Bioretention Manual

Environmental Services Division
Department of Environmental Resources
The Prince George's County, Maryland

Bioretention Manual

Environmental Services Division
Department of Environmental Resources
The Prince George's County, Maryland

Revised December 2007

TABLE OF CONTENTS

More detailed contents are listed at the beginning of each chapter.

List of Figures

List of Tables

CHAPTER 1

INTRODUCTION TO BIORETENTION

IN THIS CHAPTER

1.1 Overview

This manual has been prepared to replace and update the 1993 edition of the *Design Manual for Use of Bioretention in Stormwater Management*. This manual builds on that work and further identifies methodologies, practices, and examples of bioretention. Changes that were made focus primarily on four parameters: (1) functionality and application; (2) pollutant removal efficiency; (3) aesthetics and site integration; and (4) design simplification for cost containment.

This manual is organized into seven chapters, which include

1. Introduction
2. Bioretention Area Types and Applications
3. Siting and Location Guidance
4. Sizing and Design Guidance
5. Landscaping Techniques and Practices
6. Construction and Inspection
7. Public Outreach

In addition to these chapters, the following appendices are provided:

A – Biological Processes/Cycles in Bioretention
B – Representative Bioretention Costs
C – Sample Maintenance Covenant for Bioretention
D – Sizing Examples
E – Glossary
F – Example Bioretention Plans
G – Bioretention Operation and Maintenance

1.2 What is Bioretention

Bioretention is a terrestrial-based (upland as opposed to wetland), water quality and water quantity control practice using the chemical, biological, and physical properties of plants, microbes, and soils for removal of pollutants from stormwater runoff. Some of the processes that may take place in a bioretention facility include sedimentation, adsorption, filtration, volatilization, ion exchange, decomposition, phytoremediation, bioremediation, and storage capacity. This same principle of using biological systems has been widely used in agricultural and wastewater treatment practices for retention and the transformation of pollutants and nutrients. Bioretention can also be designed to mimic predevelopment hydrology. For specifics on how to accomplish this in conjunction with other *Low Impact Development* (LID) practices and techniques, see the Prince George's County *Low Impact Development Manual*.

Bioretention was developed to have a broad range of applications, necessitating early analysis of the overall site design. Early analysis allows the designer to place bioretention facilities integrated throughout a proposed site design. For this reason, bioretention is also referred to as an *Integrated Management Practice* (IMP). Figure 1.1 illustrates an IMP intensive residential lot. While integrating bioretention into a development site, the designer must consider and design for the following:

- Site conditions and constraints
- Proposed land uses
- Plant types
- Soil types (gradation)
- Stormwater pollutants
- Soil moisture conditions
- Proper drainage
- Groundwater recharge
- Overflows

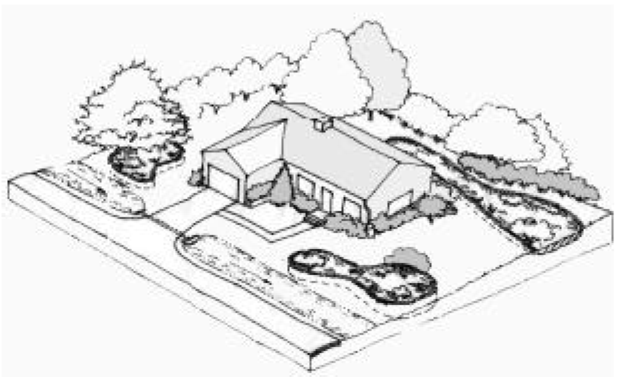


Figure 1.1. An IMP intensive residential lot

Unlike various other practices that control only peak discharge, bioretention can be designed to mimic the preexisting hydrologic conditions by treating the associated volumes of runoff. The bioretention technique has led to the creation of a new, holistic development philosophy known as LID. For more specifics on LID, see the county's *Low Impact Development Design Manual*.

Using bioretention not only provides for water quality and quantity control, but adds the many values of landscape diversity to a development. Bringing landscape diversity into the built environment

- Establishes a unique sense of place (especially when featuring plants native to the area)
- Encourages environmental stewardship and community pride
- Provides a host of additional environmental benefits (habitat for wildlife and native plant varieties, improving air quality, reducing energy use, mitigating urban climates)
- Increases real estate values up to 20 percent by using aesthetically pleasing landscaping

By design, bioretention does not require intense maintenance efforts. Therefore, the transfer of the maintenance obligations to the individual homeowners is a viable alternative. The *Kettering Urban Retrofit Study* found that nearly 70 percent of the property owners would perform yard and garden maintenance activities that would help safeguard the environment. Proper maintenance will not only increase the expected life span of the facility, but will also improve aesthetics and property value. For specifics on maintenance responsibilities, see Chapter 7.

1.3 The Bioretention Concept

A conceptual illustration of a bioretention facility is presented in Figure 1.2. Bioretention employs a simplistic, site integrated, terrestrial-based design that provides opportunity for runoff infiltration, filtration, storage and water uptake by vegetation. Bioretention facilities capture rainwater runoff to be filtered through a prepared soil medium. Once the soil pore space capacity of the medium is exceeded, stormwater begins to pool at the surface of the planting soil. This pooled water can then be dewatered either through infiltration into the subsoil (infiltration design), by means of an underdrain (filter design), or by a combination of the two methods.

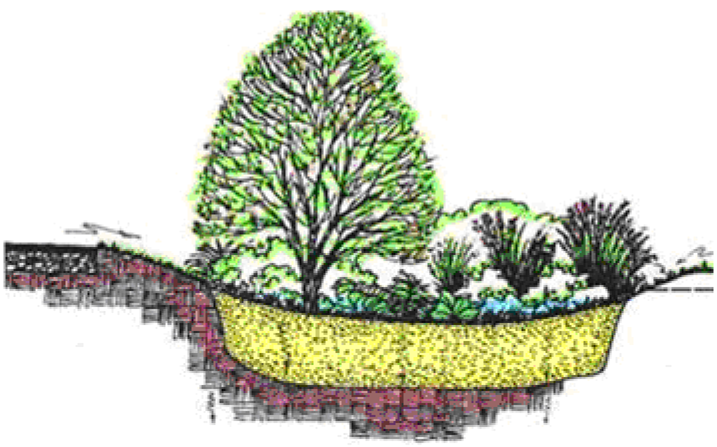


Figure 1.2. Bioretention facility conceptual cross-sectional layout (early design). Impervious area runoff, soil medium consists of sandy material, and early concept relied on infiltration and plant uptake.

Another conceptual element of bioretention is the control of runoff close to the source. Unlike end-of-pipe best management practices (BMPs), bioretention facilities are typically shallow depressions located in upland areas. The strategic, uniform distribution of bioretention facilities across a development site results in smaller, more manageable subwatersheds, and thus, will help in controlling runoff close to the source where it is generated.

1.4 Critical Processes of Bioretention

Discussion of the Physical, Chemical, & Biological Functions

Bioretention facilities are designed to function in much the same way processes occur in the natural environment. In fact, it is this principal of following the physical, chemical, and biological processes that occur in nature that we are attempting to reproduce. Depending upon the design of a facility, different processes can be maximized or minimized with respect to the type of pollutant loading expected. In this section, we briefly introduce these processes as *critical processes*.

The major critical processes that occur with respect to bioretention facilities include the following:

- ***Interception*—**The collection or capture of rainfall or runoff by plants or soils. Plant stems, leaves, and mulch within the bioretention facility intercept rainfall and runoff, which then pools at the center of the facility.
- ***Infiltration***—The downward migration of runoff through the planting soil and into the surrounding *in situ* soils. Infiltration can be a major process in bioretention facilities. Infiltration will occur in bioretention facilities, with or without underdrain systems.
- ***Settling***—As the runoff slows and ponds within the bioretention area, particles and suspended solids will settle out. This process occurs on the surface of the bioretention facility, providing pretreatment before entering the filter medium.
- ***Evaporation***—Thin films of water are changed to water vapor by the energy of sunlight. Bioretention facilities have a very shallow ponding area—only 6–12 inches deep—to facilitate evaporation.
- ***Filtration***—Particles are filtered from runoff as it moves through mulch and soil. In bioretention facilities, filtration removes most particulates from runoff.
- ***Absorption*—**Water is absorbed into the spaces between soil particles and then is taken up by plant root hairs and their associated fungi.
- ***Transpiration***—Water vapor that is lost through leaves and other plant parts. More than 90 percent of the water taken into a plant's roots returns to the air as water vapor.
- ***Evapotranspiration***—Water lost through the evaporation of wet surfaces plus water lost through transpiration. The bioretention facility design maximizes the potential for this process to occur. This plant/soil/runoff relationship is one of the processes that set bioretention apart from conventional BMPs.
- ***Assimilation***—Plants taking in nutrients and using them for growth and other biological processes. Designers can select plants used in bioretention facilities for their ability to assimilate certain kinds of pollutants.
- ***Adsorption***—The ionic attraction holding a liquid, gaseous, or dissolved substance to a solid's surface. Humus, which can be found in bioretention facilities with the breakdown of mulch and plant matter, adsorbs metals and

nitrates. Leaf mulch or compost is used as part of bioretention planting soils to provide humus. Soils with significant clay content are not used for bioretention facilities, however, because clay soils impede infiltration and might actually promote clogging.

- ***Nitrification***—Bacteria oxidize ammonia and ammonium ions to form nitrate (NO_3) a highly soluble form of nitrogen that is readily used by plants.
- ***Denitrification***—When soil oxygen is low, temperatures are high, and organic matter is plentiful, microorganisms reduce nitrate (NO_3) to volatile forms such as nitrous oxide (N_20) and Nitrogen gas (N_2), which return to the atmosphere. The designer can use various techniques outlined in this manual to maximize denitrification. One way to do this is to incorporate an anaerobic zone in the bioretention facility by raising the underdrain pipe invert above the base of the bioretention facility. Generally, mature soils with good structure denitrify more quickly.
- ***Volatilization*****—**Converting a substance to a more volatile vapor form. Denitrification is an example of volatilization as well as the transformation of complex hydrocarbons to CO_2.
- ***Thermal Attenuation***—Thermal attenuation is achieved by filtering runoff through the protected soil medium of a bioretention facility. One study showing thermal attenuation attributable to bioretention found that the temperature of input runoff was reduced from 33 degrees Celsius to about 22 ° C (Minami and Davis 1999). Bioretention facilities have an advantage over shallow marshes or ponds with respect to thermal attenuation. Thermal pollution of streams from urban runoff increases the likelihood of fish kills and degraded stream habitat.
- ***Degradation***—The breaking down of chemical compounds by microorganisms in the soil medium.
- ***Decomposition***—The breakdown of organic compounds by the soil fauna and fungi.

Each of the above processes occurs in varying degrees within a bioretention facility. As one can see, bioretention is a complex process, not just a simple filtering practice. Bioretention retains pollutants, thereby protecting receiving streams.

1.5 Pollutant Removal Efficiency of Bioretention

Studies have shown that the amount of pollutant runoff in the form of sediment, nutrients (primarily nitrogen and phosphorus), oil and grease, and trace metals increases substantially following the development of a site. Designers can incorporate bioretention into the landscape to remove pollutants generated from point and nonpoint sources.

Currently, the database on the pollutant removal performance of bioretention systems is still relatively small. The early results reported by Davis et al. (2001) were very promising and suggested that the bioretention systems have the potential to one of the most effective BMPs in pollutant removal. These results have been confirmed in a number of studies (Yu et al. 1999; Dietz and Clausen 2005, Hunt et al. 2006, Ermilio and Traver 2006).

The linkage between runoff volume capture and quality performance is strong, and designing for relatively small storms is effective. The Villanova bioinfiltration cell was designed to capture 1" of runoff and has been shown to remove over 85% of the annual rainfall input, and associated pollutants, to the surface waters over multiple years (Heasom et al., 2006, Ermilio and Traver 2006).

Table 1.1 summarizes our current knowledge of pollutant removal effectiveness by bioretention systems (Clar et al., 2007) for the following parameters; total suspended solids (TSS), Total nitrogen (TN), total phospohorus (TP), heavy metals including copper (Cu), lead (Pb) and Zinc (Zn); oil and grease, and pathogenic bacteria.

Table 1.1. Reported Pollutant Removal Performance of Bioretention Systems

Parameter	% Removal	Source(s)
TSS	97	Hsieh and Davis, 2005b; UNHSC, 2006 Ermillio & Traver, 2006
TP	35–65	Davis et al., 2006; Hunt, et al., 2006 Ermillio, 2005
TN	33–66	NHSC, 2006; Hunt et al., 2006 Sharkey, 2006, Davis et al., 2006
Cu	36–93	Ermillio, 2005; Davis, et al., 2006
Pb	24–99	Ermillio, 2005; Davis, et al., 2006
Zn	31–99	UNHSC, 2006; Ermillio, 2005
Oil & Grease	99	UNHSC, 2006; Hong, et al., 2006
Bacteria	70	Hunt, et al., 2007

Bioretention gets its name from the ability of the biomass to retain nutrients and other pollutants. Bioretention depends on the natural cleansing processes that occur in the soil/mulch/plant community. Proper bioretention design allows these natural processes and cycles to occur and maintain a perpetuating system. The two main nutrient cycles of concern are those of nitrogen and phosphorus. Nitrates and phosphates are the two key target pollutants. While these cycles are highly complex, their general application to bioretention is briefly explained in Appendix A.

1.6 Bioretention Area Types and Applications

Since the initial introduction of the bioretention concept and design manual in 1992, a number of variations and application of the concept have developed. Chapter 2 provides an overview and brief description of the major bioretention area types that are being used. These have been grouped into two major categories: commercial and industrial applications and residential applications.

The initial bioretention design concept focused on the design of an upland, terrestrial, forested system. Since then, two additional design themes have been developed. These include the meadow habitat and garden theme and the ornamental garden theme. Further sections in the chapter introduce and explain these existing design themes.

Chapter 2 also provides guidance related to bioretention site and project integration opportunities. It briefly describes a number of applications:

- New Residential Developments
- New Commercial/Industrial Developments
- Roadway Projects
- Institutional Developments
- Redevelopment Communities
- Revitalization and Smart Growth Projects
- Urban Retrofit Stormwater Management Projects
- Streetscaping Projects
- Private Residential Landscaping
- Parks and Trailways

1.7 Siting and Location Guidance

Bioretention is flexible in design, affording many opportunities for the designer to be creative. However, to develop successful bioretention applications, the designer must keep in mind a number of design issues. Some of these issues include site suitability and location, integration and site distribution of bioretention areas, and site grading considerations

Chapter 3 provides guidance to help the designer recognize and properly plan for these issues. It provides guidance related to bioretention site suitability and location; site evaluation considerations; location guidelines, integration, and site distribution of bioretention areas; and site grading considerations.

A number of bioretention site integrating criteria have been identified and described. These include the following:

- County rights-of-way
- Wellheads
- Septic fields
- Basements
- Building foundations
- Property lines
- Outlet drainage
- Underdrains
- Soil restrictions
- Cross-lot drainage
- Groundwater
- Minimum depth criteria

- Slopes and existing grades
- Wooded areas
- Median and traffic island considerations
- Utilities

1.8 Sizing and Design Guidance

Chapter 4 provides guidance on the computation methods and procedures for sizing and design of bioretention facilities. The topics that are addressed include:

- Design Goals and Objectives
- Sizing Bioretention
- Sizing and Placement Procedure
- Sizing Bioretention for Water Quality Using the Maryland Department of the Environment (MDE) Unified Stormwater Sizing Criteria
- Bioretention Design Example Using the MDE Unified Stormwater Management Sizing Chart
- Bioretention Design Example Using the Prince George's County Stormwater Management Requirements
- Bioretention Component Design
- Bioretention Site Submittal Requirements

1.9 Landscaping Techniques and Practices

Key factors in designing bioretention facilities are careful selection of plant materials that can tolerate highly variable hydrologic changes and an overall planting plan that ecologically and aesthetically blends the facility into the landscape. Designing for ease of maintenance is also a critical element of any landscape plan and is covered in Chapter 5.

Bioretention facilities have a wide range of applications from suburban residential lots to ultra-urban streetscapes. It is the landscape designer's responsibility to analyze the surrounding site considerations and design a bioretention facility that maximizes water quality enhancement and landscape values. It is our intent to provide guidance for landscape planning and design to ensure successful bioretention facilities without discouraging individual creativity.

1.10 Construction and Inspection

The effectiveness of bioretention is a function of the design and the construction techniques employed. Of these two parameters, construction is far more critical in achieving quality results. Poor construction technique will cause the best-designed facility to fail prematurely, usually from sedimentation, clogging, or both. To counter this problem, adequate and proper inspection is paramount. Chapter 6 covers the basic concepts associated with bioretention construction and inspection. The *Inspection Points* interspersed throughout the chapter pertain to the individual section of discussion. It is envisioned that contractors and inspectors will use these points for guidance.

1.11 Public Outreach

In the preceding chapter overviews, planning, design, construction, and landscaping for bioretention were highlighted. Proper implementation of these phases will ensure a successfully completed bioretention facility. However, even when these steps are performed exceptionally well, lack of care for or knowledge about the facility after installation can render all this work fruitless. Helping developers, builders, homeowners, and property managers understand the importance of environmental outreach with respect to bioretention will alleviate this concern.

Successful bioretention depends on proper maintenance. Unless the plants are in good health and the mulch layer is regularly replenished, the bioretention facility will not function as designed, and the longevity will be diminished. Therefore, it is crucial that the homeowners and property managers ultimately responsible for this maintenance understand their stewardship responsibility. Fortunately, the maintenance requirements for bioretention facilities are both simple and inexpensive.

Chapter 7 provides the strategy, process, and educational materials needed to ensure that maintenance responsibility and pollution prevention activities are clearly defined and communicated throughout the life of the facility. The chapter is organized to follow the *stewardship chain* from initial site preparation through long-term maintenance. Each section delineates the necessary maintenance and communication tasks and identifies the responsible parties in addition to containing useful tips and strategies. Responsibilities are outlined for each of the parties identified below:

- Developer/builder
- Landscape designer
- Landscaper
- Inspector
- Salesperson/real estate agent
- Homeowner/property manager
- Homeowner association/condominium association

1.12 Bioretention Economics

Why do bioretention? Beyond the environmental benefits, there are economic advantages as well. Bioretention methods modify existing site grading practices significantly compared to the conventional pipe and pond stormwater management approach. By intercepting runoff in bioretention areas near the source, the amount of the storm drainage infrastructure can be reduced, resulting in significant cost savings in site work. Several case studies have been performed comparing conventional BMP design to bioretention layouts. The results indicate that integrating bioretention across a site can achieve a net reduction of between 15 percent and 50 percent of the site development costs compared with conventional BMPs. The case study analysis demonstrates that bioretention can be an economical, environmentally effective alternative for providing treatment and control for stormwater runoff. Key economic advantages of using bioretention for stormwater management include

- Significantly reduced stormwater management design costs and complexity
- Lower safety and risk factors during construction, maintenance, and operation
- Reduced grading and sediment control costs by preserving dispersed drainage flow patterns
- Reduced installation costs by the using a nonstructural design
- Credit for subdivision landscaping
- Reduced or eliminated of storm drainage infrastructure
- Reduced runoff quantity
- Reduced or eliminated need for land area to control stormwater by placing bioretention *on-lot*
- Reduced or eliminated large-scale SWM end-of-pipe treatment areas
- Stormwater management maintenance responsibility is manageable and shifted from the local government to the homeowner
- Homeowner stewardship and ownership

Obviously, the design of the bioretention facility influences the economics greatly. For this reason, a simple and flexible design methodology has been established and is detailed in the following chapters.

Cost Considerations

Every site is unique, requiring specific cost estimating to account for the variability. In estimating the cost of using bioretention, a number of factors need to be considered:

- Site restrictions—both physical and regulatory
- Availability of materials, equipment, and labor
- Scheduling tasks for efficiency

There are also indirect cost benefits of using bioretention that designers should factor into the cost savings. These benefits include

- The reduction or elimination of conventional stormwater management BMPs
- Bonding and overall project cost reductions
- Reduced stormwater conveyance costs
- Reduced design costs with simplistic design
- Reduced maintenance and liability costs
- Aesthetic appeal not usually attributed to stormwater facilities
- Multifunctional landscaping

A number of technical documents have attempted to define cost benefit ratios based on variables such as the contributing drainage area controlled, storage area provided, or surface area consumed. The methodology typically employed attempts to derive cost formulas that a designer can use to quickly calculate stormwater costs for a project. This approach can provide insufficient criteria for BMP selection, however, if the factors listed above are not included in the cost benefit analysis. A better approach is to analyze anticipated costs of project tasks and subtasks within project phases. That is, evaluate specific costs of material, equipment, and labor with respect to the project schedule.

Table 1.2 provides a range of typical costs associated with various applications of the bioretention BMP, including (1) a homeowner installation of a residential rain garden, (2) bioretention applications within a residential lot subdivison, (3) bioretention application on a single lot basis, (4) a bioretention application on a commercial lot, and (5) a bioretention retrofit on a commercial lot. The costs are broken down by the various phases of the project schedule. The background information for this table is provided in Appendix B.

Table 1.2. Typical bioretention costs (Prince George's County, 2002)

Task/activity description	Residential rain garden	Residential lot subdivision	Single residential lot	Commercial —New	Commercial —Retrofit
Total cost	$ 1075	$ 3790	$ 7775	$ 10357	$ 12355
Planning phase	$ 25	$ 95	$ 200	$ 845	$ 350
Design phase	$ 100	$ 340	$ 875	$ 3600	$ 2410
Construction	$ 950	$ 3225	$ 5750	$ 5237	$ 7943
Close out	NA	$ 130	$ 950	$ 675	$ 1652

References:

Clar, M., A.P. Davis, W.F. Hunt, and R.G.Traver, 2007. Bioretention Technology: An Overview of Current Practice and Future Needs, Paper presented at the 2nd National Low Impact Development (LID) Conference, sponsored by North Carolina State University, Wilmington, NC.

Davis, A.P., Shokouhian, M., Sharma, H., and Minami, C. 2006. "Water Quality Improvement through Bioretention Media: Nitrogen and Phosphorus Removal," *Water Environ. Res.*, **78**(3), 284-293.

Ermilio, J.R., 2005. Characterization Study of a Bio-Infiltration Stormwater BMP, a Thesis, Department of Civil and Environmental Engineering, Villanova University, October 2005.

Ermilio, J.R., and R. G. Traver, 2006. "Hydrologic and Pollutant removal Performance of a Bio-Infiltration BMP', paper presented at the EWRI Water Congress, Omaha, Nebraska, May 2006

Hong, E., Seagren, E.A., and Davis, A.P. 2006. "Sustainable Oil and Grease Removal from Synthetic Storm Water Runoff Using Bench-Scale Bioretention Studies," *Water Environ. Res.*, **78**(2)**,** 141-155.

Hunt, W.F., A.R. Jarrett, J.T. Smith, and L.J. Sharkey. 2006. Evaluating Bioretention Hydrology and Nutrient Removal at Three Field Sites in North Carolina. *Journal of Irrigation and Drainage Engineering*. 132(6):600-608.

Hunt, W.F. and W.G. Lord. 2006. Bioretention performance, design, construction, and maintenance. North Carolina Cooperative Extension Publication # AG-588-05. Raleigh, NC. Online: http://www.bae.ncsu.edu/stormwater/PublicationFiles/Bioretention2006.pdf

Hunt, W.F., J.T. Smith, and J.M. Hathaway. 2007. Nutrient, Metal, and bacteria removal by an urban bioretention area in Charlotte, NC. Journal of Environmental Engineering (submitted)

Hsieh, C.-h and Davis, A.P. 2005. "Multiple-Event Study of Bioretention for Treatment of Urban Storm Water Runoff," *Water Sci. Technol.*, **51**(3-4), 177–181.

Prince George's County, 2002. Bioretention Manual. Programs and Planning Division, Department of Environmental Services, Prince George's County, MD

Sharkey, L. J. 2006. The Performance of Bioretention Areas in North Carolina: A Study of Water Quality, Water Quantity, and Soil Media. Thesis: North Carolina State University. Raleigh, NC.

UNHSC (University of New Hampshire Stormwater Center) 2006. *2005 Data Report*, CICEET, Durham, NH.

CHAPTER 2

BIORETENTION AREA TYPES AND APPLICATIONS

IN THIS CHAPTER

2.1 Introduction

Since the initial introduction of the bioretention concept and design manual in 1992, a number of variations and application of the concept have developed. This chapter provides an overview and brief description of the major bioretention area types that are currently being used. These have been grouped into two major categories—commercial and industrial applications and residential applications.

The initial bioretention design concept focused on the design of an upland, terrestrial, forested system. Since then, two additional design themes have been developed. These include the meadow habitat and garden theme and the ornamental garden theme. Further sections in the chapter introduce and explain these existing design themes.

This chapter also provides guidance related to bioretention site and project integration opportunities. It briefly describes a number of applications:

- New Residential Developments
- New Commercial/Industrial Developments
- Roadway Projects
- Institutional Developments
- Redevelopment Communities
- Revitalization and Smart Growth Projects
- Urban Retrofit Stormwater Management Projects
- Streetscaping Projects
- Private Residential Landscaping
- Parks and Trailways

2.2 Bioretention Area Types

This section introduces and describes various types of bioretention areas that are currently being used. Note that the layout of the bioretention area will vary according to individual sites and to site-specific constraints such as underlying soils, existing vegetation, drainage, location of utilities, sight distances for traffic, and aesthetics. Designers are encouraged to be creative in determining how to integrate bioretention into their site designs. With this in mind, the following conceptual illustrations are presented as alternative options.

2.2.1 Commercial/Industrial Bioretention

In Commercial/Industrial zoned areas, green space areas are often limited. This can present an opportunity for the designer to help a client obtain multiple credits for landscaping, green space, and stormwater management. However, even in industrially zoned areas, where landscaping traditionally has not been a focal point, combining the stormwater management requirements with landscaping options can have a positive impact. Bioretention is a perfect way to achieve this. The following bioretention area types provide design ideas for various site conditions.

2.2.1.1 Curbless Parking Lot Perimeter Bioretention

The bioretention area featured in Figure 2.1 and Figure 2.2, to be located adjacent to a parking area without a curb, has the lowest construction cost because there is no curbing, and the drainage is sheet flow. In a paved area with no curb, precast car stops can be installed along the pavement perimeter to protect the bioretention area. This application of bioretention should be attempted only where shallow grades allow for sheet flow conditions over level entrance areas. To achieve an element of stormwater quantity control beyond the confines of the bioretention surface area, water can be pooled into the parking area where parking spaces are rarely used.

The facility pictured in Figure 2.1 and Figure 2.2 is referred to as an *online facility* because the excess drainage will flow through the facility via the overflow outlet.

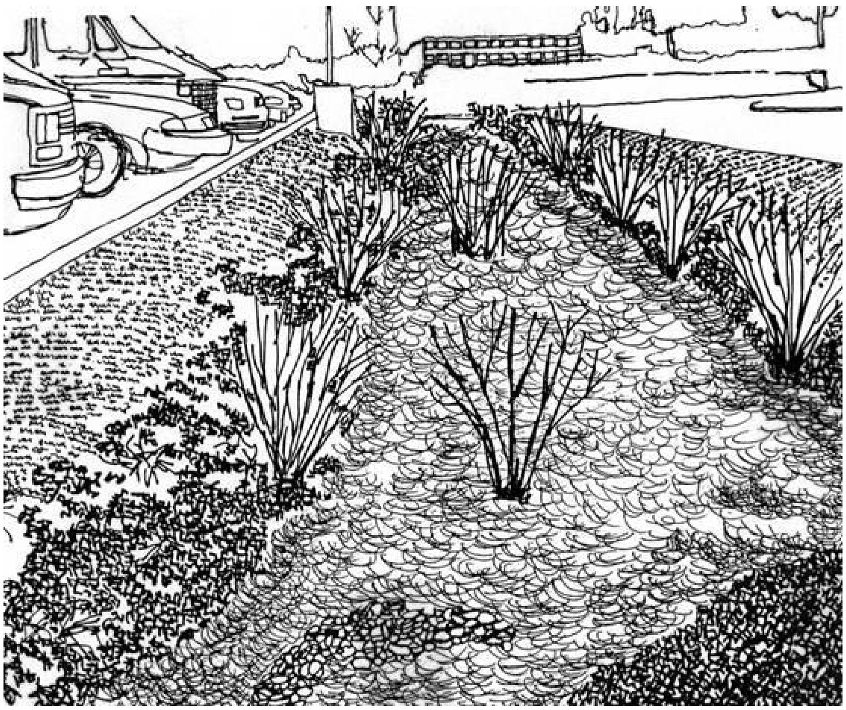


Figure 2.1. Curbless perimeter bioretention

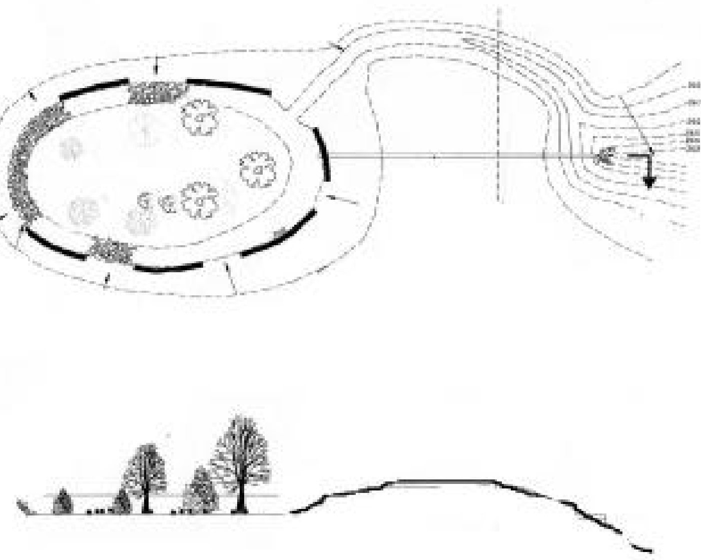


Figure 2.2. Curbless *flow-through* bioretention

2.2.1.2 Curbed Parking Lot Perimeter Bioretention

A bioretention area suitable for parking lot or traffic island green space areas is shown in Figure 2.3. For curb-cut entrance approaches, the water is diverted into the bioretention area by using an inlet deflector block, which has ridges that channel the runoff into the bioretention area. A detail of the inlet deflector block is provided in Appendix A.

Figure 2.3. Curbed parking lot island and median bioretention

2.2.1.3 Parking Lot Island and Median Bioretention

A concept for a bioretention traffic island is presented in Figure 2.4. There is no minimum width recommended for traffic islands from top of curb to top of curb. However, widths of the islands should conform to standard traffic island detail specified in the Prince George's County Landscape Manual. A 2-foot buffer is shown along the outside curb perimeter to minimize the possibility of drainage seeping under the pavement section and creating *frost heave* during winter months. Alternatively, the installation of a geotextile filter fabric *curtain wall* along the perimeter of the bioretention island will accomplish the same effect.

Parking lot island bioretention designed with an underdrain system and high-porosity soils (i.e., sand), can exhibit very high hydraulic capacity. Even though the filtration rate is high (> 4 inches an hour), water quality improvements are still achievable.

Figure 2.4. Median bioretention

2.2.1.4 Swale-side Bioretention

A bioretention area suitable for installation adjacent to a swale is shown in Figure 2.5. A 1-foot-high berm separates the swale from the bioretention area. To maintain an off-line system, the bioretention area should be graded such that the overflow from the bioretention area discharges into or near the baseline of the swale. It is recommended that the bottom of the bioretention area invert be a maximum of 3–4 inches below the swale invert to provide for the appropriate depth of ponded water.

Figure 2.5. Swale-side bioretention

Swale-side bioretention areas are typically shallow and an underdrain can be installed to discharge into the adjacent swale line. Figure 2.6 shows a plan view diagram and a cross section of the swale-side bioretention area. Note that the bioretention depth is greater than the invert of the swale itself.

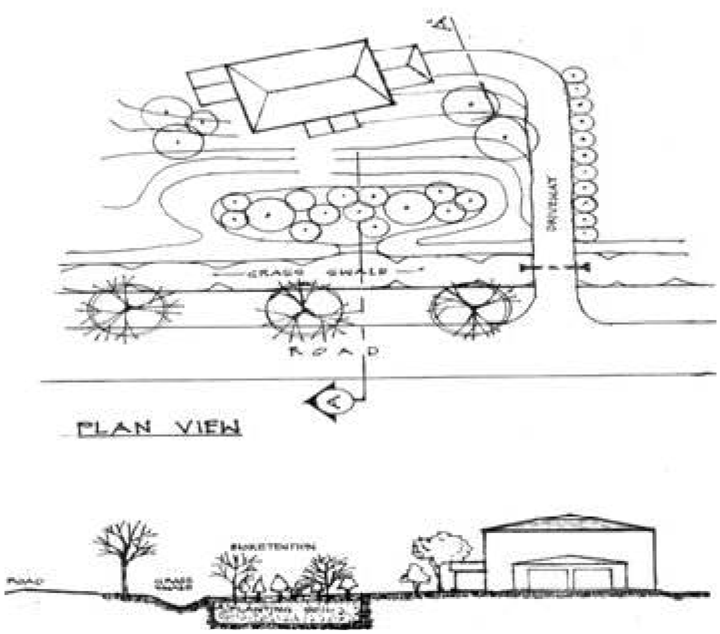


Figure 2.6. Plan view and cross section of a swaleside bioretention area

2.2.2 Residential On-lot Bioretention

When placing bioretention within residential communities, the chief concern is aesthetics and visibility. Although underdrains ensure that the facilities will drain within the design time frame, soil analysis is still recommended to avoid drainage problems. Site constraints can limit applicability of bioretention in residential communities. However, with thoughtful design and consideration of local building codes, bioretention might be used on any size residential lot. Figure 2.7 provides a schematic rendering on an on-lot bioretention area

Figure 2.7. Schematic rendering on an on-lot bioretention area

2.2.2.1 Landscaped Garden

Probably the most simplistic design, a landscaped garden bioretention facility—usually referred to as a rain garden, shown in Figure 2.8—employs the use of common flower gardens and planting arrangements. Instead of the area being mounded, the area is lowered (depressed) to intercept water and contain nutrient transport. Flower beds and other landscaped areas are depressed at least 2–3 inches to contain runoff to allow seepage into the garden area.

Figure 2.8. Rain garden or landscaped garden bioretention

2.2.2.2 Shallow-Dish Design

For bioretention facilities with small drainage areas (< one-half acre), the designer can use a shallow dish or scalloped design method as shown in Figure 2.9. This design method can be incorporated into final grading operations on the individual lot, thus minimizing the grading and excavation costs.

This bioretention area type can be implemented in areas that require bioremediation and phytoremediation techniques. For specific design criteria, see the Construction Details chapter.

Figure 2.9. Shallow dish (scalloped) bioretention

2.2.2.3 Tree and Shrub Pits

Ordinary *tree pits* can be used for bioretention needs for local drainage interception. This technique provides very shallow ponding storage areas in a *dished* mulch area around the tree or shrub. Typically, the mulched area extends to the drip-line for the tree and is similar to conventional mulching practices, with the exception of the mulch area being depressed at least 2–3 inches rather than mounded around the tree. For more detail, see Figures 2.10 and 2.11 below.

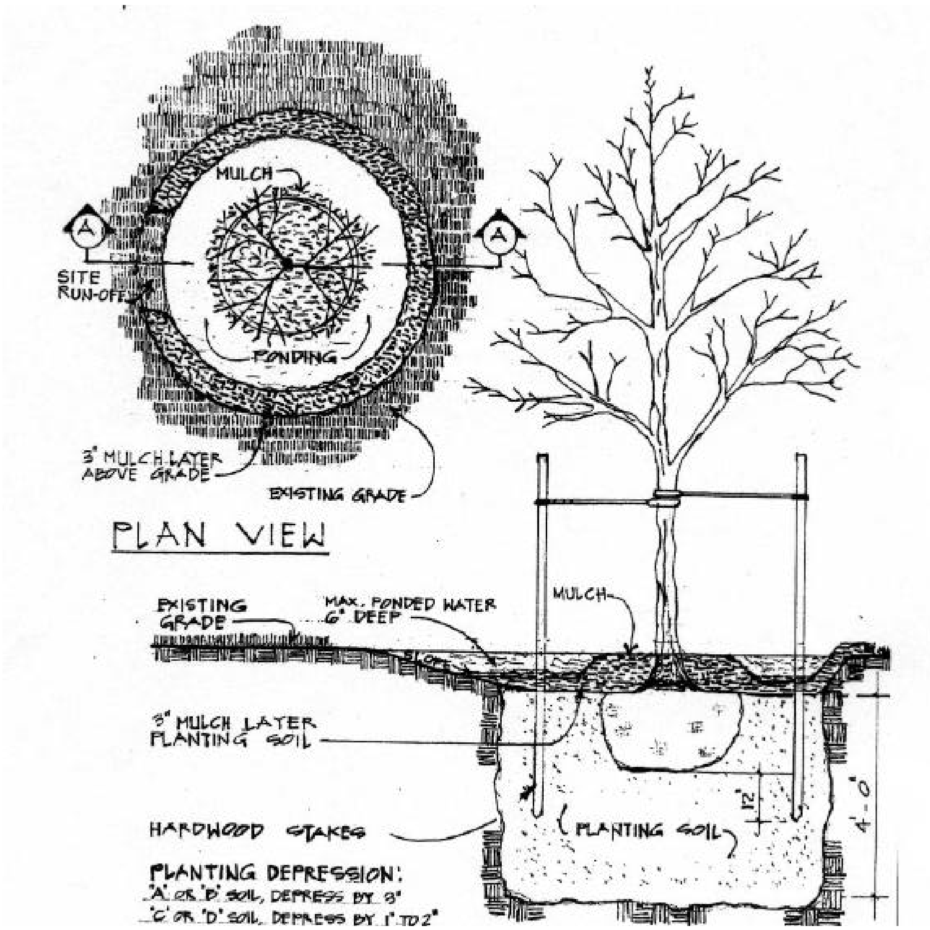


Figure 2.10. Tree pit bioretention

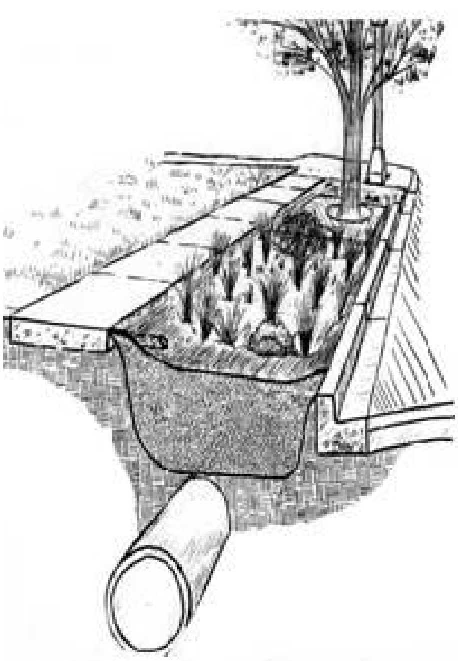


Figure 2.11. Tree-box area bioretention

2.2.2.4 Sloped "Weep Garden"

Bioretention facilities can be placed in areas that are sloped, if they are designed to accommodate the restrictive conditions. Using a downstream side stone/wooden-retaining wall allows the soil-filtered water to slowly seep through the retaining wall, as shown in Figure 2.12. This type of design is also known as a *weep garden*. For weep garden design limitations, see Chapter 3. The weep wall height should be kept below 3 feet with drainage areas of less than 1 acre. The weep wall can be made of fieldstone, gabions, or railroad ties.

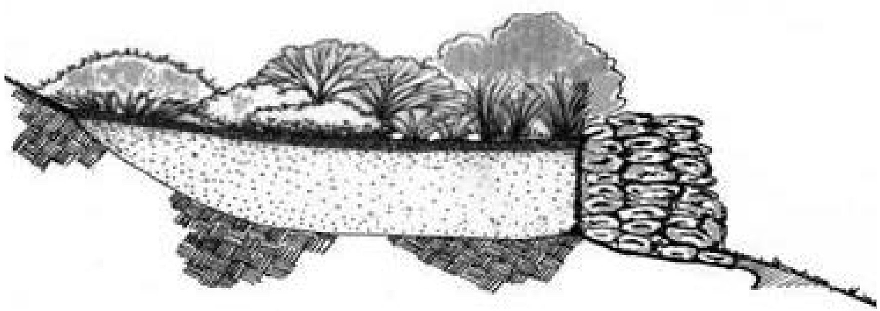


Figure 2.12. Fieldstone weep garden design

2.2.2.5 Swale-side Garden

Bioretention facilities can be placed next to roadside swales, complementing the landscape features of a residential lot. By placing the facility off-line, storage depths are regulated by the flow depth in the swale centerline. For additional details, see Figures 2.5 and 2.6.

2.3 Bioretention Facility Performance Types

The following three facility performance types have been slightly modified to optimize the expected or anticipated pollutant loadings on the basis of the proposed land use. Each of these facilities can be used as high-hydraulic capacity filtration systems. High hydraulic capacity filtration systems are defined as systems that are composed of essentially a shallow, sandy, soil mix; thick layer of mulch; an under drain or gravel discharge system; and placed off-line.

2.3.1 Infiltration/Recharge Facility

This type of facility, Figure 2.13, is recommended for areas where high recharge of groundwater would be beneficial. Because there is no underdrain, the *in situ* soils need to have a high infiltration rate to accommodate the inflow levels. The infiltration rate of the *in situ* soils must be determined through proper soil testing/diagnostics. Preferably, facilities of this type should have infiltration rates of 1 inch/hour or greater. Facilities must be at least 2.5 feet deep to allow adequate filtration processes to occur. Siting of these facilities should be in areas where visibility is not a concern because hydraulic overload can cause extended periods of standing water conditions. This facility type is suitable for areas and land uses that are expected to generate nutrient runoff (i.e., residential and business campuses) that can be infiltrated and captured by the facility.

Fresh mulch rather than aged, shredded, bark mulch can be used to enhance denitrification processes.

- Soil medium consisting of 50–60 percent sand, 20–30 percent top soil, and 20–30 percent leaf compost allows a high infiltration capacity
- No liner or geotextile fabric allows the *in situ* soils to infiltrate to their maximum capacity
- *In situ* soils must have a high porosity to allow runoff to infiltrate at a rate of greater than 0.52 inch/hour

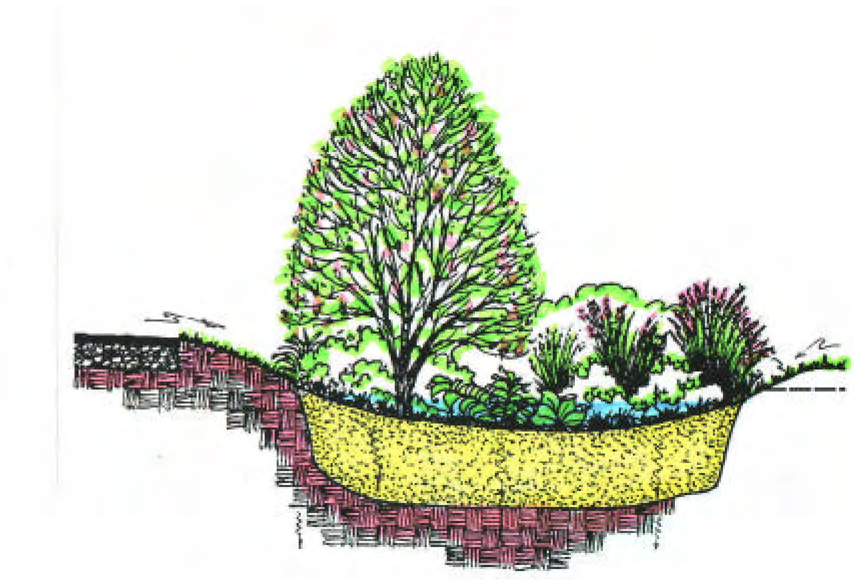


Figure 2.13. Infiltration/recharge facility (enhanced infiltration)

2.3.2 Filtration / Partial Recharge Facility

This type of facility, Figure 2.14, is recommended for areas where high filtration and partial recharge of runoff would be beneficial. This facility is designed with an underdrain at the invert of the planting soil mix to ensure that the facility drains at a desired rate. The facility allows for partial recharge, as an impervious liner is not used. The depth is also shallow (2.5 feet) to allow the facility to handle high-capacity flows if necessary. Siting of this performance type is suitable for visually prominent or gateway locations in a community. The facility type is suitable for areas and land uses that are expected to generate nutrient and metals loadings (residential, business campus, or parking lots).

Attention to mulch type and amount will ensure the adequate treatment of the anticipated loadings. The facility shown above incorporates a filter material between the gravel blanket around the underdrain and the planting soil above. The filter fabric does not need to extend to the side walls. The filter fabric can be installed horizontally above the gravel blanket—extending just 1–2 feet on either side of the underdrain pipe below. Do not wrap the underdrain with filter fabric.

- Instead of using a filter fabric, the designer could opt to use a pea-gravel diaphragm over the underdrain gravel blanket.

- Use a gravel Blanket around underdrain helps keep the drain free of possible soil transport.
- Place filter fabric over the gravel blanket in the vicinity of the underdrain pipe only.
- Use an underdrain discharge pipe.

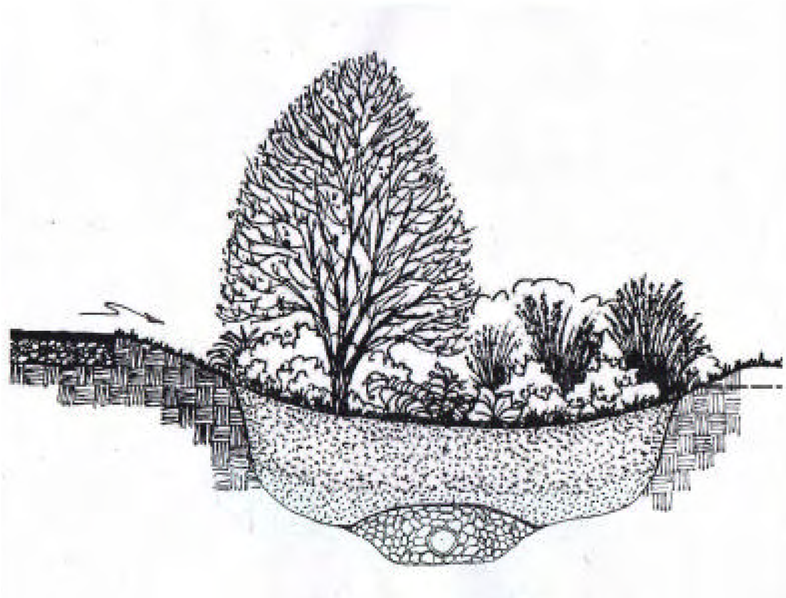


Figure 2.14. Filtration/partial recharge facility

2.3.3 Infiltration/Filtration /Recharge

This type of facility (see Figure 2.15) is recommended for areas where higher nutrient loadings (particularly nitrates) are anticipated. The facility is designed to incorporate a fluctuating aerobic/anaerobic zone below the raised underdrain discharge pipe. This fluctuation created by saturation and infiltration into the surrounding soils will achieve denitrification. With a combination of a fresh mulch covering, nitrates will be mitigated through the enhancement of natural denitrification processes. This type of facility would be suitable for areas where nitrate loadings are typically a problem (residential communities).

The raised underdrain has the effect of providing a storage area below the invert of the underdrain discharge pipe. This area also provides a recharge zone and can be used to meet the Maryland stormwater management requirements. In addition, quantity control can also be augmented with this storage area. The storage area is equal the void space of the material used. If #57 stone is used, an acceptable void space ratio is 30 percent.

- The gravel blanket area can be used to achieve several different functions when the underdrain pipe discharge elevation is set higher.
- No filter fabric is used on the side walls or at the invert of the facility discharge pipe.

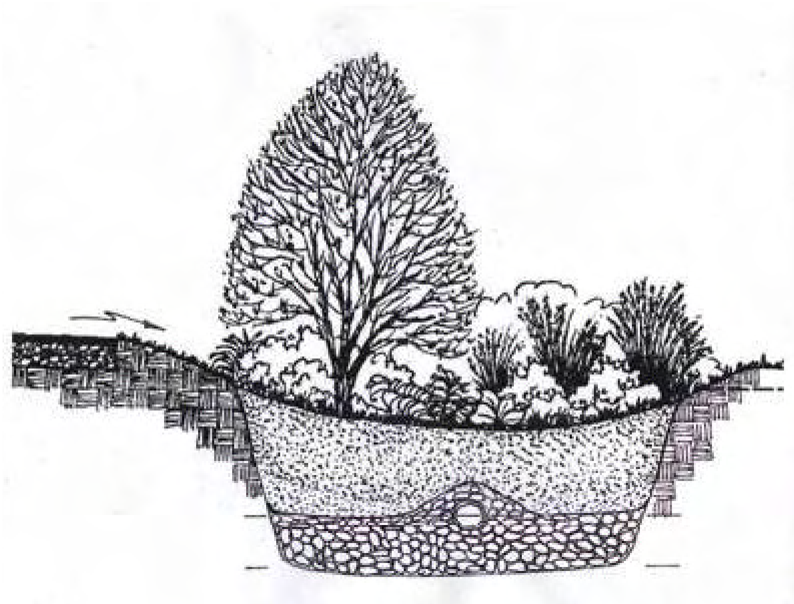


Figure 2.15. Infiltration/filtration/recharge

2.3.4 Filtration Only Facility

Filtration only facility (Figure 2.16) is recommended for areas that are known as *hot-spots* (gas stations, transfer sites, and transportation depots). An important feature of this type of facility is the impervious liner designed to reduce or eliminate the possibility of groundwater contamination. The facility provides a level of treatment strictly through filtration processes that occur when the runoff moves through the soil material to the underdrain discharge point. If there is an accidental spill, the underdrain can be blocked and the objectionable materials siphoned through the observation well and safely contained.

A liner between the *in situ* soils and the planting soil medium prevents the effluent from penetrating into the ground and reduces the likelihood of groundwater contamination by capping the underdrain pipe. This facility type can be used to capture accidental spills and contain the level of contamination

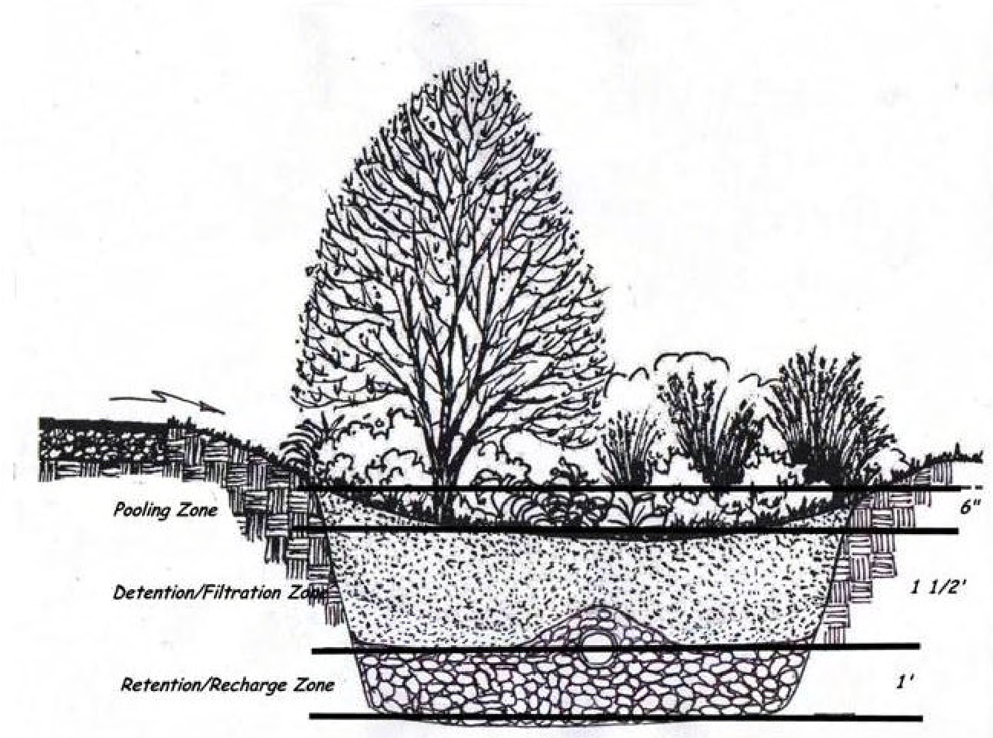


Figure 2.16. Filtration only facility

2.4 Bioretention Design Themes

One of the unique qualities of the bioretention is the flexibility of design themes that a designer can employ when integrating into the site. Making multifunctional use of existing site constraints, bioretention can blend nicely with buffers, landscape berms, and environmental setback areas. The landscape chapter of this manual goes into more detail about plantings and should be consulted. Presented below are short definitions of some of the different design themes possible:

2.4.1 Forest Habitat

The most typical design theme, and the original concept for bioretention, the forest habitat is the most efficient in terms of mimicking preexisting hydrologic conditions. Figure 2.17 presents a forest habitat landscape plan for a bioretention area.

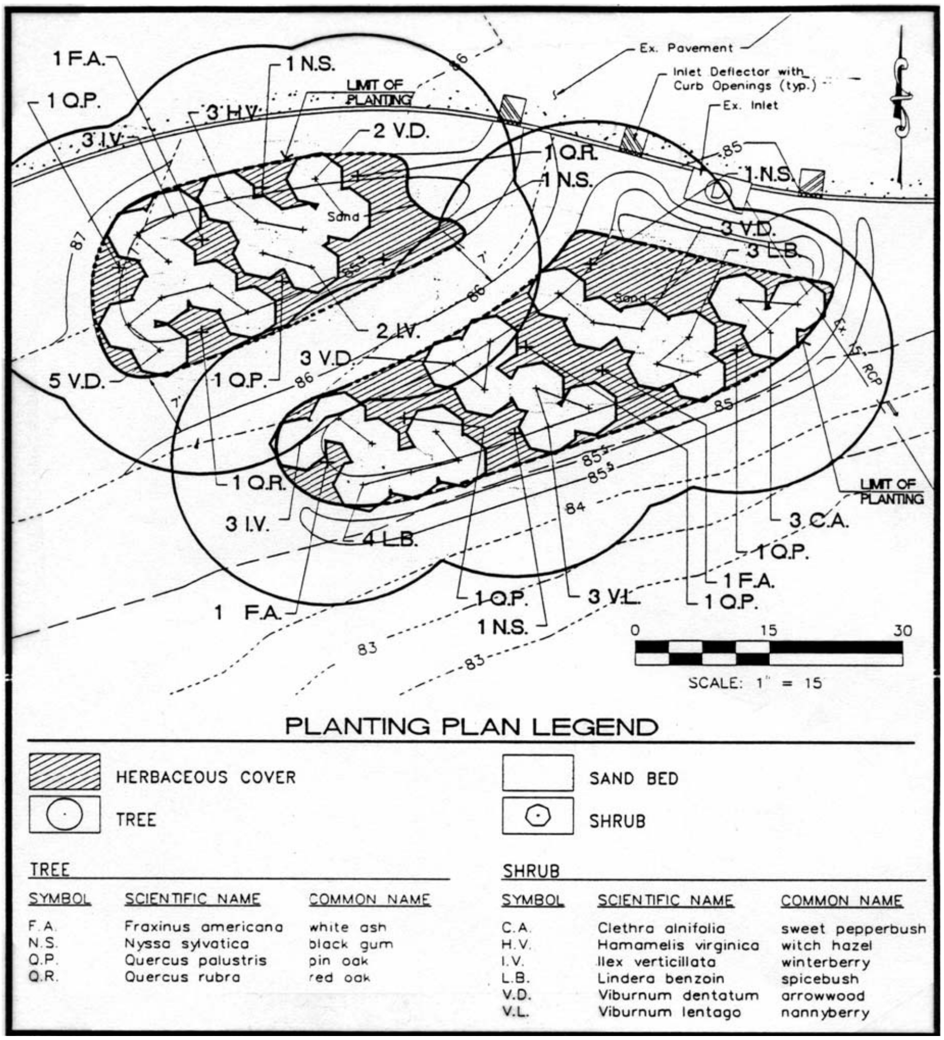


Figure 2.17. Forest habitat landscape plan for a biortention area

2.4.2 Forest Transition Zone

Forest transition zone bioretention areas are typically employed on large lots adjacent to existing forested areas or within common space areas. Figure 2.18 illustrates a forest transition bioretention area.

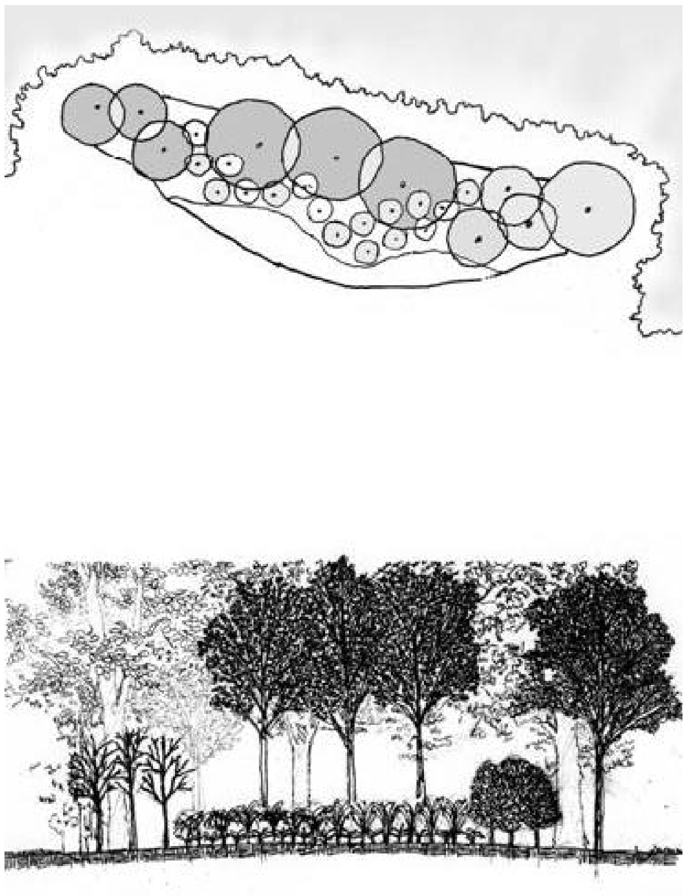


Figure 2.18. Forest transition bioretention area (boundary exaggerated)

2.4.3 Existing Forested Area

An alternative method of employing bioretention in areas that are already wooded is to install an unobtrusive low berm (3–4 inches) around a tree perimeter area to make use of the existing forest area as shown in Figure 2.19. The bioretention trap area type can be used in conjunction with wooded pathway areas in common space property. Care must be taken with this approach not to cause excessive ponding around species that are intolerant to flooding. For recommended trees tolerant to frequent ponding conditions, see the plant/tree listing in the Landscaping chapter.

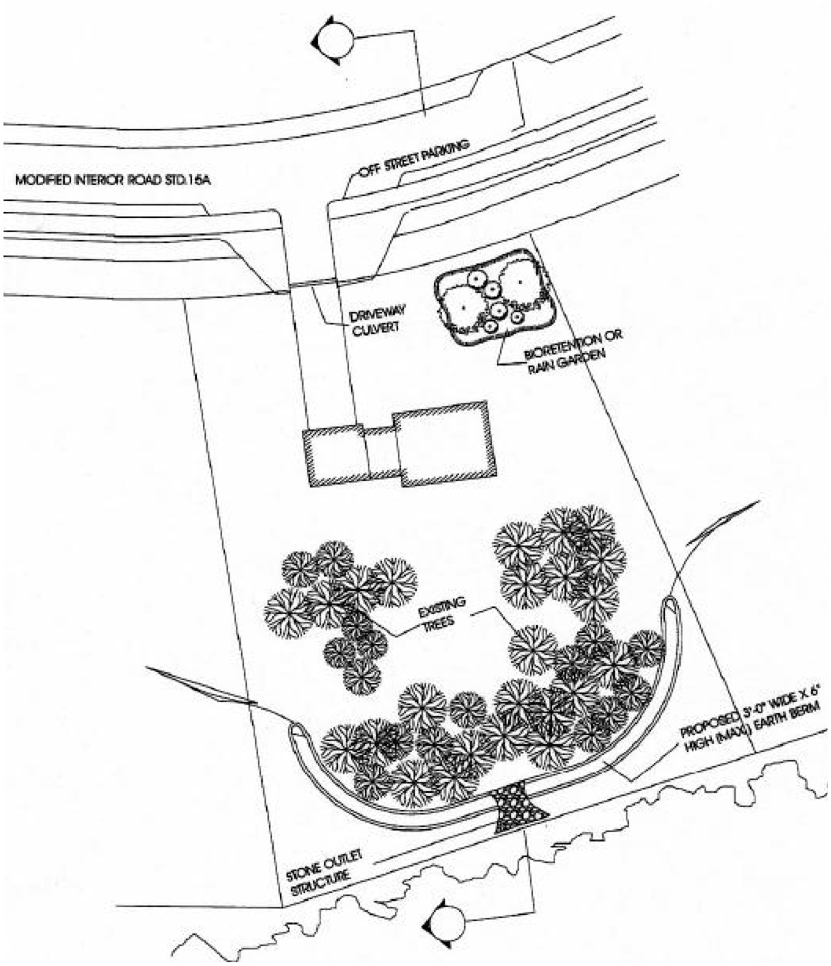


Figure 2.19. Existing wooded area converted with berm

2.4.4 Meadow Habitat

Like a forest, a meadow is a structured community of plants occupying different levels above and below ground. A variety of grasses and wildflowers are generally interspersed throughout the site. Drifts of a particular species, however, could develop over time in response to variations in moisture or as a consequence of ecological succession. While it is not difficult to design and establish a meadow, it is important to use plant communities and techniques specifically adapted to local conditions. For guidance on developing meadow gardens, see the U.S. Fish and Wildlife Service, Chesapeake Bay Field Office, BayScapes Program at http://www.fws.gov/r5cbfo/Bayscapes.htm.

2.4.5 Meadow Garden

A meadow garden is a more designed, less natural approach to using meadow plants. Plants can be seeded in sweeping bands of color within the meadow, or zones of short, medium, and tall plant mixes can be seeded to provide height progression. In small enough areas, plants can be individually placed and arranged.

2.4.6 Ornamental Garden Design

This technique is identical to traditional formal gardening design except that the display is depressed in the landscape rather than mounded. Figure 2.20 shows an example of an ornamental garden in the Capital Hill, Washington, D.C. Plant listings for recommended plants suitable for this condition are provided in the Landscape chapter.

Figure 2.20. Photo of Capitol Hill raingarden

2.5 Bioretention Site/Project Integration Opportunities

Bioretention facilities can be incorporated or integrated into any site to help improve water quality and contain increased quantities of runoff. The following site integration examples provide just a few of the various opportunities to employ the bioretention facility within a site.

2.5.1 New Residential Developments

New developments provide perfect opportunities to employ bioretention facilities for meeting stormwater management requirements. Bioretention facilities can be placed on private lots and within common areas and combined with landscaping themes, resulting in aesthetically pleasing, multifunctional landscaping. For design criteria and conditions for siting bioretention in a residential community, see Chapters 3 and 4.

2.5.2 New Commercial/Industrial Developments

Commercial and industrial sites provide an excellent opportunity to employ the use of bioretention. Many commercial and industrial sites across the county already use bioretention. Here, designers can incorporate bioretention into the landscaping buffers, parking lot islands, perimeter landscaping, entrance gardens, treebox areas (green space area between sidewalk and roadway), or even rooftops.

2.5.3 Roadway Projects

Often, roadway improvement projects have severe site constraints imposed on the designer. Transportation safety and right-of-way limitations tend to take precedence over stormwater management concerns. For these types of situations, high-hydraulic capacity bioretention facilities, strategically placed to intercept street runoff can be the solution. Locating bioretention facilities within or just outside the treebox area can be a low maintenance, yet effective, way to treat and control stormwater runoff. Bioretention facilities have the additional benefit of providing roadside landscaping variety. Roadway projects have limited funding, and landscaping options often get scaled back as a result. If, however, the landscape options also incorporate stormwater management control attributes, there is a value-added benefit and ultimate cost savings.

2.5.4 Institutional Developments

Institutional settings are owned by government or private organizations and offer many opportunities for the installation of bioretention. For government facilities, no easements are necessary, and access is usually not a major concern. Institutional facilities such as places of worship, schools, and community centers offer site conditions with *campus* green space areas, providing unlimited opportunity to employ bioretention facilities.

2.5.5 Redevelopment Communities

For properties and communities that are being redeveloped, bioretention facilities are key to the environmental retrofit aspects of the redevelopment. Redeveloping communities were typically developed initially without stormwater management controls. The redevelopment process makes it possible to go back and capture lost stormwater management options. For instance, where commercial districts are being redeveloped, greenspace areas required under county ordinances could also be used for stormwater management areas.

2.5.6 Revitalization and Smart Growth Projects

Revitalization initiatives involve community stakeholders working in partnership. Economic revitalization includes environmental components to be incorporated into the project plan. Bioretention facilities work well to achieve successful initiatives in older communities by adding an element of landscaping aesthetics in visible public spaces.

2.5.7 Urban Retrofit Stormwater Management Projects

A number of urban areas were initially constructed at a time when stormwater management requirements where nonexistent. Urban retrofits can recapture lost stormwater management opportunities in incremental steps, one project at a time. By installing bioretention facilities in older developed watersheds, the stream degradation can begin to be addressed.

2.5.8 Streetscaping Projects

Streetscaping typically involves infrastructure and façade improvements but neglects to incorporate environmental concerns because of budget limitations. With bioretention, treebox areas can become stormwater management facilities. In this case, bioretention areas can be sized as needed to fit the available space. They should also be designed to be off-line, high-hydraulic capacity facilities so that at least a portion of the drainage is intercepted

2.5.9 Private Residential Landscaping

Private property owners can also take the initiative to install bioretention facilities on their lots. Designers and landscape architects can incorporate bioretention facilities as part of the landscaping layout and design.

2.5.10 Parks and Trailways

These areas encompass open space areas, making an excellent location to install bioretention facilities. Here, the designer should site facilities near park and trail parking facilities to intercept runoff. Meandering trails can incorporate small weirs (2 inches high) to temporarily pond water on the upstream side of the trail.

CHAPTER 3

BIORETENTION SITING AND LOCATION GUIDANCE

IN THIS CHAPTER

3.1 Introduction to Bioretention Siting and Design

Bioretention is flexible in design, affording many opportunities for the designer to be creative. However, to develop successful bioretention applications, designers must keep in mind a number of design issues. This chapter provides guidance to help the designer recognize and properly plan for these issues. It provides guidance related to bioretention site suitability and location; site evaluation considerations; location guidelines, integration, and site distribution of bioretention areas; and site grading considerations

A number of bioretention site integrating criteria have been identified and described:

- County rights-of-way
- Wellheads
- Septic fields
- Basements
- Building foundations
- Property lines
- Outlet drainage
- Underdrains
- Soil restrictions
- Cross-lot drainage
- Groundwater
- Minimum depth criteria
- Slopes and existing grades
- Wooded areas
- Median and traffic island considerations
- Utilities

3.2 Site Suitability and Location

The small size of the bioretention cell gives it great flexibility and makes it very easy to integrate into a site's landscape. However, for various reasons, the application of bioretention might or might not be appropriate for your site. The following general guidelines can help the designer determine when to use bioretention for stormwater management:

1. Facilities can be placed close to the source of runoff generation.
2. The site permits the dispersion of flows and bioretention facilities can be distributed uniformly.
3. Sub-drainage areas are smaller than 2 acres and preferably less than 1 acre.
4. There is available room for installation including setback requirements.

5. The stormwater management site integration is a feasible alternative to end-of-pipe BMP design.
6. Suitable soils are available at the site.

3.3 Site Evaluation

The existing site topography and associated drainage patterns provide a good starting point for the site evaluation. Potential bioretention facilities should be applied where sub-drainage areas are limited to less than 1–2 acres and preferably less than 1 acre. Generally, commercial or residential drainage areas exceeding 1–3 acres will discharge flows greater than 5 cubic feet per second (cfs) for a 10-year storm event. When flows exceed this level, the designer should evaluate the potential for erosion to stabilized areas. Typically, flows greater than 5 cfs for the 10-year storm event will require pipe enclosure across developed lots. However, by employing drainage dispersion techniques and retaining existing contours, concentrated quantities of flow can be reduced below these thresholds, eliminating or reducing the need for a pipe conveyance system. This can be accomplished by dispersing larger drainage areas to multiple bioretention facilities. This dispersion of flow technique can reduce the cost of engineering design and site construction. In addition to reducing the need for drainage pipe conveyance systems, dispersion techniques can also eliminate the need for surface drainage easements.

3.4 Location Guidelines

Bioretention facilities can be used *anywhere* to achieve a degree of treatment. The location depends in part on the *type* of facility employed. For specific bioretention types, see Chapter 2. The following guidelines present some preferable locations for bioretention:

- On new residential subdivision lots or commercial lots, near the source of the runoff generation from impervious surfaces. Locate facilities near the perimeters and edges to maintain typical use of the property. Avoid locating near building areas (unless the design incorporates adequate waterproofing measures), wellheads, and septic systems.
- Areas upland from inlets or outfalls that receive sheet flow from graded areas.
- Areas of the site that are planned to be excavated or cut. If possible, avoid existing wooded areas or other significant natural features.
- When available, for siting the bioretention areas, use areas with soils meeting the U.S. Department of Agriculture (USDA) classification of sandy and well drained. These soil types comprise the planting soils for bioretention areas, and locating bioretention areas in these soils minimizes or eliminates the cost of importing planting soil.
- Stormwater management for retrofit and redevelopment opportunities—even where total stormwater management control is not feasible, adding a retrofit bioretention facility will provide some improvement in water quality.

3.5 Integration and Site Distribution of Bioretention Areas

The integration of bioretention areas across the development site is very important to achieve proper stormwater management controls. Each site is unique, necessitating close attention to sub-drainage areas when evaluating the net impacts on the hydrologic characteristics. Once the designer has determined the amount of site area to be dedicated to the bioretention area(s), he or she can calculate the specific size of the facility. To do this, take the following steps to distribute the facilities uniformly:

1. Delineate and subdivide sub-drainage areas (preferably less than a 1-acre drainage area). Find local low points for each sub-drainage area and evaluate the location for suitability for bioretention.
2. Using the volume derived from the hydrologic computations described in Chapter 4 and the total site area, find applicable weighted area for each sub-drainage area. For example, if a sub-drainage area represents 15 percent of the total drainage area for the whole development, 15 percent of the required volume control should be applied to that same sub-drainage area. Similarly, if only 5 percent of the total drainage area for the whole development is in a sub-drainage area, 5 percent of the volume requirement should be sited accordingly in the respective sub-drainage area.
3. The allowable pooling depth should be no greater than 6 inches. If pooling depths are less than 6 inches, the facility's surface area, or the volume (or both) must be expanded accordingly.
4. When siting bioretention facilities to intercept drainage, the designer should attempt to use the preferred *off-line* facility design. An example of an off-line facility is shown in Figure 3.1. Off-line facilities are defined by the flow path through the facility. Any facility that uses the same entrance and exit flow path upon reaching pooling capacity is considered an off-line facility.
5. Whenever possible, use underdrains for bioretention discharge. The underdrains can outfall to a suitable location such as common space area, stream valley, drainage swale, roadside open-section, or an existing enclosed drainage system.

When using bioretention in new developments, as shown in Figure 3.2, many options exist for designing and integrating bioretention facilities. The design phase of integrating bioretention BMPs should begin early in the land development process. Part of that process involves determining the appropriate development envelope and constraints. The following sections in this chapter describe the process of using bioretention to meet the requirements of stormwater management. Each section relates to the example provided, indicating which issues and information are addressed at that stage. The first issue is site integration and site constraints relative to bioretention.

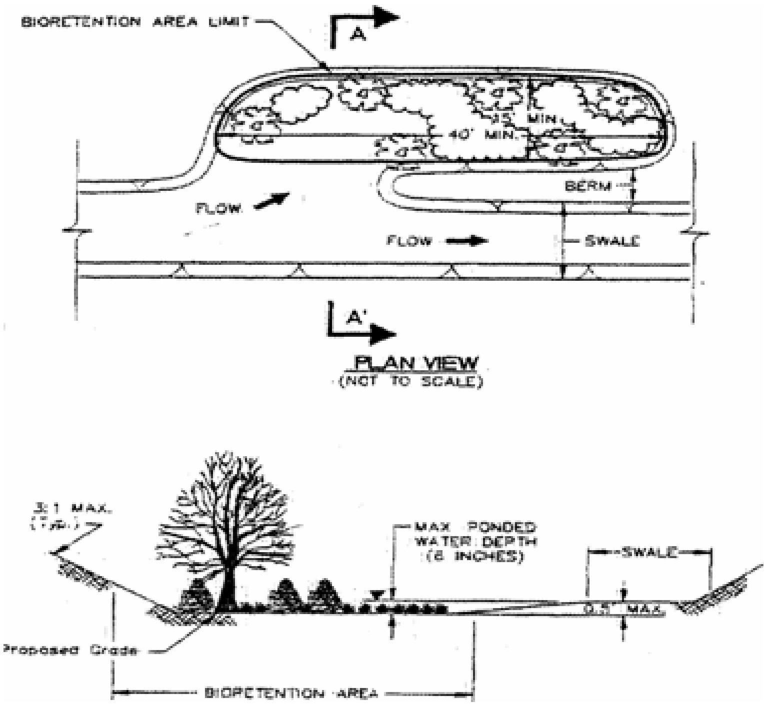


Figure 3.1. Offline bioretention

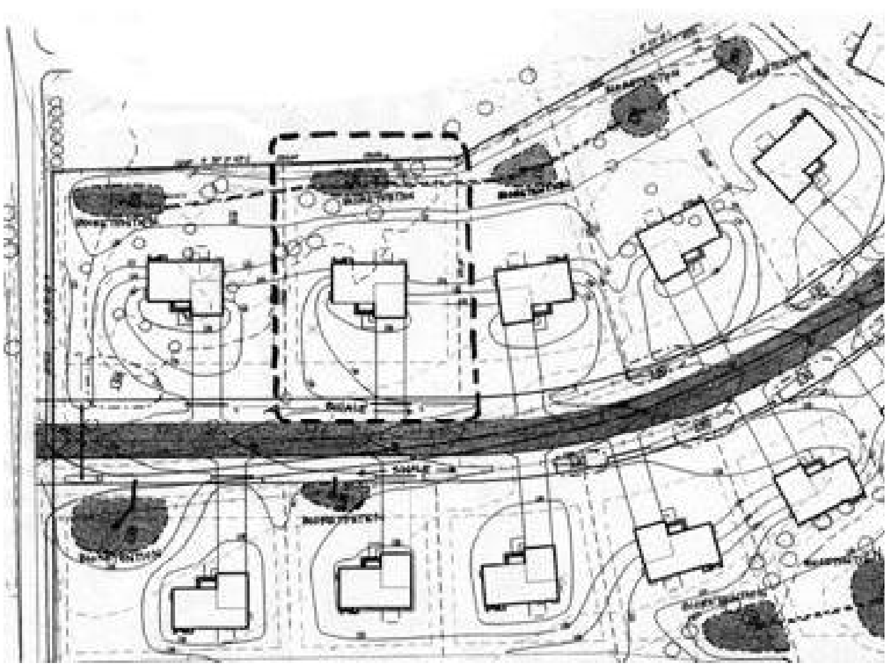


Figure 3.2. Typical site plan with bioretention

Site integration is key to the management of stormwater runoff by using bioretention. Essentially, this entails locating the facilities close to the source where the runoff is generated and making use of landscaping options. This means strategically placing facilities throughout a community, typically within residential lot areas. To do this, the designer must be aware of various site constraints and setbacks established to prevent possible contamination and seepage problems from occurring. Most of these setback and constraint criteria have been identified in the sections below.

3.6 Bioretention Site Integrating Criteria

When attempting to integrate a bioretention facility into the proposed development envelope, the designer must be aware of possible impacts to other development features. In particular, determine setbacks from utilities, property lines, buildings and roadways. In addition, areas of conservation to preserve trees and existing grading are also of concern when designing or placing a bioretention facility. The following design criteria must be incorporated into the design technical plans and shown on the plan view (if applicable).

3.6.1 County Right-of-Way

Bioretention is allowed within the county's right-of-way with the prior approval of the director of the Department of Public Works and Transportation (DPW&T).

3.6.2 Wellhead

Bioretention areas should be placed at least 100 feet from any source water location. Other restrictions may apply. For specific conditions, consult with the Department of Health, Environmental Health Sanitarians.

3.6.3 Septic Field

When siting bioretention facilities, septic areas must be avoided unless the septic field uses a hybrid design specifically designed to accept surface water. Otherwise, maintain a 50-foot setback from the septic field to avoid cross-contamination. It is preferable to locate bioretention facilities upgrade of any septic field and to divert any overflow path away from the field as well.

3.6.4 Basement

When siting bioretention facilities on lots that will have a basement, the facility offset requirements include the following:

- Maintain a 25-foot minimum setback down-gradient from the home foundation.
- If possible, the facility invert should be lower than the proposed basement floor elevation.
- The facility must be down-gradient from the home or building.

3.6.5 Building Foundation

Setback from a foundation or slab should be 5 feet or greater. Basement setbacks apply whenever the structure has a basement. Exceptions might be acquired for planter box bioretention facilities on industrial or commercially zoned property. For planter box bioretention facilities, waterproofing membranes (as a minimum) adjacent to the building wall are required.

3.6.6 Property Line

Bioretention facilities cannot cross private property lines. Additionally, when possible, bioretention areas should be on the same lot that generates the runoff. The perimeter of a bioretention area must be at least 2 feet away from any property line. Place weep garden designs at least 20 feet away from any down-gradient property boundary or line.

3.6.7 Outlet Drainage

Overflow from bioretention areas must be safely conveyed to a suitable discharge point (storm drain system, stream channel, or swale). In-line facilities are discouraged because of possible mulch-float problems. Off-line facilities are preferred to control drainage.

3.6.8 Underdrain

Underdrains are required for all residential lot facilities and recommended for all facilities in general. Underdrain material must be of approved material and have a hydraulic capacity greater than the planting soil infiltration rate. Underdrains must not be within the groundwater zone of saturation. Underdrains should be perforated with one-quarter to one-half inch openings, 6 inches center to center, and a total cross-sectional area of at least (or greater than) three times the underdrain pipe hydraulic capacity. Underdrain pipe material can be composed of Poly Vinyl Chloride (PVC), rigid Schedule 40, or Advanced Drainage System (ADS) pipe material.

3.6.9 Soil Restrictions

The main soil restriction for use in bioretention facilities is that the soil must have an infiltration rate sufficient enough to draw down any pooled water within 48 hours after a storm event. This requires that the soil infiltration rate exceed one-half inch/hour. The following USDA soil textural classifications (Table 3.1) will meet this criterion (MDE 2000):

Table 3.1. Soil textural classification

Texture class	Minimum infiltration rate (*f*) (inches per hour)	Hydrologic soil grouping
Sand	8.27	A
Loamy sand	2.41	A
Sandy loam	1.02	A
Loam	0.52	B

Other USDA soil textural classifications will not meet this requirement. For areas with unsuitable soils, designers can overcome this restriction by importing the planting soil mix and providing an underdrain system in the facility to help achieve the desired infiltration rate.

3.6.10 Cross-Lot Drainage

Drainage from bioretention facilities should not be directed to cross over another developed, private portion of a lot. Drainage from a bioretention area must have a suitable discharge point. Suitable discharge points include dispersing flows to undeveloped lots, common space areas, or to the county right-of-way. If a site is not conducive for bioretention without adversely affecting another developed lot, there is the option of conveying the flow. For an example of swale grading between lots to the right-of-way, see the Grading section.

3.6.11 Groundwater

Depth to groundwater below the facility invert should be no less than 2 feet. Determining the depth to groundwater should be done by performing an actual soil boring or test pit similar to a percolation test. Testing should be conducted during specific seasonal periods. To determine the current criteria, contact the Health Department, Division of Environmental Health.

3.6.12 Minimum Depth Criteria

Facilities using the specified soil mix can be as shallow as 1.5 feet. For facilities designed using *in situ* soils, the minimum facility depth criteria does not apply. Rain gardens can be very shallow if the drainage area is less than one-quarter acre.

3.6.13 Slopes and Existing Grades

Generally, sloped areas exceeding 20 percent should not be used for bioretention. However, a weep garden design could be used on shallow slope conditions and where no downstream seepage problems will impact buildings.

3.6.14 Wooded Areas

Wooded areas should not be cleared to make room for a bioretention facility. If the bioretention facility design incorporates the use of wooded areas as an integral part of the facility and preserves the wooded area, it is permissible. Design themes such as forest transition zones and ponded, wooded areas are examples of permissible designs.

3.6.15 Median and Traffic Island Considerations

Any bioretention facilities sited within the county right-of-way must first be approved by the DPW&T. The director of DPW&T must approve these facilities on a case-by-case basis. The Maryland State Highway Administration has begun to extensively incorporate bioretention within their roadway rights-of-way. When bioretention facilities are in close proximity to paved areas, curtain drains will be used to prevent lateral drainage under pavement sections. Curtain drain material should consist of approved linear materials (see the specifications table).

3.6.16 Utility Clearance

Utility clearances that apply to storm drainage pipe and structure placement also apply to bioretention. Standard utility clearances for storm drainage pipes have been established at 1 foot vertical and 5 feet horizontal. However, bioretention systems are shallow, nonstructural IMPs consisting of mostly plant and soil components, with a flexible underdrain discharge pipe. For this reason, other utilities can traverse a bioretention facility without adverse impact. Conduits and other utility lines can cross through the facility, but construction and maintenance operations must include safeguard provisions. In some instances, bioretention could be used where utility conflicts would make structural BMP applications impractical.

3.7 Grading for Bioretention Development

3.7.1 Site Grading for Bioretention

Siting the bioretention area(s) within a development requires the same information and analysis as conventional site design to determine the existing hydrology. Evaluating the sub-drainage divides and flow paths will help determine how to best lay out the proposed development making best use of the existing contours to minimize grading. Preserving the existing natural features (even within the development envelope) will help maintain existing flow patterns and flow paths and disperse runoff instead of concentrating it in one location.

Designers must carefully consider clearing and grading operations when integrating bioretention within lot areas. In the case of a residential community, each lot should be independently designed to ensure drainage from each lot is adequately handled—either by proper overland conveyance to a bioretention facility or by maintaining the original dispersed drainage patterns.

Once the site is evaluated to determine the flow patterns and soils, designers can place lot locations to maximize lot yield. Be careful to allow no more than two lots draining across a third lot. For portions of the lot that are to remain undisturbed, designers do not need to consider stormwater management control if no new runoff is added and the flow patterns present in the predevelopment condition have not been altered.

After the lots have been positioned to maximize existing contours and to reduce graded areas, designers must focus their attention on the portion of the lot that is to be developed. This portion of the lot will generate new runoff, particularly from the new imperious areas. Designers must place bioretention as close to the source as possible to intercept and absorb this new runoff.

Typically, placing the bioretention areas on the lowest portion of the individual lot will accomplish this. Be sure to account for proposed improvements such as building footprints and areas that could be used for pools or decks. The key point is to blend the bioretention facility into the lot in such a way so that typical use of the property will not be encumbered. The following section provides suggestions for bioretention site grading design.

3.7.2 Site Grading Design Considerations

- Locate facilities away from traveled areas such as public pathways to avoid soil compaction. Where facilities are placed near walkways, be sure to delineate boundaries and borders to make pathways clear.
- Sloped areas *immediately* adjacent to proposed bioretention areas should be less than 20 percent but greater than 2 percent to ensure positive flow at reduced velocities. Weep garden designs (see Figure 2.12) can be used where steeper slopes are encountered.
- Proposed bioretention facilities can be situated at the same location as an interim sediment control facility. If this is done, several activities must be

performed to ensure residual sedimentation does not hamper the effectiveness of bioretention:

1. The invert of the proposed facility must be 1 foot below the invert of the existing sediment control facility.
2. Bioretention must have an underdrain discharge pipe.
3. During construction of the bioretention facility, sediment and runoff must be diverted.

- Cut and fill limitations should conform to existing county grading criteria for developed lots.[1] Typically, areas that are placed in cut must have sufficient geotechnical investigation to ensure that an adequate minimum distance (2 feet) to the water table is maintained. For fill areas, berms can be used to create depression areas for use in bioretention but should be minimally used to avoid being defined, classified, and regulated as a dam. For questions regarding dam classification criteria, consult with the Prince George's County Soil Conservation District and MD378 (MDE 2000).
- Minimize grading and limits of disturbance to maintain existing dispersion of flow. The more disperse the flow paths are, the smaller the resultant sub-drainage areas will be.
- Facilities that traverse residential property lines are prohibited. Maintain a 2-foot minimum distance from property lines. For residential cross-lot drainage, a surface drainage easement must be provided.
- Where grading and excavation for underdrains or other drainage appurtenances are involved, practice standard utility practices for setback criteria when in the vicinity of other utilities.

Drainage systems designed to service the bioretention area are exempt from the setback criteria. Storm drain pipe joints in the vicinity of the bioretention area should be sealed to prevent piping and possible subsequent cavitation.

3.7.3 Developing a Grading Plan for Bioretention

In developing the grading plan, the sediment and erosion control practices used are a function of the size of the drainage area. Designers should delineate for the site the drainage area contributing to each bioretention area. Then determine the Rational Method *c* coefficient for the drainage area using the methodology specified in Chapter 4 of the Prince George's County *Stormwater Management Manual*. Additionally, for grading plan specifics, consult the Prince George's County Grading Ordinance and the PGSCD.

[1]The Prince George's County Grading Ordinance does not have a provision for bioretention. For this reason, it might be necessary to obtain a variance or waiver.

References:

Maryland Department of Environment 2000. 2000 *Maryland Stormwater Design Manual - Volumes I & II.* Maryland Department of the Environment, Water Management Administration.

CHAPTER 4

SIZING AND DESIGN GUIDANCE

IN THIS CHAPTER

4.1 Introduction to Bioretention Sizing and Design

This chapter provides guidance on the computation methods and procedures for sizing and design of bioretention facilities. It addresses the following topics:

- Design Goals and Objectives
- Sizing Bioretention
- Sizing and Placement Procedure
- Sizing Bioretention for Water Quality Using the MDE Unified Stormwater Sizing Criteria
- Bioretention Design Example Using the MDE Unified Stormwater Management Sizing Chart
- Bioretention Design Example Using the Prince George's County Stormwater Management Requirements
- Bioretention Component Design
- Bioretention Site Submittal Requirements

This Bioretention is an acceptable urban BMP option as identified in the Maryland Department of the Environment's (MDE) *2000 Maryland Stormwater Design Manual Volumes I & II*, Section 2.7, BMP Group 3 (Infiltration), and BMP Group 4 (Filtration).

4.2 Design Goals and Objectives

Bioretention is flexible in design and can be used as either an infiltration BMP or a filter BMP. Bioretention can often be used to meet one or more of the *Statewide Stormwater Criteria*, which include:

- Recharge Volume (Rev)
- Water Quality Volume (WQv)
- Channel Protection Storage Volume (Cpv)
- Overbank Flood Protection Volume (Qp)
- Extreme Flood Volume (Qf).

Many stormwater design practitioners do not yet grasp the multiple benefits that can be achieved with microscale, landscape-based practices such as the bioretention cell, and they perceive this BMP to be strictly a water quality or recharge volume BMP. However, in this section, we demonstrate with example computations, how the Bioretention BMP can be used to meet all the statewide stormwater criteria.

4.3 Sizing Bioretention

To size a bioretention facility, the designer must first determine for what purposes it is intended. For example, what are the site requirements for water quality and quantity control? What design storm is required to meet the stormwater management criteria? Can the bioretention be used for water quality and quantity control? Can the bioretention facility be used independently of other BMPs, or will it be installed along with other practices? The above questions can be answered at the stormwater management concept stage. Having determined the design storm, the designer can use the following procedural outlines for sizing bioretention areas for water quality and quantity criteria, adjusting according to the specific site constraints. Designers should pay close attention to the stormwater management criteria and waiver conditions that could help reduce the overall stormwater management control requirements.

4.4 Sizing and Placement Procedure

Designers can follow the below procedure to use bioretention within a site:

Step 1: Delineate the development site drainage area in the pre- and post-development condition. Delineate subdrainage divides for the post-development condition, identifying strategic locations for possible bioretention facilities.

Step 2: Using Technical Release #55 (TR-55) methodology, determine the pre- and post-development Curve Numbers (CN) for the proposed development site. Adjust the CN value by measuring the actual impervious versus pervious areas. Remember to incorporate other LID site design techniques to help reduce the post-development CN value. Methods such as increasing the percentage of disconnected impervious areas, preserving wooded areas, and reducing impervious surfaces will minimize the amount of control required.

Step 3: Select the required design storm and design depth for the bioretention facility(ies). The stormwater management (SWM) Concept application submission must identify the intent to use an LID approach through the use of bioretention. The design storm used depends on the objectives of the LID approach, which can vary from stream and ecosystem protection to load reduction for Total Maximum Daily Load (TMDL) requirements. **Note**: the design storm can vary significantly depending on the SWM objective.

Step 4: Determine the storage volume required to maintain runoff volume or CN. Use Chart Series A: Pre-development Runoff Volume Using Retention Storage (provided in the back of this manual).

Step 5: Determine the storage volume required to maintain the pre-development peak runoff volume using 100 percent retention. Use Chart Series B: Percentage of Site Area Required to Maintain the Predevelopment Peak Runoff Rate Using 100% Retention.

Step 6: Use the results from Chart Series A, B, and C to determine the percentage of the site needed to maintain both the pre-development peak runoff and the runoff volume.

Step 7: Determine the appropriate percentage of the site available for retention practices. If the percentage of the site available for retention practices is less than the percent determined in step 5, recalculate the amount of BMP required to maintain the peak runoff rate while attenuating some volume.

4.5 Sizing Bioretention for Water Quality Using the MDE Unified Stormwater Sizing Criteria

The MDE has developed a stormwater management design manual (MDE 2000), which provides minimum design standards for all BMP design in the state of Maryland, including bioretention. The MDE performance criteria for bioretention are provided in Table 4.1. The manual provides guidance that integrates stormwater management controls into the site design. This approach follows a similar approach to LID. In fact, MDE recognizes LID as meeting the new state criteria for stormwater management. Bioretention is just one of the components of LID.

Many stormwater management design practitioners think of bioretention as strictly a water quality BMP. However, as the following design example demonstrates, using just distributed bioretention facilities throughout a site design, the designer can achieve adequate stormwater management controls that meet the state's criteria.

For this example, we have taken excerpts from the MDE 2000 and from the Soil Conservation Service's *Technical Release #55*, Second Edition, June 1986. Additionally, the example presented is specific to Prince George's County, Maryland. To find the *Stormwater Management Regulations*, see: http://www.mde.state.md.us.

As presented in the Table 4.2 below, the state stormwater unified sizing criteria attempts to have stormwater management controls that are implemented to do five things:

- Provide an element of water quality control through filtration/infiltration of stormwater runoff.
- Provide groundwater recharge for areas that are not considered hot spots, or where the recharge will not compromise groundwater quality.
- Channel Protection Volume Storage to help reduce stream degradation.
- Overbank Flood Protection Volume to help control conveyance flooding problems.
- Extreme Flood Volume for areas that do not regulate floodplain construction activities.

In Prince George's County, when a development proposal incorporates LID methodology with distributed bioretention controls, disbursed drainage, disconnected impervious areas and flow paths, several of the above criteria are not required. This is possible because bioretention practices that are distributed throughout a watershed reduce or eliminate downstream conveyance problems and channel degradation problems. Also, the extreme flood control requirement is not required in Prince George's County because the county regulates all floodplains and prohibits new construction activities within the 100-year ultimate floodplain area.

Table 4.1. MDE performance criteria for bioretention design*

Criteria	Filtration design	Infiltration design	CPV storage design
General feasibility			
Location	All locations okay with underdrain	*In situ* soils to be certified suitable	*In situ* soils to be certified suitable[1]
Drainage area	2 acres maximum, 1 acre maximum impervious	1 acres maximum, ½ acre maximum impervious	1 acres maximum, ½ acre maximum impervious
Soils infiltration rate	See soil mixture specifications	*In situ* soils 1" /hour infiltration rate[2]	*In situ* soils 1" /hour infiltration rate[2]
Clay content	< 5%	< 5%	< 5%
Hotspots	Yes w/liner	No without proper treatment	No
Water table	> 2 vert. feet from facility invert	> 4 vert. feet from facility invert	
Water supply well	Maintain > 100" distance		
Building structures	Setback > 10^{-3} Downgradient	Setback > 25^{-3} Downgradient	Setback > 10^{-3} Downgradient
Septic system	Maintain > 50' distance		
Sloped areas	Okay with weep garden design	Not recommended greater than 20%	Not recommended
Property line setback	2' minimum		
Conveyance			
Entrance flow	Surface sheetflow	Surface sheetflow	Surface sheetflow
Entrance treatment	Riprap gabion mattress.surge stone	Riprap gabion mattress.surge stone	Riprap gabion mattress.surge stone
Surface pool dewater	3–4 hours	3–4 hours	3–4 hours
System dewater	< 48 hours		< 48 hours
Overflow outlet	Safe overflow path or appropriate Outlet	Safe overflow path	Safe overflow path or appropriate Outlet
Flow path	Off-line is preferred; where not feasible, in-line is permissible		
Flow regulator	Divert WQv		
Media filter	Non-woven filter fabric or pea gravel diaphragm	None	Non-woven filter Fabric and liner around facility
Underdrain	4" diameter minimum	N/A	4" diameter minimum
Pretreatment			
Pretreatment BMP	Surface	Required	Required
Grass filter strip	Use where space permits. Not always feasible		
Surface treatment	Allowable where impervious area > 75%		
Pretreatment volume	25% of WQv	N/A	25% of WQv
Treatment			
Volume	Entire WQv filtered – pretreatment volume	Entire WQv infiltra. – pretreatment volume	Entire WQv filtered – pretreatment volume
Porosity	n = .25 for soil mix; .40 for stone	n = .25 for soil mix	n = .25 for soil mix; 40 for stone
Landscaping	See Landscaping Chapter		
Maintenance			

* Source: MDE 2000

WQv = Water Quality Volume

Table 4.2. Summary of the statewide stormwater criteria

Sizing criteria	Description of stormwater sizing criteria
Water quality volume (WQ_v) (acre-feet)	$WQ_v = \frac{[(P)(R_v)(A)]}{12}$ *P* = rainfall depth in inches and is equal to 1.0" in the Eastern Rainfall Zone and 0.9 in the Western Rainfall Zone. R_v = volumetric runoff coefficient *A* = area in acres
Recharge volume (Re_v) (acre-feet)	Fraction of *WQ?*, depending on predevelopment soil hydrologic group. $Re_v = [(S)(R_v)(A)] / 12$ *S* = soil specific recharge factor in inches.
Channel protection storage volume (Cp_v)	Cp_v = 24 hour (12 hour in USE II and IV watersheds) extended detention of post-developed one-year, 24-hour storm event. Not required for direct discharges to tidal waters and the Eastern Shore of Maryland.
Overbank flood protection volume (Q_v)	Controlling the peak discharge rate from the 10-year storm event to the pre-development rate (Q_{p10}) is optional; consult the appropriate review authority. For Eastern Shore: provide peak discharge control for the 2-year storm event (Q_{p2}). Control of at the 10-year storm event is not required (Q_{p10}).
Extreme flood volume (Q_1)	Consult with the appropriate reviewing authority. Normally, no control is needed if development is excluded from 100-year floodplain and downstream conveyance is adequate.

4.5.1 Design Example Background Information

Several assumptions are made about the example site being presented below and summarized in Table 4.3:

1. 100 percent of the proposed site condition will have disconnected impervious surfaces with uniformly distributed bioretention facilities, open section roadway, and grass swale conveyance.
2. Site predevelopment condition is almost entirely wooded. Some wooded areas will be preserved in the proposed condition. For our example, 0.54 acres of woods in good condition will be preserved.
3. All other pervious surfaces are presumed to have a CN equal to grass in good condition.
4. Dispersed drainage patterns and preexisting flow paths will be preserved. Site topography will also be preserved as much as possible.
5. For our example, a portion (one sub-drainage area) of the entire site is being analyzed. The hydrologic analysis of this portion will be used as a representative sample for the entire site. The portion represents a typical *cross section* of the proposed development conditions.
6. The Time of Concentration (Tc) remains the same for both the pre- and post-conditions.

Table 4.3. Summary of the example site data

Existing condition					
Land cover type	Soil (HSG[1])	CN	Area (acres)	CN × area	% of site
Woods (good condition)	B	55	3.36	184.8	100
Proposed condition					
Impervious area	B	98	0.6	58.8	18
Woods (good condition)	B	55	0.54	29.7	16
Grass	B	61	2.22	135.42	66
T_C = 15 minutes (both)	B				

[1] HSG = Hydrological soil group

Site Information

The site consists of half-acre residential zoning, 25 lots, open section roadway, and swale conveyance. For details of the layout, see the site plan, Figure 4.1. We need to analyze only a portion of the whole site if proposed conditions are typical throughout.

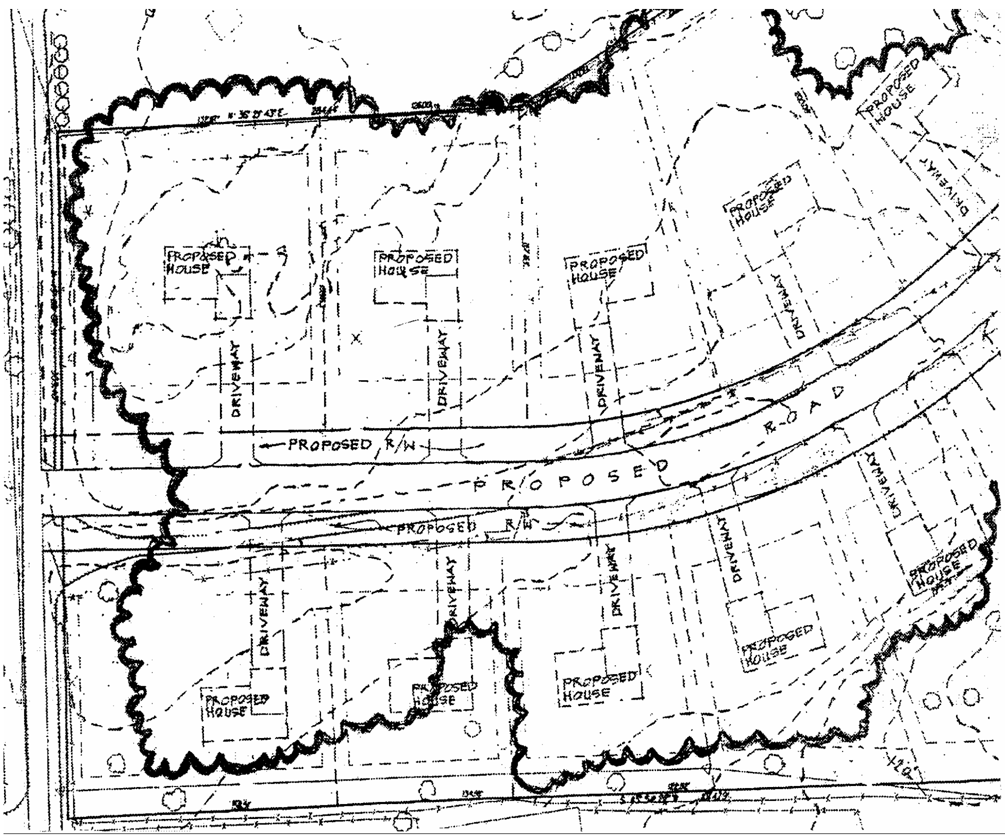


Figure 4.1. Site plan—existing

4.5.2 Water Quality Volume (WQv) Calculations

Use the MDE Water Quality Volume Equation:

$WQ_v = [(P)(R_v)(A) / 12]$

For P, use 1.0 inch (Prince George's County is in the Eastern Rainfall Zone)

For R_v, use the equation: $R_v = 0.05 + 0.009(I)$

Our example has 18 percent impervious surfaces, therefore;
$R_v = 0.05 + 0.009(18) = 0.21$
For A, use site area in acres
Our example has an area of 3.36 acres
The Water Quality Volume Equation now equals:
$WQ_v = [(1.0)\ (0.21)\ (3.36)] / 12 = 0.06$ acre feet

4.5.3 Recharge Volume Requirements (Re_v)

The Recharge Volume Requirement (Re_v) is a fractional part of the total Water Quality Volume and can be calculated by the following methodology and using the Soil Specific Recharge Factor (S) from the chart below:

From equation and table above,
$Re_v = [(S)\ (R_v)\ (A)] / 12$ = site recharge requirement.
For S, (Soil Specific Recharge Factor) use HSG B.
Our example has all "B" soils and the $S = 0.26$.
For our example, we found that R_V was equal to 0.21 and so...
$Re_v = [(0.26)\ (0.21)\ (3.36)] / 12 = 0.015$ acre feet

Recharge Volume Requirements (Re_v)

The criteria for maintaining recharge is based on the average annual recharge rate of the hydrologic soil group(s) (HSG) present at a site as determined from USDA, NRCS Soil Surveys. More specifically, each specific recharge factor is based on the USDA average annual recharge volume per soil type divided by the annual reainfall in Maryland (42 inches per year) and multiplied by 90%. This keeps the recharge calculation consistent with the WQ methodology. Thus, an annual recharge volume requirement is specified for a site as follows:

Site Recharge Volume Requirement

$Re_v = [(S)(R_v)(A)/12]$ (percent volume method)

where: R_v = 0.05 + 0.009(I) where I is percent impervious cover
A = site area in acres

$Re_v = (S)(A_i)$ (percent area method)

where: A_i = the measures impervious cover

Hydrologic Soil Group	Soil Specific Recharge Factor (S)
A	0.38
B	0.26
C	0.13
D	0.07

The recharge volume is considered part of the total WQv that must be provided at a site and can be achieved either by a structural practice (e.g., infiltration, bioretention), a nonstructural practice (e.g., buffers, disconnection of rooftops), or a combination of both.

Drainage areas having no impervious cover and no proposed disturbance during development may be excluded form the Re_v calculations. Designers are encouraged to use these areas an non-structural practices for Rev treatment (see Chapter 5, "Stormwater Credits for Innovative Site Planning").

Note: Rev and WQ_v are inclusive. When treated separately, The Re_v may be subtracted form the WQ_v when sizing the water quality BMP (see page 2.4, 'Subtraction for Structural Practices).

The recharge volume criteria do not apply to any portion of a site designated as a stormwater hotspot nor any project considered as redevelopment. In addition, the appropriate local review authority may alter or eliminate the recharge volume requirement if the site is situated on unsuitable soils (e.g., marine clays), karst or in an urban redevelopment area.

4.5.4 Channel Protection Storage Requirements

When using bioretention and integrated LID techniques to address stormwater management, channel protection storage requirements need to be calculated to meet MDE criteria. The following excerpts from the state manual have been included for comparison. In our example, the Tc from the site is 15 minutes or 0.25 hr. With distributed bioretention facilities, and dispersed drainage, the Tc remains the same as the pre-developed Tc. Tc = 15 min. = 0.25 hr

Initial Abstraction, I_a = (200 / CN) – 2 = (200 / 63) – 2 = 1.17
I_a/P = 1.17/2.7 = 0.43
From Figure D-11.1(of MDE 2000), unit peak factor, q_u = 460 *csm/in*
From Figure D-11.2 (of MDE 2000), with T=24 hr, q_o/q_i = 0.040
V_s/V_r = 0.683 – 1.43 (q_o/q_i) + 1.64 (q_o/q_i)2 – 0.804 (q_o/q_i)3 = 0.628
Where $V_r = Qa$ = 0.3” (2.7” rainfall with CN = 63);
Therefore, V_s = *0.3” x 0.628 = 0.188” = 0.188 x 3.36/12 = 0.053 acre feet*

Therefore, the total storage required
= $WQ_v + Cp_v$ = 0.06 + 0.053 = 0.113 *ac – ft*
Compare it with the storage needed for LID = 0.121 acre feet

Channel Protection Storage Volume Requirements (Cp_v)

To protect channels from erosion, **24 hour extended detention of the one-year, 24 hour storm event** (MDE, 1987) shall be provided. In Use II and IV watersheds, only 12 hours of extended detention shall be provided. The rationale for this criterion is that runoff will be stored and released in such a gradual manner that critical erosive velocities during bankfull and near-bankfull events will seldom be exceeded in downstream channels.

The Cp_v requirement does not apply to direct discharges to tidal water or Maryland’s Eastern Shore (as defined in Figure 2.4) unless specified by an appropriate review authority on a case by case basis. Local governments may wish to use alternative methods to provide equivalent stream channel protection such as the Distributed Runoff Control method or bankfull capacity/duration criteria (MacRae, 1993).

4.5.5 Overbank Flood Protection Volume Requirements

According to the state criteria stated below, if a jurisdiction has no control of conveyance, floodplain area, or downstream flooding will occur, Overbank Protection Volume is required. In Prince George’s County, the ultimate 100-year floodplain is regulated. Additionally, where needed, conveyance system improvements could be required off-site. Therefore, Overbank Protection Volume is not required for developments using bioretention for stormwater management controls.

4.5.6 Extreme Flood Volume Requirement

Extreme Flooding Volume is not required for developments in Prince George’s County except under extenuating circumstances. Extreme flood volume does not apply for developments that have been approved for LID or bioretention installations. In cases where required, follow the state requirements or the county requirements, whichever are more stringent (conservative).

4.5.7 Total Stormwater Management Volume Requirement

In the final analysis, using the state sizing methodology, the volume required for stormwater storage is 0.113 acre feet.

Determine bioretention sizing needed to accommodate volume requirements.

Use 12 inches maximum surface ponding depth and at least one facility per lot.
0.113 ac. ft = 0.113ac. ft x (43,560 sq. ft/ac.) = 4923 sq. ft
4923 sqft / 6 lots = 821 sq. ft per lot
Typical bioretention configuration = *20' x 41'* on average.

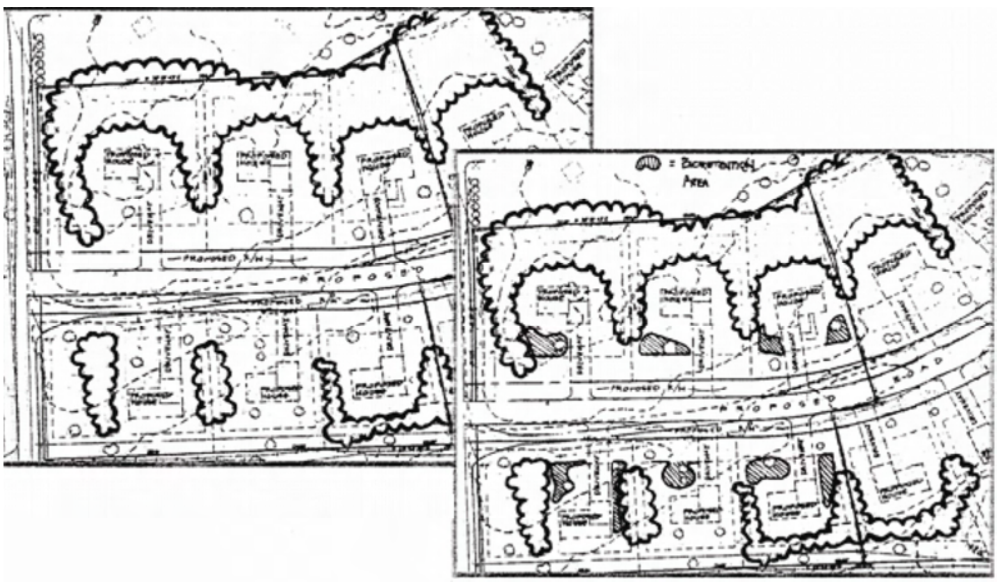


Figure 4.2. Proposed site plans without and with bioretention

Figure 4.2 above show the proposed site plan for the example provided. By calculating the total volume needed to meet the stormwater requirements, the total bioretention surface area is calculated on the basis of the depth available. The facilities are uniformly distributed throughout the site and placed at locations that can maximize each of the facilities' efficiency.

Overbank Flood Protection Volume Requirements (Q_p)

The primary purpose of the overbank flood protection volume sizing criteria is to prevent an increase in the frequency and magnitude of out-of-bank flooding generated by development (e.g., flow events that exceed the bankfull capacity of the channel and therefore must spill over into the floodplain). Overbank flood protection for the ten-year storm shall only be required if local approval authorities have no control of floodplain development, no control over infrastructure and conveyance system capacity design, or determine that downstream flooding will occur as a result of the proposed development.

For most regions of the State, the overbank flood control criteria translates to preventing the post development ten-year, 24 hour storm peak discharge rate (Q_{p10}) from exceeding the predevelopment peak discharge rate.

On the Eastern Shore of Maryland, the overbank flood control criteria is defined as preventint the post development two-year, 24 hour storm peak discharge rate (Q_{p2}) from exceeding the predevelopment peak discharge rate. The rainfall depths associated with the two and ten-year, 24 hour storm events are shown in Table 2.2.

4.5.8 Bioretention Applicability with State Criteria

Designers intending on implementing a site design employing bioretention facilities are strongly encouraged to use this *Bioretention Manual* as a supplement to the MDE regulations and standards that are applicable to bioretention. Many of the specifications detailed in the *MDE Manual* have been based on our 1993 edition of the *Bioretention Manual*. Prince George's County has been modifying that criterion over the past 10 years to help ensure successful installations. Those modifications have been itemized in the beginning of this manual under the heading, "Notice to Manual Users."

As stated previously, the MDE has endorsed the use of bioretention and LID techniques to meet the new state Stormwater Management Regulations. Within the state manual, bioretention is listed as an acceptable BMP for infiltration and filtration. The following excepts and Figure 4.3 from the state manual are provided for convenience: Used in conjunction with Non-Structural BMPs, bioretention can easily meet the state's stormwater management criteria.

Excerpts from State Manual

BMP Group 3. Infiltration Practices

Practices that capture and temporarily store the WQ_v before allowing it to infiltrate into the soil over a two day period include:

- I-1 infiltration trench
- I-2 infiltration basin

BMP Group 4. Filtering Practices

Practices that capture and temporarily store the WQ_v and pass it through a filter bed of sand, organic matter, soil or other media are considered to be filtering practices. Filtered runoff may be collected and returned to the conveyance system. Design variants include:

- F-1 surface sand filter
- F-2 underground sand filter
- F-3 perimeter sand filter
- F-4 organic filter
- F-5 pocket sand filter
- F-6 bioretention*

*May also be used for infiltration

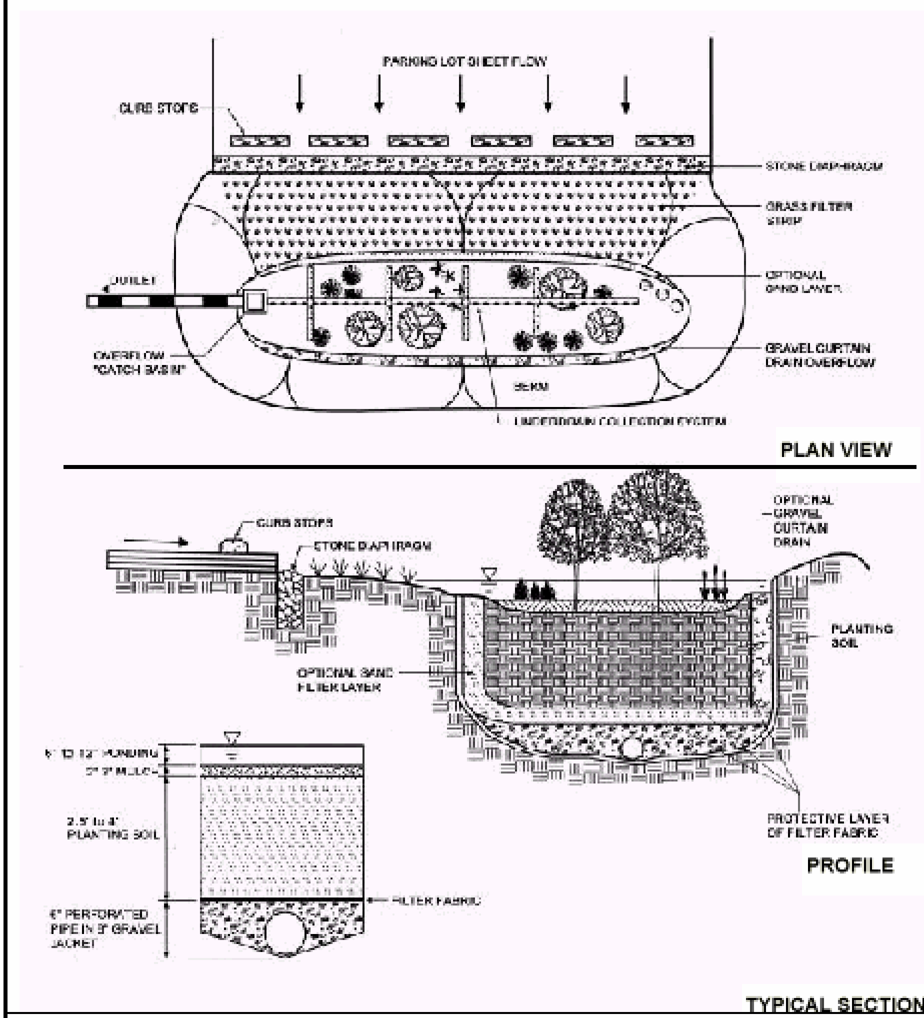
BMP Group 6. Non-structural BMPs

Non-structural BMPs are increasingly recognized as a critical feature of stormwater BMP plans, particularly with respect to site design. In most cases, non-structural BMPs shall be combined with structural BMPs to meet all stormwater requirements. The key benefit of non-structural BMPs is that they can reduce the generation of stormwater from the site; thereby reducing the size and cost of structural BMPs. In addition, they can provide partial removal of many pollutants. The non-structural BMPs have been classified into seven broad categories. To promote greater use of non-structural BMPs, a series of credits and incentives are provided for developments that use these progressive site planning techniques in Chapter 5.

- Natural area conservation
- Disconnection of rooftop runoff
- Disconnection of non-rooftop impervious area
- Sheet flow to buffers
- Open channel use
- Environmentally sensitive development
- Impervious cover reduction

Important Note:
The applicability of using bioretention to meet the MDE stormwater management criteria in the example provided above does not consider the credits that could be achieved by environmentally friendly site development practices and principles. Therefore, the designer could conceivably get additional storage volume reductions by following the credit application portion of the State Manual in addition to the above.

F-6	**Figure 3.17** Example of Bioretention	F-6



Bioretention combines open space with stormwater treatment.

Figure 4.3. Example of bioretention from the state manual

Filtering Treatment Criteria

- The entire treatment system (including pretreatment) shall temporarily hold at least 75% of the WQ_v prior to filtration.
- The filter bed typically has a minimum depth of 18”. The perimeter sand filter shall have a minimum filter bed depth of 12”.
- Filtering practices typically cannot povide Cpv or Qv under most conditions.
- The filter media shall conform to the specifications listed in Table B-3.1 (Appendix B-3) [*State’s Manual*].

4.6 Bioretention Design Example Using the Prince George's County Stormwater Management Requirements Management Sizing Criteria

The Prince George's County Bioretention design criteria are based on the LID hydrologic analysis presented in the *Low-Impact Development Hydrologic Analysis* companion document (EPA 2000). The following example assumes that the reader is familiar with LID methodology. For a more detailed description and additional sizing examples, see the LID companion document.

4.6.1 Background Information

Note: Use the same background information provided in the previous example.

4.6.2 Procedure and Solution

Step 1. Determine the percentage of each land cover occurring on site:

For our example, this information is provided in the Table 4.3 above.

Step 2. Calculate the custom composite CN for the pre- and post-conditions:

For conventional site design, the designer would refer to Figure 2.2a of the Technical Release #55 (SCS 1986). The conventional CN for our site would be 68.

Using the background information presented above, the custom predevelopment composite CN = 55 and the post development composite CN_c = 67.

$CN_c = CNp + (P_{imp}/100) \times (98 - CNp) \times (1 - 0.5R)$, *where:*

R = ratio of unconnected impervious area to total impervious area;

CN_c = composite CH;

CNp = composite pervious CN; and

P_{imp} = percent of impervious site area.

(Equation 4.2 in Chapter 4 of the *LID Hydrologic Analysis* manual.)

Step 3. Calculate LID CN based on connectivity of the site imperviousness:

For our example, we will adjust that CN to account for the disconnected imperviousness. Remember, one of our assumptions when using uniformly distributed bioretention facilities is that there is essentially 100 percent disconnected impervious surfaces. Therefore

$CN_p = (55 \times 0.54) + (61 \times 2.22)/0.54 + 2.22) = 59.8$
$CN_c = CNp + (P_{imp}/100) \times (98 - CNp) \times (1 - 0.5R)$, *where* $R = 1.0$
$CN_c = 59.8 + 0.179 \times (98 - 59.8) \times 0.5$
$CN_c = 59.8 + 3.41 = 63.2$; *Use 63*

Note: For bioretention, *R* (the ratio of disconnectivity) will always equal 1.0 because once the water is intercepted, that portion of the drainage area is disconnected. This is true for any BMP that intercepts runoff from impervious areas before the runoff enters a stream channel directly.

Step 4. Determine the Design Storm:

Determine the amount of rainfall (*P*) needed to initiate direct runoff by using the following equation:

$P_{24} = 0.2 \times [(1000/CN_{pre}) - 10]$ *(use CNpre for woods in good condition)*
$P_{24} = 0.2 \times 8.18 = 1.64$ *inches*

Step 5. Account for variation in land cover:

Multiply P_{24} *by a factor of 1.5*
1.64" x 1.5 = 2.46"; compare the one-year storm event (2.7")
and use the higher value.
Therefore, use $P_{24} = 2.7$*".*

Step 6. Determine storage volume required to maintain Predevelopment Runoff Volume using retention storage using Chart Series A:

In Prince George's County, the proper storm to use is the SCS Type II Rainfall Distribution for a 24 Hour Storm. Therefore; Chart Series A, Type II should be used for this example.

In our example, 2.7" falls between the 2 and 3 inch storm charts, so both charts will be used to find the solution through interpolation.

Using Chart A, Type II, 2" Storm, we get 0.09".
Using Chart A, Type II, 3" Storm, we get 0.22".
Through interpolation, we find the storage volume required to maintain the predevelopment runoff volume using retention storage is 0.18".
Applying the 0.18" to our site portion as shown in Figure 4.1,
(0.18" x 3.36Ac)/12 = 0.00504 acre feet
Use 0.051 ac-ft

Step 7. Determine Volume for Water Quality Control:

In Prince George's County, as well as all of Maryland, a minimum requirement for water quality control is equivalent to the first inch of runoff from impervious surfaces.

For our site, we have 18 percent impervious areas; therefore, the water quality requirement is: *(3.36acres x .18) x 1"/ 3.36 = 0.18"*. This is equal to the calculated storage volume of 0.18". Therefore, use storage for runoff volume control to meet water quality requirement.

Step 8. Determine storage volume required to maintain predevelopment peak runoff rate using 100 percent retention.

Use Chart Series B Type II, 2" and 3" storm charts
From the 2-inch chart = *0.08"*

From the 3-inch chart = *0.25"*
Interpolating, we get 0.20 inches (approximately 0.056 ac-ft).

Because this storage *(0.056 ac-ft)* is larger than the storage needed to maintain the predevelopment runoff volume *(0.051 ac-ft)*, additional detention storage is needed to maintain predevelopment peak discharge.

Use chart Series C, Type II, 2" and 3" storm chart.
From the 2-inch chart = 0.06"
From the 3-inch chart = 0.17"
Interpolating, we get 0.14 inches. Therefore; use hybrid facility design procedure to determine the additional detention storage.

X = (50/(0.20 – 0.14)) (-0.14 + squareroot of [(0.14)2 + 4(0.20 – 0.14) x 0.18]
= 92.2%

Therefore, the required retention storage (0.18") is 92.2 percent of the total storage. Therefore, the total storage required is

= 0.18/0.922 = 0.195"
Applied to our site = *0.195" x 3.36 acre /12 = 0.055 ac-ft*
(0.11 acre feet if 6" storage is used).

To reduce the surface area of the bioretention areas, we calculate the storage within soil layers in the bioretention facilities. The additional volume is derived based on the following assumptions:

1. The soil medium is composed chiefly of minimally compacted sand/leaf compost mixture, and the void ratio is 30 percent.

2. The depth of soil medium available below the underdrain is 2 feet. This volume is used for recharge and extended detention.

= 0.11 acres x 2.0 ft x 0.30 = 0.066 ac-ft
Therefore, the total storage is"
Total = 0.055 + 0.066 = 0.121 ac-ft

Step 9. Determine bioretention sizing needed to accommodate volume requirements. Use 6-inch maximum surface ponding depth and at least one facility per lot.

0.05 Ac-ft/.5 ft = 0.1 acres needed for bioretention.
0.1 acres = 4356 sq. ft / 6 lots = 726 sq. ft per lot
Typical bioretention configuration = *25' x 29'* on average.

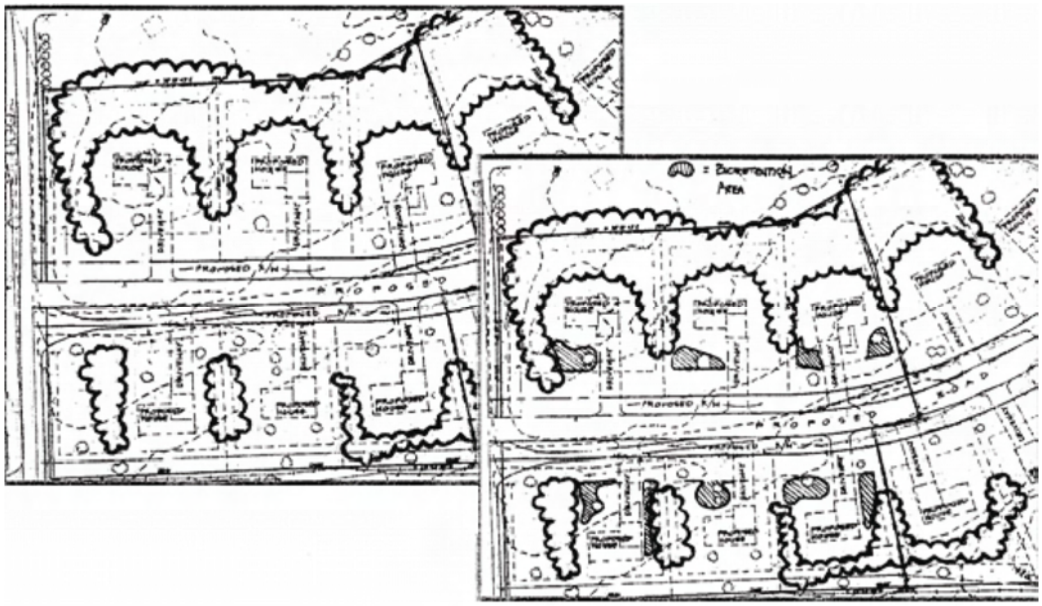


Figure 4.4. Example site plans with and without bioretentions

Figure 4.4 above show the proposed site plan for the example provided. By calculating the total volume needed to meet the stormwater requirements, the total bioretention surface area is calculated on the basis of the depth available. The facilities are uniformly distributed throughout the site and placed at locations that can maximize each of the facilities efficiency.

Note that some areas go uncontrolled, while other areas will be controlled at a higher level to compensate. In addition, portions of the site where the land cover has not changed from a preexisting natural state, no control is required unless a flooding or erosion problem must be addressed.

4.6.3 Bioretention Sizing Chart

To simplify the above bioretention sizing process, a chart has been developed. Known as the Bioretention Sizing Chart (Figure 4.5), the post development runoff CN is compared to the surface area of the facility as a percent of the contributing drainage area. Therefore, the designer needs to determine only the post-development CN and the drainage area to use the chart to come up with the surface area of a bioretention facility, which is based on the following assumptions:

1. The surface storage depth is 6 inches.

2. Soil storage capacity is equal to 2.5 feet of depth with a 30 percent void ratio and no underdrain.

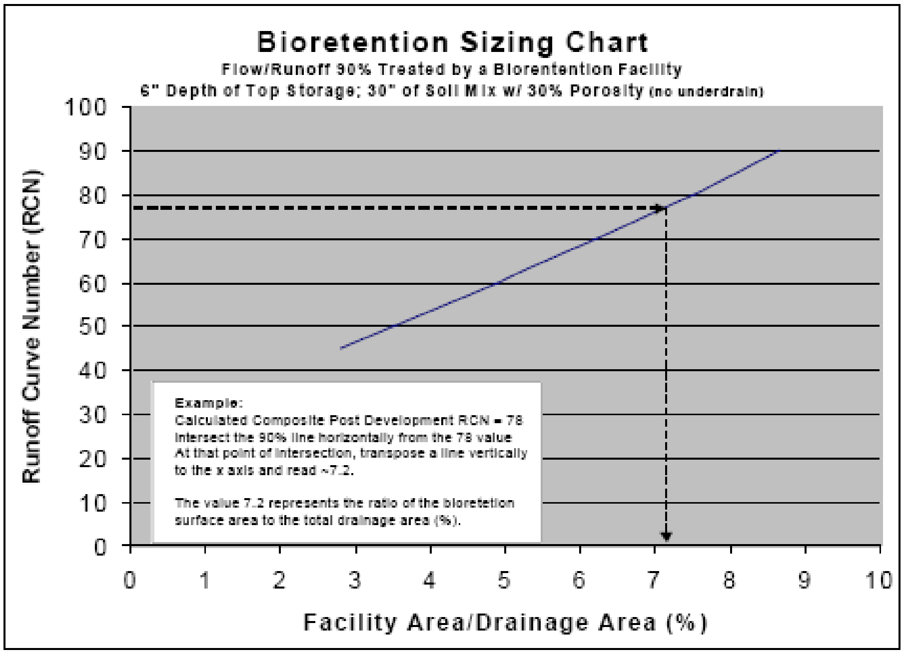


Figure 4.5. Bioretention sizing chart

4.7 Bioretention Component Design

After the designer has determined the volume of bioretention, perform a detailed design of the individual bioretention components. Guidance is provided for the following bioretention components:

- Inflow design
- Pretreatment
- Ponding area
- Overflow
- Filter/soil media
- Underdrain

4.7.1 Inflow Design

The inflow design is critical to the proper functioning of the facility. There are essentially three key considerations to address for inflow: (1) velocity control to prevent excessive erosion; (2) equal and uniform distribution of inflow across the surface of the facility; and (3) safe overflow or bypass path. Several different inflow entrance designs can be used as shown below:

1. Concrete wheel stops along perimeter facility
2. Concrete or macadam curb with curb-cut openings)
3. Sheet flow across paving or grass area
4. Stone diaphragm

4.7.2 Pretreatment

MDE recommends that adequate pretreatment for a bioretention system can be achieved when all the following elements are provided:

- A 20-foot grass filter strip below a level spreader or optional sand filter layer (**Note**: In practice, this element is often prohibitive to provide, and Prince George's County will usually waive this requirement.)
- A gravel or stone diaphragm (**Note**: The gravel size material is often inadequate to prevent erosion, and the use of larger stone material, 3–5 inches in diameter is recommended.)
- Mulch layer (**Note**: Mulch can become suspended during a storm and is subject to wash off from the site. It is recommended that the mulch be covered with an erosion blanket to prevent flotation.)

4.7.3 Ponding and Treatment Area

MDE requires that the entire treatment system (including pretreatment) must temporarily hold at least 75 percent of the WQv before filtration.

Bioretention systems should include the following treatment components:

- A 2.5- to 4.0-foot deep planting soil bed
- A surface mulch layer (3–4 inches thick)
- A 12-inch deep surface ponding area

The required ponding area (*Af*) is computed using the following equation:

$$Af = (WV)(df) / [\ (k)\ (hf + df)\ (tf)]$$

Where:

Af	=	Surface area of filter bed (ft^2)
WV	=	Design water volume, (ft^3) (WQv for water quality design; Cpv for channel protection volume)
df	=	filter bed depth (ft)
k	=	coefficient of permeability of filter media (ft/day)
hf	=	average height of water above filter bed (ft)
tf	=	design filter bed drain time (days)*

* 2.0 days are recommended for bioretention

4.7.4 Filter Media

MDE recommends a filter media or planting soil depth of 2.5 to 4.0 feet.

Coefficient of Permeability (k) values (MDE 2000):

Sand:	3.5 ft/day
Peat:	2.0 ft/day
Leaf compost:	8.7 ft/day
Bioretention soil:	0.5 ft/day*

*It should be noted that this value appears to be an error since it corresponds to the "k" value for a silt loam which is not an MDE approved bioretention soil media. The MDE approved bioretention soil media include the following soil textural classifications and "k" values:

Soil Textural Class	K value	
Loam	1.04 ft / day	0.52 in. / hr
Sandy Loam	2.04 ft/day	1.02 in. /hr
Loamy Sand	4.82 ft./day	2.41 in./hr

4.7.5 Overflow

MDE requires that if runoff is delivered by a storm drain pipe or is along the main conveyance system, the bioretention system must be designed off-line. See detail No. 5 in MDE 2000.

Overflow for the 10-year storm must be provided to a non-erosive outlet point (e.g., prevent downstream slope erosion). For critical non-erosive velocities, see Appendix D.12 of MDE 2000.

4.7.6 Underdrain Specification

The following sections provide guidance for underdrain requirements.

4.7.6.1 Underdrain Material Types

Underdrain systems can be composed of a variety of materials, with PVC pipe material being the most commonly used. PVC pipe comes in 8- to 12-foot sections. Alternative pipe material can include flexible ADS pipe. Other pipe materials can be substituted at the designer's prerogative and with concurrence of the county.

4.7.6.2 Underdrain Connections

Pipe joints and storm drain structure connections must be adequately sealed to avoid piping conditions (water seeping through pipe or structure joints). Pipe sections must be coupled using suitable connection rings and flanges. Field connections to storm drain structures and pipes must be sealed with polymer grout material that is capable of adhering to surfaces. Underdrain pipe must be capped (at structure) until completion of site. Underdrains connected directly to a storm drainage structure must be non-perforated for a distance of at least 5 feet from the structure interface to avoid possible piping problems.

4.7.6.3 Underdrain Perforations

Perforated PVC pipe sections are available from local hardware stores. The perforation locations are not too critical for proper function, as long as the total opening area exceeds the expected flow capacity of the underdrain itself. Commonly marketed perforated PVC pipe has one-quarter or one-half-inch perforations, 6 inches center to center, along two or three longitudinal rows. Whether the perforations are placed at the invert of pipe or elsewhere, depends on the design of the facility. Typically, the perforations are placed closest to the invert of the pipe to achieve maximum potential for draining the facility. The perforations can be placed near the top of the pipe if an anaerobic zone is intended.

Water below the perforated portion of the underdrain will have a tendency to accumulate during periods of saturation. Otherwise, water will have a tendency to infiltrate into the surrounding *in situ* soils. See specifications table for specifics relating to underdrain perforations. No perforations are to be within 5 feet of where the underdrain system connects to a storm drain structure.

4.7.6.4 Underdrain Locations

Underdrains are typically located at the invert of the bioretention facility to intercept any filtered water that does not infiltrate into the surrounding soils. Soil and gravel cover over the underdrain must be at least 2 feet deep. Placement of 2- to 3-inch gravel bedding is recommended beneath the discharge points. Underdrains must *daylight* or connect to an existing drainage system to achieve positive flow. Suitable discharge points include the following:

- Grass swale areas, flush cut with side slope areas
- Storm drain pipe conveyance system

4.7.6.5 Observation/Cleanout Standpipe

An observation/cleanout standpipe must be installed in every bioretention facility that has a depth greater than 2 feet or an underdrain system. The standpipe will serve three primary functions: (1) it will indicate how quickly the bioretention facility dewaters following a storm; (2) it provides maintenance cleanout port; and (3) it will be connected to the underdrain system to facilitate cleanout.

The observation standpipe must consist of a rigid non-perforated PVC pipe, 4 to 6 inches in diameter. It should be in the center of the structure and be capped flush with the ground elevation of the facility. The top of it must be capped with a screw, or flange type cover to discourage vandalism and tampering. A lock is not necessary.

4.7.7 Filter Materials

4.7.7.1 Gravels

Gravel bed materials are sometimes used to protect an underdrain pipe to reduce clogging potential. Placement of the gravel over the underdrain must be done with care. Avoid dropping the gravel high levels from a backhoe or front-end loader bucket. Spill the gravel directly over the underdrain and spread it manually. The construction specifications for gravel used to protect bioretention underdrains follows.

- Gravel stone size may not be greater than one-half inch to 1.5 inch in diameter. (Blue stone, double washed, #57 stone)
- The use of pea gravel in place of geotextile fabric is optional, but preferred.
- Depth of the gravel must not exceed 12 inches.
- River-run, washed gravel is preferred.

4.7.7.2 Pea Gravel Diaphragm

Older specifications for bioretention used a geotextile fabric to filter water and soil before passing through to the underdrain gravel blanket. The use of a pea gravel diaphragm has gained acceptance because of the reduced likelihood of blockage. If a pea gravel diaphragm is used in this manner, it should have a minimum thickness of 3–4 inches and a maximum thickness of 8 inches. Where situations permit, a greater depth can be applied. A permeable filter fabric must be placed over the underdrain gravel blanket and beneath the pea gravel diaphragm—only where the underdrain is located and extending 2 feet to either side.

4.7.7.3 Filter Fabric

Filter fabric is needed for two purposes in bioretention facilities: (1) Controlling transport of silt, and (2) Controlling the direction of flow. In some older designs, the filter fabric placed on top of the gravel bed is used to control sediment transport into the gravel bed, which otherwise could become clogged. This filter fabric must meet a minimum permittivity rate of 75 gal/min/ft^2 and must not impede the infiltration rate of the soil medium. Filter fabric can be placed along the *walls* of the facility to help direct the water flow downward and to reduce lateral flows. Filter fabric must be placed along the sidewalls (from the subgrade and over the stone), when installing a facility in a median strip or parking lot landscape island to prevent lateral flow under pavement.

4.7.8 Liners

Where bioretention is used for areas that require groundwater protection (stormwater hot spots or source water protection), a liner is employed. The minimum thickness for liners used in bioretention applications is 30 mil. Any underdrain systems should be placed above the liner with a provision to cap the underdrain discharge pipe to confine drainage if needed. Care during placement of the liner is necessary to avoid puncture. Soil medium placed over the liner should be placed by hand shovel and not with construction equipment.

4.8 Bioretention Site Submittal Requirements

Bioretention Plan Review Checklist

Project Name: ____________________ Date Received: ____________

Project Address: ____________________

Case #: ____________________

Accepted	Not Accepted	N/A	
			Plan Standard Notes and Specifications
			Notes on sediment & erosion controls.
			Sequence of Construction.
			Sediment control notes for bioretention facilities during construction.
			Specifications for construction materials.
			Specifications for planting soil medium requirements.
			Compaction Notes.
			Easements.
			Copy of concept letter.
			Storm drain notes.
			Stormwater management construction specifications.
			Plan Layout
			Vicinity map.
			Owner / developer information.
			Approval box.
			Plan view of site & facilities.
			Cross-section along centerline of bioretention.
			Cross-section along stormdrain or flow path.
			Existing grades and proposed grades.
			Elevation at surface, ponding elevation.
			Standard detail for bioretention.

Accepted	Not Accepted	N/A	
			Landscaping plan.
			Soil map.
			Inflow and discharge points/connections.
			Drainage Area to Facilities
			DAM delineated to each facility.
			Drainage area less than 2 acres max.
			Facilities located near source.
			Facilities not to be placed where concentrated water discharge exceeds 3 cfs.
			Grading
			Existing and proposed contours with limits of disturbance.
			Spot elevations at entrance invert.
			Underdrain invert elevation and facility invert elevation.
			½ inch contours for detail at facility.
			Not crossing properties and 2-foot min. from property lines.
			Not to be built in public right of ways.
			Not to be built where wooded areas would need to be cleared to make room for the facility.
			Sloped areas exceeding 20% shall not be used for bioretention except “weep-gardens” designs.
			25 ft. setback from the home foundation.

Accepted	Not Accepted	N/A	
Facility Components			
______	________	_____	Pretreatment - Erosion protection: RipRap, Reno mattress, etc.
______	________	_____	Flow entrance – Curb cut, curb deflector, pipe outfall, etc.
______	________	_____	Flow entrance – Curb cut, curb deflector, pipe outfall, etc.
______	________	_____	Ponding area – depth 6 inch max.
______	________	_____	Planting soil medium – 50% construction sand, 20-30% organic leaf compost, and 20-30% topsoil with a max. of 5% clay content.
______	________	_____	Mulch and/or groundcover
______	________	_____	Filtering mechanism - Gravel and Filter Cloth - Peagravel
______	________	_____	- Other ______________________________
______	________	_____	Underdrain or outlet - Approved pipe material, pipe size perforation size.
______	________	_____	Safe overflow allowance
Design Computations			
______	________	_____	Facilities designed for water quality and/or water quantity control
______	________	_____	Method of Sizing: MD Unified Sizing Methodolgy ____________ Prince George's LID Methodolgy ____________ Prince George's % DA Methodology ____________
______	________	_____	Post Development RCN Value.
______	________	_____	Geotechnical Report
Landscaping Detail			
______	________	_____	Plan view of landscaping.
______	________	_____	Plant list.
______	________	_____	Planting notes.
______	________	_____	Planting schedule and specifications.
______	________	_____	Standard detail for planting.
______	________	_____	Use bioretention plant list – (No exotic or invasive plants).
Permitting			
______	________	_____	Sediment / Erosion Control.
______	________	_____	Stormdrain permit for construction.
______	________	_____	Easement or Maintenance Covenant.

Comments ____

____

____

____

____

____

First Review: **Reviewer** ______________________________ **Date** ____________

Please complete all items checked "Not Accept" and return with corrections.

Second Review: **Reviewer** ______________________________ **Date** ____________

Please complete all items checked "Not Accept" and return with corrections.

I hereby approve all items listed above as being completed as per County specifications.

Reviewer's Signature ______________________________ Date ____________

Bioretention Design Specifications

The following chart itemizes the design specification standards that may be utilized in the development of a bioretention facility. The specifications are to be used as a guideline only, and may be substituted with an approved equal.

Component	Specification	Dimensions/Size	Reference Notes
Underdrain Pipe	Rigid Schedule 40	6-8" Diameter	Slope @ ___%
Underdrain Perforations		½", 6" c to c, top and sides	Smaller perforation sizes allowed
Underdrain Gravel Bed	AASHTO M-43	½"–1" diameter	Washed stone preferred #57
Pea Gravel Diaphragm	ASTM D 448	¼"–½" diameter pebbles	
Soil Medium - Sand - Top soil - Lead compost	Construction Sand, PGCODER Grading Ordinance	.02"–.04" diameter	Coarse sand, less than 5% clay
Impervious Liner		30 mil. Minimum	
Geotextile Fabric	See SWM Design Manual	Non-woven	ASTMD 4491
Mulch Material	Raw Hardwood	Varies	–
Plant Material	See Plant Listing	Varies	–
Observation Well/Cleanout Stand Pipe	Rigid Shield (no perforations	4" or 6" Diameter	Open at bottom or attached to underdrain with standard "T" connection

Comparison Examples Sizing Bioretention

The following examples show the results obtained by following the same methodology detailed in the preceding pages of this chapter. Three example results are shown, comparing the MDE Unified SWM Sizing methodology to the LID Sizing methodology.The LID charts used in the examples have also been included at the end of this chapter for ease of review and analysis by the designer.

Example No. 1	**Mde & Lid Sizing Comparison** **1/2 Acre Residential - 18% Impervious Area**

Site Information:

1/2 Acre Residential Development (18% Impervious Area)
Site Are, A = 3.36 acres
Hydrologic Soil Group = B
Existing Runoff Curve Number = 55 (Woods, Good Conditions)
Proposed Runoff Curve Number = 68 (TR-55)
Using LID approaches w/ impervious area disconnection, RCN = 63
Time of Concentration, Tc = 10 minutes
LID Design Storm, P = 2.7 inches (one-year storm, Factor = 1.5)

Storage Requirement (Maryland Design Manual)

Water Quality Volume = 0.060 acre-ft
Groundwater Recharge Volume = 0.015 acre-ft (part of WQ volume)
Channel Protection Volume = 0.053 acre-ft
TOTAL VOLUME = 0.060 + 0.053 = 0.113 acre-ft

Storage Requirement (Low-Impact Development)

6" Bioretention Storage = 0.051 acre-ft. (0.102 acre area)
Additional Detention Storage = 0.004 acre-ft
2' Soil Layer in Bioretention= 0.066 acre-ft
Total Volume = 0.051+0.004+0.066 = 0.121 acre-ft

In the above example, the 2' layer in the bioretention facility is equal to the void area (30%) below the invert of a raised underdrain.

Comparison Examples Sizing Bioretention

Example No. 2	**MDE & LID Sizing Comparison** **½ Acre Residential - 22% Impervious Area**

Site Information:

1/2 Acre Residential Development (22% Impervious Area)
Site Area, A = 21.0 acres Hydrologic Soil Group = B
Existing Runoff Curve Number = 55 (Woods, Good Conditions)
Proposed Runoff Curve Number = 69 (higher impervious area)
Time of Concentration, Tc = 0.21 hr.
LID Design Storm, P = 3.0 inches (greater than one-year storm, Factor = 1.8)

Storage Requirement (Maryland Design Manual)

Water Quality Volume = 0.434 acre-ft
Groundwater Recharge Volume = 0.109 acre-ft (part of WQ volume)
Channel Protection Volume = 0.584 acre-ft
Total Volume = 0.434 + 0.584 = 1.018 acre-ft

Storage Requirement (Low-Impact Development)

6" Bioretention Storage = 0.788 acre-ft. (1.576 acres area)
Additional Detention Storage = 0.000 acre-ft (not needed)
1 Soil Layer in Bioretention = 0.475 acre-ft
Total Volume = 0.788+0.950 = 1.238 acre-ft

Example No. 3	**Commercial Area - 63.3% Impervious Area**

Site Information:

Commercial Area (63.3% Impervious Area)
Site Area, A = 3.00 acres Hydrologic Soil Group = B
Existing Runoff Curve Number = 55 (Woods, Good Conditions)
Proposed Runoff Curve Number = 87
Time of Concentration, Tc = 0.16 hr.
LID Design Storm, P = 3.0 inches (greater than one-year storm, Factor 1.8)

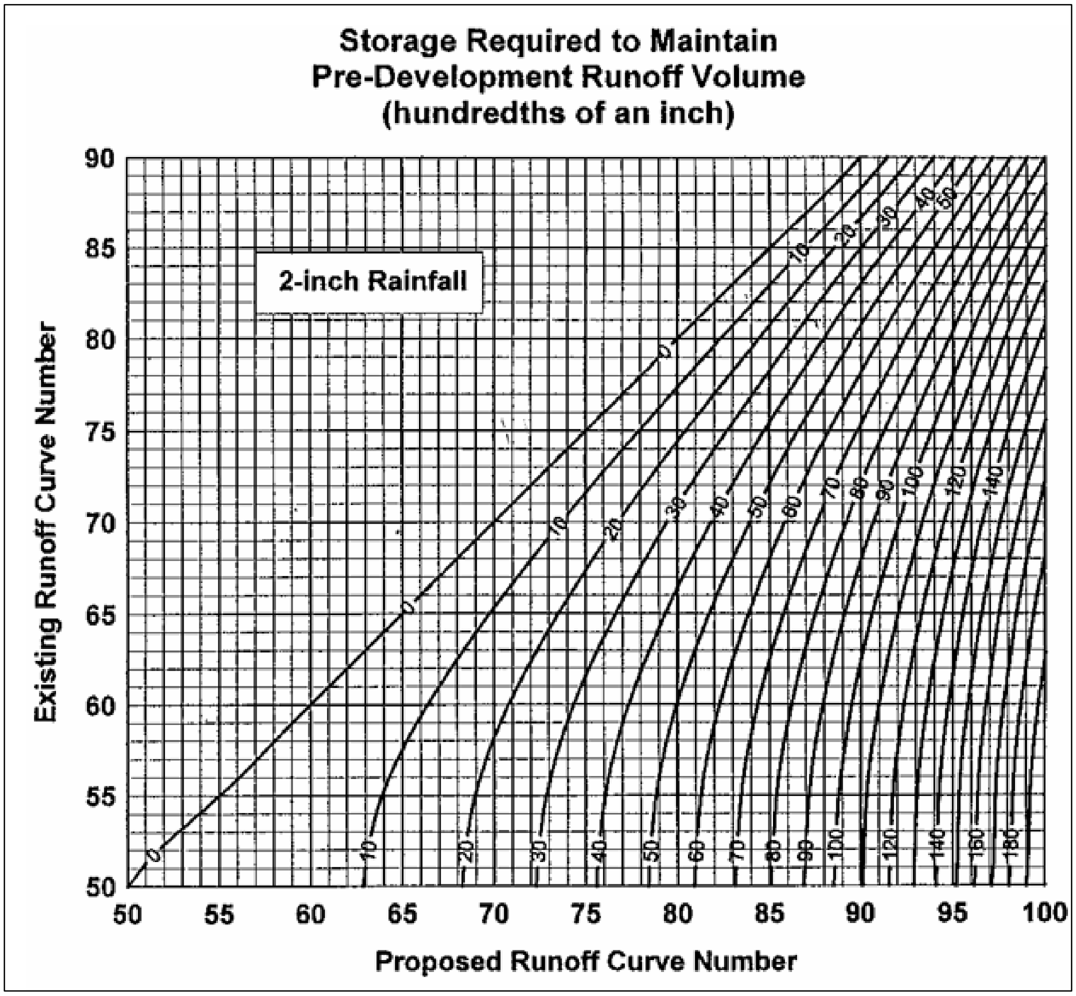
Storage Requirement (Maryland Design Manual)

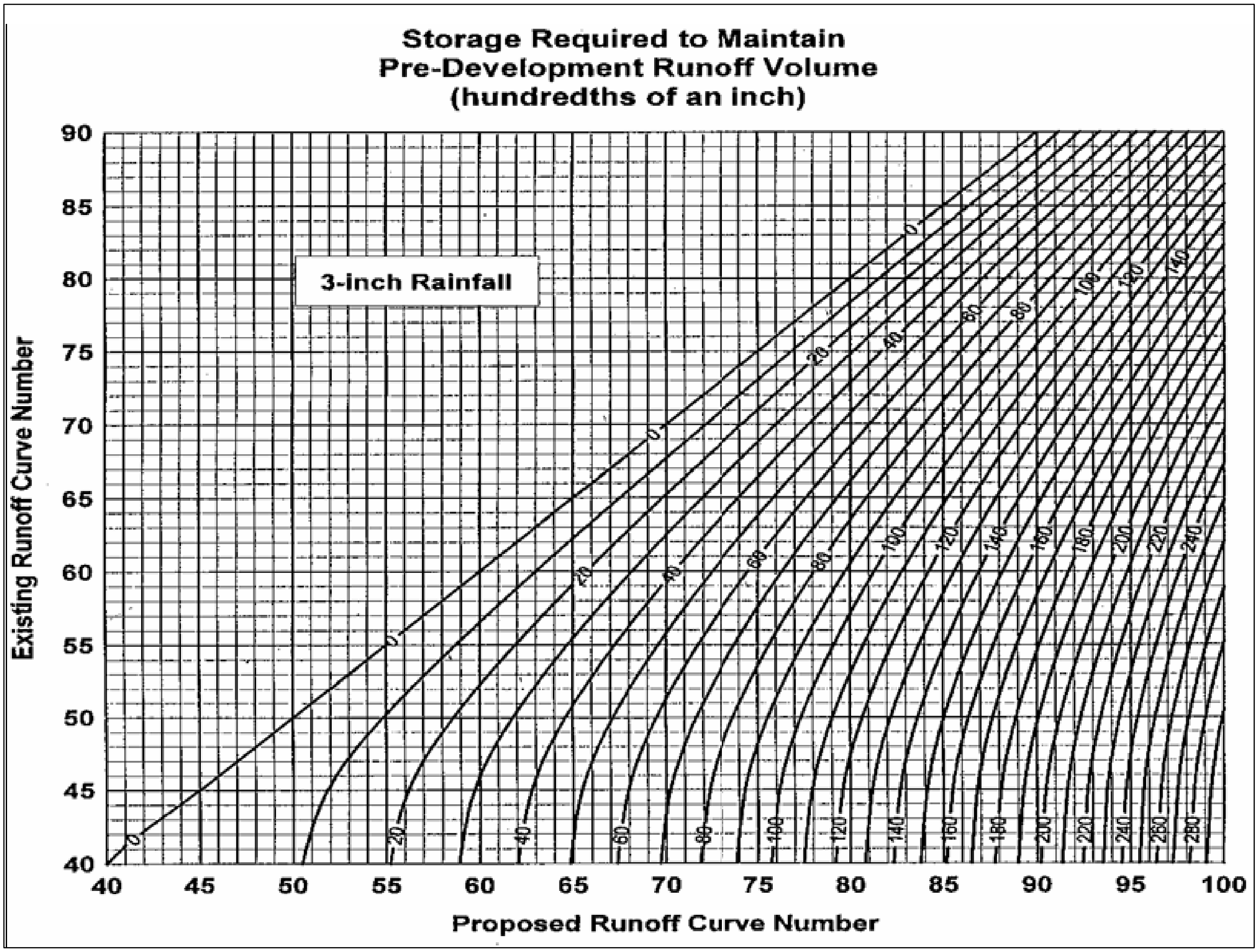
Water Quality Volume = 0.155 acre-ft
Groundwater Recharge Volume = 0.109 acre-ft (part of WQ volume)
Channel Protection Volume = 0.246 acre-ft
TOTAL VOLUME = 0.155 + 0.246 = 0.401 acre-ft

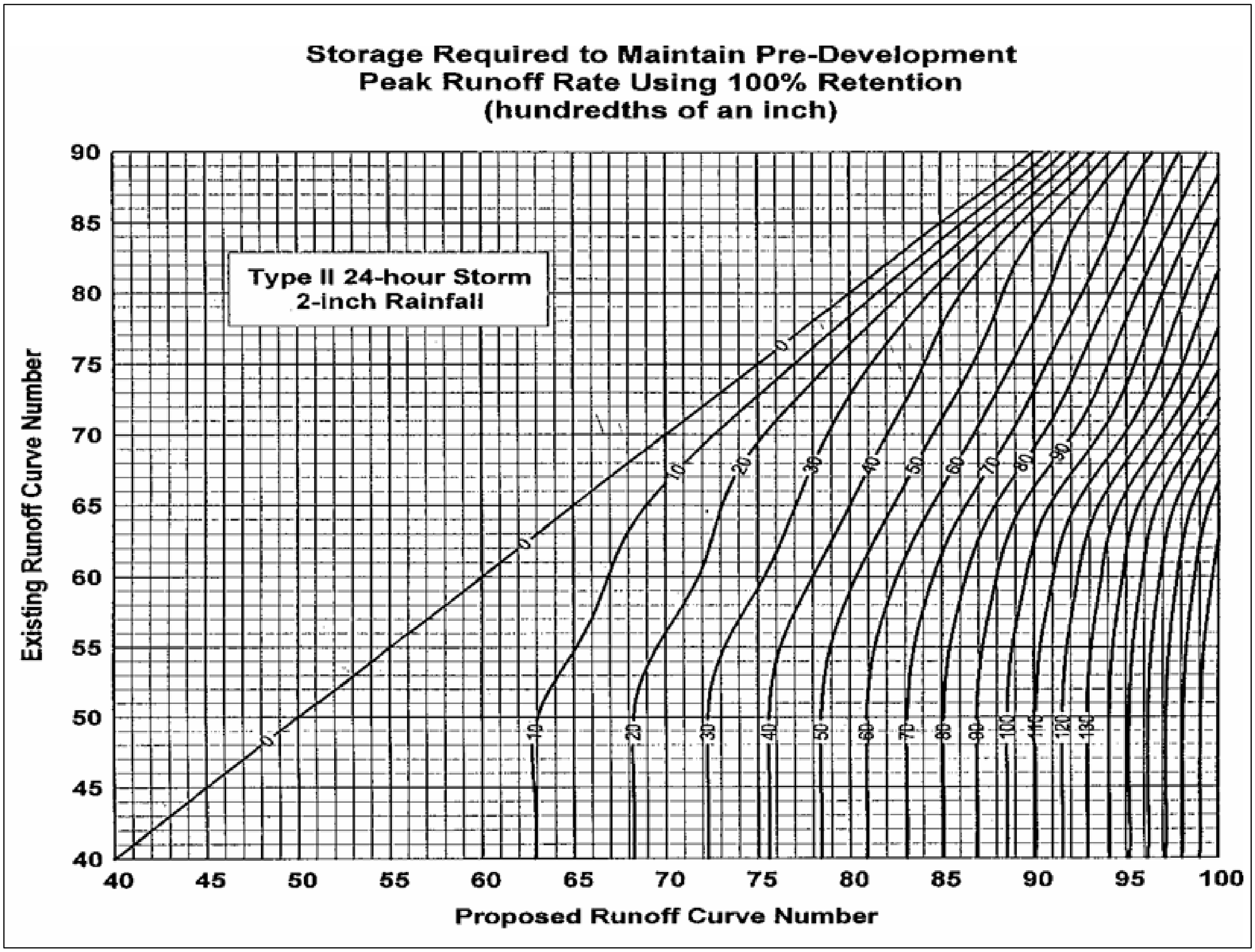
Storage Requirement (Low-Impact Development)

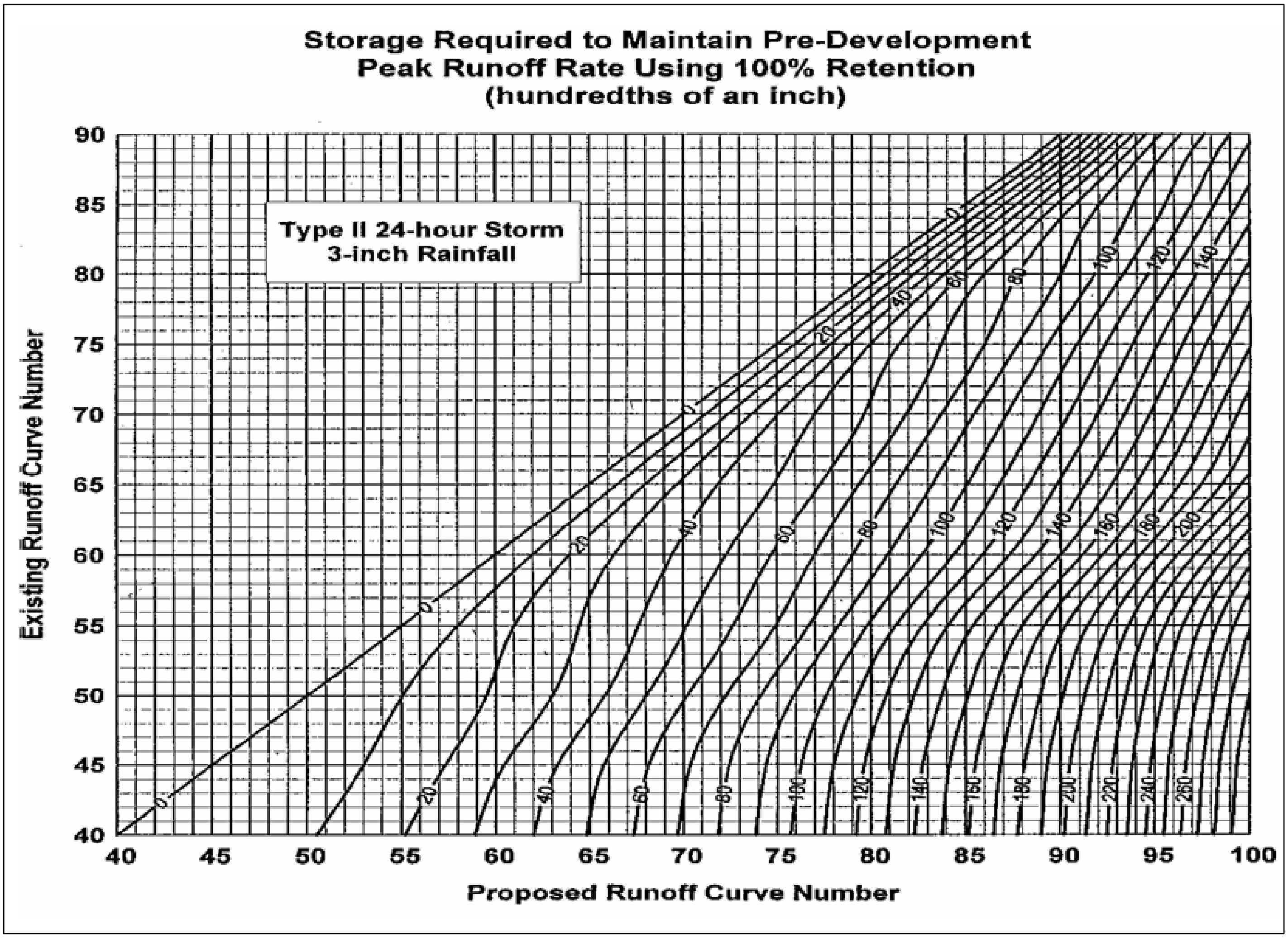
12" Bioretention Storage = 0.375 acre-ft. (0.375 acres area)
Additional Detention Storage = 0.000 acre-ft (not needed)
2' Soil Layer Layer in Bioretention = 0.225 acre-ft
TOTAL VOLUME = 0.375+0.000+0.225 = 0.600 acre-ft

LID DESIGN CHARTS

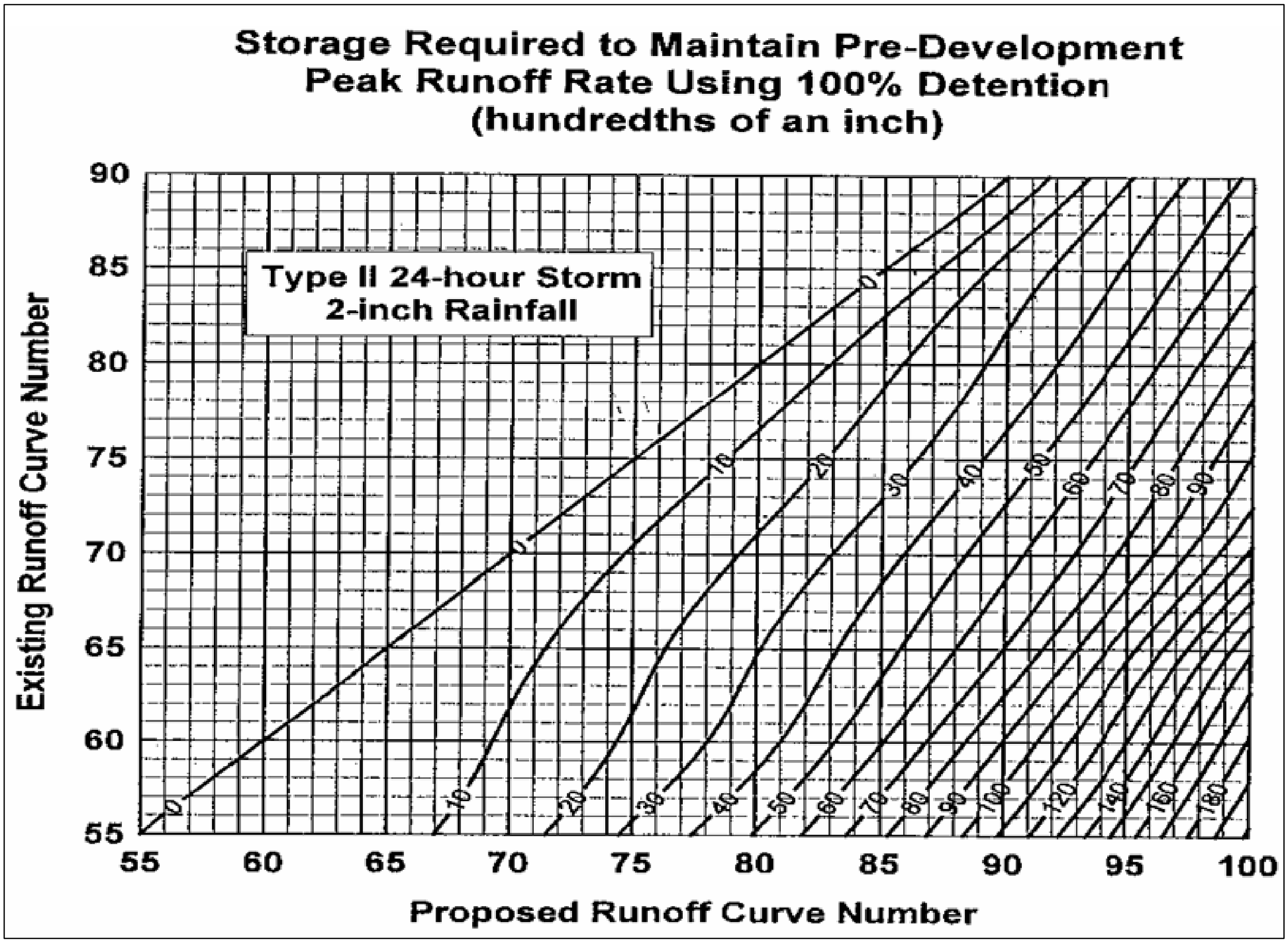


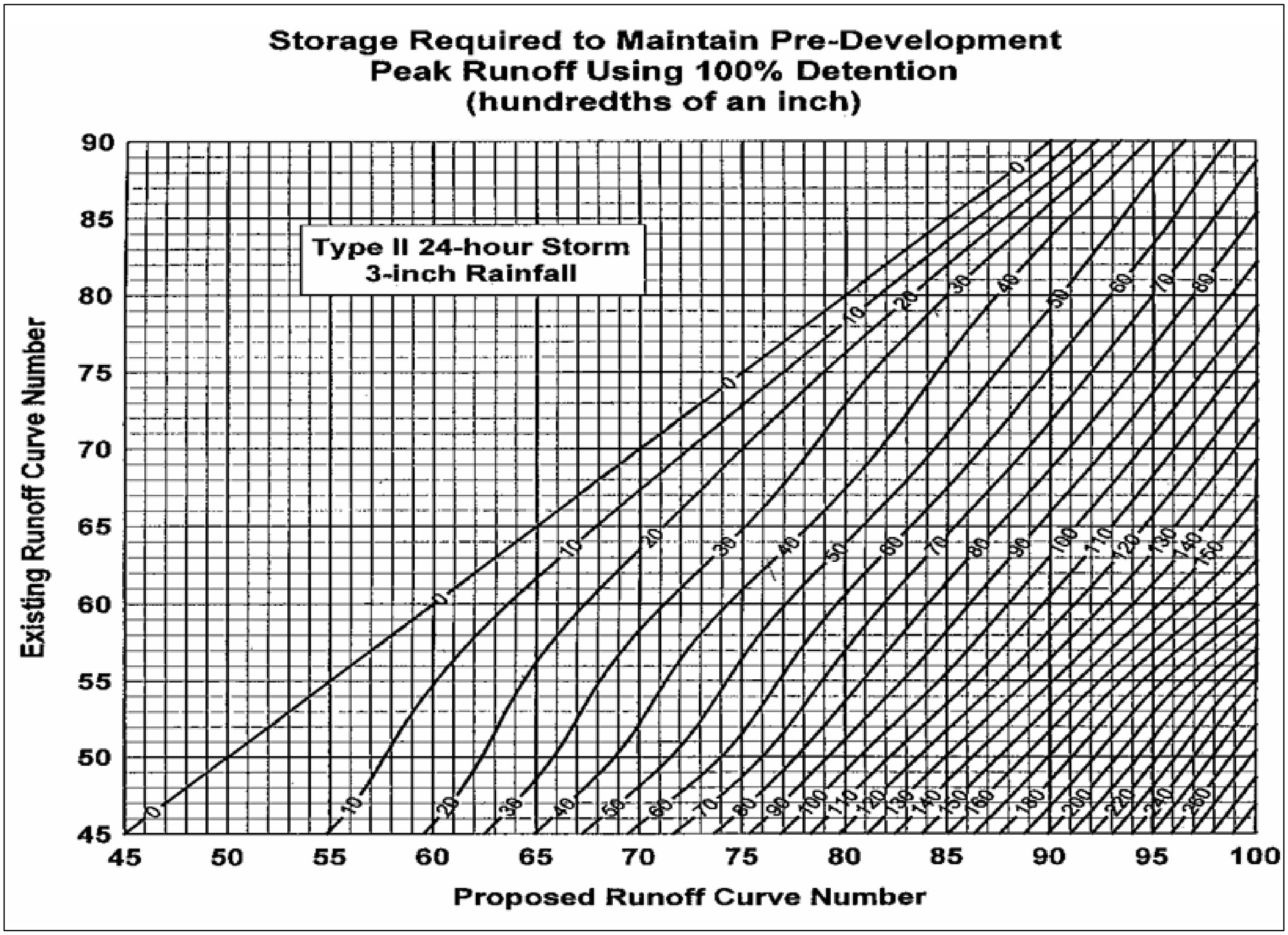

Storage Required to Maintain
Pre-Development Runoff Volume
(hundredths of an inch)
3-inch Rainfall
Existing Runoff Curve Number
90
85
80
75
70
65
60
55
50
45
40
40
45
50
55
60
65
70
75
80
85
90
95
100
Proposed Runoff Curve Number


Storage Required to Maintain Pre-Development
Peak Runoff Rate Using 100% Retention
(hundredths of an inch)
Type II 24-hour Storm
2-inch Rainfall
Existing Runoff Curve Number
Proposed Runoff Curve Number
90
85
80
75
70
65
60
55
50
45
40
40
45
50
55
60
65
70
75
80
85
90
95
100



Storage Required to Maintain Pre-Development Peak Runoff Rate Using 100% Retention (hundredths of an inch)
Type II 24-hour Storm
3-inch Rainfall
Existing Runoff Curve Number
Proposed Runoff Curve Number
40
45
50
55
60
65
70
75
80
85
90
95
100


Storage Required to Maintain Pre-Development
Peak Runoff Rate Using 100% Detention
(hundredths of an inch)
Type II 24-hour Storm
2-inch Rainfall
Existing Runoff Curve Number
Proposed Runoff Curve Number
90
85
80
75
70
65
60
55
55
60
65
70
75
80
85
90
95
100
0
10
20
30
40
50
60
70
80
90
100
120
140
160
180



Storage Required to Maintain Pre-Development
Peak Runoff Using 100% Detention
(hundredths of an inch)
Type II 24-hour Storm
3-inch Rainfall
Existing Runoff Curve Number
Proposed Runoff Curve Number
45
50
55
60
65
70
75
80
85
90
95
100

CHAPTER 5

LANDSCAPING TECHNIQUES AND PRACTICES

IN THIS CHAPTER

5.1 Landscape Plan and Design

Key factors in the design of bioretention facilities are careful selection of plant materials that can tolerate highly variable hydrologic changes and an overall planting plan that ecologically and aesthetically blends the facility into the landscape. Designing for ease of maintenance is also a critical element of any landscape plan and is covered in Chapter 5.

Bioretention facilities have a wide range of applications from suburban residential lots to ultra-urban streetscapes. It is the landscape designer's responsibility to analyze the surrounding site considerations and design a bioretention facility that maximizes water quality enhancement and landscape values. It is our intent to provide guidance for landscape planning and design to ensure successful bioretention facilities without discouraging individual creativity.

5.2 Developing a Landscaping Plan for Bioretention

The designer or landscape architect can develop a landscaping plan for bioretention in similar fashion to conventional site landscaping design. The main difference is essentially the integrated stormwater management control—*functional landscaping* as well as the aesthetic appeal. Even though the facility is being designed to capture and treat stormwater, we caution the designer not to view bioretention as a wetland, pond, or other water feature. Rather, the designer should use plant species that are tolerant to wide fluctuations in soil moisture content. A landscaping plan, such at the one in Figure 5.1, developed for the purposes of bioretention should include the following elements:

- Plan view of the facility showing landscape features
- Plant and material schedules
- Spot grades and section locations
- Cross section view
- Inflow and discharge points/connections
- Landscaping specifications

Designers should use planting materials from the planting list provided in this chapter.

5.3 Site and Ecological Considerations

Consider interactions with adjacent plant communities including the potential to provide links to wildlife corridors. Designers should evaluate adjacent plant communities for compatibility with any proposed bioretention area species. Nearby existing vegetated areas dominated by nonnative invasive species pose a threat to adjacent bioretention areas. Invasive species typically develop into monocultures by out-competing other species. Mechanisms to avoid encroachment of undesirable species include providing a soil breach between the invasive community for those species that spread through rhizomes and providing annual removal of seedlings from wind borne seed dispersal. It is equally important to determine if there are existing disease or insect infestations associated with existing species on site or in the general area that might affect the bioretention plantings.

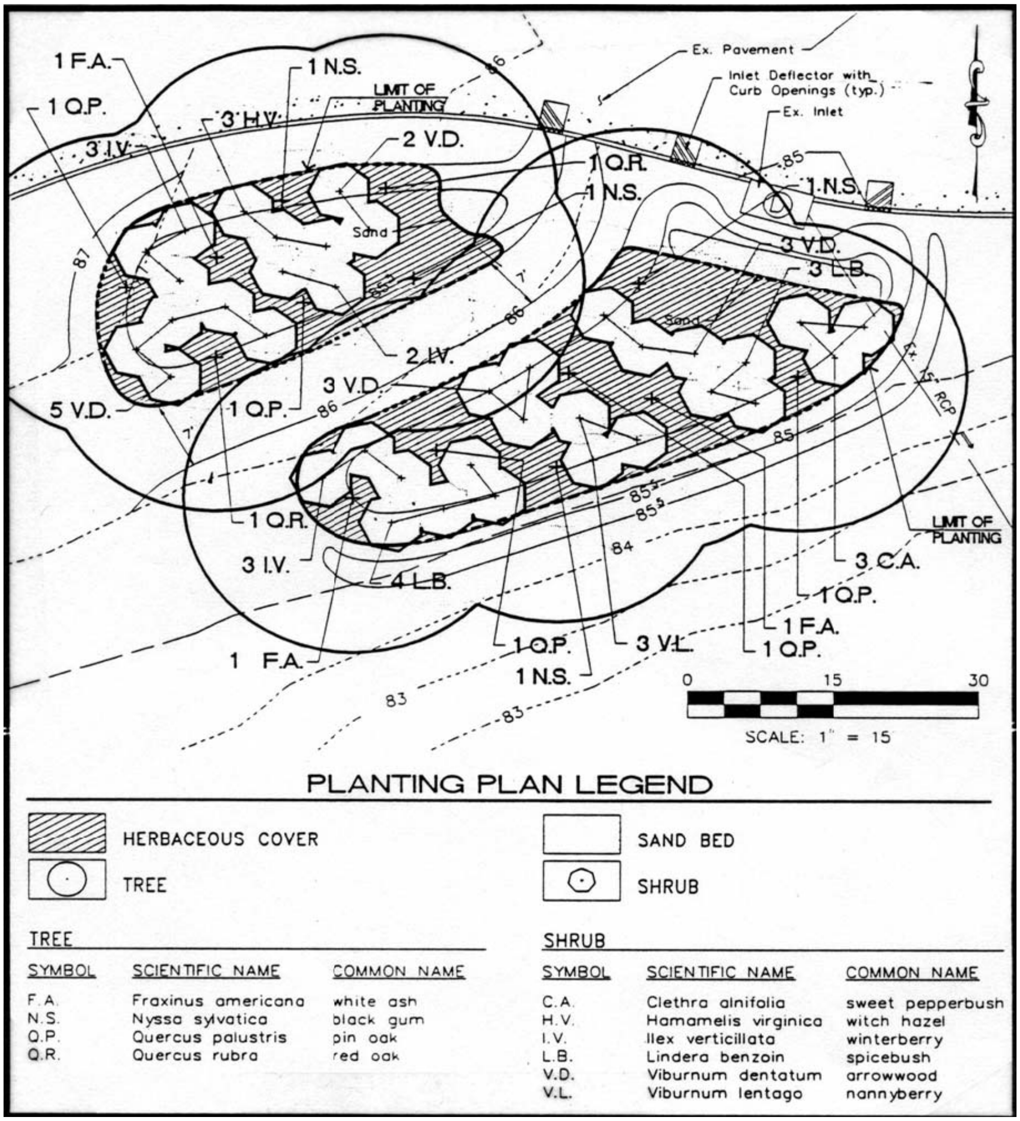


Figure 5.1. A typical bioretention landscape plan

5.4 Plant Material Guidelines

5.4.1 Plant Selection Criteria

Plant species appropriate for use in bioretention areas are provided at the end of this chapter. These species have been selected on the basis of their ability to tolerate urban stresses such as

- Expected pollutant loadings
- Highly variable soil moisture conditions
- Ponding water fluctuations
- Soil pH and texture

Important design considerations such as form, size, and type of root system are also included.

A key factor in designating a species as suitable is its ability to tolerate the soil moisture regime and ponding fluctuations associated with bioretention. Species are predominantly facultative (i.e., they are adapted to stresses associated with both wet and dry conditions); however, upland and wetland species have also been included. This is important because plants in bioretention areas will be exposed to varying levels of soil moisture and ponding depending on the facility design and weather conditions. All the species listed in Appendix C are commonly found growing in the Piedmont or Coastal Plain regions of Maryland as either native or ornamental species. Appendix C also provides information on light and soil requirements of individual plants.

Designers considering species other than ones listed in this document should consult the following reference material on plant habitat requirements and consider site conditions to ensure that alternative plant material will survive:

- Brown, M.L., and R.G. Brown. 1984. *Herbaceous Plants of Maryland*. Port City Press, Baltimore, MD.
- Brown, Melvin L., and R.G. Brown. 1984. *Woody Plants of Maryland*. Port City Press, Baltimore, MD.
- Maryland—National Capital Park & Planning Commission. 1998. *Native Plants of Prince George's County, Maryland 1997–1998*. Maryland—National Capital Park & Planning Commission, Riverdale, MD.
- Jelich, C, and B. Slattery. 1999. *Maryland Native Plants for Landscaping*. U.S. Fish and Wildlife Service, Chesapeake Bay Field Office, Annapolis, MD.
- Hightshoe, G.L., 1988. *Native Trees, Shrubs, and Vines for Urban and Rural America*. Van Nostrand Reinhold, New York, NY.
- Reed, P.B. Jr., 1988. National List of Species That Occur in Wetlands: Northeast. U.S. Fish and Wildlife Service, St. Petersburg, FL.

Reasons for excluding certain plants from bioretention areas include inability to meet the criteria outlined above (pollutant and metals tolerance, soil moisture and ponding fluctuations, morphology, and so on). In addition, species that are considered invasive or not recommended by the Urban Design Section of the Maryland-National Capital Park and Planning Commission (Prince George's County 1989) are not listed. Do not use species known to be invasive locally such as the following:

- Purple loosetrife (*Lythrum salicaria*)
- English ivy (*Hedera helix*)
- Japanese barberry (*Berberis thunbergii*)
- Burning bush (*Euonymous alata*)

For a national, up-to-date, multiagency list of invasive plants, consult the Web site, www.nps.gov/plants/alien/.

5.4.2 Plant Material Source

The plant material should conform to the current issue of the *American Standard for Nursery Stock* published by the American Association of Nurserymen. Plant material should be selected from certified nurseries that have been inspected by state or federal agencies. The botanical (scientific) name of the plant species should be in accordance with a standard nomenclature source such as *Gray's Manual of Botany*.

Some of the plant species listed in the Table at the end of this chapter might be unavailable from standard nursery sources. These are typically species native to Maryland and might not be commonly used in standard landscaping practices. Designers might need to contact nurseries specializing in native plant propagation All plant material specified must be propagated, germinated, or otherwise developed from nurseries east of Tennessee in Hardiness Zones 6 or 7. Verify that plants have not been wild collected (unless they have been obtained from a documented plant rescue site).

5.4.3 Plant Material Layout

The layout of plant material can be a flexible process; however, the designer should follow some basic guidelines. As discussed above, the designer should first review Table 3.1. The checklist table can help expose any constraints that might limit the use of a species or where a species can be installed.

There are two guidelines that should apply to all bioretention areas. First, woody plant material should not be placed directly within the entrance-inflow path. Besides possibly concentrating flows, trees and shrubs can be damaged from the flow causing soil to be washed away from the root ball. Second, keep in mind that all areas of the facility will not be subjected to the same depth of ponding and saturation. The gentle bowl shaped configuration of the facility lends itself to differing zones of saturation. This provides an opportunity to use, along the outside perimeter of the facility, plants that cannot tolerate saturated conditions. This can be especially useful when visually linking a facility into an adjacent area landscaped with a formal theme.

Often designers will find that the environmental factors such as sun, shade, wind, and temperature vary not only on-site, but also between bioretention areas. As a result, the designer might need to consider the placement of each plant. An example would be to consider placing evergreen trees or other wind tolerant species on the northern end of a bioretention area, against cold winter winds.

5.4.4 Installation

The success of bioretention areas is very dependent on the proper installation specifications that the designer develops and that the contractor subsequently properly follows. The specifications include the procedures for installing the plants and the necessary steps taken before and after installation. Specifications designed for bioretention should include the following considerations:

- Sequence of construction
- Contractor's responsibilities
- Planting schedule and specifications

- Maintenance
- Warranty

Sequence of Construction. The sequence of construction describes site preparation activities such as grading, soil amendments, allowance for compaction of soils, and any preplanting structure installation. It also should address erosion and sediment control procedures. Erosion and sediment control practices should remain in-place until the entire bioretention area is completed. Ideally, bioretention areas should be constructed concurrently with final grading and permanent site stabilization operations.

Contractor's Responsibilities. The contractor's responsibilities for landscaping and plantings must be itemized within the contract specifications. For landscaping guidelines, see Appendix A. The responsibilities should include any penalties for unnecessarily delayed work, requests for changes to the design or contract, and exclusions from the contract specifications such as vandalism to the site, and so on.

Planting Schedule and Specifications. The planting schedule and specifications include type of material to be installed (e.g., ball and burlap, bare root, or containerized material), timing of installation, and post-installation procedures. Balled and burlapped and containerized trees and shrubs should be planted during the following periods:

- March 15 through June 30
- September 15 through November 15

Ground cover, excluding grasses and legumes, can follow tree and shrub planting dates. Grasses are best seeded in late summer through early fall. Legumes typically should be planted in the spring. When planting trees and shrubs, follow the planting specifications set forth in the Prince George's County *Landscape Manual* (1989), except that trees should not be staked unless the site is exceptionally windy. The county specifications provide guidelines that ensure the proper placement and installation of plants. Designers can choose to use other specifications or to modify the County specifications. However, any deviations from the county specifications need to address the following:

- Transport of plant material
- Preparation of the planting pit
- Fertilization (if applicable)
- Installation of plant material
- Stabilization seeding (if applicable)
- Watering and general care

Maintenance. Maintenance needs of bioretention areas differ little from other landscape areas. However, in and around bioretention areas, it is important to use maintenance practices that will not compromise the facility's pollutant-removal capacity. Avoid blocking inflow entrance points with mounded mulch or raised plantings blocking flow dispersion over the entire surface area of the facility.

Adopting a low-input maintenance regime will lessen the chance of overwhelming the facility with pollutant loadings above design capacity and will protect soil life. Reducing pesticide use will also reduce the risk of damage to bioretention plants, beneficial birds and insects, and soil organisms. Moreover, such conservation techniques can also save money. For example, switching to integrated pest management (IPM) has allowed the National Arboretum in Washington, DC, to cut pesticide costs an estimated 80 percent. For more information about IPM and other low-input techniques see the Alliance for the Chesapeake Bay's BayScapes publications. Maryland Cooperative Extension also has a number of publications, including Home & Garden Mimeo #HG 62, *IPM: A Common Sense Approach to Managing Problems in your Landscape* and Bulletin 350, *Landscape IPM Guidelines for Integrated Pest Management of Insect & Mite Pests on Landscape Trees*.

5.4.5 Warranties

Typically, a warranty is established as a part of any plant installation project. The warranty covers all components of the installation for which the contractor is responsible. A professional landscape contractor should perform the plant and mulch installation for bioretention. An example of standard guidelines for landscape contract work is provided below:

- The contractor should maintain a care and replacement warranty for all plantings in accordance with industry standard or contractual arrangements with the owner.
- As a minimum, the period of care and replacement should begin after inspection and approval of the complete installation of all plants and continue for one year.
- Plant replacements should be in accordance with the maintenance schedule.

5.5 Soil Guidelines

5.5.1 Soil Medium Guidelines

The soil medium plays an important role in the improvement of water quality through the use of bioretention systems. The soil is a three-phase system composed of gas, liquid, and solid, each of which in the proper balance is essential to the pollutant removal that bioretention achieves. The soil anchors the plants and provides nutrients and moisture for plant growth. The unsaturated pore space provides plant roots with the oxygen necessary for metabolism and growth. Microorganisms inhabit the soil environment. They form an essential link providing nutrients in the appropriate forms for plant uptake. Microbes, microfauna, macrofauna, and living roots are present in immense numbers in healthy soil. In fact, the living organisms within the top 6 inches of an acre of soil can weigh as much as 20,000 pounds (Gershuny, 1993).

5.5.2 Soil Texture and Structure for Soil Medium

A desirable planting medium

- Is highly permeable to allow infiltration of runoff
- Provides adsorption of organic nitrogen and phosphorus
- Has high porosity and hydraulic conductivity

This can be achieved with a prepared soil mix consisting of 50–60 percent sand, 20–30 percent leaf compost, and 20–30 percent topsoil. Where a prepared soil mix is not used, it is recommended that the planting soils for bioretention be composed of a chiefly sandy soil. A strong, granular or crumb-like structure is also desirable. These soils have a clay content of less than 5 percent. Sandy loam, loamy sand, and loam soils have minimum infiltration rates ranging from 0.52 to 2.41 inches/hour. (Other types of loamy soils such as silt loams and sandy clay loams have infiltration rates of 0.27 inch/hour or lower and are not suitable for bioretention.) When *in situ* soils are saturated or have a high clay or silt content, underdrains must be used to help regulate planting soil infiltration rates and provide a margin of safety. For marginal soils, (< 0.52 inch/hour), the designer must consult a site-specific recommendation from geotechnical report.

5.5.3 Available Soil Moisture

Bioretention areas are typically designed with soils that have coarse-grained sand to allow for high filtration capacity. This presents a problem for retaining available soil moisture and, hence, available water for plant growth. When sandy, textured soils are used in conjunction with underdrains, the available soil water is reduced significantly and could cause the soil to reach the wilting coefficient. If this point is reached, supplemental watering is necessary to sustain the plant growth. Avoid overwatering, however, because excessive irrigation could lead to nutrient leaching from the facility. The mulch layer can help keep the soil moisture capacity higher and reduce the need for watering.

5.5.4 Soil Investigation and Testing Criteria

Whenever bioretention is to be used for a development, close attention to the soil conditions and limitations are of obvious importance. To help the designer determine the extent of testing required at the earliest stage possible and to reduce the cost associated with those tests, the following sequence of analysis is recommended:

- Determine the site limitations with respect to environmental constraints, paying special attention to the hydrologic soil groups encountered on the site.
- Using the soils information, delineate the HSGs A, B, C & D. Lay out the lots and roadways to avoid placing impervious surfaces on hydrologic soil groups A & B, which typically have high infiltration rates.
- Consider topography. Lay out the lots and roadways to minimize cut and fill as well as impacts to A & B soils. Overlay the topographic layer with the development layout and the soils map delineation.
- For areas where development of new impervious areas are over HSGs C & D, bioretention is not recommended unless an underdrain system discharge is provided. Generally, C & D soils are not well drained.
- For areas where development of new impervious areas are over A & B soils, bioretention will typically work well without the benefit of underdrain systems. However, soil testing is required to ensure adequate infiltration rates, and underdrains are strongly encouraged.
- For bioretention areas that do not incorporate underdrain systems, one soil test per facility is required that includes the following as a minimum:

- Identification of soil horizons and the corresponding USDA soil classification
- Grain size distribution (sieve analysis) indicating the percent clay, sand and silt.
- Depth to the groundwater table or impervious layer (> 2 feet below the bioretention invert), if present.
- Depth of test must be at least 3 feet below the proposed invert
- Infiltration rates must be determined using standard acceptable practices such as a percolation test.
- Check for utility lines before digging.

5.5.5 Soil Acidity

In a bioretention scheme, the desired soil pH should be between 5.5 and 6.5. Soil acidity affects the ability of the soil to adsorb and desorb nutrients and also affects the microbiological activity in the soil. In the Optimization of Bioretention experiment (Davis et al. 2000), it was found that the metals adsorbtion rate increases significantly at the upper and lower ranges of the pH scale. Test the site soils to determine pH as part of the geotechnical report. In lieu of specifying pH, however, the prepared soil mix has been shown to provide adequate pollutant removal rates.

5.6 Plant Growth and Soil Fertility

A discussion of plant growth and soil fertility development over time is important for estimating the success and lifespan of bioretention areas. The physical, chemical, and biological factors influencing plant growth and development will vary over time as well as for each bioretention area. However, there are certain plant and soil processes that will be the same for all bioretention areas.

5.6.1 Plant Growth

The role of plants in bioretention includes uptake of nutrients and pollutants and evapotranspiration of stormwater runoff. The plant materials, especially ground covers, are expected to contribute to the evapotranspiration process within the first year of planting. However, trees and shrubs that have been recently planted demonstrate slower rates of growth for the second year because of the initial shock of transplanting. The relative rate of growth is expected to increase to normal rates after the second growth season.

The growth rate for plants in bioretention areas will follow a similar pattern to that of other tree and shrub plantings (reforestation projects, landscaping). For the first two years, the majority of tree and shrub growth occurs with the expansion of the plant root system. By the third or fourth year, the growth of the stem and branch system dominates, increasing the height and width of the plant. The comparative rate of growth between the root and stem and branch system remains relatively the same throughout the life of the plant. The reproductive system (flowers, fruit) of the plants is initiated last.

The growth rates and time for ground covers to become acclimated to bioretention conditions is much faster than for trees and shrubs. The rate of growth of a typical ground cover can often exceed 100 percent in the first year. Ground covers are considered essentially mature after the first year of growth. The longevity of ground covers will be influenced by the soil fertility and chemistry as well as physical factors, such as shading and overcrowding from trees and shrubs and other ecological and physical factors.

Plants are expected to increase their contribution to the bioretention concept over time, assuming that growing conditions are suitable. The rate of plant growth is directly proportional to the environment in which the plant is established. Plants that are grown in optimal environments experience greater rates of growth. The primary factors determining this are soil fertility, water availability, and good drainage.

5.6.2 Soil Fertility

In traditional, intensively cropped landscapes, soil fertility (and especially the level of available nitrogen) is considered the limiting factor to plant growth. As already noted, however, human actions have considerably altered the cycling of nitrogen. By design, bioretention facilities are in areas where nutrients (especially nitrogen) are significantly elevated above natural levels. In addition, many of the native plants recommended in Table 3.1 do not need large nutrient inputs to flourish. Therefore, it is unlikely that soil fertility will be the limiting factor in plant growth, and thus fertilization would be unnecessary. Excess fertilization (besides compromising the facility's pollutant reduction effectiveness) leads to weak plant growth, promotes disease and pest outbreaks, and inhibits soil life.

If soil fertility is in doubt, a simple soil test can resolve the question. If fertilization should become necessary, an organic fertilizer will provide nutrients as needed without disrupting soil life. Organic fertilizers release nutrients slowly and contribute organic matter to improve soil conditions. Test the soil mixture as part of geotechnical report.

5.6.3 Microbial/Biochemical Action

The microbial/biochemical actions that take place in a bioretention facility are presumed to be important for enhancing the pollutant removal processes. Microbes are the unseen machines for recycling nutrients and decomposing organic materials. Nitrogen-fixing bacteria (both free-living forms and those in association with plants) convert atmospheric nitrogen into forms that plants can use. Decomposers break down organic matter, releasing plant nutrients and forming humus. Fungi then facilitate nutrient absorption into plant roots. Humus (partially decomposed organic matter) stores nutrients. In fact, a soil's ability to store nitrogen increases as the organic layer is built up until equilibrium is reached. Besides storing nutrients, humus helps the soil retain both oxygen and water. In turn, fungi link particles of organic matter in the litter layer and upper levels of the soil, forming a web that resists erosion and retains moisture. For all these reasons, the designer must pay careful attention to the selection of the planting soils for bioretention.

5.6.4 Soil Horizon Development

Initially, soil in bioretention areas will lack a mature soil profile. It is expected that over time, discrete soil zones, referred to as horizons, will develop. The development of a soil profile and the individual horizons is determined by the influence of the surrounding environment including physical, chemical, and biological processes. Two primary processes important to soil horizon development are microbial action (decomposition of organic material) and the percolation of runoff in the soil.

Soil microbes, microfauna, and macrofauna, together with living plant roots, build soil from minerals and organic matter. Just as geologic processes and succession create a particular ecosystem (e.g. rainforest, prairie, or salt marsh) above ground, these processes create characteristic soil profiles and complex ecosystems below ground.

Horizons expected to develop in bioretention areas include an organic layer, followed by two horizons where active leaching (eluviation) and accumulation (illuviation) of minerals and other substances occur. The time frame for the development of soil horizons will vary greatly. As an average, soil horizons could develop within 3 to 10 years. The exception to this is the formation of the organic layer often within the first or second year. The evaluation of soil fertility in bioretention could be more dependent on the soil interactions relative to plant growth than horizon development. The soil specified for bioretention is important in filtering pollutants and nutrients as well as supplying plants with water, nutrients, and support. Unlike plants that will become increasingly beneficial over time, the soil will begin to filter the stormwater runoff immediately. It is possible that the ability to filter pollutants and nutrients could decrease over time, reducing the soil fertility accordingly. Substances from runoff such as salt and heavy metals eventually disrupt normal soil functions by lowering the cation exchange capacity (CEC). The CEC, the ability to allow for binding of particles by ion attraction, decreases to the point that the transfer of nutrients for plant uptake cannot occur. However, the environmental factors influencing each bioretention area will vary enough that it is difficult to predict the lifespan of soils. Findings from other stormwater management systems suggest an accumulation of substances eliminating soil fertility within 5 years. Should this occur, organic matter can be added by the addition/replacement of the mulch material. Monitoring soil development in bioretention areas will help develop better predictions on soil fertility and development.

5.7 Mulch Layer Guidelines

The mulch layer plays a vitally important role in the overall bioretention design. This layer serves to prevent erosion and to protect the soil from excessive drying. Soil biota within the organic and soil layer are important in filtering nutrients and pollutants and helping maintain soil fertility. Bioretention areas can be designed either with or without a mulch layer. If a dense herbaceous layer or ground cover (70 to 80 percent coverage) is established, a mulch layer is no longer necessary. Areas should be mulched once trees and shrubs have been planted. Any ground cover specified as plugs can be installed once mulch has been applied.

The mulch layer recommended for bioretention can consist of either a standard landscape, fine-shredded hardwood mulch or hardwood chips. Both types of mulch are commercially available and provide excellent protection from erosion for very low velocity flows, although shredded mulch is less likely to float.

NOTE: Some facilities in the ground for more than 8 years appear to have soil structures developing that actually enhance the filtering capability.

The mulch can be either aged or fresh to maximize nitrogen and metal uptake by the facility. Mulch should be free of weed seeds, soil, roots, or any other substance not consisting of either bole or branch wood and bark. The mulch should be uniformly applied approximately 2 to 3 inches deep. Mulch applied any deeper than 3 inches reduces proper oxygen and carbon dioxide cycling between the soil and the atmosphere and keeps plant roots from making good contact with the soil.

Grass clippings are unsuitable for mulch, primarily because of the excessive quantities of nitrogen built up in the material. Adding large sources of nitrogen could limit the capability of bioretention areas to filter the nitrogen associated with runoff and possibly create a net gain of nitrogen.

While mulching provides an important function in the bioretention process, a herbaceous layer or ground cover is preferred over mulching for several reasons. First, the mulch material has the ability to float up-and-out during heavy rain events. Second, the herbaceous layer provides more opportunities to capture and hold water through interception and evapotranspiration. Finally, providing thick, lush, ground cover increases the aesthetic appeal and adds to the landscape character. A combination of ground cover and mulch is an equally preferable option.

5.8 Bioretention Types & Applications

5.8.1 Forest-Type and Forest Fringe Bioretention Facilities

The original bioretention concept was modeled from the hydrologic characteristics and properties of a terrestrial forest ecosystem. The forest community model for stormwater management was selected on the basis of a forest's documented ability to cycle and assimilate nutrients, pollutants, and metals through the interactions among plants, soil, and the organic layer. This theme is appropriate when the facility is located at wooded edges, in the rear of residential lots, or where a wooded buffer is desired. Where space is at a premium, large shrubs can be used for the canopy layer with smaller shrubs and an assortment of perennials underneath. A sample planting plan is shown in Figure 5.1

Place trees on the perimeter of bioretention areas to maximize the shading and sheltering of bioretention areas and to create a microclimate, which will limit the extreme exposure from summer solar radiation and winter freezes and winds.

The final plant material layout should resemble a random and natural placement of plants rather than a standard landscaped approach with trees and shrubs in rows or other orderly fashion.

A minimum of three species of trees and three species of shrubs should be selected to ensure diversity. This will protect the system against collapse from insect and disease infestations and can ensure a more constant rate of evapotranspiration and nutrient and pollutant uptake throughout the growing season.

Perennials can be planted along the edge of the facility where color and seasonal interest are desired, and shade tolerant perennials can be planted as an underlying herbaceous layer throughout the rest of the facility.

Use native plants in the design. Native species demonstrate a greater ability of adapting and tolerating physical, climatic, and biological stresses (Metropolitan Washington Council of Governments 1992).

Select herbaceous ground covers to prevent erosion of the mulch and the soil layers. Select at least 3–4 species of herbaceous ground cover.

The spacing guidelines are provided in Table 5.1. Two to three shrubs should be specified for each tree (2:1 to 3:1 ratio of shrubs to trees). Where the plant material for the facility is used to meet the residential landscape requirements or street tree requirement trees could be 2.5 inches in caliper. All other trees should be specified as > 1.0 inch caliper.

Table 5.1. Forested bioretention tree and shrub spacing guidelines

	Tree spacing (feet)	Shrub spacing (feet)	Total density (stems/acre)
Maximum	19	12	400
Average	12	8	1,000
Minimum	11	7.4	1,250

Shrubs must be 3 to 4 feet in height or 18 to 24 inches in spread at installation. Mixed trees and shrubs can be planted as close as 7 feet; and shrubs alone can be planted from 4 to 7 feet apart. Ground cover can be as seed or, preferably, plugs.

5.8.2 Ornamental Garden

When bioretention facilities are used for water quality improvement in residential areas, the aesthetics and visual characteristics of the design must be a prime consideration. A facility at the entrance to a commercial building, a residential neighborhood or in the front yard of a residential lot might provide a landscaped focal point for the community. It is appropriate in these settings to choose plants that have ornamental characteristics that visually link the facility into the surrounding landscape. In all cases, the landscaping requirements for bioretention are flexible enough to provide the designer with opportunities to meet the residential landscape requirements required by Maryland National Capital Park and Planning Commission.

- Consider the bioretention facility a mass bed planting. The entire facility should be planted at a density so that the foliage will completely cover the facility after the second growing season.
- Consider using the dominant species of plant material that is used around the entrance of the home to visually link the bioretention facility with the home.
- Choose a variety of plant species that will add interest to the bioretention facility with each changing season. Perennials provide vibrant colors from early spring through fall, while ornamental grasses and evergreen or berry producing shrubs can add winter interest.

- Species that require regular maintenance (shed excessive amounts of fruit or are prone to storm damage) should be restricted to areas of limited visibility and away from pedestrian and vehicular traffic.
- If the facility is below overhead utilities, select tree species that comply with local utility height and clearance requirements.
- Where the ornamental garden receives runoff from the street, choose salt-tolerant species. In the Mid-Atlantic region, most salt applications will wash through the soil and not adversely affect the plants. However, it is still recommended that snow and ice be treated with sanding applications rather than salting. If salt is used, apply sparingly within bioretention drainage areas. Never use fertilizer to melt ice. For more information, see Maryland Cooperative Extension Fact Sheet 707, *Melting Ice Safely*.
- Mulch the entire bed with 2 to 3 inches of hardwood mulch. Fresh bark mulch should be used when possible to maximize nitrogen retention. If possible, use shredded instead of the *chip* variety to minimize floating action. All mulch should be free of foreign material including plant material.

5.8.3 Open Space Meadows

Open space meadows are a very practical application of the bioretention BMP. By proper design, the long-term maintenance costs associated with common or open space areas can be reduced significantly with the use of bioretention meadows. Typically, open spaces are maintained as nondescript grassed areas with minimal landscape features. A bioretention meadow, composed of ornamental grasses interlaced with wildflowers, does much more. Bioretention meadows improve water quality, provide aesthetic value, benefit wildlife, and reduce costs.

Like a forest, a meadow is a structured community of plants occupying different levels above and below ground. Meadows, like forests, also undergo ecological succession, with short-lived pioneer species being gradually replaced by a *climax* community. A variety of grasses and wildflowers are generally interspersed throughout the site. Drifts of a particular species, however, might develop over time in response to variations in moisture or as a consequence of ecological succession. While it is not difficult to design and establish a meadow, it is important to use plant communities and techniques specifically adapted to local conditions. For guidance on developing meadow gardens, consult the U.S. Fish and Wildlife Service, Chesapeake Bay Field Office, BayScapes Program.

5.8.4 Meadow Garden

A meadow garden is a more designed, less natural approach to using meadow plants. Plants can be seeded in sweeping bands of color within the meadow or in zones of short, medium, and tall plant mixes can be seeded to provide height progression. In small enough areas, plants can be individually placed and arranged.

5.8.5 Commercial Sites

When bioretention facilities are at the entrance to a commercial building and provide a landscaped focal point for the site, an ornamental garden theme is appropriate. For information on the design of these facilities, refer to the guidelines under Ornamental

Garden. Other facility design themes such as forest or meadow can add beauty and wildlife habitat to commercial open space areas. Where the facility is in a parking island or median, additional design criteria also apply.

Consider the size of the facility and determine if adequate planting soil exists to support large shade trees. It might be more appropriate to choose smaller ornamental species. The facility can be sited where it is exposed to wind, sun, salt and toxics from parking lots that will affect the candidate species.

Bioretention facilities along roads or in the median of parking lots must be analyzed to determine if there are any traffic considerations or safety issues. An adequate site distance must be maintained along roads and intersections to provide for the safe flow of traffic. Choose low growing plants and shrubs that do not block the view of oncoming vehicular or pedestrian traffic. The DPW&T, Engineering Office, has additional information on maximum heights of plants allowed in the medians of county roads and information on tolerance to pollution, salt, and wind.

5.9 Bioretention Plant List

The following planting list (see the *Selected Plant Profiles* section below) has been derived from multiple sources and includes a variety of species that conform to many parameters and conditions. The original bioretention list from the first manual on bioretention has been more than doubled to include 150 hardy plant species (mostly natives) that can sustain themselves through climatic and seasonal fluctuations. The original listing included more than 40 parameters such as tolerance to salt, moist roots, sun and shade, and such. Some of those parameters are listed in the plant list comments column, but the designer should also consult other landscaping sources for proper application. The listing contains suggested species that, from the County's experience and others', relate to bioretention applications. The County welcomes and encourages additions and modifications to the listing.

Notes: The following list contains plants adapted to a variety of water regimes. This will allow designers to select plants appropriate to any combination of bioretention design and site constraints. Please be advised, however, that not all plants will do well in all situations, so it is important to match the plants to the expected conditions. All the plants listed are perennials, because perennial plantings require less maintenance than the traditional bedding out of annuals. Annuals, however, can be usefully employed as cover crops or nurse crops for meadow plantings and to provide temporary color in newly established plantings.

Soil Moisture and Drought Tolerance. Saturated soils are wet for a significant portion of the growing season except during times of drought. Moist soils are damp for most of the growing season, except during times of drought. They can occasionally be saturated. Some notes are included on flood tolerances and which plants can function as emergents, but designers should consult wetland references for specifics on water depths and durations tolerated.

Drought-tolerant perennials will do well in areas where water does not remain after a rain and will not need supplemental watering in all but the most extreme droughts.

Light Requirements. Full sun means direct sunlight for at least 6 hours a day during the plant's growing season. Partial shade means 3–6 hours of direct sunlight or a site with lightly filtered sun during the plant's growing season. Shade means less than 3 hours of direct sunlight or a site with heavily dappled sun during the plant's growing season.

Geographic Restrictions. While this list was designed for Prince George's County, the plants included should do well in the middle of the Mid-Atlantic region. Care should be taken, however, in using the list elsewhere. Plants listed here might not be cold hardy in the extreme north or heat hardy in the extreme south. Similarly, a plant that is drought tolerant in this generally humid area might not be adapted to drier conditions in western regions. Finally, users from other regions should be cautious and check local invasive plant lists, because native plants from one region can become invasive in another setting.

5.10 References

Fernald, M.L. 1950. *Gray's Manual of Botany*. 8th ed., Dioscorides Press, Portland, Oregon.

Natural Resources Defense Council, Stormwater Strategies, May 1999

Gershuny, Grace 1993 *Start with the Soil,* Rodale Press, Emmaus Pennsylvania.

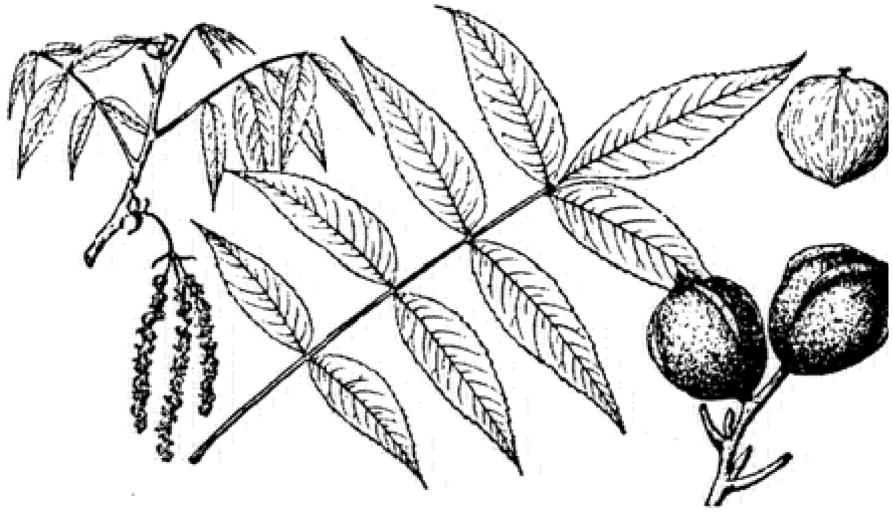
Tisdale, S. L., and W.L. Nelson. 1975. *Soil Fertility and Fertilizers*. 3rd edition. MacMillan Publishing Co., Inc., New York.

Brady, N.C. 1984. *The Nature and Properties of Soils*. MacMillian Publishing Co., New York.

SELECTED PLANT PROFILES

Blackhaw *(Viburnum prunifolium)*
White flowers are produced in spring, with the dark edible fruits maturing in autumn.

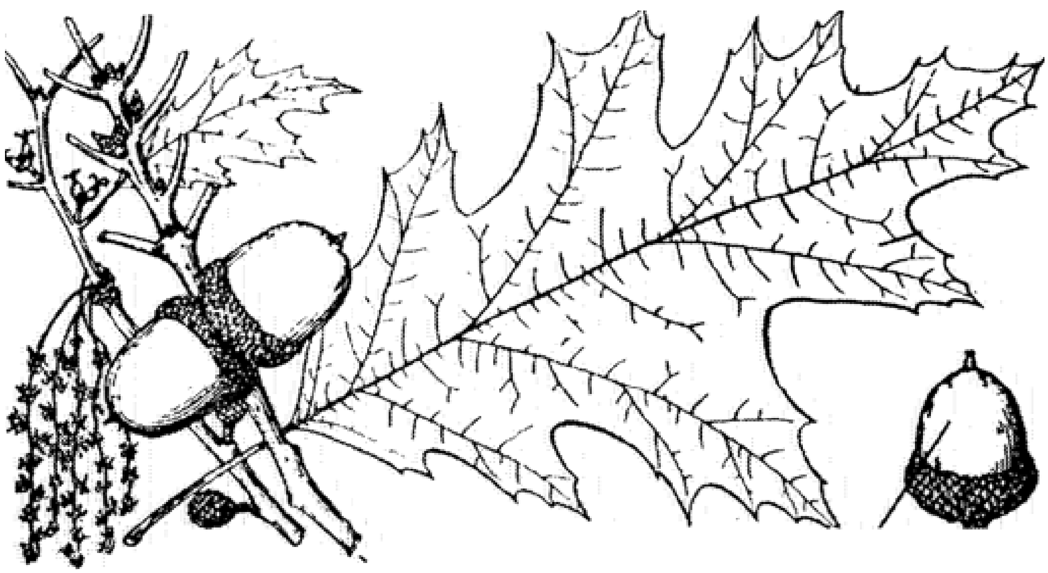
Common Winterberry (*Ilex verticillata (L.) A. Gray*)
Winter branches with the persistent bright red berries are sometimes gathered for use in Christmas decorations.



Bitternut Hickory (*Caryacordiformis (Wangenh.) K. Koch)*
Commonly occurring species that can grow in varied soil conditions

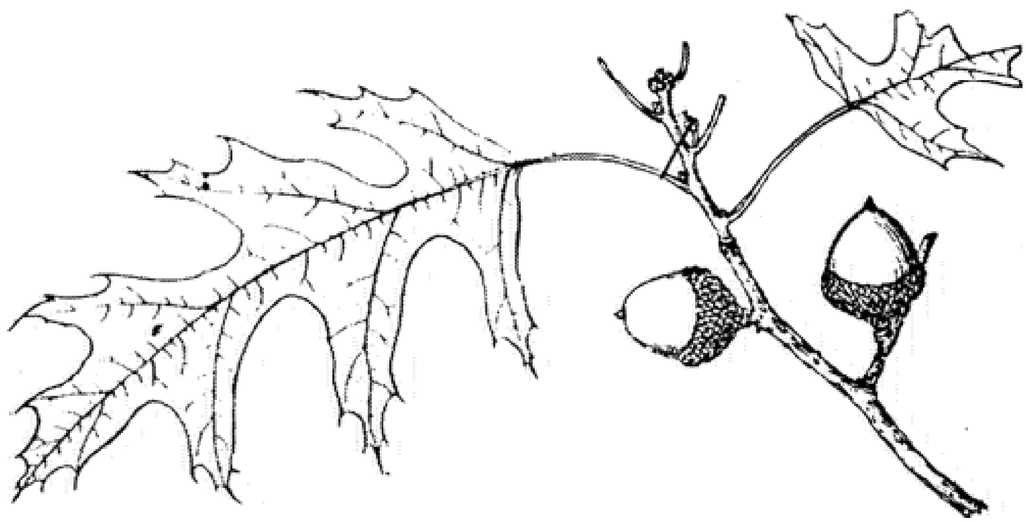
Button Bush *(Cephalanthus occidentalis L.)*
Forms dense thickets that serve as excellent cover and nesting sites for birds

Red Maple *(Acer rubrum)*
Grows equally well along the borders of swamps and dry upland sites.



Northern Red Oak *(Quercus rubra)*
Hybridizes with black oak, willow oak, shingle oak, and bear oak.

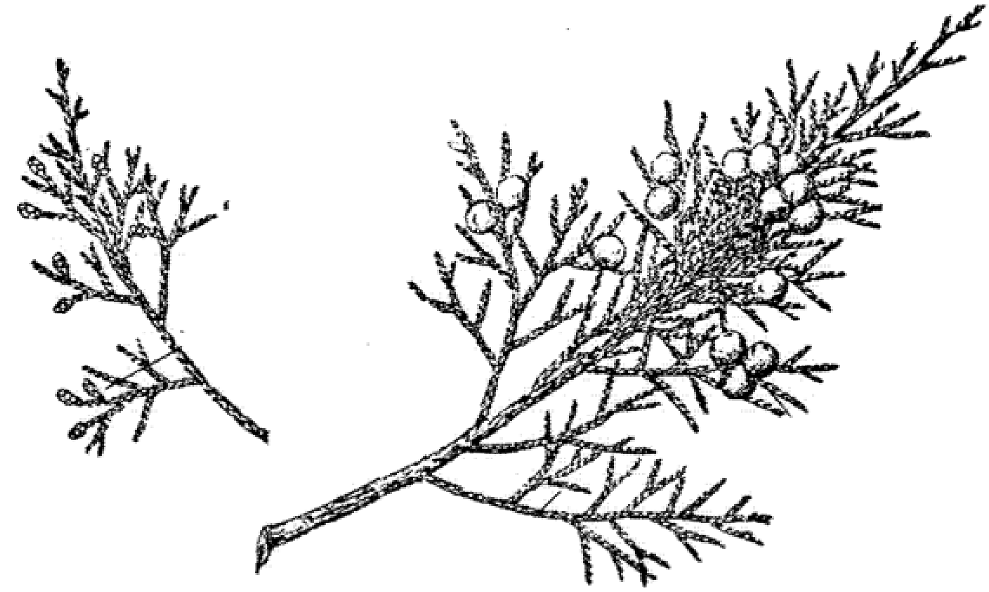
Green Ash *(Fraxinus pennsylvanica)*
Seed crop is an important food for cardinals, finches, and squirrels.



Scarlet Oak *(Quercus coccinea Muench)*
Leaves turn a bright red or scarlet in autumn.

Shining Sumac *(Rhus copallina L.)*
Attracts birds and other wildlife

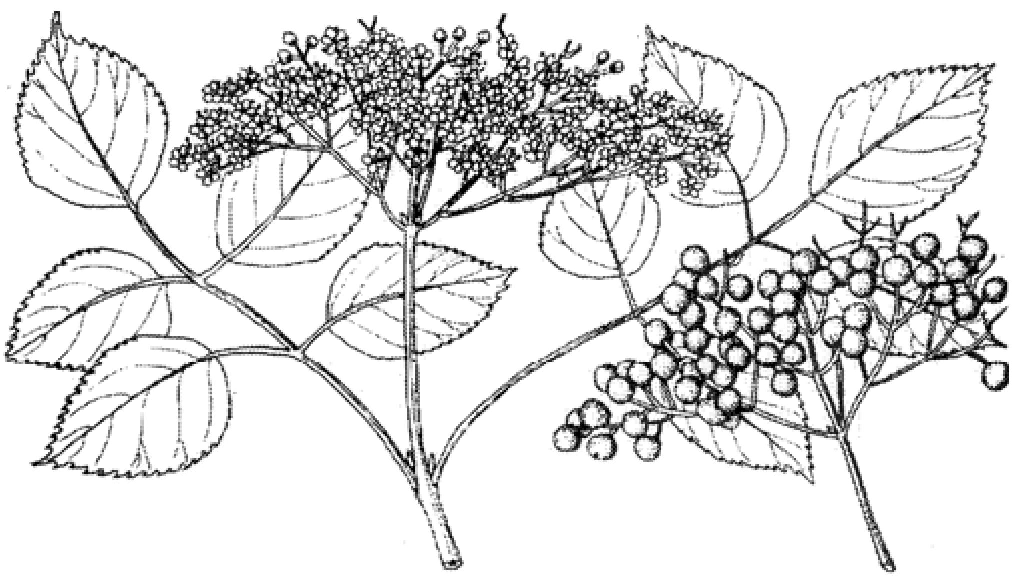
Pawpaw (*Asimina triloba Dunal*)
Early settlers made yellow dye from the ripe pulp of the fruits.



Eastern Redcedar (*Juniperus viginiana*)
The most drought resistant conifer the East.

Green Ash (*Fraxinus pennsylvanica Marsh*.)
Green ash is widely planted for shade and streetscape.

Frosted Hawthorn (*Crataegus pruinosa (Wendl.) K. Koch)*
Small tree located from Newfoundland to North Carolina.



American Elder (*Sambucus canadensis L.*)
Prefers rich moist soils along streams and rivers, margins of woodlands, fence rows, and railroad rights-of-way

Black Tupelo (*Nyssa sylvatica Marsh*.)
The small greenish flowers are an excellent source of nectar for bees.

Species Appropriate for Use In Bioretention Areas

Species/Common Name	Exposure	Mature Size	Time of Bloom	Comments
Perennials Suitable for Saturated Soils				
Asclepias incarnata / Swamp Milkweed (P)	Full sun to partial shade	2-4"	May-June	Native flowering plant that produces pink blooms in midsummer; butterfly nectar plant; monarch butterfly host plant
Aster novae angliae / New England Aster (P)	Full sun to partial shade	1-6'	September-October	Violet flowers attract butterflies, good food source for birds and mammals; saturated to dry soils
Bidens aristosa / Tickseed Sunflower (P)	Full sun	1-3'	August-October	Daisy-like yellow flower; high water tolerance
Caltha palustris / Marsh Marigold (M)	Full sun to partial shade	1-2'	Spring	Ideal for wetland gardens, clump-forming plants with yellow flowers die back in the summer
Carex stricta / Tussock Sedge (P)	Sun to partial shade	1-3'	May-August	Clumping; grass-like; used by songbirds and waterfowl; can grow as emergent
Chelone glabra / White Turtlehead (M)	Full sun to partial shade	2-3'	August-October	Snapdragon-type white flowers provide nectar for hummingbirds and butterflies; Baltimore checkerspot butterfly host plant
Chelone obliqua / Rose Turtlehead (M)	Full sun to partial shade	1-4'	Late Summer to mid Autumn	Pink snapdragon type flower ideal for a wetland garden; provides nectar for hummingbirds and butterflies; Baltimore checkerspot butterfly host plant
Eupatorium fistulosum / Joe Pye Weed (P)	Sun	1.5-6'	July-September	Huge, dusty-pink flowers attract butterflies; good food source for birds and mammals; saturated to dry soils; good Fall color
Eupatorium perfoliatum / Boneset (P)	Full sun to partial shade	3-4'	July-October	Large, flat, pearl-white flower heads attract butterflies; mallards and grouse eat seeds
Festuca rubra / Red Fescue (P)	Sun to partial shade	1-10'"		Can be used as turf; if unmowed resembles salt meadow hay; may go dormant in summer drought
Gentiana andrewsii / Fringe-tipped Closed Gentian (M)	Full sun to partial shade	1.3'	Late Summer to mid Autumn	Deep blue flowers look like buds that never open; prefers acid soil
Helianthus angustifolius / Swamp Sunflower (P)	Sun	6-8'	August-October	Yellow flowers with maroon centers; butterfly nectar plant; birds eat seeds
Hibiscus militaris / Halberd Rose Mallow (M)	Full sun	4-6'	July-September	Large plant that assumes shrub-like proportions. Large pink or white blooms; hummingbird nectar plant
Hibiscus moscheutos / Rose Mallow (P)	Full sun	3-8'	July-September	Shrub-like plant; very large pink or white flowers; hummingbird nectar plant; can grow with roots in water
Iris versicolor/ Blue Flag (M)	Full sun to partial shade	2-4'	Early Summer	Deep blue blooms on attractive grass-like foliage, spreads rapidly; butterfly nectar plant; can grow with roots in water
Kosteletzkya virginica / Seashore Mallow (P)	Full sun	1.5-4.5'	July-September	Pink hollyhock-like flowers ; can grow with roots in water
Lobelia cardinalis / Cardinal Flower (P)	Full sun to partial shade	1-5'	Mid Summer to mid Autumn	Will grow in average moist garden soil; butterfly and hummingbird nectar plant
Myosotis laxa / Smaller Forget-me-not	Partial shade	3-6"	Early Spring to Mid summer	Will die back during dry summer and reappear in winter; will not tolerate consistently dry conditions; clusters of clear blue blooms with a yellow eye; found near springs and on muddy shores; can grow with roots in water

Species/Common Name	Exposure	Mature Size	Time of Bloom	Comments
Onoclea sensibilis / Sensitive Fern (P)	Sun to shade	1-2'		Easy to grow; spreads rapidly; fronds turn rusty-gold in Fall; fertile fronds persist through Winter
*Osmunda cin*namomea / Cinnamon Fern (P)	Sun to shade	2-3'		Needs constant soil moisture if in sun
Osmunda regalis / Royal Fern (P)	Sun to shade	2-3'		Tolerates full sun if moist; good yellow-gold Fall color; resembles bamboo; can grow with roots in water
Panicum virgatum / Switch Grass (M)	Sun	3-6'	July-October	Tolerates wet to well-drained soil; flowers appear to float; high wildlife value; yellow Fall color; buff in Winter; excellent wildlife habitat and erosion control; tolerates from 15-30 days of flooding; used in swales and levees; songbirds eat seeds
Rudbeckia laciniata / Tall or Green-headed Coneflower (M)	Sun to partial shade	1.5-9'	July-September	Yellow flowers with drooping rays and green eyes provides seeds for birds; good for stream banks and pond edges
Solidago rugosa / Rough or Wrinkle Leaf Goldenro	Sun	1-6'	August to October	Does not cause hayfever; butterfly nectar plant; seeds taken by many birds; spreads rapidly
Thelypteris noveboracensis / NY Fern (P)	Partial shade to shade	1-2.5'		Pale green delicate fronds spread rapidly in moist areas
Thelypteris palustris / Marsh Fern (P)	Sun to partial shade	2-3'		Spreads rapidly in boggy ground
Vernonia noveboracensis / New York Ironweed (P	Sun	4-8'	August-October	The red-purple flowers of this wet meadow plant attract butterflies; will tolerate seasonal inundation
Perennials Suitable for Moist Organic Soils				
Amsonia hubrechtii / Willowleaf Bluestar	Full sun to partial shade	1.5-3'	Mid - Spring to early Summer	Trumpet shaped light blue flowers, delicate bottlebrush leaves give this plant an attractive, shrub-like appearance; leaves turn a beautiful yellow in Fall
Andropogon gerardii / Big Bluestem (M)	Sun	3-7'	August-September	Prairie grass with purple flowers; blue-green blades turn tawny in Fall; high wildlife value. Under ideal conditions, roots can reach 12 feet; tolerant of acid soil, sandy soil and drought; good erosion control; tolerates from 7-14 days of flooding
Aquilegia canadensis / Columbine (P)	Sun to shade	2'	April-May	Red and yellow flowers attract hummingbirds and butterflies; blue-green elegant divided foliage; tolerates moist or dry sites
Aruncus dioicus (sylvester) / Goatsbeard (M)	Full sun to partial shade	3-6'	Late Spring to early Summer	Many small creamy white to yellow flowers, prefers moist well drained loamy soil
Asclepias incarnata / Swamp Milkweed (P)	Full sun to partial shade	2-4'	May-June	Native flowering plant that produces pink blooms in midsummer; butterfly nectar plant; monarch butterfly host plant
Aster divaricatus / Wood Aster (P)	Partial shade to shade	1-3'	September-October	Good for dry shade or moist woods; white flowers attract butterflies; attractive massed at woodland edge
Aster laterifolius / Calico Aster (P)	Full sun to partial shade	1-4'	August-September	Multitude of small white flowers with raspberry to purple centers creates a lacy effect
Aster laevis / Smooth or Blue Bird Aster (P)	Sun	2-5'	August-October	Pale blue flowers attract butterflies, good food source for birds and mammals; moist to dry soils; mildew free
Aster novae angliae / New England Aster (P)	Full sun to partial shade	1-6'	September-October	Violet flowers attract butterflies, good food source for birds and mammals; saturated to dry soils

Species/Common Name	Exposure	Mature Size	Time of Bloom	Comments
Aster novi-belgii / New York Aster (M)	Full sun to partial shade	3-4'	July-October	Blue-violet flowers attract butterflies, good food source for birds and mammals
Astilbe spp. / Astilbe	Filtered sun to partial shade	1.5-3'	Late Summer to Late Autumn	Plumed sprays above fernlike foliage, requires moist nutrient rich soils
Bergenia cordifolia / Heart - leaved bergenia	Full sun to partial shade	1'	Late Winter to early Spring	Bronze Autumn foliage. Prefers well drained moist soil with some afternoon shade.
Boltonia asteroides / Boltonia	Full sun to partial shade	4-6'	Late Summer to Late Autumn	Easy to grow native with aster-like white or pink flowers. Attractive grey-green foliage. Prefers well drained moist soil
Carex stricta / Tussock Sedge (P)	Full sun to partial shade	1-3'	May-August	Clumping; grass-like; used by songbirds and waterfowl; can grow as emergent
Chasmanthium latifolium / River Oats (M)	Full sun to partial shade	2-3'	July-September	Broad-bladed grass resembles bamboo; bright green in spring, turns copper in Fall and tan in Winter; dangling "oats"; tolerates dry shade
Chelone glabra / White Turtlehead (M)	Full sun to partial shade	2-3'	August-October	Snapdragon-type white flowers provide nectar for hummingbirds and butterflies; Baltimore checkerspot host plant
Chelone obliqua / Rose Turtlehead (M)	Full sun to partial shade	1-4'	Late Summer to mid Autumn	Puffy pink snapdragon type flower ideal for a wetland garden; provides nectar for hummingbirds and butterflies; Baltimore checkerspot host plant
Cimicifuga racemosa / Black Snakeroot (P)	Full sun to partial shade	3-8'	Mid Summer to early Autumn	Bold woodland edge plant with white, wand-like blooms. Handsome foliage
Coreopsis verticillata / Threadleaf Coreopsis (P)	Full sun to partial shade	2'	June-August	Tolerates dry or moist sites and poor soil; yellow mini-daisies are held above delicate mound of lacey foliage
Dennstaedtia punctilobula / Hay-scent. Fern (P)	Full sun to partial shade	1-3'		Spreads rapidly; fragrant, light-green foliage turns yellow in Fall
Dicentra eximia / Wild Bleeding heart (P)	Partial shade to shade	1.5'	April-October	Beautiful mound of finely-cut foliage; delicate pink hearts
Elymus virginicus / Virginia Wild Rye (P)	Partial shade to shade	1.5-5.5	June-October	Found in wooded streamsides , floodplains, and the woodland edge, this grass will tolerate tolerates from 15-30 days of flooding as well as drought. Spreads easily, good for erosion control
Eupatorium fistulosum / Joe Pye Weed (P)	Sun	1.5-6'	July-September	Huge, dusty-pink flowers attract butterflies; good food source for birds and mammals; saturated to dry soils; good Fall color
Eupatorium perfoliatum / Boneset (P)	Full sun to partial shade	3-4'	July-October	Large, flat, pearl-white flower heads attract butterflies; mallards and grouse eat seeds
Eupatorium rugosum / White Snakeroot (P)	Full sun to partial shade	3-4'	June-September	Flowers so white they glow in twilight; cultivar with purple foliage is available
Festuca rubra / Red Fescue (P)	Sun to partial shade	< 1-3'		Can be used as turf; if unmowed resembles salt meadow hay; may go dormant in summer drought
Filipendula rubra / Queen of the Prairie	Full sun to light shade	4-6'	Early to Mid summer	Prefers well drained evenly moist soils but will tolerate wet soils. Foamy clusters of tiny pink blooms. Prairie native
Geranium maculatum / Cranesbill (P)	Full sun to partial shade	8-18"	April-August	Semi-evergreen fragrant foliage is scarlet to crimson in cold weather; lavender-blue or pink flowers

Species/Common Name	Exposure	Mature Size	Time of Bloom	Comments
Helenium autumnale / Sneezeweed (M)	Full sun to light shade	3-5'	Late Summer to Autumn	showy yellow daisy-like flowers
Helianthus angustifolius / Swamp Sunflower (P)	Sun	6-8'	August-October	Yellow flowers with maroon centers; butterfly nectar plant; birds eat seeds
Hemerocallis spp. / Daylilly	Full sun to light shade	1-5'	Late Spring to Summer	Daylillies grow best in soil rich in organic matter, may need to be divided periodically; caution: common orange daylily (H. fulva) is invasive; do not plant
Heuchera americana / Alumroot (M)	Partial shade to shade	1-1.5'	April-June	Semi-evergreen foliage is red to wine in cold weather; white airy flowers; good ground cover
Inula spp. / Elecampane	Full sun to light shade	1-1.5'	Midsummer	Resembles bright yellow daisies, provide good air circulation to prevent mildew
Liatris spicata / Spiked Gay-feather (P)	Full sun	1-5'	Midsummer to early Autumn	Easy to grow perennial with tall spikes of lavender blooms, foliage is grass like; butterfly nectar plant; birds eat seeds
Ligularia stenocephale / Bigleaf Ligularia	Light to partial shade	3-4'	Mid to late Summer	Bold perennial with daisy like blooms, foliage forms large mass that needs ample room.
Lobelia cardinalis / Cardinal Flower (P)	Full sun to partial shade	1-5'	Mid Summer to mid Autumn	Will grow in average moist garden soil; butterfly and hummingbird nectar plant
Lobelia siphilitica / Great Blue Lobelia (P)	Sun to shade	1-3'	August-October	Although flowers are blue, they attract hummingbirds
Lychnis chalcedonica / Maltese-cross	Full sun to late shade	2-3'	Spring to mid summer	Brilliant scarlet flower on tall stems, may be short lived but re-seeds readily
Mertensia virginica / Virginia Bluebells (P)	Full sun to partial shade	1-2'	Mid to late Spring	Woodland flower that does not tolerate dry condition; pink flowers turn to blue; entire plant dies back by midsummer
Monarda didyma / Beebalm (P)	Full sun to partial shade	2-3'	Early to late Summer	May mildew in dry weather; divide periodically; fragrant foliage; scarlet flowers; nectar plant for hummingbirds, butterflies
Monarda fistulosa / Wild Bergamot (P)	Full sun to partial shade	1.5-5'	July-August	Pink to purple flowers; fragrant foliage; nectar plant for hummingbirds, butterflies
Myosotis laxa / Smaller Forget-me-not	Partial shade	3-6"	Early Spring to Mid summer	Will die back during dry summer and reappear in winter; will not tolerate consistently dry conditions; clusters of clear blue blooms with a yellow eye; found near springs and on muddy shores
Oenothera fruticosa / Narrow Sundrops (P)	Sun	1-2'	June-September	Clear yellow flowers give this plant its name; birds eat seeds; basal rosette is evergreen, burgundy in cold weather
Onoclea sensibilis / Sensitive Fern (P)	Sun to shade	1-2'		Easy to grow; spreads rapidly; fronds turn rusty-gold in Fall; fertile fronds persist through Winter
Osmunda cinnamomea / Cinnamon Fern (P)	Sun to shade	2-3'		Needs constant soil moisture if in sun
Osmunda regalis / Royal Fern (P)	Sun to shade	2-3'		Tolerates full sun if moist; good yellow-gold Fall color; resembles bamboo; can grow with roots in water
Panicum amarum / Coastal Panicgrass (M)	Sun	1-3'		Will grow in dry or moist soil; usually found on coastal dunes and shores; deep-rooted

Species/Common Name	Exposure	Mature Size	Time of Bloom	Comments
Panicum virgatum / Switch Grass (M)	Sun	3-6'	July-October	Tolerates wet to well-drained soil; flowers appear to float; high wildlife value; yellow Fall color; buff in Winter excellent wildlife habitat and erosion control; tolerates tolerates from 15-30 days of flooding; used in swales and levees; songbirds eat seeds
Penstemon digitalis / Foxglove Beardtongue (P)	Full sun to partial shade	2-4'	June-July	White, snapdragon-like flower; semi-evergreen basal rosette; butterfly nectar plant
Physostegia virginiana / Obedient Plant (P)	Full sun to partial shade	2-4'	Late Summer to early Autumn	Tall graceful plant with pink tubular flowers on spikes, tolerates a wide range of soil types; spreads rapidly; good substitute for loosestrife
Polystichum acrostichoides / Christmas Fern (P)	Partial shade to shade	1.5-2'		Narrow, leathery, evergreen fronds; acid soil
Rudbeckia fulgida / Early Coneflower (M)	Sun to partial shade	1.5'	July-October	Yellow flowers with black eyes, 2-2 .5" wide, provide seeds for birds
Rudbeckia hirta / Black-eyed Susan (P)	Sun to partial shade	2'	June-October	Yellow flowers with black eyes, 2-4" wide, provide seeds for birds and nectar for butterflies. A short-lived perennial that re-seeds vigorously
Rudbeckia laciniata / Tall or Green-headed Coneflower (M)	Sun to partial shade	1.5-9'	July-September	Yellow flowers with drooping rays and green eyes provides seeds for birds; good for stream banks and pond edges
Rudbeckia triloba / Three-lobed or Branched Coneflower (M)	Sun to partial shade	1.5-4.5'	June-October	Yellow flowers with short rays and large, jet-black eyes provide seeds for birds; re-seeds easily
Sedum ternatum / Mountain Stonecrop (P)	Partial to full shade	<1'	April	Frothy, star-shaped flowers; evergreen
Solidago rugosa / Rough or Wrinkle Leaf Goldenrod	Sun	1-6'	August to October	Does not cause hayfever; butterfly nectar plant; seeds taken by many birds; spreads rapidly
Solidago sphacelata. / Goldenrod (M)	Full sun to partial shade	1-3'	July-September	Does not cause hayfever; butterfly nectar plant; seeds taken by many birds; spreads rapidly; attractive mound of foliage
Sorgastrum nutans / Indiangrass (P)	Sun to partial shade	5-7'	August-September	Large golden-brown plume-like flowers; adapted to dry, or moist soils; excellent wildlife habitat; grows rapidly; good for erosion control
Tellima grandiflora / Fringe Cups	Sun to shade	1-2'	Spring	Creamy yellow flowers age to pink; evergreen; spreads
Thelypteris noveboracensis / NY Fern (P)	Partial shade to shade	1-2.5'		Pale green delicate fronds spread rapidly in moist areas
Tiarella cordifolia / Foamflower (P)	Sun to shade	1'	April-July	Semi-evergreen foliage turns maroon in cold weather; spreads rapidly
Tradescantia virginiana / Spiderwort (M)	Full sun to partial shade	1-2'	Late Spring to mid Summer	long blooming plant with blue-green grass like foliage; deep blue-purple or white flower
Trollius europaeus / Globeflower	Full sun to partial shade	1-2'	Late Spring to mid Summer	Bright yellow flowers that have a long blooming season
Vernonia noveboracensis / New York Ironweed (P)	Sun	4-8'	August-October	The red-purple flowers of this wet meadow plant attract butterflies; will tolerate seasonal inundation

Species/Common Name	Exposure	Mature Size	Time of Bloom	Comments
Drought-tolerant Perennials				
Amsonia hubrechtii / Willowleaf Bluestar	Full sun to partial shade	1.5-3'	Mid - Spring to early Summer	Trumpet shaped light blue flowers, delicate bottlebrush leaves give this Southern native an attractive, shrub-like appearance; leaves turn a beautiful yellow in Fall
Andropogon gerardii / Big Bluestem (M)	Sun	3-7'	August-September	Prairie grass with purple flowers; blue-green blades turn tawny in Fall; high wildlife value. Under ideal conditions, roots can reach 12 feet; tolerant of acid soil, sandy soil and drought; good erosion control; tolerates from 7-14 days of flooding
Aquilegia canadensis / Columbine (P)	Sun to shade	2'	April-May	Red and yellow flowers attract hummingbirds and butterflies; blue-green elegant divided foliage; tolerates moist or dry sites
Asclepias tuberosa / Butterflyweed (P)	Full sun to partial shade	1.5-3'	May-June	Brilliant orange flowers attract butterflies; monarch butterfly host plant; will not tolerate too much moisture
Aster divaricatus / Wood Aster	Partial shade to shade	1-3'	September-October	Good for dry shade or moist woods; white flowers attract butterflies; attractive massed at woodland edge
Aster cordifolius / Blue Wood Aster (P)	Partial shade to shade	1.5-4'	September-October	Good for dry shade; showy blue flowers at woodland edge
Aster laevis / Smooth or Blue Bird Aster (P)	Sun	2-5'	August-October	Pale blue flowers attract butterflies, good food source for birds and mammals; moist to dry soils; mildew free
Aster novae angliae / New England Aster (P)	Full sun to partial shade	1-6'	September-October	Violet flowers attract butterflies, good food source for birds and mammals; saturated to dry soils
Boltonia asteroides / Boltonia	Full sun to partial shade	4-6'	Late Summer to Late Autumn	Easy to grow native with aster-like white or pink flowers. Attractive grey-green foliage. Prefers well drained moist soil
Chasmanthium latifolium / River Oats (M)	Sun to partial shade	2-3'	July-September	Broad-bladed grass resembles bamboo; bright green in spring, turns copper in Fall and tan in Winter; dangling "oats"; tolerates dry shade
Coreopsis verticillata / Threadleaf Coreopsis (P)	Full sun to partial shade	2'	June-August	Tolerates dry or moist sites and poor soil; yellow mini-daisies are held above mound of delicate, lacy foliage
Dennstaedtia punctilobula / Hay-scent. Fern (P)	Full sun to partial shade	1-3'		Spreads rapidly; fragrant, light-green foliage turns yellow in Fall
Elymus virginicus / Virginia Wild Rye (P)	Partial shade to shade	1.5-5.5	June-October	Found in wooded streamsides , floodplains, and the woodland edge, this grass will tolerate tolerates from 15-30 days of flooding as well as drought. Spreads easily, good for erosion control
Eupatorium fistulosum / Joe Pye Weed (P)	Sun	1.5-6'	July-September	Huge, dusty-pink flowers attract butterflies; good food source for birds and mammals; saturated to dry soils; good Fall color
Eupatorium rugosum / White Snakeroot (P)	Full sun to partial shade	3-4'	June-September	Flowers so white they glow in twilight; cultivar with purple foliage is available
Geranium maculatum / Cranesbill (P)	Full sun to partial shade	8-18"	April-August	Semi-evergreen fragrant foliage is scarlet to crimson in cold weather; lavender-blue or pink flowers
Heuchera americana / Alumroot (M)	Partial shade to shade	1-1.5'	April-June	Semi-evergreen foliage is red to wine in cold weather; white airy flowers; good ground cover
Oenotheria fruticosa / Narrow Sundrops (P)	Sun	1-2'	June-September	Clear yellow flowers give this plant its name; birds eat seeds; basal rosette is evergreen, burgundy in cold weather

Species/Common Name	Exposure	Mature Size	Time of Bloom	Comments
Panicum amarum / Coastal Panicgrass (M)	Sun	1-3'		Will grow in dry or moist soil; usually found on coastal dunes and shores; deep-rooted
Panicum virgatum / Switch Grass (M)	Sun	3-6'	July-October	Tolerates wet to well-drained soil; flowers appear to float; high wildlife value; yellow Fall color; buff in Winter; excellent wildlife habitat and erosion control; tolerates tolerates from 15-30 days of flooding; used in swales and levees; songbirds eat seeds
Penstemon digitalis / Foxglove Beardtongue (P)	Full sun to partial shade	2-4'	June-July	White, snapdragon-like flower; semi-evergreen basal rosette; butterfly nectar plant
Physostegia virginiana / Obedient Plant (P)	Full sun to partial shade	2-4'	Late Summer to early Autumn	Tall graceful plant with pink tubular flowers on spikes, tolerates a wide range of soil types; spreads rapidly; good substitute for loosestrife
Polystichum acrostichoides / Christmas Fern (P)	Partial shade to shade	1.5-2'		Narrow, leathery, evergreen fronds; acid soil
Rudbeckia hirta / Black-eyed Susan (P)	Sun to partial shade	2'	June-October	Yellow flowers with black eyes, 2-4" wide, provide seeds for birds and nectar for butterflies. A short-lived perennial that re-seeds vigorously
Schizachyrium scoparium / Little Bluestem (P)	Sun to partial shade	4'	August-October	Dense root system can reach eight feet; tolerant of poor, thin , gravelly or sandy soils; fluffy silver-white seed heads very decorative; blue-green foliage turns bright red in Fall; high wildlife value; establishes well on slopes and controls erosion on dry sites
Solidago rugosa / Rough or Wrinkle Leaf Goldenrod	Sun	1-6'	August to October	Does not cause hayfever; butterfly nectar plant; seeds taken by many birds; spreads rapidly
Solidago sphacelata. / Goldenrod (M)	Full sun to partial shade	1-3'	July-September	Does not cause hayfever; butterfly nectar plant; seeds taken by many birds; spreads rapidly; attractive mound of foliage
Sorgastrum nutans / Indiangrass (P)	Sun to partial shade	5-7'	August-September	Large golden-brown plume-like flowers; adapted to dry, or moist soils; excellent wildlife habitat; grows rapidly; good for erosion control
Groundcovers				
Arenaria montana / Moss Sandwort	Full sun to light shade	2-4"	Spring	Low cushion plant with small white flowers, requires well drained sandy-loam soil
Asarum canadense / Wild Ginger (P)	Partial to full shade	<1'	April-May	Semi-evergreen spreads rapidly. Small purple/brown flowers hide under leaves
Ceratostigma plumbaginoides / Leadwort	Sun to shade	<1'	Late Summer to Fall	Shrubby groundcover spreads rapidly in loose soil; drought tolerant; brilliant blue flowers; leaves red in Fall and Spring; non-native
Chasmanthium latifolium / River Oats (M)	Sun to partial shade	2-3'	July-September	Broad-bladed grass resembles bamboo; bright green in spring, turns copper in Fall and tan in Winter; dangling "oats"; tolerates dry shade
Chrysogonum virginianum / Green and Gold (P)	Partial shade	<1'	March-June	Golden daisy-like flowers continue sporadically until frost; spreads easily
Dennstaedtia punctilobula / Hay-scent. Fern (P)	Full sun to partial shade	1-3'		Spreads rapidly; fragrant, light-green foliage turns yellow in Fall
Epimedium grandiflorum / Bishop's Hat	Partial to full shade	8-12"	Late Spring	Foliage remains green most of the year, once established it will tolerate dry conditions, avoid soggy conditions
Festuca rubra / Red Fescue (P)	Sun to partial shade	< 1-3'		Can be used as turf; if unmowed resembles salt meadow hay; may go dormant in summer drought

Species/Common Name	Exposure	Mature Size	Time of Bloom	Comments
Geranium maculatum / Cranesbill (P)	Full sun to partial shade	8-18"	April-August	Semi-evergreen fragrant foliage is scarlet to crimson in cold weather; lavender-blue or pink flowers
Heuchera americana / Alumroot (M)	Partial shade to shade	1-1.5'	April-June	Semi-evergreen foliage is red to wine in cold weather; white airy flowers; good ground cover
Meehania cordata / Creeping Mint (M)	Shade	<1'	Late Spring to early Summer	Low-growing, semi-evergreen with bright lilac flowers held in spikes
Mentha Arvenis / Wild Mint (M)	Partial to full shade	6-18"	Summer and Fall	Spreading groundcover with lilac blooms, spreads easily and may become invasive
Myosotis laxa / Smaller Forget-me-not	Partial shade	3-6"	Early Spring to Mid summer	Will die back during dry summer and reappear in winter; will not tolerate consistently dry conditions; clusters of clear blue blooms with a yellow eye; found near springs and on muddy shores
Onoclea sensibilis / Sensitive Fern (P)	Sun to shade	1-2'		Easy to grow; spreads rapidly; fronds turn rusty-gold in Fall; fertile fronds persist through Winter
Osmunda cinnamomea / Cinnamon Fern (P)	Sun to shade	2-3'		Needs constant soil moisture if in sun
Osmunda regalis / Royal Fern (P)	Sun to shade	2-3'		Tolerates full sun if moist; good yellow-gold Fall color; resembles bamboo; can grow with roots in water
Panicum virgatum / Switch Grass (M)	Sun	3-6'	July-October	Tolerates wet to well-drained soil; flowers appear to float; high wildlife value; yellow Fall color; buff in Winter; excellent wildlife habitat and erosion control; tolerates tolerates from 15-30 days of flooding; used in swales and levees; songbirds eat seeds
Phalaris arundinacea / Ribbon Grass (M)	Sun	1-2.5'	Summer	Tolerates wide range of light and moisture regimes; aggressive spreader; striped green and white drooping stems
Polystichum acrostichoides / Christmas Fern (P)	Partial shade to shade	1.5-2'		Narrow, leathery, evergreen fronds; acid soil
Pulmonaria longifolia / Lungwort	Partial to full shade	8-18"	Spring	Will not tolerate dry conditions; may die back in summer; interesting foliage with silver-mottled hairy leaves; blue and pink flowers
Rhus aromatica / Fragrant Sumac (M)	Full sun to partial shade	2-4'	March-May	Spicy smelling leaves turn orange and scarlet in Fall; high wildlife value; variety 'gro-low' of this shrub makes a good groundcover for slopes
Sedum ternatum / Mountain Stonecrop (P)	Partial to full shade	<1'	April	Frothy, star-shaped flowers; evergreen
Solidago sphacelata. / Goldenrod (M)	Full sun to partial shade	1-3'	July-September	Does not cause hayfever; butterfly nectar plant; seeds taken by many birds; spreads rapidly; attractive mound of foliage
Tellima grandiflora / Fringe Cups	Sun to shade	1-2'	Spring	Creamy yellow flowers age to pink; evergreen; spreads
Thelypteris noveboracensis / NY Fern (P)	Partial shade to shade	1-2.5'		Pale green delicate fronds spread rapidly in moist areas
Thelypteris palustris / Marsh Fern (P)	Sun to partial shade	2-3'		Spreads rapidly in boggy ground
Tiarella cordifolia / Foamflower (P)	Sun to shade	1'	April-July	Semi-evergreen foliage turns maroon in cold weather; spreads rapidly

Species/Common Name	Exposure	Mature Size	Time of Bloom	Comments
Trees				
Acer rubrum / Red Maple (P)	Sun to shade	60-90'	March-April	Shallow root system; high wildlife value; attractive red flowers and fruit; tolerates moist or dry sites; red/yellow/orange fall color
Amelanchier canadensis / Shadbush (P)	Partial sun to shade	15-25'	March-May	Single or multi-stem; shallow roots, high wildlife value; 4 season interest: white flowers, edible fruit, orange to red fall color; smooth grey bark
Aralia spinosa / Hercules Club (P)	Sun to partial shade	10-20'	June-August	Fast growing thorny shrub/ tree; white flowers; high wildlife value; yellow to red/orange Fall color; tolerates seasonal flooding and drought
Asimina triloba / Paw Paw (P)	Sun to partial shade	6-30'	May	Unusual maroon flower; very large leaves; edible yellow fruits relished by wildlife; yellow Fall color; moist soil
Betula nigra / River Birch (P)	Sun to partial shade	50-70'	April-May	Tolerates wet feet or upland site; interesting catkins; beautiful peeling bark; yellow Fall color; high wildlife value; good bank stabilizer
Carpinus caroliniana / Musclewood (P)	Partial sun to shade	35-50'	April-May	Tolerates sun if soil is moist; tolerates irregular inundation; unique fluted silver-gray bark; yellow, red, or orange Fall color; high wildlife value
Carya cordiformis / Bitternut Hickory (P)	Sun	60-80’	May	Grows in dry, moist, or wet soil; yellow Fall color; good food source for birds and mammals; strong wood; resistant to wind throw
Celtis occidentalis / Common Hackberry (P)	Sun to partial shade	40-60’	April	Tolerates dry sites and irregular flooding ; good food source for birds and mammals; especially important for winter food; host for 7 butterfly species; only host for rare hackberry butterfly; tolerates road salt ; yellow Fall color; good for bank stabilization
Cercis canadensis / Redbud (P)	Partial sun to shade	20-35'	April-May	Tolerates sun if soil is moist; tolerates irregular inundation; Flowers pink to lavender; yellow Fall color; new leaves reddish; high wildlife value
Chionanthus virginicus / Fringetree (P)	Sun to shade	20-35'	May-June	Clumping or single-stemmed; White, pendulous, fragrant flowers; gold Fall color; birds eat fruits; tolerates drought and irregular inundation
Crataegus pruinosa / Frosted Hawthorn (P)	Sun to partial shade	24'	May	White flowers; songbirds eat purple fruits; deep blue-green waxy foliage turns orange/red in Fall; tolerates drought and irregular inundation
Crataegus viridis / Green Hawthorn (P)	Sun to shade	20-35'	April	White flowers; songbirds eat red persistent fruits; purple/scarlet Fall color; trees with thorns attract nesting birds; tolerates wet soils
Fraxinus americana / White Ash (P)	Sun to partial shade	50-80'	April-May	Tolerates short-term flooding; loose purplish flower clusters; yellow/maroon early Fall color; seeds taken by birds; host for tiger swallowtail
Fraxinus pennsylvanica / Green Ash (P)	Sun	50-75'	April-May	Tolerates range of wet to dry sites; birds take seeds; loose purplish flower clusters; yellow Fall color; good bank stabilizer; tolerates road salt and restricted root zone
Ginkgo biloba / Maidenhair Tree	Sun	50-80'		Non-native; gold Fall color; avoid female: offensive odor from fruit
Gleditsia triacanthos / Honeylocust	Sun	50-75'	June	Prefers moist, well-drained soil, but drought tolerant; taproot; U.S. native, can be invasive out of its region; may have large thorns; gold Fall color
Ilex opaca / American Holly (P)	Sun to shade	20-40'	May-June	Evergreen; need both male and female to produce berries; moist to well-drained soil; creamy white flowers; high wildlife value; slow-growing
Juniperus virginiana / Eastern Red Cedar (P)	Sun	40-60'	March-June	Tolerates dry or moist sites; taproot; dark blue berries; reddish solitary flowers; evergreen; berries taken by many birds; good bank stabilizer

Species/Common Name	Exposure	Mature Size	Time of Bloom	Comments
Koelreuteria paniculata / Golden-rain-tree	Sun	20-30'	Early to Midsummer	Yellow, hanging flower clusters; shallow root system, non-native
Liquidambar styraciflua / Sweet Gum (P)	Sun to partial shade	60-80'	March-May	Tolerates wet soils and a wide range of conditions; seeds taken by birds and mammals; spectacular Fall color
Magnolia virginiana / Sweetbay Magnolia (P	Sun to shade	15-40'	May-July	Large white fragrant flowers; small multistem tree; red berries; semi-evergreen; wildlife value; will tolerate wet soils
Nyssa sylvatica / Black Gum (P)	Sun to partial shade	50-100'	May-June	Tolerates seasonal flooding or dry, rocky uplands; tupelo honey source; blue-black berries taken by birds; brilliant scarlet Fall color ; den tree
Platanus acerifolia / London Plane-Tree	Sun	70-80'		Shallow root system; non-native; not all cultivars are resistant to disease
Platanus occidentalis / Sycamore (P)	Sun to partial shade	75-100'	May-June	Tolerates occasional inundation; white and brown peeling bark; tan/brown balls for fruit; good bank stabilizer; finches eat seeds; nesting cavities
Populus deltoides / Eastern Cottonwood (P)	Sun	75-100'	April-May	Tolerates occasional inundation; short-lived; golden Fall color
Quercus bicolor / Swamp White Oak (P)	Sun to partial shade	60-75'	April-May	Tolerates seasonal flooding or upland site; very sweet acorns much prized by wildlife; red/brown Fall color; shallow root system
Quercus coccinea / Scarlet Oak (P)	Sun	50-75'	May-June	Moist or dry sandy sites; taproot; acorns important for wildlife; scarlet Fall color
Quercus falcata / Southern Red Oak or Spanish Oak (P)	Sun	70-80'	April-May	Acorns feed wildlife (especially in winter); nesting sites; found in rich, moist woods; strong wood; wind-firm
Quercus macrocarpa / Bur Oak	Sun	75-100'		Taproot system; Midwest native; large spreading tree; tolerates drought, some flooding
Quercus nigra / Water Oak (M)	Partial shade to full shade	50-80'		Green color persists late in year; acorns feed wildlife
Quercus palustris / Pin Oak (P)	Sun	60-80'	April-May	Taproot; fast-growing large tree; high wildlife value; red Fall color; will tolerate seasonal flooding but not consistently wet sites; needs acid soils
Quercus phellos / Willow Oak (P)	Full sun to partial shade	55-75'	February--May	Fast growing, large tree; shallow root system; high wildlife value; red Fall color; tolerates seasonal flooding and drought ; prefers acidic soil
Quercus rubra / Northern Red Oak (P)	Full sun to partial shade	60-80'	April-May	Large spreading tree; deep taproot; red or yellow Fall color; high wildlife value; will tolerate drought
Sophora japonica / Japanese Pagoda	Sun	40-70'	Summer	Shade tree; shallow root system; non-native; low wildlife value; showy, yellowish white flowers
Taxodium distichum / Bald Cypress (M)	Full sun to partial shade	75-100'	Late Winter	Shallow root system; ducks and marsh birds eat seeds and foliage; deciduous conifer; once established tolerate any amount of water
Thuja occidentalis / Arborvitae (P)	Full sun to partial shade	50-75'	May	Dense single stem tree; evergreen; shallow root system; needs moist soil; low wildlife value
Zelkova serrata / Japanese Zelkova	Sun	60-70'		Dense shade tree; non-native; low wildlife value

Species/Common Name	Exposure	Mature Size	Time of Bloom	Comments
Shrubs				
Aronia arbutifolia / Red Chokeberry (P)	Full sun to partial shade	4-10'	May-June	White flowers with red stamens; bright red, edible berries persist in Winter; salmon to scarlet Fall color; wildlife; bank stabilizer; dry to wet soils
Aronia melanocarpa / Black Chokeberry (P)	Full sun to partial shade	3-5'	May	White flowers with red stamens; black berries persist in Winter; dark purple-red Fall color; wildlife; bank stabilizer; dry to wet soils
Aronia prunifolia / Purple Chokeberry (P)	Full sun to partial shade	5-12'	April-May	White flowers with red stamens; dark purple berries persist in Winter; dark purple-red Fall color; wildlife; bank stabilizer; moist to wet soils
Baccharis halimifolia / Groundsel Tree (M)	Sun	6-12’	August-September	White flowers become silver-white seed-heads lasting through November; green twigs and striped bark add winter interest; moist to wet soils
Callicarpa americana / Beautyberry (M)	Full sun to partial shade	4-8'	June-August	Lavender-pink flowers on new wood; yellow Fall color; purple berries ring branch through winter; dry to wet soils
Cephalanthus occidentalis / Buttonbush (P)	Sun	3-10'	July-August	White flower buttons turn tan and persist; yellow Fall color; moist to flooded soil; high wildlife value including butterflies and hummingbirds
Clethra alnifolia / Sweet Pepperbush (P)	Full sun to partial shade	6-10'	July-September	Very fragrant white or pink flowers; yellow Fall color; butterfly nectar plant
Cornus sericea / Red Twig Dogwood	Full sun to partial shade	7-9'	Late Spring-Summer	White flowers; blue or white berries; high wildlife value; red/maroon Fall color; scarlet twigs in winter; good bank stabilizing shrub; Northeastern native
Euonymous americanus / Hearts-a-bustin' (P)	Partial shade	1.5-6'	May-June	Small brown flowers; fuchsia hearts with scarlet seeds; yellow to orange Fall color; green stems add winter interest; moist to wet soils
Hamamelis virginiana / Witch Hazel (P)	Full sun to partial shade	4-15'	September-December	Tolerates irregular flooding or dry sites; yellow fragrant strap-like flowers; yellow Fall color ; can also be a small tree
Hydrangea arborescens / Wild Hydrangea (P)	Partial shade	3-8'	June-July	Creamy white flowers on new wood dry tan and persist; dry to moist soil
Hypericum densiflorum / St John's Wort (P)	Full sun to partial shade	3-6'	Summer	Yellow flowers; tolerates variety of moisture regimes; medium wildlife value
Ilex glabra / Inkberry (P)	Full sun to partial shade	3-10'	May-July	Slow-growing evergreen; can be formally pruned; creamy-white flowers; tolerates wet soils; need male & female for berries; high wildlife value
Ilex verticillata / Winterberry (P)	Full sun to partial shade	6-12’	June-July	Can also be trained as small tree; white flowers; yellow Fall color; need male & female for scarlet berries; high wildlife value; tolerates wet soil
Juniperus communis 'Compressa' / Juniper	Sun	3-6'		mounded shrub; deep taproot; high wildlife value, evergreen
Juniperus horizontalis / Creeping Juniper	Sun	<1-3'		matted shrub; deep taproot; high wildlife value; 'Bar Harbor' variety has plum foliage in winter; center dies back as plant ages
Leucothoe recemosa / Fetterbush (M)	Partial shade to shade	3-8'	May-June	White drooping flowers; evergreen leaves turn red/purple after frost; moist soil
Lindera benzoin / Spicebush (P)	Sun to shade	6-12'	March-May	Chartreuse flowers; scarlet berries taken by birds; leaves fragrant when crushed; yellow Fall color; butterfly host plant; tolerates wet or dry sites
Myrica cerifera / Wax Myrtle (P)	Sun to shade	6-10'	March-April	Chartreuse or white flowers; fragrant evergreen leaves; fragrant berries taken by birds and used for candles; can prune as hedge; dry to wet soils

Species/Common Name	Exposure	Mature Size	Time of Bloom	Comments
Myrica pennsylvanica / Bayberry (P)	Full sun to partial shade	6-8'	April-May	Chartreuse or white flowers; semi-evergreen fragrant leaves; fragrant berries taken by birds and used for candles; need male and female plants
Physocarpus opulifolius / Ninebark (P)	Full sun to partial shade	6-12"	May-June	Peeling bark; pink or white flower clusters; moist or wet soil; medium wildlife value
Rhododendron canescens / Sweet Azalea (P)	Full sun to partial shade	3-10'	May-June	White or pink, fragrant flowers; moist, acid, well-drained soil; red or yellow Fall color
R. periclymenoides / Pinxterbloom Azalea (	Full sun to partial shade	3-10'	April-May	Pink flowers open before leaves are out; moist, acid, well-drained soil; red/wine/orange brilliant Fall color
Rhododendron viscosum / Swamp Azalea (P)	Full sun to partial shade	6-8'	June-August	Intensely fragrant white flowers; bronze Fall color; moist to wet soils
Rhus aromatica / Fragrant Sumac (M)	Full sun to partial shade	6'	March-May	Spicy smelling leaves turn orange and scarlet in Fall; high wildlife value; variety 'gro-low' makes good groundcover for slopes
Rhus copallina / Shining Sumac (P)	Sun	20'	June-July	Chartreuse flowers; scarlet fruit; bright red Fall color; wildlife value; tolerates dry, sandy soils; spreads
Rhus glabra / Smooth Sumac (P)	Sun	9-15'	June-July	Chartreuse flowers; scarlet fruit; bright red Fall color; wildlife value; tolerates dry, sandy soils; forms colonies with interesting growth habit
Rhus typhina / Staghorn Sumac (P)	Sun	10-25'	June-July	Chartreuse flowers; scarlet fruit; bright orange Fall color; wildlife value; tolerates dry, sandy soils; forms groves with interesting growth habit;
Rosa carolina / Pasture Rose (P)	Full sun to partial shade	.5-3'	May-June	Pink, fragrant flowers; red hips; high wildlife value; good Fall color; forms thickets; dry to moist soil
Rosa palustris / Swamp Rose (P)	Full sun to partial shade	8'	July-August	Dark pink flowers; red hips; high wildlife value; good Fall color; moist to wet soil
Sambucus canadensis / Elderberry (P)	Sun to shade	6-12'	April-May	Large white flower clusters; ornamental, edible purple berries; wildlife value; moist to wet soils; forms thickets; bank stabilizer; fast-growing
Vaccinium arboreum / Farkleberry (P)	Full sun to partial shade	15'	May-June	White flowers; persistent fruit; bronze and scarlet fall color; wildlife value
Vaccinium angustifolium / Low Blueberry (P)	Full sun to partial shade	2-3'	May-June	White flowers; edible fruit; scarlet fall color; wildlife value; dry to moist soil
Vaccinium corymbosum / Highbush Blueberry (P)	Full sun to partial shade	6-12'	April-May	White flowers; edible fruit; scarlet fall color; wildlife value; dry to wet soil
Vaccinium pallidum / Early Low Blueberry (P)	Full sun to partial shade	1.5'	April-May	White flowers; sweet edible fruit; scarlet fall color; wildlife value; dry to moist soil
Vaccinium stamineum / Deerberry (P)	Full sun to partial shade	5-10'	April-June	White flowers; edible fruit; scarlet fall color; wildlife value; dry to moist soil
Viburnum acerifolium / Maple-leaved Vib. (P)	Full sun to partial shade	3-6.5'	April-May	Creamy white flowers; blue berries; pink/crimson/purple Fall color; can tolerate dry to moist soil; wildlife value; best in groups
Viburnum cassinoides / Northern Wild Raisin (I	Full sun to partial shade	6-8'	June	Fragrant white flowers; pink, red, and blue berries turn black; wine-red Fall color; high wildlife value including butterflies
Viburnum dentatum / Arrow Wood (P)	Full sun to partial shade	8-10'	May-June	Creamy white flowers; blue berries; crimson Fall color; can tolerate wet to dry soil; high wildlife value; wood was used for arrows

Species/Common Name	Exposure	Mature Size	Time of Bloom	Comments
Viburnum lentago / Nannyberry (M)	Full sun to partial shade	8-15'	May	White flowers; sweet, edible black berries; purple-red Fall color; very adaptable; high wildlife value
Viburnum prunifolium / Black Haw (P)	Full sun to partial shade	20'	April-May	White flowers; black berries; purple-red Fall color; very adaptable; high wildlife value; dry to wet soils; slow grower
Viburnum trilobum / American Cranberry	Full sun to partial shade	8-12'	May	White flowers; edible red berries; yellow-purple-red Fall color; moist to boggy soil; high wildlife value; Northern native

NOTES: The table contains plants adapted to a variety of water regimes. This will allow designers to select plants appropriate to any combination of bioretention design and site constraints. **Please be advised, however, that not all plants will do well in all situations, so it is important to match the plants to the expected conditions**. All the plants listed are perennials, since perennial plantings require less maintenance than the traditional bedding out of annuals. Annuals, however, can be usefully employed as cover crops or nurse crops for meadow plantings and to provide temporary color in newly established plantings.

Soil Moisture & Drought Tolerance –

Saturated soils are wet for a significant portion of the growing season except during times of drought.

Moist soils are damp for most of the growing season, except during times of drought. They may occasionally be saturated. Some notes are included on flood tolerances and which plants can function as emergents, but designers should consult wetland references for specifics on water depths and durations tolerated.

Drought-tolerant perennials will do well in areas where water does not remain after a rain, and will not need supplemental watering in all but the most extreme droughts.

Light Requirements - *Full sun* means direct sunlight for at least six hours a day during the plant's growing season. *Partial shade* means three-six hours of direct sunlight or a site with lightly filtered sun during the plant's growing season. *Shade* means less than three hours of direct sunlight or a site with heavily dappled sun during the plant's growing season.

Geographic Restrictions - This list was designed for Prince George's County. The plants included should do well within middle section of the Mid-Atlantic region. Care should be taken, however, in utilizing the list elsewhere. Plants listed here may not be cold hardy in the extreme north or heat hardy in the extreme south. Similarly, a plant that is drought tolerant in this generally humid area may not be adapted to drier conditions in Western regions. Finally, users from other regions should be cautious and check local invasive plant lists since native plants from one region may become invasive in another setting.

CHAPTER 6

CONSTRUCTION AND INSPECTION

IN THIS CHAPTER

The effectiveness of bioretention is a function of the design and the construction techniques employed. Of these two parameters, construction is far more critical in achieving quality results. Poor construction technique will cause the best-designed facility to fail prematurely, usually from sedimentation or clogging or both. To counter this problem, adequate and proper inspection is paramount. This chapter covers the basic concepts associated with bioretention construction and inspection. The *Inspection Points* interspersed throughout this chapter pertain to the individual section of discussion. It is envisioned that contractors and inspectors will use these points for guidance.

6.1 Permitting and Processing

Typically, the installation of bioretention is a component of the grading and stormwater management permit associated with the subdivision or individual lot. Conceptual stormwater management approval and construction permits have already been obtained by this point and are not covered here. For specific permitting information, contact the Permits and Review Division, Department of Environmental Resources.

Inspection Point. A preconstruction meeting is required for all sites with an approved stormwater management and sediment control plan. Call at least 24 hours ahead to be sure an inspector is present.

6.2 Erosion and Sediment Control Principles for Bioretention Applications

During the construction phase, sedimentation and erosion problems can be the greatest because of exposed earth, clearing and grubbing operations, and equipment soil compaction. For this reason, erosion and sediment controls are required to contain sediment on-site. For conventional stormwater management site design, this meant that the designer simply had to place a sediment control pond at the lowest point of the property under development. The sediment basin would then be used for stormwater management control after construction was completed. Sites that incorporate bioretention for stormwater control require closer attention to detail because drainage areas are reduced, and massive site grading to one low point is discouraged. As a result, grading and sediment control practices are typically applied on a lot-by-lot basis to minimize the opportunity for soil transport. The following principles are identified and briefly explained for the reader. For more specific information, consult the *Low Impact Development National Guidelines* manual.

Principle 1. Planning and Phasing: Before to construction and even design, proper planning for sediment control is needed for each lot. Bioretention is a source control IMP that requires placement within the lot area. Therefore, when laying out the lot, the designer must analyze the topography, existing tree cover to be preserved, the building location and associated setbacks, slope steepness and length, drainage ways, and soil types.

Finally, vertical and horizontal distances from the proposed building locations to the bioretention area must be adequate to prevent seepage problems (see Chapter 4).

Principle 2. Schedule of Operations: Expose the smallest practical area of land for the shortest possible time.

Inspection Point. All sediment control devices must be in place before starting the main construction. At the end of each workday, inspect the devices to be sure of their adequacy, and safeguard any trenches or excavations. Provide temporary stabilization for disturbed areas as quickly as possible or as directed by the inspector. Areas that have been disturbed and are not actively being worked as well as areas that are on final grade, must be stabilized within 14 days.

Principle 3. Soil Erosion Control: First line of defense against contamination of the bioretention area. This would include the installation of on-lot silt fences, diversion swales, stabilization, and runoff control techniques.

Inspection Point. Make sure that silt fencing is properly keyed into the ground to prevent undermining as shown in Figure 6.1. For guidance, see *Standards and Specifications for Soil Erosion and Sediment Control*.

Figure 6.1. Silt fence around bioretention

Principle 4. Sediment Control: Even with the best erosion control techniques, sediment transport will occur. For this reason, on-lot sediment traps or super silt fence control practices are recommended.

Principle 5. Inspection and Maintenance: Erosion and sediment control practices must be inspected and maintained on a routine schedule. Accumulated sediment must be removed periodically and inspected for excessive accumulation after every major storm. Pay special attention to the stabilization of disturbed areas and integrity of the sediment control devices.

Inspection Point. All sediment traps must have room for additional sediment loading capacity. Proper disposal of removed sediment is imperative to reduce the probability of downstream contamination.

Sedimentation Rates for Bioretention. Although no specific sedimentation studies have been done on bioretention to determine the rate of accumulated sediment, estimated vertical-settling rates can be derived from Stokes Law. Sedimentation rates will vary significantly and are a function of the following factors:

- Soil particle size distribution and load of the influent (affected by land use activities)
- Retention time in the ponded area (12- to 48-hour drawdown time)
- Physical features of the bioretention facility surface and resulting flowpath length
- Surface area
- Water temperature affecting fluid viscosity
- Wind resuspension (minimal affect)

6.3 Construction Technique and Sequencing for Bioretention

6.3.1 Site Preparation and Planning

First and foremost, the erosion and sediment control principles itemized above must be followed to insure sediment will not affect the facility. In the planning and lot layout phase, the potential bioretention locations are identified. Two types of sediment control techniques are typically applied to bioretention facilities.

One method (most typical) is to avoid disturbing the proposed bioretention area after the initial rough grading and temporary stabilization has been performed. During the construction phase, all drainage must be directed away from the facility to avoid excessive sedimentation. Flow can be directed away from the bioretention facility by using silt fencing materials and temporary diversion swales that direct flows to small on-lot silt traps.

The other method of erosion and sediment control design applicable to bioretention is to allow the area proposed for the bioretention facility to be used for installing a sediment control facility. This can be done even where the *in situ* soils are used without the benefit of an underdrain system. However, if a sediment control facility is to become a bioretention facility, the following conditions must be met:

- The proposed invert of the bioretention facility must be greater than 1 foot below the sediment control facility invert.

- All remnant sedimentation must be removed.
- If geotechnical tests show that the *in situ* soils meet or exceed the soil medium guidelines for infiltration rates, no underdrain will be required, although it is still highly recommended.
- The *in situ* soils and ponded sediment materials must be removed, and the remaining surface must scarified to increase the likelihood of adequate infiltration potential.

6.3.2 Minimize Lot Grading/Clearing

Bioretention facilities should be within the development envelope, minimizing the need to clear areas unnecessarily. Bioretention areas can make use of existing wooded areas without grading the wooded area to install the facility. Grading of any catchment area draining to the facility should be done sparingly and stabilized immediately (within 14 days).

6.3.3 Install Sediment Control Devices

Using the approved sediment and erosion control plans, install necessary sediment control devices to protect the facility from contamination by sediment. Essentially, placing silt fence material around the perimeter should be sufficient to prevent flow from entering the area during construction.

6.4 Bioretention Soil Mix Preparation

6.4.1 Off-site Preparation

Soil preparation can be performed off-site and transported to the facility location when ready for installation. Before transport, the soil mix must be certified as meeting the criteria established for the soil medium and approved by the site inspector.

Inspection Point. A certification of the soil must be supplied on request to the county inspector.

Soil preparation can be accomplished by thoroughly mixing soil components, amendments and additives, as needed using a backhoe or front-end loader. For specific details and specifications for soils, see the Soils section.

6.4.2 *In situ* Preparation

In situ (or *in place*) soil used for bioretention must also be prepared. Scarification of soil surfaces by manually raking to aerate and reduce soil compaction is recommended. When *in situ* soils are being used without underdrain systems, soils investigation/geotechnical reports are required.

Inspection Point. A copy of the geotechnical report must be supplied to the inspector at the preconstruction meeting. The report must include the boring location at the bioretention facility and include USDA soil classification, boring log with penetration depths at least 2 feet below the proposed facility invert, depth to groundwater or impervious layer (if present), and infiltration rate of the *in situ* soil.

6.5 Timing

A bioretention facility may not be placed in service until all the contributing drainage area has been stabilized and and the inspector has approved it. Provisions for sediment control must be in-place as specified in the sediment and erosion control plans.

6.5.1 Materials Delivery

Delivery of materials such as soil medium, plants, gravel, geotextile, and underdrains will need to be coordinated to avoid stockpiling and contamination problems. Soil materials should not be delivered until the bioretention facility location has been excavated or graded to the design elevations and geotextile fabrics and underdrain systems are in place. Planting materials should not be delivered until after the soil medium has had time to settle and has been trimmed to the proper grade elevation. Weather and seasonal conditions will also affect planting requirements. For specific information on planting requirements, see Chapter 3.

6.5.2 Inspection

Before installing the soil medium, underdrain system, geotextile fabric and planting material, the county inspector must approve that the excavation has been prepared properly.

6.6 Excavation Preparation

Excavate the facility to the design dimensions. Excavated materials must be placed away from the facility sides to avoid contamination and possible sidewall instability. Large tree roots must be trimmed flush with the side walls to prevent fabric puncturing or tearing during subsequent installation procedures. The sidewalls of the trench must be roughened where sheared and sealed by heavy equipment.

6.7 Underdrain Specification

Where underdrains are specified, the following information provides guidance for underdrain installation.

6.7.1 Underdrain Material Types

Underdrain systems can be composed of a variety of materials, with PVC pipe material being the most commonly used as shown in Figure 6.2. PVC pipe comes in 8- to 12-foot sections. Alternative pipe material can include flexible ADS pipe. Other pipe materials could be substituted at the designer’s prerogative and with concurrence of the county.

Figure 6.2. Installing an underdrain

6.7.2 Connections

Pipe joints and storm drain structure connections must be adequately sealed to avoid piping conditions (water seeping through pipe or structure joints). Pipe sections must be coupled using suitable connection rings and flanges. Field connections to storm drain structures and pipes must be sealed with polymer grout material that is capable of adhering to surfaces. The underdrain pipe must be capped (at structure) until the site is completed.

6.7.3 Perforations

Perforated PVC pipe sections (Figure 6.3) are available from local hardware stores. The perforation locations are not too critical for proper function, as long as the total opening area exceeds the expected flow capacity of the underdrain itself. Commonly marketed perforated PVC pipe has one-quarter or one-half inch perforations, 6 inches center to center, along two or three longitudinal rows. Whether the perforations are placed at the invert of pipe or elsewhere, depend on the design of the facility. Typically, the perforations are placed closest to the invert of the pipe to achieve maximum potential for draining the facility. The perforations can be placed near the top of the pipe if an anaerobic zone is intended. Water below the perforated portion of the underdrain will have a tendency to accumulate during periods of saturation. Otherwise, water will have a tendency to infiltrate into the surrounding *in situ* soils.

Figure 6.3. Installed underdrain pipe

6.7.4 Location

Underdrains are typically located at the invert of the bioretention facility to intercept any filtered water that does not infiltrate into the surrounding soils. Soil and gravel cover over the underdrain must be at least 2 feet deep. Placement of a 2- to 3-inch gravel bedding is recommended beneath the discharge points. Underdrains must *daylight* or connect to an existing drainage system to achieve positive flow. Suitable discharge points include

- Grass swale areas, flush cut with sideslope areas
- Storm drain pipe conveyance system

Inspection Point. Before covering the underdrain system, the inspector must observe the underdrain itself, the connections, gravel bedding, and any filter fabric. Manufacturer's tickets are required for the gravel, pipe, and filter fabric material. For more information, see the county's *Approved Manufacturers and Suppliers List*.

6.8 Observation/Cleanout Standpipe

An observation/cleanout standpipe must be installed in every bioretention facility that has a depth greater than 2 feet or an underdrain system. The standpipe will serve three primary functions: (1) it indicates how quickly the bioretention facility dewaters following a storm; (2) it provides maintenance cleanout port; and (3) it will be connected to the underdrain system to facilitate cleanout.

The observation standpipe must consist of a rigid, non-perforated PVC pipe, 4 to 6 inches in diameter. It should be placed in the center of the structure and capped flush with the ground elevation of the facility. The top of the standpipe must be capped with a screw or a flange type cover to discourage vandalism and tampering. A lock is not necessary.

6.9 Filter Materials

6.9.1 Gravels

Gravel bed materials are sometimes used to protect an underdrain pipe to reduce clogging potential. Placing gravel over the underdrain must be done with care. Do not drop the gravel from high levels with a backhoe or front-end loader bucket. Spill the gravel directly over underdrain and then spread it manually. The construction specifications for gravel used to protect bioretention underdrains follows:

- Gravel stone size must be no greater than one-half inch to 1.5 inches in diameter (blue stone, double washed, #57 stone).
- The use of *pea gravel* in place of geotextile fabric is optional, but preferred
- Depth of the gravel must not exceed 12 inches
- River-run, washed gravel is preferred

6.9.2 Pea Gravel Diaphragm

Older specifications for bioretention used a geotextile fabric to filter water and soil before passing through to the underdrain gravel blanket. Using a pea gravel diaphragm has gained acceptance because of the reduced likelihood of blockage. If a pea gravel diaphragm is used in this manner, it should have a minimum thickness of 3–4 inches and a maximum thickness of 8 inches. Where situations permit, a greater depth can be applied

6.9.3 Filter Fabric

Filter fabric is needed for two purposes in bioretention facilities: (1) controlling transport of silt, and (2) controlling the direction of flow. In some older designs, the filter fabric placed on top of the gravel bed is used to control sediment transport into the gravel bed, which otherwise could become clogged. This filter fabric must meet a minimum permittivity rate of 75 gallons/minute/ft^2 and must not impede the infiltration rate of the soil medium. Filter fabric can be placed along the *walls* of the facility to help direct the water flow downward and to reduce lateral flows. Filter fabric must be placed along the sidewalls (from the subgrade and over the stone), when installing a facility in a median strip or parking lot landscape island (Figure 6.4).

Figure 6.4. Installing filter fabric and soil medium

Inspection Point. The inspector must preapprove all filter fabric and liner types must before installation. Non-woven fabric is preferred over the woven variety. Filter fabric installation requires at least a 1-foot overlap at the ends and staking the turned up surfaces in-place during construction. After soil is placed over the filter fabric, excess fabric can be removed by cutting it at the desired elevations. See the approved suppliers list.

6.9.4 Liners

Where bioretention is used for areas that require groundwater protection (stormwater hot spots or source water protection), a liner is employed. The minimum thickness for liners used in bioretention applications is 30 mil. Any underdrain systems must be placed above the liner with a provision to cap the underdrain discharge pipe to confine drainage if needed. Take care while placing the liner to avoid puncturing it. Place the soil medium over the liner by hand shovel rather than with construction equipment.

6.10 Soil Installation

6.10.1 Placement

Installation of soils must be done so that it ensures adequate filtration. After scarifying the invert area of the proposed facility, place soil at 8- to 12-inch lifts. Lifts are not to be compacted but are performed to reduce the possibility of excessive settlement. Lifts can be lightly watered to encourage natural compaction.

6.10.2 Compaction

Avoid over compaction by allowing time for natural compaction (Figure 6.5) and settlement. No additional manual compaction of soil is necessary. Rake the soil material as needed to level it out. Overfill above the proposed surface invert to accommodate natural settlement to the proper grade. Depending on the soil material, up to 20 percent natural compaction can occur. For facilities designed with a liner, no scarification of the invert area is required.

Figure 6.5. Natural compaction and settlement is recommended

Inspection Point. Minimal compaction of soil can be performed using mechanical equipment (such as a backhoe bucket) to reduce the possibility of excessive settlement. Removing overfill is easier than adding soil when attempting bring the facility surface to the correct elevation.

6.11 Soil Presoak

To speed up the natural compaction process, presoaking the placed soil can be performed. Significant settlement can occur after the first presoak, and additional settlement may occur subsequent to the initial wetting. If time and construction scheduling permits, it is preferable to allow natural settlement to occur with the help of rain events to presoak the soil medium.

Inspection Point. The surface of the facility does not necessarily need to be uniform. A slight variance from settling or mulching application is acceptable as long as the possible ponding depth does not exceed 6 inches. For areas where excessive settlement occurs, apply sand to fill spots and cover with mulch as needed.

6.12 Plant Preparation and Planting Methodology

6.12.1 Ordering

When ordering plants to be installed in a bioretention facility, adequate preparation of the bedding soils must occur before delivery. Timing in relation to season and readiness of the facility is paramount. Recommended ordering times are early spring or fall, depending on the species selected.

6.12.2 Stockpiling

Often times, plant materials need to be stockpiled while the facility is being prepared. Keeping root balls wet during this period, and providing a shaded storage location will help the plants survivability.

6.12.3 Shipping

Shipping of the plant materials is typically the responsibility of the nursery or landscaping contractor. It is preferable to have the plants shipped directly to a facility site ready for planting.

6.12.4 Tags

All plant materials must be tagged for identification in accordance with the *American Standard for Nursery Stock*.

Inspection Point. The inspector must check tags for compliance with the landscaping planting list shown on the stormwater design plans. Variations of plant type, size, quantity, or quality, requires DER approval and could necessitate a plan revision submittal.

6.12.5 Density

The initial density of the planting arrangement will be thick. This is to ensure adequate vegetative cover will quickly take hold. Once the plants continue to grow and spread out, the property owner can remove or divide some plants and transplant them elsewhere in the yard. For specific density information, see the Landscaping section of this manual.

6.12.6 Timing

To ensure survivability, transport and transplanting operations must be done at the appropriate time of the year and in sequence with construction activities.

Figure 6.6. The same island-before, during and after construction

6.13 Installation of Mulching Materials

6.13.1 Placement

Mulch should be placed on the surface ponding area of the facility. The mulch material should be fresh, shredded hardwood to help retain soil moisture and maximize nutrient uptake. This type of mulch material also helps resist flotation when the facility is fully ponded. If *aged* mulch is used, select the shredded type over the chip variety to minimize floatation and washouts.

Inspection Point. The mulch layer should be placed after the plants and groundcover have been installed. Protect and lift groundcover vegetation to place mulch material underneath and in between plantings. The mulch layer surface should approximate the final elevation as shown on the design plans.

6.13.2 Mulch Cover Depth

While studies have shown that the mulch layer is an important component for water quality, the layer of mulch should not exceed 3 inches in depth. Greater depths keep plant roots from making good contact with the soil. Mulch materials should not be mounded around the base of tree trunks because this practice encourages pests and diseases.

6.14 Maintenance and Operation

6.14.1 Fertilizing

In traditional, intensively cropped landscapes, soil fertility (and especially the level of available nitrogen) is considered the limiting factor to plant growth. As already noted, however, human actions have considerably altered the cycling of nitrogen. By design, bioretention facilities are in areas where nutrients (especially nitrogen) are significantly elevated above natural levels. Therefore, it is unlikely that soil fertility will be the limiting factor in plant growth, and thus fertilization would be unnecessary. Excess fertilization (besides compromising the facility's pollutant reduction effectiveness) leads to weak plant growth, promotes disease and pest outbreaks, and inhibits soil life.

If soil fertility is in doubt, a simple soil test can resolve the question. Homeowners should consult with their local nursery or contact the local agricultural extension office to determine fertility needs. If fertilization should become necessary, an organic fertilizer will provide nutrients as needed without disrupting soil life.

6.14.2 Harvesting

Like any garden area that includes grasses or woody plant materials, harvesting and pruning of excess growth will need to be done occasionally. Trimmed materials should be recycled back in with replenished mulch material, or land should be filled in the case of hot spot locations.

Figure 6.7. The completed Colmar Manor bioretention facility

6.14.3 Watering

Typically, watering the facility will not be necessary once plants have become established, except during drought conditions. Plant species for bioretention have been selected on the basis of their hardiness and ability to survive extreme conditions. However, watering will be needed during the plant establishment stage. As with any landscaping feature, the designer should consider effects on moisture condition and the ability of the owner to apply watering as needed. Facilities susceptible to drying conditions include the following:

- Landscape parking lot islands
- Median areas
- Windy, exposed areas

Inspection Point. Watering and maintenance responsibilities during different phases of a project must generally be defined as follows, unless contractual obligations require otherwise:

- Construction Phase: Developer/Builder
- Project Acceptance: Builder
- Property Ownership Transfer: Builder/Property Owner
- Warrantee Phase: Property Owner
- Operation Phase: Property Owner

6.14.4 Weeding

Weeding of the facilities is not absolutely necessary for the proper functioning of the bioretention facility. However, unwanted plants can be invasive, consuming the intended planting and destroying the aesthetic appeal. Therefore, weeding is encouraged to control growth of unwanted plants, especially where facilities are placed in prominent settings.

6.15 Warrantees

The landscaping work and materials must be guaranteed for one year from the date the permit is finalized (closeout). Watering during this period is the responsibility of the property owner.

Inspection Point. The warrantee period begins when the as-built construction plan is approved. Landscape bonds will be released on final landscape acceptance by the inspector. It is the bondee's obligation to notify the county for a final landscape inspection request and subsequent release of landscape bond. In the case of bioretention, landscaping is bonded under the storm drain permit.

6.16 Typical Sequence of Construction for Bioretention

The sequence of construction for bioretention areas is closely tied to the grading plans for the development. Because bioretention is a source control IMP, drainage area catchments are kept relatively small and therefore, manageable during the construction phase for control of sediment. Basic sediment control practices are employed for each lot. For a typical bioretention sediment control plan, see Chapter 2.

A typical sequence of construction with typical construction schedule is provided at the end of this chapter. The sequence of construction will vary for every project, but the designer can use this sequence of construction as a general guide. Variations to the sequence must be noted and conveyed to the county inspector. The sequence of construction must be placed on the plans.

6.17 Inspectors Checklist for Bioretention

The following checklist has been derived and modified from a checklist developed by the Community Standards Division, Site Development Inspection Section for use when evaluating a bioretention facility during different phases.

6.17.1 Bioretention Inspection Checklist

1. Preconstruction Meeting
   - Approved Stormwater Management Plan
   - Disseminate inspection requirements; what needs inspection
   - Ticket and tag requirements and a copy of the geotechnical report (if available)
2. Excavation of Bioretention Area
   - Suitable subgrade materials
   - Presence of moisture or water
   - Dimensions and placement of excavation conforms with plans
   - Sediment and erosion control devices in place
3. Installation Phase
   - Optional sand layer placed per plan
   - Backfill soil conforms with specifications and placed per details and specifications
   - Correct placement of ground cover or mulch cover
   - Correct placement of underdrains (size, schedule, location) where required
   - Correct placement of filter fabric
   - Proper placement of plant materials (type, size, quantity, tags)
   - Proper grade establishment
4. Final Inspection and As-Built
   - Original signed/sealed certification letter (for private facilities) and/or As-Built Plan (for public facilities) from a Maryland Registered Professional Engineer

- Changes in grading, facility depth, size, soil medium, plant materials, and such, must require an As-built Plan whether private or public to reflect the changes.
- Maintenance Agreement/Covenant for bioretention facilities on private property
- All landscaping installed/landscape warrantee documentation received
- Bioretention configuration, size and depth are in accordance with approved plans
- Landscaping certification documentation for bioretention facility(ies)
- Drainage area conforms to approved plan
- Drainage area completely stabilized

Note. The building inspector will not issue Use and Occupancy Permits for lots with bioretention without first obtaining written approval from the site development inspector, with certifications from the builder.

Sequence of Construction for Bioretention Area

Sequence	**Construction Time (day(s))**
1. Install sediment control devices as shown on the plans.	
2. Grade site to elevations shown on plan. If applicable, construct curb openings, and/or remove and replace existing concrete as specified on the plan. Curb openings shall be blocked or other measures taken to prohibit drainage from entering construction area. At the end of each workday, all excavations shall be protected by construction safety fencing or temporary backfill as needed.	
3. Stabilize grading within Limit of Disturbance except for Bioretention Area. Bioretention areas may be used as sediment traps if the proposed invert of the bioretention facility is 1' lower then the sediment trap.	
4. Excavate bioretention area to proposed invert depth and scarify the existing soil surfaces, taking care not to compact the *in situ* materials.	
4a. Install underdrain system and observation wells, if specified	
5. Backfill bioretention area with planting soil as shown in the plans and detailed in the specifications. Overfilling is recommended to account for settlement.	
6. Presoak the planting soil prior to planting vegetation to allow for settlement. This can be done by water truck or allowing water to enter the pit from a rain event.	
7. Excavate or fill to achieve proper design grade, leaving space for the upper layer of mulch and/or topsoil that will bring the surface to final grade and ready for planting.	
8. Plant vegetation specified in the planting plan for Bioretention Area.	
9. Mulch and install erosion protection at entrance points; remove sediment control practices or entrance blocks with inspector authorization.	
Total Estimated Construction	

Note: The times above represent construction time only and not the full duration of the individual activities. For example, activity six (presoak) may be one month long allowing for natural settlement to occur before proceeding to activity 7.

CHAPTER 7

ENVIRONMENTAL OUTREACH ACCEPTANCE AND MAINTENANCE OF BIORETENTION

IN THIS CHAPTER

7.1 Introduction

In the preceding chapters, planning, design, construction and landscaping for bioretention were explored and defined. Proper implementation of these phases will ensure a successfully completed bioretention facility. However, even when these steps are performed exceptionally well, lack of care or knowledge about the facility after installation can render all this work fruitless. Helping developers, builders, homeowners, and property managers understand the importance of environmental outreach with respect to bioretention will alleviate this concern.

Successful bioretention depends upon proper maintenance. Unless the plants are in good health and the mulch layer is regularly replenished, the bioretention facility will not function as designed and the longevity will be diminished. Therefore, it is crucial that the homeowners and property managers ultimately responsible for this maintenance understand their stewardship responsibility. Fortunately, the maintenance requirements for bioretention facilities are both simple and inexpensive.

This chapter provides the strategy, process and educational materials needed to ensure that maintenance responsibility and pollution prevention activities are clearly defined and communicated throughout the life of the facility. The Chapter is organized to follow the "stewardship chain" from initial site preparation through long-term maintenance. Each section delineates the necessary maintenance and communication tasks and identifies the responsible parties in addition to containing useful tips and strategies. Responsibilities are outlined for each of the parties identified below:

- Developer/Builder
- Landscape Designer
- Landscaper
- Inspector
- Salesperson/Real Estate Agent
- Homeowner/Property Manager
- Homeowner Association/Condominium Association

7.2 Property Development

Developer/Builder: Bioretention facilities are often installed during the final phase of construction (or building completion of each lot). Therefore, the builder's first maintenance responsibility is to protect any soils that will be used for bioretention from compaction or unnecessary disturbance. Areas where pre-existing grading is to be preserved or where existing vegetation is to be saved will also require special care. Because "*micro-grading*" is so important for successful bioretention, the developer/builder needs to clearly communicate with the contractor to ensure the desired result.

Sometimes, the bioretention area is used for sediment and erosion control or even sediment traps. When this is the case, see Chapter 4 for important contamination control and bioretention area preparation for conversion to the final facility.

Landscape Designer: Bioretention IMPs with naturalistic designs will be more densely planted than conventional landscapes. Plants will be in drifts or clumps rather than formal beds. Meadow seeding requires specialized techniques. The designer is responsible for communicating these requirements to the installer. Since mulch forms an important treatment component of bioretention, the designer needs to clearly communicate with the contractor to ensure the desired result.

Landscaper: The landscaper is responsible for plant maintenance during IMP construction.

7.3 Completion of Facility Construction

Landscape Designer and Inspector: A post-construction bioretention checklist follows:

- Storm water is flowing correctly; neither bypassing nor overwhelming the facility; runoff flows onto the whole facility;
- Water ponds in the facility, and the ponding depth is between 3-6 inches;
- Ponding lasts from 4-6 hours or less;
- Plants are correctly installed and in good condition; areas with plugs or seeds have been stabilized; and
- There is a 2-3 inch deep mulch layer except in areas that have been seeded or plugged; mulch is not heaped around the base of plants.

7.4 Sale of Property

Developer/Builder: Until the property is sold, the developer/ builder is responsible for providing day-to-day maintenance of the bioretention facility or contracting with a ***Landscaper*** for maintenance as outlined below.

Real Estate/Salesperson: The salesperson is responsible for informing the potential home purchaser about the bioretention facility. Informational brochures are available through the Department of Environmental Resources at no charge. These brochures are intended to be distributed to potential buyers. During closing of a property, the homeowner documents must include legal documents concerning the bioretention facility.

7.4.1 Maintenance Checklist for Bioretention Facilities

- **Weeding -** As with any garden, bioretention requires weeding of unwanted plant materials. Mulching helps to reduce weed growth and retain moisture in the soil. Weeding should be accomplished routinely and at least monthly.
- **Watering -** If plants wilt during the heat of the day, but recover in the evening, watering is not necessary. The plants are simply conserving moisture. If they do not recover, watering is indicated. Another good rule of thumb is to stick a pencil or screwdriver about four inches into the soil. If the soil is moist at that depth, watering is not needed. If the soil is dry, and the shrubs or trees were planted within the last three years, watering is necessary.

- **Fertilization -** In traditional, intensively cropped landscapes, soil fertility (and especially the level of available nitrogen) is considered the limiting factor to plant growth. By design, however, bioretention facilities are located in areas where nutrients (especially nitrogen) are significantly elevated above natural levels. Therefore, it is unlikely that soil fertility will be the limiting factor in plant growth, and thus fertilization would be unnecessary. Excess fertilization, (besides compromising the facility's pollutant reduction effectiveness) leads to weak plant growth, promotes disease and pest outbreaks, and inhibits soil life.

  If soil fertility is in doubt, a simple soil test can resolve the question. If fertilization should become necessary, an organic fertilizer will provide nutrients as needed without disrupting soil life.

- **Mulching -** The mulch materials placed in the facility will decompose and blend with the soil medium over time. Typically, mulch material should be re-applied once every six months. The depth of the mulch layer should be no more than 3". Mulch applied any deeper than three inches reduces proper oxygen and carbon dioxide cycling between the soil and the atmosphere, and keeps plant roots from making good contact with the soil. The mulch layer provides an important role in the bioretention physical properties for removing heavy metals from the system.

- **Dividing and Replanting -** The properly designed facility should thrive and allow planting materials to expand and propagate, eventually becoming overcrowded. If this occurs, perennial plants should be divided in spring or fall. Plants that do not perform well, or die, should also be replaced.

- **Trimming and Harvesting -** Current practice is to leave ornamental grasses and perennial seed heads standing to provide winter interest, wildlife forage, and homes for beneficial insects. Plants should not be cut back until spring when new growth commences, and even then it is only done for neatness, it does not impact growth. Plants may be pinched, pruned, sheared or dead-headed during the grow-ing sea-son to encourage more flowering, a bushier plant, or a fresh set of leaves. Diseased or da-maged plant parts should be pruned as they occur, and if a plant is pest-infested, then perform cleanup in fall to deny the pest a winter home. Trees and shrubs may be pruned for shape or to maximize fruit production. Consult Cooperative Extension's Home and Garden Information Center (1-800-342-2507) for the best time to prune particular species.

- **Standing Water Problems -** Bioretention facilities are designed to have water standing for up to four hours. If this period is routinely exceeded, the facility may not be functioning properly. Should standing or pooling water become a maintenance burden, minor corrective action can usually correct it. Pooling water is usually caused by clogging or blockage of either the surface layer or fines obstructing the filter fabric used between the gravel bed/underdrain and the surrounding planting soil. The surface blockage problem may be corrected by removing the mulch layer and raking the surface. For blocked filter fabric, use lengths of small reinforcing bar (2'-3'

#4 rebar) to puncture the fabric with holes every 1' on center. If the soils themselves are causing the problem, punch holes in the soil or optionally, install a "sand window" at least 1 foot wide running vertically to the underdrain system elevation. In a worst case scenario, the entire facility may need to be re-installed. In any case, contact the Department of Environmental Resources for an evaluation of the facility and recommendations on how to correct the situation.

- **Trash and Debris -** Runoff flowing into bioretention facilities may carry trash and debris with it, particularly in commercial settings. Trash and debris should be removed regularly both to ensure that inlets do not become blocked and to keep the area from becoming unsightly. Form more information on litter control and volunteer cleanup programs contact Citizens Concerned for a Cleaner County (CCCC) and DER's Office of Recycling.
- **Pet Waste -** Prince George's County has a "pooper scooper" ordinance. Pet waste should not be left to decay in bioretention facilities because of the danger of disease-causing organisms. EPA estimates that the droppings from 100 dogs over 2-3 days can contribute enough bacteria to a small lake or bay's watershed to temporarily render the water unsafe for swimming. Seattle estimates that the city's dogs and cats generate as much waste as a city of 50,000 people.

Figure 7.1. Even in the winter months, bioretention is effective for treating stormwater while providing visual interest.

7.4.2 Maintenance Schedule for Bioretention

Table 7.1 is provided for guidance with respect to bioretention facility. The schedule should be used as a guide only. The combination of diligent maintenance and simple pollution prevention practices will provide a superior system of water quality protection over conventional approaches.

Bioretention Maintenance Schedule

Table 7.1. Example Maintenance Schedule for Bioretention Areas

Description	Method	Frequency	Time of the year
Soil			
Inspect and Repair Erosion	Visual	Monthly	Monthly
Organic Layer			
Re-mulch any void areas	By hand	Whenever needed	Whenever needed
Remove previous mulch layer before applying new layer (optional)	By hand	Once every two to	
three years	Spring		
Add fresh mulch layer	By hand	Every six months	Spring and Fall
Plants			
Removal and replacement of all dead and diseased vegetation considered beyond treatment	See planting specs.	Twice a year	3/15 to 4/30 and 10/1 to 11/30
Inspect for disease/pest problems	Visual	Once a month (average)	Inspect more frequently in warmer months
Determine if treatment is warranted; use least toxic treatment approach.	By hand	N/A	Varies, depends on disease or insect infestation
Watering of plant material shall take place for fourteen consecutive days after planting has been completed unless there is sufficient natural rainfall.	By hand	Immediately after completion of project	N/A
Remove stakes and wires after 6 months	By hand	After trees have taken root	Remove stakes and wires when possible, but at least by six months time
Remove Tags	By hand	At end of warrantee period	

7.4.3 Property Owner Notification Concerning Bioretention Practices

Salesperson/Real Estate Agent: The salesperson has the critical responsibility of introducing the buyer to the concept of bioretention and acquainting the prospective homeowner with his or her maintenance responsibilities. DER has appropriate educational materials, which are available in bulk for distribution. These materials will explain what pollution prevention measures can be taken and where to seek technical assistance from County or State agencies. Companies, of course, may also wish to create their own materials that emphasize rain gardens as a selling point. If the educational material is custom-designed, it should contain the same basic guidance to the property owner that is provided in the County's brochures.

DER can also direct salespeople to supplemental resources on pollution prevention and environmentally sound yard care such as the BayScapes program, Cooperative Extension, *Better Backyard* and our Rain Garden Rainbows Program. Pollution prevention can simply be stated as the proper use, handling and disposal of chemicals and materials to reduce the introduction of pollutants into the environment. Prevention usually means reducing the quantity and the frequency of use of potential pollutants: For example, lawn care practices that promote the use of less fertilizer, applied only once a year (in the fall) and recommend the use of pesticides when there is a known problem (avoid preventative applications). This approach translates into saving both time and money for the property owner/manager.

There are also two more formal notification mechanisms. First and most common, is the individual property maintenance agreement. This document will "run with the land" to ensure that the current (and all future) property owners will be aware of their bioretention maintenance responsibilities. Second, is the homeowner association covenants. These covenants will explain the HOA's obligation for maintenance of common open space and its role in community education and enforcement of community standards.

Each development is different. Developments may need to have their own unique blend of educational materials, agreement conditions and pollution prevention programs de-pending on the type of bioretention practice used. The educational requirements and approach of each development for main-tenance and pollution prevention will be determined during the preliminary approval stages of the subdivision, roadway and stormwater management plans. The final form and the specific conditions for the maintenance agreement can not be determined until such time as all public/private infrastructure maintenance issues have been agreed upon. At that time, the responsibilities will be clear and then must be codified in writing through the various agreements and HOA covenants described in this chapter.

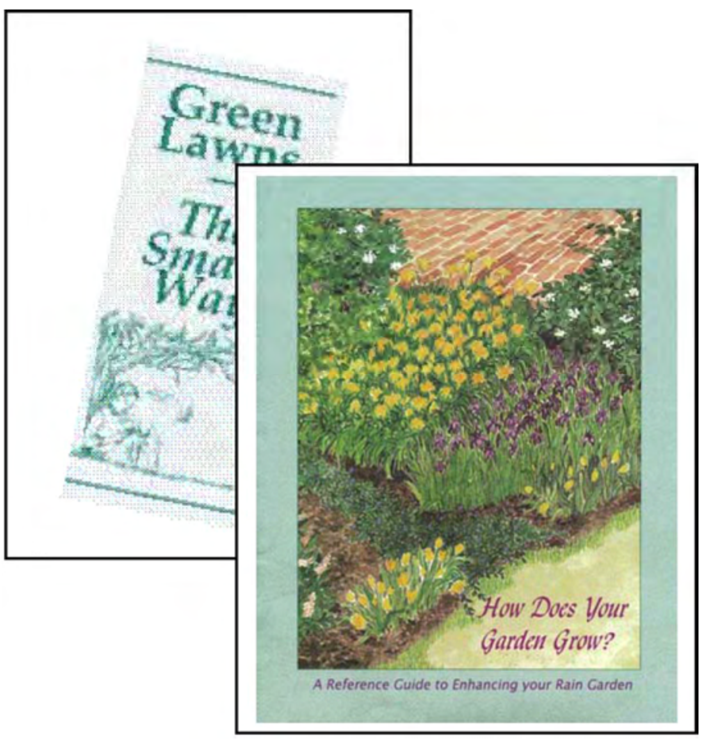


Figure 7.2. Handy brochures help explain bioretention

For residential developments the builder/developer must distribute the public educational materials by keeping them on display at the sales office and available for inspection by perspective purchasers. The builder/developer must provide all purchasers a package containing the maintenance agreements and educational materials at settlement or shortly thereafter. These materials may include (but are not limited to) the following:

- Site plans showing bioretention areas
- Easements (if any)
- Bioretention design manual
- Bioretention development brochure
- Homeowner rain garden maintenance manual
- Car care brochure
- Yard Care brochure
- Reporting pollution problems fact sheet
- County information services numbers

7.5 Easement Documentation Requirements

When bioretention facilities are located on private residential lots, serving drainage originating from that same lot, no easements or surface drainage easement are required.

If drainage originates from another lot, then surface drainage easements will be required. The surface drainage easement shall extend to, and encompass the bioretention IMP area. Surface drainage easements are only required whenever there is cross-lot drainage. This is true for conventional grading as well as LID grading practices.

In all cases where bioretention is located on a private lot, no storm drainage easements are required.

7.6 Responsibility for Facilities Transferred to Property Owners and HOAs

7.6.1 Maintenance Agreements and Conditions: Single Family Residential Property Owner Agreement

Homeowner: The Property Owner Agreement notifies the property owner and enumerates his/her maintenance responsibilities for all bioretention practices on their property and where applicable within the public right-of-way or easements. All single family homeowner agreements must be recorded in the Land Records. This is to ensure that there is a notification mechanism for future property owners. The list of conditions shown below is illustrative and should not be considered as an all-inclusive menu of conditions. Not all conditions will be applicable for all types of residential developments, as there could be any number of ways to share maintenance burdens between the property owner, homeowner associations and the local government. The specific conditions will be developed during the review and approval process of each development site. The conditions may include:

- Keep open swales and drainage easements free of trash and debris.
- Repair any erosion of the swales.
- Repair erosion, ruts or bare spots on the grassed shoulder of the road and on your property.
- Keep culverts and appurtenance free of debris blockages to maintain unobstructed flow.
- Do not obstruct the flow of runoff through the property within swales or drainage easements with fill or structural improvements.
- Do not cause alterations of the flow of water onto adjacent properties in a manner that would damage adjacent properties.
- Maintain all landscaped areas in accordance with County (or others) guidelines.
- Adopt reasonable and practicable pollution prevention measures in accordance with County programs.

7.6.2 The HOA Agreement, Covenants and Responsibilities

Homeowner Associations: The HOA would be responsible for maintenance of all bioretention practices within common areas or areas under their control. The HOA will act as primary enforcer to ensure that bioretention practices are maintained in common areas and that property owners are encouraged to properly maintain any private bioretention area and meet the conditions of the homeowner agreements. The HOA will determine its own approach to encourage property owners to adhere to bioretention maintenance and pollution prevention practices and develop community standards to be used.

As a guide, the HOA covenants should address the following:

Establish an environmental committee to provide education programs in cooperation with the County or other agencies; establish community standards for maintenance of bioretention practices and other environmental features; develop strategies to ensure proper maintenance of bioretention practices; promote pollution prevention measures and educate new residents on bioretention responsibilities. The environmental committee will help foster stewardship of the bioretention facility and accomplish the following:

1. The HOA environmental committee will help identify the maintenance needs of individual bioretention facilities and assist homeowners with determining appropriate maintenance activities that should be performed.
2. HOA may want to provide for more proactive steps for enforcement of bioretention practices through special powers to assess fees or fines to ensure compliance. Chiefly, however, the HOA environmental committee authority should be administered on a cooperative level.

3. Provisions for proper maintenance of all bioretention practices under the HOA's purview can be included in the homeowner agreement once the bioretention maintenance practices have been approved.

4. The Department of Environmental Resources will provide assistance in the form of education of the committee members about the environmental concerns. DER can provide various documents and conduct presentations about not only bioretention, but also many other activities associated with common yard care practices.

7.6.3 Commercial/Industrial Development

Home Owner/Property Manager: In general, it has been a long-standing requirement to have a maintenance agreement for on-site stormwater management for commercial/industrial properties. The standard on-site facility maintenance agreements will be used for bioretention practices with modifications as necessary. The major change will be with the educational program to promote pollution prevention and to ensure the owner/property manager is aware of the proper maintenance procedures for the bioretention practices. The following information should be supplied to the property owner/manager:

- Fact sheets on bioretention maintenance.
- Fact sheets on pollution prevention.
- Fact sheets on the NPDES stormwater discharge requirements.
- Copy of the County's pollution laws.

7.7 Enforcement Of Property Owner Responsibilities

It is not the County's intent to routinely regulate property owners' activities to ensure proper maintenance of bioretention practices and adoption of pollution prevention measures. Instead, the County requires an effective education program to ensure that all parties have an adequate understanding of maintenance responsibilities and pollution prevention measures.

Figure 7.3. Most homeowners are pleased to help the Bay by maintaining their bioretention facility

County enforcement actions would only be taken in extreme situations where public, health, safety and welfare were jeopardized- for example, the illicit use of banned chemicals, illegal discharges or dumping. In some cases, it may be necessary for the County to take action where a property owner has totally failed to keep up their property. In such instances, the County has sufficient authority under existing regulations to force property owners to share in the cost of corrective measures. It is anticipated, however, that community self-regulation through a homeowners association and the economic and environmental incentives the bioretention approach offers will motivate the property owner to perform the required maintenance and adopt pollution prevention measures.

7.8 Maintenance Covenants for Bioretention

While an easement is not always required for bioretention facilities located on private lots, maintenance covenants are required. A sample maintenance covenant document for use with bioretention and other LID IMP's is provided in Appendix B.

7.9 Health, Safety, and Welfare with Respect to Bioretention

With all stormwater practices, misconceptions abound concerning cost, performance, nuisance pests, etc. The bioretention IMP is no exception. To clarify these concerns, the following bulleted items have been researched and presented here:

1. Bioretention areas are **not** ponds. Bioretention is designed to store water temporarily (usually less than 4 hours) before the water infiltrates into the ground.
2. Bioretention areas will not provide a convenient breeding ground for mosquitoes. Mosquitoes need at least 4 days of standing water to develop as larva.
3. Bioretention does not encourage nuisance pests to inhabit the property anymore than regular landscape features and flower gardens. In fact, bioretention can be designed to attract preferred creatures such as butterflies.

4. Bioretention does not present a safety hazard. Unlike stormwater management ponds, bioretention has minimal safety and liability issues.

5. Maintenance costs associated with bioretention are lower than conventional stormwater management. This is chiefly due to the facilities being located at the source rather than at the end of pipe. The smaller drainage area means that the facility is much smaller as well, therefore, maintenance is easier to perform. In addition, bioretention facilities are non-structural IMP's, reducing costs associated with structural components.

7.10 Related Environmental Programs and Funding Opportunities

Homeowners and HOA's interested in mitigating environmental impacts from their community may consider other available programs. These programs offer limited funding opportunities and technical guidance to help the homeowner achieve an aesthetically pleasing, low maintenance, environmentally friendly landscape.

There are a number of programs at the State, Federal and Local level that can dovetail nicely with the use of bioretention. The USEPA, Maryland Department of the Environment, and the Prince George’s County Government have recognized Bioretention as a viable stormwater management IMP. Furthermore, bioretention may be integrated seamlessly into the following programs:

- Backyard Conservation Program
  Contact: Maryland State Natural Resource Conservation service Office
  (410) 757-0860
- Backyard Wildlife Habitat Program
  Contact: National Wildlife Federation
  (703) 790-4434
- BayScapes
  Contact: U.S. Fish and Wildlife Service, Chesapeake Bay Field Office
  (410) 573-4500
- Wildlife Habitat Incentives Program
  Contact: Maryland State Natural Resource Conservation Service Office
  (410) 757-0860
- Wild Acres
  Contact: Maryland Department of Natural Resources- FSSEC
  (410) 260-8522

Figure 7.4. Paul Desousa explaining the principles of bioretention in one of many workshops conducted by DER.

Figure 7.5. Students Planting a Rain Garden

Figure 7.6. Sharon Meigs helps students become environmental stewards

APPENDIX A

BIOLOGICAL PROCESSES/ CYCLES IN BIORETENTION

IN THIS CHAPTER

A.1 Nutrient Assimilation

Nutrients are required for plant growth to occur. Soils lacking in nutrients will stunt vegetative growth. However, the overuse or incorrect use of fertilizers on lawns and gardens can result in excess nutrients leaving a site through groundwater transport or stormwater runoff. Atmospheric deposition, the dumping of yard and pet wastes, and urea used to melt ice add further nutrients into the urban environment. These loadings of nutrients such as nitrogen and phosphorus can have adverse impacts on downstream aquatic environments. For this reason, nutrients must be managed, regulated and used sparingly. Bioretention facilities can help in this regard, by capturing nutrients carried in runoff through filtration, biological uptake, and storage in the planting soils. Two nutrients (Nitrogen and Phosphorus) are examined more closely in the following paragraphs.

Bioretention has been shown to be effective in the treatment of phosphorus. Studies from laboratory and field experiments indicate that phosphorus is reduced by 60-80 percent. For nitrates, the removal rates have been far lower—a typical problem for many stormwater filter BMPs. However, the standard bioretention design can be customized to specifically treat expected runoff pollutants by increasing depth, adding anaerobic zones, changing the mulch layer, adding soil amendments, or by adjusting phytoremediation components.

A.2 The Nitrogen Cycle in Soils

The natural nitrogen cycle is very efficient. Almost all the nitrogen that enters the soil community is recycled and made available for plant growth; a small amount is leached into groundwater, lost in runoff, or volatized. This was dramatically illustrated in the Hubbard Brook Forest study when clear-cutting the forest of one watershed increased nitrate loss 60-fold.

In undisturbed ecosystems, the minor amount of nitrogen lost is replaced through biological fixation of atmospheric nitrogen—and to a lesser extent through fixation by lightning. Nitrogen fixation converts nitrogen gas (N_2) to ammonium ions (NH_{4+}). Decomposers (bacteria and fungi) break down the complex organic compounds (such as proteins) in dead plant and animal matter to form ammonia and ammonium ions. Other bacteria then oxidize the ammonia and ammonium ions to form nitrates—a process called nitrification. Nitrates (NO_{3-}) are highly soluble and are readily absorbed and assimilated by plants.

Human activity, however, can alter this picture greatly. Many homeowners apply large amounts of chemical fertilizers, especially to lawns. Formulations high in nitrates are popular because they promise *quick greenup*. In addition, many homeowners overwater the lawn or apply fertilizers just before rain or snow is expected.

Additional nitrates enter the soil system as rain deposits the combustion residues from cars and power plants. Together, these factors set the scene for elevated rates of nitrogen leaching and runoff from the soil. Compacted soils tend to exacerbate matters by preventing infiltration and more importantly, destroying the soil's ecosystem and its ability to assimilate nitrogen.

Moreover, decomposer and nitrifying bacteria populations decrease under heavy fertilization. When pesticides and fungicides are heavily used, the entire spectrum of soil life is curtailed. Thus, the system becomes progressively less able to process and use even natural nutrient inputs—this often manifests in home landscapes as excessive thatch buildup in the lawn. Because many wetlands and stream buffers have been lost to development; there is little to prevent the excess nitrogen from polluting waterways. By using bioretention, however, we can capture some of the excess nitrates carried in runoff and prevent the pollution of waterways.

Figure A.1 presents the nitrogen cycle as it can apply to bioretention, together with the various natural processes.

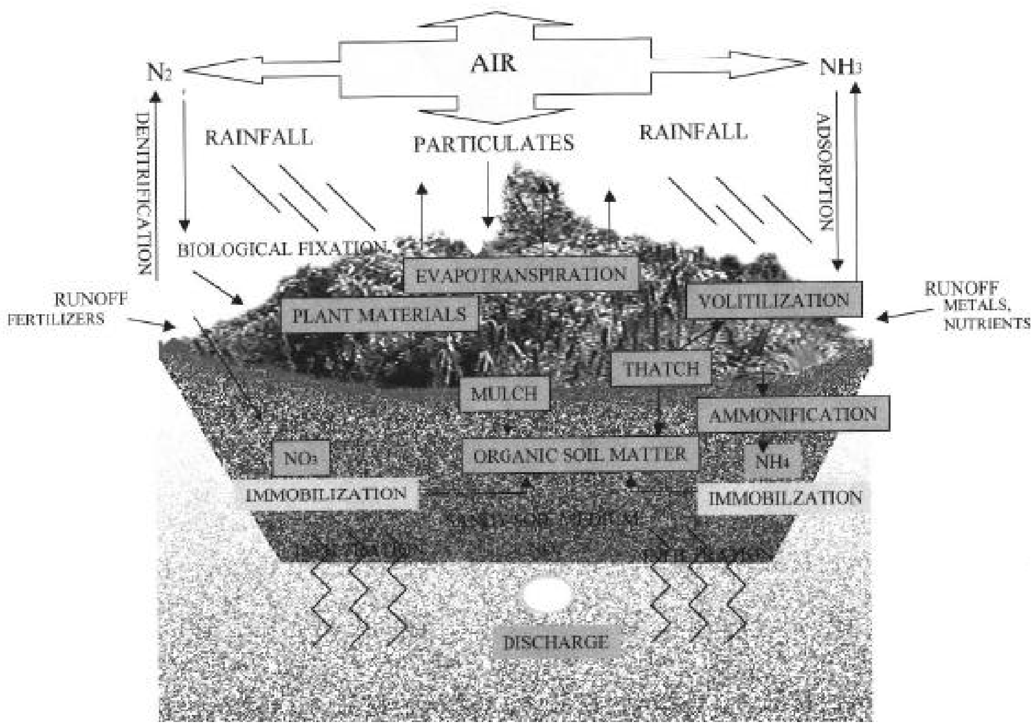


Figure A-1. Nitrogen cycle for bioretention

Nitrogen transformation formulas:

$2NH_3 + 3O_2 \rightarrow 2NO_2^- + 2H^+ + 2H_2O$

$2NO_2 + O \rightarrow 2NO_3^-$

Compounds and elements defined:

NH_3 Ammonia	NH_4 Ammonium Ion
N_2 Nitrogen Gas	NO_3 Nitrates
NO_2 Nitrites	2H Hydrogen Gas
$2H_2O$ Water	O_2 Oxygen

Nitrates are highly soluble and can infiltrate into and contaminate groundwater. To minimize this problem, an anaerobic area can be designed into a bioretention facility or it can be lined to prevent infiltration.

A.3 The Phosphorus Cycle in Soils

The natural cycle of phosphorus is even more efficient than the nitrogen cycle because phosphate is adsorbed in compounds containing iron, aluminum, and calcium. Thus, phosphate tends to be held within the soil instead of being leached away. Many homeowners do not realize this, however, and continue to apply excessive amounts of phosphorus-containing fertilizers year after year. Human activities have also dramatically increased soil erosion, which transports phosphorus-laden soil particles into waterways. Again, bioretention facilities can intercept and remove much of this phosphorus before it enters waterways.

Phosphorus is also necessary for plant growth and production and most importantly in bioretention, lateral and fibrous rootlet development. Unfortunately, overuse of this element adversely affects the environment, while little or no gain is made for the intended purpose. Figure A.2 shows the phosphorus cycle as it relates to bioretention.

Phytoremediation is the use of vegetation for the *in situ* treatment of contaminated soils and water. Typically used for sites that show shallow contamination of soils, phytoremediation has been highly successful. According to Groundwater Remediation Technologies Analysis Center (GWRTAC)—an organization that compiles, analyzes, and disseminates information on innovative groundwater remediation technologies—this concept has been successfully applied to brownfield sites.

The phytoremediation concept has been adapted to stormwater management by transferring this technology to ultra-urban applications and stormwater management hotspot opportunities. Bioretention uses the same concept and applies it to stormwater management in the urban environment.

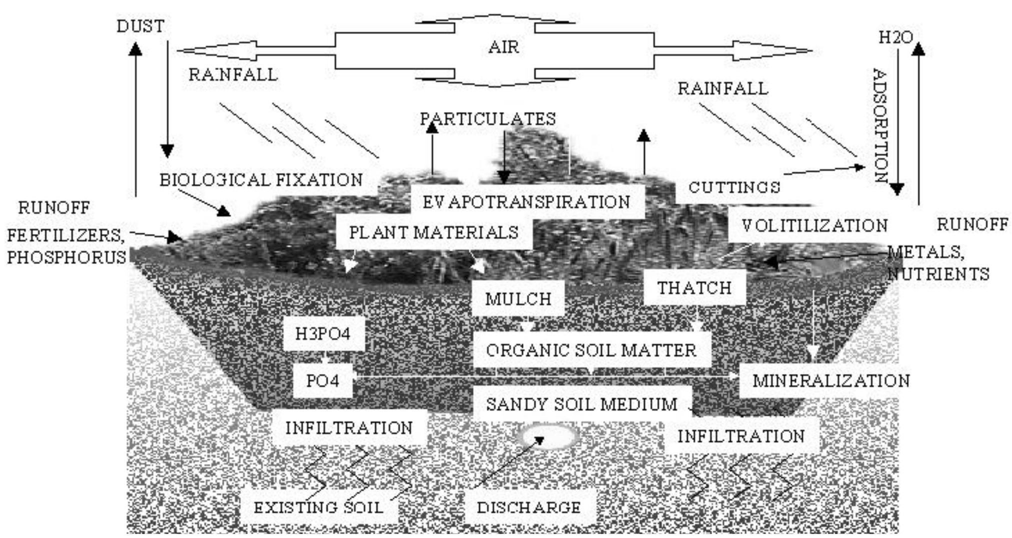


Figure A.2. Phosphorus cycle for bioretention

Phytoremediation can be implemented for contaminated retrofit sites. Essentially the same process as bioretention using *in situ* soils, phytoremediation applications use plant species known for their specific ability to uptake high concentrations of toxic chemicals and process them to a less toxic state.

The bioretention system components (Figure A.3.) have been selected to achieve and encourage biologic and physical processes mentioned in the above text to not only occur, but to self-perpetuate as well.

The components will blend over time with plant and root growth, organic decomposition, and the development of a macro and microorganism community. This, in turn, will help develop a natural soil horizon and structure that will lengthen the facility's life span and reduce the need for maintenance other than for aesthetics.

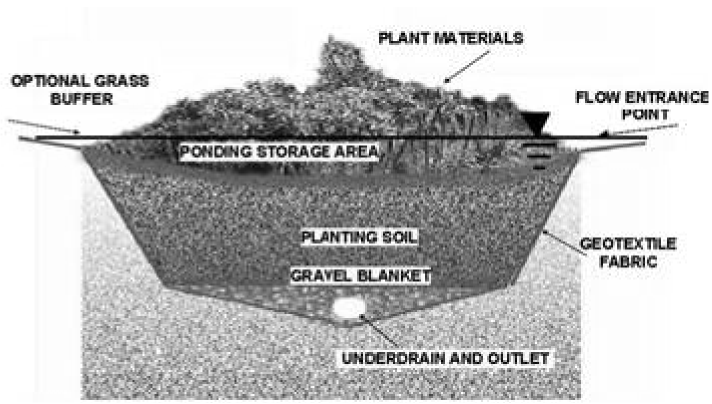


Figure A.3. Bioretention components

APPENDIX B

BIORETENTION COST AND SCHEDULE ESTIMATES

IN THIS CHAPTER

Estimating the Cost of Bioretention

Every site is unique, requiring specific cost estimating to account for the variability. In estimating the cost of using bioretention, a number of factors need to be considered:

1. Site restrictions- both physical and regulatory;
2. Availability of materials, equipment and labor; and
3. Scheduling of tasks for efficiency.

There are also indirect cost benefits of utilizing bioretention that should be factored into the cost savings. These benefits include:

1. The reduction or elimination of conventional stormwater management bmp's
2. Bonding and overall project cost reductions
3. Reduced stormwater conveyance costs
4. Reduced design costs with simplistic design
5. Reduced maintenance and liability costs
6. Aesthetic appeal not usually attributed to stormwater facilities
7. Multifunctional landscaping

A number of technical documents have attempted to define cost benefit ratios based on variables such as the contributing drainage area controlled, storage area provided, or surface area consumed. The methodology typically employed attempts to derive cost formulas that a designer can use to quickly calculate stormwater costs for their project. We believe that this approach is erroneous due to the factors listed above. A better approach is to analyze anticipated costs of project tasks and sub-tasks within project phases. That is to say, evaluate specific costs of material, equipment, and labor with respect to the project schedule.

The following Gantt chart (developed in Microsoft Project) provides a template to be used to help the designer formulate a cost estimate as well as a schedule of tasks that must be completed to properly implement bioretention. The fixed cost was derived from material costs, overhead, and historical project data for similar tasks. The total cost includes resources (equipment, materials, and labor costs) associated with a particular task. Designers can utilize this chart to derive their own numbers for specific tasks. For example, take the task #32- Place Planting Materials. The fixed cost ($2,500) in this case was based on the quantity and type of plants utilized. The total cost ($2,892) includes the cost of installation. For each project, planting costs will vary significantly depending upon the type of plants, availability, quantity, and scheduling efficiency. Numbers for estimating task costs can also be derived from Mean's Estimating Handbook for Site Work or the County's 1993 Price List.

Scheduling Tasks

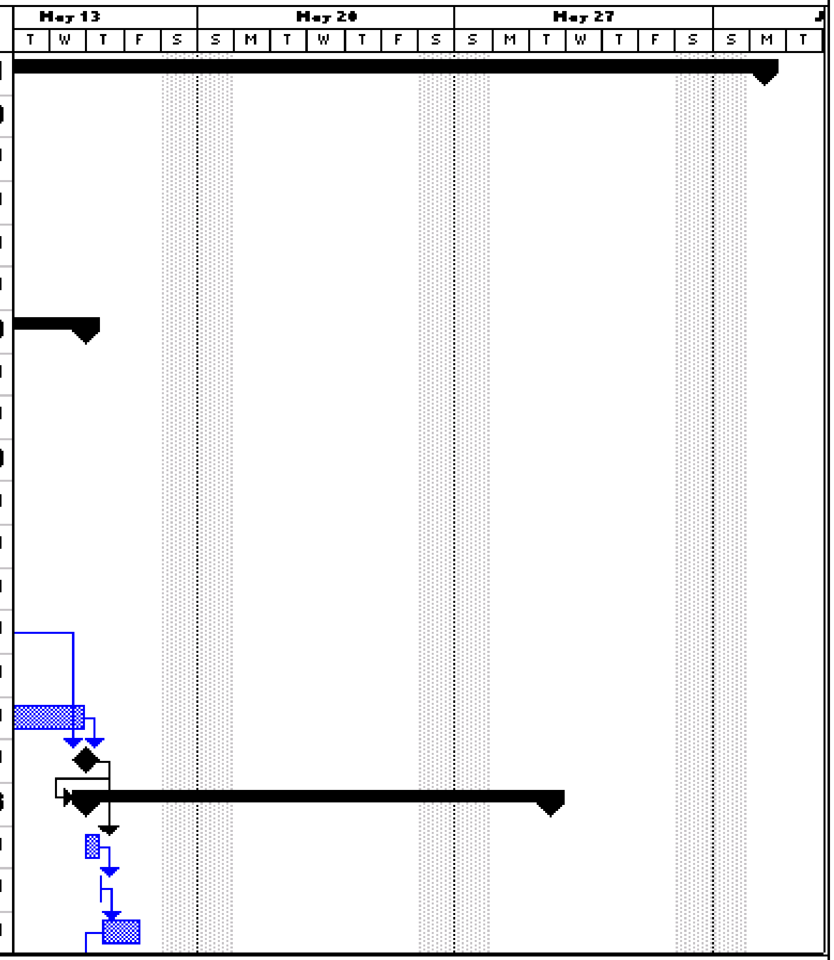
The facility in this example is designed to control (filter) runoff generated from approximately 1acre of residential development and the construction phase is completed within two weeks. Scheduling of tasks will impact available resources, and thus, the overall cost of implementing bioretention. Some of the tasks can occur simultaneously while others such as watering may be delayed considerably. Therefore, the designer/estimator must be cognizant of this variability to accurately estimate the probable project costs when applying the template to their site.

Example Estimates

Following the Gantt Chart, a Task Sheet itemizing costs for five different bioretention scenarios is provided. The assumptions for each of the scenarios are listed as well, allowing the designer/estimator to adjust the cost figures to meet their own site conditions.

BIORETENTION TYPICAL CONSTRUCTION COST AND SCHEDULE ESTIMATION

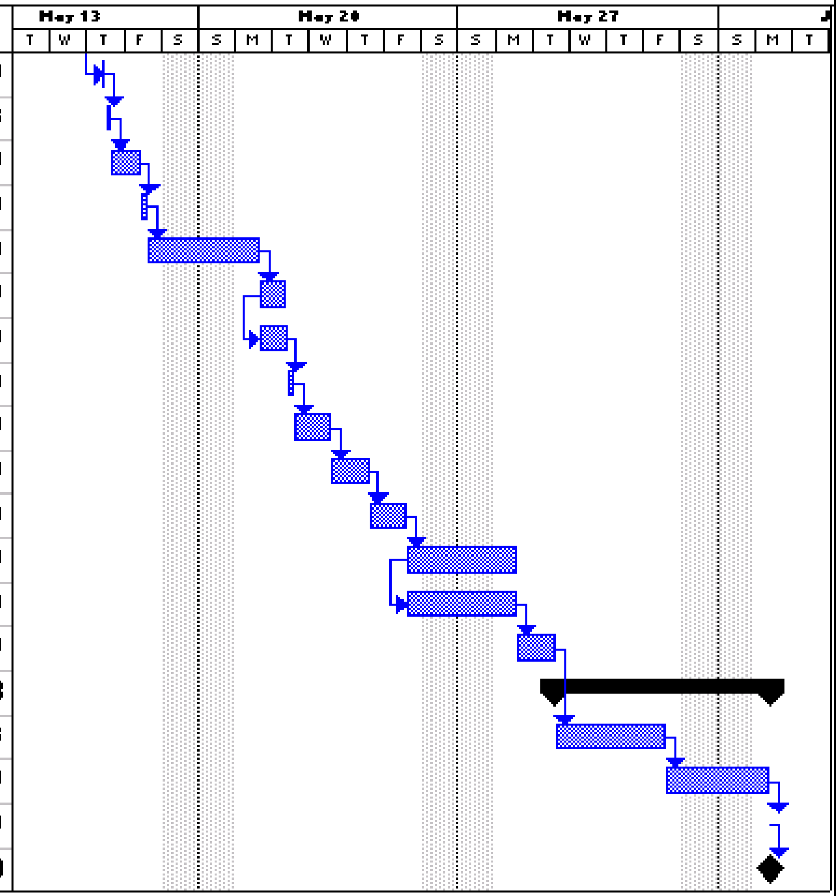
ID	Task Name	Fixed Cost	Total Cost
1	**Bioretention Project Template**	**$0.00**	**$16,054.81**
2	**Planning Phase**	**$0.00**	**$1,350.00**
3	Site Analysis	$250.00	$250.00
4	Concept Development	$500.00	$500.00
5	Preliminary Plan Review & Apı	$100.00	$100.00
6	SWM Concept Approval	$500.00	$500.00
7	**Design Phase**	**$0.00**	**$4,030.00**
8	Sediment and Erosion Control	$150.00	$250.00
9	S/C Plan Review and Approval	$100.00	$100.00
10	**Technical Plan**	**$0.00**	**$2,240.00**
11	Plan View	$250.00	$820.00
12	Standard Details	$75.00	$105.00
13	Standard Notes	$75.00	$105.00
14	H & H Computations	$1,000.00	$1,210.00
15	Landscaping Design	$250.00	$530.00
16	Permit and Technical Review F	$100.00	$660.00
17	Obtain Permit	$250.00	$250.00
18	**Construction Phase**	**$0.00**	**$9,022.73**
19	Notice to Proceed	$0.00	$35.00
20	Preconstruction Meeting	$0.00	$190.00
21	Mobilize and Stakeout	$300.00	$600.00



NOTE: THIS EXAMPLE IS BASED ON
DESIGNED FOR A D.A. OF 1 ACRE I

BIORETENTION TYPICAL CONSTRUCTION COST AND SCHEDULE ESTIMATION

ID	Task Name	Fixed Cost	Total Cost
22	Order Planting Delivery	$50.00	$85.00
23	Prepare Soil Medium	$0.00	$217.13
24	Install Sediment Control Devic	$250.00	$346.00
25	Removal & Excavation	$400.00	$986.00
26	Install Filter Fabric	$100.00	$342.00
27	Place Stone	$250.00	$442.00
28	Install and Connect Underdrair	$150.00	$342.00
29	Place Soil Medium	$600.00	$1,215.60
30	Water to Promote Settlement	$100.00	$196.00
31	Dress-up Final Grade	$150.00	$250.00
32	Place Planting Materials	$2,500.00	$2,892.00
33	Apply Mulch/Groundcover	$250.00	$346.00
34	Water and Clean-up	$250.00	$346.00
35	Stabilze and Remove S/C	$0.00	$192.00
36	**Closeout Phase**	**$0.00**	**$1,652.08**
37	As-built Plan	$500.00	$1,227.08
38	Final Inspection	$100.00	$325.00
39	Issue U & O	$50.00	$100.00
40	**Bioretention Project Complete**	**$0.00**	**$0.00**



NOTE: THIS EXAMPLE IS BASED ON
DESIGNED FOR A D.A. OF 1 ACRE I

Task | Summary | Rolled Up Progress
Progress | Rolled Up Task
Milestone | Rolled Up Milestone

ID	Task Name	Resid. Rain Garden	Resid. Lot - Subdiv.	Resid. Lot- Single	Commercial - New	Commercial Retrofit
1	**Bioretention Project Cost Template**	**$1075.00**	**$3790.00**	**$7775.00**	**$10357.00**	**$12355.21**
2	**Planning Phase (bioretention portion)**	**$25.00**	**$95.00**	**$200.00**	**$845.00**	**$350.00**
3	Site Analysis	$25.00	$50.00	$50.00	$250.00	$150.00
4	Concept Development	n/a	$10.00	$100.00	$500.00	$100.00
5	Preliminary Plan Review & Approval	n/a	$25.00	n/a	$345.00	n/a
6	SWM Concept Approval	n/a	$10.00	$50.00	$500.00	$100.00
7	**Design Phase (bioretention portion)**	**$100.00**	**$340.00**	**$875.00**	**$3600.00**	**$2410.00**
8	Sediment and Erosion Control Plan	n/a	$15.00	n/a	$250.00	$150.00
9	S/C Plan Review and Approval	n/a	$25.00	n/a	$100.00	$100.00
10	**Technical Plan**	**n/a**	**$300.00**	**$875.00**	**$3250.00**	**$2160.00**
11	Plan View	n/a	$100.00	$250.00	$820.00	$500
12	Standard Details	n/a	$50.00	$100.00	$105.00	$100.00
13	Standard Notes	n/a	$50.00	$25.00	$105.00	$50.00
14	H & H Computations	n/a	$10.00	$150.00	$1210.00	$550.00
15	Permit and Technical Review Processi	n/a	$15.00	$100.00	$660.00	$660.00
16	Develop Landscape Plan	n/a	$25.00	$250.00	$100.00	$150.00
17	Develop Sketch and Planting Plan	$100.00	n/a	n/a	n/a	n/a
18	Obtain Permit	n/a	$50.00	$100.00	$250.00	$150.00
19	**Construction Phase**	**$950.00**	**$3225.00**	**$5750.00**	**$5237.00**	**$7943.13**
20	Notice to Proceed	n/a	$20.00	$50.00	$35.00	$35.00
21	Preconstruction Meeting	n/a	$5.00	$50.00	$25.00	$25.00
22	Mobilize and Stakeout	n/a	$250.00	$250.00	n/a	$250.00
23	Order Planting Delivery	$50.00	$50.00	$50.00	$50.00	$85.00
24	Prepare Soil Medium	$50.00	$50.00	$150.00	$217.13	$217.13
25	Install Sediment Control Devices	$25.00	$150.00	$150.00	$346.00	$150.00
26	Removal & Excavation	$50.00	$150.00	$450.00	n/a	$500.00
27	Install Filter Fabric	n/a	$300.00	$300.00	$342.00	$342.00
28	Place Stone	n/a	$275.00	$350.00	$442.00	$442.00
29	Install and Connect Underdrain	n/a	$250.00	$250.00	$342.00	$342.00
30	Place Soil Medium	$100.00	$325.00	$750.00	$1500.00	$1500.00

ID	Task Name	Resid. Rain Garden	Resid. Lot - Subdiv.	Resid. Lot- Single	Commercial - New	Commercial Retrofit
31	Water to Promote Settlement	$25.00	$25.00	$125.00	$196.00	$196.00
32	Dress-up Final Grade	$50.00	$150.00	$150.00	$100.00	$100.00
33	Place Planting Materials	$400.00	$1000.00	$1500.00	$1000.00	$2,892.00
34	Apply Mulch/Groundcover	$50.00	$125.00	$225.00	$200.00	$346.00
35	Water and Clean-up	$50.00	$25.00	$200.00	$250.00	$346.00
36	Stabilze and Remove S/C	$100.00	$75.00	$75.00	$192.00	$175.00
37	**Closeout Phase**	**n/a**	**$130.00**	**$950.00**	**$675.00**	**$1652.08**
38	As-built Plan	n/a	$100.00	$800.00	$550.00	$1,227.08
39	Final Inspection	n/a	$20.00	$100.00	$100.00	$325.00
40	Issue U & O	n/a	$10.00	$50.00	$25.00	$100.00

Assumptions used in estimates:

[a] Residential Rain Garden

1. Shallow-type Rain Garden incorporating in-situ soils and no underdrain system- Infiltration type bioretention.
2. Planting materials moderately expensive.
3. Labor costs are negligible- Homeowner, garden group, or volunteers provide labor.
4. No heavy construction equipment utilized- Mostly hand labor or small power equipment.
5. Disturbed area is small enough to avoid permits and fees- Considered homeowner landscaping project.
6. Drainage area assumed to be 1 acre.

[b]Residential Lot in Subdivision

1. Average cost per facility installed, assuming 100 lot subdivision.
2. All facilities have underdrain systems.
3. Planning, Design, and Construction costs are all pro-rated as portion of the overall site cost work.
4. Sediment Control, permits, fees, and technical plan approval are required
5. Many facilities will be constructed simultaneously.

[c]Residential Lot – Single Lot

1. Site planning costs increased, but no subdivision review or preliminary plan costs included.
2. Sediment control plan costs not included; on-lot sediment control devices required.
3. Design costs increased substantially due to small scale of project requiring same level of engineering.
4. Closeout costlier due to as-built requirements.

[d]Commercial - New

1. Facility costs for site lower then single residential lot because of the greater amount of other site work
2. Drainage area to the proposed facility is no greater then 1 acre.
3. There are no removal costs attributable to the bioretention area.
4. Storm drainage discharge system not part of bioretention costs- associated with general site costs.

[e]Commercial – Retrofit

1. Cost data information derived from Microsoft Project software.
2. Resource data information (salaries, materials & duration) included in each task and sub-task to find final cost.
3. Retrofit costs higher then new construction cost due to economies of scale.
4. Design costs are less expensive because existing drainage conveyance system already in place.
5. Preliminary Plan costs are not included in the cost calculations.

Post Project Cost Accounting

In order to adequately predict (estimate) costs of bioretention, cost accounting practices must be applied by utilizing historical project cost data. In Cost Accounting, once a project is complete, the orginal cost estimate is checked against the actual project cost to determine the variance. In this way, future bioretention project task costs can be determined more acturately. By reviewing the actual task costs, specific site constraints and unique problems encountered during design and construction, subsequent cost estimating becomes more refined. In this way, designers can confidently address their client's inquiry- *How much will it cost me?*

APPENDIX C

SAMPLE MAINTENANCE COVENANT FOR BIORETENTION

SAMPLE MAINTENANCE COVENANT FOR BIORETENTION

DECLARATION OF COVENANTS
For Storm and Surface Water Facility, and Integrated Management System Maintenance

This DECLARATION OF COVENANTS, made this __________ day of _____, 20____, by _________________________________ hereinafter refered to as the "Covenantor(s)" to and for the benefit of (governing body-state, county, city, etc.) and its successors and assigns hereinafter referred to as the "(State, County, City, etc.)."

WITNESSETH:

WHEREAS, the (State, County, City) is authorized and required to regulate the control the disposition of storm and surface waters within the County's Stormwater management District set forth in (cite governing laws or regulations): and

WHEREAS, Covenantor(s) is (are) the owner(s) of a certain tract or parcel of land more particularly described as:
____
__________________________________ being all or part of the land which it acquired by deed dated _____________ from__________________________________ grantors, and recorded among the Land Records of (governing body), in Liber _________________ at Folio_________________such property being hereinafter referred to as the "the property"; and

WHEREAS, the Covenantor(s) desires to construct certain improvements on its p5roperty which will alter the extent of storm and surface water flow conditions on both the property and adjacent lands; and

WHEREAS, in order to accommodate and regulate these anticipate changes in existing storm and surface water flow conditions, the Covenantor(s) desires to build and maintain at its expense, as storm and surface water management facility and system more particularly described and shown on plans titled
____
____

And further identified under approval number __________________________________; and ____________________________.

WHEREAS, the (State, County, City, etc.) has reviewed and approved these plans subject to the execution of this agreement.

NOW THEREFORE, in consideration of the benefits received by the Covenantor(s), as a result of the (State, County, City) approval of his plans. Covenantor(s), with full authority to execute deeds, mortgages, other covenants, and all rights, title and interest in the property described above do hereby covenant with the (State, County, City) as follows:

1. Covenantor(s) shall construct and perpetually maintain, at its sole expense, the above-referenced storm and surface management facility and system in strict accordance with the plan approval granted by the (State, County, City).

2. Covenantor(s) shall, at its sole expense, make such changes or modifications to the storm drainage facility and system as may, in the (State, County, City) discretion, be determined necessary to insure that the facility and system is properly maintained and continues to operate as designed and approved.

3. The (State, County, City), its agents, employees and contractors shall have the perpetual right of ingress and egress over the property of the Covenantor(s) and the right to inspect at reasonable times and in reasonable manner, the storm and surface water facility and system in order to insure that the system is being properly maintained and is continuing to perform in an adequate manner.

4. The Covenantor(s) agrees that should it fail to correct any defects in the above-described facility and system within ten (10) days from the issuance of written notice, or shall fail to maintain the facility in accordance with the approved design standards and with the law ans applicable executive regulation or, in the event of an emergency as determined by the (State, County, City) in its sole discretion, the (State, County, City) is authorized to enter the property to make all repairs, and to perform all maintenance, construction and reconstruction as (State, County, City) deems necessary. The (State, County, City) shall then assess the Covenantor(s) and/or all landowners served by the facility for the cost of the work, both direct and indirect, and applicable penalties. Said assessment shall be a lien against all properties served by the facility and may be placed on the property tax bills of said properties and collected as ordinary taxes by the (State, County, City).

5. Covenantor (s) shall indemnify, save harmless and defend the (State, County, City) from and against any and all claims, demands, suits, liabilities, losses, damages and payments including attorney fees claimed or made by persons not parties to this Declaration against the (State, County, City) that are alleged or proven to result or arise from the Covenantor(s) construction, operation, or maintenance of the storm and surface water facility and system that is the subject of this Covenant.

6. The covenants contained herein shall run with the land and the Covenantor(s) further agrees that whenever the property shall be held, sold and conveyed, it shall be subject to the covenants, stipulations, agreements and provisions of this Declaration, which shall apply to, bind and be obligatory upon the Covenantor(s) hereto, its heirs successors and assigns and shall bind all present and subsequent owner's of the property served by the facility.

7. The Covenantor(s) shall promptly notify the (State, County, City) when the Covenantor(s) legally transfers any of the Covenantor(s) responsibilities for the facility. The Covenantor(s) shall supply the (State, County, City) with a copy of any document of transfer, executed by both parties.
8. The provisions of this Declarations shall be severable and if any phrase, clause, sentence or provisions is declared unconstitutional, or the applicability thereof to the Covenantor is held invalid, the remainder of this Covenant shall not be affected thereby.

9. The Declaration shall be recorded among the Land Records of (Governing Body) at the Covenantor(s) expense. In the event that the (State, County, City) shall determine at its sole discretion at future time that the facility is no longer required, then the (State, County, City) shall at the request of the Covenantor(s) execute a release of this Declaration of Covenants which the Covenantor(s) shall record at its expenses.

IN WITNESS WHEREOF, the Covenantor(s) have executed this Declaration of Covenants as of this ____ day of ________________, 20_____.

ATTEST: FOR THE COVENANTOR(S)

_____________________ _________________________
(Signature) (Signature)

_____________________ _________________________
(Printed Name) (Printed Name and Title)

STATE OF ___________________________:

COUNTY OF _________________________:

On this ________ day of ______________, 20___, before me, the undersigned officer, a Notary Public in and for the State and County aforesaid, personally appeared ___________________________, who acknowledged himself to be _________________ _________________, of ________________________________, and he as such authorized to do so, executed the foregoing instrument for the purposes therein contained by signing his name as _______________________ for said _________________.

WITNESS my hand and Notarial Seal

My commissions expires: _____________ _____________
Notary Public

Seen and approved: ________________________________

APPENDIX D

FILTRATION SIZING

BIORETENTION SIZING

BIORETENTION SIZING BASED ON HISTORICAL RAINFALL DISTRIBUTION

Background

Because of the flexibility in application and design, bioretention sizing standards are difficult to define within certain parameters. In many instances, stormwater management BMPs are sized to accommodate a specified design storm volume or a volume based on a contributing drainage area. While these methods are simplistic, they do not account for climatic variability or site specific characteristics. In this example, sizing bioretention facilities to function efficiently, evaluation of pre and post CN values of the site are analyzed in relation to local historical rainfall data. Dr. Mow-Soung Cheng of the Prince George's County Government developed filtration sizing charts from analyzing historical rainfall distribution patterns for the Washington, D.C. area over the past 29 years. The sizing charts can be utilized to determine the percent of treatment desired and the required dimensions of the bioretention facility.

This method of sizing a bioretention facility a function of the CN values of the before and after development condition. The soil medium recommended for bioretention application should have a minimum infiltration rate of 1"/hr. Infiltration rates below 1"/hr may clog prematurely. The soil medium currently recommended consists of a homogenous blend of 50% (by volume) construction sand, 20-30% topsoil, and 20-30% leaf compost material. This mixture is estimated to have a very high hydraulic capacity with an infiltration rate between 1"/hr and 10"/hr (see chart below). Soils that have a minimum infiltration rate of 1"/hr or greater equate to USDA soil textural classifications of Sandy Loam, Loamy Sand, or Sand (Rawls, et al. 1982). The filtration rate of the facility tested by Davis in the field was found to be about 40"/0.25hr, or 120"/hr. Even with this extremely high infiltration rate, pollutant removal rates were good. The depth of the soil medium was about 3½ feet. Using the mix recommended above, the infiltration rate is outlined in the following chart:

Bioretention Soil Medium – Infiltration Rate Estimation

Soil Medium Component	USDA Text. Class.	Min. Infiltration Rate	HSG Type
Construction Sand (50%)	SAND	8.27in/hr.	A
Top Soil (20-30%)	~ LOAM	0.52in/hr	~ B
Leaf Compost (20-30%)	N/A	>8.27in/hr	N/A
Composite	~ LOAMY SAND	~5 in/hr (use 2.41)	~A

The estimated infiltration rate is presumed to be at least equivalent to a Loamy Sand ~ 2.41 in/hr, although in this case, we use 1"/hr to be conservative.

Rainfall Intensity Rates and Infiltration Efficiencies

Historical rainfall distributions and intensities for the last 29 years (1969-1998) from data collected at Ronald Reagan National Airport were analyzed to determine device filtration efficiencies of the runoff generated. To perform the analysis, several assumptions were made:

1. Drainage area is approximately ¼ acre
2. Land cover is 100% impervious and all rainfall translates to runoff
3. Uniform 6 inch ponding depth above facility
4. Surface area of facility is 5% of the contributing drainage area

5. A 1”/hr infiltration rate

Analyzing the total daily rainfall received over the 29 year period, over 90% of the 24-hour duration storms were less than or equal to a 1 inch storm event. The surface area of the bioretention facility is assumed to be 5% of the drainage area, or 544.5 sq ft. This surface area may be adjusted to represent available retrofit area within a specific site. Increasing the surface area of the device would have an effect of increasing the filtered runoff efficiency. Likewise, increasing the presumed infiltration rate would increase the efficiency as well.

Small Surface Area with High Infiltration Rate

The calculations and assumptions shown on the following page where utilized to develop the spreadsheets for bioretention filtering devices expected to have a very high hydraulic capacity.

LID Bioretention Devices

Controlling Area (Drainage Area)	1/4 acres (10,890 ft2)
Site Condition	100% Impervious Area
Size of the Devices (5.0% of the site)	544.5 ft2
Soil Infiltration Rate (B soil)	1.0"/hour

Devices Flow Volume = 544.5 x 1 /12 = 45.375 cu ft/hr

Runoff Volume = P / 12 x 10890 = 907.5 P cu ft/hr (P in inches/hr)

(a) **Rainfall** **(in/hr)**	(b) **Runoff Volume** **(cu. ft / hr)**	(c) **Runoff Treated** **(cu. ft / hr)**	(d) **Cumulative** **Frequency**	(e) **Probability/** **Frequency**	(f) **(C) x (e)** **(cu. ft / hr)**	(g) **(b) x (e)** **(cu. ft / hr)**
0.020	18.15	18.15	0.4205	0.4205	7.6321	7.6321
0.040	36.30	36.30	0.6027	0.1822	6.6139	6.6139
0.060	54.45	45.38	0.7133	0.1106	5.0185	6.0222
0.080	72.60	45.38	0.7850	0.0717	3.2534	5.2054
0.100	90.75	45.38	0.8352	0.0502	2.2778	4.5557
0.125	113.44	45.38	0.8745	0.0393	1.7832	4.4581
0.150	136.13	45.38	0.9030	0.0285	1.2932	3.8796
0.200	181.50	45.38	0.9382	0.0352	1.5972	6.3888
0.250	226.88	45.38	0.9570	0.0188	0.8531	4.2653
0.300	272.25	45.38	0.9687	0.0117	0.5309	3.1853
0.350	317.63	45.38	0.9756	0.0069	0.3131	2.1916
0.400	363.00	45.38	0.9810	0.0054	0.2450	1.9602
0.450	408.38	45.38	0.9856	0.0046	0.2087	1.8785
0.500	453.75	45.38	0.9881	0.0025	0.1134	1.1344
0.550	499.13	45.38	0.9899	0.0018	0.0817	0.8984
0.600	544.50	45.38	0.9918	0.0019	0.0862	1.0346
0.650	589.88	45.38	0.9930	0.0012	0.0545	0.7079
0.700	635.25	45.38	0.9942	0.0012	0.0545	0.7623
0.750	680.63	45.38	0.9950	0.0008	0.0363	0.5445
0.800	726.00	45.38	0.9957	0.0007	0.0318	0.5082
0.900	816.75	45.38	0.9971	0.0014	0.0635	1.1435
1.000	907.50	45.38	0.9979	0.0008	0.0363	0.7260
1.500	1361.25	45.38	0.9999	0.0020	0.0908	2.7225
2.000	1815.00	45.38	1.0000	0.0001	0.0045	0.1815
			Total	1.0000	**32.2734**	**68.6002**

Percent Infiltrated = 47.05%

LID Filtration Devices

The focus here is on filtration treatment of rainfall.

This is best used for highly impervious urban areas (CN>=98) where most of the rainfall becomes runoff.

Device Information (overwrite data in shaded cells, other cells will be automatically calculated)

Controlling Area (Drainage Area)	0.08 acres = 3484 sq.ft.
Site Condition	institutional
device area	174 sq.ft. = 5.0% of the site
device storage depth (above ground)	4 inches = 0.33 ft.
infiltration porosity (volume fraction of soil pores)	0.2 **use 0 if you only want to count above-ground storage
soil depth	30 inches = 2.5 ft.
device's total volume (above ground + soils)	**145 cubic ft./day**

Runoff Information (overwrite data in shaded cells, other cells will be automatically calculated)

Land Use	Impervious
CN	98
S	0.20

(a) Rainfall (P) (in/day)	(b) Runoff (Q) (in/day)	(c) Rainfall Volume (cu.ft./day)	(d) Runoff Volume (cu.ft./day)	(e) Runoff Treated (cu.ft./day)	(f) Cumulative Frequency	(g) Probability/ Frequency	(h) (e) x (g) (cu.ft./day)	(i) (d) x (g) (cu.ft./day)	(j) (c) x (g) (cu.ft./day)
0.05	0.000	14.52	0.11	0.11	0.259	0.259	0.03	0.03	3.75
0.10	0.013	29.03	3.86	3.86	0.387	0.128	0.50	0.50	3.72
0.15	0.038	43.55	11.05	11.05	0.463	0.076	0.84	0.84	3.31
0.20	0.070	58.07	20.25	20.25	0.517	0.054	1.09	1.09	3.14
0.30	0.145	87.10	42.10	42.10	0.620	0.103	4.34	4.34	8.97
0.40	0.229	116.13	66.50	66.50	0.702	0.082	5.45	5.45	9.51
0.50	0.318	145.17	92.30	92.30	0.765	0.063	5.81	5.81	9.13
0.60	0.410	174.20	118.94	118.94	0.812	0.047	5.61	5.61	8.22
0.80	0.598	232.27	173.72	145.00	0.875	0.063	9.16	10.98	14.68
1.00	0.791	290.33	229.63	145.00	0.918	0.044	6.31	9.99	12.63
1.25	1.035	362.92	300.37	145.00	0.954	0.036	5.21	10.78	13.03
1.50	1.280	435.50	371.67	145.00	0.972	0.017	2.49	6.39	7.49
2.00	1.774	580.67	515.15	145.00	0.990	0.019	2.71	9.63	10.86
3.00	2.768	871.00	803.72	145.00	0.997	0.007	0.99	5.47	5.92
4.00	3.765	1161.33	1093.14	145.00	0.999	0.002	0.33	2.51	2.67
5.00	4.763	1451.67	1382.91	145.00	1.000	0.001	0.07	0.69	0.73
6.00	5.762	1742.00	1672.86	145.00	1.000	0.000	0.03	0.33	0.35
					Total	1.000	**50.96**	**80.44**	**118.11**
							Q Treated	**Q Total**	**P Total**

Percent of Total Rainfall Treated = 43.15%

LID Bioretention Devices

The focus here is on infiltration and runoff volume reduction.

Device Information (overwrite data in shaded cells, other cells will be automatically calculated)

Controlling Area (Drainage Area)	0.08 acres = 3484 sq.ft.
Site Condition	institutional
device area	174 sq.ft. = 5.0% of the site
device storage depth (above ground)	4 inches = 0.33 ft.
infiltration porosity (volume fraction of soil pores)	0.2 **use 0 if you only want to count above-ground storage
soil depth	30 inches = 2.5 ft.
device's total volume (above ground + soils)	145 cubic ft./day

Runoff Information (overwrite data in shaded cells, other cells will be automatically calculated)

Land Use	Impervious
CN	98
S	0.20

(a) Rainfall (P) (in/day)	(b) Runoff (Q) (in/day)	(c) Rainfall Volume (cu.ft./day)	(d) Runoff Volume (cu.ft./day)	(e) Runoff Treated (cu.ft./day)	(f) Cumulative Frequency	(g) Probability/ Frequency	(h) (e) x (g) (cu.ft./day)	(i) (d) x (g) (cu.ft./day)	(j) (c) x (g) (cu.ft./day)
0.05	0.000	14.52	0.11	0.11	0.259	0.259	0.03	0.03	3.75
0.10	0.013	29.03	3.86	3.86	0.387	0.128	0.50	0.50	3.72
0.15	0.038	43.55	11.05	11.05	0.463	0.076	0.84	0.84	3.31
0.20	0.070	58.07	20.25	20.25	0.517	0.054	1.09	1.09	3.14
0.30	0.145	87.10	42.10	42.10	0.620	0.103	4.34	4.34	8.97
0.40	0.229	116.13	66.50	66.50	0.702	0.082	5.45	5.45	9.51
0.50	0.318	145.17	92.30	92.30	0.765	0.063	5.81	5.81	9.13
0.60	0.410	174.20	118.94	118.94	0.812	0.047	5.61	5.61	8.22
0.80	0.598	232.27	173.72	145.00	0.875	0.063	9.16	10.98	14.68
1.00	0.791	290.33	229.63	145.00	0.918	0.044	6.31	9.99	12.63
1.25	1.035	362.92	300.37	145.00	0.954	0.036	5.21	10.78	13.03
1.50	1.280	435.50	371.67	145.00	0.972	0.017	2.49	6.39	7.49
2.00	1.774	580.67	515.15	145.00	0.990	0.019	2.71	9.63	10.86
3.00	2.768	871.00	803.72	145.00	0.997	0.007	0.99	5.47	5.92
4.00	3.765	1161.33	1093.14	145.00	0.999	0.002	0.33	2.51	2.67
5.00	4.763	1451.67	1382.91	145.00	1.000	0.001	0.07	0.69	0.73
6.00	5.762	1742.00	1672.86	145.00	1.000	0.000	0.03	0.33	0.35
					Total	1.000	**50.96**	**80.44**	**118.11**
							Q Treated	**Q Total**	**P Total**

Percent of Total Runoff Infiltrated = 63.35%

LID Filtration Devices

The focus here is on filtration treatment of rainfall.

This is best used for highly impervious urban areas (CN>=98) where most of the rainfall becomes runoff.

Device Information (overwrite data in shaded cells, other cells will be automatically calculated)

Controlling Area (Drainage Area)	1 acres = 43550 sq.ft.
Site Condition	institutional
device area	398 sq.ft. = 0.9% of the site
device storage depth (above ground)	12 inches = 1.00 ft.
infiltration porosity (volume fraction of soil pores)	0.3 ****use 0 if you only want to count above-ground storage*
soil depth	42 inches = 3.5 ft.
device's total volume (above ground + soils)	**815.9 cubic ft./day**

Runoff Information (overwrite data in shaded cells, other cells will be automatically calculated)

Land Use	Impervious
CN	98
S	0.20

(a) Rainfall (P) (in/day)	(b) Runoff (Q) (in/day)	(c) Rainfall Volume (cu.ft./day)	(d) Runoff Volume (cu.ft./day)	(e) Runoff Treated (cu.ft./day)	(f) Cumulative Frequency	(g) Probability/ Frequency	(h) (e) x (g) (cu.ft./day)	(i) (d) x (g) (cu.ft./day)	(j) (c) x (g) (cu.ft./day)
0.05	0.000	181.46	1.44	1.44	0.259	0.259	0.37	0.37	46.91
0.10	0.013	362.92	48.29	48.29	0.387	0.128	6.19	6.19	46.53
0.15	0.038	544.38	138.11	138.11	0.463	0.076	10.50	10.50	41.37
0.20	0.070	725.83	253.15	253.15	0.517	0.054	13.67	13.67	39.20
0.30	0.145	1088.75	526.25	526.25	0.620	0.103	54.20	54.20	112.14
0.40	0.229	1451.67	831.24	815.90	0.702	0.082	66.82	68.08	118.89
0.50	0.318	1814.58	1153.70	815.90	0.765	0.063	51.32	72.57	114.14
0.60	0.410	2177.50	1486.76	815.90	0.812	0.047	38.51	70.17	102.78
0.80	0.598	2903.33	2171.47	815.90	0.875	0.063	51.56	137.24	183.49
1.00	0.791	3629.17	2870.33	815.90	0.918	0.044	35.49	124.86	157.87
1.25	1.035	4536.46	3754.64	815.90	0.954	0.036	29.29	134.79	162.86
1.50	1.280	5443.75	4645.85	815.90	0.972	0.017	14.03	79.91	93.63
2.00	1.774	7258.33	6439.43	815.90	0.990	0.019	15.26	120.42	135.73
3.00	2.768	10887.50	10046.51	815.90	0.997	0.007	5.55	68.32	74.04
4.00	3.765	14516.67	13664.20	815.90	0.999	0.002	1.88	31.43	33.39
5.00	4.763	18145.83	17286.33	815.90	1.000	0.001	0.41	8.64	9.07
6.00	5.762	21775.00	20910.75	815.90	1.000	0.000	0.16	4.18	4.35
					Total	1.000	**395.22**	**1005.54**	**1476.38**
							Q Treated	**Q Total**	**P Total**

Percent of Total Rainfall Treated = 26.77%

LID Bioretention Devices

The focus here is on infiltration and runoff volume reduction.

Device Information (overwrite data in shaded cells, other cells will be automatically calculated)

Controlling Area (Drainage Area)	1 acres = 43550 sq.ft.
Site Condition	institutional
device area	1131 sq.ft. = 2.6% of the site
device storage depth (above ground)	12 inches = 1.00 ft.
infiltration porosity (volume fraction of soil pores)	0.3 **use 0 if you only want to count above-ground storage
soil depth	42 inches = 3.5 ft.
device's total volume (above ground + soils)	**2318.55 cubic ft./day**

Runoff Information (overwrite data in shaded cells, other cells will be automatically calculated)

Land Use	Impervious
CN	98
S	0.20

(a) Rainfall (P) (in/day)	(b) Runoff (Q) (in/day)	(c) Rainfall Volume (cu.ft./day)	(d) Runoff Volume (cu.ft./day)	(e) Runoff Treated (cu.ft./day)	(f) Cumulative Frequency	(g) Probability/ Frequency	(h) (e) x (g) (cu.ft./day)	(i) (d) x (g) (cu.ft./day)	(j) (c) x (g) (cu.ft./day)
0.05	0.000	181.46	1.44	1.44	0.259	0.259	0.37	0.37	46.91
0.10	0.013	362.92	48.29	48.29	0.387	0.128	6.19	6.19	46.53
0.15	0.038	544.38	138.11	138.11	0.463	0.076	10.50	10.50	41.37
0.20	0.070	725.83	253.15	253.15	0.517	0.054	13.67	13.67	39.20
0.30	0.145	1088.75	526.25	526.25	0.620	0.103	54.20	54.20	112.14
0.40	0.229	1451.67	831.24	831.24	0.702	0.082	68.08	68.08	118.89
0.50	0.318	1814.58	1153.70	1153.70	0.765	0.063	72.57	72.57	114.14
0.60	0.410	2177.50	1486.76	1486.76	0.812	0.047	70.17	70.17	102.78
0.80	0.598	2903.33	2171.47	2171.47	0.875	0.063	137.24	137.24	183.49
1.00	0.791	3629.17	2870.33	2318.55	0.918	0.044	100.86	124.86	157.87
1.25	1.035	4536.46	3754.64	2318.55	0.954	0.036	83.24	134.79	162.86
1.50	1.280	5443.75	4645.85	2318.55	0.972	0.017	39.88	79.91	93.63
2.00	1.774	7258.33	6439.43	2318.55	0.990	0.019	43.36	120.42	135.73
3.00	2.768	10887.50	10046.51	2318.55	0.997	0.007	15.77	68.32	74.04
4.00	3.765	14516.67	13664.20	2318.55	0.999	0.002	5.33	31.43	33.39
5.00	4.763	18145.83	17286.33	2318.55	1.000	0.001	1.16	8.64	9.07
6.00	5.762	21775.00	20910.75	2318.55	1.000	0.000	0.46	4.18	4.35
					Total	1.000	**723.04**	**1005.54**	**1476.38**
							Q Treated	**Q Total**	**P Total**

Percent of Total Runoff Infiltrated = 71.91%

LID Bioretention Devices

The focus here is on infiltration and runoff volume reduction.

Device Information (overwrite data in shaded cells, other cells will be automatically calculated)

Controlling Area (Drainage Area)	1 acres = 43550 sq.ft.
Site Condition	institutional
device area	3393 sq.ft. = 7.8% of the site
device storage depth (above ground)	12 inches = 1.00 ft.
infiltration porosity (volume fraction of soil pores)	0.3 ***use 0 if you only want to count above-ground storage*
soil depth	42 inches = 3.5 ft.
device's total volume (above ground + soils)	6955.65 cubic ft./day

Runoff Information (overwrite data in shaded cells, other cells will be automatically calculated)

Land Use	Impervious
CN	98
S	0.20

(a) Rainfall (P) (in/day)	(b) Runoff (Q) (in/day)	(c) Rainfall Volume (cu.ft./day)	(d) Runoff Volume (cu.ft./day)	(e) Runoff Treated (cu.ft./day)	(f) Cumulative Frequency	(g) Probability/ Frequency	(h) (e) x (g) (cu.ft./day)	(i) (d) x (g) (cu.ft./day)	(j) (c) x (g) (cu.ft./day)
0.05	0.000	181.46	1.44	1.44	0.259	0.259	0.37	0.37	46.91
0.10	0.013	362.92	48.29	48.29	0.387	0.128	6.19	6.19	46.53
0.15	0.038	544.38	138.11	138.11	0.463	0.076	10.50	10.50	41.37
0.20	0.070	725.83	253.15	253.15	0.517	0.054	13.67	13.67	39.20
0.30	0.145	1088.75	526.25	526.25	0.620	0.103	54.20	54.20	112.14
0.40	0.229	1451.67	831.24	831.24	0.702	0.082	68.08	68.08	118.89
0.50	0.318	1814.58	1153.70	1153.70	0.765	0.063	72.57	72.57	114.14
0.60	0.410	2177.50	1486.76	1486.76	0.812	0.047	70.17	70.17	102.78
0.80	0.598	2903.33	2171.47	2171.47	0.875	0.063	137.24	137.24	183.49
1.00	0.791	3629.17	2870.33	2870.33	0.918	0.044	124.86	124.86	157.87
1.25	1.035	4536.46	3754.64	3754.64	0.954	0.036	134.79	134.79	162.86
1.50	1.280	5443.75	4645.85	4645.85	0.972	0.017	79.91	79.91	93.63
2.00	1.774	7258.33	6439.43	6439.43	0.990	0.019	120.42	120.42	135.73
3.00	2.768	10887.50	10046.51	6955.65	0.997	0.007	47.30	68.32	74.04
4.00	3.765	14516.67	13664.20	6955.65	0.999	0.002	16.00	31.43	33.39
5.00	4.763	18145.83	17286.33	6955.65	1.000	0.001	3.48	8.64	9.07
6.00	5.762	21775.00	20910.75	6955.65	1.000	0.000	1.39	4.18	4.35
					Total	1.000	**961.13**	**1005.54**	**1476.38**
							Q Treated	**Q Total**	**P Total**

Percent of Total Runoff Infiltrated = 95.58%

APPENDIX E

BIORETENTION GLOSSARY

Bioretention Glossary

BayScapes: Environmentally-sound landscaping to help Chesapeake Bay. Developed by the Alliance for the Chesapeake Bay and the U.S. Fish and Wildlife Service, BayScapes applies ecological principles to the landscape.

Bedding Out: The practice of using mass plantings of annuals that are replaced frequently throughout the growing season.

Bioremediation: Remediation of contaminated soils by natural processes enhanced through purposeful cultivation of microbes.

Bioretention: On-lot retention of stormwater through the use of vegetated depressions engineered to collect, store, and infiltrate runoff. Also known as Rain Garden, Bio-Filter and an LID BMP.

BMP: Best Management Practice; a practice or combination of practices that are the most effective and practicable (including technological, economic, and institutional considerations) means of controlling point or nonpoint source pollutants at levels compatible with environmental quality goals.

Buffer: A vegetated zone adjacent to a stream, wetland, or shoreline where development is restricted or controlled to minimize the effects of development.

CN: SCS Runoff Curve Number used to derive runoff amounts associated with different land coverages and described in NEH-4 (SCS 1985).

Cluster Development: Buildings concentrated in specific areas to minimize infrastructure and development costs while achieving the allowable density. This approach allows the preservation of natural open space for recreation, common open space, and preservation of environmentally sensitive features.

Curb-Cut: A cut in a concrete curb designed to allow water to flow through.

Curbs: Concrete barriers on the edges of streets used to direct stormwater runoff to an inlet or storm drain and to protect lawns and sidewalks from vehicles.

DAM: Drainage Area Map.

DER: Department of Environmental Resources, Prince George's County, Maryland.

Design Storm: A rainfall event of specific size, intensity, and return frequency (e.g., the 1-year, 24 hour storm) that is used to calculate runoff volume and peak discharge rate.

Detention: The temporary storage of stormwater to control discharge rates, allow for infiltration, and help improve water quality.

Development Envelope: The area of a proposed subdivision slated for improvements.

Disconnected Impervious Areas: Impervious areas separated by pervious drainage pathways, allowing water to flow over pervious surfaces.

Distributed SWM: An integrated stormwater management site design technique that distributes small SWM IMP's throughout the site.

Dry Well: Small excavated pits filled with stone to store and infiltrate rooftop runoff.

Energy Dissipater: Any blockage, device or obstruction used to reduce the velocity of water and protect against soil erosion.

Extended Detention: The storage of runoff for an extended period of time before release. In bioretention, extended detention may be achieved by adjusting the underdrain discharge pipe elevation or size perforations.

Erosion: The process of soil detachment and movement by the forces of water.

Filter Strips: Bands of closely growing vegetation, usually grass, planted between pollution sources and downstream receiving waterbodies.

First Flush: The initial runoff during a rainstorm event, thought to contain the highest concentration of pollutants.

Gravel Bed/Blanket: A level of washed gravel (1-2" diameter) with a thickness of 6-12" used to protect underdrains from premature clogging in a bioretention facility.

Greenway: A linear open space; a corridor composed of natural vegetation. Greenways can be used to create connected networks of open space that include traditional parks and natural areas.

Groundwater: Natural water present underground in the pore spaces between soil particles or rock fractures.

Groundwater Table: The highest level or elevation of groundwater.

Habitat: An area or type of area that supports plant and animal life.

Hydrology: The science dealing with the waters of the earth, their distribution on the surface and underground, and the cycle involving evaporation, precipitation, flow to the seas, etc.

IMP: Intregrated management practice. A LID practice or combination of practices that are the most effective and practicable (including technological, economic, and institutional considerations) means of controlling the predevelopment site hydrology.

Impervious Area: A surface material (e.g., parking lot or rooftop) that prevents or retards the entry of water into the soil, thus causing water to run off the surface in greater quantities and at an increased rate of flow.

Infiltration: The downward movement of water from the land surface into the soil.

Initial Abstraction: All water losses before runoff begins; Includes interception by vegetation, infiltration, evaporation, and retained water in surface depressions.

Invasive Exotic Species: Non-native plant species that grow and spread rapidly, free of any natural controls such as pests and herbivores, that overrun and replace native species.

Invasive species (sometimes called biological pollution) escape cultivation; damage ecosystems; and threaten native plants and animals.

LID Charts: Charts developed by Dr. Mow Soung Cheng of PPD, DER for the purposes of sizing bioretention as well as other LID IMP's.

Level Spreader: An outlet designed to convert concentrated runoff to sheet flow and disperse it uniformly across a slope to prevent erosion.

Lot: Parcel of property, typically private and adhering to zoning requirements.

Low Impact Development (LID): The integration of site ecological and environmental goal and requirements into all phases of urban planning and design that ranges in size from the individual residential lot to an entire watershed.

Maintenance Covenant: In reference to SWM, an agreement between the County and a property owner to have a stormwater management facility maintained and inspected on a routine schedule.

Mulch Material: Shredded (or chipped) hardwood used to retain moisture and minimize erosion. Fresh mulch (rather than aged) is preferred in Bioretention facilities.

Multifunctional Landscaping: Landscaping that serves several purposes including stormwater management.

Native Plant: A plant that naturally occurs in a given region without human intervention or transportation. Plants native to Prince George's County were here before European colonization; are adapted to local conditions; and play a key role in maintaining local ecosystems.

Naturalized Plant: Naturalized plants are non-native plants which were brought (intentionally or accidentally) by humans and which have escaped cultivation. Naturalized plants, which displace other plants and cause damage, are called invasives.

Nonpoint Source Pollution: Water pollution caused by rainfall or snowmelt moving both over and through the ground and carrying with it a variety of pollutants associated with human land uses. A nonpoint source is any source of water pollution that does not meet the legal definition of point source in section 502(14) of the Federal Clean Water Act.

NPDES: National Pollutant Discharge Elimination System; a regulatory program in the Federal Clean Water Act that prohibits the discharge of pollutants into surface waters of the United States without a permit.

Off-Line BMP: A BMP that does not have flow-through discharge.

Open Drainage: A non-structural, surface drainage conveyance system, usually sodded and synonymous with drainage swale.

Open Section: Type of roadway section with open drainage system and a curbless paving.

Open Space: Land set aside for public or private use within a development that is not built upon.

PPD: Programs and Planning Division, DER

Permeable: Soil or other material that allows the infiltration or passage of water or other liquids.

Phytoremediation: The use of vegetation for the in-situ treatment of contaminated soils and water.

Planting Soil: Also known as soil medium, a very sandy soil complex designed to filter water and provide a high rate of infiltration.

Rain Barrels: Barrels designed to collect and store rooftop runoff.

Rain Garden: Synomonous with bioretention, this term is typically used for marketing and general audience discussions.

Raw Mulch: Fresh mulch. Mulch which has not been aged or composted for 12 months.

Recharge Area: A land area in which surface water infiltrates the soil and reaches the zone of saturation or groundwater table.

Riparian Area: Vegetated ecosystems along a waterbody through which energy, materials, and water pass. Riparian areas characteristically have a high water table and are subject to periodic flooding.

Runoff: Water from rain, melted snow, or irrigation that flows over the land surface.

SCD: Soil Conservation District; In Prince George's County- PGSCD

SCS: U.S. Department of Agriculture Soil Conservation Service; renamed the Natural Resources Conservation Service (NRCS).

SWM: Stormwater Management

Site Fingerprinting: Development approach that places development away from environmentally sensitive areas (wetlands, steep slopes, etc.), future open spaces, tree save areas, future restoration areas, and temporary and permanent vegetative forest buffer zones. Ground disturbance is confined to areas where structures, roads, and rights-of-way will exist after construction is complete.

Source Control Treatment: An LID practice by which IMP's are sited close to the source of runoff generation, such as on a private lot.

Subdivision: The process of dividing parcels of land into smaller building units, roads, open spaces, and utilities.

Swale: An open drainage channel designed to detain or infiltrate stormwater runoff.

Underdrain: A perforated pipe, typically 4-6" in diameter placed longitudinally at the invert of a bioretention facility for the purposes of achieving a desired discharge rate.

Urbanization: Changing land use from rural characteristics to urban (city-like) characteristics.

USGS: United States Geological Survey, an agency within the Department of the Interior.

Watershed: The topographic boundary within which water drains into a particular river, stream, wetland, or body of water.

Watershed-based Zoning: Zoning that achieves watershed protection goals by creating a watershed development plan, using zoning as the basis (flexible density and subdivision layout specifications), that falls within the range of density and imperviousness allowable for the watershed to prevent environmental impacts. Watershed-based zoning usually employs a mixture of zoning practices.

Weed: (1) A subjective term indicating an out-of-place or undesired plant. (2) Old term meaning an herbaceous plant, as in "butterfly weed."

Weep Garden: A bioretention facility designed for slope-side conditions, typically incorporating a short retaining wall at the lower side.

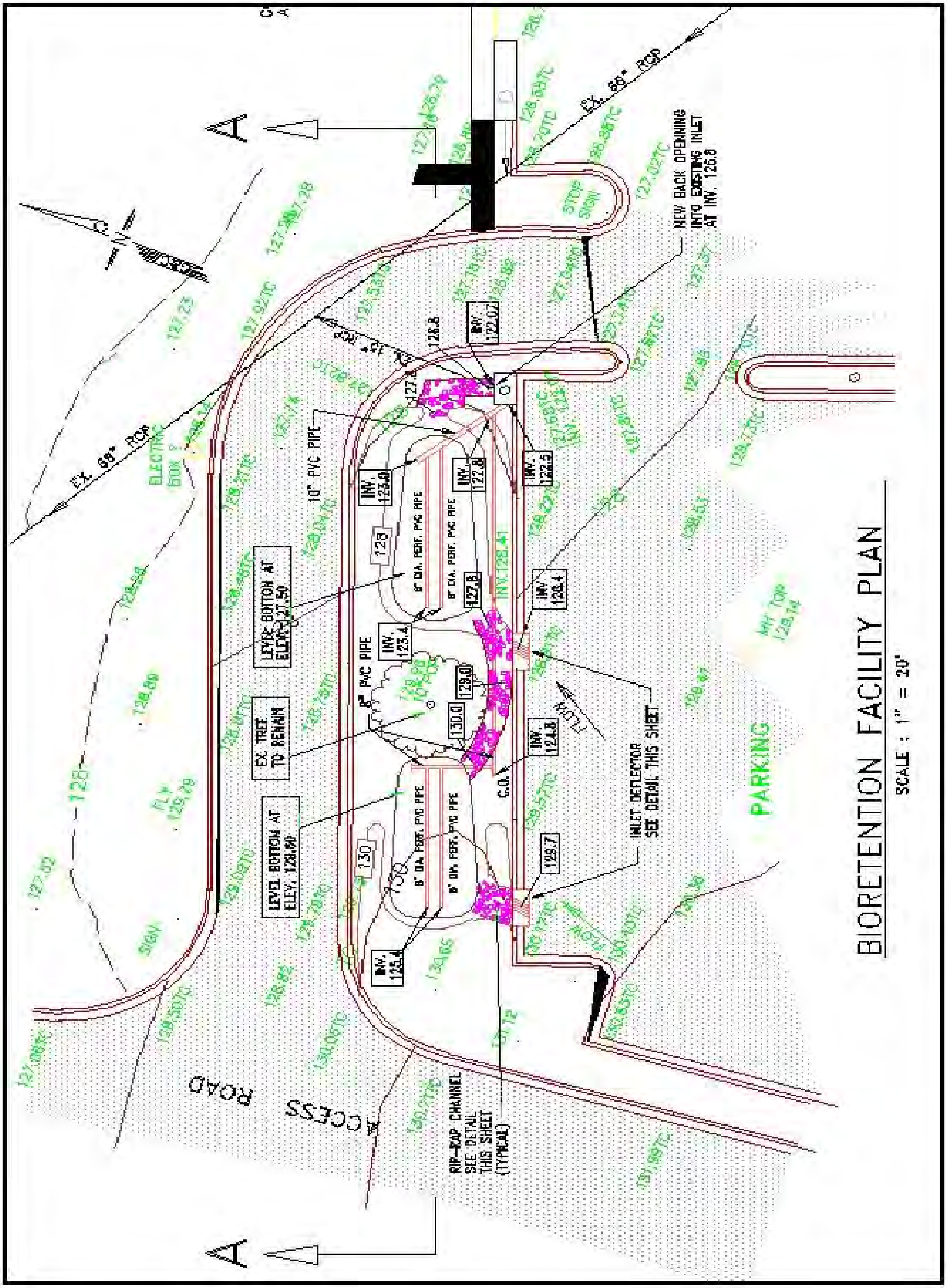
Wet pond: A stormwater management pond designed to detain urban runoff and always contain water.

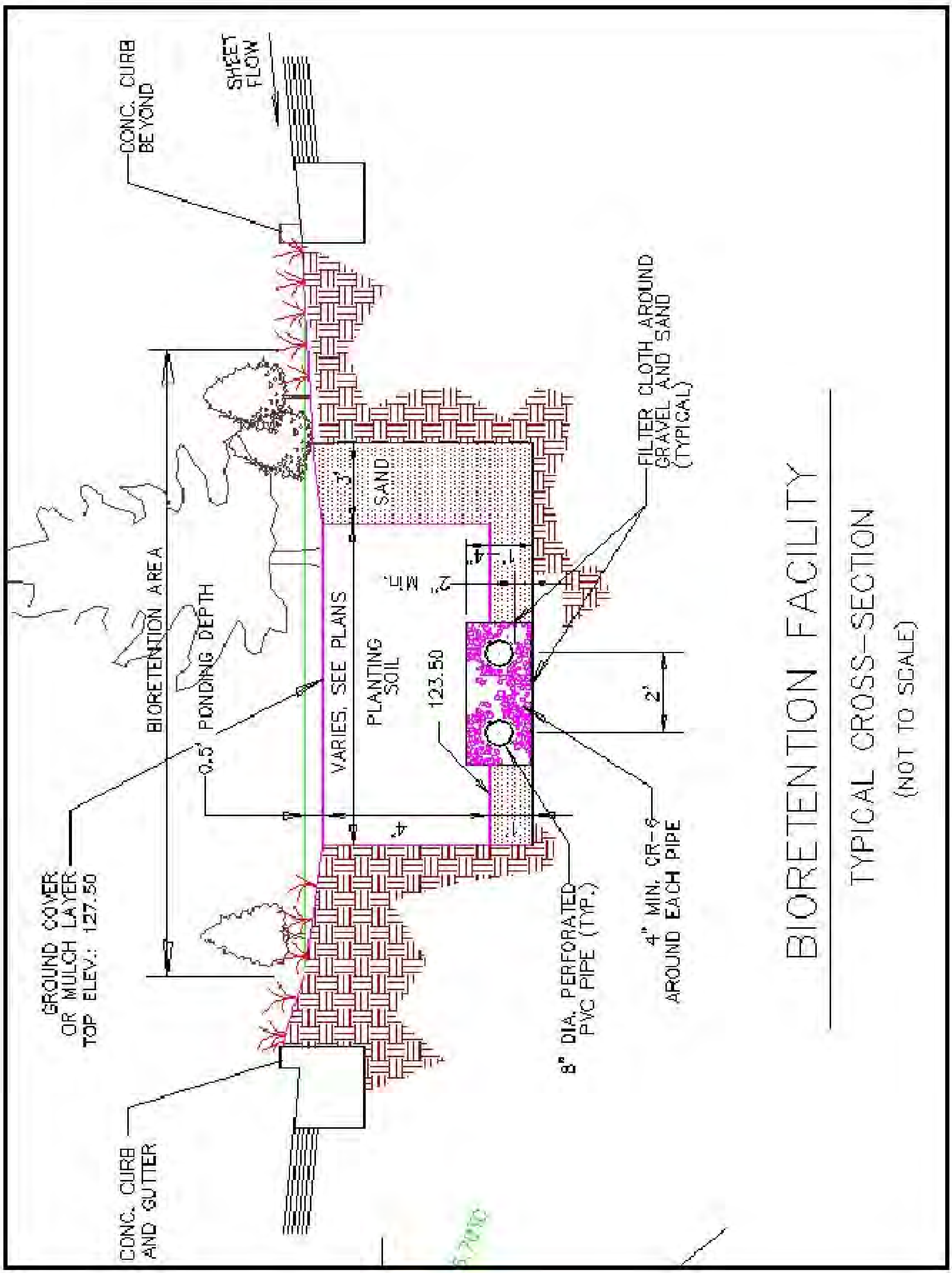
Zoning: Regulations or requirements that govern the use, placement, spacing, and size of land and buildings within a specific area.

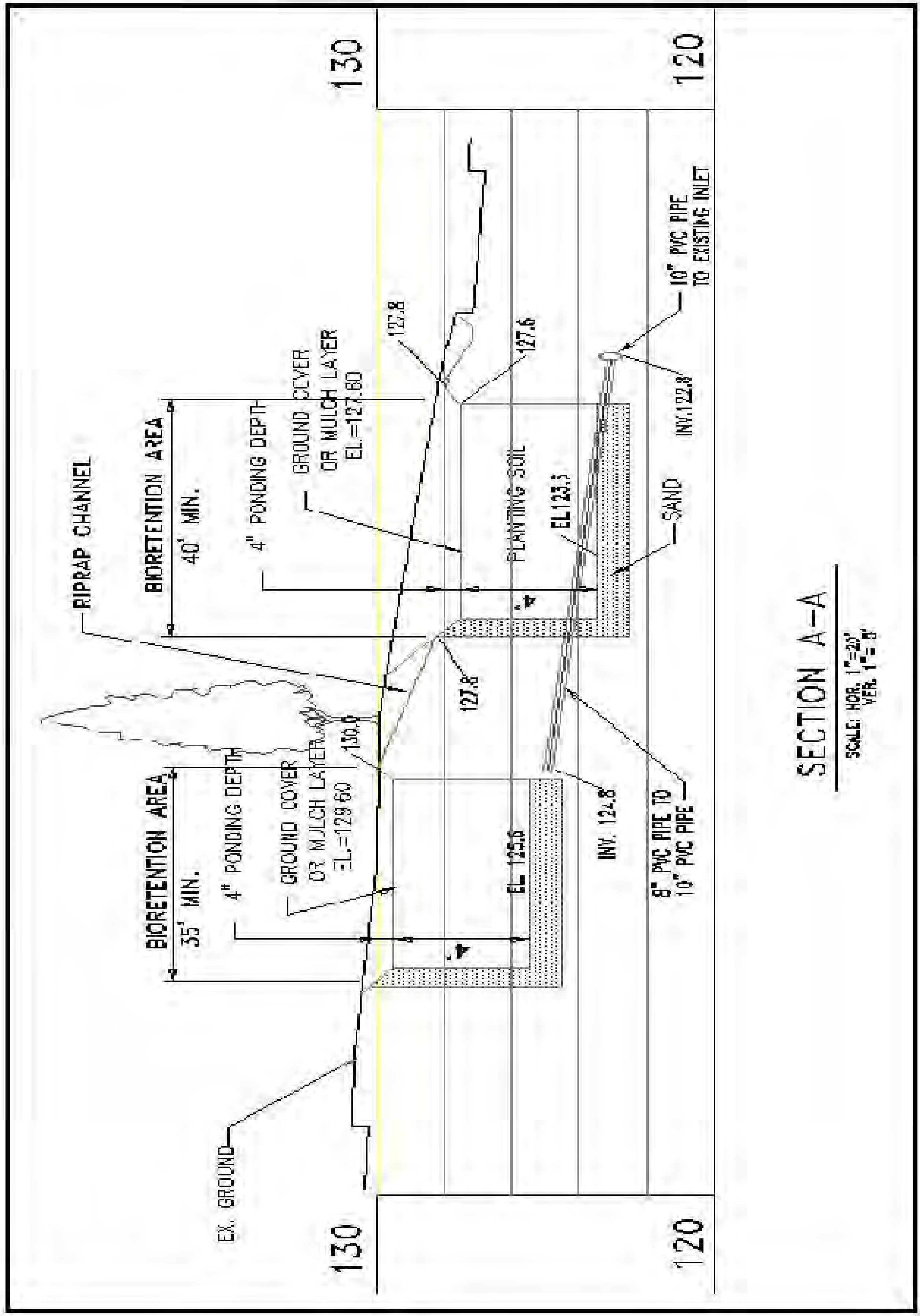
APPENDIX F

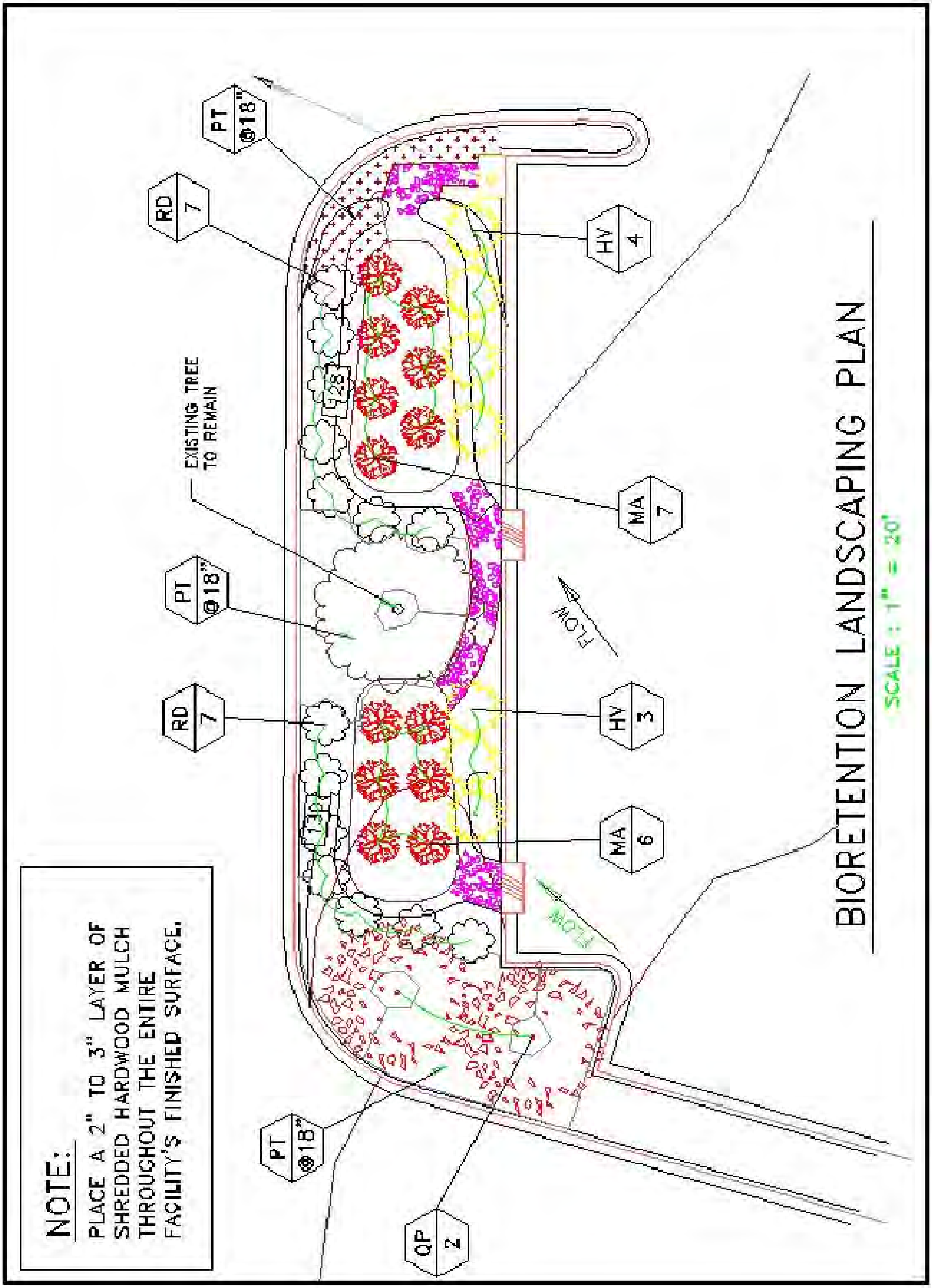
EXAMPLE BIORETENTION PLANS

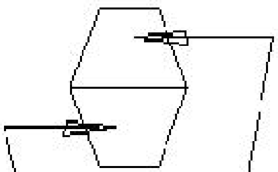
Six example bioretention plans are presented on the following pages.


BIORETENTION FACILITY PLAN
SCALE : 1" = 20'
PARKING
ACCESS ROAD
EX. TREE TO REMAIN
LEVEL BOTTOM AT ELEV. 127.50
LEVEL BOTTOM AT ELEV. 126.60
10" PVC PIPE
8" PVC PIPE
8" DIA. PERF. PVC PIPE
INLET DEFLECTOR SEE DETAIL THIS SHEET
RIP-RAP CHANNEL SEE DETAIL THIS SHEET (TYPICAL)
NEW BACK OPENNING INTO EXISTING INLET AT INV. 126.8
EX. 66" RCP
STOP SIGN
FLOW


CONC. CURB BEYOND
SHEET FLOW
GROUND COVER OR MULCH LAYER TOP ELEV.: 127.50
BIORETENTION AREA
0.5' PONDING DEPTH
VARIES, SEE PLANS
PLANTING SOIL
SAND
3'
4'
1'
2" Min.
4"
123.50
2'
FILTER CLOTH AROUND GRAVEL AND SAND (TYPICAL)
8" DIA. PERFORATED PVC PIPE (TYP.)
4" MIN. CR-6 AROUND EACH PIPE
CONC. CURB AND GUTTER
BIORETENTION FACILITY
TYPICAL CROSS-SECTION
(NOT TO SCALE)

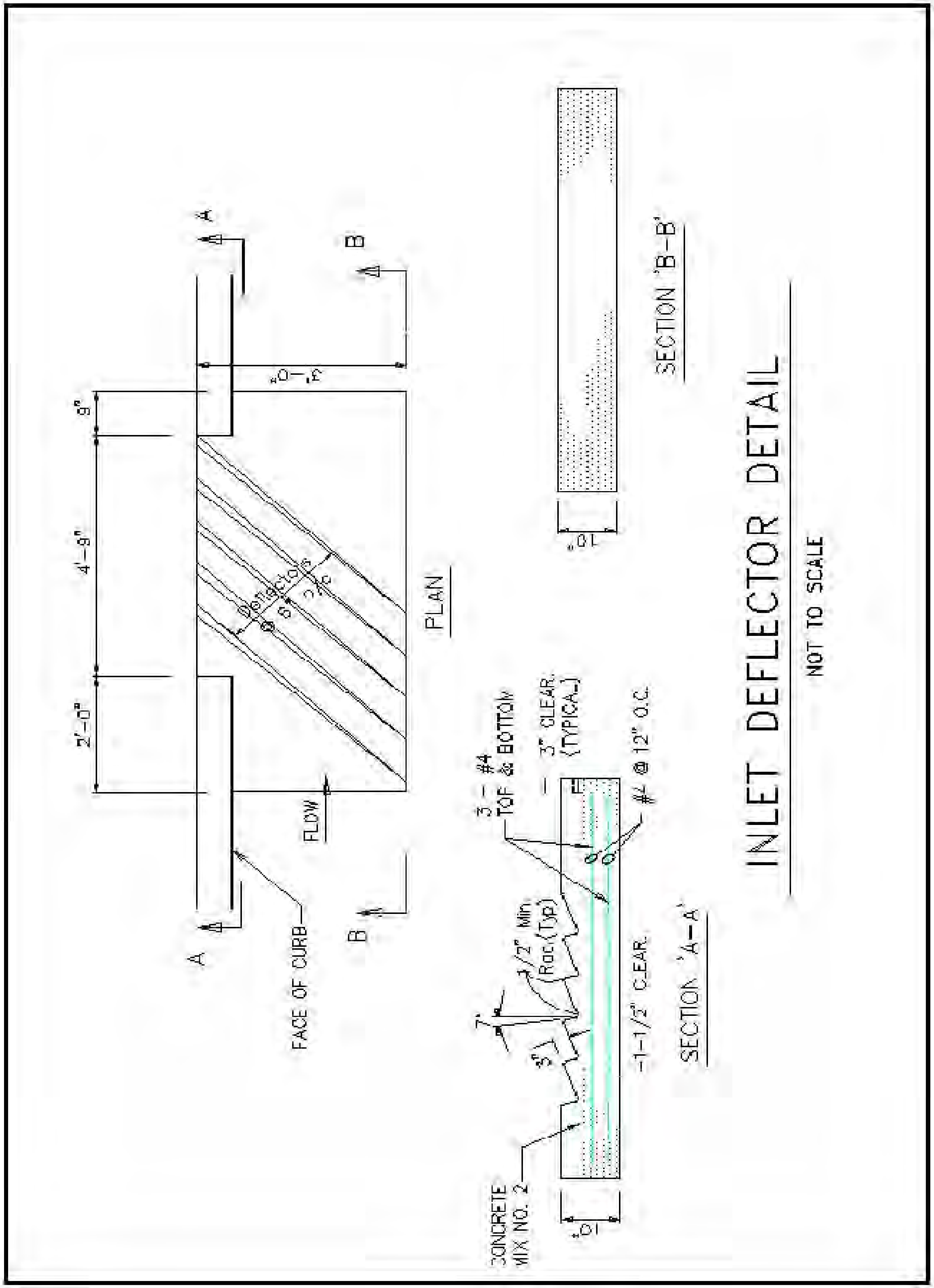

130
120
130
120
EX. GROUND
BIORETENTION AREA
35' MIN.
4" PONDING DEPTH
GROUND COVER
OR MULCH LAYER
EL.=129.60
EL 125.6
INV. 124.8
8" PVC PIPE TO
10" PVC PIPE
130.0
RIPRAP CHANNEL
127.8
BIORETENTION AREA
40' MIN.
4" PONDING DEPTH
GROUND COVER
OR MULCH LAYER
EL.=127.60
PLANTING SOIL
EL 123.5
SAND
127.8
127.6
INV.122.8
10" PVC PIPE
TO EXISTING INLET
SECTION A-A
SCALE: HOR. 1"=20'
VER. 1"=5'


NOTE:
PLACE A 2" TO 3" LAYER OF SHREDDED HARDWOOD MULCH THROUGHOUT THE ENTIRE FACILITY'S FINISHED SURFACE.
PT @18"
QP 2
RD 7
PT @18"
EXISTING TREE TO REMAIN
RD 7
PT @18"
128
130
MA 6
HV 3
FLOW
FLOW
MA 7
HV 4
BIORETENTION LANDSCAPING PLAN
SCALE : 1" = 20'



BIORETENTION FACILITY

LANDSCAPING PLANTING SCHEDULE						
QUANT.	KEY	BOTANICAL NAME	COMMON NAME	CONDITION	SIZE	REMARKS
2	QP	Quercus Palustris	PIN OAK	B & B	2" – 2-1/2"	Branching
7	HV	Hamamelis Virginiana	WITCH-HAZEL	Container	18" – 24"	
14	RD	Rhododendron "Delaware Valley"	WHITE AZALEA "Delaware Valley"	Container	18" – 24"	
1800	PT	Pachisandra Terminallis	PACHISANDRA		6" – 8"	
13	MA	Mentha Arvensis	WILD MINT		8" – 12"	


INLET DEFLECTOR DETAIL
NOT TO SCALE
PLAN
SECTION 'B-B'
SECTION 'A-A'
FACE OF CURB
FLOW
2'-0"
4'-9"
9"
3'-0"
10"
3 - #4
TOP & BOTTOM
3" CLEAR
(TYPICAL)
#4 @ 12" O.C.
1-1/2" CLEAR
CONCRETE
MIX NO. 2

APPENDIX G

OPERATION AND MAINTENANCE FOR BIORETENTION

IN THIS APPENDIX

Prince George's County, Maryland

May 2003

Special Acknowledgement to The Bioengineering Group, Inc. for developing a Maintenance and Operation Manual for the Western Branch Patuxent River, LID Retrofit Program in Prince George's County, Maryland. A large portion of this appendix has been composed from that document. Any reproduction of this appendix, in part or in whole, requires written permission from The Bioengineering Group, Inc., Salem, Massachusetts.

Operation and Maintenance

The proper functioning of bioretention areas depends on their long-term maintenance. While maintenance is relatively minimal and similar to regular landscaped areas, extra care must be taken to maintain the bioretention area's pollutant removal and infiltration capacity. This is accomplished by maintaining soil structure, caring for soil invertebrates, mulching as needed, and periodic removal of debris. A Maintenance Schedule (Table G-1) has been included to provide guidance on the timing of maintenance activities for the bioretention areas.

In general, maintenance strategies should reflect a commitment to environmentally sensitive methods. Such methods typically favor physical labor over chemical applications; the use of low-toxicity, low-residue compounds; and strategies such as Integrated Pest Management.

Table G-1. Maintenance Schedule for Bioretention Areas

1.0 Plant Care		**Spring**			**Summer**			**Fall**			**Winter**		
1.1	Trimming, Pruning, & Thinning	R							R	R			
1.2	Mowing		L	R	R	R	R	R	L				
1.3	Weeding		L	L	R	R	R	L	L				
1.4	Watering (estab. & drought)	N	N	N	N	N	N	N	N	N			
1.5	Fertilizing				N	N	N						
1.6	Pest Management		R	R	R	R	R	R	R				
1.7	Plant Replacement	N	N						N	N			
2.0 Infiltration Maintenance		**Spring**			**Summer**			**Fall**			**Winter**		
2.1	Ponding and Drainage	N	N	N	N	N	N	N	N	N			
2.2	Trash and Debris Removal	N	N	N	N	N	N	N	N	N	N	N	N
2.3	Composting												
2.4	Mulching	R					R						
2.5	Pet Waste Removal	N	N	N	N	N	N	N	N	N	N	N	N
2.6	Snow Removal												
2.7	De-Icing												

R: Required
L: Required at low frequency
N: Required as necessary

1 Plant Care

1.1 Trimming, Pruning, and Thinning

Trimming and pruning of excess vegetation will occasionally be necessary. Dead, dying, diseased, or hazardous branches should be trimmed and removed as they occur. Trees and shrubs may also be pruned for shape or to maximize fruit production. Trees, shrubs, and flowers may be pinched, pruned, thinned or dead-headed during the growing season to encourage more flowering, a bushier plant, or a fresh set of leaves. Pruning of trees should occur before bud-break (usually by mid-March). Pruning of flowering shrubs should be performed immediately after the plants have finished blooming. For specific pruning instructions for particular species consult the Maryland Cooperative Extension's Home and Garden Information Center at 800-342-2507 or www.hgic.umd.edu**.**

1.2 Mowing

Mowing is recommended for grassed areas (e.g., dry swales) where turf grass is the only plant-type. Minimal grass height should not be shorter than 4" for turf grasses and 8" for native grasses. Mowing should be scheduled so as to maintain a neat, trim appearance. High-use areas should be mowed at a frequency of once a week during the peak growing season (late spring and early fall). However, these areas should be mowed less frequently during early spring, mid-summer and late fall when blade growth is much slower. Low-use areas should be mowed less frequently, perhaps as infrequently as once a year, as dictated by on-site needs and landowner preference.

Mowing of bioretention areas is not necessary or recommended. By design, plants in bioretention areas are meant to flourish throughout the growing season, leaving dry standing stalks during the dormant months. When mowing near bioretention areas, either use a mulching blade, or point the mower away from the bioretention area. Fresh grass clippings are high in nitrogen and should not be applied to bioretention areas, as they will compromise the facility's pollutant reduction effectiveness.

1.3 Weeding

Weeding should be limited to invasive and exotic species, which can overwhelm the desired plant community. However, native non-invasive volunteer species are often desirable, as they add to the diversity of the plant community. Weeding should occur once a week during the summer and at least once a month during the remainder of the growing season. Non-chemical methods (hand pulling and hoeing) are preferable. Chemical herbicides should be avoided. A list of invasive species is included in (Table G-2). For updated information on invasive species consult the Maryland Invasive Species Council at http://www.mdinvasivesp.org.

1.4 Watering

Watering is most critical during the first few weeks after planting, and less critical yet important, during the first three years after planting. During the first three years, plants should be watered whenever the soil is dry at a minimum depth of 4". After the first three years, once plants are established, watering should only be necessary during drought conditions. During drought conditions, plants should be watered a minimum of every seven to ten days.

To conserve water, reduce the potential for immediate evaporation, disease and fungal infestation, and improve the potential for infiltration, watering should be performed from sunset to sunrise, roughly from 8:00pm to 8:00am.

A general rule of thumb when monitoring plant success is: if plants wilt during the day but recover in the evening, watering is not necessary. If plants do not recover in the evening, then watering is likely to be necessary. Another rule of thumb is to stick a pencil or screwdriver about 4" into the soil. If the soil is moist at that depth, watering is not needed.

In addition, although plantings have been selected for their ability to withstand both dry and wet conditions, care should be taken to not over-water. Signs of stress associated with over-watering include: wilting of leaves or petals, yellowing of leaves, ringed spots on leaves, and soft or rotting plant base.

Table G-2. INVASIVE PLANT SPECIES OF CONCERN IN PRINCE GEORGE'S COUNTY, MD

Taxon	Common Name	Description
Acer platanoides	Norway Maple	Tree that escapes from cultivation, invades open fields, meadows and woods where it forms thickets, very prolific seeder
Ailanthus altissima	Tree of Heaven	Tree that spreads clonally over large areas, will freely seed, very difficult to control
Alliaria petiolata	Garlic Mustard	Herbaceous biennial that overtakes floodplain flora and mesic uplands, very adaptable to shady forests
Allium vineale	Wild Garlic	Perennial bulb that invades lawns, fields, and meadows, subject to state quarantines
Ampelopsis brevipedunculata	Porcelain Berry	Woody vine, well established in a variety of habitats, introduced as a cultivated plant, berries spread by birds and other wildlife
Artemisia vulgaris	Mugwort	Herbaceous perennial that escapes from fields, roadsides and waste places into native habitats
Berberis thunbergii	Japanese Barberry	Shrub, well established in woodlands and forests, introduced as a cultivated plant, seeds spread by birds and other wildlife
Carduus acanthoides	Plumeless Thistle	Herbaceous biennial that invades roadsides, pastures, and open native habitats, seeds dispersed by wind and wildlife
Carduus nutans	Musk Thistle	Herbaceous biennial that invades roadsides, pastures and open native habitats, hybridizes with plumeless thistle
Celastrus orbiculatus	Oriental Bittersweet	Woody vine established in woodlands and forests, introduced as a cultivated plant, berries dispersed by birds and other wildlife
Centaurea maculosa	Spotted Knapweed	Herbaceous perennial that escapes from fields and roadsides into native habitats
Cirsium arvense	Canada Thistle	Herbaceous perennial that invades fields and pastures, establishes clonal colonies, seeds distributed by wind and wildlife
Cirsium vulgare	Bull Thistle	Herbaceous biennial that escapes from fields and roadsides into native open habitats, seeds distributed by wildlife
Elaeagnus umbellate	Autumn Olive	Shrub that invades a variety of native habitats from grassland to forest, introduced as a cultivated plant, berries distributed by wildlife
Hedera helix	English Ivy	Woody vine that invades forests and woodlands, introduced as a cultivated plant, berries distributed by birds and other wildlife
Hemerocallis fulva	Daylily	Herbaceous perennial that invades a variety of native habitats, introduced as a cultivated plant
Humulus japonicus	Japanese Hops	Annual vine, introduced as a cultivated plant
Lonicera japonica	Japanese Honeysuckle	Woody vine that invades a variety of habitats, introduced as a cultivated plant
Lonicera maackii	Amur Honeysuckle	Shrub that invades a variety of habitats, introduced as a cultivated plant, fruit is dispersed by birds and other wildlife
Lonicera morrowi	Morrow's Honeysuckle	Shrub that invades a variety of habitats, introduced as a cultivated plant, fruit is dispersed by birds and other wildlife
Lonicera tatarica	Tartarian Honeysuckle	Shrub that invades a variety of habitats, introduced as a cultivated plant, fruit is dispersed by birds and other wildlife
Lythrum salicaria	Purple Loosestrife	Herbaceous perennial that overtakes native wetlands, prolific seeder, biological control organisms available
Microstegium vimineum	Japanese Stiltgrass	Herbaceous annual rapidly expanding into numerous native habitats, shade-tolerant

Taxon	Common Name	Description
Miscanthus sinensis	Eulalia Herbaceous	perennial grass widely grown in nursery trade, early flowering cultivars have viable seed and are spreading to roadsides
Perilla frutescens	Perilla	Herbaceous annual that invades a variety of habitats, introduced as a cultivated plant, used medicinally
Phragmites australis	Phragmites	Herbaceous perennial that overtakes wetland ecosystems, forms large colonies
Polygonum cuspidatum	Japanese Knotweed	Herbaceous perennial that invades a variety of habitats, forms large colonies, introduced as a cultivated plant
Polygonum perfoliatum	Mile-a-minute	Annual thorny vine that rapidly overtakes shrubs and trees, seeds dispersed by water
Pueraria montana var.*lobata*	Kudzu	Woody vine that rapidly overtakes shrubs and trees
Ranunculus ficaria	Lesser Celandine	Herbaceous perennial that overtakes native floodplain flora, difficult to control due to persistent underground tubers
Sorghum bicolor	Shattercane	Annual grass that invades agricultural and natural ecosystems
Sorghum halepense	Johnsongrass	Perennial grass that invades agricultural and natural ecosystems
Rosa multiflora	Multiflora Rose	Shrub that overtakes a variety of open and semi-open habitats, fruits dispersed by birds and other wildlife

Excerpted from "Invasive Species of Concern in Maryland", Maryland Invasive Species Council (http://www.mdinvasivesp.org)

1.5 Fertilizing

By design, bioretention facilities are located in areas where nutrients, (especially nitrogen), are typically elevated above natural levels. Therefore, it is unlikely that soil fertilization will be necessary. Excess fertilization compromises the facility's pollutant reduction effectiveness, leads to weak plant growth, promotes disease and pest outbreaks, and inhibits soil life. If soil fertility is in doubt, call the Maryland Cooperative Extension Home and Garden Information Center at 800-342-2507 or access the their website at www.hgic.umd.edu for information on soil testing. If fertilization is necessary, only organic fertilizers should be used. For more information, consult one of the following organic fertilizer suppliers (or a similar manufacturer): Home Harvest, tel. 800-348-4769, http://homeharvest.com (Maryland), or North Country Organics, tel. 802-222-4277, http://www.norganics.com/ (Vermont).

1.6 Pest Management

Trees and shrubs should be monitored for the appearance of, or damage to plants by pests and disease. Monitoring should occur once a week during the growing season. For identification of specific pests and diseases, and for treatment recommendations, consult the Maryland Cooperative Extension's Home and Garden Information Center at 800-342-2507 or http://www.hqic.umd.edu.

It is important to keep in mind that insects and soil microorganisms perform a vital role in maintaining soil structure. Therefore, the use of pesticides should be avoided so as not to harm beneficial organisms. An alternative to pesticide use is to adopt an Integrated Pest Management (IPM) approach. This involves reducing pests to acceptable levels using a combination of biological, physical, mechanical, cultural, and chemical controls. For more information, consult University of Maryland's IPM website at http://www.agnr.umd.edu/users/nrsl/entm/.

1.7 Plant Replacement

In the even that plant mortality occurs, dead plants should be removed and replaced with healthy new plants. When replacing a plant, place the new plant in the same location as the old plant, or as near as possible to the old location. The exception to this recommendation is if plant mortality is due to initial improper placement of the plant (i.e. in an area that is too wet or too dry) or if diseased/infected plant material was used and there is risk of persistence of the disease or fungus in the soil.

The best time to plant is in early to mid-fall or early to mid-spring. Trees can be planted as long as the soil temperature remains above 32 degrees Fahrenheit at a depth of 6". Plants should be planted as soon as possible after purchase to ensure the best chance of survival. If possible, new plants should be approximately the same size as those that are being replaced. If surrounding plants have already become well established, care may need to be given to the new plants to ensure successful growth. Use native species where possible, and avoid exotic or invasive species. See the planting list provided in Insert C for suggested species.

2 Infiltration Maintenance

2.1 Ponding and Drainage Problems

Bioretention facilities are designed to have water standing for up to 6 hours at a time. If this water period is routinely exceeded, the facility may not be functioning properly. Excessive pooling of water is usually a result of clogging or blockage of the filtration layer (in some cases, the pea gravel layer). If clogging of the pea gravel layer has occurred, use lengths of small reinforcing bar (2'-3' #4 rebar) to puncture the layer with holes every 1' on center. Another maintenance alternative is to remove the mulch layer and rake the sediment on top of the pea gravel. This will loosen some of the fine-grained sediments that may be filling the pore spaces. After raking has been conducted, the mulch layer should be returned. Care should be given to not disturb the existing, well-established plants.

In a worst -case scenario, the entire facility may need to be re-installed. If this is the case, contact the programs and Planning Division, Department of Environmental Resources for an evaluation of the facility and recommendations on how to correct the situation.

2.2 Trash and Debris Removal

Runoff flowing into bioretention facilities may carry trash and debris. Trash and debris should be removed weekly to ensure that inlets do not become blocked and to keep the area from becoming unsightly. Inspect bioretention areas after rainstorms to ensure drainage paths are free from blockages. Curb cuts in parking areas will need to periodically be cleared of accumulated sediment and debris. For more information on debris control and volunteer cleanup programs contact Citizens Concerned for a Cleaner County (CCCC) at 301-883-5843 or www.KeepPrinceGeorgesBeautiful.com.

2.3 Composting

Plant waste (e.g., fallen branches and leaves) should be collected from paved surfaces and lawn areas and composted on site. Composted material can be used to amend the soil in mown grass areas and in tree and shrub beds, saving the cost of both waste disposal and soil amendments. Composting should be established in a location with limited public access, yet close enough for easy access by maintenance staff. Invasive plant species, weeds with ripe seed heads, diseased plants, or unshredded woody debris larger than ¼” diameter should not be composted.

Note that composted material should NOT be applied to bioretention areas.

2.4 Mulching

Mulch has many benefits: it reduces competition by grass roots with tree and plant roots; controls weeds; prevents and reduces soil compaction; preserves soil moisture; and discourages potentially injurious practices like mowing and string trimming near tree trunks or woody stems. Bioretention areas should receive a protective layer of mulch over root areas, similar to that provided by leaf litter in a natural forest. Mulch layers should not exceed 3” in depth around trees and shrubs, and should be limited to 1-2” in depth around perennials. Avoid blocking inflow entrance points with mounded mulch or raised plantings. To avoid bark rot and subsequent infestation by pests, mulch should not be mounded around the base of woody plants. Mulch material should be re-applied once every 6 months during the first three growing seasons. The use of aged mulch is recommended and should consist of the shredded type rather than the chip type, to minimize floating. The mulch materials placed in the facility will decompose and blend with the soil medium over time. Once a full groundcover is established, mulching may not be necessary.

The following materials may be used as mulch in bioretention areas:

- Shredded bark mulch
- Decayed grass clippings
- Buckwheat
- Pine needles
- Cocoa shells
- Shredded leaf mold
- Compost

The following materials should NOT be used as mulch in bioretention areas:

- Fresh grass clippings
- Animal waste

2.5 Pet Waste Removal

Pet waste should not be left to decay in bioretention facilities because of the danger of disease-causing organisms.

2.6 Snow Removal

Plowed or shoveled snow piles should not block inlet structures or be placed in bioretention areas.

Note that snow removal is NOT recommended in bioretention areas.

2.7 De-icing

When de-icing compounds are necessary for roads and walkways, the least harmful chemicals should be used. Chemicals should be evaluated for their potential to damage vegetation (evidenced by foliage burn on grass at the edge of pavements, stunted perennial growth, and deformed buds on trees and shrubs); metals (corrosion and accelerated rusting of railings, furniture, grates, and drains); and hardscapes (scaling or flaking of surface layers of concrete). Environmentally friendly ice control agents are available that have been shown to have fewer adverse effects on pavement, infrastructure, vehicles, and plants. For example, calcium magnesium acetate (CMA) can be used as an alternative to salt in environmentally sensitive areas. Although CMA is environmentally friendly, it is effective only to 21 degrees Fahrenheit (-6 degrees Celsius) and has a higher cost than conventional chemicals. Other anti-icing agents that prevent the formation of ice are also available. Ice Ban, (http://www.cerf.org/about/press/10_27_99.htm) for example, is made from agricultural residues and is considered to be environmentally friendly.

Abrasives such as sand and gravel are frequently used alone or in conjunction with salt to provide traction on slippery surfaces. Use of large amounts of sand and gravel should be avoided, however, since they may obstruct waterway conveyance systems.

Ice removal is NOT recommended in bioretention areas.

3 Other Sources of Bioretention Maintenance

For additional sources on bioretention maintenance and operation issues, see Chapter 5, Environmental Outreach and Appendix A, Bioretention Guidelines.

4 References

How Does Your Garden Grow? - A Reference Guide to Enhancing Your Rain Garden, Prince George’s County Department of Environmental Resources

Bioretention Yahoo! Discussion Group - http://groups.yahoo.com/group/bioretention/

Recommended Plant Species for Prince George's County, MD

Canopy Trees	
Taxon	**Common Name**
Acer rubrum	Red Maple
Diospyros virginiana	Persimmon
Fraxinus pennsylvanica	Green Ash
Liquidambar styraciflua	Sweetgum
Nyssa sylvatica	Black gum
Quercus alba	White Oak
Quercus palustris	Pin Oak
Quercus rubra	Northern Red Oak
Understory Trees	
Amelanchier canadensis	Serviceberry
Asimina triloba	Paw Paw
Betula nigra	River Birch
Carpinus caroliniana	Hornbeam
Cercis Canadensis	Redbud
Crataegus viridis	Green Hawthorne
Hamamelis virginiana	Witch Hazel
Shrubs	
Aronia melanocarpa	Black Chokecherry
Comptonia peregrina	Sweet Fern
Ilex glabra	Inkberry
Leucothoe axillaris	Coastal Leucothoe
Lindera benzoin	Spicebush
Kalmia latifolia	Mountain Laurel
Myrica cerifera	Wax Myrtle
Rhododendron caroliniana	Carolina Rhododendron
Rhododendron roseum	Roseshell Azalea
Vaccinium angustifolium	Low-Bush Blueberry
Vaccinium corymbosum	High-Bush Blueberry
Viburnum acerifolium	Maple-Leaf Viburnum
Ferns	
Osmunda claytonia	Interrupted Fern
Polystichum acrostichoides	Christmas Fern
Thelypteris kunthii	Southern Shield Fern
Understory Plug Mix	
Aquilegia canadensis	Columbine
Asarum canadense	Wild Ginger
Chrysogonum virginianum var. australe	Southern Green-and-Gold
Elymus hystrix	Bottlebrush Grass
Gaultheria procumbens	Wintergreen
Geranium maculatum	Cranesbill Geranium
Heuchera americana	Alum Root
Phlox divaricata	Blue Woodland Phlox
Polygonatum biflorum	Solomon's Seal
Saxifraga virginiensis	Early Saxifrage
Sedum ternatum	Mountain Stonecrop