is completely stabilized with respect to erosion and sedimentation. A thorough and complete sediment control system, utilizing such means as silt fencing, berms, diversions, etc., to protect the trench during its construction, shall be included in the site plan. A temporary stormwater bypass should be constructed prior to construction of the infiltration trench. Technical guidance for sediment control is available in Standards and Specifications for Infiltration Practices (Md DNR, 1984) , Controlling Urban Runoff (MWCOG, 1987), the 1988 Check List for Erosion and Sediment Control (Fairfax County DEM/NVSWCD, 1988) and the Virginia Erosion and Sediment Control Handbook (VDSWC, 1992).

Other filtration requirements include lining the sides and top of the infiltration trench with geotextile filter cloth. The top layer of the cloth should be covered by six to twelve inches of smaller sized gravel (3/4"). This top filter layer, which will typically trap coarse sediment, can be cleaned and replaced in a relatively easy manner. By replacing the top layer annually, or more frequently, the life of the infiltration trench will be prolonged. The bottom of the trench should be covered with a clean layer of sand.

It is imperative that the facility design include a durable, maintainable system for removing sediment from stormwater before it enters the infiltration structure. Systems which can route sediment laden water into the infiltration structure upon failure, such as water quality inlets, should be utilized only at sites served by a full-time maintenance staff or where such devices are considered necessary to contain high hydrocarbon loads or contaminant spills. All other sites should employ means which deny entry for stormwater into the structure upon failure. Such means generally rely upon some type of replaceable filter. Clogging of the filter results in a highly noticeable overland flow indicating the need to replace the filter while protecting the infiltration structure itself. Any sediment collection structure must be adequate to handle the expected flows. Filter systems should be designed with an additional capacity to accommodate decreases due to partial clogging of the fabric over time.

Sediment control systems may be discussed depending upon mode of input.

1) *Concentrated Input*

These systems collect runoff and transport it to the facility by means of gutters, inlets, and pipes. Generally the water enters the facility at one or more point sources. Concentrated input into large facilities, such as infiltration trenches, usually requires an internal input distribution system. This is often in the form of a corrugated metal pipe (CMP) set horizontal at the top of the stone aggregate reservoir. Holes in the CMP allow input water to be distributed along the length of the trench. The CMP also provides increased storage capacity.

Sediment control systems may be in the form of in-line structures such as water quality inlets (oil/grit separators), sediment collection sumps, or similar structures, provided there is an assured means of regular inspection and maintenance. In-line sediment controls which protect the trench upon failure generally involve incorporating geotextile filter fabric into the collection and transport structures. One approach is to use an oversized gutter which is filled with large serge stone. An appropriate geotextile fabric is placed over the coarse stone with a blanket of coarse aggregate on top. Sufficient space is left over the aggregate within the gutter to contain large flows. Stormwater passes through the filter along the entire length of the gutter and filtered input water flows through the coarse aggregate at the bottom of the gutter. Failure occurs when the filter eventually clogs and routes stormwater past the input point as easily observed overflow. Maintenance consists of replacing the filter fabric.

The design of sediment control systems for concentrated input facilities invites innovation. Redundant controls or back-up systems should be employed wherever there is an opportunity. One type of back-up sediment control used for trenches with large diameter CMP pipe storage consists of lining the interior surface of the pipe with a geotextile fabric. This continuous liner is retained on the interior metal surface of the pipe by expandable rings. If routine monitoring of water levels reveals that water is not being released from the pipe, the filter is inspected and replaced if necessary.

2) *Dispersed Input*

These systems allow input water to enter the top of the storage reservoir over a wide area. A common dispersed input system for infiltration trenches is overland sheet flow directed over a gently sloping grassed filter strip to the surface of the storage chamber. The grassed filter strip is the primary control and must be at least 20 feet wide and of a 5 percent slope or less. The entry berm must be parallel to the contour to maintain uniform flow to the trench. Seed mixture and seed bed preparation for the filter strip should be performed according to procedures established by the Northern Virginia Soil and Water Conservation District for a grassed waterway. It is essential that a complete cover of dense turf be established before stormwater flows are allowed to enter the facility.

The trench itself is protected from sediment entry by a layer of geotextile filter fabric (sediment barrier). The sediment barrier is separate from the filter fabric lining the trench sides so it can be replaced as part of routine maintenance. It is placed over the top of the crushed stone storage chamber and covered with one half to one foot of 3/4 inch crushed stone. The edges of the filter fabric must be placed in such a way to ensure that no runoff can bypass the sediment barrier. All input water must flow over the grassed filter strip and enter the trench through the sediment barrier at the top.

J) Construction Considerations

A summary of construction guidelines for infiltration facilities is presented below. These considerations are based on those included in the Maryland Specifications and Standards (Md DNR, 1984). These standards were modified and expanded for application in Northern Virginia by the Fairfax County Soil Science Office.

1) The infiltration measure should not be constructed or placed in service until the entire contributing drainage area has been stabilized.

2) After the facility is excavated to design dimensions, the excavated materials should be placed away from, and downstream of the facility to prevent redeposition during subsequent runoff events. Large tree roots should be trimmed flush to the sides to protect the filter fabric during its installation.

3) Construction equipment shall not be allowed to compact or smear the soil surface of the trench bottom. Excavation should be performed with a backhoe or similar means which allows the equipment to stand-off from the bottom of the trench excavation. The trench bottom surface should be scarified with the excavator bucket teeth on the final pass to eliminate any smearing or shearing surfaces of the soil at the trench bottom. The sand filter material shall be placed on the trench bottom by means which do not compact or smear the soil surface. The sand must be deposited ahead of the loader so the equipment is always supported by a minimum of 8 inches of sand.

4) The roll of filter fabric should be cut to the proper width before installation. Width should allow for perimeter irregularities plus a minimum of six inches of overlap at the top. When fabric overlap is required elsewhere, the upstream section should overlap the downstream section by a minimum of two feet to ensure that the fabric conforms to the excavation surface during aggregate placement.

5) The crushed stone aggregate shall be placed in the trench using a backhoe or front-end loader with a drop height near the bottom of the trench. Aggregate shall not be dumped into the trench by a truck.

6) The clean, washed stone aggregate should be placed in loose lifts of about 12 inches, and lightly compacted with plate compactors. Compaction ensures fabric conformity to the sides, and should reduce the potential for clogging and settlement problems.

7) After the aggregate is placed, the filter fabric should be folded over the aggregate to leave at least 6 inches of overlap with the top layer of fabric. Some small amount of aggregate should temporarily secure this overlap until the last layer (6 - 12 inches) of smaller sized aggregate (3/4") is placed on top; this layer should not be compacted.

8) There should be no mixing of clean aggregate with natural or fill soils. All contaminated aggregate should be removed and replaced with clean aggregate.

9) There should be no voids between the filter fabric and the excavation sides. If boulders or similar obstacles are removed from the excavation sides, natural soils should be placed in these voids before the filter fabric is installed.

10) In Fairfax County, and in other jurisdictions as required, an observation well shall be installed in an infiltration trench to monitor performance as part of routine maintenance. The exact depth of the observation well shall be permanently marked on the well cap.

The reader is referred to the Maryland Specifications and Standards (Md DNR, 1984), the Maryland Inspector's Guidelines Manual (Md DNR, 1985) and MWCOG (1987) for more detailed information concerning proper construction of these measures.

K) Other Types of Infiltration Measures

All pervious surfaces utilize infiltration processes and some may receive BMP credit. Modular pavement and gravel roads, for example, are considered BMPs by many jurisdictions. Runoff coefficients for gravel roads vary from C = 0.65 for moderately drained soils to C = 0.70 for soils with a large percentage of clay. These coefficients correspond to an imperviousness of 65 percent. It is necessary to perform a voids ratio analysis to estimate BMP credit. The reader should check with the review agency of the appropriate jurisdiction to confirm this estimated BMP credit. Details for several of these other types of infiltration BMPs are included in Appendix 5-5 (dry wells), and Appendix 5-6 (modular paving). For additional information on modular pavement see Tourbier (1981), Virginia State Water Control Board (1979), and Tahoe Regional Planning Agency (1978). Porous pavement is further discussed in Chapter 7.

Chapter 6
A General Guide for Privately Maintained BMP Facilities

NOTE: The maintenance requirements cited herein are general in nature and are focused toward privately maintained facilities. They are not intended to supplant the requirements of individual jurisdictions. In the cases of Fairfax County and Prince William County, maintenance of public stormwater management facilities is governed by policies developed by the County, in conformance with the standards established by the respective standards manuals.

I. Introduction

Although the actual time that a BMP facility performs its design function is relatively brief (during and immediately following a storm event), it must constantly be ready to do so. This is due to the random nature of rainfall events and the impracticality of inspecting the facility and performing the maintenance immediately prior to them. Additionally, pollutant removal efficiencies will decline over time if adequate maintenance is not performed. To maintain maximum pollutant removal, it is important to have BMPs fully operational at all times. To provide this operational level, the BMP operator must establish and sustain a comprehensive, regularly scheduled maintenance program.

The essential element of an effective maintenance program is that the maintenance requirements must be evaluated when selecting the appropriate BMP for a site. This is discussed further in Chapter 3.

The positive aspects of a properly functioning facility, such as flood control and water quality benefits, enhance downstream environments by mitigating the environmental impacts of land development; conversely, BMPs can diminish the positive impact on the environment if they are not properly maintained.

The following criteria will provide BMP designers with a guide for maintenance considerations when designing a private BMP facility in Northern Virginia. For more information, refer to the specific standards adopted by the various local jurisdictions. These considerations include access and maintenance easements, routine inspection of outlet structures, sediment disposal, maintenance agreements, and other considerations specific to wet ponds, extended detention dry ponds, and infiltration trenches.

II. Access for Maintenance

Access for inspections, maintenance personnel, and equipment must be provided to all areas of a facility that require observation or maintenance. The location and configuration of easements must be established during the design phase, built to those standards during the initial construction of the facility, and maintained on a regular basis. The areas requiring access include the dam embankment, emergency spillway, side slopes, inlets, sediment forebays, riser structures, BMP devices, and pond outlets. In order to provide access for heavy equipment, a suitable 10 ft. wide roadway within a 20 ft. wide cleared access easement must be provided to the BMP facility. A typical cross section of reasonable access is provided in Figure 6-1. On large or regional facilities, additional easements to both upstream and downstream areas should be provided for maintenance access and additional improvements such as all-weather roads, access restrictions, and vandalism deterrents should be considered.

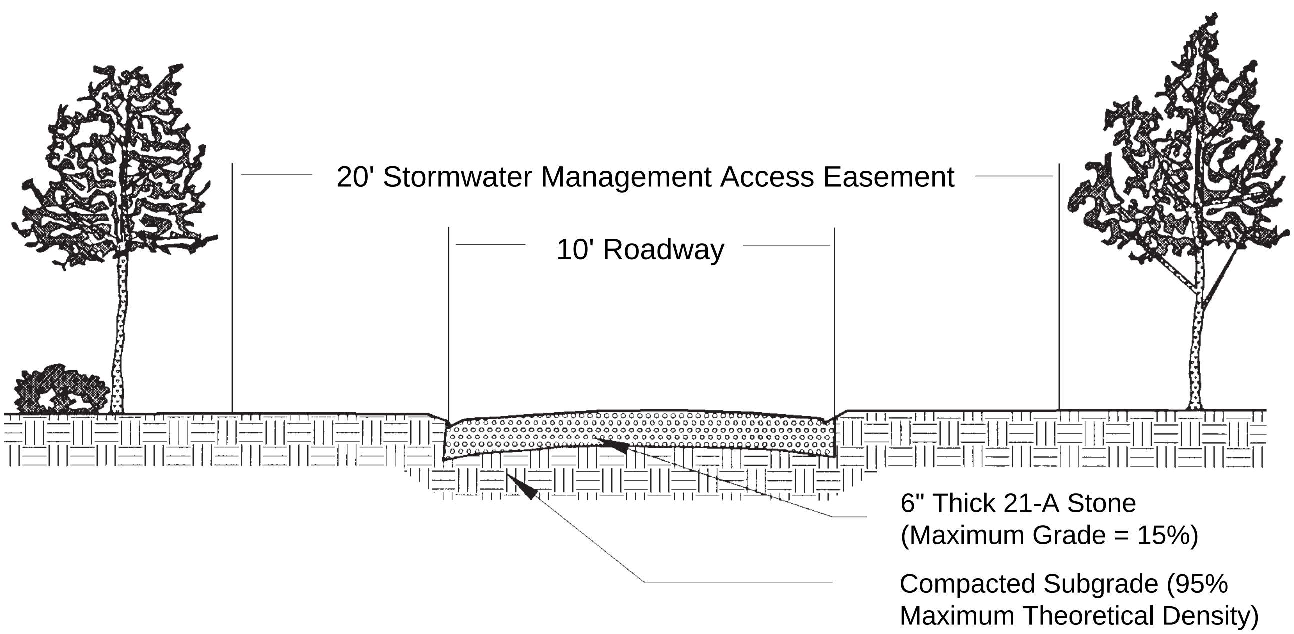


Figure 6-1: Profile of a Typical Access for Maintenance Easement

III. <u>Sediment Accumulation and Removal</u>

Sediment accumulation resulting from the normal operation of BMP measures must be recognized in the design phase. Accommodations should be included during site design for the removal and disposal of sediments. For most facilities, disposal should be provided onsite in reserved areas, or used as fill or topsoil supplement, provided that proper erosion and sediment controls are taken to avoid transport of the sediment into local waterways. Such controls must be applied to all disturbed areas until a complete vegetative cover or other means of containment is achieved.

Facilities designed for onsite disposal of pond sediment should be sufficient to accommodate a minimum of two dredging cycles. The dredging cycle is dependent upon the silt loading in the watershed, and for extended detention dry ponds may vary from every 2 to 10 years and for wet ponds, 5 to 15 years. These figures vary substantially from one watershed to another. Each watershed must be evaluated independently to determine the maintenance required from the silt loading. The following should be used to calculate the area needed to be reserved for onsite sediment disposal.

Onsite Sediment Disposal Area Calculations

1) Compute Long Term Post-Development Sediment Load *(lbs/yr)* (A) __________

   - Use the "Chesapeake Bay Method" in Chapter 4 (IIIb) to determine the long term post-development sediment load from the upland watershed and replace "L = phosphorus loadings (lbs/yr)" with "S = sediment loadings (lbs/yr)."
   - The flow-weighted mean pollutant concentration (the variable "C" in the "Chesapeake Bay Method" calculation) for sediment should be determined from Figure 6-2.
   - Place the long term sediment load in the space marked (A).

2) Sediment Removal Efficiency (%/100) (B) __________

   - Estimate the sediment removal efficiency of the BMP facility from Table 6-1. Enter the efficiency in decimal form into the space marked (B).

3) Compute Total Trapped Sediment per Cycle (lbs/cycle) [(A) x (B)] x (____ yrs) = (C) __________

   - Compute the total trapped sediment per dredging cycle by deriving the product of Line (A) and Line (B) and multiplying by the number of years anticipated between dredging cycles. Check with the local jurisdiction for the appropriate number of years for sizing purposes. Insert the result into Line (C).

4) Convert Pounds of Sediment per Cycle to Tons per Cycle (tons/cycle) (C)/2,000 = (D) __________

5) Account for Sediment Density (E) __________

- Account for different sediment densities by selecting from the following and inserting into Line (E).

i) Occasionally Submerged Sediment (0.8 cubic yards)
ii) Dry Sediment (1.0 cubic yards)

- It is assumed that one ton of sediment will require 0.8 or 1.0 cubic yards of storage space depending on sediment density. Therefore, Line (E) serves as a conversion from tons to cubic yards in the following Step (6) (MWCOG, 1987).

6) Final Volume Calculation (cubic yards) [{(E) x (D)} x 2] = Volume (F) __________

- The volume required for the onsite disposal of sediments is the product of Line (E) and Line (D). Insert the product into Line (F).

- In order to hold the two dredging cycles required, it is necessary to multiply the product of Lines (E) and (D) by 2.

7) Solve for Area L x W x H = V

- Solve for the required area by configuring Length, Width, and Height to equal or exceed the needed volume.

For larger BMPs, access must be provided for equipment to dredge or otherwise remove accumulated silt materials since offsite disposal would likely be necessary. Appendix 6-1 includes a list of local agencies to contact regarding disposal alternatives such as landfills.

IV. Maintenance Agreements

An agreement stating maintenance responsibility, schedule, and operations must be included in the plan submission. An example of a maintenance agreement is presented in Appendix 6-2. Some facilities are eligible for public maintenance. An inquiry with the appropriate local jurisdiction is suggested regarding questions of responsibility for maintenance. Easements for non-publicly maintained BMPs should include provisions to permit public inspection and maintenance (including reimbursement to the public agency for incurred costs) if a private organization fails in its maintenance responsibility and creates a public nuisance.

In Fairfax County and Prince William County, facilities for commercial, industrial, and rental residential developments are maintained by the owner. The County Department of Public Works maintains BMPs for residential subdivisions, excluding wet ponds, which are the responsibility of private owners, unless they are determined to meet Regional Pond Criteria, in which case they may be County maintained.

Figure 6-2: Relationship Between Watershed Area and Sediment Event Mean Concentration

(Source: MWCOG, 1987)

According to the Washington area NURP study (1983), sediment concentrations in urban runoff are generally related to the watershed area draining to the BMP facility. It should be stressed that the relationship is general in nature and that watershed specific information should be considered when available. The relationship demonstrated in Figure 1 is for a stabilized watershed. The designer of the BMP facility should check with the local jurisdiction to determine which concentration curve to use. This will depend on the overall health of the watershed.

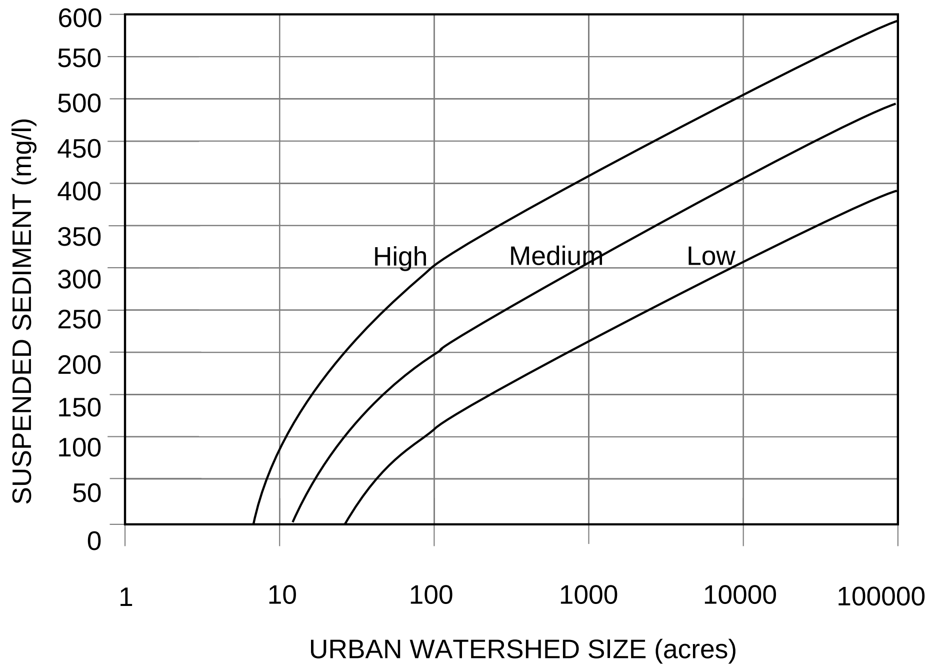


Table 6-1: Generalized Sediment Removal Efficiencies for Extended Detention Dry Ponds and Wet Ponds

(Source: MWCOG, 1987)

Facility Type	Removal Rate
Extended Detention Dry Pond	
• 48 Hour Draw-Down	92%
Wet Pond	
• 2.5 x Vr*	75%
• 4.0 x Vr	85-90%

* Removal rate does not take into consideration the required extended detention for this facility. Consult the local jurisdiction for guidance.

The sediment removal efficiencies cited in Table 1 are to be used for the sizing of onsite sediment disposal areas only. Settling rates for wet ponds and extended detention dry ponds will often vary considerably due to specific site characteristics. The removal efficiencies in Table 6-1 may be considerably higher than actual sediment removal efficiencies. However, a higher assumed removal efficiency will ensure that adequate onsite disposal area is provided. Therefore, the efficiency rates cited in Table 1 may be used if more site specific efficiency rates are not available. The designer will want to consult with the local jurisdiction for guidance and to determine if more accurate numbers are available.

In the remaining jurisdictions, the responsibility for maintenance is usually the owner's. Appendix 6-3 presents the general maintenance responsibility guidelines for Northern Virginia localities. A check with the jurisdiction during the planning stages of a BMP facility is encouraged to clarify this point.

V. Operation and Maintenance Costs

It is clear that the maintenance needs of BMPs are somewhat site specific, and the costs of conducting needed maintenance will vary accordingly. However, it is possible to determine cost estimates using some general BMP maintenance parameters. The operation and maintenance of a BMP facility will usually involve routine and non-routine maintenance procedures. Routine maintenance procedures will include inspections, debris and litter control, mechanical components maintenance, vegetation management, and other routine tasks as determined for the specific facility. Non-routine costs are those associated with removing accumulated sediments from the facility and long term structural repairs. Non-routine maintenance costs will vary greatly depending upon the size and depth of the facility, the volume of sediment trapped in the BMP, the accessibility of the BMP, and whether or not onsite disposal of the dredged sediments is possible.

A study by Woodward-Clyde Federal Services (1991) produced estimates for the average annual operation and maintenance costs of various BMP facilities. The data was obtained from several published sources and varies according to region, labor rates, proximity of equipment, and time of year. These cost estimates are to be used as a general planning guideline only and not for estimating and bidding on maintenance contracts. For these purposes, local contractors and suppliers must be contacted. For infiltration trenches, extended detention dry ponds, and wet ponds, the average annual operation and maintenance costs are directly linked to the storage volume capacity of the facility.

The average annual operation and maintenance costs of an infiltration trench are estimated at 9% of the capital cost of the facility. Reported costs ranged from 5% to 15% of capital costs. The average annual operation and maintenance costs of an extended detention dry pond are estimated at 4% of the capital cost of the facility. Reported costs ranged from 3% to 5% of capital costs. The average annual operation and maintenance costs of a wet pond are estimated at 3% of capital costs. Probable costs for a wet pond less than 100,000 cubic feet is 5% of capital costs, while the probable costs for a wet pond greater than 1,000,000 cubic feet is 1% of capital costs. Initial capital costs will vary considerably depending on the type and size of the BMP facility. The reader should refer to MWCOG (1987) or Woodward-Clyde Federal Services (1991) for general BMP construction cost estimates.

While these cost estimates provide a general guideline to annual operation and maintenance costs, the owner of the BMP facility should plan ahead to ensure that funds are available when non-routine expenses are necessary. The costs of maintaining a BMP over the long run can be considerable, particularly when dredging or performing other non-routine maintenance. To lessen the immediate financial impact of these non-routine costs, it is strongly advised that any party responsible for BMP maintenance create a sinking fund for this eventuality. For extended detention dry ponds, which need to have sediment removed every 2 to 10 years, 10% to 50% of the anticipated dredging costs should be collected per year. For wet ponds, which need to be dredged every 5 to 15 years, approximately 6% to 20% of the anticipated costs should be accrued per year. Present value of the assessment can include anticipated interest.

VI. Maintenance Specific to Wet Ponds and Extended Detention Dry Ponds

Both wet ponds and extended detention dry ponds experience conditions which can lead to degraded efficiency and objectionable conditions. Areas of concern include: excessive weed growth, maintaining adequate vegetative cover, sedimentation, bank erosion, insect control, outlet stoppages, soggy surfaces, algal growth, fence maintenance, unsatisfactory emergency spillway, and dam failures/leakages. The main problem for extended detention dry ponds is a tendency for a soggy bottom, which hinders facility maintenance and the growth of effective vegetative cover. Many of these concerns will be site specific and should be addressed by the engineer during the design stage.

A) Inspections

Scheduled, periodic inspections should provide the foundation for a comprehensive maintenance program. Detailed inspections, occurring at least annually, should be conducted by a qualified inspector to ensure that the facility is operating as designed and to provide a chance to schedule any maintenance which the facility may require. The American Public Works Association recommends that the following items be checked as minimum inspection requirements.

RECOMMENDED MINIMUM INSPECTION REQUIREMENTS
◆ Dam settling, woody growth, and signs of piping.
◆ Signs of seepage on the downstream face of the embankment.
◆ Condition of grass cover on the embankment, pond floor, and perimeter of the pond.
◆ Riprap displacement or failure.
◆ Principal and emergency spillway meet design plans for operation.
◆ Outlet controls, debris racks, and mechanical and electrical equipment.
◆ Outlet channel conditions.
◆ Safety features of the facility.
◆ Access for maintenance equipment.

Table 6-2: Recommended Minimum Inspection Requirements

If possible, inspections should be made during periods of wet weather to ensure that the facility is maintaining desirable retention times. A sample inspection checklist can be found in Appendix 6-4. In addition to regularly scheduled inspections, the opportunity should be taken to note deficiencies during any visits by maintenance personnel. After major storm events the facility should be checked for clogging of the outlet structure.

B) Sediment Accumulation

Typical extended detention dry ponds and wet ponds are designed to provide effective pollutant removal capabilities by enhancing sediment deposition. The accumulation of sediment is an important parameter to consider when designing BMP ponds. Periodic removal is important to the effectiveness of these facilities; therefore, a schedule of sediment removal should be established.

For large ponds, the costs associated with sediment removal and offsite disposal are high. To reduce such costs, the designer should include an onsite area for disposal of dredged material or for use as a topsoil conditioner. Standard erosion and sedimentation measures should also be taken here to avoid transport of the sediment into local waterways. Refer to Section III of this chapter for a method of sizing an onsite sediment disposal area. Other options may include disposal or use of sediment as cover at the local landfill. See Appendix 6-1 for appropriate local waste management contacts and local landfill policies concerning disposal of sediment.

Another possible option to lower sediment removal costs in wet ponds is to include a sediment forebay in the facility design. Forebays should be located at pond inflows and should have a storage capacity enabling them to receive sediment over a twenty year period. It is important to include an access to the forebay that is stabilized to accept heavy equipment traffic necessary for sediment removal operations and the capability to dewater the forebay area during the desiltation process. Sediment forebays, especially when used in conjunction with onsite disposal areas, can greatly reduce costs as well as facilitate improved sediment removal.

C) Vegetative Cover

If allowed to become established, small trees and brush with woody root systems can grow to cause destabilization and seepage in pond embankments which may result in the structural failure of the facility. For this reason the dam embankment, side-slopes, and emergency spillway of an extended detention dry pond or wet pond should be kept free of woody growth and undesirable vegetation. This will require periodic mowing and a policy of not allowing plantings on these facilities. The frequency of mowing may need to be greater if the facility is located in an area of high visibility. However, if possible, the facility should be managed as an upland meadow with grass no shorter than 6-8 inches. Keeping grass much shorter than this can cause areas of the turf to die off or require a much higher level of maintenance. For this reason, it is best to keep facilities off of residential lots and in natural surroundings where they may be maintained as a meadow and not as a lawn. Fairfax County does not permit stormwater management facilities (stormwater quantity rather than quality) to be located on private lots in residential subdivisions.

Gradual slopes are necessary for establishing vegetative cover and for ease of mowing. Guidelines recommend a maximum of 3h:1v slopes for areas to be maintained by mowing. The pool and bank slopes should be shallow enough to allow for dredging and mowing equipment and the pond bottom should have sufficient slope (minimum 2%) to avoid areas of ponded water. In poorly drained soils, low flow concrete trenches will be required to help prevent long-term saturated conditions.

Erosion and bare areas noted during site visits should be backfilled with topsoil, compacted, and reseeded. These problems, if taken care of promptly, can help to avoid more costly repairs made necessary by continued erosion of unstabilized soils.

No trees, brush, or other woody vegetation should be allowed to grow within 10 feet of the embankment or side slopes. Any old growth, and its root system, should be completely removed. The excavation should then be filled, compacted, reseeded, and protected until properly vegetated. Any seedlings or planting should be removed at the earliest opportunity and the disturbed areas properly stabilized.

D) Shorelines

To minimize the maintenance of the area surrounding the shoreline of the facility, the slopes should be relatively flat and bank stabilization materials such as riprap and vegetative growth cover should be incorporated into the design. As a minimum requirement, areas of the shoreline which are adjacent to the embankment of those areas that are most subject to wind erosion must be properly stabilized. The layer of stones should be 12 inches thick and placed on a 10 inch bed of gravel and should extend 3 feet below the normal pool elevation. It may also be necessary to add a slight berm on the upstream face of the dam to support the riprap and prevent it from slipping.

E) Structural Repairs

The inlet, outlet, and riser structures of the facility should be constructed of precast or reinforced concrete because of its greatly extended service life. Perhaps the largest single expense involved in BMP maintenance will be the eventual repair or replacement of these parts of the facility; therefore, the use of quality materials with a long service life should be used. Structural use of corrugated metal pipe or plastic products is discouraged.

VII. Maintenance Specific to Infiltration Trenches

NOTE: Fairfax County does not accept infiltration trenches for public maintenance; any such facility should be located outside of public easements.

Maintenance is an extremely important aspect of operating infiltration measures. It is estimated that without controlling sediment accumulation, the effective life span of infiltration measures is, at most, about five to ten years. With proper design, inspection, and maintenance, these facilities should last much longer. Clogging of the stone aggregate reduces infiltration capacity which is the primary process utilized to mitigate water quality impacts.

A) Inspections

Since infiltration systems rely on the availability of pore space for stormwater storage, which can be easily clogged by excess sediments, infiltration trenches will need to be inspected more often than either wet or extended detention dry ponds. Sediment accumulation will eventually render an infiltration trench ineffective; therefore, regular inspections of these structures are necessary. Because these structures are below ground and out of sight, there is a tendency to forego maintenance, leading to subsequent water quality problems. Regular inspections will ensure that problems are identified before they worsen to the point where their evidence is exhibited above ground. Infiltration trenches should not be used as an erosion/sedimentation control during construction of a site. The trench will become clogged quickly during construction activities and clean out after site stabilization would be a major effort.

B) Access for Maintenance

Access to these facilities should be provided in the form of an access easement. Heavy vehicular traffic and the like should be excluded to avoid compaction of the aggregate material and surrounding areas. Constant foot traffic should be discouraged. A maintenance easement should extend around the entire facility. It should be clearly stated in a legally binding maintenance agreement how and when the facility will be maintained and who the responsible party will be.

C) Monitoring Wells

A monitoring well for observation purposes should be included in the design of infiltration facilities. The well should consist of a four to six inch diameter perforated PVC pipe with a locking cap. The well should be placed near the center of the facility, with the invert at the excavated bottom of the facility. A detail for a typical monitoring well is presented in Figure 6-3.

Some jurisdictions require the installation of an observation well with such structures to monitor sediment accumulation and facility performance. For the first year of operation, the installation is inspected quarterly and after each major storm. Notes should be kept on rates of dewatering, water depth, and depth of accumulated sediment. The inspection schedule can be adjusted based on the first year’s performance. It is recommended that such use of observation wells be included in all infiltration facilities.

D) Filter Strips

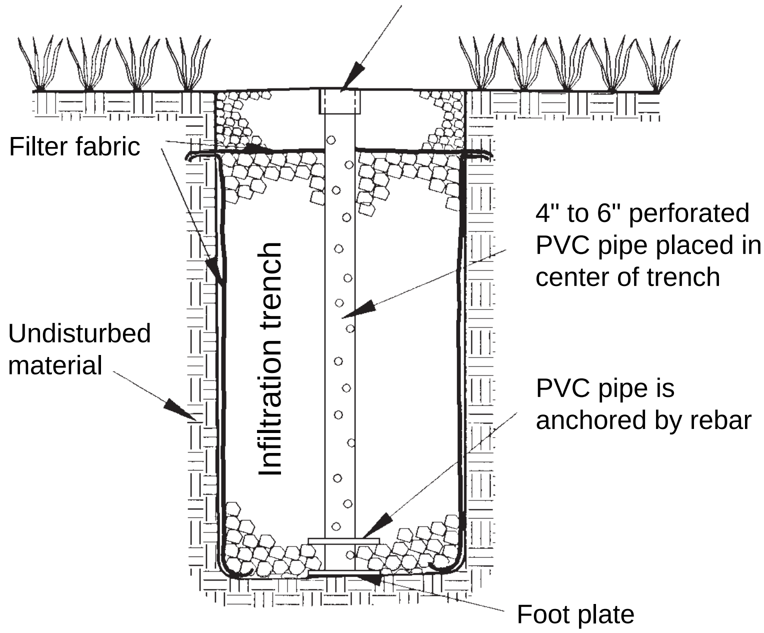


Figure 6-3: Typical Monitoring Well
(Adapted from Maryland Department of Natural Resources, 1984)

Grassed filter strips must be incorporated into these facilities in order to trap large debris above ground before the runoff enters the facility, thereby improving the effectiveness of the aggregate. Grassed filter strips should be given periodic landscape care to maintain their viability.

It is recommended that the top several inches of medium and the filter cloth along the top of the trench be replaced annually or at least when the facility exhibits evidence that infiltration rates have been reduced. Proper disposal of the materials removed is necessary. The aggregate and cloth should be appropriately packaged and delivered to the local landfill if approved for disposal by the operating authority. Appendix 6-1 includes a list of local agencies to contact regarding disposal at landfills.

Chapter 7
Unconventional and Experimental BMPs

I. Introduction

The purpose of unconventional and experimental BMPs is to allow some flexibility for developments where standard BMP facilities can not be accommodated due to the severe physical constraints of the site or other extenuating circumstances. Their use is not intended to circumvent the preferred implementation of standard BMPs with proven water quality improvement efficiencies and acceptable operation and maintenance provisions. The use of any unconventional or experimental BMP in Northern Virginia requires specific approval on a case by case basis by the appropriate review agency official. The developer of any unconventional or experimental BMP facility must provide full details and supporting data including:

- Justification of the unconventional or experimental BMP facility.
- Technical information with research data supporting efficiencies (when available).
- Provisions for a pollutant removal efficiency monitoring program.
- Maintenance considerations and program (private maintenance will generally be required for unconventional and experimental BMP facilities).
- Any safety considerations.
- Aesthetic considerations.
- Location and interaction of the facility with populated areas.
- Pest control program, if required.
- Provisions for following up and evaluation of efficiencies.

The following sections provide an outline of general planning considerations for some of the more common structural (Section II) and nonstructural (Section III) unconventional and experimental BMPs. Structural BMPs outlined in this section include porous pavement, water quality inlets, and underground storage tanks. Nonstructural BMPs outlined in this section include street sweeping, grassed swales, vegetative buffer areas, and marsh vegetation.

II. <u>Structural BMPs</u>

A) Porous Pavement

Porous pavement is an open-graded asphalt concrete created by using no fine aggregate in the mix. The resulting concrete mixture is characterized as having approximately 16 percent voids as opposed to conventional asphalt concrete which has 3 to 5 percent voids. The basic porous pavement system consists of a top layer of porous asphalt concrete covering a layer of gravel which covers a layer of uniformly sized large aggregate, which is placed on top of the existing soil sub-base (see Figure 7-1). Stormwater penetrates the porous asphalt and is filtered through the first layer of gravel. The voids in the lower level of large aggregate are filled with runoff. Gradually the stored runoff infiltrates into the underlying soil. A sheet of filter fabric below the aggregate prohibits the underlying soil from entering and clogging the facility.

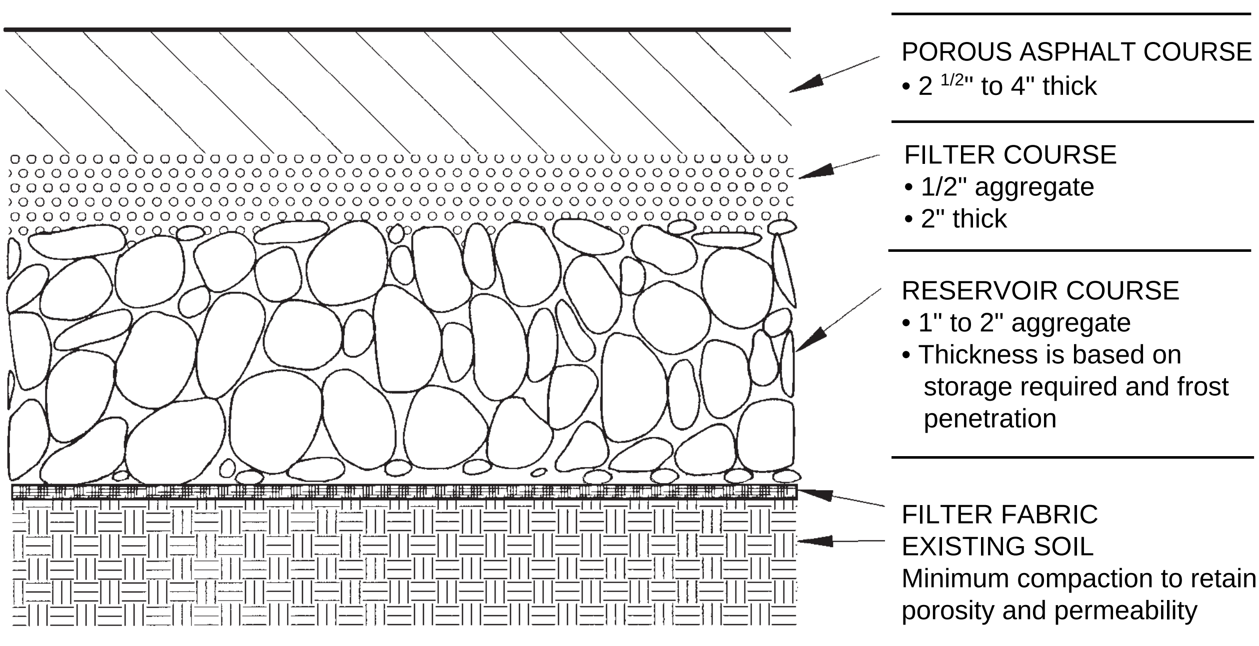


Figure 7-1: Profile of a Typical Asphalt Porous Pavement Section
(Adapted from Maryland Department of Natural Resources, 1984)

Porous pavement is used to recharge groundwater supplies, reduce stormwater runoff and reduce water pollution from paved low volume traffic areas. The surface of the pavement is designed to provide adequate strength to accommodate vehicles while allowing infiltration of surface water and filtration of pollutants. If infiltration into the soil is not practical, the filtered runoff can be discharged through a sub-base drainage system which would outfall into a storm sewer system or into a natural drainage path. Pollutant filtration is greatly reduced when the pavement drains into a storm sewer.

1) *Principles of Mitigating Water Quality Impacts*

The first pollutant removal process occurs in the large aggregate reservoir. Pollutants adsorb to and are absorbed by the aggregate material. Suspended matter will settle out at the bottom of the aggregate layer.

The second process for removing pollutants occurs only if the runoff drains into the soil instead of being discharged by a drain. Pollutants that enter the soil sub-base are also adsorbed to and absorbed by the soil particles. In addition, aerobic decomposition as well as chemical precipitation of the pollutants occurs within the soil strata.

2) *Pollutant Removal Rates*

The data on removal rates for porous pavement ranges from a phosphorus removal efficiency of 62 percent to 90 percent soon after construction. Based on results from the Occoquan Watershed Monitoring Laboratory tests performed at the Davis Ford Park site, approximately 62 percent of the total phosphorus was removed and 88 percent of the total nitrogen was removed. Local Nationwide Urban Runoff Program (NURP) monitoring data showed that removal of most pollutants (including sediments) at a properly constructed porous pavement site approached 90 percent (US EPA, 1983).

3) *Applicability and Practicability*

- <u>Applicability</u>

  Porous pavement is applicable in parking areas and low traffic volume roads provided that grades, subsoils, drainage characteristics, and groundwater conditions are suitable as discussed below. The subsoil must have an acceptable load bearing capacity. See Table 7-1 for acceptable ranges. The grade at the site should be generally flat to maximize the storage volume in the aggregate reservoir.

Porous pavement is recommended for low traffic volume areas because it has a lower tensile strength than conventional pavement. It has been shown that porous pavement is more skid resistant than conventional pavement in rainy weather and the markings on porous pavement are easier to see on rainy nights.

Another advantage of porous pavement systems is the allowance of groundwater to be recharged with 70 percent to 90 percent of the rainfall. Porous pavement, however, should be located at a minimum of 100 feet horizontally from any water supply well, and should be located at least 10 feet down gradient from nearby building foundations. The most suitable drainage area for porous pavement sites will generally be between 1/4 acre to 10 acres. The depth from the bottom of the aggregate to the level of the seasonally high water table or to bedrock must be sufficient (approximately four feet) to allow for adequate infiltration and filtering of water released through the bottom of the structure.

The design of porous pavement systems should include a seepage analysis. Possible adverse impacts of seepage from infiltration measures to building foundations, basements, roads, parking lots, and sloping areas should be addressed. It is recommended that the porous pavement be located ten or more feet down gradient of foundation walls, particularly in residential areas.

The most critical factor to consider in determining if it is applicable to use porous pavement as a BMP device is the infiltration capacity of the underlying soil. A series of core samples should be obtained at the site and tested to determine if the soils are sufficiently permeable to accept the filtered runoff from the stone reservoirs. Refer to Appendix 5-1 for infiltration capacities for various soils. Porous pavement systems may require subsurface drainage if the soil does not have an adequate infiltration capacity (i.e. greater than 0.27 in/hr.). Subsoils are generally susceptible to frost heave if the soil contains more than 3 percent of particles smaller than 0.02 mm in diameter. If this is the case, infiltration from the facility will not be possible and therefore, these soils should be avoided.

- Practicability

  Several studies have shown that the cost of a porous pavement system is comparable to the cost of a conventional pavement system. Additional costs involved in a porous pavement system include the following; large volume of stone required for the aggregate layer, higher costs for porous asphalt, installation of filter cloth, extra investment in sediment and erosion control, establishment and maintenance of buffer areas, additional design, and extra post-construction maintenance. This additional cost increment should be weighed against those of conventional BMPs.

  Potential cost savings from using porous pavement that can offset the additional costs described above stem from the reduced need (or no need) for the various components of a storm sewer system including curbs and gutters, inlets, manholes, and underground conveyance pipes. For actual cost data the reader is referred to MWCOG (1987) and Woodward-Clyde Federal Services (1991).

  Another limit to the practicality of using porous pavement is governed by local demand. Most asphalt producers will not produce porous mix for jobs less than 1/2 acre due to the demand for conventional asphalt mixes to be used in the numerous local development projects.

  Several studies have concluded that porous asphalt pavement is sufficiently strong and able to withstand freeze/thaw cycles such that it will last as long as conventional pavement. The key factor in maximizing the useful life of the pavement is the prevention of clogging of the voids.

4) *General Design Parameters*

Since the surface area of the porous pavement will typically depend on how large a parking lot will be built, the critical design consideration will be the depth of the large aggregate layer. As with infiltration trenches, the maximum depth of the large aggregate layer is a function of allowable detention time, the porosity of the aggregate, and the soil infiltration rate. The bottom of the facility should be below the frost line and approximately 4 feet above bedrock and the level of the seasonally high water table. The same design steps as those presented in Chapter 5 for infiltration facilities apply for porous pavement (pg. 5-28).

Note that there is an additional step which involves determining the thickness of the porous pavement layer. The depth of the asphalt layer and underlying stone reservoir depends on the strength of the sub-base soil and the projected traffic intensities.

The asphalt layer is typically 2.5 to 4 inches thick. As a check, determine the following:

i) Anticipated traffic levels.
ii) California Bearing Ratio (CBR) of the soil - Typical CBR values for various soils are shown in Appendix 7-1. Methods for conducting the CBR test are described in ASTM D1883 and AASH0 T193. Two types of soil classification systems are presented in Appendix 7-2 and 7-3.
iii) From Table 7-1, determine minimum combined thickness of the asphalt layer and stone reservoir.

Traffic Group	General Character	California Bearing Ratio				EAL
		15 plus	10-14	6-9	5 less*	
1	Light Traffic	5"	7"	9"		5 less
2	Med. Light Traffic (Max. 1,000 VPD)	6"	8"	11"		6-20
3	Medium Traffic (Max. 3,000 VPD)	7"	9"	12"		21-75

*Studies indicate that for all traffic groups with CBR of 5 or less, the subgrade was improved to CBR 6 with crushed stone 2" size.
VPD = Vehicles Per Day
EAL = Equivalent Axle Load (18 Kips) average daily
Note: Thicknesses refer to the minimum combined depth of asphalt layer and stone reservoir necessary to carry appropriate load.

Table 7-1: Minimum Thickness of Porous Paving
(Source: Thelen and Howe, 1978)

This depth should be checked against the minimum depth as determined by the minimum and maximum allowable depth determined in Chapter 5 - Infiltration Trenches.

The aggregate gradation specification recommended to obtain a porous asphaltic concrete pavement is presented in Appendix 7-4. The specific pavement design should be determined by a licensed professional engineer.

5) *Handling Overflow*

Please refer to the discussion pertaining to overflow considerations as presented in Chapter 5 - Infiltration Trenches, Section G, on page 5-30.

6) *Filtering Runoff*

Because the voids in the porous asphalt layer can become clogged quite easily, it is important to prevent large amounts of sediment from being introduced to the site. Any significant amount of offsite flow should be diverted around the pavement surface. Limited offsite runoff and all onsite runoff should be filtered before it flows over the pavement.

Please refer to the discussion in Chapter 5 - Infiltration Trenches, Section I, on page 5-32 for further recommendations that apply to filtering runoff in both infiltration trenches and porous pavement systems.

7) *Operation and Maintenance*

The major concern for maintenance of porous pavement systems is the prevention of clogging in the voids. The best approach is to prevent any runoff from offsite areas from flowing over the paved area. This can be done by building a berm around the perimeter of the paved area which allows offsite flow to be conveyed away from the pavement. Another method involves the use of filter strips (minimum 20' wide) which trap large sediment before allowing the runoff to flow over the pavement. It is important to note that these methods should be implemented both during and after construction.

The best approach to cleaning the porous pavement is by vacuum cleaning with a street sweeper followed by a high pressure washing. This should be done a minimum of four times per year. During periods of snow it is important not to apply abrasive materials since they will clog voids in the pavement after the snow and ice melt and prohibit future infiltration. Refer to Standards and Specifications for Infiltration Practices (Md DNR, 1984) for additional operation and maintenance considerations.

Periodic inspections ensure that problems will be identified before the pavement system becomes ineffective. It is recommended that a monitoring well for observation purposes be included in the design of the porous pavement system. The well should consist of a four to six inch perforated PVC pipe with a locking cap. The well should be placed at the downstream end of the paved area. Details for a typical monitoring well are included in Chapter 6, Section VII(C), on page 6-11.

8) *Construction Considerations*

The most important aspect in the construction of porous pavement systems is the high level of workmanship required to ensure that an effective BMP is built. Numerous inspections should be performed while the porous pavement facility is being built to ensure proper construction techniques. Refer to Standards and Specifications for Infiltration Practices (Md DNR, 1984) for details. The specifications include recommendations regarding the desired asphalt content, the gradation of the aggregate, the type and quality of the aggregate, and the suitable mixing temperatures for the porous asphalt mix.

The reader is also referred to a general summary of construction considerations presented in Chapter 5 - Infiltration Trenches, Section J, on page 5-34. In order to retain an effective porosity for the system, it is important to allow only minimum compaction of the subsoil, the stone layers, and the porous asphalt layer. See Appendix 5-4 for standard aggregate sizes for use in the reservoir course.

B) Water Quality Inlets

Water quality inlets, or oil/grit separators, are designed to provide limited pollutant removal on small, urban lots where land and cost restraints prohibit the use of any larger BMP device. The inlets are designed primarily for the removal of sediment and hydrocarbon loadings which are frequently concentrated in parking lots and other areas where there is a substantial level of vehicular traffic. Water quality inlets are usually used as a pre-treatment device before stormwater is conveyed into a storm sewer or an infiltration device. However, site constraints and some innovative modifications may make it feasible for a water quality inlet to act as a BMP on its own. Figure 7-2 presents a profile of a typical water quality inlet designed for use in Montgomery County, Maryland (MCDEP, 1984). The Montgomery County design, however, has proven to be ineffective in many cases because of the propensity for new storms to resuspend collected sediments and flush them into the receiving waters. A more recent modification to this design is presented in Figure 7-3. This design utilizes an additional orifice and chamber to aid in oil/grit removal.

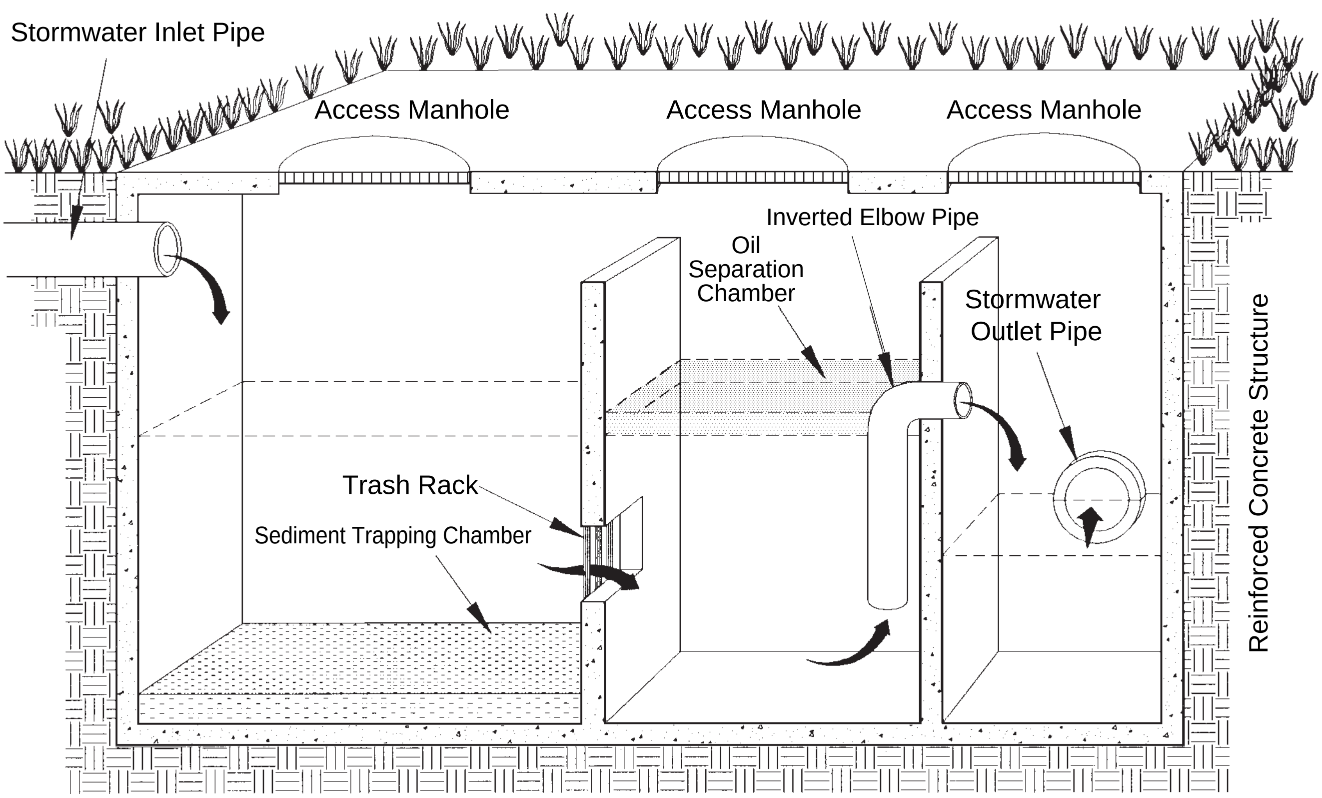


Figure 7-2: Profile of a Typical Water Quality Inlet
(Adapted from Montgomery County Department of Environmental Protection, 1984)

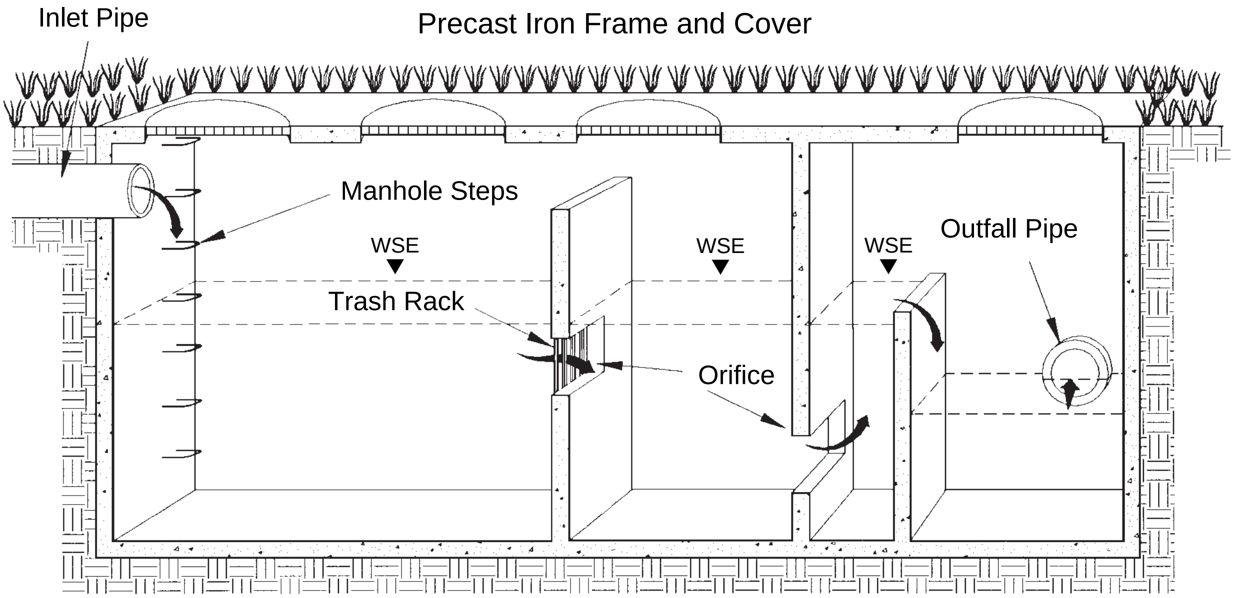


Figure 7-3: Modified Oil/Grit Separator
(Adapted from Washington, D.C. Stormwater Design Handout, 1992)

1) *Pollutant Removal Rates*

Pollutant removal rates for water quality inlets have not been tested in the field to date. However, studies of similar mechanisms makes it possible for the effectiveness of water quality inlets to be inferred. Water quality testing suggests that water quality inlets are only effective in removing coarse sediments, oil/grease, and debris from the water. Settling column studies have shown a 20 to 40 percent settling rate per hour depending on the initial sediment concentration. Removal of fine grained particulates, including silt, clay, trace metals, and nutrients is severely limited. Soluble pollutants, including phosphorus, pass through the system unmodified. These limitations are due primarily to the following design constraints.

- The storage area provided by the permanent pool in a water quality inlet is typically only one-quarter the size of the average storm in the Washington D.C. metropolitan area (0.40 inches of rainfall).

- Due to the small capacity of the facility and the limited drainage area, storm runoff passes through the facility very quickly thus preventing settling. The average detention time of a water quality inlet is barely over one hour.

- Pollutants are not permanently removed until the facility is cleaned out, therefore increasing the risk of resuspension of sediments during a large storm event.

To overcome these limitations, MWCOG (1987) has suggested five ways in which the pollutant removal efficiency rates for water quality inlets may be enhanced.

- The volume of the permanent pools in the first two chambers should be maximized. The third chamber, if possible, should also contain a permanent pool.

- The orifice draining between the first two chambers should be protected with a trash rack in order to prevent clogging.

- The inverted elbow pipe connecting the second and third chambers should extend a minimum of three feet into the permanent pool to more efficiently remove oil.

- Maintenance should be performed at least twice a year. This should include the removal of any sediments and collected debris.

Because information on pollutant removal efficiencies for inlet facilities is limited, monitoring would be required if the inlet were to be used for BMP purposes.

2) *Applicability and Practicability*

- <u>Applicability</u>
  Water quality inlets are typically used for areas of one acre or less. They are particularly applicable for parking lots, garages, and other areas which experience high levels of vehicular traffic. Water quality inlets are also unobtrusive and easy to access. The only site prerequisite for installation of a water quality inlet is that there must be a storm drain network in close proximity that it can be connected to.

- <u>Practicability</u>
  For those designing water quality inlets in Northern Virginia, the largest consideration is the limited phosphorus removal capabilities of the facility. Innovative designs to enhance removal rates are encouraged, but must be approved by each individual jurisdiction and subsequently monitored.

The cost of installing a water quality inlet ranges from between $5,000 and $15,000 depending on the size and location of the facility. Operation costs for the facility are high because routine maintenance is required for the inlet to continue to function properly. It is recommended that the facility be cleaned of trapped sediments at least twice a year.

3) *Stormwater Management Benefits*

The stormwater management benefits of the water quality inlet are marginal due to their limited storage space. Standard water quality inlets only provide approximately one-third of the needed storage for a two-year design storm. Therefore, inlets do not greatly reduce the peak discharge rate. Further, because the inlet connects directly to a storm sewer system, no aquifer recharge occurs.

C) Underground Storage Tanks

In many intense urban areas, which are usually served by structural sub-surface storm sewers, there is so little available space that the only means of providing non-point source pollution control is through the use of underground facilities. Currently, one of the primary stormwater management techniques for heavily urbanized areas is the underground detention tank (UDT). A first flush detention system may provide for the use of collected stormwater onsite (i.e., toilet flush water, evaporative airconditioner cooling water, or landscape irrigation water), for diversion via a timed ‘smart-box’ to the wastewater treatment plant during off-peak hours, or for treatment and release into the stormwater conveyance system. There are, however, many questions regarding the effectiveness of underground detention tanks. To date, all standard designs have raised serious questions about their capacity to keep subsequent storms from resuspending or simply flushing out accumulated sediments and particulate nutrients out into the storm sewers and from there into the receiving waters (NVPDC, 1992d). Contacts with jurisdictions throughout the U.S. have failed to identify examples of functioning underground tank BMPs for stormwater quality management. However, some jurisdictions (such as Seattle, Washington) have postulated underground vault BMPs with design analyses based on the assumption that they would function as an extended dry detention or as a quasi-wet detention facility if a permanent pool were maintained. This section will examine the underground detention tank as a BMP facility and introduce innovative ways in which underground detention tanks may be utilized more efficiently for BMP purposes. Such innovative designs are unproven and would require special review and monitoring requirements.

1) *Pollutant Removal Rates*

For an underground detention system which discharges first flush detention water directly into the sanitary sewer or via toilet flush water from a cistern stormwater recycling system, the discharged wastewater is converted from non-point source water into point source wastewater (and as such permitting requirements should be considered). The pollutant removal efficiency in such instances can be assumed to be that of the receiving wastewater treatment plant. The phosphorus removal capacity of such plants is typically in the 95 to 100 percent range. Further, according to a study at the Blue Plains wastewater treatment plant, in Washington, D.C., a majority of other pollutants including synthetic organic compounds, heavy metals, and hydrocarbons, are also removed during the treatment process (Coastal Environmental Services, Inc., 1992). This option however, would require the approval of the local sanitation authority and would face severe regulatory, administrative, and interjurisdictional obstacles. No such system should be planned unless a detailed study into the water quality and quantity impacts of such a system on the wastewater treatment plant were performed.

Another stormwater recycling option is to use the detained stormwater for use as landscape irrigation water. For such facilities, the pollutant removal efficiency could be assumed to be roughly that of an infiltration system. Further, a certain amount of biological uptake may also occur as the stormwater interacts with the vegetative ground cover. However, sites with landscaped area sufficient to utilize the water quality volume of stormwater would tend to lend themselves to conventional BMPs.

For facilities which do not flush into a sanitary system and are not used for other recycled purposes, efficiencies are calculated on the assumption that the settling out of particulate phosphorus and sediments are the only beneficial processes taking place. However, the pollutant removal efficiency achieved through the settling process may be negated if subsequent storms are allowed to resuspend and flush out the collected sediment or nutrients. The use of permanent pools, peat/sand filters, or sediment forebays to prevent flushing, are the only potentially viable solutions identified to date. The use of underground detention also presents the opportunity to introduce chemical or biological agents to increase the nutrient removal efficiency of the pool beyond the mechanical settling threshold.

Three design modifications that may enhance the efficiency of an underground detention tank are:

- The establishment of a forebay.
- The use of peat/sand filters.
- The diversion and detention of stormwater for routing through the sanitary lines to the wastewater treatment plant during off-peak hours.
- Inclusion of a modified swimming pool filter system or modified small sewer treatment plant (typically used for single lots) for use in conjunction with underground detention tanks to provide water quality improvement.

Additionally, cistern collection and recycling of stormwater for toilet flush water, evaporative cooling water, and/or landscape irrigation water utilizes the same concept of collection and diversion.

2) *Applicability and Practicability*

- Applicability

  Underground detention tanks are primarily used in extremely high density urban environments where either space is not available, or land costs become prohibitive for a larger, more traditional BMP facility.

  First flush detention tanks are not intended to be used as an alternative to traditional BMPs, such as wet ponds or extended detention dry ponds, on sites where sufficient room exists to install such devices. Capacity at the wastewater treatment plant should be investigated first. The plant operators will want to evaluate the potential cumulative impact of accepting such a policy for stormwater treatment prior to the acceptance of the stormwater. This consideration is most likely to be the primary constraint. Normally, first flush detention with wastewater treatment plant processing should be limited to a maximum of two acres.

Site appropriateness for cistern collection and improved BMP underground designs should be examined on a case-by-case basis. The reader is referred to *Rainwater Catchment Systems as Best Management Practices*, NVPDC, 1992, and *Underground Detention Tanks as Best Management Practices*, NVPDC, 1992, for more detailed information on the design and site appropriateness of such facilities.

- Practicability

  While underground detention tanks allow for BMP facilities to be located in urbanized areas without occupying valuable land, there are drawbacks to the facility which inhibit its effectiveness as well as its practicability. Such inhibiting factors, depending on the design, may include:

  - Underground stormwater detention tanks with the required storage volume are very expensive to build.
  - The typical outflow control for this BMP, while simple, often ceases to function due to improper maintenance or never does function as theoretically indicated.
  - The rated efficiencies for most conventional underground BMPs are so low that the BMP cannot compensate for the increased pollutant loads resulting from intense development.
  - Maintenance of stormwater underground detention tanks is essential if they are to serve as a BMP.

  These drawbacks often make development and/or redevelopment extremely difficult in intense urban areas and it is important to recognize the economic importance of these areas to the locality. At the same time, some of the heaviest transporters of non-point source pollutant loads on a land area basis are the intense urban areas. Since these areas are served by existing stormwater conveyance systems, a well designed underground detention tank may provide an alternative to conventional BMPs.

3) *General Design Parameters*

For detailed design procedures for underground storage tanks and cistern stormwater collection systems, the reader is directed to the following documents:

- *Underground Detention Tanks as a Best Management Practice*, Northern Virginia Planning District Commission, 1992.
- *Alexandria Supplement to the Northern Virginia BMP Handbook*, Alexandria Department of Transportation and Environmental Services, 1992.
- *Rainwater Catchment Systems as a Best Management Practice*, Northern Virginia Planning District Commission, 1992.

4) *Design Modifications*

- Forebay Requirements

  Standard underground detention tank design utilizes chambers separated by check dams to reduce velocities and achieve settling. Concerns have been raised regarding resuspension during actual first flush, unless the detention tank was maintained after each storm (which is unlikely). Innovative designs in forebay sediment traps are currently being examined along with design modifications to reduce the flushing of accumulated sediment, such as baffles and regular pump-out.

- Sand Filters

  Each sand filter system has a compartment to trap oil, trash and grit; and another compartment that contains a sand filter that can filter out and trap fine sediments and pollutants. The *Alexandria Supplement to the Northern Virginia BMP Handbook* contains procedures involved with the engineering design of three different underground sand filters, the Washington D.C. Sand Filter, the Delaware Sand Filter, and the Austin Sand Filter. Sand filters can be designed to be contained within an underground detention tank or as a separate tank that precedes an underground detention tank. Refer to Figure 7-4 for a general design schematic of a Washington, D.C. Sand Filter.

  As with water quality volume storage tanks, storage time for sand filters should not exceed 48 hours so that the facility will be free to process subsequent storms. The

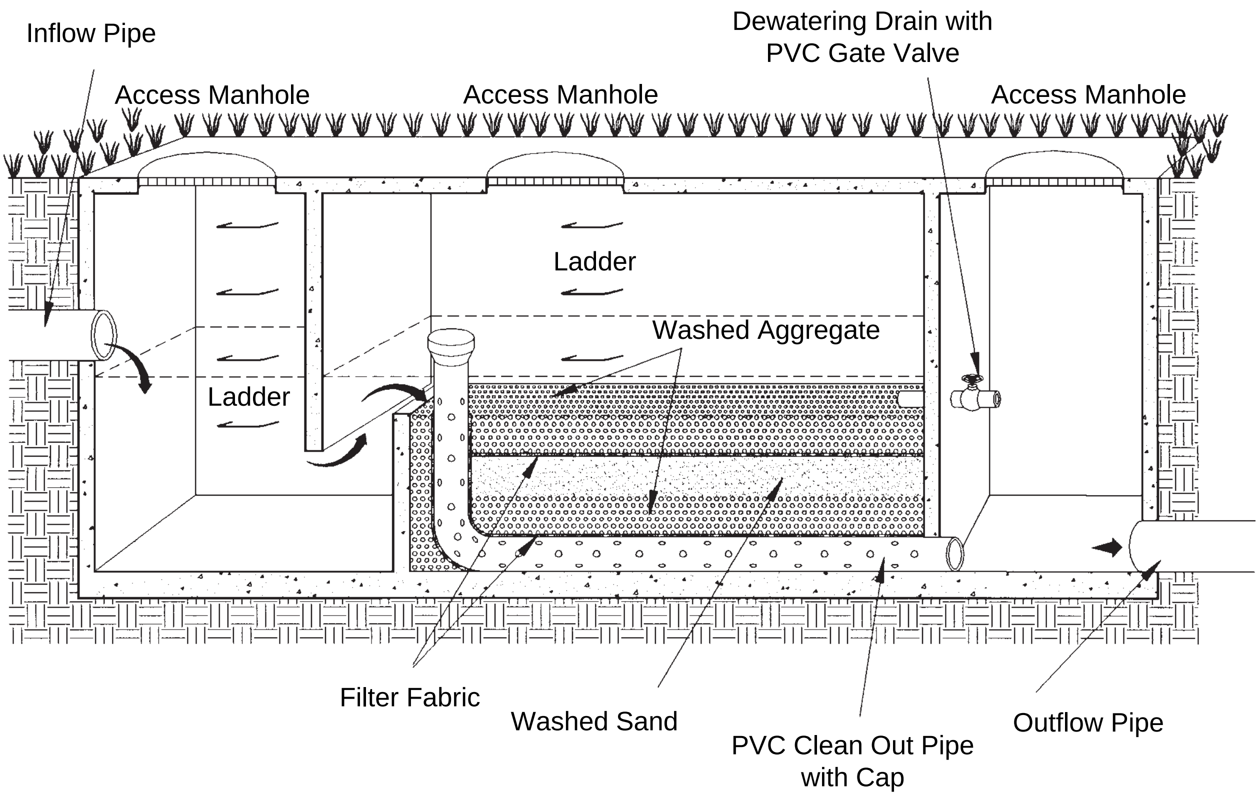


Figure 7-4: Washington, D.C. Sand Filter Design
(Adapted from Alexandria Supplement to the Northern Virginia BMP Handbook, 1992)

load carrying capacity of the filter structure must be considered when it is located under parking lots, driveways, and roadways. The structure should be designed by a structural engineer. There must be sufficient vertical clearance between the invert of the prospective inflow storm piping and the invert of the storm sewer that will receive the outflow. This will allow the filter system to work by gravity. If this cannot be accomplished, the outflow area of this tank may be designed below the invert of the receiving storm sewer pipe. In such cases, the use of clear well pumps to discharge the effluent into the storm sewer will be required. This will have to be approved by each locality. These facilities can be used on drainage areas of up to five acres. For larger drainage areas the construction costs may be prohibitive, which would favor the choice of an alternative above ground facility.

Approximately every three to five years, the filter can be expected to clog to the point that removal and replacement of the top layer of washed gravel or sand and the filter cloth will be required. Provisions must be made in the design for access to the filter media for this refurbishment. A minimum headspace of five feet above the filter will be required if the ceiling to the chamber is a fixed structure. When site conditions dictate placement of the filter too near the surface to provide adequate headspace, segmented, removable covers, such as are employed over shallow underground utility tunnels, must be provided above the filter chamber. It should be noted that there are some options in this area based on the various sand-filtration designs to date. For example, the Delaware Sand Filter can be placed in a three foot deep trench. However, complete maintenance access can only be provided by placing removable metal grates and plates (as mentioned above) over the entire length of the facility. The Washington D.C. Sand Filter basic design would require at least an eight to nine foot deep structure but can be modified to a shallower depth if grates are used as the ceiling.

- Diversion to Wastewater Treatment Plant

  Conventional BMPs are all essentially detention systems which prevent the release of first flush stormwater (the first half-inch of runoff from impervious surfaces—also known as the 'water quality volume') into the storm sewers and receiving waters. Such first flush detention systems utilizing underground detention tanks may provide for controlled discharge into the sanitary sewers for treatment in wastewater treatment plants, where there is sufficient capacity during off-peak hours. This design would not require a settling-out period. However, this option would require, at a minimum, the approval of the local sanitation authority.

  Under this design, first flush stormwater runoff is channeled through a 'smart box' diverter, which directs the first flush volume into the collection tank and then allows the remaining runoff to enter a peak flow rate reducer or exit directly into the storm sewer. If the wastewater treatment plant contains sufficient capacity, the first flush water could be pumped into the sanitary sewer during off-peak hours. Central control of such discharges by the wastewater treatment plant staff through telemetry may be required to assure that the storm has ended and that the plant is immediately able to process the additional volume. (Special billing arrangements would have to be worked out with the wastewater utility.) Detention tanks must be designed to preclude the possibility of system failure resulting in a direct stormwater flow into the sanitary sewer.

- Mechanical/Chemical Treatment

  Another innovative design modification is the addition of *mechanical/chemical filtration systems* to underground tanks and then routing them into the storm sewer lines. Several questions regarding this method have been raised. First, with an average resident time in a permanent pool, could the introduction of an agent to precipitate or chemically alter the nutrients cause the efficiency of the underground facility to approach that of a conventional wet pond? Second, what agents should be introduced and what would be the associated environmental impacts on the receiving waters? Third, how often would the forebay have to be cleaned and what costs would be involved?

  Another potential approach which may be considered would be an “off-line” (diversion) system which would 1) detain the first flush (water quality) volume; 2) filter or otherwise mechanically separate the solidified/coagulated nutrients from the water; 3) release the treated water back into the storm sewers; and 4) transfer the nutrients and sediment to a storage tank for periodic removal.

  There are three potential advantages to the systems described above: First, it is expected that the efficiency of including a treatment device will prove to be much higher than conventional BMPs. Since settling will not be relied upon as the primary treatment process, this may help reduce the required size of the underground tank and allow properties to meet the NPS performance criteria where they otherwise may not. Cost estimates will evaluate the extent to which the reduced size of the BMP could compensate for the increased cost of the treatment plant, thereby offsetting the economic impact in achieving significant water quality gains. Second, as the treatment plant is designed for regular maintenance, the prescriptive maintenance program should assure the long term efficiency of the facility and avoid many of the current problems. The typical use for such a facility, a large commercial development, would have building maintenance staff capable of performing the maintenance. Third, as other local governments find that this is a valid solution, the reluctance to require BMPs for new development in highly urbanized areas will be minimized.

- <u>Cistern Stormwater Recycling (Rainwater Catchment Systems)</u>
  Stormwater recycling has been extensively utilized as a water conservation technique in arid areas such as the western United States and in areas with limited fresh water supplies. These systems are designed to collect stormwater from impervious areas and store it in a cistern until it can be used for landscape irrigation, bath water, laundry water and drinking water. Not until recently, however, have rainwater catchment systems (RWCSs) been considered for use as a BMP as well. The use of a RWCS as a BMP measure has great water quality potential. Unlike traditional RWCSs, which are designed for water conservation purposes, RWCSs as BMPs are designed to collect only the first flush stormwater runoff from impervious areas of a site. Several water conservation projects in the West, most notably the *Casa del Agua,* which is administered by the University of Arizona, have demonstrated the use of collected rainwater for these purposes. The collected stormwater, in turn, is used to supplement or completely augment public water supplies for toilet flush water, airconditioner cooling water, or landscape irrigation water. The pollutant removal efficiency of the RWCS will be reflected in the end use of the water. The pollutant removal rates for stormwater used as toilet flush water could be assumed to be that of the wastewater treatment plant, which is about 95 to 100 percent. The pollutant removal rate of stormwater used as irrigation water would include the settling and pretreatment that would take place in the cistern storage tank as well as any biological or chemical interaction that would be experienced from infiltration through the soil strata. The pollutant removal efficiency of stormwater used as evaporative cooling water is much harder to anticipate, although at a minimum, some settling of particulates and sediments would occur during storage.

  Because first flush stormwater contains a number of pollutants, the Virginia Department of Health (VDH) and local jurisdictions would currently require some level of pretreatment for the use of stormwater depending on the water use application. For outdoor uses, such as landscape irrigation, only disinfection (for fecal coliforms) and/or filtration would be required. However, for use in a domestic setting, such as toilet flush water, additional pretreatment would be required and would have to be based on a detailed water quality analysis. Further, some amount of pretreatment would be required for the water to be discharged into the sanitary sewer system. The Fairfax County Department of

Public Works would require the use of an oil/grit separator at a minimum. The Alexandria Sanitation Authority, while having no set regulations, would require the prohibition of, or control of such things as petroleum products, solid matter, pH, and a number of toxic substances and compounds. The VDH and local regulatory agencies would also require the use of lockable faucets, a color coded dual piping system, warning signs, and any other measures deemed necessary to ensure that the stormwater was not accidentally consumed or used as a potable water resource.

The two most important parameters involved with the feasibility of an individual RWCS is the sizing of the storage tank and the amount of water volume that can be used to draw down the collected storm water. Unless the constant draw-down of the cistern can empty the storage tank between storm events, then the storage tank must be sized to hold the next storm event plus the residual water until the stormwater can be used for irrigation or cooling water during the summer months. This would require the use of a larger storage tank as compared to normal underground detention tanks. In many cases, unless the water can be released slowly, i.e. through the sanitary sewer system, then the storage tank may be too large to fit underground, thus negating the land conservation benefits of the system. Further, the costs of the distribution system for indoor use, because there must be a dual system of conveyance, makes the use of a RWCS prohibitively expensive in many instances.

The water conservation benefits of a RWCS, while they have the potential to pay for or at least offset the maintenance and operation costs of the facility, do not alleviate the high initial costs of installation and construction.

The key to the feasibility of a RWCS as a BMP rests in either increasing the amount of constant water draw-down volume for the site or decreasing the amount of stormwater collected. The latter alternative in uncontrollable in Northern Virginia, where the first half inch or rainfall must be collected to meet water quality goals, although a RWCS may be feasible for an area of the United States which experiences less frequent rainfall than does Northern Virginia. However, if the constant water draw-down can be increased to produce a water deficit during the year, then the RWCS would be feasible for Northern Virginia. Constant water draw-down could also significantly decrease the amount of storage volume required for the RWCS tank, thus substantially decreasing the costs associated with storage tank construction and excavation. The most readily available method of increasing constant water draw-down while maintaining health and water quality considerations, would be the regulated discharge of stormwater to the wastewater treatment plant during non-peak hours. However, as discussed previously, many regulatory and logistical questions would need to be addressed prior to planning such a facility.

III. Nonstructural BMPs

Although most traditional pollutant control measures are characterized as structural controls, there exists a range of non-point source controls which do not involve the use of fixed physical structures for the reduction of pollutant loadings. The innate flexibility and relatively low costs associated with the implementation and maintenance of nonstructural controls may offer communities an innovative alternative to costly structural pollutant control programs. This section includes information on four types of nonstructural controls: street sweeping, grassed swales, the incorporation of vegetative buffer areas, and the establishment of marsh vegetation.

A) Street Sweeping

Although street sweeping has been widely practiced for litter and dust control, its implementation as a stormwater pollution control practice is a fairly recent development. For street sweeping to have a beneficial effect on water quality in urban areas, a schedule of frequent sweeping must be established. Currently, the City of Manassas and Arlington County are the only jurisdictions in the Northern Virginia region that use street sweeping as a BMP.

1) *Principles of Mitigating Water Quality Impacts*

The physical removal of particulates and attached fine pollutant particles from the street surface will lessen the pollutant load transferred to receiving waters. The water quality in the receiving streams will be improved due to the lower total solids and heavy metal loads. Aquatic life and other water uses will benefit from the lower turbidity and toxic effects. The removal of pollutant particles from street surfaces also lessens the pollutant load that enters into the atmosphere (Lynard et al., 1980).

2) *Pollutant Sources and Removal Rates*

Studies have shown that there are certain times when street sweeping is very effective in improving water quality. In areas with defined wet and dry seasons, sweeping prior to the wet season is likely to be beneficial. Other times when sweeping is beneficial are following snow melt and heavy leaf fall. Table 7-2 presents the sources of the most common street surface pollutants.

Results of the Nationwide Urban Runoff Program (NURP) studies show that street sweeping produces no significant reduction in nitrogen or phosphorus concentrations (US EPA, 1983). A study performed in San Jose, California showed that 50 percent of the total solids and heavy metals could be removed from urban runoff when the streets are cleaned once or twice a day. When the cleaning activities occur once or twice a month, the removal rate drops to less than 5 percent (Pitt, 1979).

SOURCE	POLLUTANT
◆ Local Soil Erosion	Particulates (inert)
◆ Local Plants and Soils (transported by wind and traffic)	Nitrogen and Phosphorus
◆ Wear of Asphalt Street Surface	Phenolic Compounds
◆ Spills and Leaks from Vehicles	Grease, Petroleum, N-Paraffin, and Lead
◆ Spills from Vehicles (oil additives)	Phosphorus and Zinc
◆ Combustion of Leaded Fuels	Lead
◆ Tire Wear	Lead, Zinc, and Asbestos
◆ Wear of Clutch and Brake Linings	Asbestos, Lead, Chromium, Copper, and Nickel
◆ Deicing Compounds (traffic dependent); Possibly Roadway Abrasion and Local Soils	Chlorides
◆ Wear of Vehicle and Metal Parts	Copper, Nickel, and Chromium

Table 7-2: Sources of Common Street Surface Pollutants
(Source: Lynard et al., 1980)

3) *Applicability and Practicability*

- <u>Applicability</u>
  Accumulation rates of street pollutants vary for different localities in relation to local land use patterns, road surface characteristics, and local weather patterns. Local monitoring programs should be carried out prior to the design of a comprehensive street cleaning program. Street sweeping is likely to be beneficial in high density urban areas subject to high levels of traffic. It may not be applicable in areas where parking can not be periodically banned. Further, street sweeping may not be beneficial on paved surfaces that are in poor condition.

- Practicability
  To implement a cost effective street cleaning program, one must consider the appropriate cleaning equipment for the site in conjunction with the development of an acceptable cleaning schedule for the site. Before establishing a street cleaning program, there should be clear evidence that considerable amounts of pollutants are present on the street surfaces.

  Existing street cleaning techniques are inefficient in picking up fine solids (less than 43 microns) which account for only 5.9 percent of the total solids, but which account for 1/4 of the oxygen demand and 1/2 of the algal nutrient source (VSWCB, 1979). Downstream water quality can be greatly improved by using a street sweeper to reduce the amount of particulate pollutants in conjunction with a BMP effective in trapping the fine solids not removed by the street sweeper.

4) *General Design Parameters*

- Choice of Equipment
  The two types of street sweepers most commonly used are abrasive brush devices and vacuum devices. The vacuum devices are more effective in the capture of fine materials when the surface is dry. Estimates of the efficiency of street sweepers in removing total dust and dirt on paved surfaces are 90 percent for vacuum sweepers and 50 percent for brush sweepers, assuming a smoothly paved surface and no interference from parked vehicles. Table 7-3 outlines available street cleaning equipment.

- Determination of Schedule
  The following steps, as presented in the US EPA Case Histories (Lynard et al., 1980), are used to establish a street cleaning schedule:

  i. Determine an allowable street surface residual loading**.** The allowable load is selected after reviewing the locality's street cleaning objectives. These objectives are determined by reviewing environmental, aesthetic, safety, and public relations considerations. Requirements are then established to meet acceptable urban runoff pollution loads. The requirements are also established to control debris and oil accumulation in traffic lanes and to reduce service area complaints.

ii. Measure or estimate the long-term average particulate accumulation rate on street surfaces. This will vary with the type of surface and with street cleaning frequencies.

iii. Determine the maximum allowable time interval between cleaning operations from accumulation estimates. It is recommended that two passes per run by the street sweeper be incorporated into the schedule.

5) *Operation and Maintenance*

Studies have shown that nearly 90 percent of contaminants on the street will accumulate within 12 inches of the curb (VSWCB, 1979). The effectiveness of a street cleaning program can, therefore, be greatly reduced if curbside parking is permitted. For this reason, the feasibility of utilizing enforcement mechanisms must be considered prior to implementing the program. Due to the relative similarities in efficiencies of available equipment, the selection of a cleaning schedule is more important than the selection of specific equipment. An additional benefit of street sweeping is the reduction in maintenance required for underground stormwater facilities due to the reduction in the amount of sediment contained in the runoff.

6) *Aesthetics and Safety*

Implementation of a street cleaning program has direct and indirect effects on the aesthetic appeal of the community. The removal of large particulates from the streets has a positive visible effect on the aesthetic quality of the community. A possible indirect benefit of street cleaning is the raised awareness of homeowners to keep their streets and driveways free of litter.

The removal of particulates and dust from the streets is believed to contribute to safer roadway conditions for the driving public. The reduction of particulates from the streets is also likely to result in health benefits for those suffering from respiratory illnesses.

TYPE	CHARACTERISTICS	USE
Mechanical Street Cleaner	Rotating brooms, plus water spray to control dust. Dirt is transported to storage hopper on moving conveyor. May be self-dumping, 3 or 4 wheel.	Used for most street cleaning in most U.S. communities.
Vacuum Assisted Mechanical Street Sweeper	Vacuum system transports dirt from rotating brooms to hopper. Transported dirt is saturated with water.	Used in Europe for many years. Has seen limited use in U.S. for some time.
Regenerative Street Cleaner	Recycled air blasts dirt and debris from road surface into hopper; air is then regenerated through dust separation system.	Relatively minor use.
Small, Industrial Type Vacuum Sweeper	Vacuum is applied directly to street.	Most useful for parking lots, sidewalks, and factory floors. Of limited use on city streets.
Hand Sweeping	Push cart or motor scooter and hand tools.	To back up machines and for areas machines can not reach, particularly around parked cars in business districts.
Street Flusher	Water tank, pressure supply, and three or more individually controlled nozzles.	Mostly for aesthetic purposes. Generally (and preferably) used to quickly displace dirt and debris from traffic lanes to gutter. Up to 22 ft wide street on one pass. Has potential problems with transport rates and volumes, and if pollutants enter storm sewer they might be flushed into the receiving water.

Table 7-3: Types of Available Street Cleaning Equipment
(Source: Lynard et al., 1980)

B) Grassed Swales

The term grassed swales, also known as grassed water courses or vegetated swales, refers to the use of grassed conveyances designed to infiltrate runoff from intermittent storm events or to transfer rainfall excess to desired locations for retention, detention, storage, or discharge. Although the use of grassed swales for the sole purpose of conveying stormwater has become a common practice in residential and institutional settings, the effective use of grassed swales for the purpose of water quality control is a fairly recent practice. To meet the objectives of a BMP facility, the design and maintenance of grassed swales requires close attention to design specifications and standards designed to convey runoff at non-erosive velocities through grass-lined channels at rates conducive to infiltration and sedimentation.

1) *Principles of Mitigating Water Quality Impacts*

The primary pollutant removal mechanisms associated with grassed swales are sedimentation and infiltration. Adsorption and filtration mechanisms can be considered as secondary removal mechanisms. Changes in the flow hydraulics affected by routing the flow through grassed channels increases the opportunity for infiltration of soluble pollutants, deposition of suspended solids, filtration of suspended solids by vegetation, and adsorption of soluble particles by plants. The surface runoff must pass slowly through the filter to provide sufficient contact time for the afore mentioned removal mechanisms to function effectively.

2) *Pollutant Removal Rates*

Reported estimates of low pollutant removal efficiencies for grassed swales verify the need to improve standard design procedures for grassed swales to make them more effective for BMP purposes. Studies involving existing grassed swales have indicated the ineffectiveness of the devices for non-point source pollutant control (Yousef, 1985). The results of the Nationwide Urban Runoff Program (US EPA, Executive Summary, 1983) indicate removal efficiencies of 50 percent for heavy metals, 25 percent for COD, NH_3, and NO_3, and negligible removal of phosphorus as tested using artificial swales. The report by Yousef stated that design practices which increase the retention time of urban runoff will increase removal efficiencies for soluble forms of nitrogen and phosphorus. Sediment removal efficiencies for grassed swales range from 75 to 95 percent and are a function of the slope and roughness coefficient (See Appendix 7-5).

3) *Applicability and Practicability*

- Applicability

  Grassed swales are best suited for residential or institutional areas of low to moderate density with rolling open spaces. An attempt should be made to maintain existing drainage patterns which have been naturally eroded so as to prevent additional erosion which would occur during runoff events in the newly formed grassed swales. Level spreaders may be needed to allow runoff to enter the swales in the form of sheet flow.

  Site conditions such as soil type, topography, and the depth to the water table should also be considered in the evaluation of this BMP method. To allow for pollutants to be removed by infiltration processes, grassed swales should not be used on soils with infiltration rates less than 0.27 inches per hour. For approximate values of minimum infiltration rates for various soils, refer to Appendix 5-1 of this Handbook. The topography of the site should permit the design of a channel with a slope and cross sectional area sufficient to maintain an appropriate flow velocity and, thereby, prevent erosion of the channel. Research has shown that the removal of soluble particles, such as phosphorus, is reciprocally related to the average velocity of the flow over vegetative surfaces (Yousef, 1985). The seasonally high water table should not be less than two feet below the bottom of the swale to ensure an adequate opportunity for infiltration.

- Practicability

  The benefits derived from the use of grassed swales as a BMP device stem from both the limited pollutant removal capabilities and the additional aesthetic value gained by the community. When compared to traditional curb and gutter systems, grassed swales are generally less expensive to install and maintain and have the additional benefit of aesthetic appeal to offer to the community. The use of grassed swales also provides an additional source of water for onsite vegetation.

  The effectiveness of grassed swales may be reduced as the number of driveway culverts increases. Grassed swales are not especially compatible with extensive sidewalk systems. The most appropriate layout of swales in combination with roads and sidewalks is to place the swale between the two impervious ground covers. If public maintenance is designated, access and maintenance easements will need to be provided or the swale should be placed within a public right-of-way.

4) *Operation and Maintenance*

Maintenance of grassed swales basically includes common practices to support the continued health of the vegetative cover and to ensure the proper hydraulic properties of the device. As a result of the familiarity of the general public with the suggested maintenance procedures, those duties can often be effectively delegated to the land owner, if proper education and agreements are included in the title to the land. The delegation of maintenance responsibilities to individual land owners is a benefit to the locality in terms of costs associated with the device.

In order to ensure proper maintenance of the devices, localities must provide an active educational program to encourage recommended practices. For example, to maintain maximum efficiency, swales must be periodically maintained through frequent mowing, removal of grass clippings, and collection of loose debris and litter. The use of fertilizers and herbicides should be minimized or prohibited to avoid unnecessary pollution. Care must be taken to protect the swales from damage due to snow removal procedures and off-street parking. Compaction of the soil will lessen the rate of infiltration that occurs within the swale. The sediment that accumulates within the swale should be manually removed so as to avoid the transport of resuspended sediment in periods of low flow and to prevent a damming effect from sand bars.

5) *General Design Parameters*

- <u>Size and Shape of the Facility</u>

  In general, the contact time of the runoff with the vegetative surface should be increased to improve the efficiency of grassed swales. The following suggestions apply:

  i. Reduce the slope of the channel.

  ii. Increase the wetted perimeter (perimeter of cross section below the water surface).

  iii. Reduce conditions that promote constant soil wetness.

  iv. Periodically remove obstructions, such as sediment, grass clippings, and debris that reduce soil infiltration.

  v. Install dense, slow growing vegetation, with low maintenance requirements.

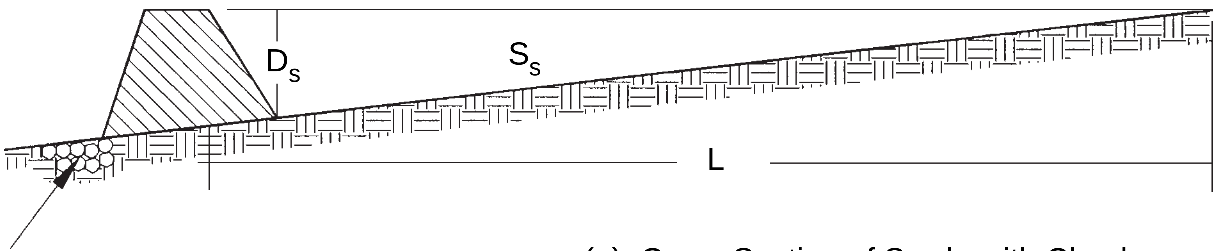
The capacity of the channel should accommodate peak flows from the design storm. For more information on this subject, the reader is referred to local stormwater management requirements. The cross sectional shape of the grassed swale can be parabolic, triangular, or trapezoidal. Parabolic cross sections are preferred for aesthetic reasons, but the design and construction procedures are more complex. For a step by step outline of procedures to be used in designing parabolic grassed swales, the reader is referred to the Virginia Erosion and Sediment Control Handbook (VDSWC, 1992).

For ease of maintenance, the side slopes of the swale should be no steeper than 3h:1v. As stated previously, longitudinal slopes should be no greater than five (5) percent to reduce the erosion potential and to increase contact time for infiltration. The proper design of a grassed swale includes an appropriate selection of vegetation to ensure continued vegetative stability. The Virginia Erosion and Sediment Control Handbook and most textbooks on hydraulics present tables of permissible velocities for a variety of types of vegetative cover.

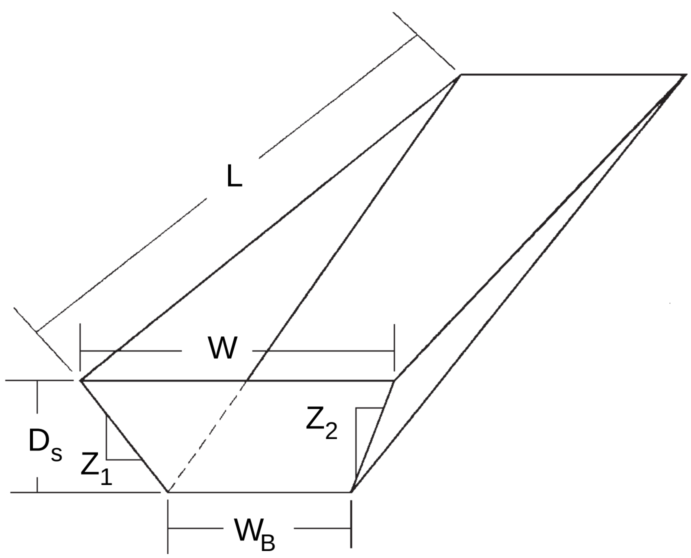
To maximize the retention time within the swale, the design engineer should consider the incorporation of check dams within the swale system. See Figure 7-5 for an example. The structures should be of a more permanent nature than those normally designed for erosion and sediment control purposes. Utilization of these structures will decrease the chance for erosion and will increase the contact time for the flow to infiltrate into the soil profile.

- Outlets

  Discharge from grassed swales must be conveyed at non-erosive velocities to either a stream or a stabilized channel in order to prevent scour at the outlet. The reader is referred to the Virginia Erosion and Sediment Control Handbook for design procedures and specifications to accomplish outlet stabilization. Conveyances of flow through culverts should be considered as outlets and appropriate energy dissipaters should be installed. Outlets should be sized in accordance with design storm requirements.



(a) Cross Section of Swale with Check Dam



(b) Dimensional View of Swale Impoundment Area

NOTATION

L= LENGTH OF SWALE IMPOUNDMENT AREA PER CHECK DAM (FT)
D_S= DEPTH OF CHECK DAM (FT)
S_S= BOTTOM SLOPE OF SWALE (FT/FT)
W= TOP WIDTH OF CHECK DAM (FT)
W_B= BOTTOM WIDTH OF CHECK DAM (FT)
$Z_{1\&2}$= RATIO OF HORIZONTAL TO VERTICAL CHANGE IN SWALE SIDE SLOPE (FT/FT)

Figure 7-5: Schematic of Vegetated Swale with Check Dam
(Adapted from Maryland Department of Natural Resources, 1984)

C) Vegetative Buffer Areas

A vegetative buffer area (VBA) is a nonstructural BMP option, most often used in conjunction with a structural BMP, that is designed to ameliorate non-point source stormwater pollution through the routing or diversion of runoff in sheet flow across the buffer area providing for removal of sediments, phosphorus, and other pollutants through filtration, infiltration, nutrient uptake by plants, and adsorption (Hochheimer, Cavacas and Shoemaker, 1991). According to the US EPA (1991), a vegetative buffer area, or strip in many cases, is defined as a "permanent, maintained strip of planted or indigenous vegetation located between non-point sources of pollution and receiving water bodies for the purpose of removing or mitigating the effects of non-point source pollutants such as nutrients, pesticides, sediments, and suspended solids." The vegetation in the VBA should be water and erosion resistant.

The discussion of vegetative buffer areas presented in this section is applicable to the use of "open space" as a physical *active* control which is *designed and maintained* to filter and infiltrate pollutants as opposed to the concept of a *passive* land use control whose benefits derive from the fact that a land use (e.g. lawns) which generates pollutants is replaced with a land use (e.g. natural unmanaged open space) which essentially generates no pollutants. The latter concept, since it is not designed to actively remove pollutants, is treated as a land use credit rather than a BMP facility. The reader is referred to Chapter 4, page 4-1, for a discussion of "open space" as a passive land use control.

1) *Principles of Mitigating Water Quality Impacts*

The vegetation in a VBA acts to filter and settle out particulate sediment and any attached pollutants. The reduction in the velocity of runoff within the vegetated areas permits an increased contact time of the runoff with the soil and vegetative surfaces. It follows that nutrient uptake, adsorption, and infiltration mechanisms may result in a decreased pollutant load entering the natural waterways. The reduced velocity also lessens the potential for resuspension of particles as the flow travels towards the waterway.

Results of modeling studies indicate that VBAs are somewhat effective in removing particulate pollutants although settling is not optimized. The removal of soluble nutrients such as phosphorus and nitrogen is less effective (Dillaha et al., 1986; MWCOG, 1987).

2) *Applicability and Practicability*

- Applicability

  The use of a VBA as a BMP is applicable on well drained or moderately well drained sites where the bedrock and the water table are at least four feet below ground level. If the soil is moderately erodible in the drainage area, additional precautions will need to be taken to avoid excessive buildup of sediment in the grassed areas. The topography should be such that runoff will travel downslope by sheet flow. It may be necessary to construct level spreaders to prevent gullying or other forms of concentrated flows from occurring. Research has indicated that concentrated flows greatly reduce, or render ineffective, the VBA's capacity for pollutant removal (Dillaha, et al., 1989). Longitudinal slopes should be less than five percent to reduce the potential for increased erosion (Md DNR, 1984). Utilization of the recommended slopes will also increase the chances of rainfall being filtered by vegetation and infiltrated into the soil.

  Most alternative uses within the VBA, either pedestrian or vehicular, should be avoided if possible to minimize soil compaction and damage to the vegetation (Hochheimer, Cavacas and Shoemaker, 1991). However, lightly used play areas, informal grass recreational areas, meadows, etc., may, in some cases, be compatible with grassed area stormwater infiltration. Heavily used areas are likely to become too compacted to permit sufficient percolation. It should be noted that the more intensive the use of the VBA, the more likely that maintenance will have to be performed at more frequent intervals. Maintenance practices such as core soil aeration can relieve compaction. It is important that infiltration be rapid so that no standing water remains for more than four hours following a storm. The soils in the VBA should allow infiltration to occur to an extent that the area is usable within 24 hours of a storm. Adequate filter area and length are necessary to provide desired levels of treatment. Runoff over a VBA with steep slopes will require greater lengths to provide adequate treatment. In the absence of suitable permeable soils, infiltration will be minimal; however, some particulate sediment will still be trapped by filtration through the vegetation. Appendix 7-5 shows a graph relating slope, sediment trap efficiency, runoff velocity, and effective buffer strip length.

- Practicability

  The costs associated with implementing and maintaining VBAs are slight in comparison with other BMP practices. Because of the land intensiveness of this practice, it may not be practical in areas of high land value. Consideration of the possible additional benefits of recreational opportunities and aesthetics should be included in any decision process. When correctly designed and maintained, groundwater recharge can be an additional benefit of a VBA.

3) *Operation and Maintenance*

To maintain the effectiveness of the VBA, a maintenance and inspection schedule must be incorporated into the design. Monitoring of soil moisture, vegetative health, soil stability, soil compaction, and soil erosion must be conducted to maintain the water quality protection provided by the facility. The presence of vegetation will lessen the chances of resuspension of previously settled sediment; however, the effectiveness of the VBA will gradually decrease with time as the depth of the sediment increases. Regular inspections will be useful in notifying maintenance crews to manually remove sediment and debris before any adverse impacts to the vegetation are evident. Irrigation, reseeding, and other repairs may be necessary if irreparable damage has occurred to the vegetative cover. As noted previously, maintenance practices such as core soil aeration may be necessary to relieve compaction if alternative uses are allowed on the VBA. VBAs are not accepted by local jurisdictions for public maintenance unless otherwise indicated by the local plan review agency.

4) *Aesthetics*

The incorporation of a VBA into a development plan may enhance the visual quality of the site. Commercial and residential landowners can increase the value of their properties by having a variety of land uses, each separated by a VBA. VBAs attract urban wildlife referred to as edge species, such as song birds and squirrels, which can further the site's aesthetic appeal. Research has shown that abrupt variations in land use from a developed area to a VBA makes an attractive habitat for some types of wildlife species, particularly if the appropriate vegetation is established (MWCOG, 1987).

5) *Selection of Vegetation*

The choice of vegetative cover to be utilized in the VBA should be made with respect to its tolerance to water, growth rate, climatic preference, and its stabilization capacity, as well as available maintenance considerations. The reader is referred to the Virginia Erosion and Sediment Control Handbook (VDSWC, 1992) and MWCOG (1987) for specific vegetative recommendations in addition to any local ordinances which may be applicable.

D) Marsh Vegetation

Marsh vegetation can be considered a non-point source pollution control measure by providing water quality protection through the mechanisms of natural filtering action, soluble nutrient uptake, hydraulic resistance, and shading effects. The efficiency of the removal of water pollutants by aquatic vegetation has been recognized by design engineers in the development of industrial and municipal waste treatment facilities. However, marsh vegetation has not commonly been used as a BMP in non-industrial developments. In this section, the utilization of marsh vegetation is limited to the incorporation of such vegetation in wet pond detention basins. For more detailed information concerning the development of urban wetlands, the reader can consult MWCOG (1987) and Md DNR (1987).

1) *Principles of Mitigating Water Quality Impacts*

The effectiveness of marsh vegetation in the removal of water pollutants is contingent upon both physical and biological removal mechanisms. The physical means of water quality protection provided by marsh vegetation include mechanical filtering, or entrapment of suspended particles by plant roots and rhizomes, the absorption of dissolved and suspended particles by plant roots, and the aeration of wastewater through the vegetative release of oxygen. Marsh vegetation can remove pollutants by respirational uptake of inorganic substances and cations through plant tissues. The decay of vegetation and subsequent release of nutrients into the environment is a major consideration in the effectiveness of biological uptake. For extended detention wet ponds, the release of nutrients occurs during the winter months when eutrophication is not a problem. However, these nutrients are released downstream and eventually reach estuaries such as the Chesapeake Bay, where they may contribute significantly to algal growth.

Although a considerable amount of research has been conducted in relation to intensive vegetative systems for industrial and municipal waste treatment, very few studies have been directed towards smaller scale uses of the technology. In spite of the lack of available data, the Nationwide Urban Runoff Program (NURP) Report states that "wetlands are considered to be a promising technique for urban runoff quality" (US EPA, 1983). Removal estimates of 55 to 89 percent for BOD, 94 to 99 percent for suspended solids, and 97 percent for heavy metals have been reported in a study conducted at the EPA Municipal Environmental Research Laboratory in Cincinnati, Ohio (Adams and Dove, 1983).

2) *Applicability and Practicability*

- Applicability

  The use of marsh vegetation for BMP purposes is generally applicable to wet pond sites provided that the runoff passing through the vegetation has a velocity less than 8 feet per second to prevent dislodging of aquatic vegetation (MWCOG, 1987). Vegetative systems may not be effective where the water's edge is extremely unstable or where there is heavy use of the water's edge. Some types of marsh vegetation are not effective in flood prone areas due to the alteration of the hydraulic characteristics of the water course.

- Practicability

  The costs associated with incorporating marsh vegetation into a wet pond design are extremely low due to the low maintenance and installation costs. The benefits to be attributed to the use of marsh vegetation include an increased species diversity and thus, an increased stability of the aquatic ecosystem due to the provision of natural shade and cover for aquatic species and nesting areas for various waterfowl.

  By combining vegetative systems within a wet pond design, the designer is able to achieve higher pollutant removal capabilities without having to utilize greater land areas. The associated increase in wildlife diversity will add to the aesthetic appeal of the site. The reader is referred to the publications by Md DNR (1987) and MWCOG (1987), for more information on how to encourage the establishment of a wetland wildlife population through the forage and cover provided by vegetation.

3) *Operation and Maintenance*

Extreme care should be taken in the establishment of the vegetative community. Expert advice should be obtained concerning proper installation and management of the marsh vegetation. The appropriate species of water's edge vegetation may be difficult to obtain through local nurseries. See Md DNR (1987) and MWCOG (1987) for uses and sources of various species. The narrow range of tolerance of aquatic vegetation to levels of soil moisture dictates a careful selection and installation of marsh vegetation (MWCOG, 1987). A planting schedule should be included in the design to ensure the establishment of a stable vegetative community.

In a stabilized system of marsh vegetation, the maintenance requirements are few. Plants regenerate naturally and plant communities can adjust to changes in stream flow volumes and waterway configurations. The stabilization of the aquatic ecosystem should be allowed to follow a natural pattern of succession to ensure a natural diversity of flora and fauna. The services of a local biologist or ecologist should be procured for periodic inspections of marsh systems.

To prevent safety hazards associated with floating driftwood or vegetative overgrowth to recreational users of the wet pond, periodic inspection of the facility should be conducted. As part of the inspection, it should be assessed whether or not the extent of vegetation around the pond will cause hydraulic or recreational obstructions.

4) *General Design Parameters*

- <u>Vegetative Layout</u>

  Marsh vegetation is most stable when established in a three-tiered system (Tourbier, 1981). The tolerance of vegetative species to soil moisture levels is relatively narrow and, therefore, the selection of vegetation must take into account this sensitivity. The natural zonation of plant communities corresponds closely with the flow stages of a stream. Three specific zones separating vegetative soil moisture tolerances are shown in Figure 7-6.

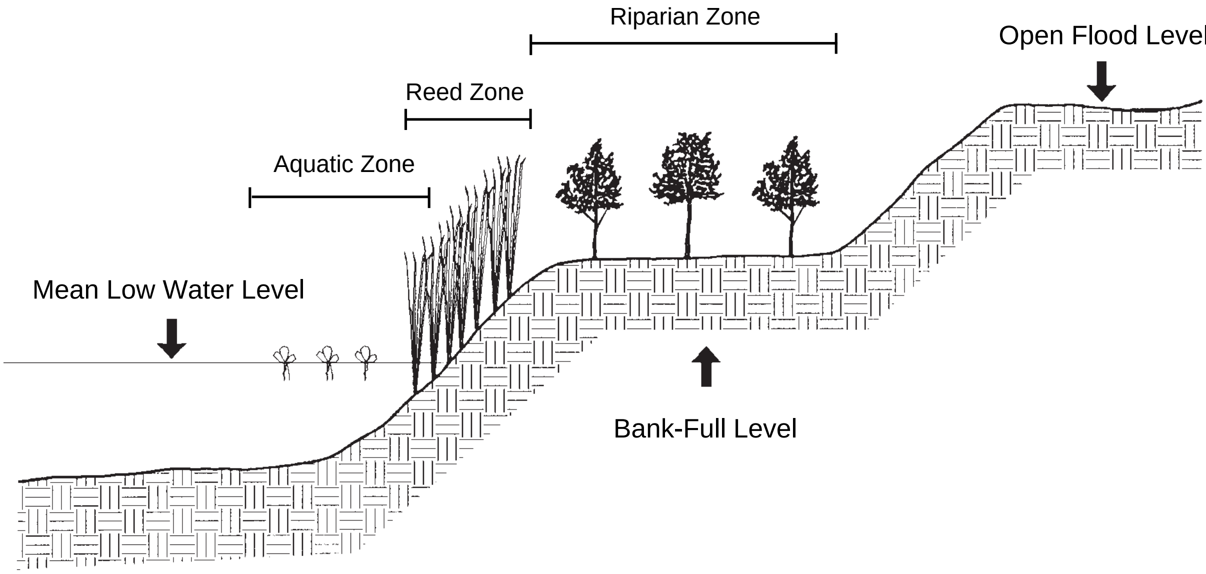


Figure 7-6 Zones of Marsh Vegetation
(Adapted from Tourbier, 1981)

The lower riparian zone corresponds to the area between the bank-full and open floodway level. It is extremely important to stabilize this area in order to prevent streambank erosion, especially where there is heavy use of the water's edge. The lower riparian zone is commonly colonized by willow alder, buttonbush, red maple, and sweetgum.

The second zone is the reed zone which is commonly colonized exclusively by reed vegetation. The reed zone begins slightly above the mean low water level and extends for a short distance into the permanent pool. Reeds are not tolerant of extended periods of moisture deficiency, therefore the reed zone should be subject to regular intervals of flooding. To ensure the establishment of the deeply rooted reed vegetation, planting should be carried out during periods of expected dry weather. It is not possible to establish a reed community in fast currents or on eroding banks.

The third zone is referred to as the aquatic zone which includes the area in which plants are either floating or rooted in the streambed. The vegetation in this zone is found in shallow, still, or slow moving waters with plenty of light and sufficient nutrients. The most effective means of planting these species is to surround the roots in peat moss bound in wire and to sink the container into the streambed.

- <u>Selection of Vegetation</u>

  Vegetation selection should be guided by the following criteria: tolerance to high moisture conditions, climatic compatibility, pollutant removal capabilities, and ease of establishment. For specific information concerning water tolerance, provision of wildlife cover and forage, suitable environment, and regeneration, the reader is referred to the following three sources: VSWCB (1979), Md DNR (1987), and MWCOG (1987).

  Lower riparian species with a high tolerance to moisture from occasional inundation should be selected. Aquatic species must be tolerant of continual high moisture conditions and should be tolerant of local climatic conditions.

  The selection of vegetation for the reed zone should involve the additional criterion of pollutant removal capabilities in light of the available information on the subject. As indicated in recent studies, the common reed (Phragmites cummunis) is well suited for this purpose. The common reed has deeply rooted, strong, and densely intertwined rhizomes which provide a large surface area for nutrient absorption. Other acceptable species for water quality protection are: reed grass (Phalarix arundinacea), reed mace (Typhae), bullrush (Scirpus lacustris), sweet flag (Acorus calamu), and yellow flag (Iris pseudacorus).

  A common complaint associated with wet ponds in residential neighborhoods is the development of insect breeding grounds associated with nonvegetated basins. For this reason, time of vegetative establishment should also be considered in the design of marsh vegetation systems. Perennials are less likely to produce emergent vegetation during the first growing season as much of their energy is spent developing deep root systems. Therefore, to minimize insect nuisances prior to the establishment of vegetation and wildlife, a mixture of perennials and annuals should be included in the choice of vegetation for the site. Appendix 7-6 includes a summary of design criteria for the establishment of a wetland as required in Maryland (Md DNR, 1987).

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** Publications under the Prince William County Development Administration are now available from the Prince William County Department of Public Works.

Glossary

Glossary

Absorption

Absorption is the assimilation or incorporation of a gas, liquid, or dissolved substance into another substance.

Acre-Foot

The volume of water that will cover 1 acre to a depth of 1 foot (43,560 cubic feet per acre).

Adsorption

The adhesion of the molecules of a gas, liquid, or dissolved substance to a surface.

Aggregate

Term for the stone or rock gravel needed to fill in an infiltration BMP such as a trench or porous pavement. Clean-washed aggregate is simply aggregate that has been washed clean so that it contains no sediment.

Anoxic

An aquatic environment characterized by a lack of free (uncombined) oxygen.

Anti-Seep Collar

A plate which is attached to the barrel running through an embankment of a pond that prevents seepage of water around the pipe and pipe failures.

Aquatic Bench

A bench around the inside perimeter of a permanent pool which is normally vegetated with emergent plants. The bench augments pollutant removal, provides habitat, conceals trash and water level drops, and enhances safety.

Aquifer

An underground porous, water-bearing geological formation. The term is generally restricted to materials capable of yielding an appreciable supply of water.

Argillic Soil Horizon

A diagnostic illuvial subsurface soil horizon (a soil horizon in which material carried from an overlying layer has been precipitated from solution or deposited from suspension) characterized by an accumulation of silicate clays.

Atmospheric Deposition

Dispersion of particulate matter or precipitation from the atmosphere.

Bank Stabilization

Methods of securing the structural integrity of earthen stream channel banks with structural supports to prevent bank slumping and undercutting of riparian trees and overall erosion prevention.

Baseflow

The portion of stream flow that is not due to storm runoff and is supported by groundwater seepage into a channel.

Bedrock

The more or less solid rock in place either on or beneath the surface of the earth.

Benthic Aquatic Life

Aquatic organisms dwelling on (epifaunal) or within (infaunal) the floor of a lake or another body of water.

Berm

Usually an earthen mound used to direct the flow of runoff around or through a BMP.

Best Management Practice (BMP)

Are structural or nonstructural practices which are designed to minimize the impacts of development on surface water quality. Most structural BMPs are designed to detain runoff until pollutants are allowed to settle out or infiltrate through the underlying soil.

Biological Oxygen Demand (BOD)

The quantity of dissolved oxygen used by microorganisms in the biochemical oxidation of organic matter and oxidization of inorganic matter by aerobic biological action.

Biological Uptake

Biological organisms can have the ability to degrade organic compounds as food resources and to absorb nutrients and metals into their tissues to support growth.

Buffer Strip

A strip of turf grass or other erosion resistant vegetation placed between a water course and a developed site.

Catchment Area

The portion of a watershed which contributes its runoff to a BMP facility.

Channel Erosion

The widening, deepening, and headward cutting of small channels and waterways due to erosion caused by flooding.

Check Dam

An earthen or log structure used in grass swales to reduce water velocities, promote sediment deposition, and enhance infiltration.

Chemical Breakdown

Any of several aqueous chemical reactions which render comparatively complex compounds into less complex products.

Chemical Oxygen Demand (COD)

A monitoring test that measures all the oxidizable matter found in a runoff sample, a portion of which could deplete dissolved oxygen in receiving waters.

Chesapeake Bay Preservation Act

The Virginia statue enacted in 1988 to protect the Chesapeake Bay by placing restrictions on development in sensitive areas and requiring the suppression of pollutants in stormwater runoff. Sections 10.1-2100 through 10.1-2115 of the Code of Virginia.

Chesapeake Bay Preservation Area

Those lands designated by a local jurisdiction within its boundaries which require restrictions on development and/or require reduction of pollutants in stormwater runoff in order to comply with the Chesapeake Bay Preservation Act. Chesapeake Bay Preservation Areas include Resource Protection Areas and Resource Management Areas.

Chroma

The relative purity, strength, or saturation of a color; directly related to the dominance of the determining wavelength of the light and inversely related to grayness. See Munsell color system.

Core Soil Aeration

A process by which a machine removes cores of soil from the ground surface and deposits them on the surface or removes them completely. The purpose of core soil aeration is to decompact a surface to facilitate better infiltration and to allow air to permeate the soil to facilitate vegetative growth.

Cutoff Trench

A trench cut under the embankment which penetrates an underlying impervious layer. The trench is backfilled with layers of clay or sand clay and compacted. The cutoff trench serves to prevent undermining of the dam by seepage and acts to key the embankment into the substrata.

Denitrification

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

Design Life

The period of time for which a facility is expected to perform its intended function.

Design Storm

A rainfall event of specified size and return frequency (e.g., a storm that occurs only once every 2 years) that is used to calculate the runoff volume and peak discharge rate to a BMP.

Detention Time

The amount of time that stormwater is actually present in a BMP facility.

De-Watering

Refers to a process used in detention/retention facilities, whereby water is completely discharged or drawn down to a pre-established pool elevation by way of a perforated pipe. De-watering also refers to the process of drying out dredged sediments in preparation for disposal.

Divide, Drainage Divide

The boundary between one drainage basin and another.

Drainage Basin

A geological area or region that is sloped and contoured so that surface runoff from streams and other natural water courses is carried away by a single drainage system by gravity to a common outlet or outlets.

Embankment

A man-made deposit of soil, rock, or other material used to form an impoundment.

Emergency Spillway

A channel used to safely convey flood discharges in excess of the capacity of the principal spillway.

Emergent Plants

An aquatic plant that is rooted in the sediment but whose leaves are at or above the water surface. Such wetland plants provide habitat for wildlife and waterfowl in addition to aiding in the removal of urban pollutants.

Energy Dissipater

A device used to reduce the energy of flowing water.

Eutrophication

The process by which a body of water experiences an increase in the level of nutrients which results in algal blooms and oxygen depletion. In fresh water bodies, the controlling nutrient is phosphorus. Eutrophic conditions can lead to taste and odor problems in drinking water, fish kills, and unsightly conditions.

Exfiltration

The movement of water out of an underground storage structure into the surrounding soil.

Extended Detention

A stormwater design feature that provides for the detention and gradual release of a volume of water over a specified period of time to increase the settling of urban pollutants and to protect the channel from frequent flooding.

Extended Detention Pond (Dry Pond)

Extended detention ponds, also known as *dry ponds*, are man-made basins which retain water for specific periods of time (a minimum of 48 hours for new facilities in Northern Virginia). Extended detention basins do not contain a permanent pool of water and are normally dry during non-rainfall periods. Water is impounded temporarily to allow much of the sediment carried by the runoff to settle to the bottom. Many of the particulate pollutants are also removed. The impounded water is discharged via an outlet device.

Fecal Coliform

A common type of water-borne bacteria that is transported primarily through animal feces. Fecal coliforms are often an indicator of other potentially serious water-borne viruses and parasites.

Filter Fabric

Textile of relatively small mesh or pore size that is used to allow water to pass through while keeping sediment out (permeable) or prevent both runoff and sediment from passing through (impermeable).

First Flush

The initial amount of runoff from a storm event which flushes a disproportionate amount of pollutants from impervious areas. The first flush is used to size infiltration facilities and is considered the first half inch of runoff for water quality purposes.

Flood Plain

The land bordering a watercourse, built up of sediments from overflow of the water-course and subject to inundation when the water course is at flood stage.

Foliation

A rock fabric typified by parallel orientation of minerals which is commonly expressed as a plate-like physical structure. The term is usually applied to high grade metamorphic rocks.

Fragipan

Dense and brittle pan or layer in soils that owe their hardness mainly to extreme density or compactness rather than high clay content or cementation. Removed fragments are friable, but the material in place is so dense that roots cannot penetrate and water moves through very slowly.

Free Board

The space from the top of an embankment to the highest water elevation expected for the largest design storm stored. The space is required as a safety margin in a pond or basin.

Frequency of Storm (Design Storm Frequency)

The anticipated period in years that will elapse, based on average probability of storms in the design region, before a storm of a given intensity and/or total volume will recur; thus a 10-year storm can be expected to occur on the average of once every 10 years.

Friable

A soil consistency term pertaining to the ease of crumbling of soils.

Gabion

A large basket of heavy gauge wire mesh which holds large cobbles or boulders. Used in streams and ponds to change flow patters, stabilize banks, or prevent erosion.

Gravitational Settling

The tendency of particulate matter to “drop out” of stormwater runoff as it flows downstream when runoff is slowed or detained.

Groundwater Mounding

A phenomenon resulting in the increased elevation of the groundwater table centered directly beneath a point source of infiltration. It is a dynamic condition comprised of infiltrated water in transit to equilibrium with the static water table.

Hydraulic Conductivity

An expression of the readiness with which a liquid such as water flows though a soil in response to a given potential gradient. Hydraulic conductivity is a constant physical property of soil or rock, one of several components responsible for the dynamic phenomenon of flow.

Hydrograph

A graph showing the variation in the water depth or discharge in a stream or waterway over time at a specified monitoring point.

Impervious Cover

Land area which has been altered so that the permeability of the surface is decreased to the extent that most stormwater runs off rather than infiltrating.

Infiltration

The gradual, downward movement of water from the surface into the subsoil.

Infiltration Rate

The rate at which a land surface or soil surface can absorb rainfall. It is a dynamic phenomenon subject to change with time and prevailing conditions. The infiltration rate is volume per unit surface area over time (flux) and is usually simplified to length per unit time (in/hr, cm/hr, ft/s, m/s).

Infiltration Trench

Infiltration trenches are gravel-filled excavations that temporarily store stormwater runoff and allow it to infiltrate into the soil beneath the trench excavation. There are two basic types of infiltration trenches which are distinguished by how stormwater enters the facility. *Dispersed input* facilities allow stormwater to enter the top of the trench as overland runoff while *concentrated input* facilities receive stormwater from curb inlets, gutters, and pipes.

Invert

The lowest point on the inside of a sewer or other conduit.

Level Spreader

A device used to spread out stormwater runoff uniformly over the ground surface as sheet flow. The purpose of a level spreader is to prevent concentrated, erosive flows from occurring and to enhance infiltration.

Maintenance Agreement

A legally binding agreement between the private owner of a BMP facility and the jurisdiction that the BMP facility is located in outlining each party's responsibility towards the operation, maintenance, and general upkeep of the said facility.

Mean Storm

The mean amount of rainfall produced by a storm event for a particular area or region. The mean storm for Northern Virginia produces 0.40 inches of rain. The mean storm is used to size wet ponds.

Non-Point Source Pollution

Refers to contaminants such as sediments, nutrients, hydrocarbons, heavy metals, and toxics which are transported by stormwater runoff. The term is used to distinguish such diffuse overland runoff from point source pollution such as that that flows from a pipe.

Nutrients

Elements or substances, such as nitrogen and phosphorus, that are necessary for plant growth. Large amount of these substances entering into water bodies can create a nuisance by promoting excessive algal growth which can lead to eutrophic conditions.

Observation Well

A test well in an infiltration facility to monitor stormwater draining times after installation.

Oligotrophic Conditions

Opposite of eutrophic conditions and characterized by low phosphorus and chlorophyll concentrations as well as low algal productivity. Oligotrophic conditions are often associated with a healthy aquatic environment.

Outfall

The point, location, or structure where stormwater or other liquid discharges from a sewer or other conduit to a receiving body of water.

Peak Flow (Discharges)

The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

Peak Shaving

Controlling post-development peak discharge rates to pre-development levels by providing temporary detention in a BMP.

Percolation

The movement of water through the soil.

Permeability

The ability of a rock, earth, or other material to transmit gases or fluids.

Phosphorus

The controlling nutrient for fresh water systems, excessive quantities of which will result in eutrophication. Phosphorus exists in two forms, particulate (40 to 50 percent) and soluble (50 to 60 percent).

Platy Structure

Consisting of soil aggregates that are developed predominantly along the horizontal axes; laminated; flaky.

Plug Flow

Particles pass through the BMP and are discharged in the same sequence in which they enter. Particulates remain in the BMP for a time equal to the theoretical detention time.

Porous Pavement

An open-graded asphalt concrete created by using no fine aggregate in the mix creating voids through which stormwater runoff may infiltrate through into an underlying layer of aggregate (1/2"), a reservoir course (1" to 2"), and then into the soil substrata.

Prismatic Structure

A soil structure type with prism-like aggregates that have a vertical axis much longer than the horizontal axis.

Rational Formula

A technique developed for estimating peak discharge rates for small developments based on the rainfall intensity, watershed time of concentration, and a runoff coefficient.

Recharge

Replenishment of groundwater reservoirs by infiltration through permeable soils.

Redox Potential

The potential for an aqueous environment to accept or donate electrons in a reaction with a given species. The values are measured as a deviation in electric potential volts (E_H) from a standard set of conditions (E^0). The higher the value of E_H, the more oxidizing the conditions (a greater potential that the chemical environment will accept electrons from a given species resulting in an increase in electrical charge for that species).

Resource Management Area (RMA)

An area designated by a locality under the Chesapeake Bay Act of 1988. RMAs are those lands which, if not properly managed, have the potential to degrade water quality or diminish the effectiveness of Resource Protection Areas (RPAs). RMAs include but are not limited to floodplains, highly erodible or permeable soils, and non-tidal wetlands.

Resource Protection Area (RPA)

An area designated by a locality under the Chesapeake Bay Act of 1988. RPAs are those lands which are considered to have intrinsic water quality benefits. All tidal wetlands, tidal shores, non-tidal wetlands hydrologically connected by surface flow and bordering on tidal wetlands or tributary streams, and 100 foot buffer areas landward of wetlands, shores, and tributaries must be designated as RPAs.

Return Interval

The statistical parameter that describes the probable interval between storm events, usually in years, of a specific magnitude.

Rhizomes

A horizontal, subterranean plant structure capable of producing root, stem, and sometimes leaf tissue from buds and nodes. Often utilized for self propagation and storage of carbohydrates by certain grasses.

Riparian

A relatively narrow strip of land that borders a stream or river which often coincides with the maximum water surface elevation of the 100-year storm.

Riprap

A layer or mound of large stones placed to prevent erosion of a structure or embankment.

Riser

A vertical pipe extending from the bottom of a pond BMP that is used to control the discharge rate from a BMP for a specified design storm.

RWCS (Rainwater Catchment System)

Also known as cistern stormwater recycling. A system which collects the water quality volume of runoff from a storm event and stores it for eventual re-use as toilet flush water, landscape irrigation water, airconditioner cooling water, etc.

Safety Ledge

Level or almost level area located immediately landward of a permanent pool. The bench extends around the entire shoreline to provide for access of maintenance and to eliminate hazards.

Saprolite

Igneous rock which has been chemically weathered in place to a semi-porous, unconsolidated state which can usually be excavated with hand tools.

Sedimentation

The process by which heavier suspended materials settle to the bottom of a medium (usually water) as the medium's velocity decreases. The heavier materials settle out first while lighter materials may take more time and/or slower velocities.

Sediment Forebay

Stormwater design feature that employs the use of a small settling basin to settle out incoming sediments before they are delivered to a stormwater BMP. Particularly useful in tandem with infiltration devices, wet ponds, or marshes.

Sheet Flow

Flow which is evenly distributed across the width of a structure and is not concentrated.

Silviculture

Relating to forestry, development, cultivation, and reproduction of forest trees.

Slickensides

Polished and striated (scratched) surface that results from friction along a fault plane.

Soil Horizon

A layer of soil, approximately parallel to the surface, that has distinct characteristics produced by the interaction between the original parent material and soil-forming factors.

Soil Strata

The various horizontal layers of soil which are a result of differential deposition.

Spillway

The point of discharge for a river, drain pipe, etc.

Swale (Grassed)

A depression or wide shallow ditch, usually grassed, used to temporarily store, divert, route, or filter stormwater runoff.

Tensile Strength

The maximum force of tension to which a material can respond without breaking.

Thermal Stratification

A result in the formation of distinct layers within nonflowing bodies of water. During the summer, a surface layer (epilimnion) is heated by solar radiation and, because of its lower density, floats upon the bottom layer, or hypolimnion.

Trash Rack

A grate or grate-like device designed to prevent the passage of debris through the intake or discharge orifice.

Trickle Ditch

An incised or paved channel from inlet to outlet which is designed to carry low flow runoff or baseflow directly to the outlet without detention.

Underground Detention Tank

An ultra-urban BMP which utilizes an underground tank for stormwater detention. Detained stormwater may be recycled, i.e., for toilet flush water, landscape irrigation water, and/or evaporative cooling water, or released via a timed diversion system to a storm sewer or a sanitary sewer during non-peak hours.

Urban Runoff

Surface runoff originating from an urban drainage area including streets, parking lots, and roof tops.

Water Quality Inlet

A BMP most often used as a pretreatment measure but sometimes as a primary BMP in ultra urban sites consisting of a three stage underground retention system designed to settle larger particulates and to float absorbed hydrocarbons. Also known as an oil/ grit separator.

Water Quality Volume

The volume equal to the first half-inch of stormwater runoff from the total impervious areas of a development site.

Water Table

The uppermost extent of groundwater saturation where all pore spaces are filled with water.

Weir

Device of measuring or regulating the flow of water.

Wet Pond (Retention Basin)

Wet ponds, also known as retention basins, are man-made basins which contain a permanent pool of water much like a lake or natural pond. The wet pond is designed to hold a permanent pool above which storm runoff is stored and released at a controlled rate. The release is regulated by an outlet device designed to discharge flows at various rates similar to the methods employed in an extended detention pond.

Appendices

APPENDIX 1

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Appendix 1-2 .... Occoquan Watershed Technical Advisory Committee

Appendix 1-3 .... ESI Joint Public/Private BMP Handbook Committee

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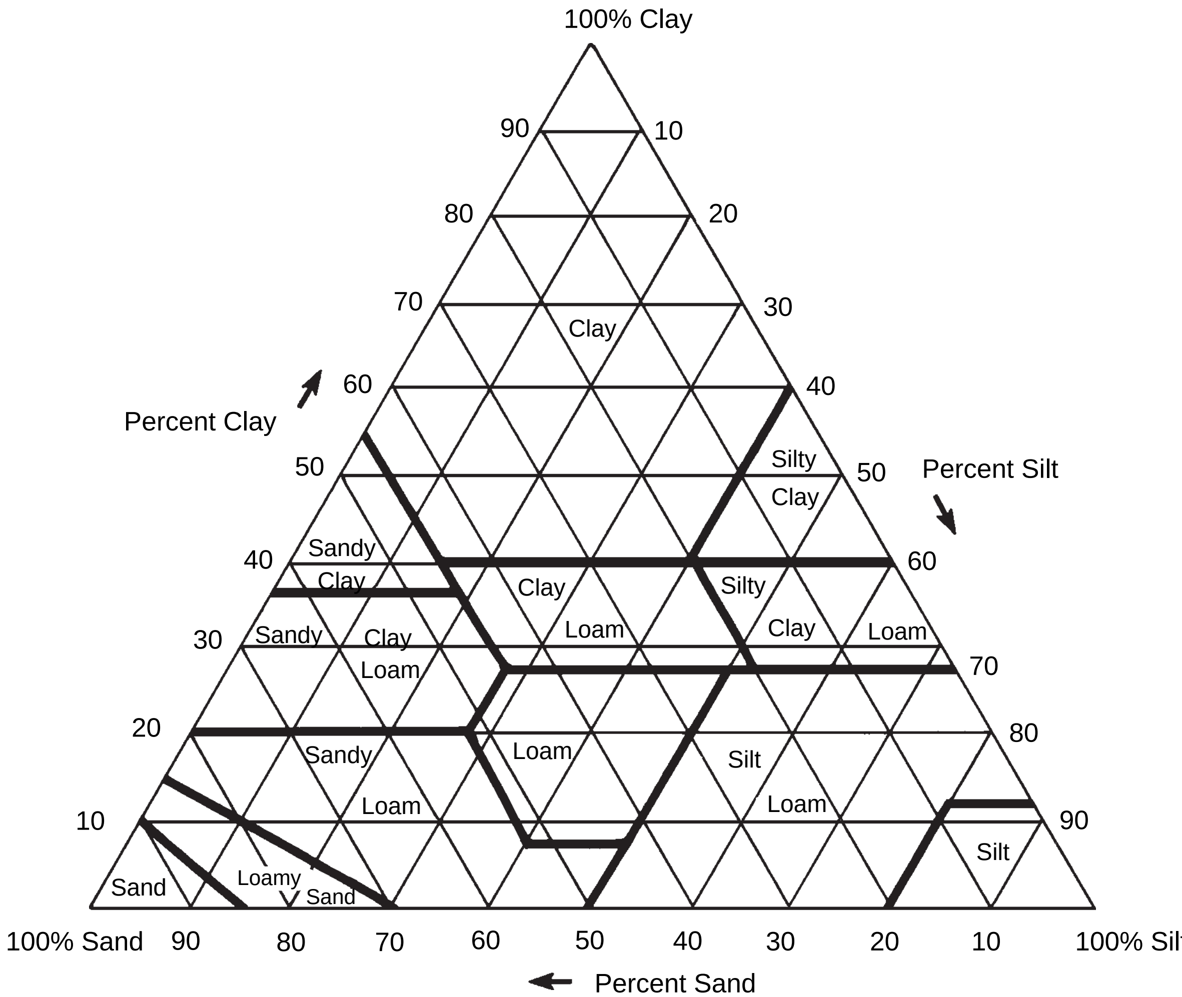
APPENDIX 2

(No Appendices for Chapter Two. Included to Maintain Numeric Progression of Appendices.)

APPENDIX 3

Appendix 3-1 .... USDA Textural Triangle



USDA Textural Triangle

APPENDIX 4

Appendix 4-1 .... Runoff Coefficients and Inlet Times (Fairfax PFM Chart A6-19)

Appendix 4-2 .... Coefficients of Runoff to be Used with the Rational Formula in Prince William County (Prince William D&CSM, Exhibit 1)

Appendix 4-3 .... Water Quality Storage Requirements Related to Percent Imperviousness and Rational Formula "C" Factor (Fairfax PFM Chart A6-40)

Appendix 4-4 .... BMP Facility Design Calculations Worksheets

Appendix 4-5 .... BMP Facility Design Calculations Examples

ZONING CLASSIFICATION	Runoff Coefficients	Percent Impervious	Inlet Times (minutes)
Business, Commercial & Industrial	0.80 - 0.90	90%	5
Apartments & Townhouses	0.65 - 0.75	75%	5 - 10
Schools & Churches	0.50 - 0.60	50%	10 -15
Single Family Units Lots 10,000 SF	0.40 - 0.50	35%	
Single Family Units Lots 12,000 SF	0.40 - 0.45	30%	
Single Family Units Lots 17,000 SF	0.35 - 0.45	25%	
Lots 1/2 Acre or More	0.30 - 0.40	20%	
Parks, Cemeteries & Unimproved Areas	0.25 - 0.35	15%	To be computed
TYPE SURFACE		According to zoning classification of composite runoff coefficient	
Pavement & Roofs	0.90		
Lawns	0.25 - 0.35		

1. The lowest range of runoff coefficients may be used for flat areas (areas where the majority of the grades and slopes are 2% and less).

2. The average range of runoff coefficients should be used for intermediate areas (areas where the majority of the grades and slopes are from 2% to 5%).

3. The highest range of runoff coefficients shall be used for steep areas (areas where the majority of the grades are greater than 5%), for cluster areas, and for development in clay soil areas.

4. For unimproved areas containing less than 5% impervious cover and storm frequencies 2-year or less, use C = 0.10 to 0.20.

Runoff Coefficients and Inlet Times

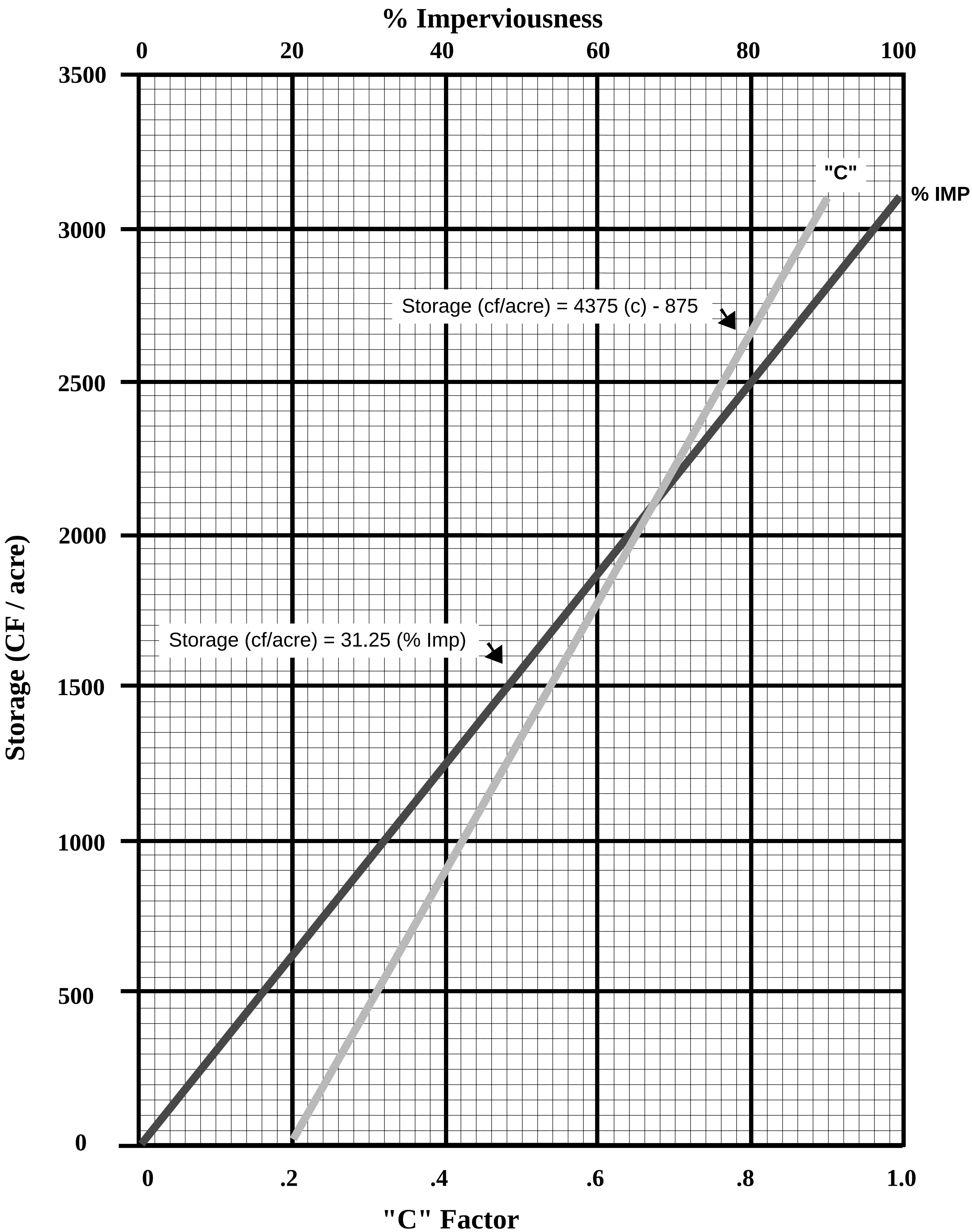
(Source: Fairfax County Public Facilities Manual, Chart A6-19, 1988)

ZONE			Tc (MIN)
--	Residential (average lot size)		
	a. 10,000 sq. ft. to 20,000 sq. ft.	0.35 - 0.45	10 - 15
	b. 20,000 sq. ft. to 5 ac.	0.30 - 0.40	10 - 15
--	Parks and Agriculture (over 5 ac.)	0.25 - 0.35	To be computed
--	Cemeteries	0.25 - 0.35	To be computed
R-T	Townhouses	0.65 - 0.75	5 - 10
--	Schools	0.50 - 0.60	10 - 15
RM-1	Apartments	0.65 - 0.75	5 - 10
M-1	Industrial	0.80 - 0.90	5
B-1	Business, Commercial, or Offices	0.80 - 0.90	5
RPC	Residential Planned Community		
	a. High Density	0.80 - 0.90	5
	b. Medium Density	0.65 - 0.75	5 - 10
	c. Low Density	0.35 - 0.45	10 - 15
	d. Commercial or Industrial	0.80 - 0.90	5
	e. Schools	0.50 - 0.60	5 - 10
	f. Open Space	0.25 - 0.35	10 - 15
	g. Gravel Lots	0.65 - 0.75	5 - 10
	h. Asphalt or Concrete Parking Lots and Roofs	0.90 - 0.95	5
	i. Grass Areas	0.30 - 0.40	10 - 15
RMH	Residential Mobile Homes	0.50 - 0.60	5 - 10

NOTES:
1. When calculating flow to a structure if all runoff to the structure is from impervious areas (i.e. pavement and roofs) the C to be used is 0.90.
2. The lowest range of runoff coefficients may be used for flat areas (areas where the majority of the grades and slopes are 2% and less).
3. The average range of runoff coefficients should be used for intermediate areas (areas where the majority of the grades and slopes are from 2% to 5%).
4. The highest range of runoff coefficients shall be used for steep areas (areas where the majority of the grades are greater than 5%), for cluster areas, and for development in clay soil areas.

Coefficients of Runoff to be Used with the Rational Formula in Prince William County

(Source: Prince William County Design and Construction Standards Manual, Exhibit 1)



Water Quality Storage Requirements Related to Percent Imperviousness and Rational Formula "C" Factor
(Equivalent to Fairfax County Public Facilities Manual, Chart A6-40, 1988)

BMP Facility Design Calculations

Plan Name: Date:

Plan Number: Engineer:

I. Water Quality Narrative

II. Watershed Information

Part 1: List all of the Subareas and "C" Factors used in the BMP Computations

Subarea Designation and Description (1)	"C" (2)	Acres (3)

NOTE: Rational formula "C" factors are taken from the general zoning values listed in Appendix 4-1 or 4-2 depending on the location of the BMP facility (Fairfax County Public Facilities Manual Chart A6-19 or Prince William County Design and Construction Standards Manual, Exhibit 1).

III. Phosphorus Removal - General

BMP phosphorus removal efficiencies are the same for Northern Virginia jurisdictions unless otherwise noted. Table 4-1 presents the accepted removal efficiencies for BMPs in Northern Virginia.

Facility Type	Removal Rate
• Extended Detention Dry Pond	
Design (i) (Chart "A")	40%
Regional	50%*
• Wet Pond	
Design (i) (4.0 x Vr)	50%
Design (ii) (2.5 x Vr + Extended Detention)	45%
Regional (4.0 x Vr)	65%*
• Infiltration Trench	
Design (i) (0.5 in/imp. ac.)	50%
Design (ii) (1.0 in/imp. ac.)	65%
Design (iii) (2-year 2-hour storm)	70%

* *NOTE:* Phosphorus removal credit and specific requirements for the establishment of regional ponds may vary between jurisdictions. The designer should contact the appropriate agency before consideration of such a facility.

Table 4-1: Phosphorus Removal Efficiencies for Different BMP Facilities

IIIa. Phosphorus Removal - "Occoquan Method"

This section is for use in the jurisdictions which do not utilize CBLAD's "Chesapeake Bay Method" for phosphorus removal calculations. The "Chesapeake Bay Method" is addressed in Section IIIb of this worksheet. Please check with your local jurisdiction to determine which method to use.

Part 2: Compute the Weighted Average "C" Factor for the Site

(A) Area of the site (a) ____________ acres

(B)

Subarea Designation (1)	"C" (2)		Acres (3)		Product (4)
________________	______	X	______	=	________
________________	______	X	______	=	________
________________	______	X	______	=	________
________________	______	X	______	=	________
________________	______	X	______	=	________
________________	______	X	______	=	________
________________	______	X	______	=	________
________________	______	X	______	=	________
________________	______	X	______	=	________
________________	______	X	______	=	________

(b) Total = __________

(C) Weighted average "C" factor (b) / (a) = (c) __________

Part 3: Compute the Total Phosphorus Removal for the Site

Subarea Designation (1)	BMP Type (2)	Removal Eff. (%) (3)		Area Ratio (4)		"C" Factor Ratio (5)		Product (6)
______	______	______	X	________	X	________	=	______
______	______	______	X	________	X	________	=	______
______	______	______	X	________	X	________	=	______
______	______	______	X	________	X	________	=	______
______	______	______	X	________	X	________	=	______
______	______	______	X	________	X	________	=	______
______	______	______	X	________	X	________	=	______
______	______	______	X	________	X	________	=	______
______	______	______	X	________	X	________	=	______
______	______	______	X	________	X	________	=	______

(a) Total = __________%

Part 4: Determine Compliance with Phosphorus Removal Requirement

(A) Select Requirement (a) _______

- Water Supply Overlay District (Occoquan Watershed) = 50% (Fairfax County and Prince William County)
- Chesapeake Bay Preservation Area (New Development) = 40% (Fairfax County) 50% (Prince William County)
- Chesapeake Bay Preservation Area (Redevelopment) = [1-0.9 x (“I”pre / “I”post)] x 100 = __%

(B) If Line 3(a) ______ ≥ Line 4(a) ______ then Phosphorus removal requirement is satisfied.

IIIb. Phosphorus Removal Calculations - "Chesapeake Bay Method"

This section is for use by jurisdictions which utilize the CBLAD "Chesapeake Bay Method." Please check with the local jurisdiction to determine which method to use. The "Chesapeake Bay Method" used in these calculations is as follows:

$$L = P \times Pj \times \{0.05 + 0.009(I)\} \times C \times A \times 2.72 / 12$$

Where:

L = phosphorus loadings (lbs / yr)
P = average rainfall depth (inches)
  P = 40 inches per year for Northern Virginia
Pj = unitless correction factor for storms that produce no runoff
  Pj = 0.9
I = the percent of site imperviousness in whole numbers.
C = flow-weighted mean pollutant concentration (mg / l)
  C = 0.26 mg / l when I<20%
  C = 1.08 mg / l when I>20%
A = area of development site (acres)

NOTE: Section IIIb Phosphorus Removal Calculations replaces Parts 2 Through 4 of Section IIIa.

1) Enter Site Name ____

2) Calculate Existing Site Imperviousness

(A) Pavement Area
(Include roads, driveways, sidewalks, paved trails, etc.) _____________S.F.
(B) Structures Area
(Include houses, sheds, patios, etc.) _____________S.F.
(C) Landscaped Areas
(Include lawns, gardens, unpaved walks or trails, etc.) _____________S.F.
(D) Undisturbed Areas
(Include woods, wetlands, unmaintained or natural areas) _____________S.F.

Total area (E) = _____________S.F.
/ 43,560 = ___________acres
Site imperviousness {(A+B)/E} x 100 = ______________%

3) Calculate Proposed Site Imperviousness

(A) Pavement Area
(Include roads, driveways, sidewalks, paved trails, etc.) _____________S.F.
(B) Structures Area
(Include houses, sheds, patios, etc.) _____________S.F.
(C) Landscaped Areas
(Include lawns, gardens, unpaved walks or trails, etc.) _____________S.F.
(D) Undisturbed Areas
(Include woods, wetlands, unmaintained or natural areas) _____________S.F.

Total area (E) = _____________S.F.
/ 43,560 = ___________acres
Site imperviousness {(A+B)/E} x 100 = ______________%

4) Site Conditions

(A) Enter Name of Watershed ____

(B) Enter Watershed Imperviousness as a Percentage ________%

(C) Determine Whether Proposal is Considered New Development
or Redevelopment ____

5) Phosphorus Loadings

(A) Existing Phosphorus Loading:

New Development:
L(pre)= 36 x {0.05 + 0.009(Iwshed_______)} x (C)______ x (A)______ x 2.72 / 12

Redevelopment:
L(pre)= 36 x {0.05 + 0.009(Isite/pre_______)} x (C)______ x (A)_____ x 2.72 / 12

L(pre) = _________Lbs/Year

(B) Proposed Phosphorus Loading:

New Development:
L(post) = 36 x {0.05 + 0.009(Isite/post______) x (C)_____ x (A)______ x 2.72 / 12

Redevelopment:
L(post) = 36 x {0.05 + 0.009(Isite/post______) x (C)_____ x (A)______ x 2.72 / 12

L(post)= _________Lbs/Year

6) Phosphorus Removal Required

(A) Phosphorus Removal Required:
New Development
Removal Required = Lpost ________- Lpre________ = ___________Lbs/year

Redevelopment
Removal Required = Lpost ________- 0.9 (Lpre______) = __________Lbs/year

(B) BMP Removal Required:
Removal Required__________ x 100 / Lpost __________= ____________%

7) Phosphorus Removal Satisfaction

(A)

BMP Facility	Removal Eff. (%/100)	x	Imp. Site Coverage (Onsite) (Offsite)	x	Lpost (lbs/yr)	=	Load Removed (lbs/yr)
________	__________		(_______ + _______)		_______		__________
________	__________		(_______ + _______)		_______		__________
________	__________		(_______ + _______)		_______		__________

Total = __________

x 100/Lpost = (A) __________%

(B)

If Line 6(B) _____ < Line 7(A) _____ then phosphorus removal is satisfied.

If Line 6(B) _____ > Line 7(A) _____ then phosphorus removal is not satisfied.

IV. Site Coverage

Part 5: Determine Compliance with Site Coverage Requirement

Sum all the uncontrolled onsite areas and compute a weighted average “C” factor. Do not include qualifying open space.

Subarea Designation (1)	“C” (2)		Acres (3)		Product (4)
______________________________	_______	X	_______	=	__________
______________________________	_______	X	_______	=	__________
______________________________	_______	X	_______	=	__________
______________________________	_______	X	_______	=	__________
______________________________	_______	X	_______	=	__________

(A) Total equivalent uncontrolled area (a) Total = _________

(B) Total uncontrolled area (b) __________

(C) Weighted average “C” factor (a)/(b) = (c) ____________

(D) If Line 5(b) < 20% of Line 2(a), then the site coverage requirement is satisfied. Line 5(a) is the equivalent offsite area for which coverage may be required.

100 x Line 5(b) ___________ / Line 2(a) ___________ = (d) ___________ %

Part 6: Determine the Offsite Areas for which Coverage is Required

(A) For the offsite areas listed in Part 1 which flow to proposed onsite BMPs compute the equivalent areas.

Subarea Designation (1)	“C” (2)		Acres (3)		Product (4)
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	

(a) Total = __________

If the equivalent offsite area, Line 6(a), draining to all proposed BMP facilities is greater than the equivalent uncontrolled area of the site shown in Line 5(a); then, the offsite area controlled by the proposed BMP facilities may be reduced until the two are equal. Otherwise, all uncontrolled offsite areas draining to the proposed BMP facilities must be included. All offsite areas thus reduced should be marked with an “*” wherever they appear in the computations.

V. Storage

Part 7: Compute The Weighted Average "C" Factor for Each Proposed BMP Facility

(A) List the areas to be controlled by the proposed BMP.

Subarea Designation (1)	"C" (2)		Acres (3)		Product (4)
______________	______	X	______	=	________
______________	______	X	______	=	________
______________	______	X	______	=	________
______________	______	X	______	=	________
______________	______	X	______	=	________
______________	______	X	______	=	________

(a) ________

(B) (b) ________

(C) Weighted average "C" factor (b)/(a) = (c) ________

Part 8: Determine the Storage Required for Each Proposed Facility

(A) Extended Detention Dry Pond

Chart A6-40 value (Appendix 4-3) for BMP storage per acre
[(4375 x "C") - 875] or [31.25 x %Imp.] = (a) ________ cf/ac

• Design 1 (48 hour drawdown)

Line 7(a) ________ x Line 8(a) ________ = ________ cf

(B) Wet Pond

Volume of runoff per acre from mean storm.
[1452 x "C"] = 1452 x Line 7(c) = (b) ________ cf/ac

• Design 1 (2.5 x Volume of runoff from mean storm event in wet storage with extended detention above the permanent pool)

Wet Storage

2.5 x Line 7(a) ________ x Line 8(b) ________ = ________ cf

Extended Detention

Line 7(a) ________ x Line 8(a) ________ = ________ cf

- Design 2 (4.0 x Volume of runoff from mean storm)
  4.0 x Line 7(a) _______ x Line 8(b) ________ = _________ cf

(C) Infiltration Trench

- Design 1 (0.50 inch per impervious acre)
  0.50 x 36.30 x (% imp.) _____ x Line 7(a) ______ = _______ cf
- Design 2 (1.0 inch per impervious acre)
  1.0 x 36.30 x (% imp.) _____ x Line 7(a) _______ = _______ cf
- Design 3 (2-year 2-hour storm)
  (2.0/12) x 43,560 x “C” _____ x Line 7(a) ______ = _______ cf

VI. Outlet Computation

Part 9: Determine The Required Orifice Size for Each Extended Detention Facility

(A) BMP storage requirement (S) from Part 8. (a) __________

(B) Maximum Head (h) at the required BMP storage from the elevation-storage curve for the facility. (b) __________

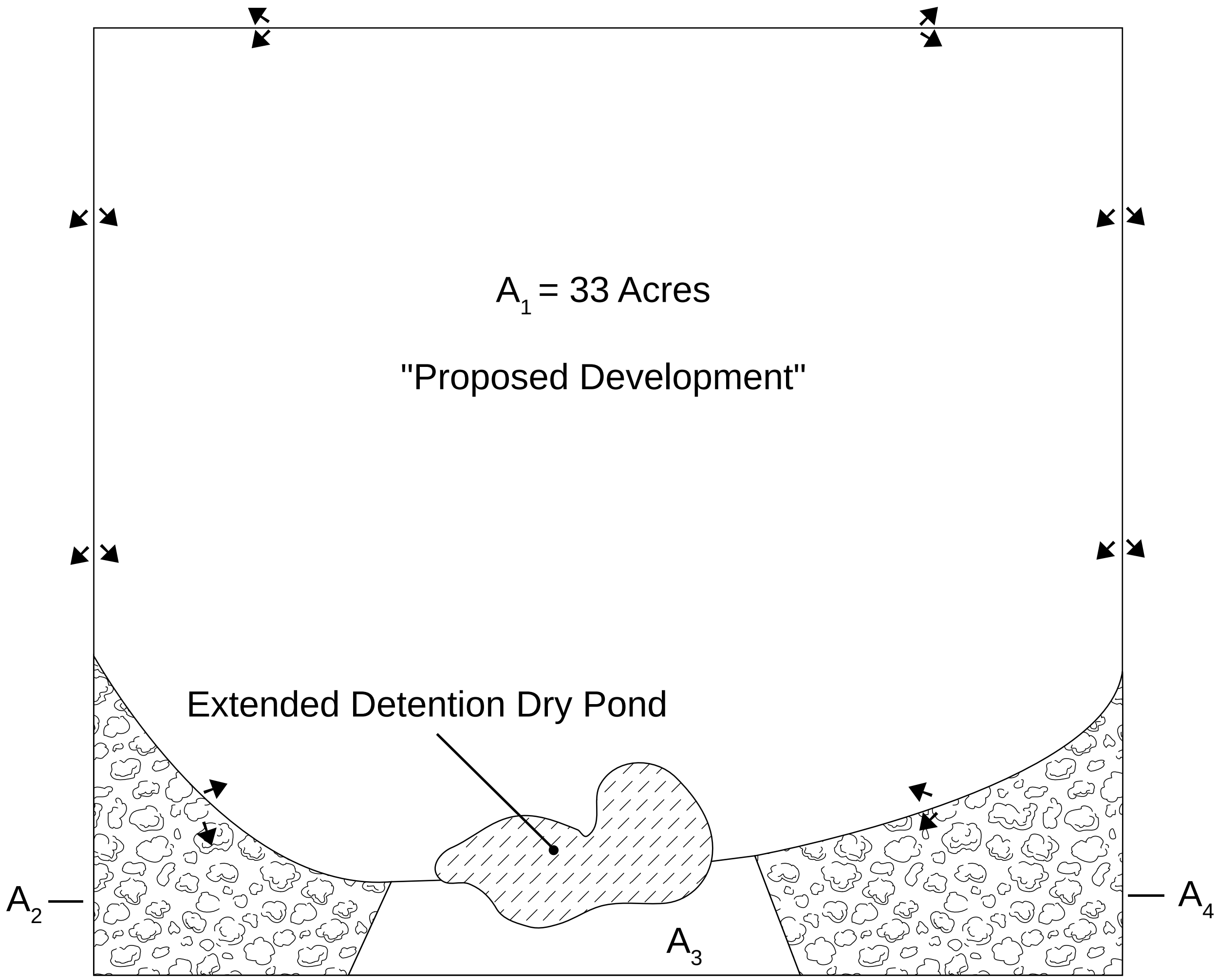
(C) Peak outflow rate (Q_p) at the maximum head for a drawdown time of 48 hrs [Q_p = S/(0.5 x 3600 x 48)].
0.0000116 x Line 9(a) _________ = (c) __________

(D) Required orifice area (A) [$A = Q_p / (0.6 \times (64.4 \times h)^{0.5})$]
Line 9(c) _______ / [0.6 x (64.4 x Line 9(b) ________ $)^{0.5}$] = (d) __________

(E) Diameter of a circular orifice.
2.0 x (Line 9(d) _________ / 3.1415927$)^{0.5}$ = (e) ____________

EXAMPLE # 1

Onsite Drainage Only



TOTAL SITE AREA = 40 ACRES ($\bar{c}$ = 0.71)

A_1 =	To be Developed with Controls	33 Acres (c = 0.80)
A_2 =	Open Space “Undisturbed”	2 Acres (c = 0.20)
A_3 =	Uncontrolled	1 Acre (c = 0.80)
A_4 =	Open Space “Undisturbed”	4 Acres (c = 0.20)

BMP Facility Design Calculations

Plan Name: **Example Number One** Date:

Plan Number: Engineer:

I. Water Quality Narrative

The site consists of a 40 acre commercial development project consisting of 34 acres of developed/disturbed area and 6 acres of undisturbed area. 33 acres of the development area shall drain to a proposed extended detention dry BMP pond, 6 acres not draining to the BMP qualify for open space BMP credit, and 1 acre of developed area is uncontrolled. No offsite drainage enters the BMP facility. The facility will be placed within an easement and will be maintained by the local municipality. The site is located within the Occoquan Watershed and therefore requires that the phosphorus load after development be reduced by 50%.

II. Watershed Information

Part 1: List all of the Subareas and "C" Factors used in the BMP Computations

Subarea Designation and Description (1)	"C" (2)	Acres (3)
A_1 Controlled Disturbed	0.8	33
A_2 Uncontrolled Open Space	0.2	2
A_3 Uncontrolled Disturbed	0.8	1
A_4 Uncontrolled Open Space	0.2	4

NOTE: Rational formula "C" factors are taken from the general zoning values listed in Appendix 4-1 or 4-2 depending on the location of the BMP facility (Fairfax County Public Facilities Manual Chart A6-19 or Prince William County Design and Construction Standards Manual, Exhibit 1).

III. Phosphorus Removal - General

BMP phosphorus removal efficiencies are the same for Northern Virginia jurisdictions unless otherwise noted. Table 4-1 presents the accepted removal efficiencies for BMPs in Northern Virginia.

Facility Type	Removal Rate
• Extended Detention Dry Pond	
Design (i) (Chart "A")	40%
Regional	50%*
• Wet Pond	
Design (i) (4.0 x Vr)	50%
Design (ii) (2.5 x Vr + Extended Detention)	45%
Regional (4.0 x Vr)	65%*
• Infiltration Trench	
Design (i) (0.5 in/imp. ac.)	50%
Design (ii) (1.0 in/imp. ac.)	65%
Design (iii) (2-year 2-hour storm)	70%

* *NOTE:* Phosphorus removal credit and specific requirements for the establishment of regional ponds may vary between jurisdictions. The designer should contact the appropriate agency before consideration of such a facility.

Table 4-1: Phosphorus Removal Efficiencies for Different BMP Facilities

In this example, the "Occoquan Method" of phosphorus removal is to be used. Refer to Examples 4 and 5 for a demonstration of the "Chesapeake Bay Method."

IIIa. Phosphorus Removal - "Occoquan Method"

This section is for use in the jurisdictions which do not utilize CBLAD's "Chesapeake Bay Method" for phosphorus removal calculations. The "Chesapeake Bay Method" is addressed in Section IIIb of this worksheet. Please check with your local jurisdiction to determine which method to use.

Part 2: Compute the Weighted Average "C" Factor for the Site

(A) Area of the site (a) **40** acres

(B)

Subarea Designation (1)	"C" (2)		Acres (3)		Product (4)
		X		=	
A_1 Controlled Disturbed	**0.8**	X	**33**	=	**26.4**
A_2 Uncontrolled Open Space	**0.2**	X	**2**	=	**0.4**
A_3 Uncontrolled Disturbed	**0.8**	X	**1**	=	**0.8**
A_4 Uncontrolled Open Space	**0.2**	X	**4**	=	**0.8**
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	

(b) Total = **28.4**

(C) Weighted average "C" factor (b) / (a) = (c) **0.71**

Part 3: Compute the Total Phosphorus Removal for the Site

Subarea Designation (1)	BMP Type (2)	Removal Eff. (%) (3)		Area Ratio (4)		"C" Factor Ratio (5)		Product (6)
			X		X		=	
A_1	Dry Pond	40	X	33/40=0.825	X	0.8/0.71=1.13	=	37.18
			X		X		=	
A_2	Open Space	100*	X	2/40=0.05	X	1	=	5.0
			X		X		=	
A_3	Uncontrolled	-	X	-	X	-	=	0
			X		X		=	
A_4	Open Space	100*	X	4/40=0.1	X	1	=	10.0
			X		X		=	
			X		X		=	

*** Per Fairfax County PFM**

(a) Total = **52.18** %

Part 4: Determine Compliance with Phosphorus Removal Requirement

(A) Select Requirement (a) **50%**

- Water Supply Overlay District (Occoquan Watershed) = 50% (Fairfax County and Prince William County)
- Chesapeake Bay Preservation Area (New Development) = 40% (Fairfax County) 50% (Prince William County)
- Chesapeake Bay Preservation Area (Redevelopment) = [1-0.9 x (“I”pre / “I”post)] x 100 = __%

(B) If Line 3(a) **52.2%** ≥ Line 4(a) **50.0%** then Phosphorus removal requirement is satisfied.

NOTE: **Since the "Occoquan Method" of phosphorus removal is being used, proceed to Section IV., Site Coverage.**

IIIb. Phosphorus Removal Calculations - "Chesapeake Bay Method"

This section is for use by jurisdictions which utilize the CBLAD "Chesapeake Bay Method." Please check with the local jurisdiction to determine which method to use. The "Chesapeake Bay Method" used in these calculations is as follows:

$$L = P \times Pj \times \{0.05 + 0.009(I)\} \times C \times A \times 2.72 / 12$$

Where:

L = phosphorus loadings (lbs / yr)
P = average rainfall depth (inches)
    P = 40 inches per year for Northern Virginia
Pj = unitless correction factor for storms that produce no runoff
    Pj = 0.9
I = the percent of site imperviousness in whole numbers.
C = flow-weighted mean pollutant concentration (mg / l)
    C = 0.26 mg / l when I<20%
    C = 1.08 mg / l when I>20%
A = area of development site (acres)

NOTE: Section IIIb Phosphorus Removal Calculations replaces Parts 2 Through 4 of Section IIIa.

1) Enter Site Name ____

2) Calculate Existing Site Imperviousness

(A) Pavement Area
(Include roads, driveways, sidewalks, paved trails, etc.) ____________S.F.
(B) Structures Area
(Include houses, sheds, patios, etc.) ____________S.F.
(C) Landscaped Areas
(Include lawns, gardens, unpaved walks or trails, etc.) ____________S.F.
(D) Undisturbed Areas
(Include woods, wetlands, unmaintained or natural areas) ____________S.F.

Total area (E) = ____________S.F.
/ 43,560 = __________acres
Site imperviousness {(A+B)/E} x 100 = _____________%

3) Calculate Proposed Site Imperviousness

(A) Pavement Area
(Include roads, driveways, sidewalks, paved trails, etc.) ____________S.F.
(B) Structures Area
(Include houses, sheds, patios, etc.) ____________S.F.
(C) Landscaped Areas
(Include lawns, gardens, unpaved walks or trails, etc.) ____________S.F.
(D) Undisturbed Areas
(Include woods, wetlands, unmaintained or natural areas) ____________S.F.

Total area (E) = ____________S.F.
/ 43,560 = __________acres
Site imperviousness {(A+B)/E} x 100 = _____________%

4) Site Conditions

(A) Enter Name of Watershed ____

(B) Enter Watershed Imperviousness as a Percentage _______%

(C) Determine Whether Proposal is Considered New Development or Redevelopment ____________________

5) Phosphorus Loadings

(A) Existing Phosphorus Loading:

<u>New Development:</u>
L(pre)= 36 x {0.05 + 0.009(Iwshed_______)} x (C)______ x (A)______ x 2.72 / 12

<u>Redevelopment:</u>
L(pre)= 36 x {0.05 + 0.009(Isite/pre_______)} x (C)______ x (A)_____ x 2.72 / 12

L(pre) = _________Lbs/Year

(B) Proposed Phosphorus Loading:

<u>New Development:</u>
L(post) = 36 x {0.05 + 0.009(Isite/post______) x (C)_____ x (A)______ x 2.72 / 12

<u>Redevelopment:</u>
L(post) = 36 x {0.05 + 0.009(Isite/post______) x (C)_____ x (A)______ x 2.72 / 12

L(post)= _________Lbs/Year

6) Phosphorus Removal Required

(A) Phosphorus Removal Required:
<u>New Development</u>
Removal Required = Lpost ________- Lpre________ = ___________Lbs/year

<u>Redevelopment</u>
Removal Required = Lpost ________- 0.9 (Lpre______) = __________Lbs/year

(B) BMP Removal Required:
Removal Required__________ x 100 / Lpost __________= ____________%

7) Phosphorus Removal Satisfaction

(A)

BMP Facility	Removal Eff. (%/100)	x	Imp. Site Coverage (Onsite)	+	(Offsite)	x	Lpost (lbs/yr)	=	Load Removed (lbs/yr)
________	________		(______	+	______)		______		________
________	________		(______	+	______)		______		________
________	________		(______	+	______)		______		________
								Total =	________

x 100/Lpost = (A) ________%

(B)

If Line 6(B) _____ < Line 7(A) _____ then phosphorus removal is satisfied.

If Line 6(B) _____ > Line 7(A) _____ then phosphorus removal is not satisfied.

IV. Site Coverage

Part 5: Determine Compliance with Site Coverage Requirement

Sum all the uncontrolled onsite areas and compute a weighted average "C" factor. Do not include qualifying open space.

Subarea Designation (1)	"C" (2)		Acres (3)		Product (4)
		X		=	
A_3 Uncontrolled Disturbed	**0.8**	X	**1**	=	**0.8**
		X		=	
		X		=	
		X		=	

(A) Total equivalent uncontrolled area (a) Total = **0.8**

(B) Total uncontrolled area (b) **1**

(C) Weighted average “C” factor (a)/(b) = (c) **0.8**

(D) If Line 5(b) < 20% of Line 2(a), then the site coverage requirement is satisfied. Line 5(a) is the equivalent offsite area for which coverage may be required.

100 x Line 5(b) **1** / Line 2(a) **40** = (d) **2.5** %

Part 6: Determine the Offsite Areas for which Coverage is Required

(A) For the offsite areas listed in Part 1 which flow to proposed onsite BMPs compute the equivalent areas. **Not applicable since no offsite drainage flows to onsite BMP.**

Subarea Designation (1)	“C” (2)		Acres (3)		Product (4)
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	

(a) Total = __________

If the equivalent offsite area, Line 6(a), draining to all proposed BMP facilities is greater than the equivalent uncontrolled area of the site shown in Line 5(a); then, the offsite area controlled by the proposed BMP facilities may be reduced until the two are equal. Otherwise, all uncontrolled offsite areas draining to the proposed BMP facilities must be included. All offsite areas thus reduced should be marked with an “*” wherever they appear in the computations.

V. Storage

Part 7: Compute The Weighted Average "C" Factor for Each Proposed BMP Facility

(A) List the areas to be controlled by the proposed BMP.

Subarea Designation (1)	"C" (2)		Acres (3)		Product (4)
		X		=	
A_1 Controlled Disturbed	0.8	X	33	=	26.4
		X		=	
		X		=	
		X		=	
		X		=	

(a) 33

(B) (b) 26.4

(C) Weighted average "C" factor (b)/(a) = (c) 0.8

Part 8: Determine the Storage Required for Each Proposed Facility

(A) Extended Detention Dry Pond

Chart A6-40 value (Appendix 4-3) for BMP storage per acre
[(4375 x "C") - 875] or [31.25 x %Imp.] = (a) 2,625 cf/ac

• Design 1 (48 hour drawdown)
Line 7(a) 33 x Line 8(a) 2,625 = 86,625 cf

(B) Wet Pond

Volume of runoff per acre from mean storm.
[1452 x "C"] = 1452 x Line 7(c) = (b) ________ cf/ac

• Design 1 (2.5 x Volume of runoff from mean storm event in wet storage with extended detention above the permanent pool)

Wet Storage
2.5 x Line 7(a) ______ x Line 8(b) ______ = ______ cf

Extended Detention
Line 7(a) ______ x Line 8(a) ______ = ______ cf

- Design 2 (4.0 x Volume of runoff from mean storm)
  4.0 x Line 7(a) _______ x Line 8(b) ________ = _________ cf

(C) Infiltration Trench
- Design 1 (0.50 inch per impervious acre)
  0.50 x 36.30 x (% imp.) _____ x Line 7(a) ______ = _______ cf
- Design 2 (1.0 inch per impervious acre)
  1.0 x 36.30 x (% imp.) _____ x Line 7(a) _______ = _______ cf
- Design 3 (2-year 2-hour storm)
  (2.0/12) x 43,560 x "C" _____ x Line 7(a) ______ = _______ cf

VI. Outlet Computation

Part 9: Determine The Required Orifice Size for Each Extended Detention Facility

(A) BMP storage requirement (S) from Part 8. (a) **86,625 cf**

(B) Maximum Head (h) at the required BMP storage from the elevation-storage curve for the facility. (b) **8 ft**

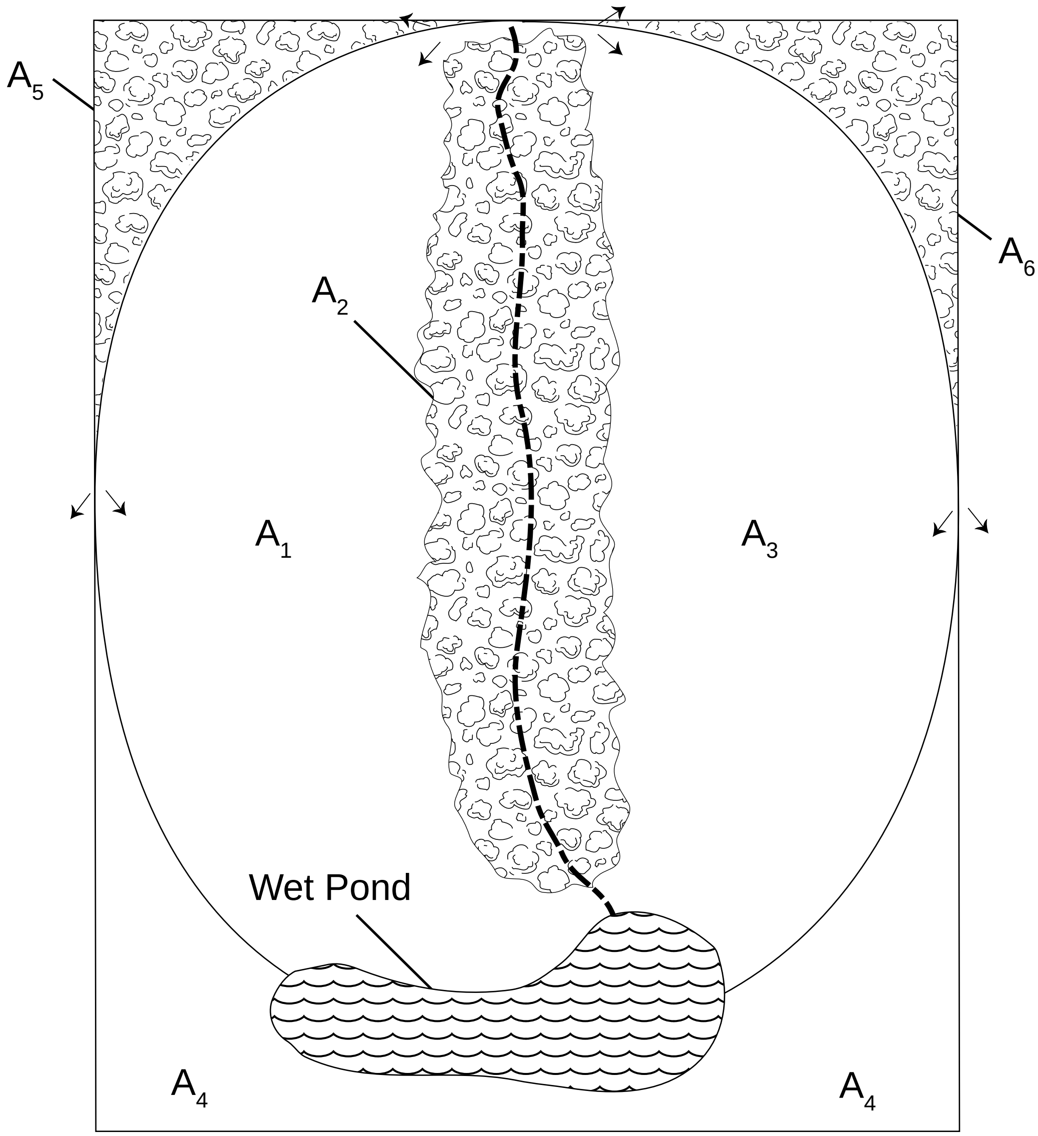
(C) Peak outflow rate (Q_p) at the maximum head for a drawdown time of 48 hrs [$Q_p = S/(0.5 \times 3600 \times 48)$].
0.0000116 x Line 9(a) **86,625** = (c) **1.00485**

(D) Required orifice area (A) [$A = Q_p / (0.6 \times (64.4 \times h)^{0.5})$]
Line 9(c) **1.00485** / [0.6 x (64.4 x Line 9(b) **8**)$^{0.5}$] = (d) **0.0738 sf**

(E) Diameter of a circular orifice.
2.0 x (Line 9(d) **0.0738** / 3.1415927)$^{0.5}$ = (e) **= 0.3065'**
= 3.68"
Use 3.5" Dia. Orifice

EXAMPLE # 2

Onsite Drainage Only



TOTAL SITE AREA = 50 ACRES ($\bar{c}$ = 0.515)

A_1 =	To be Developed with Controls …..….	15 Acres (c = 0.65)
A_2 =	Open Space “Undisturbed” …………	10 Acres (c = 0.20)
A_3 =	To be Developed with Controls……...	10 Acres (c = 0.65)
A_4 =	Uncontrolled …………………..……….	10 Acres (c = 0.65)
A_5 =	Open Space "Undisturbed"...……....	3 Acres (c = 0.20)
A_6 =	Open Space "Undisturbed"...………...	2 Acres (c = 0.20)

BMP Facility Design Calculations

Plan Name: **Example Number Two** Date:

Plan Number: Engineer:

I. Water Quality Narrative

The site consists of a 50 acre townhouse development consisting of 35 acres of developed land and 15 acres of undisturbed qualified open space. 25 acres of developed area and 10 acres of undisturbed area will drain to the proposed retention (wet) pond. 10 developed acres and 5 acres of open space drain uncontrolled from the site. No offsite drainage enters the BMP facility. The facility will be maintained by the Homeowner's Association to be established for this community. The site is located in a Resource Management Area outside of the Occoquan Watershed; therefore, 40% phosphorus removal is required.

NOTE: Certain jurisdictions may have regulations restricting the use of wet ponds in residential areas.

II. Watershed Information

Part 1: List all of the Subareas and “C” Factors used in the BMP Computations

Subarea Designation and Description (1)	“C” (2)	Acres (3)
A_1 **Developed with Controls**	**0.65**	**15**
A_2 **Open Space "Undisturbed" to Pond**	**0.20**	**10**
A_3 **Developed with Controls**	**0.65**	**10**
A_4 **Developed Uncontrolled**	**0.65**	**10**
A_5 **Open Space "Undisturbed" Uncontrolled**	**0.20**	**3**
A_6 **Open Space "Undisturbed" Uncontrolled**	**0.20**	**2**

NOTE: Rational formula “C” factors are taken from the general zoning values listed in Appendix 4-1 or 4-2 depending on the location of the BMP facility (Fairfax County Public Facilities Manual Chart A6-19 or Prince William County Design and Construction Standards Manual, Exhibit 1).

III. Phosphorus Removal - General

BMP phosphorus removal efficiencies are the same for Northern Virginia jurisdictions unless otherwise noted. Table 4-1 presents the accepted removal efficiencies for BMPs in Northern Virginia.

Facility Type	Removal Rate
• Extended Detention Dry Pond	
Design (i) (Chart "A")	40%
Regional	50%*
• Wet Pond	
Design (i) (4.0 x Vr)	50%
Design (ii) (2.5 x Vr + Extended Detention)	45%
Regional (4.0 x Vr)	65%*
• Infiltration Trench	
Design (i) (0.5 in/imp. ac.)	50%
Design (ii) (1.0 in/imp. ac.)	65%
Design (iii) (2-year 2-hour storm)	70%

* *NOTE:* Phosphorus removal credit and specific requirements for the establishment of regional ponds may vary between jurisdictions. The designer should contact the appropriate agency before consideration of such a facility.

Table 4-1: Phosphorus Removal Efficiencies for Different BMP Facilities

In this example, the "Occoquan Method" of phosphorus removal is to be used. Refer to Examples 4 and 5 for a demonstration of the "Chesapeake Bay Method."

IIIa. Phosphorus Removal - "Occoquan Method"

This section is for use in the jurisdictions which do not utilize CBLAD's "Chesapeake Bay Method" for phosphorus removal calculations. The "Chesapeake Bay Method" is addressed in Section IIIb of this worksheet. Please check with your local jurisdiction to determine which method to use.

Part 2: Compute the Weighted Average "C" Factor for the Site

(A) Area of the site (a) **50** acres

(B)

Subarea Designation (1)	"C" (2)		Acres (3)		Product (4)
A_1 Developed with Controls	0.65	X	15	=	9.75
A_2 Open Space "Undisturbed" to Pond	0.20	X	10	=	2.0
A_3 Developed with Controls	0.65	X	10	=	6.5
A_4 Developed without Controls	0.65	X	10	=	6.5
A_5 Open Space "Undisturbed" Uncontrolled	0.20	X	3	=	0.6
A_6 Open Space "Undisturbed" Uncontrolled	0.20	X	2	=	0.4

(b) Total = **25.75**

(C) Weighted average "C" factor (b) / (a) = (c) **0.515**

Part 3: Compute the Total Phosphorus Removal for the Site

Subarea Designation (1)	BMP Type (2)	Removal Eff. (%) (3)		Area Ratio (4)		"C" Factor Ratio (5)		Product (6)
A_1	Wet Pond	45	X	15/50=0.3	X	0.65/0.515=1.26	=	17.01
A_2	Open Space	100*	X	10/50=0.2	X	1	=	20.0
A_3	Wet Pond	45	X	10/50=0.2	X	0.65/0.515=1.26	=	11.34
A_4	Uncontrolled	-	X	-	X	-	=	0.0
A_5	Open Space	100*	X	3/50=0.06	X	1	=	6.0
A_6	Open Space	100*	X	2/50=0.04	X	1	=	4.0

*** Per Fairfax County PFM**

(a) Total = **58.35** %

Part 4: Determine Compliance with Phosphorus Removal Requirement

(A) Select Requirement (a) **40%**

- Water Supply Overlay District (Occoquan Watershed) = 50% (Fairfax County and Prince William County)
- Chesapeake Bay Preservation Area (New Development) = 40% (Fairfax County) 50% (Prince William County)
- Chesapeake Bay Preservation Area (Redevelopment) = [1-0.9 x (“I”pre / “I”post)] x 100 = __%

(B) If Line 3(a) **58.4%** ≥ Line 4(a) **40.0%** then Phosphorus removal requirement is satisfied.

NOTE: **Since the "Occoquan Method" of phosphorus removal is being used, proceed to Section IV., Site Coverage.**

IIIb. Phosphorus Removal Calculations - "Chesapeake Bay Method"

This section is for use by jurisdictions which utilize the CBLAD "Chesapeake Bay Method." Please check with the local jurisdiction to determine which method to use. The "Chesapeake Bay Method" used in these calculations is as follows:

$$L = P \times Pj \times \{0.05 + 0.009(I)\} \times C \times A \times 2.72 / 12$$

Where:

L = phosphorus loadings (lbs / yr)
P = average rainfall depth (inches)
P = 40 inches per year for Northern Virginia
Pj = unitless correction factor for storms that produce no runoff
Pj = 0.9
I = the percent of site imperviousness in whole numbers.
C = flow-weighted mean pollutant concentration (mg / l)
C = 0.26 mg / l when I<20%
C = 1.08 mg / l when I>20%
A = area of development site (acres)

NOTE: Section IIIb Phosphorus Removal Calculations replaces Parts 2 Through 4 of Section IIIa.

1) Enter Site Name ____

2) Calculate Existing Site Imperviousness

(A) Pavement Area
(Include roads, driveways, sidewalks, paved trails, etc.) _____________S.F.
(B) Structures Area
(Include houses, sheds, patios, etc.) _____________S.F.
(C) Landscaped Areas
(Include lawns, gardens, unpaved walks or trails, etc.) _____________S.F.
(D) Undisturbed Areas
(Include woods, wetlands, unmaintained or natural areas) _____________S.F.

Total area (E) = _____________S.F.
/ 43,560 = ___________acres
Site imperviousness {(A+B)/E} x 100 = ______________%

3) Calculate Proposed Site Imperviousness

(A) Pavement Area
(Include roads, driveways, sidewalks, paved trails, etc.) _____________S.F.
(B) Structures Area
(Include houses, sheds, patios, etc.) _____________S.F.
(C) Landscaped Areas
(Include lawns, gardens, unpaved walks or trails, etc.) _____________S.F.
(D) Undisturbed Areas
(Include woods, wetlands, unmaintained or natural areas) _____________S.F.

Total area (E) = _____________S.F.
/ 43,560 = ___________acres
Site imperviousness {(A+B)/E} x 100 = ______________%

4) Site Conditions

(A) Enter Name of Watershed ____

(B) Enter Watershed Imperviousness as a Percentage _______%

(C) Determine Whether Proposal is Considered New Development
or Redevelopment ____

5) Phosphorus Loadings

(A) Existing Phosphorus Loading:

New Development:
L(pre)= 36 x {0.05 + 0.009(Iwshed_______)} x (C)______ x (A)______ x 2.72 / 12

Redevelopment:
L(pre)= 36 x {0.05 + 0.009(Isite/pre_______)} x (C)______ x (A)_____ x 2.72 / 12

L(pre) = _________Lbs/Year

(B) Proposed Phosphorus Loading:

New Development:
L(post) = 36 x {0.05 + 0.009(Isite/post______) x (C)_____ x (A)______ x 2.72 / 12

Redevelopment:
L(post) = 36 x {0.05 + 0.009(Isite/post______) x (C)_____ x (A)______ x 2.72 / 12

L(post)= _________Lbs/Year

6) Phosphorus Removal Required

(A) Phosphorus Removal Required:
New Development
Removal Required = Lpost ________- Lpre________ = ___________Lbs/year

Redevelopment
Removal Required = Lpost ________- 0.9 (Lpre______) = __________Lbs/year

(B) BMP Removal Required:
Removal Required__________ x 100 / Lpost __________= ____________%

7) Phosphorus Removal Satisfaction

(A)

BMP Facility	Removal Eff. (%/100)	x	Imp. Site Coverage (Onsite)	+	(Offsite)	x	Lpost (lbs/yr)	=	Load Removed (lbs/yr)
________	________		(________	+	________)		________		________
________	________		(________	+	________)		________		________
________	________		(________	+	________)		________		________
								Total =	________

x 100/Lpost = (A) ____________%

(B)

If Line 6(B) _____ < Line 7(A) _____ then phosphorus removal is satisfied.

If Line 6(B) _____ > Line 7(A) _____ then phosphorus removal is not satisfied.

IV. Site Coverage

Part 5: Determine Compliance with Site Coverage Requirement

Sum all the uncontrolled onsite areas and compute a weighted average "C" factor. Do not include qualifying open space.

Subarea Designation (1)	"C" (2)		Acres (3)		Product (4)
		X		=	
A_4 Developed Uncontrolled	0.65	X	10	=	6.5
		X		=	
		X		=	
		X		=	

(A) Total equivalent uncontrolled area (a) Total = 6.5

(B) Total uncontrolled area (b) **10**

(C) Weighted average "C" factor (a)/(b) = (c) **0.65**

(D) If Line 5(b) < 20% of Line 2(a), then the site coverage requirement is satisfied. Line 5(a) is the equivalent offsite area for which coverage may be required.

100 x Line 5(b) **10** / Line 2(a) **50** = (d) **20** %

Part 6: Determine the Offsite Areas for which Coverage is Required

(A) For the offsite areas listed in Part 1 which flow to proposed onsite BMPs compute the equivalent areas. **Not applicable since no offsite drainage flows to onsite BMP.**

Subarea Designation (1)	"C" (2)		Acres (3)		Product (4)
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	

(a) Total = ____

If the equivalent offsite area, Line 6(a), draining to all proposed BMP facilities is greater than the equivalent uncontrolled area of the site shown in Line 5(a); then, the offsite area controlled by the proposed BMP facilities may be reduced until the two are equal. Otherwise, all uncontrolled offsite areas draining to the proposed BMP facilities must be included. All offsite areas thus reduced should be marked with an "*" wherever they appear in the computations.

V. Storage

Part 7: Compute The Weighted Average "C" Factor for Each Proposed BMP Facility

(A) List the areas to be controlled by the proposed BMP.

Subarea Designation (1)	"C" (2)		Acres (3)		Product (4)
		X		=	
A_1 Developed with Controls	0.65	X	15	=	9.75
A_2 Open Space "Undisturbed"		X		=	
to Pond	0.20	X	10	=	2.0
A_3 Developed with Controls	0.65	X	10	=	6.5
		X		=	

(a) 35

(B) (b) 18.25

(C) Weighted average "C" factor (b)/(a) = (c) 0.52

Part 8: Determine the Storage Required for Each Proposed Facility

(A) Extended Detention Dry Pond

Chart A6-40 value (Appendix 4-3) for BMP storage per acre

[(4375 x "C") - 875] or [31.25 x %Imp.] = (a) 1,400 cf/ac

- Design 1 (48 hour drawdown)

  Line 7(a) ________ x Line 8(a) ________ = ________ cf

(B) Wet Pond

Volume of runoff per acre from mean storm.

[1452 x "C"] = 1452 x Line 7(c) = (b) 755 cf/ac

- Design 1 (2.5 x Volume of runoff from mean storm event in wet storage with extended detention above the permanent pool)

  Wet Storage

  2.5 x Line 7(a) 35 x Line 8(b) 755 = 66,063 cf

  Extended Detention

  Line 7(a) 35 x Line 8(a) 1,400 = 49,000 cf

• Design 2 (4.0 x Volume of runoff from mean storm)
4.0 x Line 7(a) _______ x Line 8(b) ________ = _________ cf

(C) Infiltration Trench
• Design 1 (0.50 inch per impervious acre)
0.50 x 36.30 x (% imp.) _____ x Line 7(a) ______ = _______ cf
• Design 2 (1.0 inch per impervious acre)
1.0 x 36.30 x (% imp.) _____ x Line 7(a) _______ = _______ cf
• Design 3 (2-year 2-hour storm)
(2.0/12) x 43,560 x "C" _____ x Line 7(a) ______ = _______ cf

VI. Outlet Computation

Part 9: Determine The Required Orifice Size for Each Extended Detention Facility

(A) BMP storage requirement (S) from Part 8. (a) **49,000 cf**

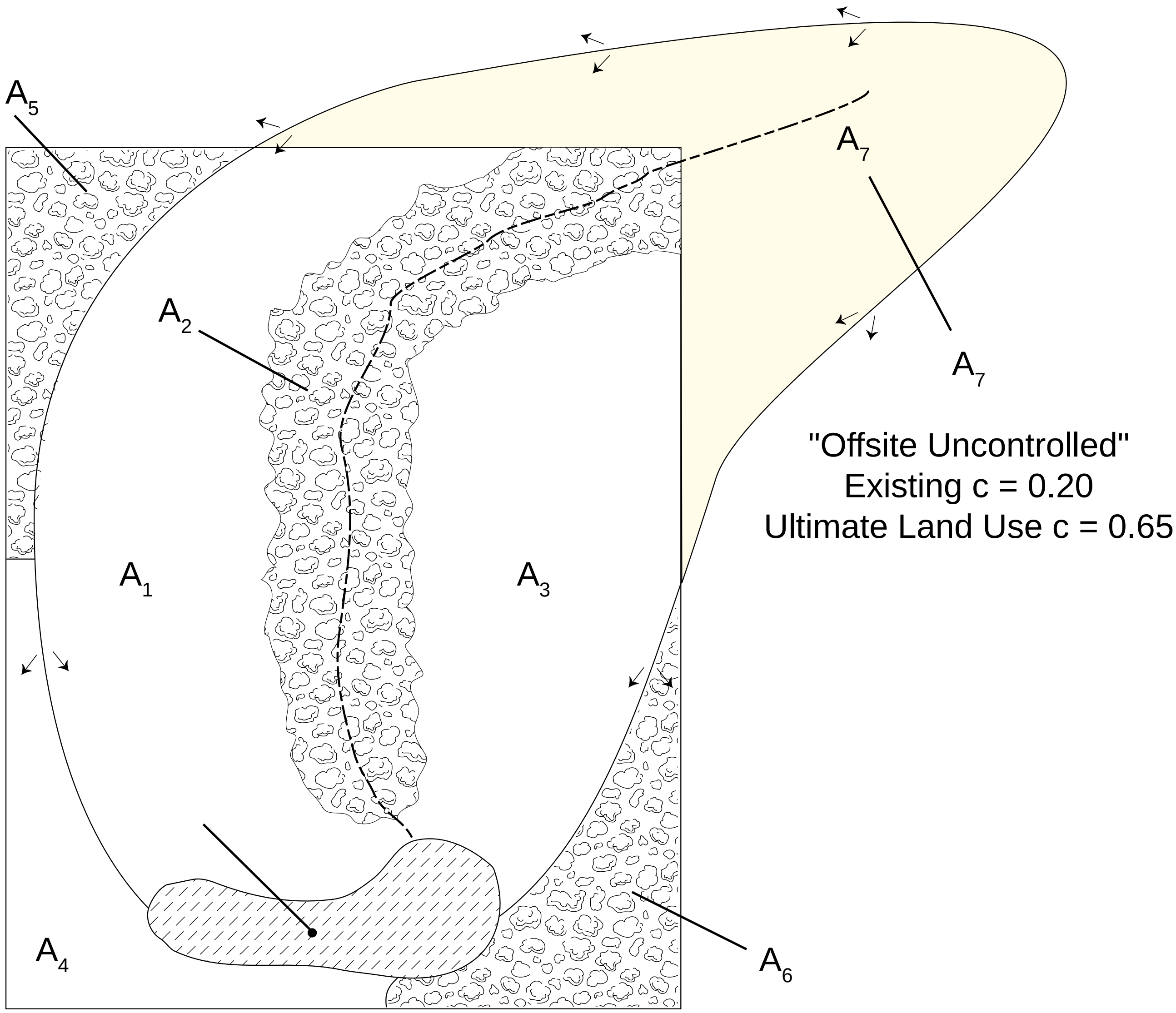
(B) Maximum Head (h) at the required BMP storage from the elevation-storage curve for the facility. (b) **3 ft**

(C) Peak outflow rate (Q_p) at the maximum head for a drawdown time of 48 hrs [Q_p = S/(0.5 x 3600 x 48)].
0.0000116 x Line 9(a) **49,000** = (c) **0.5684**

(D) Required orifice area (A) [$A = Q_p / (0.6 \times (64.4 \times h)^{0.5})$]
Line 9(c) **0.5684** / [0.6 x (64.4 x Line 9(b) **3** $)^{0.5}$] = (d) **0.06816 sf**

(E) Diameter of a circular orifice.
2.0 x (Line 9(d) **0.06816** / 3.1415927$)^{0.5}$ = (e) **= 0.2946'**
= 3.54"
Use 3.5" Dia. Orifice

EXAMPLE # 3



TOTAL SITE AREA = 50 ACRES ($\bar{c}$ = 0.515)
TOTAL OFFSITE AREA = 15 ACRES ($\bar{c}$ = 0.65**)

A_1 =	To be Developed with Controls …..…	15 Acres (c = 0.65)
A_2 =	Open Space "Undisturbed" …………	10 Acres (c = 0.20)
A_3 =	To be Developed with Controls ……..	10 Acres (c = 0.65)
A_4 =	Uncontrolled …………………..………	10 Acres (c = 0.65)
A_5 =	Open Space "Undisturbed" …………..	3 Acres (c = 0.20)
A_6 =	Open Space "Undisturbed" …………..	2 Acres (c = 0.20)
A_7 =	Offsite Uncontrolled........... …………..	15 Acres (c = 0.65**)

** c factor is determined from ultimate land use

BMP Facility Design Calculations

Plan Name: **Example Number Three** Date:
Plan Number: Engineer:

I. Water Quality Narrative

The site consists of a 50 acre townhouse development consisting of 35 acres of developed land and 15 acres of undisturbed qualified open space. 25 acres of developed area and 10 acres of undisturbed area will drain to the proposed extended detention dry pond. 10 developed acres and 5 acres of open space drain uncontrolled from the site. 15 acres of offsite undeveloped land drains to the proposed BMP facility. The facility will be maintained by the local municipality. The site is located in a Resource Management Area outside of the Occoquan Watershed; therefore, 40% phosphorus removal is required.

II. Watershed Information

Part 1: List all of the Subareas and "C" Factors used in the BMP Computations

Subarea Designation and Description (1)	"C" (2)	Acres (3)
A_1 **Developed with Controls**	**0.65**	**15**
A_2 **Open Space "Undisturbed" to Pond**	**0.20**	**10**
A_3 **Developed with Controls**	**0.65**	**10**
A_4 **Developed without Controls**	**0.65**	**10**
A_5 **Open Space "Undisturbed" Uncontrolled**	**0.20**	**3**
A_6 **Open Space "Undisturbed" Uncontrolled**	**0.20**	**2**
A_7 **Offsite Undeveloped to Pond**	**0.65***	**15**

*** Assumed c factor is based on ultimate planned land use.**

NOTE: Rational formula "C" factors are taken from the general zoning values listed in Appendix 4-1 or 4-2 depending on the location of the BMP facility (Fairfax County Public Facilities Manual Chart A6-19 or Prince William County Design and Construction Standards Manual, Exhibit 1).

III. Phosphorus Removal - General

BMP phosphorus removal efficiencies are the same for Northern Virginia jurisdictions unless otherwise noted. Table 4-1 presents the accepted removal efficiencies for BMPs in Northern Virginia.

Facility Type	Removal Rate
• Extended Detention Dry Pond	
Design (i) (Chart "A")	40%
Regional	50%*
• Wet Pond	
Design (i) (4.0 x Vr)	50%
Design (ii) (2.5 x Vr + Extended Detention)	45%
Regional (4.0 x Vr)	65%*
• Infiltration Trench	
Design (i) (0.5 in/imp. ac.)	50%
Design (ii) (1.0 in/imp. ac.)	65%
Design (iii) (2-year 2-hour storm)	70%

* *NOTE:* Phosphorus removal credit and specific requirements for the establishment of regional ponds may vary between jurisdictions. The designer should contact the appropriate agency before consideration of such a facility.

Table 4-1: Phosphorus Removal Efficiencies for Different BMP Facilities

In this example, the "Occoquan Method" of phosphorus removal is to be used. Refer to Examples 4 and 5 for a demonstration of the "Chesapeake Bay Method."

IIIa. Phosphorus Removal - "Occoquan Method"

This section is for use in the jurisdictions which do not utilize CBLAD's "Chesapeake Bay Method" for phosphorus removal calculations. The "Chesapeake Bay Method" is addressed in Section IIIb of this worksheet. Please check with your local jurisdiction to determine which method to use.

Part 2: Compute the Weighted Average "C" Factor for the Site

(A) Area of the site (a) **50** acres

(B)

Subarea Designation (1)	"C" (2)		Acres (3)		Product (4)
A_1 **Developed with Controls**	**0.65**	X	**15**	=	**9.75**
A_2 **Open Space "Undisturbed" to Pond**	**0.20**	X	**10**	=	**2.0**
A_3 **Developed with Controls**	**0.65**	X	**10**	=	**6.5**
A_4 **Developed without Controls**	**0.65**	X	**10**	=	**6.5**
A_5 **Open Space "Undisturbed" Uncontrolled**	**0.20**	X	**3**	=	**0.6**
A_6 **Open Space "Undisturbed" Uncontrolled**	**0.20**	X	**2**	=	**0.4**

(b) Total = **25.75**

(C) Weighted average "C" factor (b) / (a) = (c) **0.515**

Part 3: Compute the Total Phosphorus Removal for the Site

Subarea Designation (1)	BMP Type (2)	Removal Eff. (%) (3)		Area Ratio** (4)		"C" Factor Ratio (5)		Product (6)
A_1	Dry Pond	40	X	15/50=0.3	X	0.65/0.515=1.26	=	15.1
A_2	Open Space	100*	X	10/50=0.2	X	1	=	20.0
A_3	Dry Pond	40	X	10/50=0.2	X	0.65/0.515=1.26	=	10.1
A_4	Uncontrolled	-	X	-	X	-	=	0.0
A_5	Open Space	100*	X	3/50=0.06	X	1	=	6.0
A_6	Open Space	100*	X	2/50=0.04	X	1	=	4.0
A_7	Dry Pond	40	X	0.2(15)/50=0.06	X	0.65/0.515=1.26	=	3.0

*** Per Fairfax County PFM**

**** For Offsite Area (A_7) See Instructions on Page 4-23**

(a) Total = **58.2** %

Part 4: Determine Compliance with Phosphorus Removal Requirement

(A) Select Requirement (a) 40%

- Water Supply Overlay District (Occoquan Watershed) = 50% (Fairfax County and Prince William County)
- Chesapeake Bay Preservation Area (New Development) = 40% (Fairfax County) 50% (Prince William County)
- Chesapeake Bay Preservation Area (Redevelopment) = [1-0.9 x (“I”pre / “I”post)] x 100 = __%

(B) If Line 3(a) 58.2% ≥ Line 4(a) 40.0% then Phosphorus removal requirement is satisfied.

NOTE: **Since the "Occoquan Method" of phosphorus removal is being used, proceed to Section IV., Site Coverage.**

IIIb. Phosphorus Removal Calculations - "Chesapeake Bay Method"

This section is for use by jurisdictions which utilize the CBLAD "Chesapeake Bay Method." Please check with the local jurisdiction to determine which method to use. The "Chesapeake Bay Method" used in these calculations is as follows:

$$L = P \times Pj \times \{0.05 + 0.009(I)\} \times C \times A \times 2.72 / 12$$

Where:

L = phosphorus loadings (lbs / yr)

P = average rainfall depth (inches)

P = 40 inches per year for Northern Virginia

Pj = unitless correction factor for storms that produce no runoff

Pj = 0.9

I = the percent of site imperviousness in whole numbers.

C = flow-weighted mean pollutant concentration (mg / l)

C = 0.26 mg / l when I<20%

C = 1.08 mg / l when I>20%

A = area of development site (acres)

NOTE: Section IIIb Phosphorus Removal Calculations replaces Parts 2 Through 4 of Section IIIa.

1) Enter Site Name ____

2) Calculate Existing Site Imperviousness

(A) Pavement Area
(Include roads, driveways, sidewalks, paved trails, etc.) ____________S.F.
(B) Structures Area
(Include houses, sheds, patios, etc.) ____________S.F.
(C) Landscaped Areas
(Include lawns, gardens, unpaved walks or trails, etc.) ____________S.F.
(D) Undisturbed Areas
(Include woods, wetlands, unmaintained or natural areas) ____________S.F.

Total area (E) = ____________S.F.
/ 43,560 = __________acres
Site imperviousness {(A+B)/E} x 100 = _____________%

3) Calculate Proposed Site Imperviousness

(A) Pavement Area
(Include roads, driveways, sidewalks, paved trails, etc.) ____________S.F.
(B) Structures Area
(Include houses, sheds, patios, etc.) ____________S.F.
(C) Landscaped Areas
(Include lawns, gardens, unpaved walks or trails, etc.) ____________S.F.
(D) Undisturbed Areas
(Include woods, wetlands, unmaintained or natural areas) ____________S.F.

Total area (E) = ____________S.F.
/ 43,560 = __________acres
Site imperviousness {(A+B)/E} x 100 = _____________%

4) Site Conditions

(A) Enter Name of Watershed ____

(B) Enter Watershed Imperviousness as a Percentage _______%

(C) Determine Whether Proposal is Considered New Development
or Redevelopment ____

5) Phosphorus Loadings

(A) Existing Phosphorus Loading:

New Development:
L(pre)= 36 x {0.05 + 0.009(Iwshed_______)} x (C)______ x (A)______ x 2.72 / 12

Redevelopment:
L(pre)= 36 x {0.05 + 0.009(Isite/pre_______)} x (C)______ x (A)_____ x 2.72 / 12

L(pre) = _________Lbs/Year

(B) Proposed Phosphorus Loading:

New Development:
L(post) = 36 x {0.05 + 0.009(Isite/post______) x (C)_____ x (A)______ x 2.72 / 12

Redevelopment:
L(post) = 36 x {0.05 + 0.009(Isite/post______) x (C)_____ x (A)______ x 2.72 / 12

L(post)= _________Lbs/Year

6) Phosphorus Removal Required

(A) Phosphorus Removal Required:
New Development
Removal Required = Lpost ________- Lpre________ = ___________Lbs/year

Redevelopment
Removal Required = Lpost ________- 0.9 (Lpre______) = __________Lbs/year

(B) BMP Removal Required:
Removal Required__________ x 100 / Lpost __________= ____________%

7) Phosphorus Removal Satisfaction

(A)

BMP Facility	Removal Eff. (%/100)	x	Imp. Site Coverage (Onsite)		(Offsite)	x	Lpost (lbs/yr)	=	Load Removed (lbs/yr)
________	________		(________	+	________)		________		________
________	________		(________	+	________)		________		________
________	________		(________	+	________)		________		________

Total = ____________

x 100/Lpost = (A) ____________%

(B)

If Line 6(B) _____ < Line 7(A) _____ then phosphorus removal is satisfied.

If Line 6(B) _____ > Line 7(A) _____ then phosphorus removal is not satisfied.

IV. Site Coverage

Part 5: Determine Compliance with Site Coverage Requirement

Sum all the uncontrolled onsite areas and compute a weighted average "C" factor. Do not include qualifying open space.

Subarea Designation (1)	"C" (2)		Acres (3)		Product (4)
________	________	X	________	=	________
A_4 Developed w/o Controls	**0.65**	X	**10**	=	**6.5**
________	________	X	________	=	________
________	________	X	________	=	________
________	________	X	________	=	________

(A) Total equivalent uncontrolled area (a) Total = **6.5**

(B) Total uncontrolled area (b) **10**

(C) Weighted average "C" factor (a)/(b) = (c) **0.65**

(D) If Line 5(b) < 20% of Line 2(a), then the site coverage requirement is satisfied. Line 5(a) is the equivalent offsite area for which coverage may be required.

100 x Line 5(b) **10** / Line 2(a) **50** = (d) **20** %

Part 6: Determine the Offsite Areas for which Coverage is Required

(A) For the offsite areas listed in Part 1 which flow to proposed onsite BMPs compute the equivalent areas.

Subarea Designation (1)	"C" (2)		Acres* (3)		Product (4)
		X		=	
A_7	0.65	X	(0.2)(15)=3	=	1.95
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	

*** See Page 4-23 of Instructions.** (a) Total = **1.95**

If the equivalent offsite area, Line 6(a), draining to all proposed BMP facilities is greater than the equivalent uncontrolled area of the site shown in Line 5(a); then, the offsite area controlled by the proposed BMP facilities may be reduced until the two are equal. Otherwise, all uncontrolled offsite areas draining to the proposed BMP facilities must be included. All offsite areas thus reduced should be marked with an "*" wherever they appear in the computations.

V. Storage

Part 7: Compute The Weighted Average "C" Factor for Each Proposed BMP Facility

(A) List the areas to be controlled by the proposed BMP.

Subarea Designation (1)	"C" (2)		Acres (3)		Product (4)
		X		=	
A_1 Developed with Controls	0.65	X	15	=	9.75
A_2 Open Space "Undisturbed"		X		=	
to Pond	0.20	X	10	=	2.0
A_3 Developed with Controls	0.65	X	10	=	6.5
A_7 Offsite Undeveloped to Pond	0.65	X	(0.2)(15)=3	=	1.95

(a) 38

(B) (b) 20.2

(C) Weighted average "C" factor (b)/(a) = (c) 0.53

Part 8: Determine the Storage Required for Each Proposed Facility

(A) Extended Detention Dry Pond

Chart A6-40 value (Appendix 4-3) for BMP storage per acre
[(4375 x "C") - 875] or [31.25 x %Imp.] = (a) 1,444 cf/ac

• Design 1 (48 hour drawdown)
Line 7(a) 38 x Line 8(a) 1,444 = 54,872 cf

(B) Wet Pond

Volume of runoff per acre from mean storm.
[1452 x "C"] = 1452 x Line 7(c) = (b) ________ cf/ac

• Design 1 (2.5 x Volume of runoff from mean storm event in wet storage with extended detention above the permanent pool)

Wet Storage
2.5 x Line 7(a) ______ x Line 8(b) ______ = ______ cf

Extended Detention
Line 7(a) ______ x Line 8(a) ______ = ______ cf

- Design 2 (4.0 x Volume of runoff from mean storm)
  4.0 x Line 7(a) _______ x Line 8(b) ________ = _________ cf

(C) Infiltration Trench

- Design 1 (0.50 inch per impervious acre)
  0.50 x 36.30 x (% imp.) _____ x Line 7(a) ______ = _______ cf
- Design 2 (1.0 inch per impervious acre)
  1.0 x 36.30 x (% imp.) _____ x Line 7(a) _______ = _______ cf
- Design 3 (2-year 2-hour storm)
  (2.0/12) x 43,560 x "C" _____ x Line 7(a) ______ = _______ cf

VI. Outlet Computation

Part 9: Determine The Required Orifice Size for Each Extended Detention Facility

(A) BMP storage requirement (S) from Part 8. (a) **54,872 cf**

(B) Maximum Head (h) at the required BMP storage from the elevation-storage curve for the facility. (b) **5 ft**

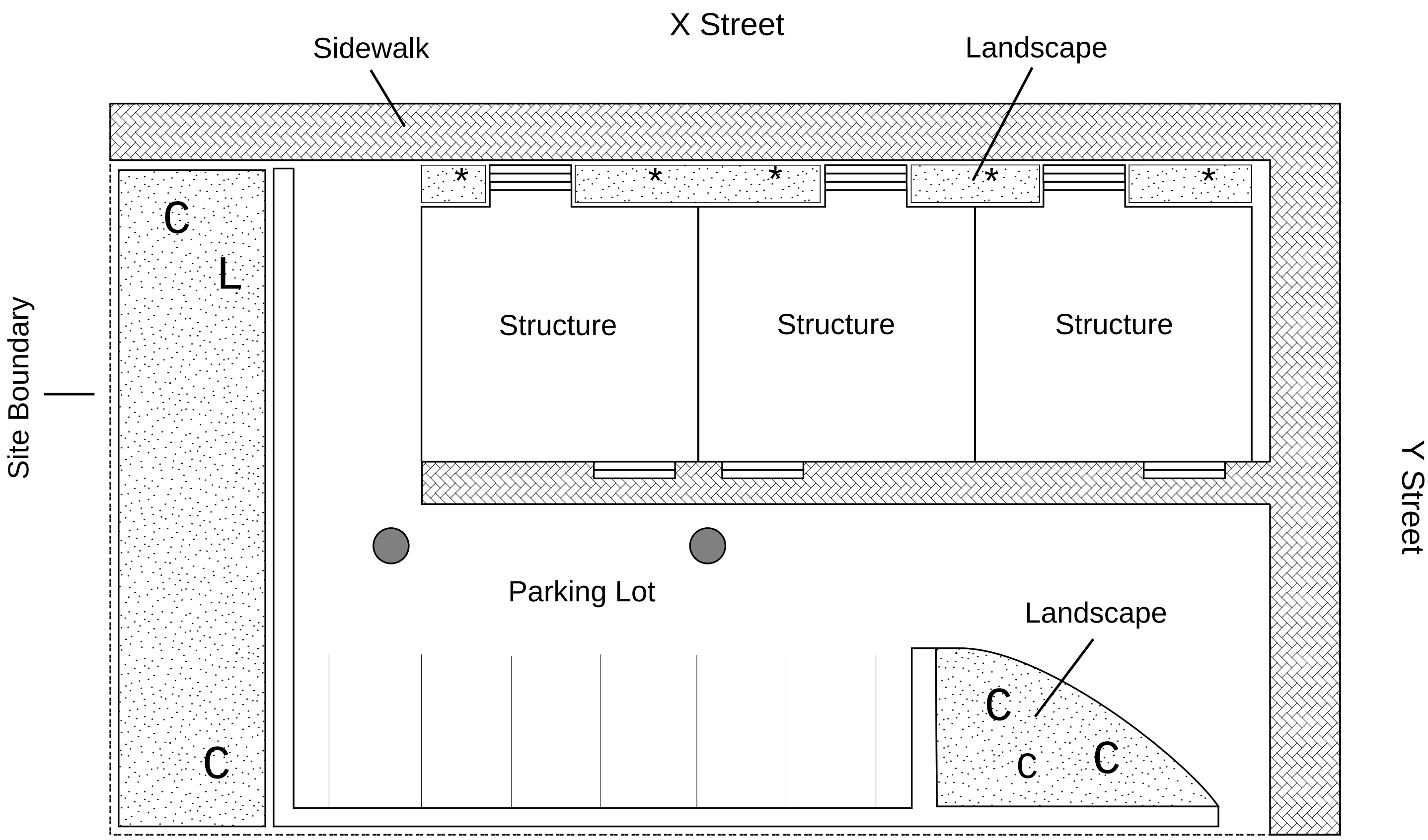
(C) Peak outflow rate (Q_p) at the maximum head for a drawdown time of 48 hrs [$Q_p = S/(0.5 \times 3600 \times 48)$].
0.0000116 x Line 9(a) **54,872** = (c) **0.6365**

(D) Required orifice area (A) [$A = Q_p / (0.6 \times (64.4 \times h)^{0.5})$]
Line 9(c) **0.6365** / [0.6 x (64.4 x Line 9(b) **5** $)^{0.5}$] = (d) **0.0591 sf**

(E) Diameter of a circular orifice.
2.0 x (Line 9(d) **0.0591** / 3.1415927$)^{0.5}$ = (e) **= 0.274'**
= 3.29"
Use 3.25"
Dia. Orifice

POST-DEVELOPMENT SITE PLAN FOR EXAMPLE #4 (New Development) and EXAMPLE #5 (Redevelopment)

"Chesapeake Bay Method" Phosphorus Removal Calculations Only



Example #4 and Example #5 demonstrate the "Chesapeake Bay Method" of calculating phosphorus removal for the same site assuming different pre-development conditions. Example #4 will demonstrate the phosphorus removal calculations required for new development while Example #5 will demonstrate the phosphorus removal calculations required for redevelopment.

Post Development Conditions for Both Examples #4 and #5

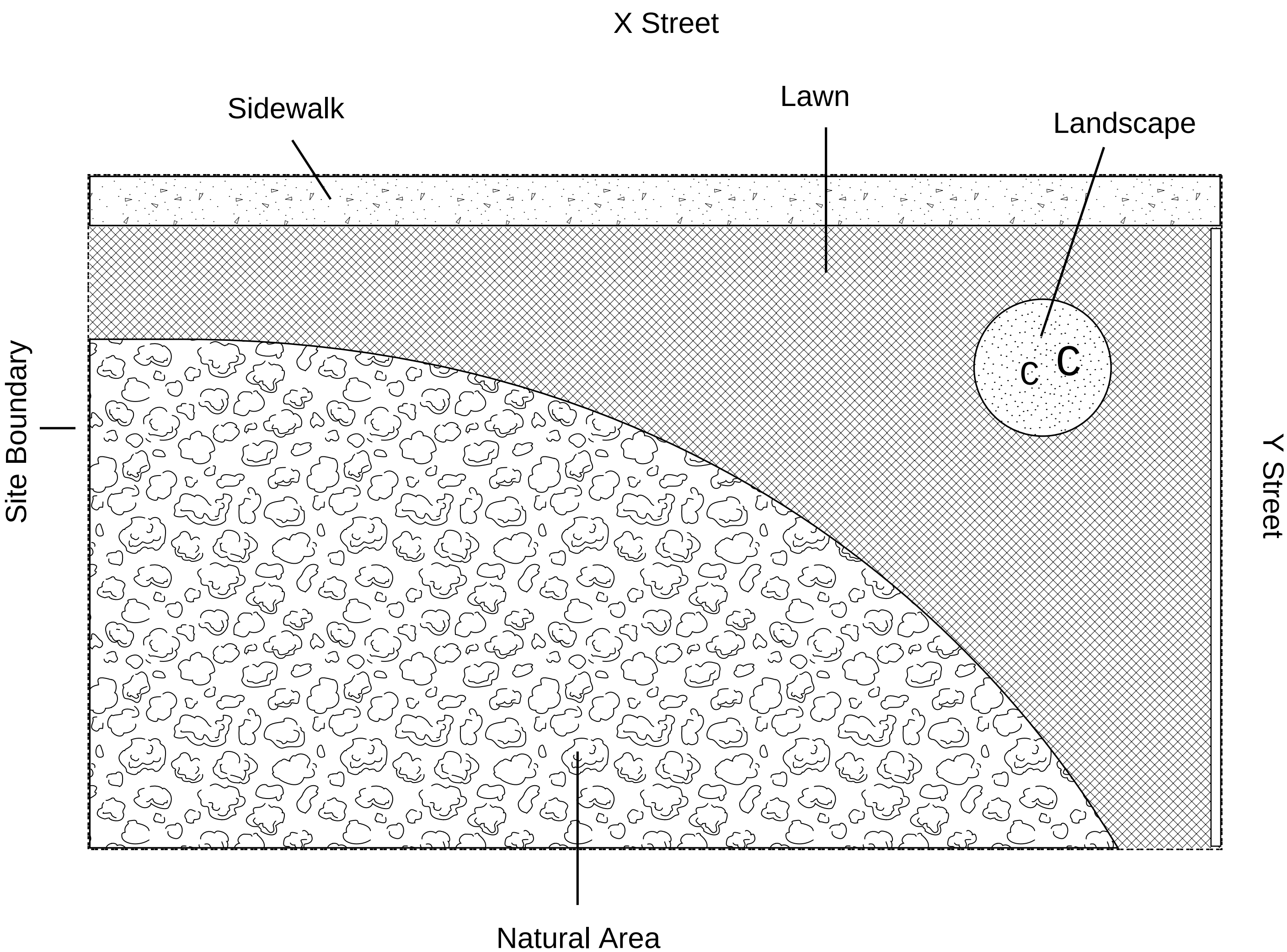
Parking Lot	5,183.64 S.F.
Brick Walkways	1,742.4 S.F.
Structures	3,702.6 S.F.
Landscape	2,439.36 S.F.

TOTAL SITE AREA = 0.3 ACRES

EXAMPLE #4

"Chesapeake Bay Method" for New Development

(Use Same Post-Development Site Plan for both Example #4 and Example #5)



New Development: Pre-existing Conditions for Example #4

Concrete Walkway	653.4 S.F.
Lawn and Landscape	5,711.04 S.F.
Natural Area	6,703.56 S.F.

TOTAL SITE AREA = 0.3 ACRES

IIIb. Phosphorus Removal Calculations - "Chesapeake Bay Method"

This section is for use by jurisdictions which utilize the CBLAD "Chesapeake Bay Method." Please check with the local jurisdiction to determine which method to use. The "Chesapeake Bay Method" used in these calculations is as follows:

$$L = P \times Pj \times \{0.05 + 0.009(I)\} \times C \times A \times 2.72 / 12$$

Where:

L = phosphorus loadings (lbs / yr)

P = average rainfall depth (inches)

P = 40 inches per year for Northern Virginia

Pj = unitless correction factor for storms that produce no runoff

Pj = 0.9

I = the percent of site imperviousness in whole numbers.

C = flow-weighted mean pollutant concentration (mg / l)

C = 0.26 mg / l when I<20%

C = 1.08 mg / l when I>20%

A = area of development site (acres)

NOTE: **Section IIIb Phosphorus Removal Calculations replaces Parts 2 Through 4 of Section IIIa.**

1) Enter Site Name **Example #4 - New Development**

2) Calculate Existing Site Imperviousness

(A) Pavement Area
(Include roads, driveways, sidewalks, paved trails, etc.) **653.40** S.F.

(B) Structures Area
(Include houses, sheds, patios, etc.) ________ S.F.

(C) Landscaped Areas
(Include lawns, gardens, unpaved walks or trails, etc.) **5,711.04** S.F.

(D) Undisturbed Areas
(Include woods, wetlands, unmaintained or natural areas) **6,703.56** S.F.

Total area (E) = **13,068.00** S.F.

/ 43,560 = **0.30** acres

Site imperviousness {(A+B)/E} x 100 = **5.00** %

3) Calculate Proposed Site Imperviousness

(A) Pavement Area
(Include roads, driveways, sidewalks, paved trails, etc.) **6,926.04** S.F.

(B) Structures Area
(Include houses, sheds, patios, etc.) **3,702.60** S.F.

(C) Landscaped Areas
(Include lawns, gardens, unpaved walks or trails, etc.) **2,439.36** S.F.

(D) Undisturbed Areas
(Include woods, wetlands, unmaintained or natural areas) ________ S.F.

Total area (E) = **13,068.00** S.F.
/ 43,560 = **0.30** acres
Site imperviousness {(A+B)/E} x 100 = **81.33** %

4) Site Conditions

(A) Enter Name of Watershed **Arlington County**

(B) Enter Watershed Imperviousness as a Percentage **38** %

(C) Determine Whether Proposal is Considered New Development or Redevelopment **New Development**

5) Phosphorus Loadings

(A) Existing Phosphorus Loading:

New Development:
L(pre)= 36 x {0.05 + 0.009(Iwshed **38**)} x (C) **1.08** x (A) **0.30** x 2.72 / 12

Redevelopment:
L(pre)= 36 x {0.05 + 0.009(Isite/pre ________)} x (C) ______ x (A) _____ x 2.72 / 12

L(pre) = **1.04** Lbs/Year

(B) Proposed Phosphorus Loading:

New Development:
L(post) = 36 x {0.05 + 0.009(Isite/post **81.33**) x (C) **1.08** x (A) **0.30** x 2.72 / 12

Redevelopment:
L(post) = 36 x {0.05 + 0.009(Isite/post ______) x (C) _____ x (A) ______ x 2.72 / 12

L(post)= **2.07** Lbs/Year

6) Phosphorus Removal Required

(A) Phosphorus Removal Required:
New Development
Removal Required = Lpost **2.07** - Lpre **1.04** = **1.03** Lbs/year

Redevelopment
Removal Required = Lpost ________ - 0.9 (Lpre ______) = __________ Lbs/year

(B) BMP Removal Required:
Removal Required **1.03** x 100 / Lpost **2.07** = **49.76** %

7) Phosphorus Removal Satisfaction
(A)

BMP Facility	Removal Eff. (%/100)	x	Imp. Site Coverage (Onsite)		(Offsite)	x	Lpost (lbs/yr)	=	Load Removed (lbs/yr)
Inf. Trench	**0.50**		(**1.00**	+	)		**2.07**		**1.035**
			(	+	)				
			(	+	)				

Total = **1.035**

x 100/Lpost = (A) **50.00** %

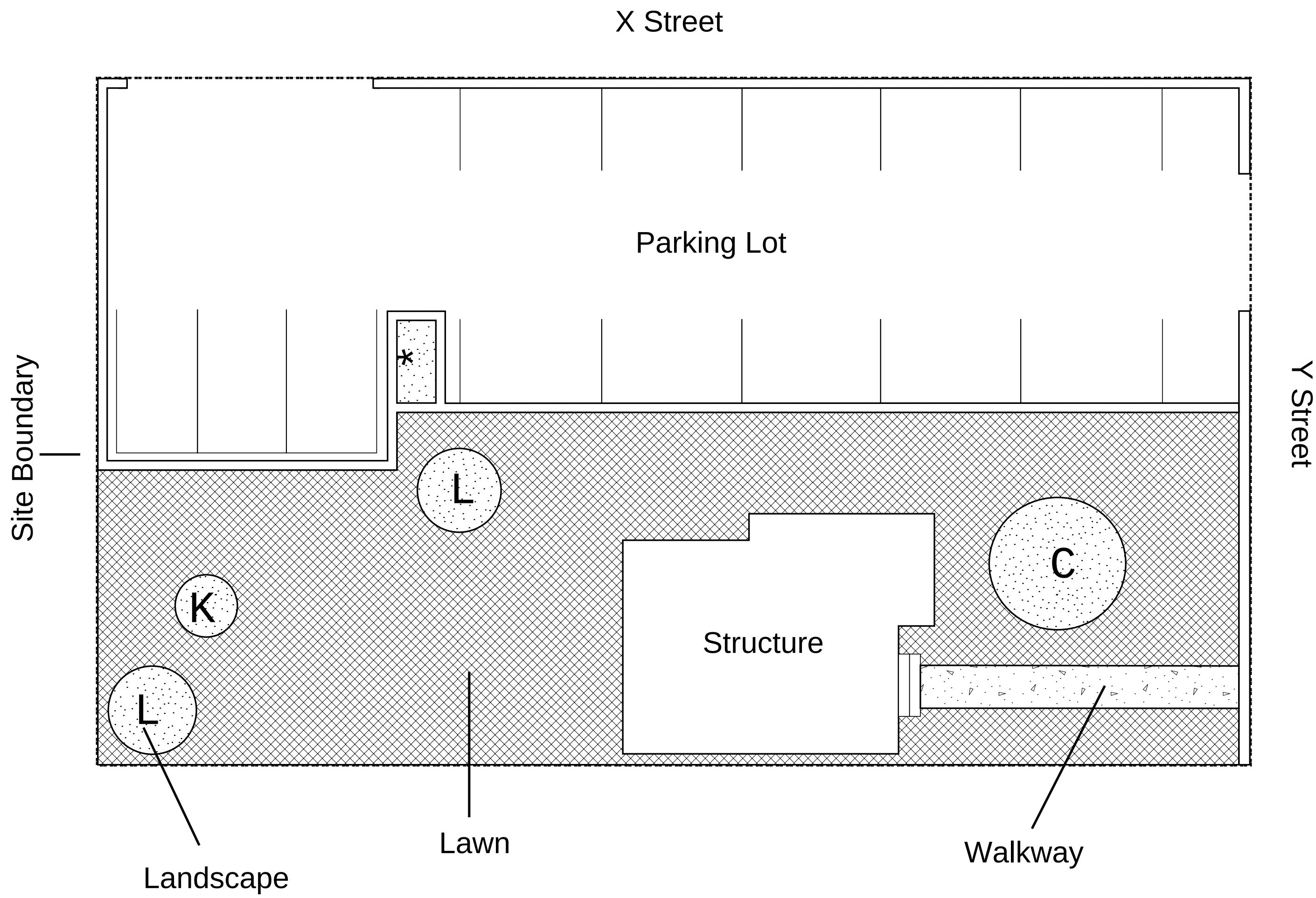
(B)

If Line 6(B) **49.76** < Line 7(A) **50.00** then phosphorus removal is satisfied.

If Line 6(B) _____ > Line 7(A) _____ then phosphorus removal is not satisfied.

EXAMPLE #5

"Chesapeake Bay Method" for Redevelopment
(Use Same Post-Development Site Plan for both Example #4 and Example #5)



Redevelopment: Pre-existing Conditions for Example #5

Parking Lot .... 6,969.6 S.F.
Concrete Walkway .... 217.8 S.F.
Structure.......... 1,089 S.F.
Lawn and Landscape .... 4,791.6 S.F.

TOTAL SITE AREA = 0.3 ACRES

IIIb. Phosphorus Removal Calculations - "Chesapeake Bay Method"

This section is for use by jurisdictions which utilize the CBLAD "Chesapeake Bay Method." Please check with the local jurisdiction to determine which method to use. The "Chesapeake Bay Method" used in these calculations is as follows:

L = P x Pj x {0.05 + 0.009(I)} x C x A x 2.72 / 12

Where:

L = phosphorus loadings (lbs / yr)
P = average rainfall depth (inches)
  P = 40 inches per year for Northern Virginia
Pj = unitless correction factor for storms that produce no runoff
  Pj = 0.9
I = the percent of site imperviousness in whole numbers.
C = flow-weighted mean pollutant concentration (mg / l)
  C = 0.26 mg / l when I<20%
  C = 1.08 mg / l when I>20%
A = area of development site (acres)

NOTE: **Section IIIb Phosphorus Removal Calculations replaces Parts 2 Through 4 of Section IIIa.**

1) Enter Site Name ____**Example #5 - Redevelopment**____

2) Calculate Existing Site Imperviousness

(A) Pavement Area
(Include roads, driveways, sidewalks, paved trails, etc.) **7,187.40** S.F.

(B) Structures Area
(Include houses, sheds, patios, etc.) **1,089.00** S.F.

(C) Landscaped Areas
(Include lawns, gardens, unpaved walks or trails, etc.) **4,791.60** S.F.

(D) Undisturbed Areas
(Include woods, wetlands, unmaintained or natural areas) ________ S.F.

Total area (E) = **13,068.00** S.F.

/ 43,560 = **0.30** acres

Site imperviousness {(A+B)/E} x 100 = **63.33** %

3) Calculate Proposed Site Imperviousness

(A) Pavement Area
(Include roads, driveways, sidewalks, paved trails, etc.) **6,926.04** S.F.

(B) Structures Area
(Include houses, sheds, patios, etc.) **3,702.60** S.F.

(C) Landscaped Areas
(Include lawns, gardens, unpaved walks or trails, etc.) **2,439.36** S.F.

(D) Undisturbed Areas
(Include woods, wetlands, unmaintained or natural areas) ______ S.F.

Total area (E) = **13,068.00** S.F.
/ 43,560 = **0.30** acres
Site imperviousness {(A+B)/E} x 100 = **81.33** %

4) Site Conditions

(A) Enter Name of Watershed **Arlington County**

(B) Enter Watershed Imperviousness as a Percentage **38** %

(C) Determine Whether Proposal is Considered New Development or Redevelopment **Redevelopment**

5) Phosphorus Loadings

(A) Existing Phosphorus Loading:

New Development:
L(pre)= 36 x {0.05 + 0.009(Iwshed______)} x (C)______ x (A)______ x 2.72 / 12

Redevelopment:
L(pre)= 36 x {0.05 + 0.009(Isite/pre **63.33**)} x (C) **1.08** x (A) **0.30** x 2.72 / 12

L(pre) = **1.64** Lbs/Year

(B) Proposed Phosphorus Loading:

New Development:

L(post) = 36 x {0.05 + 0.009(Isite/post______) x (C)_____ x (A)______ x 2.72 / 12

Redevelopment:

L(post) = 36 x {0.05 + 0.009(Isite/post **81.33**) x (C) **1.08** x (A) **0.30** x 2.72 / 12

L(post)= **2.07** Lbs/Year

6) Phosphorus Removal Required

(A) Phosphorus Removal Required:

New Development

Removal Required = Lpost ________- Lpre________ = ___________Lbs/year

Redevelopment

Removal Required = Lpost **2.07** - 0.9 (Lpre **1.64**) = **0.59** Lbs/year

(B) BMP Removal Required:

Removal Required **0.59** x 100 / Lpost **2.07** = **28.50** %

7) Phosphorus Removal Satisfaction

(A)

BMP Facility	Removal Eff. (%/100)	x	Imp. Site Coverage (Onsite)	(Offsite)	x	Lpost (lbs/yr)	=	Load Removed (lbs/yr)
Inf. Trench	0.50		(1.00 +	)		2.07		1.035
			(+	)				
			(+	)				
							Total =	1.035

x 100/Lpost = (A) **50.00** %

(B)

If Line 6(B) **28.50** < Line 7(A) **50.00** then phosphorus removal is satisfied.

If Line 6(B) _____ > Line 7(A) _____ then phosphorus removal is not satisfied.

APPENDIX 5

Appendix 5-1 .... Soil Permeability Estimates Based on Soil Texture

Appendix 5-2 .... Guide for Predicting the Class of Saturated Vertical Hydraulic Conductivity from Soil Properties

Appendix 5-3 .... Example of a Schematic Cross Section Based Upon Four Sample Points

Appendix 5-4 .... VDOT Coarse Aggregate Standards

Appendix 5-5 .... Cross Section Through a Dry Well

Appendix 5-6 .... Modular Pavement

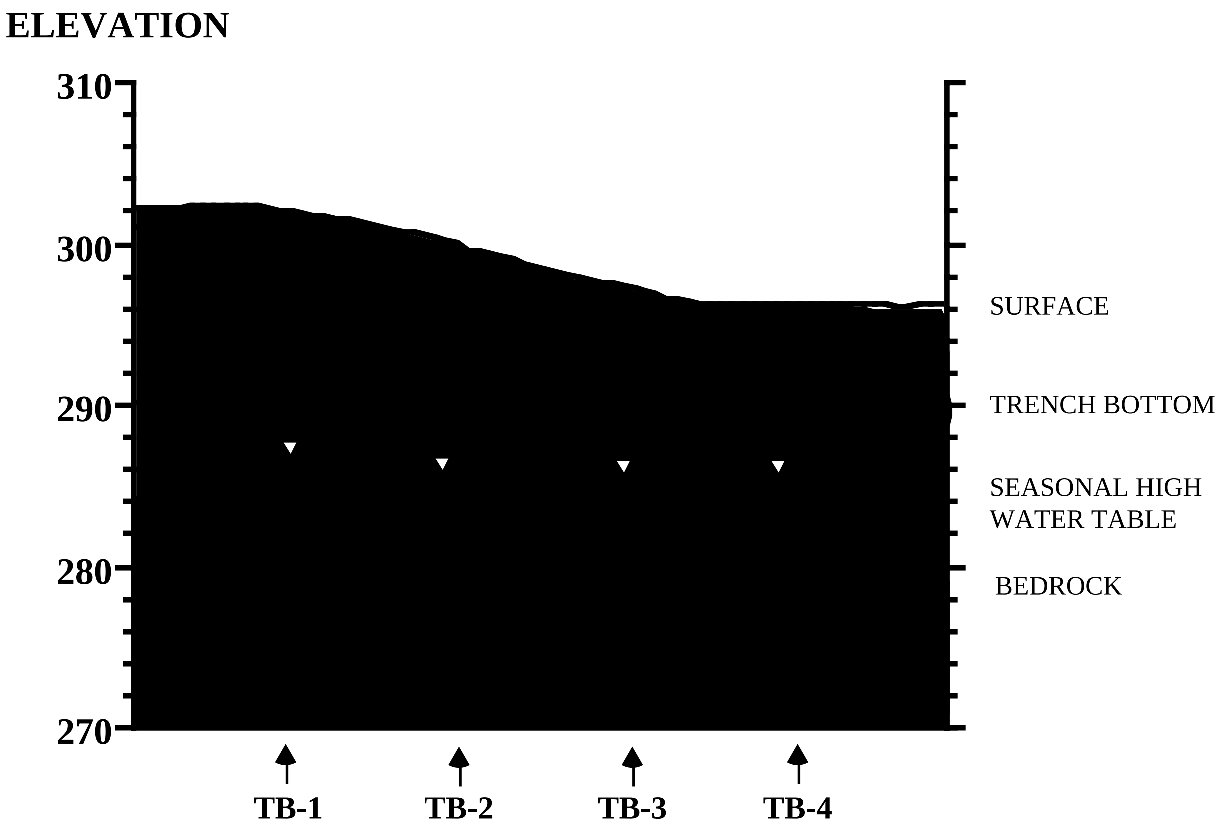
TEXTURE	ESTIMATED PERMEABILITY (IN/HR)
Sand	8.27
Loamy Sand	2.41
Sandy Loam	1.02
Loam	0.52
Silt Loam	0.27
Sandy Clay Loam	0.17
Clay Loam	0.09
Silty Clay Loam	0.06
Sandy Clay	0.05
Silty Clay	0.04
Clay	0.02

Soil Permeability Estimates Based on Soil Texture
(Source: Rawls, Brakensiek, and Saxton, 1982)

CLASS	RATE (in/hr)	SOIL PROPERTIES
Very High	> 14	• Fragmental. • Sandy with coarse sand or sand texture and loose consistence. • More than 0.5 percent medium or coarser vertical pores with high continuity.
High	14 - 1.4	• Other sandy, sandy skeletal, or coarse-loamy soil materials that are very friable, friable, soft, or loose. • When very moist or wet has moderate or strong granular structure, or, strong blocky structure of any size or prismatic finer than very coarse and many features except stress surfaces or slickensides on vertical surfaces of structural units. • 0.5 to 0.2 percent medium or coarser vertical pores with high continuity.
Moderate	1.4 - 0.14	• Sandy in other consistence classes except extremely firm or cemented. • 18 to 35 percent clay with moderate structure except platy or with strong very coarse prismatic and with common surface features except stress surfaces or slickensides on vertical surfaces of structural units. • 0.1 to 0.2 percent medium or coarser vertical pores with high continuity.
Moderately Low	0.14 - 0.01	• Other sandy classes that are extremely firm or cemented. • 18 to 35 percent clay with other structures and surface conditions except pressure or stress surfaces. • > 35 percent clay and moderate structure except if platy or very coarse prismatic and with common vertical surface features except stress surfaces or slickensides. • Medium or coarser vertical pores with high continuity percent but < 0.1 percent.
Low	0.01 - 0.001	• Continuous moderate or weak cementation > 35 percent clay and meets one of the following: weak structure; weak structure with few or no vertical surface features; platy structure; common or many stress surfaces or slickensides.
Very Low	< 0.001	• Continuously indurated or strongly cemented and less than common roots. • > 35 percent clay and massive or exhibits horizontal depositional strata and less than common roots.

Guide for Predicting the Class of Saturated Vertical Hydraulic Conductivity from Soil Properties

(Source: National Soils Handbook, USDA Soil Conservation Service, 1983)



Horizontal Scale = 1":30' (#) = Permeability Test as in/hr TB = Test Boring Location

Example of a Schematic Cross Section Based Upon Four Sample Points
(Source: Fairfax County Soils Science Office, 1992)

Virginia Department of Transportation (VDOT) Coarse Aggregate Standards

(Source: Virginia Department of Transportation Drainage Manual: March, 1986)

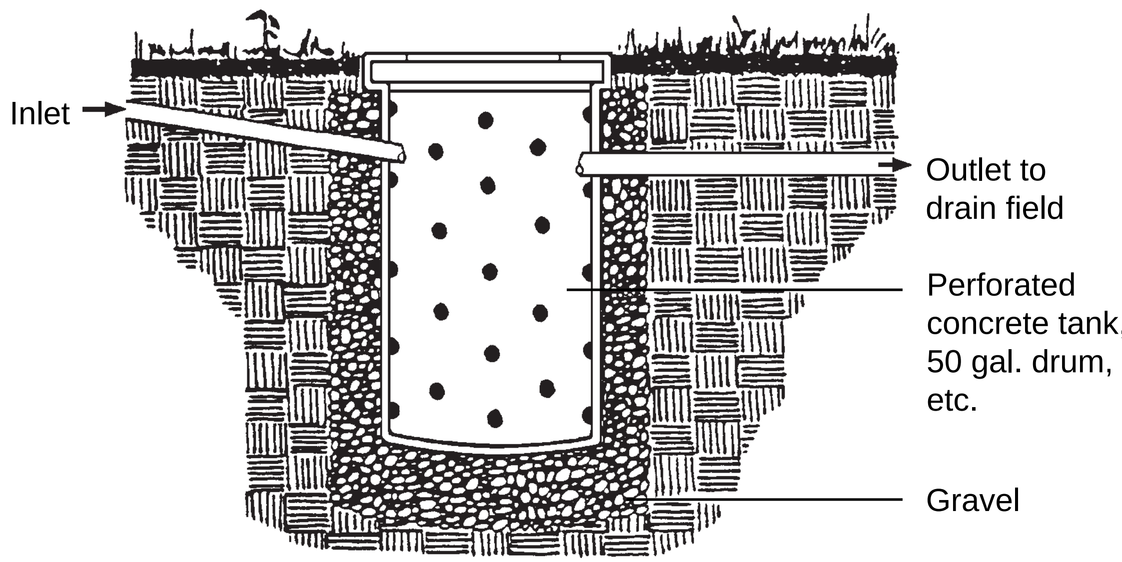
NOTE: The common unit of measurement for stone is the Mean Spherical Diameter (MSD). This indicates a piece of spherically shaped stone which weighs the same as a stone of some other shape.

If a gradation or sieve analysis were run on a batch of stone, it would be found that a certain quantity of material would be retained on the largest sieve. The remainder of the material would pass through to the next largest sieve where some of it would be retained. If this procedure were repeated using successively smaller sieves, a gradation or rating curve could be developed for the entire batch of rock material. The MSD of the material retained on a given sieve indicates by its plotted position on the gradation curve that a percentage of the sample is smaller. For example, if a six inch MSD particle plots at the 67% point on a gradation curve, it indicates that 67% of the total sample is smaller than six inches MSD. The standard designation would be to label this size particle as D_{67}.

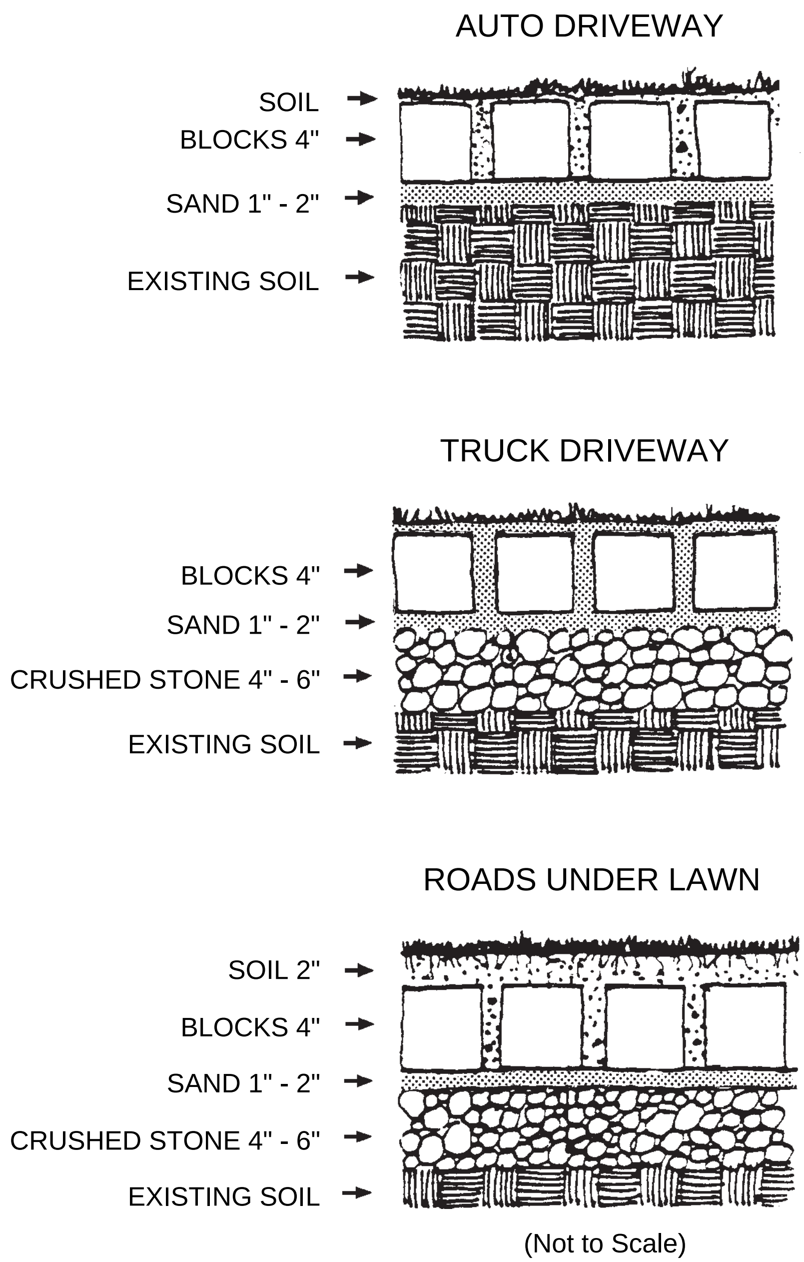
Appendix 5-4 presents the VDOT coarse aggregate standards. As noted, VDOT #56, 57, and 357 are considered acceptable for use in infiltration trenches. The designer of the BMP facility should refer to the Virginia Department of Transportation's most recent Drainage Manual for further information.

VDOT Standard Aggregate Sizes

Course Agg#	D_{15} Particle Size	D_{50} Particle Size	D_{85} Particle Size
VDOT Standards	MM	MM	MM
1	37.5	63	90
2	19	37.5	63
3	19	25	37.5
357	12.5	19	25.0
5	12.5	19	25.0
56	9.5	17	25.0
57	4.8	12.5	25.0
68	4.8	9.5	19.0
7	4.8	8	12.5
78	4.8	8	12.5
8	4.8	7.3	9.5
9	2.4	3.6	4.8
10	0.15	0.9	4.8



Cross Section Through a Dry Well
(Source: Day and Crafton, 1978)



Modular Pavement
(Source: Tourbier, 1981)

APPENDIX 6

Appendix 6-1 .... Contact Points for the Offsite Disposal of Dredged Material

Appendix 6-2 .... Sample BMP Maintenance Agreement

Appendix 6-3 .... BMP Maintenance Responsibility Guidelines

Appendix 6-4 .... Sample BMP Operation and Maintenance Inspection Report

JURISDICTION	DEPARTMENT	PHONE NUMBER
City of Alexandria	See Fairfax County	
Arlington County	See Fairfax County	
Town of Dumfries	See Prince William County	
City of Fairfax	See Fairfax County	
Fairfax County[1]	Department of Waste Management I-95 Sanitary Landfill 9850 Furnace Road Lorton, Virginia 22079	690-1703
City of Falls Church	See Fairfax County	
Town of Herndon	See Fairfax County	
Town of Leesburg	See Loudoun County	
Loudoun County[2]	Loudoun County Sanitary Landfill Route 621 (South of Leesburg) Department of General Services 750 Miller Drive Leesburg, Virginia 22075	777-8418
City of Manassas	See Prince William County	
City of Manassas Park	See Prince William County	
Prince William County[3]	Prince William County Sanitary Landfill 14811 Dumfries Road Manassas, Virginia 22111	792-6468
Town of Vienna	See Fairfax County	

1 No contaminated soil is accepted at this landfill. On occasion, clean fill dirt is accepted if it is needed for the daily cover. The superintendent must be contacted to see if fill dirt is needed. The sediment must pass an EP Toxicity Test before being accepted. Further, the sediment must be de-watered before it can be accepted.

2 Dredged material is accepted at this landfill. If the material is from an industrial site, an EP Toxicity Test is required. The test is not required for materials generated from other land uses. It is preferred that the material be dry, however, it can be held onsite for 30 to 60 days to allow de-watering.

3 Dredged sediment can be accepted at this landfill if it passes an EP Toxicity Test and it is de-watered. Sometimes a special arrangement may be set up to let the sediment dry at the landfill if it is not de-watered when deposited. An extra handling charge would apply in this case.

EP = Extraction Procedure

Contact Points for the Offsite Disposal of Dredged Material

Sample BMP Maintenance Agreement

THIS AGREEMENT, made and entered into this _______ day of ____________, 19 ___, by and between _________________________ (inset full name of owner) hereinafter called the "Landowner," and the _________________________ (elected governing body) hereinafter called the "County";

WITNESSETH, that

WHEREAS, the Landowner is the owner of certain real property, more particularly described as:

____

____

as recorded by deed in the land records of ______________________ (insert location), Virginia, in Deed Book ____________ at Page _____, hereinafter called the "Property"; and

WHEREAS, the Landowner is proceeding to build on and develop the Property; and

WHEREAS, Site Plan/Subdivision Plan _____________________________ hereinafter call the "Plan," which is expressly made part hereof, as approved or to be approved by the County, provides for BMPs within the confines of the property; and

WHEREAS, the County and the Landowner agree that the health, safety, and welfare of the residents of ____________________, Virginia, require/recommend that onsite Best Management Practices be constructed and maintained on the property; and

WHEREAS, the County requires that onsite Best Management Practice facilities as shown on the Plan be constructed and adequately maintained by the Landowner;

NOW, THEREFORE, in consideration of the foregoing premises, the mutual covenants contained herein, and the following terms and conditions, the parties hereto agree as follows;

1. The onsite BMP facility shall be constructed by the Landowner in accordance with the plans and specifications identified in the Plan.

2. The Landowner shall maintain the BMP facilities as shown on the Plan in good working order acceptable to the County and in accordance with the specific maintenance requirements noted on the Plan and attached hereto as Attachment A.

3. The Landowner hereby grants permission to the County, its authorized agents and employees, to enter upon the Property and to inspect the BMP facilities whenever it deems necessary. Whenever possible, the County shall notify the Landowner prior to entering the Property.

4. In the event the Landowner fails to maintain the BMP facilities as shown on the Plan in good working order acceptable to the County, the County may enter upon the Property and take whatever steps it deems necessary to maintain said BMP facilities. This provision shall not be construed to allow the County to erect any structure of a permanent nature on the land of the Landowner. It is expressly understood and agreed that the County is under no obligation to maintain or repair said facilities, and in no event shall this Agreement be construed to impose any such obligation on the County.

5. In the event the County, pursuant to this Agreement, performs work of any nature, or expends and funds in performance of said work for labor, use of equipment, supplies, materials, and the like, the Landowner shall reimburse the County upon demand, within ten (10) days of receipt thereof for all costs incurred by the County hereunder.

6. It is the intent of this Agreement to insure the proper maintenance of onsite BMP facilities by the Landowner; provided, however, that this Agreement shall not be deemed to create or effect any additional liability of any party for damage alleged to result from or be caused by non-point source pollution runoff.

7. The Landowner, its executors, administrator, assigns, and any other successors in interest, shall indemnify and hold harmless the County and its agents and employees for any and all damages, accidents, casualties, occurrences or claims which might arise or be asserted against the County from the construction, presence, existence or maintenance of the BMP facilities by the Landowner or the County.

In event a claim is asserted against the County, its agents or employees, the County shall promptly notify the Landowner and the Landowner shall defend at his own expense any suit based on such claim. If any judgment or claims against the County, its agents or employees shall be allowed, the Landowner shall pay all costs and expenses in connection herewith.

8. This Agreement shall be recorded among the land records of _________________ (insert location), Virginia, and shall constitute a covenant running with the land, and shall be binding on the Landowner, its administrators, executors, assigns, heirs and any other successors in interest.

WITNESS the following signatures and seals:

____
Landowner (Seal)

By: _______________________________________

ATTEST:

____
Type Name

___________________________ Its: _______________________________________
Type Title

____
Landowner (Seal)

By: _______________________________________

ATTEST:

____
Type Name

___________________________ Its: _______________________________________
Type Title

BMP Maintenance Responsibility Guidelines

(Adapted from NVPDC, 1992a)

JURISDICTION	MAINTENANCE RESPONSIBILITY GUIDELINES
City of Alexandria	It is the policy of the City that all stormwater quality management BMPs and all stormwater detention facilities be maintained by the owner. Maintenance agreements are therefore required in all cases where the owner is other than the City. Approval of the use of unconventional BMPs discussed in Chapter 2 of the Alexandria Supplement to the Northern Virginia BMP Handbook is conditioned by the requirement that the developer agree to participate with the City and the Northern Virginia Planning District Commission (NVPDC) in a program of monitoring to establish the actual pollutant removal efficiency of the BMP. The approval of other experimental BMPs for which criteria is not provided will be conditioned on the developer agreeing to monitor the BMP at the developer's expense to establish the actual pollutant removal efficiency. A clause setting forth such agreements will be included in the maintenance agreement for unconventional and experimental BMPs.
Arlington County	All stormwater management and BMP facilities are to be maintained by private property owners. A maintenance schedule should be part of the BMP plan. A maintenance agreement which specifies the frequency of maintenance and which alerts the County of such maintenance activities is required.
Fairfax County	Facilities serving commercial, industrial, and rental residential developments are maintained by the owner. Generally, the County maintains BMPs in storm drainage easements in residential developments, except for wet ponds which are always the responsibility of the owners. The County requires a maintenance agreement and inspects private ponds on a annual basis to ensure that proper maintenance is being performed on these facilities.
Loudoun County	Maintenance of BMP facilities is the responsibility of the facility owner. While the County does not require a maintenance agreement at the present time, their inclusion in BMP plans is encouraged.

Prince William County

The owners of commercial, industrial, and multi-family rental developments are responsible for maintenance of BMP facilities. For townhouse and condominium developments, and single-family developments, the County is responsible for inspections and maintenance of BMP facilities. However, the County does not maintain facilities that are under pavement or that have permanent pools. Regional BMP facilities are maintained by the Department of Public Works. The County keeps an inventory of publicly maintained BMP facilities and makes semi-annual inspections and performs the required maintenance. The County requires a maintenance agreement and a yearly inspection report on new commercial and industrial facilities. The County requires stormwater management easements around all BMP/stormwater management facilities.

Sample BMP Operation and Maintenance Inspection Report

(Source: Anne Arundel County, Maryland, 1989)

Inspector Name ______________________ Community ______________________

Inspection Date ______________________ Address ______________________

Type of BMP ______________________ ______________________

Watershed ______________________ Tax Map ______________________

ITEM INSPECTED	CHECKED Yes	No	MAINTENANCE Reqd.	Not Reqd.	OBSERVATIONS & REMARKS
I. POND FACILITIES A. Pond Dam Embankments and Emergency Spillway					
1. Vegetation and Ground Cover Adequate					
2. Surface Erosion					
3. Animal Burrows					
4. Unauthorized Planting					
5. Cracking, Bulging, or Sliding of Dam					
a. Upstream Face					
b. Downstream Face					
c. At or Beyond Toe					
Upstream					
Downstream					
d. Emergency Spillway					
6. Pond, Toe & Chimney Drains Clear &Funct.					
7. Seeps/Leaks on Downstream Face					
8. Slope Protection or Rip Rap Failures					

ITEM INSPECTED	CHECKED Yes	No	MAINTENANCE Reqd.	Not Reqd.	OBSERVATIONS & REMARKS
9. Vertical and Horizontal Alignment of Top of Dam as Per "As-Built" Plans					
10. Emergency Spillway Clear of Obstructions and Debris					
11. Other (Specify)					
B. Riser and Principal Spillway Type: Reinforced Concrete ___ Corrugated Pipe ___ Masonry ___ * Indicates Dry Ponds Only 1.* Low Flow Orifice Obstructed					
2.* Low Flow Trash Rack					
a. Debris Removal Necessary b. Corrosion Control					
3. Weir Trash Rack Maintenance					
a. Debris Removal Necessary					
b. Corrosion Control					
4. Excessive Sediment Accumulation Inside Riser					
5. Concrete/Masonry Condition Riser & Barrels					
a. Cracks or Displacement					
b. Minor Spalling (<1")					
c. Major Spalling (Rebars Exposed)					
d. Joint Failures					
e. Water Tightness					
6. Metal Pipe Condition					

ITEM INSPECTED	CHECKED Yes	No	MAINTENANCE Reqd.	Not Reqd.	OBSERVATIONS & REMARKS
7. Control Valve					
a. Operational/Exercised					
b. Chained and Locked					
8. Pond Drain Valve					
a. Operational/Exercised					
b. Chained and Locked					
9. Outfall Channels Functioning					
10. Other (Specify)					
C. Permanent Pool - Wet Ponds					
1. Undesirable Vegetative Growth					
2. Floating or Floatable Debris Removal Required					
3. Visible Pollution					
4. Shoreline Problems					
5. Other (Specify)					
D. Dry Pool Areas - Dry Pond					
1. Vegetation Adequate					
2. Undesirable Vegetative Growth					
3. Undesirable Woody Growth					
4. Low Flow Channels Clear of Obstructions					
5. Standing Water or Wet Spots					
6. Sediment and/or Trash Accumulation					
7. Other (Specify)					

ITEM INSPECTED	CHECKED Yes	No	MAINTENANCE Reqd.	Not Reqd.	OBSERVATIONS & REMARKS
E. Condition of Outfalls into Pond Area					
1. Rip Rap Failures					
2. Slope Invert Erosion					
3. Storm Drain Pipes					
4. Endwalls/Headwalls					
5. Other (Specify)					
F. Other					
1. Encroachments on Pond or Easement Area (Be Specific)					
2. Complaints from Local Residents (Describe on Back)			N/A	N/A	
3. Aesthetics					
a. Grass Mowing Reqd.					
b. Graffiti Removal Reqd.					
c. Other					
4. Public Hazards (Be Specific)					
5. Maintenance Access					

II. SUMMARY

1. Inspector's Remarks: ____

____
____
____
____
____
____

2. Overall Condition of Facility (Check One)

Acceptable ____________
Unacceptable ____________

APPENDIX 7

Appendix 7-1 .... Soil Support Categories

Appendix 7-2 .... Unified Soil Classification System

Appendix 7-3 .... AASHO Soil Groups

Appendix 7-4 .... Open Graded Asphalt Concrete Formulation

Appendix 7-5 .... Effective Buffer Length Determination for Sediment Trap Efficiencies

Appendix 7-6 .... Maryland Summary of Shallow Wetland Planning Criteria

GENERAL SOIL DESCRIPTION		STRENGTH CBR
Excellent		
Containing a uniformly high percentage of granular materials.		15 plus
Unified Soil Classes*	GW, GM, GC, GP, some SM, SP, and SC	
AASHO Soil Groups**	A-1, A-2, some A-3s	
Good		
Containing some granular materials intermixed with silt and/or light clay.		10 - 14
Unified Soil Classes	SM, SP, SC, some ML, CL, CH	
AASHO Soil Groups	A-2, A-3, some A-4s, a few A-6s or A-7s	
Fair		
Sand clays, sandy silts, or lightly silty clays if low in mica content; may have some plasticity.		6 - 9
Unified Soil Classes	ML, CL, some MH, and CH	
AASHO Soil Groups	Ranging from A-4 to A-7 (low group indices)	
Poor		
Plastic clays, fine silts, or very fine or micaceous silty clays.		5 or less
Unified Soil Classes	MH, CH, OL, OH; (PT unsuitable)	
AASHO Soil Groups	Ranging from A-4 to A-7 (higher group indices)	

*See Appendix 7-2
**See Appendix 7-3

Soil Support Categories
(Source: Thelen and Howe: Adapted from the
National Crushed Stone Association, Washington, D.C.)

NOT INCLUDED

Unified Soil Classification System
(Source: U.S. Waterways Experimental Station, 1953)

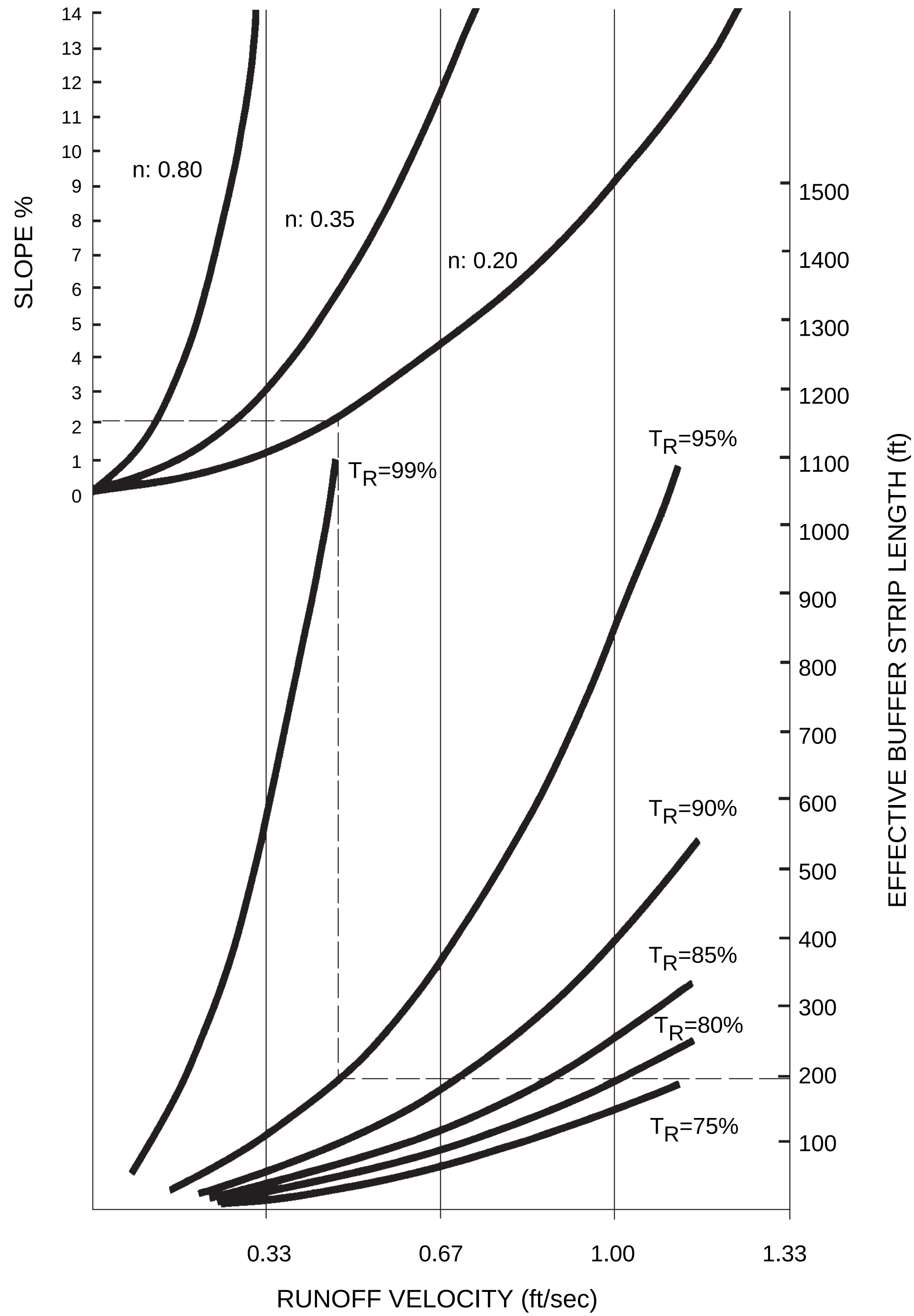
NOT INCLUDED

AASHO Soil Groups
(Source: Highway Research Board, 1945)

Material	U.S. Sieve Series Size	Opening (mm)	Specification: Percent Passing by Weight
Aggregate	1/2 in.	12.70	100
	3/8 in.	9.51	95 - 100
	#4	4.76	30 - 50
	#8	2.38	5 - 15
	#200*	0.074	2 - 5
Asphalt			5.5

*Aggregate should be uniformly graded between #8 and #200 sieves.

Open Graded Asphalt Concrete Formulation
(Source: Maryland Department of Natural Resources, 1984)



Effective Buffer Length Determination for
Sediment Trap Efficiencies, (T_R) of 75% to 99%
(Assumes Sediment is Coarse Silt Loam)
(Source: Wong and McCuen, 1982)

Maryland Construction Specifications for Porous Pavement

(Source: Maryland Department of Natural Resources, 1987a)

NOT INCLUDED

Maryland Summary of Shallow Wetland Planning Criteria
(Source: Maryland Department of Natural Resources, 1987)

NOT INCLUDED