VIRGINIA DCR STORMWATER DESIGN SPECIFICATION No. 9

BIORETENTION

VERSION 2.0
January 1, 2013

SECTION 1: DESCRIPTION

Individual bioretention areas can serve highly impervious drainage areas less than two (2) acres in size. Surface runoff is directed into a shallow landscaped depression that incorporates many of the pollutant removal mechanisms that operate in forested ecosystems. The primary component of a bioretention practice is the filter bed, which has a mixture of sand, soil, and organic material as the filtering media with a surface mulch layer. During storms, runoff temporarily ponds 6 to 12 inches above the mulch layer and then rapidly filters through the bed. Normally, the filtered runoff is collected in an underdrain and returned to the storm drain system. The underdrain consists of a perforated pipe in a gravel layer installed along the bottom of the filter bed. A bioretention facility with an underdrain system is commonly referred to as a *Bioretention Filter*.

Bioretention can also be designed to infiltrate runoff into native soils. This can be done at sites with permeable soils, a low groundwater table, and a low risk of groundwater contamination. This design features the use of a "partial exfiltration" system that promotes greater groundwater recharge. Underdrains are only installed beneath a portion of the filter bed, above a stone "sump" layer, or eliminated altogether, thereby increasing stormwater infiltration. A bioretention facility without an underdrain system, or with a storage sump in the bottom is commonly referred to as a *Bioretention Basin*.

Small-scale or Micro-Bioretention used on an individual residential lot is commonly referred to as a *Rain Garden*.

SECTION 2: PERFORMANCE

Bioretention creates a good environment for runoff reduction, filtration, biological uptake, and microbial activity, and provides high pollutant removal. Bioretention can become an attractive landscaping feature with high amenity value and community acceptance. The overall stormwater functions of the bioretention are summarized in **Table 9.1**.

Table 9.1. Summary of Stormwater Functions Provided by Bioretention Basins

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR)	40%	80%
Total Phosphorus (TP) EMC Reduction[1] by BMP Treatment Process	25%	50%
Total Phosphorus (TP) Mass Load Removal	55%	90%
Total Nitrogen (TN) EMC Reduction[1] by BMP Treatment Process	40%	60%
Total Nitrogen (TN) Mass Load Removal	64%	90%
Channel and Flood Protection	• Use the Virginia Runoff Reduction Method (VRRM) Compliance Spreadsheet to calculate the Curve Number (CN) Adjustment ***OR*** • Design extra storage (optional; as needed) on the surface, in the engineered soil matrix, and in the stone/underdrain layer to accommodate a larger storm, and use NRCS TR-55 Runoff Equations[2] to compute the CN Adjustment.	

[1] Change in event mean concentration (EMC) through the practice. Actual nutrient mass load removed is the product of the removal rate and the runoff reduction rate(see Table 1 in the *Introduction to the New Virginia Stormwater Design Specifications*).
[2] NRCS TR-55 Runoff Equations 2-1 thru 2-5 and Figure 2-1 can be used to compute a curve number adjustment for larger storm events based on the retention storage provided by the practice(s).

Sources: CWP and CSN (2008) and CWP (2007)

Leadership in Energy and Environmental Design (LEED®). The LEED® point credit system designed by the U.S. Green Building Council (USGBC) and implemented by the Green Building Certification Institute (GBCI) awards points related to site design and stormwater management. Several categories of points are potentially available for new and re-development projects. **Chapter 6** and the introduction to this chapter provide a more thorough discussion of the site planning process and design considerations as related to the environmental site design and potential LEED credits. However, VDCR is not affiliated with the USGBC or GBCI and any information on applicable points provided here is based only on basic compatibility. **Designers should research and verify scoring criteria and applicability of points as related to the specific project being considered through USGBC LEED resources**

Table 9.2. Potential LEED® Credits for Bioretention[1]

Credit Category	Credit No.	Credit Description
Sustainable Sites	SS5.1	Site Development: Protect or Restore Habitat
Sustainable Sites	SS5.2	Site Development: Maximize Open Space
Sustainable Sites	SS6.1	Stormwater Design: Quantity Control
Sustainable Sites	SS6.2	Stormwater Design: Quality Control
Water Efficiency	WE1.1	Water Efficient Landscaping: Reduce by 50%
Water Efficiency	WE1.2	Water Efficient Landscaping: No Potable Water Use or No Irrigation

[1] Actual site design and/or BMP configuration may not qualify for the credits listed. Alternatively, the project may actually qualify for credits not listed here. Designers should consult with a qualified individual (LEED AP) to verify credit applicability.

SECTION 3: DESIGN TABLES

The most important design factor to consider when applying bioretention to development sites is the **scale** at which it will be applied, as follows:

Micro-Bioretention or Rain Gardens. These are small, distributed practices designed to treat runoff from small areas, such as individual rooftops, driveways and other on-lot features in single-family detached residential developments. Inflow is typically sheet flow, or can be concentrated flow with energy dissipation, when located at downspouts.

Bioretention Basins. These are structures treating parking lots and/or commercial rooftops, usually in commercial or institutional areas. Inflow can be either sheetflow or concentrated flow. Bioretention basins may also be distributed throughout a residential subdivision, but ideally they should be located in common area or within drainage easements, to treat a combination of roadway and lot runoff.

Urban Bioretention. These are structures such as expanded tree pits, curb extensions, and foundation planters located in ultra-urban developed areas such as city streetscapes. Please refer to **Appendix 9-A** of this specification for design criteria for Urban Bioretention.

The major design goal for bioretention is to maximize runoff volume reduction and nutrient removal. To this end, designers may choose to go with the baseline design (Level 1) or choose an enhanced design (Level 2) that maximizes nutrient and runoff reduction. If soil conditions require an underdrain, bioretention areas can still qualify for the Level 2 design if they contain a stone storage layer beneath the invert of the underdrain.

Both stormwater quality and quantity credits are accounted for in the Virginia Runoff Reduction Method (VRRM) compliance spreadsheet. The water quality credit represents an annual load reduction as a combination of the annual reduction of runoff volume (40% and 80% from Level 1 and Level 2 designs, respectively) and the reduction in the pollutant event mean concentration (EMC) (25% and 50% from Level 1 & 2 designs, respectively).

Figure 9.1. Typical Bioretention Filters

To compute the water quantity reduction for larger storm events, the designer can similarly use the VRRM Compliance spreadsheet or, as an option, the designer may choose to compute the adjusted curve number associated with the retention storage using the TR-55 Runoff Equations, as noted in **Table 9.1**. The adjusted curve number is then used to compute the peak discharge for the required design storms.

Tables 9.3 and 9.4 outline the Level 1 and 2 design guidelines for the two scales of bioretention design.

Table 9.3. Micro-Bioretention (Rain Garden) Design Criteria[1]

Level 1 Design (RR 40 TP: 25)	**Level 2 Design (RR: 80 TP: 50)**
Sizing: Tv_{BMP} = [(1)(Rv)(A) / 12] ~~Filter surface area (sq. ft.) = 3% [2] of the contributing drainage area (CDA).~~	Sizing: Tv_{BMP} = [(1.25)(Rv)(A) / 12] ~~Filter surface area (sq. ft.) = 4% [2] of the CDA~~ (can be divided into different cells at downspouts).
Maximum contributing drainage area = 0.5 acres; 25% Impervious Cover (IC) [2]	
One cell design (can be divided into smaller cells at downspout locations) [2]	
Maximum Ponding Depth = 6 inches	
Filter Media Depth minimum = 18 inches; Recommended maximum = 36 inches	Filter Media Depth minimum = 24 inches; Recommended maximum = 36 inches
Media: mixed on-site or supplied by vendor	Media: supplied by vendor
All Designs: Media mix tested for an acceptable hydraulic conductivity (or permeability) and phosphorus content (**Section 6.6**)	
Sub-soil testing: not needed if an underdrain is used;	Sub-soil testing: one per practice; Min infiltration rate > 1/2 inch/hour and > 1 inch/hour in order to remove the underdrain requirement.
Underdrain: corrugated HDPE or equivalent.	Underdrain: corrugated HDPE or equivalent, with a minimum 6-inch stone sump below the invert; ***OR*** none, if soil infiltration requirements are met
Clean-outs: not needed	
Inflow: sheetflow or roof leader	
Pretreatment: external (leaf screens, grass filter strip, energy dissipater, etc.).	Pretreatment: external *plus* a grass filter strip
Vegetation: turf, herbaceous, or shrubs (min = 1 out of those 3 choices).	Vegetation: turf, herbaceous, shrubs, or trees (min = 2 out of those 4 choices).
Building setbacks[3]: 10 feet	
[1] Consult **Appendix 9-A** for design criteria for Urban Bioretention Practices. [2] Micro-Bioretention (Rain Gardens) can be located at individual downspout locations to treat up to ~~1,000~~2,500 sq. ft. of impervious cover (100% IC).~~; the surface area is sized as 5% of the roof area (Level 1) or 6% of the roof area (Level 2), with the remaining Level 1 and Level 2 design criteria as provided in **Table 9.2**. If the Rain Garden is located so as to capture multiple rooftops, driveways, and adjacent pervious areas, the sizing rules within **Table 9.2** should apply~~. [3] These are recommendations for simple building foundations. If an in-ground basement or other special conditions exist, the design should be reviewed by a licensed engineer. Also, a special footing or drainage design may be used to justify a reduction of the setbacks noted above.	

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Table 9.4. Bioretention Filter and Basin Design Criteria

Level 1 Design (RR 40 TP: 25)	Level 2 Design (RR: 80 TP: 50)
Sizing (**Section 6.1**): *Tv_{BMP}* = [(1)(Rv)(A) / 12] + any remaining volume from upstream BMP Surface Area (sq. ft.) = ~~(~~*Tv_{BMP}* ~~Tv – the volume reduced by an upstream BMP)~~ / Storage Depth [1]	Sizing (**Section 6.1**): *Tv_{BMP}* = [(1.25)(Rv)(A) / 12] + any remaining ~~volume from upstream BMP~~ Surface Area (sq. ft.) = ~~[(1.25)(T_v) – the volume reduced by an upstream BMP]~~ *Tv_{BMP}* /Storage Depth [1]
Recommended maximum contributing drainage area = 2.5 acres, or with local approval up to 5 acres and a maximum of 50% impervious	
Maximum Ponding Depth = 6 to 12 inches [2]	Maximum Ponding Depth = 6 to 12 inches [2]
Filter Media Depth minimum = 24 inches; recommended maximum = 48 inches~~" feet~~	Filter Media Depth minimum = 36 inches; recommended maximum = 48 inches~~" feet~~
Media & Surface Cover (**Section 6.6**) = supplied by vendor; tested for acceptable hydraulic conductivity (or permeability) and phosphorus content	
Sub-soil Testing (**Section 6.2**): not needed if an underdrain used; Min infiltration rate > 1/2 inch/hour in order to remove the underdrain requirement.	Sub-soil Testing (**Section 6.2**): one soil profile and two infiltration tests per facility (up to 2,500 ft^2 of filter surface); Min infiltration rate > 1/2 inch/hour in order to remove the underdrain requirement.
Underdrain (**Section 6.7**) = Schedule 40 PVC with clean-outs	Underdrain & Underground Storage Layer (**Section 6.7**) = Schedule 40 PVC with clean outs, and a minimum 12-inch stone sump below the invert; ***OR***, none, if soil infiltration requirements are met (**Section 6.2**)
Inflow: sheetflow, curb cuts, trench drains, concentrated flow, or the equivalent	
Geometry (**Section 6.3**): Length of shortest flow path/Overall length = 0.3; ***OR***, other design methods used to prevent short-circuiting; a one-cell design (not including the pre-treatment cell).	Geometry (**Section 6.3**): Length of shortest flow path/Overall length = 0.8; ***OR***, other design methods used to prevent short-circuiting; a two-cell design (not including the pretreatment cell).
Pre-treatment (**Section 6.4**): a pretreatment cell, grass filter strip, gravel diaphragm, gravel flow spreader, or another approved (manufactured) pre-treatment structure.	Pre-treatment (**Section 6.4**): a pretreatment cell *plus* one of the following: a grass filter strip, gravel diaphragm, gravel flow spreader, or another approved (manufactured) pre-treatment structure.
Conveyance & Overflow (**Section 6.5**)	Conveyance & Overflow (**Section 6.5**)
Planting Plan (**Section 6.8**): a planting template to include turf, herbaceous vegetation, shrubs, and/or trees to achieve surface area coverage of at least 75% within 2 years.	Planting Plan (**Section 6.8**): a planting template to include turf, herbaceous vegetation, shrubs, and/or trees to achieve surface area coverage of at least 90% within 2 years. If using turf, must combine with other types of vegetation ~~1~~.
Building Setbacks [3] (**Section 5**): 10 feet if down-gradient from building or level (coastal plain); 50 feet if up-gradient. (Refer to additional setback criteria in **Section 5**)	
Deeded Maintenance O&M Plan (**Section 8**)	
[1] Storage depth is the sum of the ~~Void Ratio~~porosity (η ~~V_r~~) of the soil media and gravel layers multiplied by their respective depths, plus the surface ponding depth. (**Section 6.1**). [2] A ponding depth of 6 inches is preferred. Ponding depths greater than 6 inches will require a specific planting plan to ensure appropriate plant selection (**Section 6.8**). [3] These are recommendations for simple building foundations. If an in-ground basement or other special conditions exist, the design should be reviewed by a licensed engineer. Also, a special footing or drainage design may be used to justify a reduction of the setbacks noted above.	

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SECTION 3: TYPICAL DETAILS

Figures 9.2 through 9.5 provide some typical details for several bioretention configurations. Also see additional details in **Appendix 9-B** of this design specification.

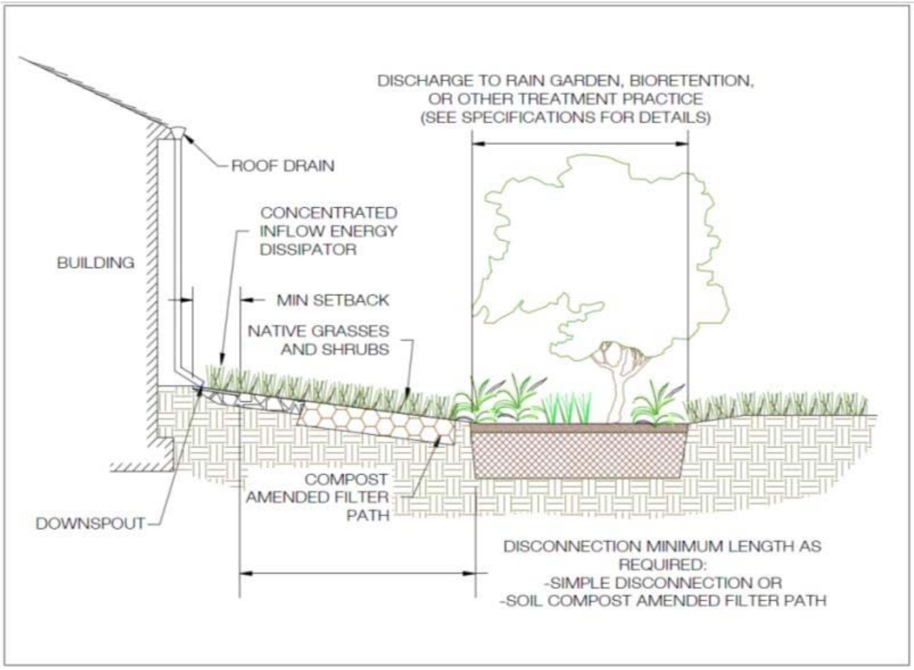

Figure 9.2. Rain Garden (Micro Bioretention):
(a) Simple Disconnection to downstream Raingarden; (b) Disconnection Alternate Practice: Compost Amended Filter Path to downstream Raingarden

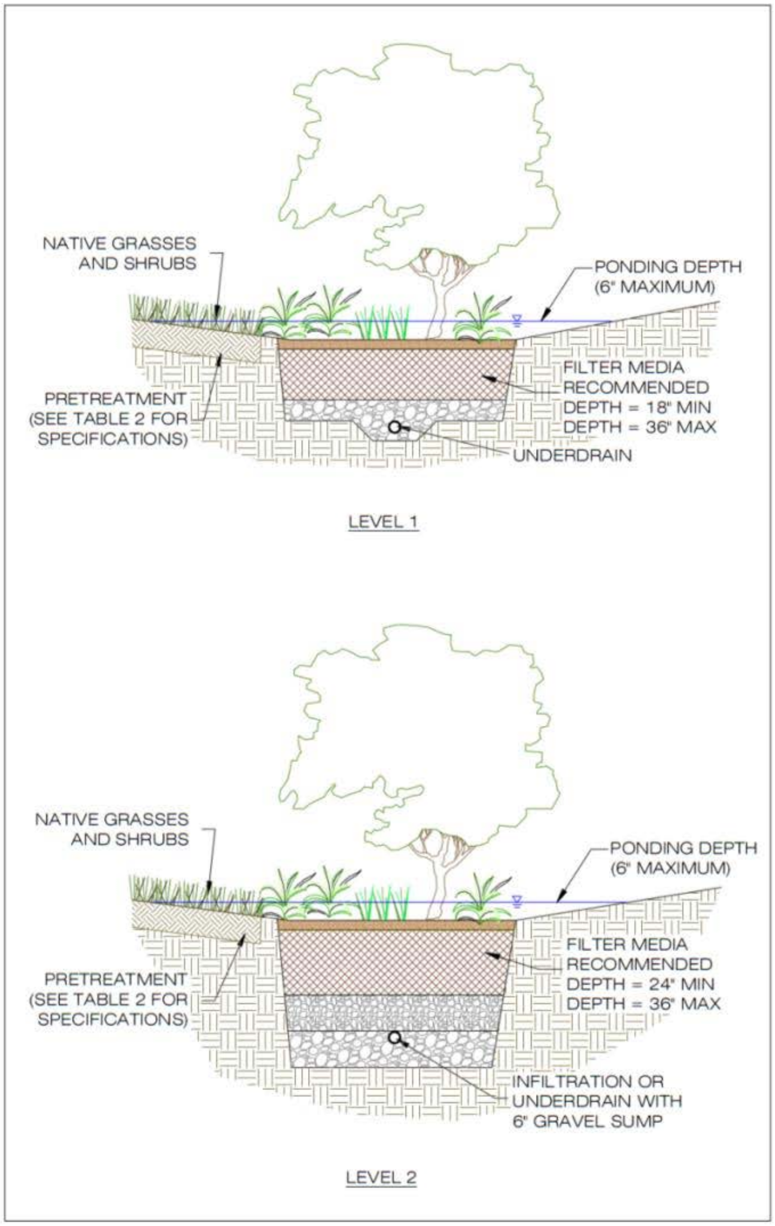

Figure 9.3. Typical Micro-Bioretention Basin (Rain Garden) Level 1 and Level 2

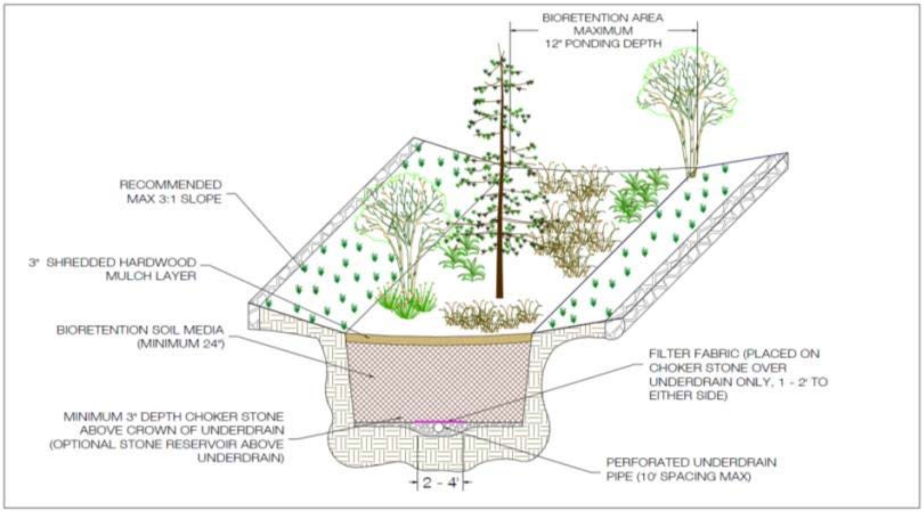

Figure 9.4a: Typical Bioretention Basin Level 1

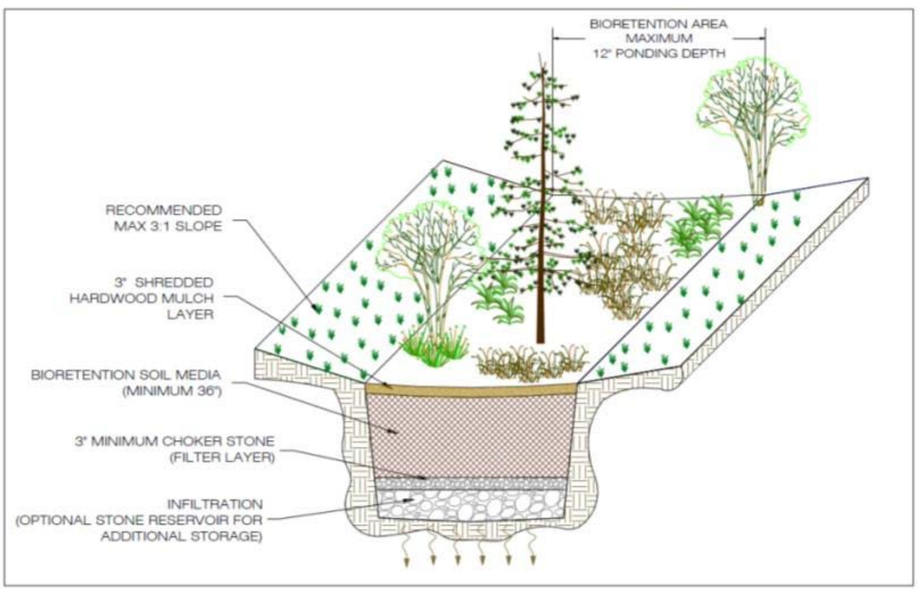

Figure 9.4b: Typical Bioretention Basin Level 2: Infiltration

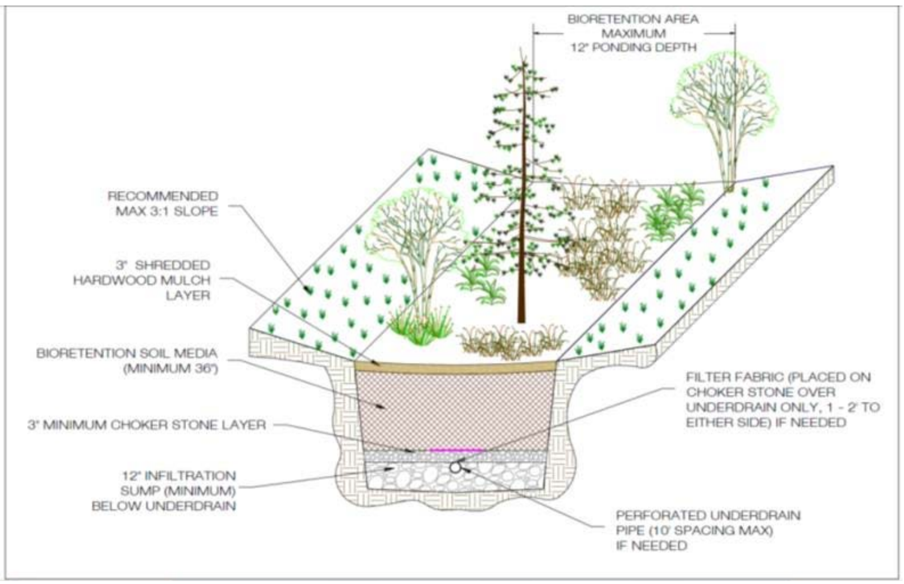

Figure 9.4c: Typical Bioretention Basin Level 2: Infiltration Sump

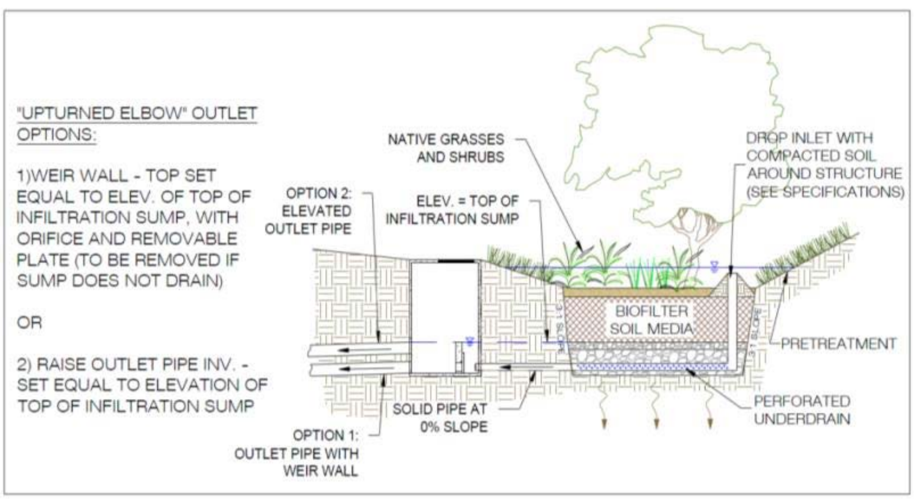

Figure 9.4d: Typical Bioretention Level 2: Infiltration Sump with "Upturned Elbow" or Weir

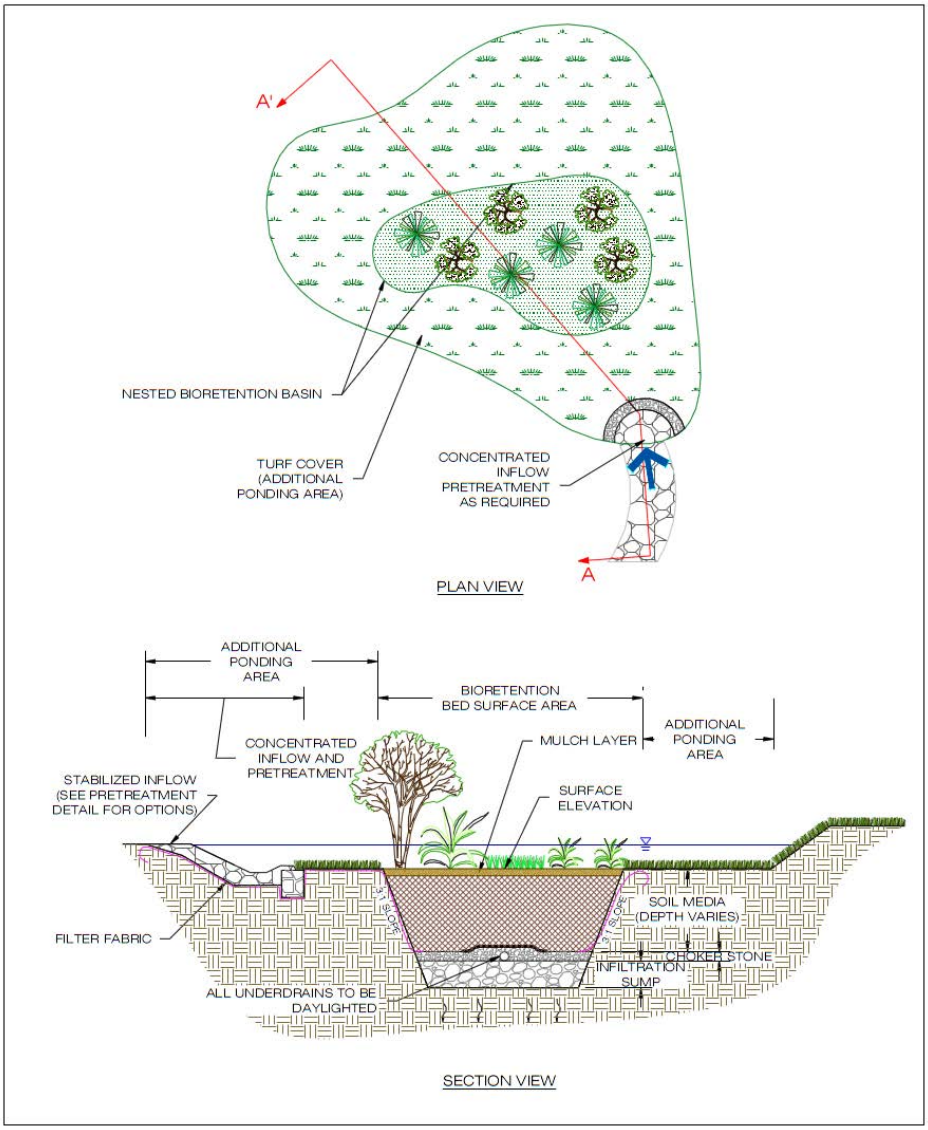

Figure 9.5. Typical Detail of Bioretention with Additional Surface Ponding

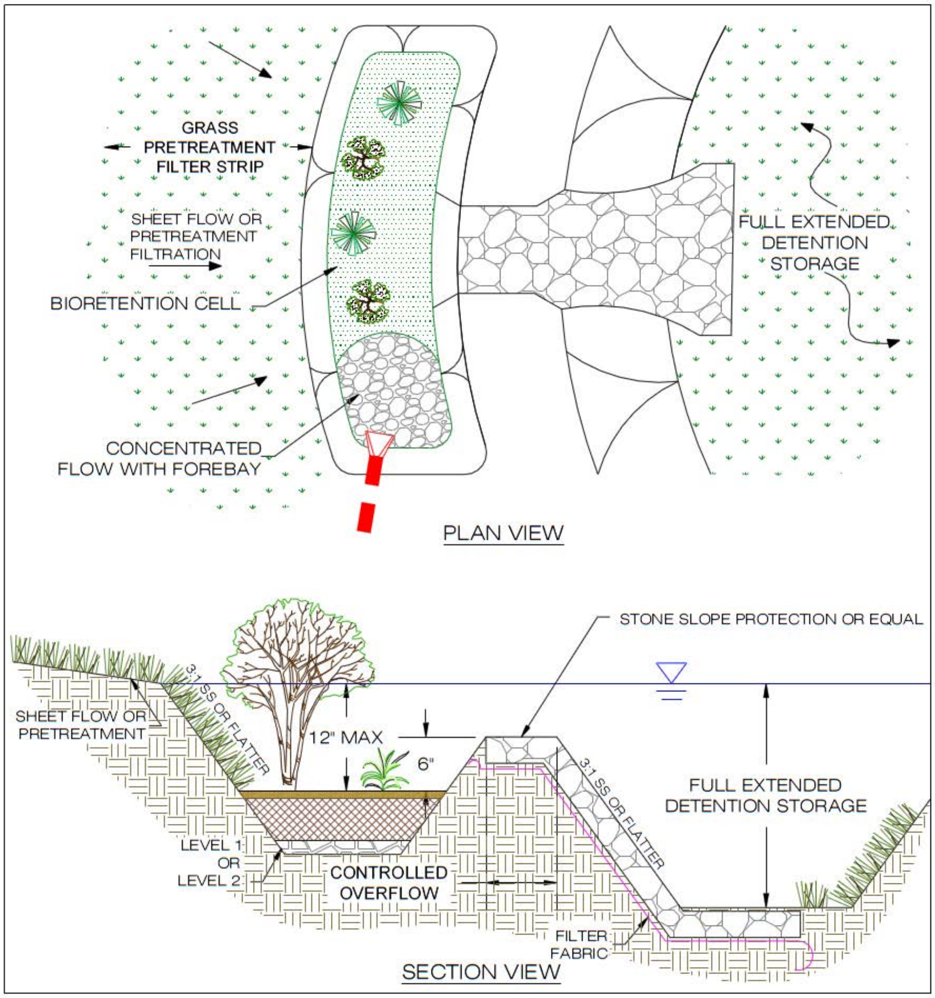

Figure 9.6. Typical Detail of a Bioretention Basin within the Upper Shelf of an ED Pond

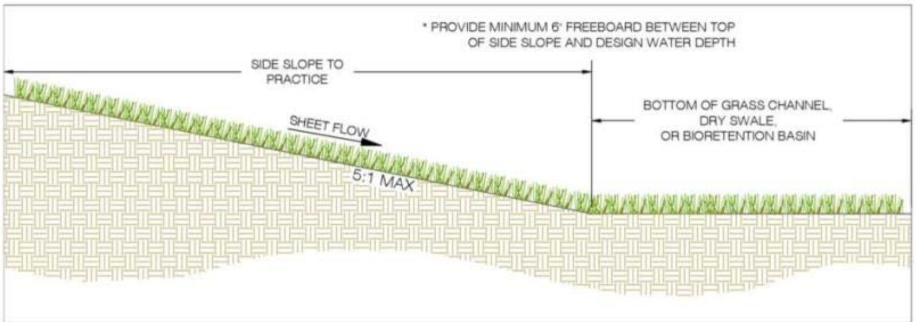

Figure 9.7a. Pretreatment I – Grass Filter for Sheet Flow

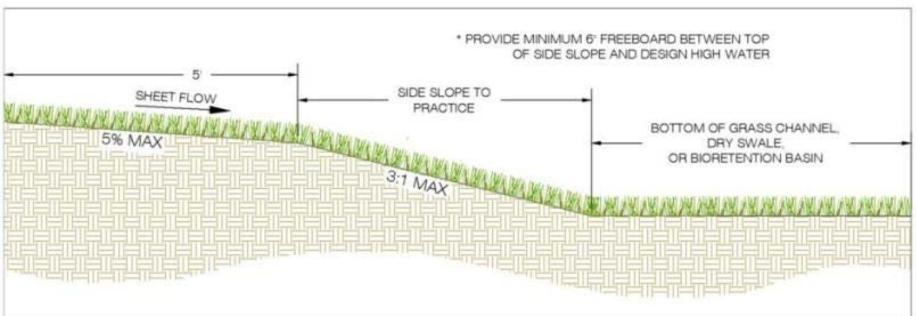

Figure 9.7b. Pretreatment II – Grass Filter for Sheet Flow

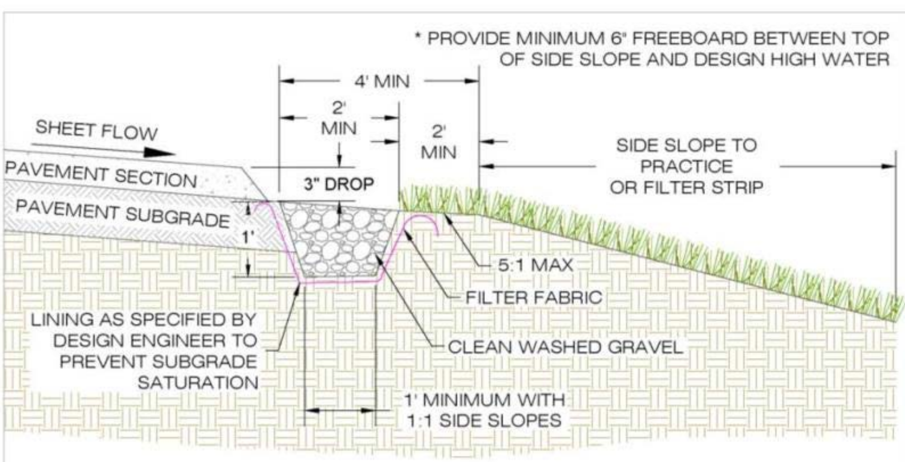

Figure 9.8 - Pretreatment – Gravel Diaphragm for Sheet Flow from Impervious or Pervious

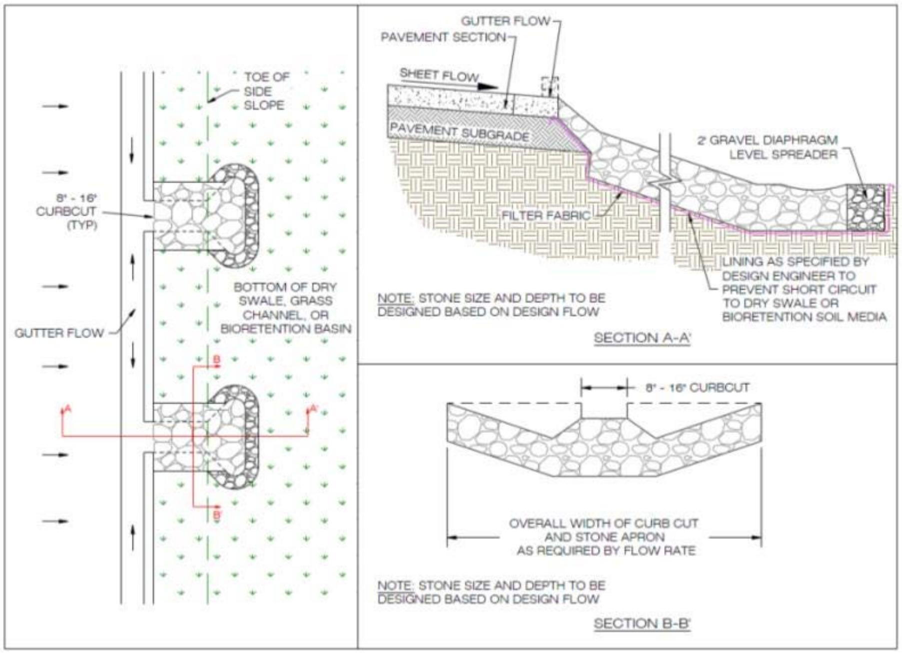

Figure 9.9: Pre-Treatment – Gravel Flow Spreader for Concentrated Flow

SECTION 5: PHYSICAL FEASIBILITY & DESIGN APPLICATIONS

5.1 Physical Feasibility

Bioretention can be applied in most soils or topography, since runoff simply percolates through an engineered soil bed and is returned to the stormwater system. Key constraints with bioretention include the following:

Available Space. Planners and designers can assess the feasibility of using bioretention facilities based on a simple relationship between the contributing drainage area and the corresponding required surface area. The bioretention surface area will be approximately 3% to 6% of the contributing drainage area, depending on the imperviousness of the CDA and the desired bioretention design level.

Site Topography. Bioretention is best applied when the grade of contributing slopes is greater than 1% and less than 5%.

Contributing Drainage Area. Bioretention cells work best with smaller contributing drainage areas, where it is easier to achieve flow distribution over the filter bed. Typical drainage area size can range from 0.1 to 2.5 acres and consist of up to 100% impervious cover. Three scales of bioretention are defined in this specification: (1) micro-bioretention or *Rain Gardens* (up to 0.5 acre contributing drainage area); (2) bioretention basins (up to 2.5 acres of contributing drainage area); and (3) Urban Bioretention (**Appendix 9-A**). Each of these has different design requirements (refer to **Tables 9.3 and 9.4** above). The maximum recommended drainage area to a single bioretention basin or single cell of a bioretention basin is 2.5 acres, however, there are successful examples of bioretention basins treating up to 5 acres; however, the drainage areas are not entirely impervious. Therefore, if approved by the plan approving authority, the drainage area to a single bioretention basin can be increased to a maximum of 5 acres provided that the contributing impervious cover is limited to 2.5 acres (50% impervious cover), and the design elements intended to address the peak rate and energy of the inflow, such as forebay, energy dissipators, high flow diversions, etc., are designed for the expected flows. In such cases, the bioretention facility should be located within the drainage area so as to capture the Treatment Volume (*Tv*) equally from the entire contributing area, and not fill the entire volume from the immediately adjacent area, thereby bypassing the runoff from the more remote portions of the site.

Available Hydraulic Head. Bioretention is fundamentally constrained by the invert elevation of the downstream conveyance system to which the practice discharges (i.e., the bottom elevation needed to tie the underdrain from the bioretention area into the storm drain system). In general, 4 to 5 feet of elevation above this invert is needed to create the hydraulic head needed to drive stormwater through a proposed bioretention filter bed. Less hydraulic head is needed if the underlying soils are permeable enough to dispense with the underdrain.

Water Table. Bioretention should always be separated from the water table to ensure that groundwater does not intersect the filter bed. Mixing can lead to possible groundwater contamination or failure of the bioretention facility. A separation distance of 2 feet is recommended between the bottom of the excavated bioretention area and the seasonally high ground water table. The separation distance may be reduced to 12 inches in coastal plain residential settings (Refer to **Section 7.2 –** Regional Adaptations).

Utilities. Designers should ensure that future tree canopy growth in the bioretention area will not interfere with existing overhead utility lines. Interference with underground utilities should also be avoided, particularly water and sewer lines. Local utility design guidance should be consulted in order to determine the horizontal and vertical clearance required between stormwater infrastructure and other dry and wet utility lines.

Soils. Soil conditions do not constrain the use of bioretention, although they determine whether an underdrain is needed. Impermeable soils such as those in Hydrologic Soil Group (HSG) C or D usually require an underdrain, whereas HSG A and some B soils generally do not. When designing a bioretention practice, designers must verify soil permeability by using the on-site soil investigation methods provided in **Appendix 8-A** of **Stormwater Design Specification No. 8 (Infiltration)**.

Hotspot Land Uses. Runoff from hotspot land uses should not be treated with infiltrating bioretention (i.e., constructed *without* an underdrain). For a list of potential stormwater hotspots, please consult **Section 10.1** of **Stormwater Design Specification No. 8 (Infiltration)**. An impermeable bottom liner and an underdrain system must be employed when bioretention is used to receive and treat hotspot runoff.

Floodplains. Bioretention areas should be constructed outside the limits of the ultimate 100-year floodplain.

***Avoidance of Irrigation or Baseflow*. The planned bioretention area should not receive baseflow, irrigation water, chlorinated wash-water or other such non-stormwater flows that are not stormwater runoff.

***Setbacks*.** To avoid seepage and frost heave concerns, bioretention areas should not be hydraulically connected to structure foundations or pavement. Setbacks to structures and roads vary based on the scale of the bioretention design (see **Table 9.2** and **9.3** above). Expected effluent concentrations of typical urban runoff (TP, TN, metals) from bioretention basins are reported by the International BMP Database, and are considered to be acceptable in terms of groundwater impacts provided that the feasibility factors of water table, hotspot land uses, karst (**Section 7**) are met. However, if ground-water contamination is a concern, it is recommended that ground-water mapping be conducted to determine possible connections to adjacent ground-water wells. Otherwise, it is recommended that at a minimum, bioretention basins be located a horizontal distance of 50 feet from any water supply well, 35 feet from septic systems (20 feet if the bioretention filter is lined), and at least 5 feet from down-gradient wet utility lines. Dry utility lines such as gas, electric, cable and telephone may cross under bioretention areas if they are protected in accordance with the particular utility requirements and can be routinely accessed without disturbing the bioretention basin.

5.2 Potential Bioretention Applications

Bioretention can be used wherever water can be conveyed to a surface area. Bioretention has been used at commercial, institutional, and residential sites in spaces that are traditionally pervious and landscaped. It should be noted that special care must be taken to provide adequate pre-treatment for bioretention cells in space-constrained high traffic areas. Typical locations for bioretention include the following:

Parking lot islands. The parking lot grading is designed for sheet flow towards linear landscaping areas and parking islands between rows of spaces. Curb-less pavement edges can be used to convey water into a depressed island landscaping area. Curb cuts can also be used for this purpose, but they are more prone to blockage, clogging and erosion.

Parking lot edge. Small parking lots can be graded so that flows reach a curb-less pavement edge or curb cut before reaching catch basins or storm drain inlets. The turf at the edge of the parking lot functions as a filter strip to provide pre-treatment for the bioretention practice. The depression for bioretention is located in the pervious area adjacent to the parking lot.

Road medians, roundabouts, interchanges and cul-de-sacs. The road cross-section is designed to slope towards the center median or center island rather than the outer edge, using a curb-less edge.

Right-of-way or commercial setback. A linear configuration can be used to convey runoff in sheet flow from the roadway, or a grass channel or pipe may convey flows to the bioretention practice.

Courtyards. Runoff collected in a storm drain system or roof leaders can be directed to courtyards or other pervious areas on site where bioretention can be installed.

Individual residential lots. Roof leaders can be directed to small bioretention areas, often called "rain gardens," located at the front, side, or rear of a home in a drainage easement. For smaller lots, the front yard bioretention corridor design may be preferable (See Stormwater Design Specification No. 1: Rooftop Disconnection).

Unused pervious areas on a site. Storm flows can be redirected from a storm drain pipe to discharge into a bioretention area.

Dry Extended Detention (ED) basin. A bioretention cell can be located on an upper shelf of an extended detention basin, after the pre-treatment forebay, in order to boost treatment. Depending on the ED basin design, the designer may choose to locate the bioretention cell in the bottom of the basin. However, the design must carefully account for the potentially deeper ponding depths (greater than 6 or 12 inches) associated with extended detention.

Retrofitting. Numerous options are available to retrofit bioretention in the urban landscape, as described in Profile Sheet ST-4 of Schueler et al (2007).

SECTION 6: DESIGN CRITERIA

6.1. Sizing of Bioretention Practices

6.1.1 Stormwater Quality

Sizing of the surface area (SA) for bioretention practices is based on the computed BMP design Treatment Volume, Tv_{BMP}. The Tv_{BMP} is the treatment volume based on the contributing drainage area to the BMP, Tv_{DA}, ~~less~~ plus any remaining runoff volume from ~~reduced by~~ upstream runoff reduction practices. The required surface area (in square feet) is computed as the Tv_{BMP} (in cubic feet) divided by the equivalent storage depth (in feet). The equivalent storage depth is computed as the depth of media, gravel, or surface ponding (in feet) multiplied by the accepted porosity. Therefore, the designer can influence the required surface area by adjusting the depth of each material layer (within the required minimums and maximums of **Table 9.3**.

The accepted porosity (η) for each of the materials is (see **Figure 9.10** below):

Bioretention Soil Media $\eta = 0.25$
Gravel $\eta = 0.40$
Surface Storage $\eta = 1.0$

The equivalent storage depth for Level 1 with a 6-inch surface ponding depth, a 24-inch soil media depth, and a 12-inch gravel layer is therefore computed as:

Equation 9.1. Bioretention Level 1 Design Storage Depth

$$(2\ ft.\ x\ 0.25) + (1\ ft.\ x\ 0.40) + (0.5\ x\ 1.0) = 1.40\ ft.$$

And the equivalent storage depth for Level 2 with a 6-inch surface ponding depth and a 12-inch gravel layer is computed as:

Equation 9.2. Bioretention Level 2 Design Storage Depth

$$(3\ ft.\ x\ 0.25) + (1\ ft.\ x\ 0.40) + (0.5\ x\ 1.0) = 1.65\ ft$$

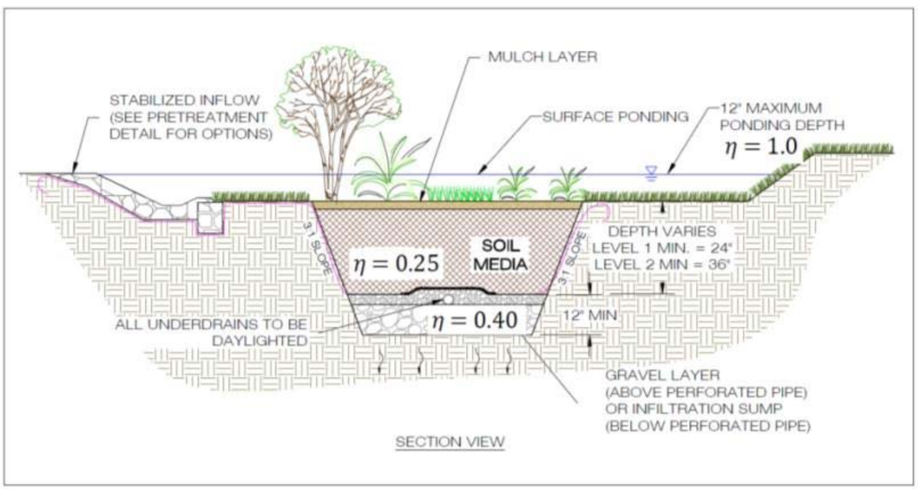

Figure 9.10. Typical Bioretention Section with Porosity for Volume Computations

Therefore, the Level 1 bioretention surface area (SA) is computed as:

Equation 9.3. Bioretention Level 1 Design Surface Area

$$SA\ (sq.\ ft.) = Tv_{BMP} / 1.40\ ft.$$

And the Level 2 bioretention surface area is computed as:

Equation 9.4. Bioretention Level 2 Design Surface Area

$$SA\ (sq.\ ft.) = (~~1.25 *~~ Tv_{BMP}) / 1.65\ ft.$$

Where:

SA = Minimum surface area of bioretention filter (sq. ft.)

Tv_{BMP} = Level 1 BMP design treatment volume (cu. ft.) = [(1.0 in.)(R_v)(A) / 12];
= Level 2 BMP design treatment volume (cu. ft.) = 1.25[(1.0 in.)(R_v)(A) / 12]

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(**NOTE:** R_v = the composite volumetric runoff coefficient from the VRRM Compliance Spreadsheet, or **Chapter 11**.)

Equations 9.1 through 9.4 should be modified if the storage depths of the soil media, gravel layer, or ponded water vary in the actual design or with the addition of any surface or subsurface storage components (e.g., additional area of surface ponding, subsurface storage chambers, etc.).

NOTE: The infiltration rate of the soils must be verified at 0.5 inches per hour in order for the volume infiltration sump to be counted towards the storage volume. Refer to **Section 6.7** or **Figure 9.4C** for information on implementing an "upturned elbow" configuration to create the infiltration sump. If the field verified infiltration rate is less than 0.5 inches per hour, the sump will still qualify as a Level 2 design, however, any additional storage needed must be added above the sump through additional stone, media, or surface ponding.

6.1.2 Stormwater Quantity

The water quality *Tv* can be counted as part of the Channel Protection Volume or Overbank Flood Protection Volume to satisfy stormwater quantity control requirements. In addition, designers may be able to create additional surface storage by expanding the surface ponding footprint in order to accommodate a greater quantity credit for channel and/or flood protection, without necessarily increasing the soil media footprint. In other words, the engineered soil media would only underlay part of the surface area of the bioretention (see **Figure 9.10** above).

In this regard, the ponding footprint can be increased as follows to allow for additional storage:

- 50% surface area increase if the ponding depth is 6 inches or less.
- 25% surface area increase if the ponding depth is between 6 and 12 inches.

These values may be modified as additional data on the long term permeability of bioretention filters becomes available.

6.2. Soil Infiltration Rate Testing

In order to determine if an underdrain will be needed, one must measure the infiltration rate of subsoils at the invert elevation of the bioretention area, as noted in the soil testing requirements for each scale of bioretention, in Design **Tables 9.3 and 9.4** above. The infiltration rate of subsoils must exceed 1 inch per hour in order to dispense with the underdrain requirement for Rain Gardens (micro-bioretention), and 1/2 inch per hour for bioretention basins. On-site soil infiltration rate testing requirements and procedures are outlined in **Appendix 8-A** of the **Stormwater Design Specification No. 8** (Infiltration). Soil testing is not needed for Level 1 bioretention areas, where an underdrain is used.

6.3. BMP Geometry

Bioretention basins must be designed with an internal flow path geometry such that the treatment mechanisms provided by the bioretention are not bypassed or short-circuited. Examples of short-circuiting include inlets or curb cuts that are very close to outlet structures (see **Figure 9.11** below), or incoming flow that is diverted immediately to the underdrain through stone layers. Short-circuiting can be particularly problematic when there are multiple curb cuts or inlets.

Figure 9.11. Examples of Short-Circuiting at Bioretention Facilities

In order for these bioretention areas to have an acceptable internal geometry, the "travel time" from each inlet to the outlet should be maximized, and incoming flow must be distributed as evenly as possible across the filter surface area.

One important characteristic is the length of the shortest flow path compared to the overall length, as shown in **Figure 9.12** below. In this figure, the ratio of the shortest flow path to the overall length is represented as:

Equation 9.5. Ratio of Shortest Flow Path to Overall Length

$$SFP / L$$

Where:

SFP = length of the shortest flow path

L = length from the most distant inlet to the outlet

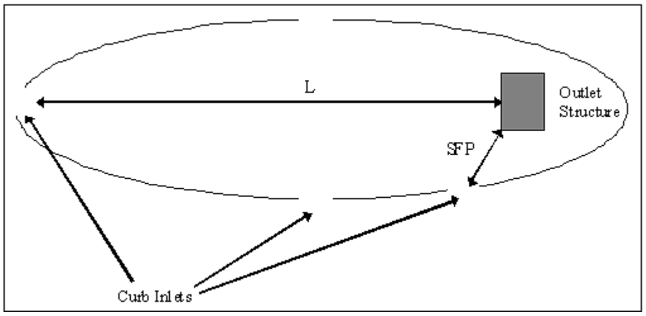

Figure 9.12. Diagram showing shortest flow path as part of BMP geometry

For Level 1 designs, the SFP/L ratio must be 0.3 or greater; the ratio must be 0.8 or greater for Level 2 designs. In some cases, due to site geometry, some inlets may not be able to meet these ratios. However, the drainage area served by such inlets should constitute no more than 20% of the contributing drainage area. Alternately, the designer may incorporate other design features that prevent short-circuiting, including features that help spread and distribute runoff as evenly as possible across the filter surface.

> ***Note: Local reviewers may waive or modify the guideline for the shortest flow path ratio in cases where (1) the outlet structure within the bioretention area is raised above the filter surface to the ponding depth elevation; and (2) the filter surface is flat.***

With regard to the first condition stated in the note above, field experience has shown that soil media immediately around a raised outlet structure is prone to scouring, erosion and, thus, short-circuiting of the treatment mechanism. For example, water can flow straight down through scour holes or sinkholes to the underdrain system (Hirschman et al., 2009). Design options should be used to prevent this type of scouring. One example is shown in **Figure 9.13**.

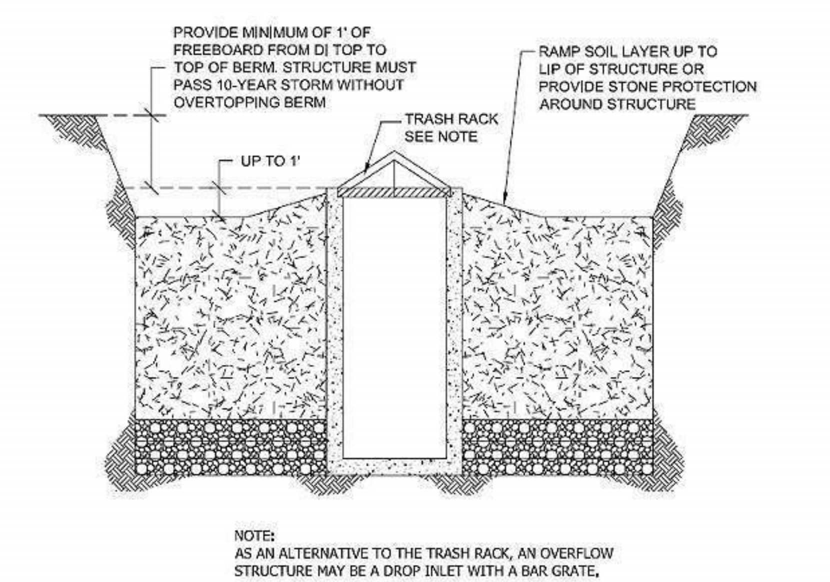

Figure 9.13. Typical Detail of how to prevent bypass or short-circuiting around the overflow structure

The designer should ensure that incoming flow is spread as evenly as possible across the filter surface to maximize the treatment potential.

6.4. Pre-treatment

Pre-treatment of runoff entering bioretention areas is necessary to trap coarse sediment particles before they reach and prematurely clog the filter bed. Pre-treatment measures must be designed to evenly spread runoff across the entire width of the bioretention area. Several pre-treatment measures are feasible, depending on the scale of the bioretention practice and whether it receives sheet flow, shallow concentrated flow or deeper concentrated flows. The following are appropriate pretreatment options:

For Micro Bioretention (Rain Gardens):

- **Leaf Screens** as part of the gutter system serve to keep the heavy loading of organic debris from accumulating in the bioretention cell.
- ***Grass Filter Strips*** (for sheet flow), applied on residential lots, where the lawn area can serve as a grass filter strip adjacent to a rain garden.
- ***Gravel or Stone Diaphragm*** (for either sheet flow or concentrated flow); this is a gravel diaphragm at the end of a downspout or other concentrated inflow point that should run perpendicular to the flow path to promote settling.

For Bioretention Basins:

- ***Pre-treatment Cells*** (channel flow): Similar to a forebay, this cell is located at piped inlets or curb cuts leading to the bioretention area and consists of an energy dissipater sized for the expected rates of discharge. It has a storage volume equivalent to at least 15% of the total *Tv* (inclusive) with a 2:1 length-to-width ratio. The cell may be formed by a wooden or stone check dam or an earthen or rock berm. Pretreatment cells do not need underlying engineered soil media, in contrast to the main bioretention cell.
- ***Grass Filter Strips*** (for sheet flow): Grass filter strips extend from the edge of pavement to the bottom of the bioretention basin at a 5:1 slope or flatter. Alternatively, provide a combined 5 feet of grass filter strip at a maximum 5% (20:1) slope and 3:1 or flatter side slopes on the bioretention basin. (**See Figure 9.7**)
- ***Gravel or Stone Diaphragms*** (sheet flow). A gravel diaphragm located at the edge of the pavement should be oriented perpendicular to the flow path to pre-treat lateral runoff, with a 2 to 4 inch drop. The stone must be sized according to the expected rate of discharge. (**See Figure 9.8**)
- ***Gravel or Stone Flow Spreaders*** (concentrated flow). The gravel flow spreader is located at curb cuts, downspouts, or other concentrated inflow points, and should have a 2 to 4 inch elevation drop from a hard-edged surface into a gravel or stone diaphragm. The gravel should extend the entire width of the opening and create a level stone weir at the bottom or treatment elevation of the basin. (**See Figure 9.9**)
- ***Innovative or Proprietary Structure*****:** An approved proprietary structure with demonstrated capability of reducing sediment and hydrocarbons may be used to provide pre-treatment. Refer to the Virginia BMP Clearinghouse web site (http://www.vwrrc.vt.edu/swc/) for information on approved proprietary structures.

6.5. Conveyance and Overflow

For on-line bioretention: An overflow structure should always be incorporated into on-line designs to safely convey larger storms through the bioretention area. The following criteria apply to overflow structures:

- The overflow associated with the 2 and 10 year design storms should be controlled so that velocities are non-erosive at the outlet point (i.e., to prevent downstream erosion).
- Common overflow systems within bioretention practices consist of an inlet structure, where the top of the structure is placed at the maximum water surface elevation of the bioretention area, which is typically 6 to 12 inches above the surface of the filter bed (6 inches is the preferred ponding depth).
- The overflow capture device (typically a yard inlet) should be scaled to the application – this may be a landscape grate inlet or a commercial-type structure.
- The filter bed surface should generally be flat so the bioretention area fills up like a bathtub.

For off-line bioretention: Off-line designs are preferred (see **Figure 9.14** below for an example). One common approach is to create an alternate flow path at the inflow point into the structure such that when the maximum ponding depth is reached, the incoming flow is diverted past the facility. In this case, the higher flows do not pass over the filter bed and through the facility, and additional flow is able to enter as the ponding water filtrates through the soil media.
Another option is to utilize a low-flow diversion or flow splitter at the inlet to allow only the *Tv* to enter the facility. This may be achieved with a weir or curb opening sized for the target flow, in combination with a bypass channel. Using a weir or curb opening helps minimize clogging and reduces the maintenance frequency. (Further guidance on determining the *Tv* design peak flow rate will be necessary in order to ensure proper design of the diversion structure.)

6.6. Filter Media and Surface Cover

The filter media and surface cover are the two most important elements of a bioretention facility in terms of long-term performance. The ultimate performance goals of the combination of engineered soil mix and surface cover (plants) is to maintain a design infiltration rate and soil permeability so as to treat the stormwater runoff to remove phosphorus (P) and other nutrients and contaminants during a wide range of storm intensities and volumes.

Some important definitions to help designers, contractors, and material suppliers achieve these goals include:

Soil infiltration: the rate at which stormwater enters the surface of the soil. Infiltration is influenced by soil structure, compaction/bulk density, organic matter, moisture content, and other physical characteristics at the soil surface. The design infiltration rate is usually expressed as a constant value, but the actual infiltration rate can vary due to differences in depth of ponding (hydraulic head) or other surface and subsurface soil conditions during the receiving event. Initial rates of infiltration into dry surface soils can be quite rapid and then will decrease as the soil wets and/or swells. Assuming constant head conditions, the infiltration rate will equilibrate after some period of time to approach and reflect the internal permeability (see below) of the underlying soil mix as described below.

Soil media permeability: the rate at which percolating stormwater flows ***through*** the soil after it has infiltrated.

> **NOTE:** *Infiltration and Permeability are used interchangeably in many reference materials but refer to two different physical processes.*

The infiltration and permeability of a given soil are related to the hydraulic conductivity of the soil (K). The rate at which water enters the soil (*infiltration*), under optimal conditions, starts very fast and then declines and eventually approaches a constant rate of entry. This constant rate of infiltration is sometimes called the soil's permeability, but is technically defined as the *saturated hydraulic conductivity* (*Ksat*) when it equals or approaches the internal permeability of the underlying soil medium. In almost all cases, reference to an infiltration rate implies this long-term constant rate (permeability or Ksat; Jarrett, 2008). For the purpose of bioretention and other engineered media system design, it is reasonable to assume that the soil media should *infiltrate* the stormwater at a rate equal to the long-term Ksat of the underlying soil media mix.

Therefore, the design goal of the soil media is to provide a mixture that has a porosity that will maintain the desired permeability, while also providing limited soil fines and sufficient organic matter to support plant growth and adsorb P and other stormwater contaminants. It is expected that over time, the seasonal cycle of plant growth within the bioretention basin will lead to an adequate accumulation of organic matter to maintain plant growth. The challenge, therefore, is to provide enough organic matter within the initial soil media mix to support the initial seasons of plant establishment and growth, while not overloading the system with excessive nutrients or soil fines (from the organic matter or topsoil) which might cause leaching of nutrients or gradual clogging of the soil porosity. It is also expected that the organic matter will enhance aggregation/structure of the media mix over time to aid in maintenance of permeability.

Soil porosity is the fraction of a volume of soil material that is not solid, also referred to as the void space. As the volume of fines, defined as either clay particles (less than 2 microns, or 0.002 mm) or silt particles (between 2 and 50 microns, or 0.002 and 0.05 mm) within a given soil mix is increased, there is a possibility that those fines may be flushed or migrate downward through the soil mix with each runoff event and eventually fill or otherwise clog the void space randomly throughout the mix and create preferential flow paths. In the short term this can lead to short circuiting and reduced volume reduction and pollutant removal, and in the long term may clog the soil layer. This tendency is offset by addition and maintenance of appropriate amounts of soil organic matter which binds soil fines into larger non-mobile aggregates.

- ***General Filter Media Physical Composition.*** The mineral soil texture of the bioretention soil mix should be loamy coarse sand with no more than 10% clay, no more than 20% silt + clay and at least 75% of the sand fraction should be coarse or very coarse sand.

- To allow for appropriate Cation Exchange Capacity (CEC) and nutrient removal, ***the mix should contain at least 10% soil fines (silt + clay)*** while meeting the overall texture specification above. The particle size analysis must be conducted on the mineral fraction only or following appropriate treatments to remove organic matter before particle size analysis.

- The Filter Media should contain ***3% to 5% organic matter*** by conventional Walkley-Black soil organic matter determination method or similar analysis. Soil organic matter is expressed on a dry weight basis and does not include coarse particulate (visible) components.

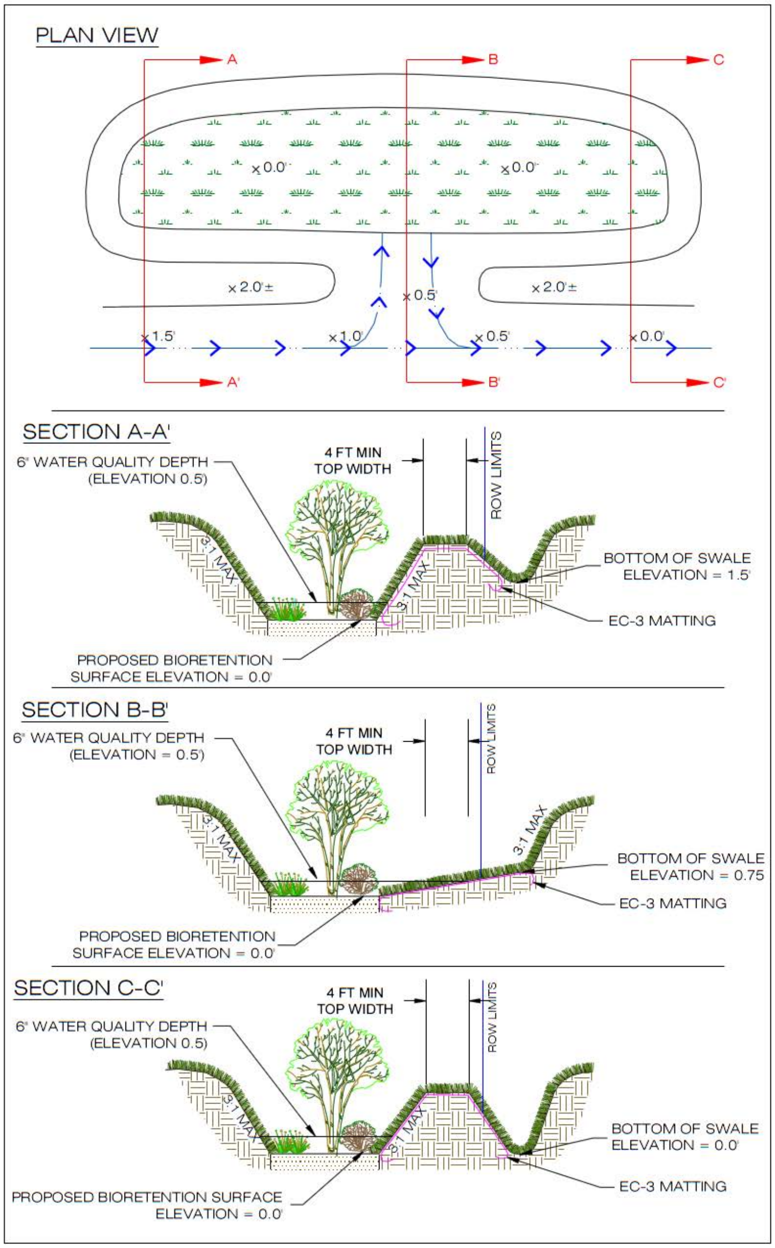

Figure 9.14. Typical Details for Off-Line Bioretention Basin

- The overall particle size distribution of the mix will vary since the sand fraction may contain some finer sizes as will native topsoils if utilized. As stated previously, the goal of the mixture is to achieve the desired constant head permeability. Therefore, the filter media composition noted above serves as the target recipe for the three ingredients, while the ultimate performance goal is to achieve a verified soil permeability or hydraulic conductivity (Ksat) of 1 to 2 inches per hour (or 30 to 60 cm/day).

- The following is the recommended composition of the three media ingredients:
  - **Sand** shall consist of silica based coarse aggregate, angular or round in shape and meet the mixture grain size distribution below. No substitutions of alternate materials such as diabase, calcium carbonate, rock dust or dolomitic sands are accepted. In particular, mica can make up no more than 5% of the total sand fraction. The sand fraction may also contain a limited amount of particles > 2.0 mm and < 9.5 mm per the table below, but the overall sand fraction must meet the specification of >75% being coarse or very coarse sand.

Sieve	**Size**	**% Passing**
3/8 in	9.50 mm	100
No. 4	4.75 mm	95 to 100
No. 8	2.36 mm	80 to 100
No. 16	1.18 mm	45 to 85
No. 30	0.6 mm	15 to 60
No. 50	0.3 mm	3 to 15
No. 100	0.15 mm	0 to 4
Effective Particle size (D10) > 0.3mm		
Uniformity Coefficient (D60/D10) < 4.0		

  - **Topsoil** is generally defined as the combination of the other ingredients referenced in the bioretention soil media: sand, fines (silt and clay), and any associated soil organic matter. Since the objective of the specification is to carefully establish the proper blend of these ingredients, the designer (or contractor or materials supplier) must carefully select the topsoil source material in order to not exceed the amount of any one ingredient.

    Generally, the use of a topsoil defined as a loamy sand, sandy loam, or loam (per the USDA Textural Triangle) will be an acceptable ingredient and in combination with the other ingredients meet the overall performance goal of the soil media.

  - **Organic matter** materials used in the soil media mix should consist of well-decomposed natural C-containing organic materials such as peat moss, humus, compost (consistent with the material specifications found in **Design Specification #4 Compost Soil Amendments**), pine bark fines or other organic soil conditioning material. However, per above, the combined soil mix should contain 3% to 5% soil organic matter on dry weight basis (grams organic matter per 100 grams dry soil) by the Walkley-Black method or other similar analytical technique.

It may be advisable to start with an open-graded coarse sand material and proportionately mix in the topsoil materials that may contain anywhere from 10% to 30% soil fines (sandy loam, loamy sand, loam) to achieve the desired ratio of sand and fines. Sufficient suitable organic amendments can then be added to achieve the 3% to 5% soil organic matter target. The exact composition of organic matter and topsoil material will vary, making the exact particle size distribution of the final total soil media mixture difficult to define in advance of evaluating available materials.

- ***Available Soil Phosphorus (P).*** Plant-available soil P should be within the range of Low$^+$ (L^+) to Medium (M) as defined in Table 2.2 of DCR (2005) Virginia Nutrient Management Standards and Criteria. ***For the Mehlich I extraction procedure this equates to a range of 5 to 15 mg/kg P or 18 to 40 mg/kg P for the Mehlich III procedure.***

  The filter media should contain sufficient plant available P to support initial plant establishment and plant growth, but not serve as a significant source of P for long term leaching. The media must also be relatively loose and non-compacted to allow for adequate inter-connected porosity to meet the required permeability (Ksat) specification. Saxton et al. (1986) estimated generalized bulk densities and soil-water characteristics from soil texture assumptions. The expected bulk density of the loamy sand soil composition described above should be in the range of 1.6 to 1.7 g/cm^3.

- ***Cation Exchange Capacity (CEC).*** The relative ability of soils to hold and retain nutrient cations like Ca and K is referred to as *cation exchange capacity* or CEC and is measured as the total amount of positively charged cations that a soil can hold per unit dry mass. CEC is also used as an index of overall soil reactivity and is commonly expressed in milliequivalents per 100 grams (meq/100g) of soil or cmol$^+$/kg (equal values). A soil with a moderate to high CEC indicates a greater ability to capture and retain ~~phosphorus and other~~ positively charged contaminants, which encourages conditions to remove phosphorus, assuming that soil fines (particularly fine silts and clays) are at least partially responsible for CEC. The minimum CEC of a bioretention soil media mix for pollutant removal is 5.0 (meq/100 g or cmol$^+$/kg) or greater. The filter media CEC should be determined by the Unbuffered Salt, Ammonium Acetate, Summation of Cations or Effective CEC techniques (Sumner and Miller, 1996) or similar methods that do not utilize strongly acidic extracting solutions.

  Coatings of Fe- and Al-oxides on mineral soil surfaces are also responsible for significant P retention and may be present in soils with low CEC. Thus, it is important for filter media P removal efficiency that some amount of mineral fines (10% - 20%) be present as long as the texture and permeability specifications cited herein are met. This is important due to the fact that soil organic matter per se is not active in adsorption of P.

  The CEC of the soil is determined in part by the amount of clay and/or humus or organic matter present. Since the bioretention media is a coarse mineral texture, and since the added organic matter may not have the relatively high CEC of native humus, it may be difficult to achieve the ideal CEC for the mixture as a whole in freshly blended materials. However, it is expected that over time, natural accumulation of organic matter will improve soil reactivity. Therefore, the initial media mixture may require additional suitable organic matter to increase the CEC to the extent possible without overly compromising the filter media composition or elevating the available P.

- ***Filter Media Permeability:*** The bioretention soil media should have a minimum infiltration rate of 1 to 2 inches per hour (or 30 to 60 cm/day). Note: a proper soil mix will have an initial infiltration rate that is significantly higher.
- ***Depth.*** The standard minimum filter bed depth ranges from 24 and 36 inches for Level 1 and Level 2 designs, respectively, (18 to 24 inches for rain gardens or micro-bioretention). If trees are included in the bioretention planting plan, tree planting holes in the filter bed must be at least 4 feet deep to provide enough soil volume for the root structure of mature trees. Use turf, perennials or shrubs instead of trees to landscape shallower filter beds.
- ***Filter Media for Tree Planting Areas.*** A more organic filter media is recommended within the planting holes for trees, with a ratio of 50% sand, 30% toposoil and 20% acceptable leaf compost.
- ***Mulch.*** A 2 to 3 inch layer of mulch on the surface of the filter bed enhances plant survival, suppresses weed growth, and pre-treats runoff before it reaches the filter media. Shredded, aged hardwood bark mulch makes a very good surface cover, as it retains a significant amount of nitrogen and typically will not float away.
- ***Alternative to Mulch Cover.*** In some situations, designers may consider alternative surface covers such as turf, native groundcover, erosion control matting (coir or jute matting), river stone, or pea gravel. The decision regarding the type of surface cover to use should be based on function, cost and maintenance. Stone or gravel are not recommended in parking lot applications, since they increase soil temperature and have low water holding capacity.
- ***Media for Turf Cover.*** One adaptation is to design the filter media primarily as a sand filter with organic content only at the top. Leaf compost tilled into the top layers will provide organic content for the vegetative cover. If grass is the only vegetation, the ratio of compost may be reduced.

6.7. Underdrain and Underground Storage Layer

Some Level 2 designs will not use an underdrain (where soil infiltration rates meet minimum standards; see **Section 6.2** and **Section 3** design tables). For Level 2 designs with an underdrain, an underground storage layer, referred to as an infiltration sump, of 12 inches should be incorporated below the invert of the underdrain.

The total depth of the storage layer, including the sump, will depend on the target treatment and storage volumes needed to meet water quality, channel protection, and/or flood protection criteria. However, the bottom of the storage layer must be at least 2 feet above the seasonally high water table. The storage layer should consist of clean, washed #57 stone, and when needed, an approved infiltration or storage module.

The infiltration sump can consist of a 12-inch stone layer underneath the perforated underdrain pipe, or as an alternative, the infiltration sump can be created with an “upturned elbow” configuration on the underdrain. This configuration places the perforated underdrain at the bottom of the stone reservoir layer, with the outlet elevated to the same elevation as the top of the sump. **Figure 9.4.C** illustrates this design variant. The sump will dewater by percolating into the native soils. A minimum field verified infiltration rate of ½-inch per hour is required in order to count the stone reservoir as storage.

The underdrain transitions to a solid wall pipe prior to exiting the stone reservoir layer and is directed towards an outlet manhole or other structure. (This run of pipe should be straight, or include cleanouts at 45 degree (maximum) horizontal bends, and be set at a minimal grade.) In order to create the higher outlet elevation, the outlet manhole is configured with an internal weir wall with the top of the weir set at the same elevation as the top of the stone sump. This is preferred over installing a vertical bend on the outlet pipe that can be difficult to maintain. This design variant can also include a drain orifice in the bottom of the weir to allow the sump to be drained if, over time, the exfiltration into the soil becomes restricted. This orifice should be covered with a plate with clear indication that it remain blocked under normal operating conditions.

All bioretention basins should include observation wells (**Figure 9.B.4.**). The observation wells should be tied into any T's or Y's in the underdrain system, and should extend upwards to be flush with the surface, with a vented cap.

6.8. Bioretention Planting Plans

A landscaping plan must be provided for each bioretention area. Minimum plan elements shall include the proposed bioretention template to be used, delineation of planting areas, the planting plan, including the size, the list of planting stock, sources of plant species, and the planting sequence, including post-nursery care and initial maintenance requirements. The planting plan should be prepared by a qualified landscape architect in order to tailor the planting plan to the site-specific conditions.

Native plant species are preferred over non-native species, but some ornamental species may be used for landscaping effect if they are not aggressive or invasive. Some popular native species that work well in bioretention areas and are commercially available can be found in **Table 9.5**. Internet links to more detailed bioretention plant lists developed in piedmont and coastal plain communities of the Chesapeake Bay region are provided in **Table 9.6**.

The planting template refers to the form and combination of native trees, shrubs, and perennial ground covers that maintain the appearance and function of the bioretention area. There is a growing consensus among horticulturists that a diverse herbaceous cover will create a dynamic ground-plane of native perennials and grasses that, working in concert with the soil, will be more effective at filtering pollutants a sparse collection of woody trees or shrubs. Where trees and shrubs are recommended (typically Level 2 designs), the designer should consider the long term growth of the plants – trees can dominate a facility and require extensive maintenance. In either case, a diverse mixture will allow plants best suited to the particular wet/dry regime of the practice's micro-environment to thrive. This will result in more rigorous growth, greater pollutant removal performance, and less (or easier) maintenance.

The six most common bioretention templates are as follows:

- ***Turf.*** This option is typically restricted to on-lot micro-bioretention applications, such as a front yard rain garden. Grass species should be selected that have dense cover, are relatively slow growing, and require the least mowing and chemical inputs (e.g., fine fescue, tall fescue).

- ***Perennial garden.*** This option uses herbaceous plants and native grasses to create a garden effect with seasonal cover. It may be employed in both micro-scale and small scale bioretention applications. This option is attractive, but it requires more maintenance in the form of weeding.
- ***Perennial garden with shrubs.*** This option provides greater vertical form by mixing native shrubs and perennials together in the bioretention area. This option is frequently used when the filter bed is too shallow to support tree roots. Shrubs should have a minimum height of 30 inches.
- ***Tree, shrub and herbaceous plants.*** This is the traditional landscaping option for bioretention. It produces the most natural effect, and it is highly recommended for bioretention basin applications. The landscape goal is to simulate the structure and function of a native forest plant community.
- ***Turf and tree.*** This option is a lower maintenance version of the tree-shrub-herbaceous option 4, where the mulch layer is replaced by turf cover. Trees are planted within larger mulched islands to prevent damage during mowing operations.
- ***Herbaceous meadow.*** This is another lower maintenance approach that focuses on the herbaceous layer and may resemble a wildflower meadow or roadside vegetated area (e.g., with Joe Pye Weed, New York Ironweed, sedges, grasses, etc.). The goal is to establish a more natural look that may be appropriate if the facility is located in a lower maintenance area (e.g., further from buildings and parking lots). Shrubs and trees may be incorporated around the perimeter. Erosion control matting can be used in lieu of the conventional mulch layer.

Table 9.5. Popular Native Plant Materials for Bioretention

Perennials/Herbaceous	Shrubs	Trees
Virginia Wild Rye *(Elymus virginicus)*	Common Winterberry *(Ilex verticillatta)*	River Birch *(Betula nigra*)
Redtop Grass *(Agrostis alba)*	Inkberry *(Ilex glabra)*	Red Maple *(Acer rubrum)*
Swamp Milkweed *(Asclepias incarnata)*	Sweet Pepperbush *(Clethra ainifolia)*	Pin Oak *(Quercus palustris)*
Switchgrass *(Panicum virgatum)*	Wax Myrtle *(Myrica cerifera)*	Willow Oak *(Quercus phellos)*
Cardinal Flower *(Lobelia cardinalis)*	Virginia Sweetspire *(Itea virginica)*	Sweetgum *(Liquidambar styraciflua)*
Common Three Square *(Scirpus americanus)*	Swamp Azeala *(Azeala viscosum)*	Black Willow *(Salix nigra)*
Sensitive Fern *(Onoclea sensibilis)*	Button Bush *(Cephalanthus occidentalis)*	Grey Birch *(Betula populifolia)*
Blue Flag *(Iris versicolor)*	Black Haw *(Virburnum prunifolium))*	Black Gum *(Nyassa sylvatica)*
Woolgrass *(Scirpus cyperninus)*	Indigo Bush *(Amorpha fruticosa)*	Sycamore *(Platanus occidentalis)*
Indian Grass *(Sorghastrum nutans)*	Arrowwood *(Virburum dentatum)*	Green Ash *(Fraxinus pennsylvanica*
Marsh Marigold *(Caltha palustris)*		Sweetbay Magnolia* *(Magnolia virginiana)*
Joe Pye Weed *(Eupatorium purpureum)*		Atlantic White Cedar* *(Charnaecyparis thyoides)*
Turk's cap lily (*Lilium superbum*)		Bald Cypress* *(Taxodium distichum)*
Bee Balm *(Mornarda didyma)*		Grey Dogwood *(Cornus racernosa)*
Northern Sea Oats *(Chasmanthium latifolium)*		Smooth Alder *(Alnus serrulata))*
		Serviceberry *(Amelanchier canadensis)*
		Redbud (*Cercis candensis*)
		Box Elder *(Acer negundo)*
		Fringe Tree (*Chionanthus virginicus*)

Note: Prior to selection, please consult bioretention plant lists for more detailed information regarding inundation, drought and salt tolerance for each species.
* most applicable to the coastal plain

Table 9.6. Sources of Bioretention Plant Lists

Fairfax County, VA https://166.94.9.135/dpwes/publications/lti/07-03attach3.pdf **Prince Georges County, MD** http://www.co.pg.md.us/Government/AgencyIndex/DER/ESD/Bioretention/pdf/Plant_list.pdf **City of Suffolk, VA** http://www.suffolk.va.us/citygovt/udo/apdx_c/appendix_c9-2_plant_list.pdf **Virginia** http://www.ext.vt.edu/pubs/waterquality/426-043/426-043.html **Bay Directory of Native Plant Nurseries** http://www.montgomerycountymd.gov/Content/DEP/Rainscapes/nurseries.htm **Delaware Green Technology Standards and Specifications** http://www.dnrec.state.de.us/DNREC2000/Divisions/Soil/Stormwater/New/GT_Stds%20&%20Specs_06-05.pdf

The choice of which planting template to use depends on the scale of bioretention, the context of the site in the urban environment, the filter depth, the desired landscape amenities, and the future owner's capability to maintain the landscape. In general, the vegetative goal is to cover up the filter surface with vegetation in a short amount of time. This means that the herbaceous layer is equally or more important than widely-spaced trees and shrubs. In the past, many bioretention areas in Virginia did not include enough herbaceous plants.

The following additional guidance is provided regarding developing an effective bioretention landscaping plan:

- Plants should be selected based on a specified zone of hydric tolerance and must be capable of surviving both wet and dry conditions.
- "Wet footed" species should be planted near the center, whereas upland species do better planted near the edge.
- Woody vegetation should not be located at points of inflow; trees should not be planted directly above underdrains, but should be located closer to the perimeter.
- If trees are part of the planting plan, a tree density of approximately one tree per 250 square feet (i.e., 15 feet on-center) is recommended.
- Shrubs and herbaceous vegetation should generally be planted in clusters and at higher densities (10 feet on-center and 1 to 1.5 feet on-center, respectively).
- Temporary or supplemental irrigation may be needed for the bioretention plantings in order for plant installers to provide a warranty regarding plant material survival.
- Supplemental irrigation by a rain tank system is also recommended (See Stormwater Design Specification No. 6: Rainwater Harvesting).
- Designers should also remember that planting holes for trees need must be at least 4 feet deep to provide enough soil volume for the root structure of mature trees. This applies even if the remaining soil media layer is shallower than 4 feet.

- If trees are used, plant shade-tolerant ground covers within the drip line.
- Maintenance is an important consideration in selecting plant species. Plant selection differs if the area will be frequently mowed, pruned, and weeded, in contrast to a site which will receive minimum annual maintenance.
- If the bioretention area is to be used for snow storage or is to accept snowmelt runoff, it should be planted with salt-tolerant, herbaceous perennials.

6.9. Bioretention Material Specifications

Table 9.7 outlines the standard material specifications used to construct bioretention areas.

Table 9.7. Bioretention Material Specifications

Material	Specification	Notes
Filter Media Composition	Filter Media to contain: • 80% - 90% sand • 10%-20% soil fines • 3%-5% organic matter	The volume of filter media based on 110% of the plan volume, to account for settling or compaction.
Filter Media Testing	Available P between L+ and M per DCR 2005 Nutrient Management Criteria.	The media should be certified by the supplier.
Mulch Layer	Use aged, shredded hardwood bark mulch or stable coarse compost.	Lay a 2 to 3 inch layer on the surface of the filter bed.
Alternative Surface Cover	Use river stone or pea gravel, coir and jute matting, or turf cover.	Lay a 2 to 3 inch layer of to suppress weed growth.
Top Soil For Turf Cover	Loamy sand or sandy loam texture, with less than 5% clay content, pH corrected to between 6 and 7, and an organic matter content of at least 2%.	3 inch surface depth.
Geotextile/Liner	Use a non-woven geotextile fabric with a flow rate of > 110 gal./min./sq. ft. (e.g., Geotex 351 or equivalent)	Apply only to the sides and directly above the underdrain. For hotspots and certain karst sites only, use an appropriate liner on bottom.
Choking Layer	Lay a 2 to 4 inch layer of sand over a 2 inch layer of choker stone (typically #8 or #89 washed gravel), which is laid over the underdrain stone.	
Stone Jacket for Underdrain and/or Storage Layer	1 inch stone should be double-washed and clean and free of all fines (e.g., VDOT #57 stone).	12 inches for the underdrain; 12 to 18 inches for the stone storage layer, if needed
Underdrains, Cleanouts, and Observation Wells	Use 6 inch rigid schedule 40 PVC pipe (or equivalent corrugated HDPE for micro-bioretention), with 3/8-inch perforations at 6 inches on center; position each underdrain on a 1% or 2% slope located nor more than 20 feet from the next pipe.	Lay the perforated pipe under the length of the bioretention cell, and install non-perforated pipe as needed to connect with the storm drain system. Install T's and Y's as needed, depending on the underdrain configuration. Extend cleanout pipes to the surface with vented caps at the Ts and Ys.
Plant Materials	Plant one tree per 250 square feet (15 feet on-center, minimum 1 inch caliper). Shrubs a minimum of 30 inches high planted a minimum of 10 feet on-center. Plant ground cover plugs at 12 to 18 inches on-center; Plant container-grown plants at 18 to 24 inches on-center, depending on the initial plant size and how large it will grow.	Establish plant materials as specified in the landscaping plan and the recommended plant list. In general, plant spacing must be sufficient to ensure the plant material achieves 80% cover in the proposed planting areas within a 3-year period. If seed mixes are used, they should be from a qualified supplier, should be appropriate for stormwater basin applications, and should consist of native species (unless the seeding is to establish maintained turf).

SECTION 7: REGIONAL & SPECIAL CASE DESIGN ADAPTATIONS

7.1 Karst Terrain

Karst regions are found in much of the Ridge and Valley province of Virginia, which complicates both land development and stormwater design. While bioretention areas produce less deep ponding than conventional stormwater practices (e.g., ponds and wetlands), Level 2 bioretention designs (i.e., infiltration) are not recommended in any area with a moderate or high risk of sinkhole formation (Hyland, 2005). On the other hand, Level 1 designs that meet separation distance requirements (3 feet) and possess an impermeable bottom liner and an underdrain should work well. In general, micro-bioretention and bioretention basins with contributing drainage areas not exceeding 20,000 square feet are preferred (compared to bioretention with larger drainage areas), in order to prevent possible sinkhole formation. However, it may be advisable to increase standard setbacks to buildings.

7.2 Coastal Plain

The flat terrain, low hydraulic head, and high water table of many coastal plain sites can constrain the application of deeper bioretention areas (particularly Level 2 designs). In such settings, the following design adaptations may be helpful:

- A linear approach to bioretention, using multiple cells leading to the ditch system, helps conserve hydraulic head.
- The minimum depth of the filter bed may be 18 to 24 inches. It is useful to limit surface ponding to 6 to 9 inches and avoid the need for additional depth by establishing a turf cover rather than using mulch. The shallower media depth and the turf cover generally comply with the Dry Swale specification, and therefore will be credited with a slightly lower pollutant removal (See Stormwater Design Specification No. 10: Dry Swales).
- The minimum depth to the seasonally high water table from the invert of the system can be 1 foot, as long as the bioretention area is equipped with a large-diameter underdrain (e.g., 6 inches).
- Maintain at least 0.5% slope in the underdrain to ensure positive drainage.
- The underdrain should be tied into the ditch or conveyance system.
- The mix of plant species selected should reflect coastal plain plant communities and should be more wet-footed and salt-tolerant than those used in typical Piedmont applications.

While these design criteria permit bioretention to be used on a wider range of coastal plain sites, it is important to evaluate the specific constraints represented by the particular site and avoid using bioretention on marginal sites that directly impact the pollutant removal and volume reduction pathways. Other stormwater practices, such as wet swales, ditch wetland restoration, and smaller linear wetlands, are often preferred alternatives for coastal plain sites.

7.3 Steep Terrain

In steep terrain, land with a slope of up to 15% may drain to a bioretention area, as long as a two cell design is used to dissipate erosive energy prior to filtering. The first cell, between the slope and the filter media, functions as a forebay to dissipate energy and settle any sediment that migrates down the slope. Designers may also want to terrace a series of bioretention cells to manage runoff across or down a slope. The drop in slope between cells should be limited to 1 foot and should be armored with river stone or a suitable equivalent.

7.4 Cold Climate and Winter Performance

Bioretention areas can be used for snow storage as long as an overflow is provided and they are planted with salt-tolerant, non-woody plant species. (NOTE: Designers may want to evaluate Chesapeake Bay wetland plant species that tolerate slightly brackish water, or consult the Minnesota Stormwater Manual for a list of salt-tolerant grass species (MSSC, 2005.) Tree and shrub locations should not conflict with plowing and piling of snow into storage areas.

While several studies have shown that bioretention facilities operate effectively in Pennsylvania and West Virginia winters, it is a good idea to extend the filter bed and underdrain pipe below the frost line and/or oversize the underdrain by one pipe size to reduce the freezing potential.

7.5 Linear Highway Sites

Bioretention is a preferred practice for constrained highway right of ways when designed as a series of individual on-line or off-line cells. In these situations, the final design closely resembles that of dry swales. Salt tolerant species should be selected if salt compounds will be used to de-ice the contributing roadway in the winter.

SECTION 8: CONSTRUCTION

8.1. Construction Sequence

***Construction Stage E&S Controls*.** Micro-bioretention and small-scale bioretention areas should be fully protected by silt fence or construction fencing, particularly if they will rely on infiltration (i.e., have no underdrains). Ideally, bioretention should remain outside the limit of disturbance during construction to prevent soil compaction by heavy equipment. Bioretention basin locations may be used as small sediment traps or basins during construction. However, these must be accompanied by notes and graphic details on the ESC plan specifying that (1) the maximum excavation depth at the construction stage must be at least 1 foot above the post-construction maximum excavation, (2) the facility must contain an underdrain, and (3) the plan must also show the proper procedures for converting the temporary sediment control practice to a permanent bioretention facility, including dewatering, cleanout and stabilization.

8.2 Bioretention Installation

The following is a typical construction sequence to properly install a bioretention basin. The installation of a bioretention basin will include intermediate inspections at critical stages of construction with inspector sign-off that the particular elements of the bioretention are constructed according the approved plans and specifications. As an alternative, if allowed by the VSMP Authority, the contractor may rely on the engineer of record or other qualified individual to conduct the intermediate inspections and certifications of compliance. The construction sequence for micro-bioretention is more simplified. These steps may be modified to reflect different bioretention applications or expected site conditions:

Step 1. Construction of the bioretention area may only begin after the entire contributing drainage area has been stabilized with vegetation. It may be necessary to block certain curb or other inlets while the bioretention area is being constructed. The proposed site should be checked for existing utilities prior to any excavation.

Step 2. The designer and the installer should have a preconstruction meeting, checking the boundaries of the contributing drainage area and the actual inlet elevations to ensure they conform to original design. Since other contractors may be responsible for constructing portions of the site, it is quite common to find subtle differences in site grading, drainage and paving elevations that can produce hydraulically important differences for the proposed bioretention area. The designer should clearly communicate, in writing, any project changes determined during the preconstruction meeting to the installer and the plan review/inspection authority.

Step 3. Temporary E&S controls are needed during construction of the bioretention area to divert stormwater away from the bioretention area until it is completed. Special protection measures such as erosion control fabrics may be needed to protect vulnerable side slopes from erosion during the construction process.

Step 4. Any pre-treatment cells should be excavated first and then sealed to trap sediments.

Step 5. Excavators or backhoes should work from the sides to excavate the bioretention area to its appropriate design depth and dimensions. Excavating equipment should have scoops with adequate reach so they do not have to sit inside the footprint of the bioretention area. Contractors should use a cell construction approach in larger bioretention basins, whereby the basin is split into 500 to 1,000 sq. ft. temporary cells with a 10-15 foot earth bridge in between, so that cells can be excavated from the side.

Step 6. It may be necessary to rip the bottom soils to a depth of 6 to 12 inches to promote greater infiltration.

Step 7. Place geotextile fabric on the sides of the bioretention area with a 6-inch overlap on the sides. If a stone storage layer will be used, place the appropriate depth of #57 stone on the bottom, install the perforated underdrain pipe, pack #57 stone to 3 inches above the underdrain pipe, and add approximately 3 inches of choker stone/pea gravel as a filter between the underdrain and the soil media layer. If no stone storage layer is used, start with 6 inches of #57 stone on the bottom, and proceed with the layering as described above.

Step 8. Obtain soil the media from a qualified vendor, and store it on an adjacent impervious area or plastic sheeting. After verifying that the media meets the specifications, apply the media in 12-inch lifts until the desired top elevation of the bioretention area is achieved. Wait a few days to check for settlement, and add additional media, as needed, to achieve the design elevation.

Step 9. Prepare planting holes for any trees and shrubs, install the vegetation, and water accordingly. Install any temporary irrigation.

Step 10. Place the surface cover in both cells (mulch, river stone or turf), depending on the design. If coir or jute matting will be used in lieu of mulch, the matting will need to be installed prior to planting (**Step 9**), and holes or slits will have to be cut in the matting to install the plants.

Step 11. Install the plant materials as shown in the landscaping plan, and water them during weeks of no rain for the first two months.

8.3 Construction Inspection

Inspections during and immediately after construction are needed to ensure that all the elements of bioretention basins are built in accordance with these specifications. Use a detailed inspection checklist that requires sign-offs by qualified individuals at critical stages of construction and to ensure that the contractor's interpretation of the plan is consistent with the designer's intent. The following identifies the critical stages of construction where an intermediate inspection and sign-off by a qualified individual is recommended since the items can't be verified after construction is completed. A construction inspection checklist that includes certifications of inspection at critical stages is provided at the end of this specification.

The following represents items that are frequently overlooked during construction inspection but represent important elements for ensuring the success of the bioretention facility during the initial break-in period.

- Verify the proper coverage and depth of mulch, vegetation, or soil matting has been achieved following construction, both on the filter bed and the side-slopes.
- Inspect the pre-treatment forbays and filter strips to verify that they are properly installed, stabilized, and working effectively before opening the facility to runoff.
- Check that outfall protection/energy dissipation measures at concentrated inflow and outflow points are stable.

Upon final acceptance of the facility, log the practice's GPS coordinates and submit them for entry into the VSMP Authority's BMP maintenance tracking database.

SECTION 9: MAINTENANCE

9.1. Maintenance Agreements

The Virginia Stormwater Management regulations (4 VAC 50-60) specify the circumstances under which a maintenance agreement must be executed between the owner and the VSMP authority, and sets forth inspection requirements, compliance procedures if maintenance is neglected, notification of the local program upon transfer of ownership, and right-of-entry for local program personnel.

- All bioretention practices must include a long term maintenance agreements consistent with the provisions of the VSMP regulations, and must include the recommended maintenance tasks and a copy of an annual inspection checklist.
- When micro-scale bioretention practices are applied on private residential lots, homeowners should be educated regarding their routine maintenance needs by being provided a simple document that explains their purpose and routine maintenance needs. .
- A deed restriction, drainage easement or other mechanism enforceable by the VSMP authority must be in place to help ensure that rain gardens and bioretention filters are maintained and not converted or disturbed, as well as to pass the knowledge along to any subsequent owners.
- The mechanism should, if possible, grant authority for the VSMP authority to access the property for inspection or corrective action.

9.2. First Year Maintenance Operations

Successful establishment of bioretention areas requires that the following tasks be undertaken in the first year following installation:

- ***Initial inspections.*** For the first 6 months following construction, the site should be inspected at least twice after storm events that exceed 1/2 inch of rainfall.
- ***Spot Reseeding.*** Inspectors should look for bare or eroding areas in the contributing drainage area or around the bioretention area, and make sure they are immediately stabilized with grass cover.
- ***Fertilization.*** One-time, spot fertilization may be needed for initial plantings.
- ***Watering.*** Watering is needed once a week during the first 2 months, and then as needed during first growing season (April-October), depending on rainfall.
- ***Remove and replace dead plants.*** Since up to 10% of the plant stock may die off in the first year, construction contracts should include a care and replacement warranty to ensure that vegetation is properly established and survives during the first growing season following construction. The typical thresholds below which replacement is required are 85% survival of plant material and 100% survival of trees.

9.3. Maintenance Inspections

It is highly recommended that a spring maintenance inspection and cleanup be conducted at each bioretention area. The following is a list of some of the key maintenance problems to look for:

- Check to see if 75% to 90% cover (mulch plus vegetative cover) has been achieved in the bed, and measure the depth of the remaining mulch.
- Check for sediment buildup at curb cuts, gravel diaphragms or pavement edges that prevents flow from getting into the bed, and check for other signs of bypassing.
- Check for any winter- or salt-killed vegetation, and replace it with hardier species.
- Note presence of accumulated sand, sediment and trash in the pre-treatment cell or filter beds, and remove it.
- Inspect bioretention side slopes and grass filter strips for evidence of any rill or gully erosion, and repair it.
- Check the bioretention bed for evidence of mulch flotation, excessive ponding, dead plants or concentrated flows, and take appropriate remedial action.

- Check inflow points for clogging, and remove any sediment.
- Look for any bare soil or sediment sources in the contributing drainage area, and stabilize them immediately.
- Check for clogged or slow-draining soil media, a crust formed on the top layer, inappropriate soil media, or other causes of insufficient filtering time, and restore proper filtration characteristics.

Example maintenance inspection checklists for Bioretention areas can be accessed in Appendix C of Chapter 9 of the *Virginia Stormwater Management Handbook* (2010).

9.4. Routine and Non-Routine Maintenance Tasks

Maintenance of bioretention areas should be integrated into routine landscape maintenance tasks. If landscaping contractors will be expected to perform maintenance, their contracts should contain specifics on unique bioretention landscaping needs, such as maintaining elevation differences needed for ponding, proper mulching, sediment and trash removal, and limited use of fertilizers and pesticides. A customized maintenance schedule must be prepared for each bioretention facility, since the maintenance tasks will differ depending on the scale of bioretention, the landscaping template chosen, and the type of surface cover. A generalized summary of common maintenance tasks and their frequency is provided in **Table 9.8**.

The most common non-routine maintenance problem involves standing water. If water remains on the surface for more than 48 hours after a storm, adjustments to the grading may be needed or underdrain repairs may be needed. The surface of the filter bed should also be checked for accumulated sediment or a fine crust that builds up after the first several storm events. There are several methods that can be used to rehabilitate the filter (try the easiest things first, as listed below):

- Open the underdrain observation well or cleanout and pour in water to verify that the underdrains are functioning and not clogged or otherwise in need of repair. The purpose of this check is to see if there is standing water all the way down through the soil. If there is standing water on top, but not in the underdrain, then there is a clogged soil layer. If the underdrain and stand pipe indicates standing water, then the underdrain must be clogged and will need to be snaked.
- Remove accumulated sediment and till 2 to 3 inches of sand into the upper 8 to 12 inches of soil.
- Install sand wicks from 3 inches below the surface to the underdrain layer. Sand wicks can be installed by excavating or augering (using a tree auger or similar tool) down to the gravel storage zone to create vertical columns which are then filled with a clean open-graded coarse sand material (coarse sand mix similar to the gradation used for the soil media). A sufficient number of wick drains of sufficient dimension should be installed to meet the design dewatering time for the facility.
- Last resort - remove and replace some or all of the soil media.

Table 9.8. Suggested Annual Maintenance Activities for Bioretention

Maintenance Tasks	Frequency
• Mowing of grass filter strips and bioretention turf cover	At least 4 times a year
• Spot weeding, erosion repair, trash removal, and mulch raking	Twice during growing season
• Add reinforcement planting to maintain desired the vegetation density • Remove invasive plants using recommended control methods • Stabilize the contributing drainage area to prevent erosion	As needed
• Spring inspection and cleanup • Supplement mulch to maintain a 3 inch layer • Prune trees and shrubs	Annually
• Remove sediment in pre-treatment cells and inflow points	Once every 2 to 3 years
• Replace the mulch layer	Every 3 years

Sample Construction Inspection Checklist for Bioretention Practices: The following checklist provides a basic outline of the anticipated items for the construction inspection of Bioretention Practices. This checklist does not necessarily distinguish between all the design variations and differences in construction between the family of practices: bioretention basins, micro-bioretention (or raingardens), and urban bioretention. Similarly, the use of an infiltration sump below an underdrain, or an infiltration sump with an "upturned elbow", and other variations between Level 1 and Level 2 bioretention may not be clearly identified in this checklist. Inspectors should review the plans carefully, and adjust these items and the timing of inspection verification as needed to ensure the intent of the design is met. Finally, users of this information may wish to incorporate these items into a VSMP Authority Construction Checklist format consistent with the format used for erosion and sediment control and BMP construction inspections.

Pre-Construction Meeting

☐ Pre-construction meeting with the contractor designated to install the bioretention practice has been conducted.

☐ Identify the tentative schedule for construction and verify the requirements and schedule for interim inspections and sign-off.

☐ Subsurface investigation and soils report supports the placement of an bioretention practice in the proposed location.

☐ Impervious cover has been constructed/installed and area is free of construction equipment, vehicles, material storage, etc.

☐ All pervious areas of the contributing drainage areas have been adequately stabilized with a thick layer of vegetation and erosion control measures have been removed.

☐ Area of bioretention practice has not been impacted during construction.

☐ Stormwater has been diverted around the area of the bioretention practice and perimeter erosion control measures to protect the facility during construction have been installed. .

Excavation

☐ Compare the bioretention surface and invert design elevations with the actual constructed elevations of the inflow and outlet inverts and adjust design elevations as needed.

☐ Area of bioretention excavation is marked and the size and location conforms to plan.

☐ If the excavation area has been used as a sediment trap: verify that the bottom elevation of the proposed stone reservoir is lower than the bottom elevation of the existing trap.

☐ For Level 2 bioretention, ensure the bottom of the excavation is scarified prior to placement of stone.

☐ Subgrade surface is free of rocks and roots, and large voids. Any voids should be refilled with the base aggregate to create a level surface for the placement of aggregates and underdrain (if required).

☐ No groundwater seepage or standing water is present. Any standing water is dewatered to an acceptable dewatering device.

☐ Excavation of the bioretention practice has achieved proper grades and the required geometry and elevations without compacting the bottom of the excavation.

☐ **Certification of Excavation Inspection**: Inspector certifies the successful completion of the excavation steps listed above.

Filter Layer, Underdrain, and Stone Reservoir Placement

☐ All aggregates, including, as required, the filter layer (choker stone & sand), the stone reservoir layer or infiltration sump conform to specifications as certified by quarry.

☐ Underdrain size and perforations meet the specifications.

☐ For Level 2 installations: placement of filter layer and initial lift of stone reservoir layer aggregates with underdrain or infiltration sump, spread (not dumped) to avoid aggregate segregation; or

☐ Impermeable liner, when required, meets project specifications and is placed in accordance with manufacturers specifications.

☐ Sides of excavation covered with geotextile, when required, prior to placing stone reservoir aggregate; no tears or holes, or excessive wrinkles are present.

☐ Placement of underdrain, observation wells, and underdrain fittings (45 degree wyes, cap at the upstream end, etc.) are in accordance with the approved plans.

☐ Elevations of underdrain and outlet structure are in accordance with approved plans, or as adjusted to meet field conditions.

☐ Placement of remaining lift of stone reservoir layer as needed to achieve the required reservoir depth.

☐ **Certification of Filter Layer and Underdrain Placement Inspection:** Inspector certifies the successful completion of the filter layer and underdrain placement steps listed above.

Bioretention Soil Media Placement

☐ Soil media is certified by supplier or contractor as meeting the project specifications.

☐ Soil media is placed in 12-inch lifts to the design top elevation of the bioretention area. Elevation has been verified after settlement (2 to 4 days after initial placement).

☐ Side slopes of ponding area are feathered back at the required slope (no steeper than 3H:1V).

☐ **Certification of Soil Media Placement Inspection:** Inspector certifies the successful completion of the soil media steps listed above.

Pretreatment and Plant Installation

☐ Placement of energy dissipators and pretreatment practices (forebays, gravel diaphragms, etc.) are installed in accordance with the approved plans.

☐ Riser, overflow weir, or other outflow structure is set to the proper elevation and functional; or.

☐ External bypass structure is built in accordance with the approved plans.

☐ Appropriate number and spacing of plants are installed in accordance with the approved plans.

☐ All erosion and sediment control practices have been removed.

☐ Follow-up inspection and as-built survey/certification has been scheduled.

☐ GPS coordinates have been documented for all bioretention practice installations on the parcel.

SECTION 9: REFERENCES

ASCE International BMP Database. Available online at www.bmpdatabase.org

CWP. 2007. *National Pollutant Removal Performance Database, Version 3.0*. Center for Watershed Protection, Ellicott City, MD.

DCR, (2005) Virginia Nutrient Management Standards and Criteria. Table 2.2, Page 41.

Hirschman, D., L. Woodworth and S. Drescher. 2009. *Technical Report: Stormwater BMPs in Virginia's James River Basin – An Assessment of Field Conditions and Programs*. Center for Watershed Protection. Ellicott City, MD.

Hunt, W.F. III and W.G. Lord. 2006. "Bioretention Performance, Design, Construction, and Maintenance." *North Carolina Cooperative Extension Service Bulletin.* Urban Waterways Series. AG-588-5. North Carolina State University. Raleigh, NC.

Hyland, S. 2005. "Analysis of sinkhole susceptibility and karst distribution in the Northern Shenandoah Valley (Virginia): impacts for LID site suitability models." M.S. Thesis. Virginia Polytechnic Institute and State University. Blacksburg, VA.

Jarrett, Albert R. (2008) *Infiltrating Stormwater*. A B E Fact Sheet No. F 260. Agricultural and Biological Engineering, Penn State University, University Park, PA 16802.

Lake County, OH. *Bioretention Guidance Manual*. Available online at: http://www2.lakecountyohio.org/smd/Forms.htm

Maryland Department of the Environment. 2001. *Maryland Stormwater Design Manual*. http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp

Minnesota Stormwater Steering Committee (MSSC). 2005. *The Minnesota Stormwater Manual*.

North Shore City. 2007. *Bioretention Design Guidelines*. Sinclair, Knight and Merz. Auckland, New Zealand.

Prince George's Co., MD. *Bioretention Manual*. Available online at: http://www.goprincegeorgescounty.com/Government/AgencyIndex/DER/ESD/Bioretention/bioretention.asp?nivel=foldmenu(7)

Saxton, K.E., W.J. Rawls, J.S. Romberger, and R.I. Papendick. 1986. Estimating generalized soil-water characteristics from texture. *Soil Sci. Soc. Am. J.* 50(4):1031-1036

Schueler et al. 2007. *Urban Stormwater Retrofit Practices*. Manual 3 in the Urban Subwatershed Restoration Manual Series. Center for Watershed Protection. Ellicott City, MD.

Schueler, T. 2008. Technical Support for the Baywide Runoff Reduction Method. Chesapeake Stormwater Network. Baltimore, MD. www.chesapeakestormwater.net

Sumner, M.E. and W.P. Miller. 1996. Cation Exchange Capacity and Exchange Coefficients. P. 1201-1230 In: D.L. Sparks et al., Methods of Soil Analysis, Part 3: Chemical Methods. Soil Sci. Soc. Am. Book Series 5; SSSA, Madison, WI.

Wisconsin Department of Natural Resources. *Stormwater Management Technical Standards*. http://www.dnr.state.wi.us/org/water/wm/nps/stormwater/techstds.htm#Post

APPENDIX 9-A

URBAN BIORETENTION

Stormwater Planters
Expanded Tree Pits
Stormwater Curb Extensions

VERSION 1.7
January 1, 2013

SECTION 9-A-1: DESCRIPTION

Urban bioretention practices are similar in function to regular bioretention practices except they are adapted to fit into "containers" within urban landscapes. Typically, urban bioretention is installed within an urban streetscape or city street right-of-way, urban landscaping beds, tree pits and plazas, or other features within an ultra-urban area ~~*Urban Development Area*~~. Urban bioretention is not intended for large commercial areas, nor should it be used to treat small sub-areas of a large drainage area such as a parking lot. Rather, urban bioretention is intended to be a containerized practice incorporated into small fragmented drainage areas such as shopping or pedestrian plazas within a larger urban development.

Urban bioretention features hard edges, often with vertical concrete sides, as contrasted with the more gentle earthen slopes of regular bioretention. These practices may be open-bottomed, to allow some infiltration of runoff into the sub-grade, but they generally are served by an underdrain.

Stormwater planters (also known as vegetative box filters or foundation planters) take advantage of limited space available for stormwater treatment by placing a soil filter in a container located above ground or at grade in landscaping areas between buildings and roadways (**Figure 9-A.1**). The small footprint of foundation planters is typically contained in a precast or cast-in-place concrete vault. Other materials may include molded polypropylene cells and precast modular block systems.

Figure 9-A.1. Stormwater Planters

Extended tree pits are installed in the sidewalk zone near the street where urban street trees are normally installed. The soil volume for the tree pit is increased and used as a stormwater (**Figure 9-A.2**). Treatment is increased by using a series of connected tree planting areas together in a row. The surface of the enlarged planting area may be mulch, grates, permeable pavers, or conventional pavement. The large and shared rooting space and a reliable water supply increase the growth and survival rates in this otherwise harsh planting environment.

Figure 9-A.2. Expanded Tree Pits

Stormwater curb extensions (also known as parallel bioretention) are installed in the road right-of way either in the sidewalk area or in the road itself. In many cases, curb extensions serve as a traffic calming or street parking control device. The basic design adaptation is to move the raised concrete curb closer to the street or in the street, and then create inlets or curb cuts that divert street runoff into depressed vegetated areas within the expanded right of way (**Figure 9-A.3**).

Figure 9-A.3. Stormwater Curb Extensions

Each urban bioretention variant is planted with a mix of trees, shrubs, and grasses as appropriate for its size and landscaping context.

SECTION 9-A-2: PERFORMANCE

The typical stormwater functions of an urban bioretention area are described in **Table 9-A.1**. The three major design variants of urban bioretention are described below:

Table 9-A.1. Summary of Stormwater Functions Provided by Urban Bioretention Areas

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR)	40% (for Water Quality credit in the VRRM Compliance spreadsheet only) 0% credit for Channel Protection	NA
Total Phosphorus (TP) EMC Reduction[1] by BMP Treatment Process	25%	NA
Total Phosphorus (TP) Mass Load Removal	55%	
Total Nitrogen (TN) EMC Reduction[1] by BMP Treatment Process	40%	NA
	64%	
Channel and Flood Protection	• Use the Virginia Runoff Reduction Method (VRRM) Compliance Spreadsheet to calculate the Curve Number (CN) Adjustment ***OR*** Design extra storage (optional; as needed) on the surface, in the engineered soil matrix, and in the stone/underdrain layer to accommodate a larger storm, and use NRCS TR-55 Runoff Equations[2] to compute the CN Adjustment.~~None;~~	

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	or if sized according to Bioretention Basin, follow the Level 1 Bioretention basin criteria.
Flood Mitigation	None
[1] Change in the event mean concentration (EMC) through the practice. The actual nutrient mass load removed is the product of the removal rate and the runoff reduction rate (see Table 1 in the *Introduction to the New Virginia Stormwater Design Specifications*). [2] NRCS TR-55 Runoff Equations 2-1 thru 2-5 and Figure 2-1 can be used to compute a curve number adjustment for larger storm events based on the retention storage provided by the practice(s).	

Sources: CWP and CSN (2008) and CWP (2007)

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Leadership in Energy and Environmental Design (LEED®). The LEED® point credit system designed by the U.S. Green Building Council (USGBC) and implemented by the Green Building Certification Institute (GBCI) awards points related to site design and stormwater management. Several categories of points are potentially available for new and re-development projects. **Chapter 6** and the introduction to this chapter provide a more thorough discussion of the site planning process and design considerations as related to the environmental site design and potential LEED credits. However, VDCR is not affiliated with the USGBC or GBCI and any information on applicable points provided here is based only on basic compatibility. **Designers should research and verify scoring criteria and applicability of points as related to the specific project being considered through USGBC LEED resources**

Table 9-A.2. Potential LEED® Credits for Urban Bioretention[1]

Credit Category	Credit No.	Credit Description
Sustainable Sites	SS5.1	Site Development: Protect or Restore Habitat[2]
Sustainable Sites	SS5.2	Site Development: Maximize Open Space
Sustainable Sites	SS6.1	Stormwater Design: Quantity Control
Sustainable Sites	SS6.2	Stormwater Design: Quality Control
Water Efficiency	WE1.1	Water Efficient Landscaping: Reduce by 50% [4]
Water Efficiency	WE1.2	Water Efficient Landscaping: No Potable Water Use or No Irrigation [4]

[1] Actual site design and/or BMP configuration may not qualify for the credits listed. Alternatively, the project may actually qualify for credits not listed here. Designers should consult with a qualified individual (LEED AP) to verify credit applicability.

SECTION 9-A-3: DESIGN TABLE

Table 9-A.3. Urban Bioretention Design Criteria

Level 1 Design Only (RR: 40; TP: 25)
Sizing (Refer to **Section 9-A-6.1**): Tv_{BMP} = [(1)(Rv)(A) / 12]Surface Area (sq. ft.) = T_v/2 = {[(1.0 inch)(R_v)(A)/12)] – the volume reduced by an upstream BMP}/2
Underdrain = Schedule 40 PVC with clean-outs (Refer to the Main Bioretention Design Specification, **Section 6.7**)
Recommended Maximum Drainage Area = 2,500 sq. ft.[1] (100% impervious)
Maximum Ponding Depth = 6 to 12 inches [2]
Filter media depth minimum = 24 18 inches; recommended maximum = 36 inches
Media and Surface Cover (Refer to the Main Bioretention Design Specification, **Table 9-4 and Section 6.6**)
Sub-soil testing (Refer to the Main Bioretention Design Specification, **Section 6.2**)
Inflow = sheetflow, curb cuts, trench drains, roof drains, concentrated flow, or equivalent
Building setbacks (Refer to **Section A-4 9-A-5**)
Deeded maintenance O&M plan (Refer to the Main Bioretention Design Specification, **Section 9.1**)
[1]Larger drainage areas may be allowed with sufficient flow controls and other mechanisms to ensure proper function, safety, and community acceptance; however, the urban bioretention filter must then be designed in accordance with the Level 1 bioretention filter criteria (**Table 9-4**). [2]Ponding depth above 6 inches will require a specific planting plan to ensure appropriate plants (Refer to the Main Bioretention Design Specification, **Section 6.1**).

SECTION 9-A-4: TYPICAL DETAILS

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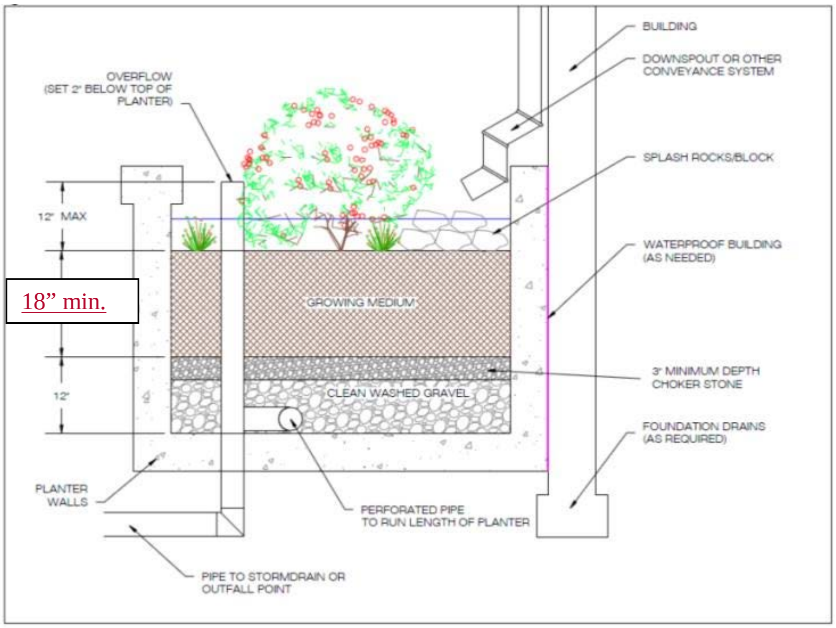

Figure 9-A.4. Stormwater Planter Cross-Section

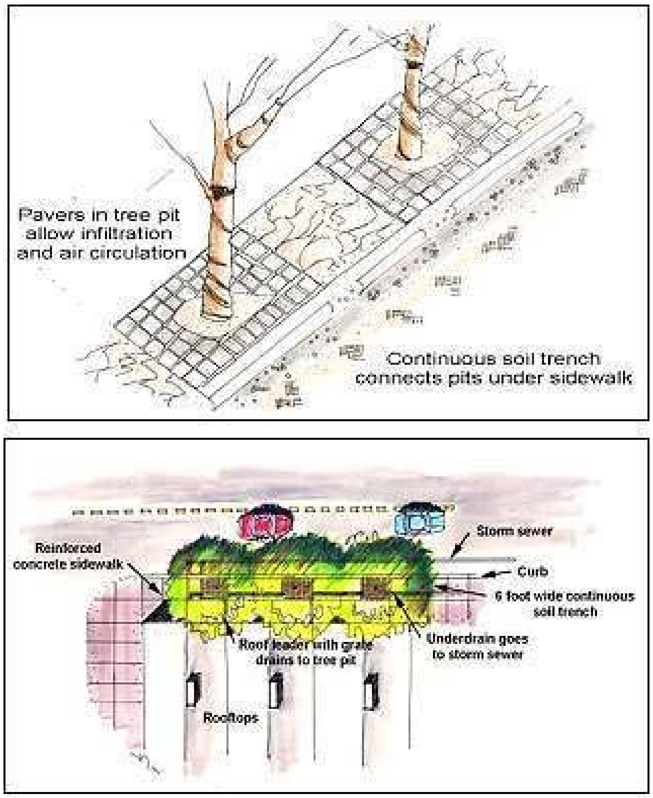

Figure 9-A.5. Expanded Tree Pit Details

Portland, Oregon (Portland BES, 2004) has thorough construction details for stormwater curb extensions, expanded tree pits, and utility house connections, available online at http://www.portlandonline.com/bes/index.cfm?c=44213& .

SECTION 9-A-5: PHYSICAL FEASIBILITY & DESIGN APPLICATIONS

In general, urban bioretention has the same constraints as regular bioretention, along with a few additional constraints as noted below:

Contributing Drainage Area. The drainage areas in these urban settings are typically ~~considered to be~~ 100% impervious. Urban bioretention ~~is~~ can be considered ~~classified as~~ a micro-bioretention practice **(Table 9-3)** and is therefore limited to 2,500 sq. ft. of drainage area (100% impervious) to each unit when using the minimum soil depth of 18 inches. ~~However, this is considered a general recommendation; larger~~ Larger drainage areas may be allowed with sufficient flow controls and other mechanisms to ensure proper function, safety, and community acceptance; however, the urban bioretention filter must then be designed in accordance with the Level 1 bioretention filter

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criteria (**Table 9-4**). ~~The drainage areas in these urban settings are typically considered to be 100% impervious.~~ While multiple units can be installed adjacent to large buildings, parking decks, etc., to maximize the treatment area in ultra-urban watersheds, urban bioretention is not intended to be used as treatment for large impervious areas (such as parking lots) as noted in **Section 9-A-1**.

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Adequate Drainage. Urban bioretention practice elevations must allow the untreated stormwater runoff to be discharged at the surface of the filter bed and ultimately connect to the local storm drain system.

Available Hydraulic Head. In general, 3 to 5 feet of elevation difference is needed between the downstream storm drain invert and the inflow point of the urban bioretention practice. This is generally not a constraint, due to the standard depth of most storm drains systems.

Setbacks from Buildings or Roads. If an impermeable liner and an underdrain are used, no setback is needed from the building. Otherwise, the standard 10 foot down-gradient setback applies.

Proximity to Underground Utilities. Urban bioretention practices frequently compete for space with a variety of utilities. Since they are often located parallel to the road right-of-way, care should be taken to provide utility-specific horizontal and vertical setbacks. However, conflicts with water and sewer laterals (e.g., house connections) may be unavoidable, and the construction sequence must be altered, as necessary, to avoid impacts to existing service.

Overhead Wires. Designers should also check whether future tree canopy heights achieved in conjunction with urban bioretention practices will interfere with existing overhead telephone, cable communications and power lines.

Minimizing External Impacts. Because urban bioretention practices are installed in highly urban settings, individual units may be subject to higher public visibility, greater trash loads, pedestrian use traffic, vandalism, and even vehicular loads. Designers should design these practices in ways that prevent, or at least minimize, such impacts. In addition, designers should clearly recognize the need to perform frequent landscaping maintenance to remove trash, check for clogging, and maintain vigorous vegetation. The urban landscape context may feature naturalized landscaping or a more formal deign. When urban bioretention is used in sidewalk areas of high foot traffic, designers should not impede pedestrian movement or create a safety hazard. Designers may also install low fences, grates or other measures to prevent damage from pedestrian short-cutting across the practices.

SECTION 9-A-6: DESIGN CRITERIA

Urban bioretention practices are similar in function to regular bioretention practices except they are adapted to fit into "containers" within urban landscapes. Therefore, special sizing accommodations are made to allow these practices to fit in very constrained areas where other surface practices may not be feasible.

6.1. Sizing of Urban Bioretention

The requirementsd for sizing surface area of thean urban bioretention filter is are the same as that of bioretention and micro-bioretention described in **Bioretention Section 6**. one-half of the BMP design Treatment Volume, Tv_{BMP} (**Equation 9-A.1** below). This criterion represents a balance between the need to size these structures so as to provide a reasonable alternative in ultra urban settings and the relationship between the surface area size, media permeability, and drawdown requirements. Ideally, urban bioretention facilities are in close proximity to the public or users of the adjacent buildings and/or commercial areas, and thus subjected to increased scrutiny. This provides a theoretical basis for adjusting the clogging factor for the media permeability coefficient (k, ft/day), or an increase in the allowable maximum drawdown time, resulting in the smaller sizing. However, as a result, Level 1 urban bioretention will only count towards water quality credit through the 40% volume reduction and/or the 25% TP pollutant removal. There is no credit given to channel protection due to the reduced surface area and storage volume.

Equation 9-A.1. Urban Bioretention Sizing

$$SA \text{ (sq. ft.)} = Tv_{BMP} \text{ (cu. ft.)} / 2.0 \text{ ft.}$$

Where:

SA = the surface area of the urban bioretention facility (in square feet)

Tv_{BMP} = the required design treatment volume (in cubic feet) = the treatment volume for the contributing drainage area, Tv_{DA}, less any volume reduced by upstream runoff reduction practices.

6.2 General Design Criteria for Urban Bioretention

Design of urban bioretention should follow the general guidance presented in the main part of this Bioretention design specification. The actual geometric design of urban bioretention is usually dictated by other landscape elements such as buildings, sidewalk widths, utility corridors, retaining walls, etc. Designers can divert fractions of the runoff volume from small impervious surfaces into micro-bioretention units that are integrated with the overall landscape design. Inlets and outlets should be located as far apart as possible. The following is additional design guidance that applies to all variations of urban bioretention:

- Each individual urban bioretention unit should be stenciled or otherwise permanently marked to designate it as a stormwater management facility. The stencil or plaque should indicate (1) its water quality purpose, (2) that it may pond briefly after a storm, and (3) that it is not to be disturbed except for required maintenance.
- The ground surface of the micro-bioretention cell should slope 1% towards the outlet, unless a stormwater planter is used.
- The soil media depth should be a minimum of 24 18 inches.
- If large trees and shrubs are to be installed, soil media depths should be a minimum of 4 feet.
- All urban bioretention practices should be designed to fully drain within 24 hours.
- Any grates used above urban bioretention areas must be removable to allow maintenance access.
- The inlet(s) to urban bioretention should be stabilized using VDOT #3 stone, splash block, river stone or other acceptable energy dissipation measures. The following forms of inlet stabilization are recommended:
  - Downspouts to stone energy dissipators.

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  - Sheet flow over a depressed curb with a 3-inch drop.
  - Curb cuts allowing runoff into the bioretention area.
  - Covered drains that convey flows across sidewalks from the curb or downspouts.
  - Grates or trench drains that capture runoff from the sidewalk or plaza area.
- Pre-treatment options overlap with those of regular bioretention practices. However, the materials used may be chosen based on their aesthetic qualities in addition to their functional properties. For example, river rock may be used in lieu of rip rap. Other pretreatment options may include one of the following:
  - A trash rack between the pre-treatment cell and the main filter bed. This will allow trash to be collected from one location.
  - A trash rack across curb cuts. While this trash rack may clog occasionally, it keeps trash in the gutter, where it can be picked up by street sweeping equipment.
  - A pre-treatment area above ground or a manhole or grate directly over the pre-treatment area.
- Overflows can either be diverted from entering the bioretention cell or dealt with via an overflow inlet. Optional methods include the following:
  - Size curb openings to capture only the *Tv* and bypass higher flows through the existing gutter.
  - Use landscaping type inlets or standpipes with trash guards as overflow devices.
  - Use a pre-treatment chamber with a weir design that limits flow to the filter bed area.

6.3 Specific Design Issues for Stormwater Planters

Since stormwater planters are often located near building foundations, waterproofing by using a watertight concrete shell or an impermeable liner is required to prevent seepage.

6.4 Specific Design Issues for Expanded Tree Pits

- The bottom of the soil layer must be a minimum of 4 inches below the root ball of plants to be installed.
- Extended tree pits designs sometimes cover portions of the filter media with pervious pavers or cantilevered sidewalks. In these situations, it is important that the filter media is connected beneath the surface so that stormwater and tree roots can share this space.
- Installing a tree pit grate over filter bed media is one possible solution to prevent pedestrian traffic and trash accumulation.
- Low, wrought iron fences can help restrict pedestrian traffic across the tree pit bed and serve as a protective barrier if there is a dropoff from the pavement to the micro-bioretention cell.
- A removable grate capable of supporting typical H-20 axel loads may be used to allow the tree to grow through it.
- Each tree needs a minimum of 400 cubic feet of shared root space.

6.5 Specific Design Issues for Stormwater Curb Extensions

Roadway stability can be a design issue where stormwater curb extensions are installed. Consult design standards pertaining to roadway drainage. It may be necessary to provide a barrier to keep water from saturating the road's sub-base and demonstrate it is capable of supporting H-20 axel loads.

6.6 Planting and Landscaping Considerations

Plant selection for urban bioretention areas should take into account the extreme conditions of the urban landscape: reduced sunlight due to building shade, heat island effects, safety concerns related to volume of pedestrian traffic and visibility, etc. Also, the degree of landscape maintenance that can be provided will determine some of the planting choices for urban bioretention areas. The planting cells can be formal gardens or naturalized landscapes.

In areas where less maintenance will be provided and where trash accumulation in shrubbery or herbaceous plants is a concern, consider a "turf and trees" landscaping model. Spaces for herbaceous flowering plants can be included. This may be attractive at a community entrance location.

Native trees or shrubs are preferred for urban bioretention areas, although some ornamental species may be used. As with regular bioretention, the selected perennials, shrubs, and trees must be tolerant of salt, drought, and inundation. Additionally, tree species should be those that are known to survive well in the compacted soils and polluted air and water of an urban landscape.

SECTION 9-A-7: URBAN BIORETENTION MATERIAL SPECIFICATIONS

Please consult the **main part of this design specification** (**Table 9.7**) for the typical materials needed for filter media, stone, mulch and other bioretention features. The unique components for urban bioretention may include the inlet control device, a concrete box or other containing shell, protective grates, and an underdrain that daylights to another stormwater practice or connects to the storm drain system. The underdrain should:

- Consist of slotted pipe greater than or equal to 4 inches in diameter, placed in a layer of washed (less than 1% passing a #200 sieve) VDOT #57 stone.
- Have a minimum of 2 inches of gravel laid above and below the pipe.
- Be laid at a minimum slope of 0.5 %.
- Extend the length of the box filter from one wall to within 6 inches of the opposite wall, and may be either centered in the box or offset to one side.
- Be separated from the soil media by an appropriate filter fabric for the particular application based on AASHTO M288-06 or a 2 to 3 inch layer of either washed VDOT #8 stone or 1/8 to 3/8 inch pea gravel.

SECTION 9-A.8: CONSTRUCTION

The construction sequence and inspection requirements for urban bioretention are generally the same as micro-bioretention practices. Consult the construction sequence and inspection guidance provided in **the main part of this design specification**. In cases where urban bioretention is constructed in the road or right-of-way, the construction sequence may need to be adjusted to account for traffic control, pedestrian access and utility notification.

Urban bioretention areas should only be constructed after the drainage area to the facility is completely stabilized. The specified growth media should be placed and spread by hand with minimal compaction, in order to avoid compaction and maintain the porosity of the media. The media should be placed in 8 to 12 inch lifts with no machinery allowed directly on the media during or after construction. The media should be overfilled above the proposed surface elevation, as needed, to allow for natural settling. Lifts may be lightly watered to encourage settling. After the final lift is placed, the media should be raked (to level it), saturated, and allowed to settle for at least one week prior to installation of plant materials.

SECTION 9-A-9: MAINTENANCE

Routine operation and maintenance are essential to gain public acceptance of highly visible urban bioretention areas. Weeding, pruning, and trash removal should be done as needed to maintain the aesthetics necessary for community acceptance. During drought conditions, it may be necessary to water the plants, as would be necessary for any landscaped area.

To ensure proper performance, inspectors should check that stormwater infiltrates properly into the soil within 24 hours after a storm. If excessive surface ponding is observed, corrective measures include inspection for soil compaction and underdrain clogging. Consult the maintenance guidance outlined in **the main part of this design specification**.

SECTION 9-A-10: DESIGN REFERENCES

Center for Watershed Protection. 2006. *Urban Watershed Forestry Manual. Part 2: Conserving and Planting Trees at Development Sites.* Ellicott City, MD. Available online at: http://www.cwp.org/forestry/index.htm

City of Portland. Bureau of Environmental Services. (Portland BES). 2004. *Portland Stormwater Management Manual*. Portland, OR. http://www.portlandonline.com/bes/index.cfm?c=dfbcc

Credit Valley Conservation. 2008. *Credit River Stormwater Management Manual*. Mississauga, Ontario.

Northern Virginia Regional Commission. 2007. *Low Impact Development Supplement to the Northern Virginia BMP Handbook*. Fairfax, Virginia

Saxton, K.E., W.J. Rawls, J.S. Romberger, and R.I. Papendick. 1986. "Estimating generalized soil-water characteristics from texture." *Soil Sci. Soc. Am. J.* 50(4):1031-1036.

Schueler, T., D. Hirschman, M. Novotney and J. Zielinski. 2007. *Urban stormwater retrofit practices*. Manual 3 in the Urban Subwatershed Restoration Manual Series. Center for Watershed Protection, Ellicott City, MD.

APPENDIX 9-B

ADDITIONAL DETAILS AND SCHEMATICS FOR REGULAR BIORETENTION PRACTICES

VERSION 2.0
January 1, 2013

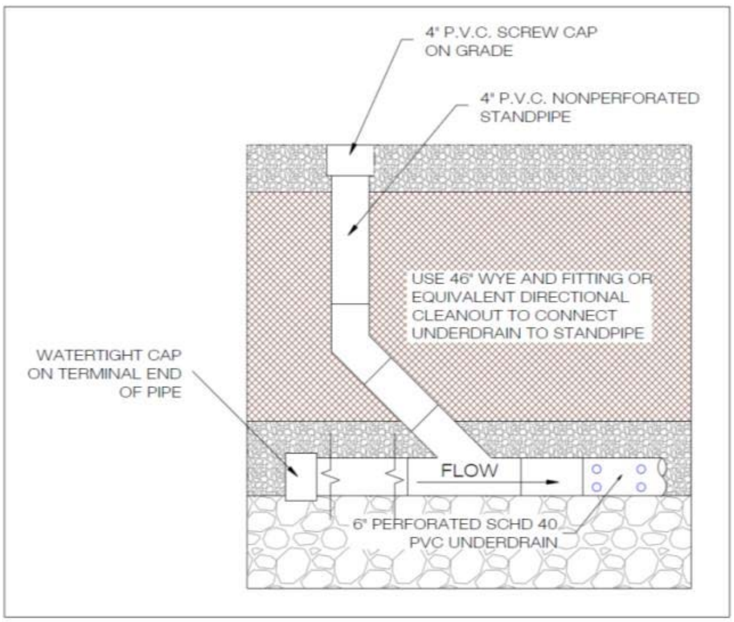
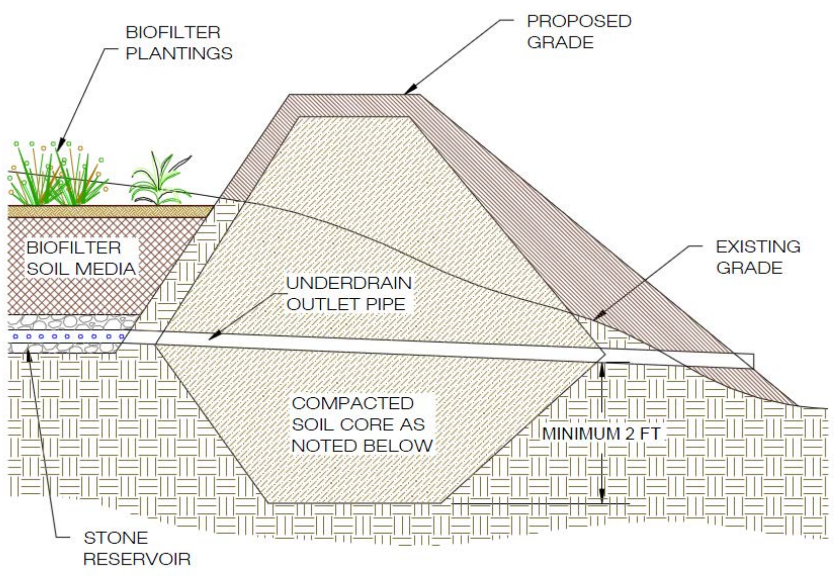


Figure 9-B.1. 4" P.V.C. Cleanout Detail



NOTES:

1) STABILIZE BERM AND SPILLWAY WITH EC-3 MATTING.

2) REMAINING DISTURBED SLOPES SHALL BE STABILIZED WITH EC-3 MATTING.

3) ALL BERM FILL MATERIAL SHALL CONSIST OF ML, CL, SC, OR GC SOILS (USCS) OR AS APPROVED BY GEOTECHNICAL ENGINEER TO CREATE AN ACCEPTABLE EMBANKMENT AS APPLICATBLE FOR THE CONDISTIONS. COMPACTED FILL SHALL BE FREE OF WOOD, ROOTS, ROCKS, OR ANY OTHER NON-COMPACTIBLE SOIL. COMPACTED FILL SHALL BE INSTALLED IN MAXIMUM 6-INCH LIFTS TO A DRY DENSITY OF 95% OF THE STANDARD PROCTOR MAXIMUM DRY DENSTIY ASTM D698.

Figure 9-B.2. Typical Bioretention Basin Berm